University of St.Gallen

The Potential of Blockchain Technology to Combat Illegal Logging in the Amazon Rainforest

Lynn Sara Tschirky
lynn.tschirky@student.unisg.ch
M.A. Strategy and International Management

7th of November 2021

Supervised by: Prof. Dr. Florian Wettstein
Institute for Business Ethics at the University of St. Gallen

Co-supervised by: Prof. Dr. Vanessa Boanada Fuchs
St. Gallen Institute of Management in Latin America

Abstract

Despite ongoing efforts to curb illegal logging in the Brazilian Amazon, the phenomenon remains prevalent, with estimates numbering illegality between 50 and 90 percent of the timber trade (Sheikh, Bermejo, & Procita, 2019, p. 1). Given the Amazon rainforest's importance to humankind, the imminent threat of a global environmental disaster, and the grave repercussions of illegal logging on the economy, society, and the environment, this thesis investigates illegal logging in the Brazilian Amazon. Specifically, it examines the main causes of illegal logging, strategies timber companies can pursue to combat illegal logging, and the potential of blockchain technology to complement these efforts, a technology that has been adopted in other industries to address illegality but has remained scarcely researched in the timber industry. To this end, a literature review was conducted and complemented by expert interviews and case studies to draw insights from practice. The occurrence of illegal logging can be ascribed to multiple factors of interrelated and reinforcing nature related to deficiencies in Brazil's licensing, control, and monitoring system and the overarching socio-economic and political-legal environment. Strategies that timber companies can pursue to combat illegal logging were illustrated in a framework consisting of five areas: Companies can pledge to tackle illegal logging, implement supply chain initiatives to verify timber legality and track timber, conduct continuous monitoring and periodic audits, and engage in political advocacy for government action. The fifth category, which links together the other four areas, entails aligning company approaches with those of other stakeholders and forming multi-stakeholder collaborations. Blockchain technology can complement these strategies by operationalising company pledges, storing information related to legality and traceability in an immutable manner, and maintaining an immutable audit trail. While the technology can strengthen multi-stakeholder collaborations, its applicability to align efforts undertaken by different stakeholders and to advocate for government action is limited. Overall, blockchain technology can reduce the risk of illegality occurring in timber supply chains. Yet, given the weaknesses of the technology related to data veracity and challenges in the timber supply chain associated with the physical transformation of timber, which complicate the linkage between the physical timber and its virtual counterpart in the blockchain, blockchain technology is seen as a complement rather than a substitute to corporate strategies that address illegal logging.

Table of Contents

Table of Figures

List of Abbreviations

API	Application Programming Interface
AUTEF	*Autorização de Exploração Florestal*
AUTEX	*Autorização de Exploração Florestal*
BFS	Brazilian Forest Service
B2B	Business-to-business
B2C	Business-to-consumer
CAR	*Cadastro Ambiental Rural*
CEO	Chief Executive Officer
CO_2	Carbon Dioxide
COVID-19	Corona Virus Disease of 2019
DETER	*Detecção de Desmatamento em Tempo Real*
DOF	*Documento de Origem Florestal*
EC	European Commission
EFI	European Forest Institute
FAO	Food and Agriculture Organization of the United Nations
FSC	Forest Stewardship Council
GF	*Guia Florestal*
GIGO	Garbage in, Garbage out
GPS	Global Positioning System
HRW	Human Rights Watch
IBAMA	*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis*
ICMBio	*Instituto Chico Mendes de Conservação da Biodiversidade*
IoT	Internet of Things
INCRA	*Instituto Nacional de Colonização e Reforma Agrária*
INPA	*Instituto Nacional de Pesquisas da Amazônia*
INPE	*Instituto Nacional de Pesquisas Espaciais*
INTERPOL	International Criminal Police Organisation
IPCC	Intergovernmental Panel on Climate Change
IPFS	InterPlanetary File System
LA	*Licença Ambiental*
LAU	*Licença Ambiental Única*
LF	*Licença Florestal*
LO	*Licença de Operação*
NEPCon	Nature Economy and People Connected
NGO	Non-governmental Organisation
ODC	*Observatório do Clima*
OSINFOR	*Organismo de Supervisión de los Recursos Forestales y de Fauna Silvestre*
PEFC	Program for the Endorsement of Forest Certification
PMFS	*Planos de Manejo Florestal Sustentável*
POA	*Plano Operacional Anual*
PoA	Proof of Authority
PoS	Proof of Stake
PoW	Proof of Work
PRODES	*Projeto de Estimativa do Desflorestamento da Amazônia*
RFB	*República Federativa do Brasil*
RFID	Radio Frequency Identification
SDG	Sustainable Development Goal
SEFA	*Secretaria de Estado da Fazenda do Pará*
SEMA	*Secretaria de Estado de Meio Ambiente*
SEMAS	*Secretaria de Estado de Meio Ambiente e Sustentabilidade do Pará*
SERFOR	*Servicio Nacional Forestal y de Fauna Silvestre*
SINAFLOR	*Sistema Nacional de Controle da Origem dos Produtos Florestais*
SISFLORA	*Sistema de Comercialização e Transporte de Produtos Florestais*
UK	United Kingdom

UN	United Nations
UNEP	United Nations Environment Programme
US	United States
USD	US Dollars
VPN	Virtual Private Network
WBCSD	World Business Council for Sustainable Development
WCMC	World Conservation Monitoring Centre
WRI	World Resources Institute
WTP	Wood Tracking Protocol
WTO	World Trade Organisation
WWF	World Wide Fund for Nature

1 Introduction

„Today, we stand exactly in a moment of destiny: The tipping point is here, it is now. The peoples and leaders of the Amazon countries together have the power, the science, and the tools to avoid a continental-scale, indeed, a global environmental disaster."
- Lovejoy & Nobre, 2019, p. 2

Leading scientists Carlos Nobre and Thomas Lovejoy (2018) found evidence that the Amazon is approaching a tipping point, after which an irreversible process of self-destruction would begin, causing the mass extinction of trees and animals, the release of billions of tons of carbon dioxide, and the permanent distortion of weather patterns across large parts of South America (p. 1). With estimates placing this tipping point at 20 to 25 percent of deforested areas in the Amazon, humankind is rapidly approaching this point, with deforestation[1] numbered at ca. 17 percent in 2019, of which ca. 80 percent is estimated to be illegal (Lovejoy & Nobre, 2018, p. 1; Lovejoy & Nobre, 2019, p. 1; Schipani, 2019). Illegal logging[2] plays a particularly critical role since it acts both as a precursor of deforestation and a direct driver of forest degradation (de Lima et al., 2018, p. 2). Identifying illegally felled trees on time could prevent loggers from moving forward with deforestation in the subsequent stage (Human Rights Watch [HRW], 2019, p. 21, 33). Yet, progress in reducing illicit timber has stalled, considering that illegality continues to be prevalent in the Amazonian timber industry, constituting between 50 and 90 percent of the timber trade (Greenpeace, 2018, p. 6; Sheikh et al., 2019, p. 1). New solutions and targeted action from timber companies and other stakeholders are required to tackle illegal logging and exclude illicit timber from supply chains (The World Bank, 2019, p. 12).

Companies in other industries suffering from illegality are looking at blockchain technology for answers: Many have begun exploring this technology to mitigate the risk of illicit products entering supply chains. For instance, tuna company Sea Quest Fiji implemented a blockchain pilot to eliminate illegal tuna from its supply chain (Whiting, 2020, ¶18). Similarly, the diamond company de Beers developed a blockchain-based platform called Tracr to counter "blood diamonds" that are illegally sold to fund conflicts, particularly in Western and Central Africa (Shapshak, 2018, ¶1; Walker & Kemp, 2019, p. 251). Beyond that, academia has recognised the potential of blockchain technology to curb illegal business practices, criminal activities, and illegal trade (Hastig & Sodhi, 2020, p. 942). Researchers have suggested that it may represent a solution for commodities susceptible to fraud, such as timber (Figorilli et al., 2018, p. 11; Vilkov & Gang, 2019, p. 390). Despite the recognition of blockchain's[4] potential, research on blockchain's applicability in the timber industry and the Brazilian Amazon remains markedly meagre (see Appendix Chapter 1.1). Case study-driven research in the blockchain field remains rare, partially explained by the recent emergence and complexity of the technology (Hastig & Sodhi, 2020, p. 947; Hinckeldeyn, 2019, p. 3; Treiblmaier, 2020, p. 3). Treiblmaier (2020) states: "Both industry and academia are at an early stage of Blockchain development and the careful description and documentation of case studies can help the industry to build on previous success stories and avoid pitfalls" (p. 25).

This thesis seeks to evaluate the potential of blockchain to complement corporate strategies in curbing illegal logging in the Brazilian Amazon. This is the first paper to address this research gap, to the best of the author's knowledge. It is a response to Subramanian, Chaudhuri, and Kayikci's call (2020, p. 6)

[1]Deforestation can be defined as the permanent removal of forests for conversion to non-forest use (e.g., agriculture) (Ometto et al., 2014, p. 576).
[2]Illegal logging can be defined as „all practices related to the harvesting, processing and trading of timber inconsistent with national and sub-national laws" (Kleinschmit, Leipold, & Sotirov, 2016a, p. 14).
[3]Due to practicability, this thesis will from time to time refer to "blockchain technology" as "blockchain."

for understanding blockchain's potential application, challenges, and opportunities in supply chains and Düdder and Ross' (2017, p. 5) call for research on a blockchain-based solution in the timber industry. Additionally, Varriale Cammarano, Michelino, and Caputo (2020, p. 12) express the need for more case studies that reflect blockchain applications in the business world, and Vilkov and Gang (2019) state that "due to the overall complexity of the technology and the lack of information about its successful implementation in the forest industry, there is a need for critical investigative analyses" (p. 391). Thus, this thesis seeks to answer the following three research questions:

1. What are the main causes of illegal logging in the Brazilian Amazon?
2. How can companies operating in the timber industry contribute to combating illegal logging in the Brazilian Amazon?
3. How can blockchain technology complement corporate action to combat illegal logging in the Brazilian Amazon?

Therefore, this thesis lies at the intersection of two streams of literature. On the one hand, it contributes to the existing literature on illegal logging by dissecting the root causes of illegal logging in the Brazilian Amazon and by outlining strategies timber companies can undertake to address this issue. On the other hand, it contributes to the nascent literature on blockchain applications in supply chains by developing three in-depth case studies addressing illegality and evaluating how this technology could address illicit timber in the Brazilian Amazon. An in-depth literature review was conducted to answer the research questions, for which secondary data, such as academic papers, consulting studies, company reports, books, websites, and media articles, was consulted. Particularly the newspaper discourse proved helpful to access recent information, complementing the scientific discourse, which typically requires time for publishing (Kleinschmit, Ziegert, & Walther, 2021, p. 9). Additionally, primary data was collected by conducting nine interviews with representatives from timber companies, technology providers, academia, NGOs, and certification companies. For the development of the in-depth case studies, both primary and secondary data were used. Where adequate, examples from other companies were included for illustrative purposes.

The thesis is organised in the following manner. Chapter 2 describes the importance of the Amazon rainforest and the threat of forest degradation and deforestation. The subsequent chapter focuses on understanding the phenomenon of illegal logging by providing an overview of legal logging (see Chapter 3.1) and contrasting it with illegal logging (see Chapter 3.2). This provides the foundation for investigating the causes of illegal logging in the Brazilian Amazon (see Chapter 3.3). The environmental, societal, and economic impact of illegal logging is assessed in Chapter 3.4. Chapter 4 discusses corporate responsibility before outlining the strategies that timber companies can undertake to curb illegal logging in the Brazilian Amazon. Chapter 5 evaluates blockchain as a potential solution and begins with laying out the methodological approach for this evaluation (see Chapter 5.1). The defined approach comprises two steps, with the first step representing the blockchain ideation phase (see Chapter 5.2) and the second step the blockchain validation phase (see Chapter 5.3), where a specified use case is analysed for its technical, operational, market, and financial feasibility (see Chapter 5.3.1). The results are synthesised in an overall discussion (see Chapter 5.3.2) before the outlook, limitations, and areas for future research are delineated in Chapter 5.3.3. Lastly, the thesis is concluded in Chapter 6, where the answers to the three research questions are presented.

2 The Amazon Rainforest

The Amazon rainforest is the world's largest tropical rainforest, spanning Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname, French Guiana, and Brazil (Ortiz, 2019, p. 3). Holding 40 percent of the world's remaining rainforests, it represents an ecosystem of great environmental, social, and economic importance (Lovejoy, 2019, ¶2). At the same time, the Amazon is being threatened by forest degradation and deforestation, which are, amongst others, driven by the cattle ranching, soy, and timber industries.

2.1 Importance of the Amazon Rainforest

In terms of the Amazon's environmental importance, the rainforest provides both extractive and non-extractive benefits (Gray et al., 2015, p. 2). The former includes the supply of timber as well as non-timber products and the provision of shelter from which flora and fauna benefit (United Nations [UN], 2017, p. 3). The latter encompasses ecosystem services, such as conserving biodiversity, regulating hydrological systems, and mitigating climate change (Assunção & Gandour, 2019, p. 2). As the world's largest gene bank, the Amazon contains an extraordinary variety of plants, animals, microorganisms, and bacteria, numbered at around ten percent of known biodiversity (Kehl, Todt, Veronez, & Cazella, 2015, p. 1; Lovejoy, 2019, ¶4). In fact, given that many species remain yet to be discovered, scientists believe that the Amazon harbours up to 30 percent of the world's biodiversity (Piotrowski, 2019, p. 3). The rainforest also plays a decisive role in the global climate system and water cycle by regulating ocean currents and generating ca. 20 percent of the global freshwater supply, in addition to controlling cloud cover and rainfall (Barreto & Muggah, 2019, ¶2; Lovejoy & Nobre, 2019, p. 1; Nobre & Castilla-Rubio, 2012, ¶3). The moisture is not confined to the Amazon basin but covers large areas of South America and beyond: There is evidence that the Amazon influences precipitation as far away as the northwest United States [US] (see Medvigy, Walko, Otte, & Avissar, 2013, p. 9115) (Lovejoy & Nobre, 2019, p. 1). Besides its role as a mediator of the global water system, the rainforest acts as a carbon sink by absorbing carbon emissions that would otherwise remain in the atmosphere (Lovejoy & Schmitz, 2020, ¶8; Ortiz, 2019, p. 3). Between 150 and 200 billion tons of CO_2 emissions – equivalent to more than 15 years' worth of global, human-induced fossil fuel emissions – are estimated to be stored by the rainforest (Nobre & Castilla-Rubio, 2012, ¶3; Ometto, Aguiar, & Martinelli, 2014, p. 575). Other non-extractive ecosystem services include pollination, erosion prevention, and fire control (Ding et al., 2016, p. 1).

Humankind can benefit from the extractive and non-extractive advantages that the Amazon offers. The rainforest provides shelter to around 30 million people, who benefit from the Amazon's extractive resources, such as timber, fruits, and fuelwood (Ortiz, 2019, p. 3; The World Bank, 2019, p. 16). For some of them, the Amazon is of cultural, spiritual, and historical value, as it represents the place where their ancestors lived for generations, giving them a sense of belonging (Gray et al., 2015, p. 1; Lovejoy & Schmitz, 2010, ¶6). "Their history is in the trees, the plants, and even the soil" (Levis, 2020, ¶1). Furthermore, the Amazon contributes to poverty reduction and sustainable development, as many local communities depend on the Amazon for subsistence, income, employment, and access to forest products (UN, 2017, p. 3; The World Bank, 2019, p. 12). Benefits from the non-extractive ecosystem services, such as the conservation of biodiversity, accrue to societies on the local, national, and global level: Every species in the Amazon represents solutions to certain biological problems and some of them may be key in solving human health challenges (Lovejoy, 2019, ¶5).

The Amazon "is a huge economic asset" (Mortimer, 2019, ¶1): Its extractive goods typically have a financial or market value from which local communities and companies profit (The World Bank, 2019, p. 16). Today, numerous companies in the timber, meat, agricultural, pharmaceutical, and mining industries generate profits by harvesting, processing, and selling these forest products domestically and

internationally, contributing to their countries' economic growth (Barreto & Muggah, 2019, ¶2; Piotrowski, 2019, p. 3). Flourishing industries, in turn, contribute to poverty reduction, job creation, and government income, in addition to the creation of new vibrant economic centres in the rainforest (Piotrowski, 2019, p. 3; The World Bank, 2019, pp. 12, 16).

2.2 Forest Degradation and Deforestation in the Amazon Rainforest

Despite the Amazon's significance for humankind and the environment, the rainforest is being destroyed at an alarming pace (Ortiz, 2019, p. 3). Since 2015 deforestation rates have been increasing across most Amazonian countries, contrasting starkly with the marked reduction in overall deforestation by 80 percent between 2004 and 2012 (Carvalho & Nobre, 2020, ¶7; Piotwroski, 2019, p. 6). The razing and conversion of intact land continue largely unabated, as the attention is focused on controlling the COVID-19 outbreak: In Brazil, for instance, deforestation had risen for 15 consecutive months until July 2020, reaching the highest recorded level since over a decade (Butler, 2020b, ¶1; Macedo & Pereira, 2020, ¶2). Since razing and burning forests releases carbon emissions stored by trees, these developments could jeopardize the achievement of international commitments on forests, climate change, and biodiversity (Castilla-Rubio & Nobre, 2016, ¶5; Eaton, 2018, p. 19; Ortiz, 2019, p. 4).

The United Nations [UN] (2017) described the vision of a world where forests support sustainable development and provide environmental, social, and economic benefits for both present and future generations (p. 2). At the COP26 Summit, over 100 world leaders pledged to end deforestation by 2030 (Einhorn & Buckley, 2021, ¶1). There have been similar declarations in the past, most notably the New York Declaration on Forests, where governments, NGOs, and companies committed to halving deforestation by 2020 and ending it in 2030 (The Economist, 2021). "The 2020 target was missed and the 2030 at the minute looks like it's going to be a stretch" (The Economist, 2021). Deforestation undermines the advancement of various Sustainable Development Goals [SDGs], such as SDG 13, which targets climate action, or SDG 15, which focuses on sustainably managing forests and halting biodiversity loss and deforestation (Hewitt, 2020, ¶13). Notably, all eight Amazonian countries committed to reducing emissions from deforestation and forest degradation in the Paris Agreement in 2015, in addition to keeping the increase in the global average temperature well below two degrees Celsius above pre-industrial levels (UN, 2015, pp. 3, 6). Nonetheless, these targets remain far from being accomplished as forest loss continues to challenge the Amazon (HRW, 2019, p. 138; Khadka, 2019, ¶1; Ortiz, 2019, p. 4). "Without keeping our intact forests, it will be impossible to implement our climate goals outlined in the Paris Agreement," (Volckhausen, 2019, ¶8) says Tom Evans, the forest conservation director at the Wildlife Conservation Society. If the commitments from the COP26, the Paris Agreement, the New York Declaration on Forests, the SDGs, and other forest-related goals are to be met, it is imperative that the Amazonian countries – especially Brazil – take decisive action against deforestation and forest degradation (Azevedo-Ramos & Moutinho, 2018, p. 126; UN, 2017, p. 2).

Brazil is central to the protection of the Amazon rainforest, partially due to geographic reasons: Around 60 percent of the tropical rainforest fall under Brazilian territory (Barreto & Muggah, 2019, ¶4; Kehl et al., 2015, p. 1). At the same time, Brazil is also the country that recorded the greatest loss of primary forest in 2019, driving the increase in forest loss worldwide (Correa, 2019, ¶1, 10). It appears that the country will not only fail to meet its Paris Agreement target of cutting 43 percent of emissions by 2030, but also other goals, such as achieving zero illegal deforestation (Mendonça, 2019, ¶, 3; Piotrowski, 2019, p. 6). Furthermore, Brazil's systematic dismantling of forest protection mechanisms has inspired officials from neighbouring countries to follow suit (see Chapter 3.3.2) (Romero, 2019, ¶18). This can be seen in one Colombian province, where deforestation rates skyrocketed after the governor called for

ranchers to double the number of cattle raised following Brazil's weakening of forest protections (Romero, 2019, ¶18). Brazil taking on a leading role in protecting the rainforest would, as observed in the past, empower other Amazonian countries to implement measures to curb deforestation (Lovejoy & Nobre, 2019, p. 1; Romero, 2019, ¶18). These measures are likely to differ from country to country, as the economic sectors driving deforestation vary between the Amazonian countries and thus, require contextualised solutions (Piotrowski, 2019, p. 4). Due to the aforementioned reasons, namely Brazil's wide coverage of the Amazon, its high deforestation rate, and its strong influence on its neighbouring countries, this thesis will focus on the Brazilian Amazon.

The cattle ranching, soy, and timber industry are the driving forces of deforestation in Brazil (Piotrowski, 2019, p. 9). The cattle sector represents the main contributor of deforestation in Brazil, as it accounts for around 65 percent of deforested areas in the Amazon (Jezequel, 2019, ¶5). These deforested areas harbour 40 percent of the country's cows and bulls, contributing to Brazil becoming the largest beef exporter worldwide (Piotrowski, 2019, p. 8; Zia, Hansen, Hjort, & Valdes, 2019, ¶1). The soy industry comes second, constituting around 6.5 percent of deforested areas (Jezequel, 2019, ¶11). While the growth of this industry has come at the expense of large areas of the rainforest, it strengthened Brazil's position in the global soy market (McCarthy, 2019, ¶1). The logging industry ranks third, supporting Brazil's role as a leading producer of wood-based products (Piotrowski, 2019, p. 9; Wellesley, 2014, p. 5). In 2018, Brazil was the 2nd largest producer of wood fuel, the 4th largest producer of industrial roundwood, and the 3rd largest producer of pulp worldwide (Food and Agriculture Organisation of the United States [FAO], 2019, p. 2). Furthermore, it is important to acknowledge the role played by logging in the conversion of lands (Müller, 2020, p. 17).

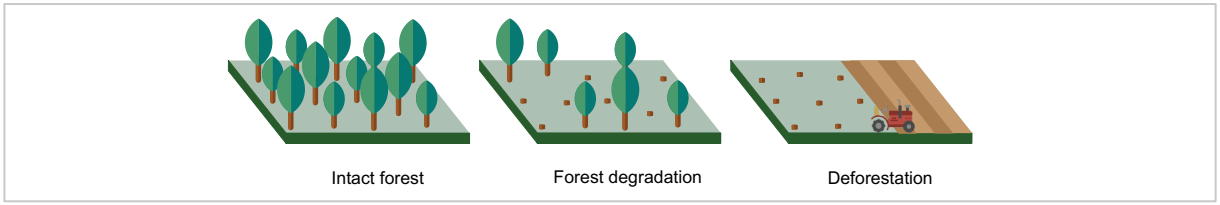


Image 1: The two-stage process of deforestation
(own image based on Gandour, Menezes, Vieira, & Assunção, 2021, n. p. & WWF, 2021, p. 39)

The conversion of lands often occurs in two phases: In the first phase, valuable timber is removed and sold in domestic or international markets, leaving most of the trees standing (HRW, 2019, p. 33; Kleinschmit et al., 2016b, p. 127; Müller, 2020, p. 17). The resulting proceeds are often used to finance the activities in the second phase, since these are more labour-intensive and thus, require considerable investments (Eaton, 2018, p. 20; HRW, 2019, p. 33). Activities in the second phase include cutting down the remaining trees and setting them on fire to clear areas for cattle and agriculture (Harris, 2020a, ¶6; McCarthy, 2019, ¶2). In this sense logging typically does not contribute directly to deforestation, but rather to forest degradation (Piotrowski, 2019, p. 9). However, since forest degradation is the precursor of deforestation, logging represents the doorway to the removal and conversion of forests and, therefore, a significant indirect driver of deforestation (de Lima et al., 2018, p. 2; World Wide Fund For Nature [WWF], 2016b, p. 4). Considering that around 90 percent of deforestation in Brazil was illegal in 2018, identifying illegally felled trees in the supply chain bears considerable potential to prevent criminals from moving forward with deforestation (HRW, 2019, pp. 21, 33). Additionally, there has been an increasing trend in forest degradation (Assunção & Gandour, 2019, p. 5): "Small-scale forest loss events have not only increased in number but have also increased greatly in geographical spread across Amazonia" (Kalamandeen et al., 2018, p. 7). Due to the considerable direct impact of logging on forest degradation and indirect impact on deforestation, this paper will focus on the logging industry.

3 The Problem of Illegal Logging in the Brazilian Amazon

A major problem in the Brazilian logging industry is the pervasiveness of illegal timber (Wellesley, 2014, p. 26). Before delving into the specifics of the illicit timber trade, the different forest and logging types as well as the supply chain of legal timber are outlined, serving as the foundation for understanding how illicit timber is laundered throughout the supply chain. Subsequently, the main causes of illegal logging are determined since previous studies highlight the importance of understanding these drivers before developing any interventions aimed at reducing illegal logging (Ken, Sasaki, Entani, Ma, Thuch, & Tsusaka, 2020, p. 2). Lastly, the repercussions of illegal logging are examined.

3.1 Legal Logging in the Brazilian Amazon

Logging requirements differ depending on land ownership (private or public) and timber type (native or planted) (Greenpeace, 2018, p. 5). For moving wood along the supply chain, different documents need to be obtained to comply with forestry regulations and provide proof of legality during transport (BVRio, 2017, p. 7). An example of a simplified legal supply chain will be presented in Chapter 3.1.2. Note that a supply chain can encompass a range of different players and numerous stages in practice – in some cases up to 20 stages – as timber may need to pass through various processing facilities before attaining the desired end state (Interview Lentini; Vilkov & Gang, 2019 p. 391). The timber supply chain can be marked by high complexity, as it can encompass numerous wood producers across several countries and timber products can comprise wood sourced from different suppliers (World Business Council for Sustainable Development [WBCSD] & World Resources Institute [WRI], 2014, p. 25).

3.1.1 Forest and Logging Types

From the perspective of land ownership, logging in the Brazilian Amazon rainforest is carried out in public or private forest areas, while in terms of forest types, forestry activities can take place in natural or planted forests (NEPCon, 2017, p. 5; Wellesley, 2014, p. 4). Natural forests are publicly or privately owned, while plantations are only established on private lands (NEPCon, 2017, p. 5). Overall, logging may occur in three scenarios: On plantations on private lands, in natural forests on public lands, and in natural forests on private lands (Greenpeace, 2018, p. 5; NEPCon, 2017, p. 9). However, only few plantations are located in the Brazilian Amazon and illegal timber in planted forests has remained at a low level (Interview Lentini; UN Environment Programme [UNEP]-World Conservation Monitoring Centre [WCMC], 2018, p. 3; Wellesley, 2014, p. 24). Marco Lentini, forest engineer at IMFALORA, states: “There is not a large concern about planted forests in Brazil” (Interview Lentini). Therefore, this thesis will focus on timber from natural forests.

In private, natural forests, logging is required to comply with the Brazilian Forest Code 2012, which distinguishes between areas of permanent protection, legal reserves, and areas of intense exploration (República Federativa do Brasil [RFB], 2012, Art. 4, 12, 31). Areas that provide important environmental services and are ecologically fragile, such as mountain slopes, mangroves, and lagoons, benefit from permanent protection, with very few exceptions (e.g., national security) (RFB, 2012, Art. 4; WWF, 2016a, p. 40). Legal reserves represent portions of land that owners must set aside to promote the sustainable use of natural resources and the conservation of flora and fauna (WWF, 2016a, p. 18). Logging and collecting non-timber products are permitted in these areas as long as volumes, harvesting practices, and harvesting periods comply with existing regulations (WWF, 2016a, p. 43). According to the Forest Code (RFB, 2012, Art. 12), landowners in the Amazon rainforest must maintain 80 percent of their properties as legal reserves, while the other 20 percent can be intensively explored with, for instance, construction and agricultural activities (see Image 2). Therefore, what differentiates the areas

designated for intense exploration from legal reserves is that trees may be cleared to convert the land for non-forest use as opposed to selectively cutting trees (Perazzoni, 2012, p. 40).

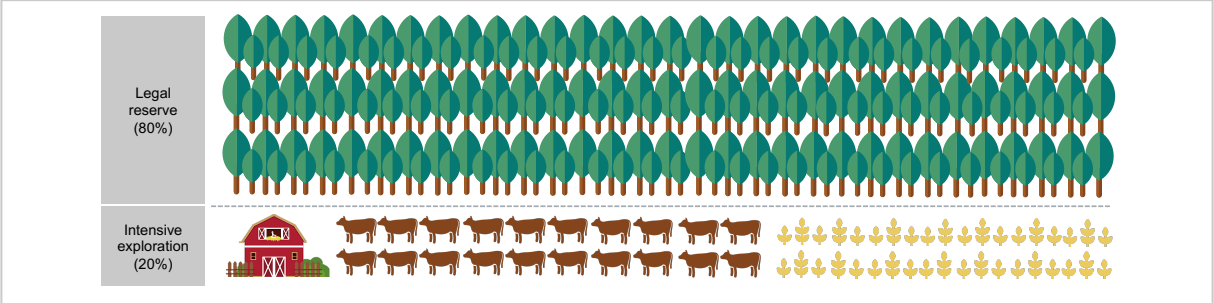


Image 2: Legal reserve requirements according to the Forest Code (own image based on Perazzoni, 2012, p. 37)

Logging in public forests is subject to the Public Forest Management Law (RFB, 2006). Public forests can be segmented into destined and non-destined areas, of which the former includes protected or indigenous lands, where indigenous communities have the right to sustainable forest use (Fernandes et al., 2017, p. 497; Gray et al., 2015, pp. 10–11). Public forests may also be destined for community, military, and concessionary use (Fernandes et al., 2017, p. 497). The government allocates concessions in a public, competitive bidding process, where private entities submit bids and present their sustainable forest management plan (Lima & Azevedo-Ramos, 2020, p. 1). The winning party signs a long-term contract, which grants them the right to perform sustainable forest management in the respective land in exchange for paying concession fees and royalties (Greenpeace, 2018, p. 5). Logging is prohibited in protected areas, indigenous lands, and public lands without a concession (Greenpeace, 2018, p. 5). Besides these destined uses of public forests, other forest areas may not receive any designation.

It is important to differentiate between small- and large-scale logging, as the conditions under which they take place differ: Small-scale logging supports rural employment and livelihoods and is usually carried out individually by farmers and people from indigenous communities in private and public lands. (Tacconi et al., 2016, p. 31) They harvest small timber volumes as they rarely have the financial, operational, and logistical capacity to clear large forest areas (Tacconi et al., 2016, p. 25; Noor, Kadir, & Muhamad, 2020, p. 610). In contrast, logging companies have the necessary resources at their disposal to undertake large-scale operations, commonly on the basis of concessions issued for public forest areas (Pacheco et al., 2016, p. 105; Tacconi et al., 2016, p. 32). They typically operate on a profit-oriented basis and supply domestic and international markets, while small-scale producers focus on regional markets if timber is not used for self-consumption (Pacheco et al., 2016, p. 100; Tacconi, Rodrigues, & Maryudi, 2019, p. 2). Most logging operations in the Brazilian Amazon are small-scale (McDermott, Irland, & Pacheco, 2015, p. 138). All commercial logging activities in natural forests in both private and public domain require the approval of a sustainable forest management plan, known as the *Planos de Manejo Florestal Sustentável* [PMFS], and include similar steps in the supply chain (BFS, 2013, p. 70; Greenpeace, 2018, p. 5; Tacconi et al., 2016, p. 32; RFB, 2006, Art. 31).

3.1.2 Supply Chain of Legal Timber

Before delving into the necessary requirements for legal timber, it is important to note that different requirements exist depending on which licensing and control system applies (Costa, Costa, & Barros, 2016, p. 20). The objective of the systems is to document every activity, trace timber products throughout the supply chain, and enforce forest management regulations (Costa et al., 2016, p. 18). Two systems exist in Brazil: The state system *Sistema de Comercialização e Transporte de Produtos*

Florestais [SISFLORA], and the federal system *Sistema Nacional de Controle da Origem dos Produtos Florestais* [SINAFLOR] (Carvalho et al., 2019, p. 127). SISFLORA is operated by the states Mato Grosso and Pará, which account for around 70 percent of timber production in Brazil, while SINAFLOR is adopted by the other states (Carvalho et al., 2019, p. 127). While the systems are largely similar, they contain marked differences – even between the states Mato Grosso and Pará using SISFLORA – that timber companies need to be aware of when engaging in logging or transportation activities (Interview Horowitz-Burdick). An overview summarizing the differences can be found in Appendix Chapter 1.2.

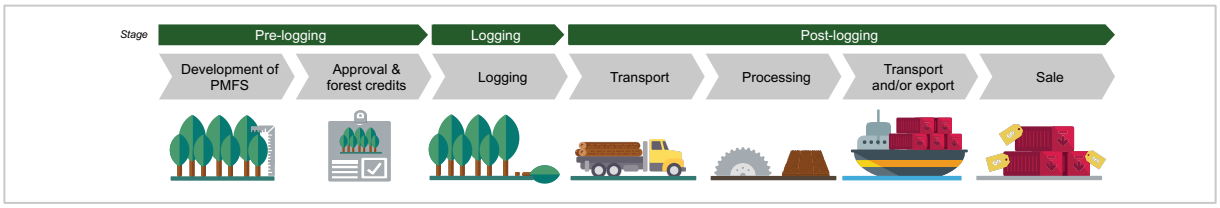


Image 3: Legal timber supply chain (own image based on BVRio, 2017, pp. 7, 17–19)

Common to all systems is the creation of a sustainable forest management plan by a qualified forest engineer, which represents the first step in the legal timber supply chain (Greenpeace, 2018, p. 5). This document contains planned procedures and techniques for conducting, exploring, and managing the forest area in a way that is compatible with the local ecosystem (Greenpeace, 2018, p. 5; RFB, 2006, Art. 31). It, for instance, comprises information on the tree inventory describing quantities, location, species, width, and height estimations of all trees in that area, which trees are to be felled, and mitigating measures for the potentially adverse social and environmental impact (Perazzoni, 2018, pp. 28, 30). A prerequisite for all rural landholders who are initiating the licensing process, is registering their property in the environmental register, known as *Cadastro Ambiental Rural* [CAR], which became mandatory in 2012 (Klingler & Mack, 2020, p. 425). Moreover, both SINAFLOR and SISFLOR require the creation of an annual operation plan, known as the *Plano Operacional Anual*, which details the forest inventory and information on the trees to be extracted (Costa et al., 2016, p. 19).

In the second step, the sustainable forest management plan is submitted for approval to the relevant forest authority and in the case of concessions also to the *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* [IBAMA], the administrative arm of Brazil's Ministry of Environment (Greenpeace, 2018, p. 5; RFB, 2006, Art. 31). If the plan is approved, a timber extraction permit called *Autorização de Explorção Florestal* [AUTEX] is issued in all states except Pará, where the equivalent permit is named *Autorização de Exploração Florestal* as well but abbreviated differently with AUTEF (BVRio, 2017, p. 18; UNEP-WCMC, 2018, p. 6). Additionally, the estimation of the total volume of timber produced of each species – based on the estimated height and trunk numbers provided in the plan – is converted into "forestry credits" that form the basis of the Brazilian government's control system (Greenpeace, 2018, p. 5; Perazzoni, 2018, pp. 29, 31). These credits will be transferred to the approval holder's account in the SISFLORA and SINAFLOR systems (Greenpeace, 2018, p. 6; Perazzoni, Bacelar-Nicolau, & Painho, 2020, p. 2). The systems electronically document transactions, transfer forestry credits, and control the credit balance, which changes with every purchase or transfer made (Perazzoni, 2018, p. 31). With each transaction, the system transfers credits – corresponding to the amount of timber purchased – from the seller's account to the buyer's one (Perazzoni, 2018, p. 29).

In the third step, the approval holder may harvest and sell the designated trees while exercising sustainable forest management after the sustainable forest management plan is authorized (Lima, Castro, Baptista, & Silva, 2020, p. 2; Perazzoni, 2018, p. 28). The harvesting process includes – amongst others

– preparing the necessary infrastructure (e.g., roads), clearing the path of obstacles, planning the cutting approach, felling the trees, measuring the logs, and loading them onto transportation vehicles (Lima et al., 2020, p. 6). In the fourth step, the logs are transported along roads and may reach harbours or landing strips where boats or planes take over domestic or international transportation (UNEP & International Criminal Police Organisation [INTERPOL], 2012, p. 41). Regardless of the transportation method used, a document identifying the timber's origin must accompany all timber from natural forests to its destination (with few exceptions[4]) and be shown to the authorities in case of inspections (NEPCon, 2017, p. 65; Perazzoni, 2018, pp. 30–31; Perazzoni et al., 2020, p. 2). In the states that adopted the SISFLORA system, this document is called *Guia Florestal* [GF] and in states operating under the SINAFLOR system *Documento de Origem Florestal* [DOF] (BVRio, 2017, p. 19). Both the GF and DOF disclose the seller and buyer data, a unique identification number, the transit route, transportation vehicles, transportation date as well as origin, quantities, species, and prices of the products transported (BVRio, 2017, pp. 27–28; Perazzoni, 2018, p. 33; RFB, 2012, Art. 36). In theory, these documents should verify the licit origin of the cargo by allowing authorities and buyers to check whether the transported species, diameter, and volume match the permit and to trace it back to its origin irrespective of where the timber is being transported to (Greenpeace, 2018, pp. 6, 17).

In the fifth step, buyers of the cargo, such as saw and pulp mills, may process the timber into more refined wood products before reselling them (UNEP & INTERPOL, 2012, p. 19). Each processing facility must possess a license to operate and daily report the amount of timber received and delivered in addition to the in- and outputs by product and species to SINAFLOR or SISFLORA (BVRio, 2017, pp. 7, 18). This allows the systems to keep track of the product's volume and transformation, for instance, when it has been cut into boards (Greenpeace, 2018, p. 17; Perazzoni, 2018, p. 31). In the sixth step, the timber may be transported within Brazil for sales to the end consumer or abroad to a wholesaler, processor, or retailer before being sold for final consumption in the last step (Goncalves et al., 2012, p. 18). The SINAFLOR and SISFLORA systems, together with the transport documents DOF and GF, form the government's tracking system that accompanies the timber from the forest to its destination and, in theory, guarantees its origin and legality. During inspections of authorities, the consistency between the data of the transported goods and the data registered in the SINAFLOR and SISFLORA systems is considered proof of legality. (Greenpeace, 2018, pp. 5–17).

The tracking efforts are complemented by monitoring activities, which represent an essential component of Brazil's law enforcement approach (Tacconi et al., 2019, p. 4). The monitoring systems in use are mainly DETER, DETER-B, and PRODES that oversee deforestation and forest degradation in real-time and provide the basis for enforcing environmental laws and combating illegal practices (Assunção & Gandour, 2019, p. 5; Perazzoni, 2018, p. 34). The system DETER acts as the primary monitoring tool in the Brazilian Amazon by using satellite imagery to identify areas where forest loss of over 25 hectares occurred and publishing results monthly for IBAMA and law enforcement to act upon (Assunção & Gandour, 2019, p. 4; Tacconi et al., 2019, p. 4). This system is complemented by DETER-B, which reports on forest loss of over one hectare and is better suited to identify forest degradation due to its ability to differentiate between forest fire damage, selective logging, and degradation (Assunção & Gandour, 2019, pp. 4–5). The system PRODES monitors the annual level of deforestation and detects deforested areas of over 6.25 hectares in the Amazon (Perazzoni, 2018, p. 35). By identifying regions with progressing deforestation or forest degradation, the systems provide valuable insights for law enforcement to plan and execute their operations (Tacconi et al., 2019, p. 4).

[4]For timber from natural forests, the transport document is not required for certain sub-products, such as doors, windows, furniture, wood paste, and cellulose. For timber from plantations, the transport document is not required for exotic tree species (NEPCon, 2017, pp. 64–65).

As a closing remark on legal logging, it should be noted that "legal is not sustainable and sustainable is not legal" (Ozinga & Mowat, 2012, p. 196). Sustainable forest management often goes beyond just fulfilling legal requirements and includes environmental and social practices that may go beyond the law (Ozinga & Mowat, 2012, p. 196). Therefore, legally sourced timber does not automatically guarantee well-managed forests and fair working conditions (Ozinga & Mowat, 2012, p. 196; WWF, 2011, p. 2). Similarly, sustainability is not always legal: In countries where regulations are unjust, undesirable forestry practices may be legal (Ozinga & Mowat, 2012, p. 196). For example, if President Jair Bolsonaro were to follow through with his promise to reduce areas demarcated as indigenous lands and would grant private companies concessionary rights to these lands instead, indigenous people continuing to practice sustainable forest management practices on these lands would be considered illegal loggers (Fellet, 2020, ¶13; Ozinga & Mowat, 2012, p. 196). However, many Brazilian forestry laws and regulations are based on the premise of sustainability, for instance, seen in the sustainable forestry management plan required by the Forest Code, meaning legality is not entirely detached from sustainability (RFB, 2006, Art. 31). Additionally, legality may lead to sustainability since widespread legal compliance means "companies will have a better starting position and are less likely to be undercut by illegal operators [and] it enables governments to implement effective monitoring and planning" (Hoare, 2015, p. 51). Furthermore, given the scope of this paper, the prevalence of illegal logging (see Chapter 3.2), and its serious repercussions (see Chapter 3.4), and the fact that "keeping timber production and trade legal is crucial to the protection of forests [and] sustainable livelihoods" (Hewitt, 2020, ¶1), the focus will lie timber legality, respectively on illegal logging.

3.2 Illegal Logging in the Brazilian Amazon

Illicit logging remains widespread in the Brazilian Amazon as loggers use sophisticated strategies to launder timber on its journey to the end consumer. It is important to understand the different ways of how laws can be violated throughout the supply chain to develop adequate counter measures (Muggah, 2021, ¶2). The elaborations on how illegal timber may be sourced and laundered throughout the supply chain should not be understood as comprehensive as illegal loggers are likely to use other schemes that have remained undetected and "there are still tremendous knowledge gaps when it comes to environmental crime in the Amazon" (Muggah, 2012, ¶2).

3.2.1 Prevalence of Illegal Logging

An exact quantification of the amount of timber logged illegally is challenging due to lacking large-scale data on and the clandestine nature of illicit activities (Wellesley, 2014, p. 24; Sheikh et al., 2019, p. 1). Alexandre Saraiva, former[5] chief of the federal police of the Amazonas state, in 2019 stated that in an optimistic scenario, 90 percent of timber leaving the Brazilian Amazon is illegally harvested (Farias, 2019, ¶1). Estimates from consulted authors range between 50 and 90 percent, indicating that the majority of logging in the Amazon rainforest is carried out illegally (Ortiz, 2019, p. 4; May, 2017, p. 71; Sheikh et al., 2019, p. 1; van Solinge, 2014, p. 37; Tacconi et al., 2019, p. 3). The level of risk for illegal logging occurring depends on the forest type and land ownership (Wellesley, 2014, p. 24). Though illicit activities may take place on plantations, the risk to the legality is lower than for native timber (NEPCon, 2017, p. 9; UNEP-WCMC, 2018, p. 3). Beyond that, Lima et al. (2018) stated that "undesignated Lands are particularly vulnerable to illegal logging and deforestation" (p. 14). This was also observed by Fernandes et al. (2017, p. 497) who found that public forests that do not have a designated use are the most prone to illegal logging.

[5]Alexandre Saraiva was removed from his position after he accused the Minister of Environment Ricardo Salles of obstructing investigations of an illegal logging operations (Mattoso, Serapaião, & Seto, 2021).

In terms of the type of logging, illegal logging is present in both small- and large-scale logging (Kleinschmit et al., 2021, p. 6). High levels of illegality have been observed among small-scale producers and have been difficult to detect despite increasingly advanced remote sensing technologies (Hoare, 2015, p. 13; Kauano, Silva, & Michalski, 2017, p. 3). Likewise, logging companies and organised crime groups[6] have been found complicit in illegal logging (Tacconi et al., 2019, p. 2; WWF, 2021, p. 78). According to Teixeira, Lima, and Ferreira (2018, p. 3167) and the Human Rights Watch (2019, p. 1), a large part of illegal deforestation and forest degradation is driven by such organisations that have the capacity to carry out large-scale timber extractions.

3.2.2 Supply Chain of Illegal Timber

Definitions for illegal logging vary (Goncalves et al., 2012, p. 9). Kleinschmit et al. (2016) define illegal logging as "all practices related to the harvesting, processing and trading of timber inconsistent with national and sub-national laws" (p. 14), which is consistent with definitions used by other authors (Hoare, 2015, p. 2; Ozinga & Mowat, 2012, p. 181; WRI, 2018, p. 5). The restriction to national laws is given since neither an internationally acknowledged definition of the constituents of illegal logging nor an overarching international regulation concerning illegal logging exists (Kleinschmit et al., 2016a, p. 14; WRI, 2018, p. 5). The presented definition takes into account illegal forest conversions (Hoare, 2015, p. 2; The World Bank, 2019, p. 10). Moreover, illegal logging is not restricted to activities in the forest itself but can include subsequent supply chain steps (Kleinschmit et al., 2021, p. 6). While illicit activities may occur in the pre-logging stage, they alone are not sufficient to be attributed to illegal logging since, by definition, logging is "the activity of cutting down trees in order to get wood that can be sold" (Cambridge Dictionary, 2021b) and the authors considered did not include the pre-harvest step in their definitions (Hoare, 2015, p. 2; Ozinga & Mowat, 2012, p. 181; WRI, 2018, p. 5). Nonetheless, it is important to acknowledge the illegal activities occurring in the pre-logging phase since they form the basis of Brazil's entire timber control system (see Chapter 3.1) and lay the foundations for the illegal harvest of thousands of hectares of forests every year (Greenpeace, 2018, p. 6; Piotrowski, 2019, p. 3).

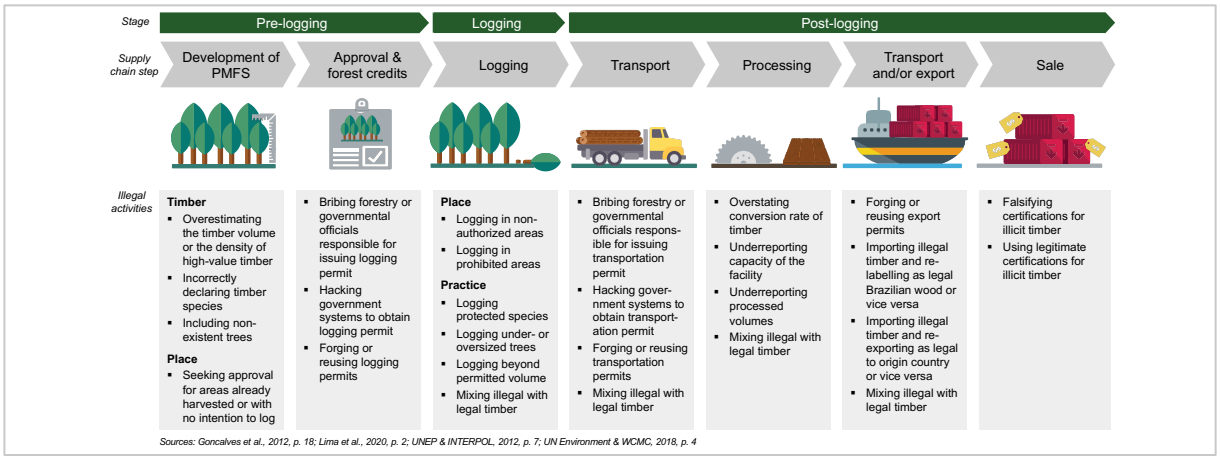


Image 4: Potential sources of illegality in the supply chain (own image based on BVRio, 2017, pp. 7, 17–19)

The strategies used by illegal loggers in the Brazilian Amazon are manifold, and violations of forestry laws can occur at multiple instances of the supply chain (Goncalves et al., 2012, p. 18; Tacconi et al., 2016, p. 30). In the first step, loggers need to present a forest inventory of the area to be harvested and quantify the exact amount of timber available for each species (see Chapter 3.1.2) (Kugler, 2018, ¶4).

[6]Brazilian law defines criminal organisations as a group of four or more people characterized by the division of tasks with the goal of obtaining an advantage through the commission of criminal offenses whose maximum penalty exceeds four years (RFB, 2013, Art. 1 §1).

The main strategies used to deceive the licensing system include overestimating the expected timber volume, misstating the timber species, and listing non-existent trees (Carvalho et al., 2019, p. 124; Greenpeace, 2018, p. 25; Perazzoni et al., 2020, p. 3). For example, in the case of overestimation, the delta between the indicated and the actual timber volume leaves room for laundering illegal timber through the legal logging site as soon as the request gets approved (Tritsch et al., 2016, p. 12). High-value timber appears to be at higher risk of overestimation than low-value timber (UNEP-WCMC, 2018, p. 4): "It seems to be no coincidence that the species whose volumes were commonly overestimated by loggers are exactly the ones of higher commercial value" (Brancalion, 2018 as cit. in Kugler, 2018, ¶8). A study conducted in the eastern Amazonian state Pará found that 74.2 percent of the 33,389 cubic meters of the high-value timber Ipe authorised to be logged in 2017 had a high risk of overestimation. Beyond providing incorrect information on the timber, loggers may request to log in forest areas that have already been harvested or areas where loggers do not intend to harvest but from which they plan to use the forest credits to launder illicit timber. (Brancalion et al., 2018, p. 4).

After the submission of the PMFS, loggers may try to manipulate the licensing process by bribing the officials responsible for approving logging permits, creating fictitious forest credits, or issuing credits in excess of the credits calculated with the PMFS by directly paying officials a fixed commission or a percentage of the extracted timber's value (BVRio, 2017, p. 20; Hoare, 2015, p. 30; UNEP-WCMC, 2018, p. 4). Another strategy includes hacking into the government's control system to access permits and alter records (Perazzoni et al., 2020, p. 3). In one high-profile hacking incident in Pará, hackers working for 107 charcoal and logging companies succeeded in compromising the government's tracking system by modifying existing company records and issuing fake transport permits (UNEP & INTERPOL, 2012, p. 41). According to estimates, they removed around 1.7 million cubic meters of illicit timber worth ca. USD 1.1 billion (Greenpeace, 2008, ¶5). Besides bribery and hacking, loggers may resort to forging or reusing permits: "One company may log an area for a certain volume, then move on to the next, and sell the permit to a second party who will then extract a similar volume of timber from the original area on the same permit" (UNEP & INTERPOL, 2012, p. 32). These described strategies establish the foundations for illegal loggers to harvest, transport, process, and sell timber originating from prohibited or non-authorized areas (Brancalion et al., 2018, p. 4).

Logging activities can be categorised into those that are illegal due to their place and those that are illegal due to their practice (Gutierrez-Velez & MacDicken, 2008, p. 249). The former refers to logging in non-authorized or prohibited areas, which includes protected lands, public forests without a concession, and zones benefiting from permanent protection (see Chapter 3.1) (Brancalion et al., 2018, p. 2; Perazzoni, 2018, p. 25). The latter is defined as logging in authorized areas, but with practices violating the approved PMFS or Brazilian forestry laws (Gutierrez-Velez & MacDicken, 2008, p. 250). Examples include harvesting protected species, under- or oversized[7] trees, and timber in excess of the authorized limit or concession quota (Goncalves et al., 2012, p. 19; Perazzoni et al., 2020, p. 3). In this supply chain step – and during transport, processing, and export – illegal timber may be mixed with legal timber (UNEP & INTERPOL, 2012, pp. 45, 47).

Illegal activities may occur during transport when loggers bribe officers, hack government systems or forge documents to pass control checkpoints or obtain transportation permits, which falsify the origin of the timber products and other product-related information (UNEP-WCMC, 2018, p. 5). The required transportation documents GF and DOF may be falsified by, for instance, declaring a lower transported volume than the actual transported volume (Interview Lentini). Furthermore, the GF and DOF may be

[7]Certain trees are protected due to their particular size and may not be logged (Goncalves, Panjer, Greenberg, & Magrath, 2012, p. 18).

reused multiple times: "You enter the internet, […] you print [the document], you give it to the truck driver, the truck driver comes back and uses the same one for the same transportation event" (Interview Lentini). Processing facilities may overstate the conversion rate of logs to timber to inflate the total volume authorized by the system (BVRio, 2017, p. 20). Chatham House (Wellesley, 2014), an independent policy institute monitoring forest governance in 19 countries, found that "the rate of conversion of logs to sawn timber employed by the [DOF] system (…) is thought to be 10–20 per cent higher than the real conversion rates, which allows additional timber volume credits to be traded or transported" (p. 14). Additionally, processing facilities may understate their total processing capacity or the total volume of wood processed (BVRio, 2017, p. 20; UNEP & INTERPOL, 2012, p. 47).

Of all wood exported from the Brazilian Amazon, around 70 percent is estimated to be illegal (Perazzoni, 2018, p. 24). Illegal loggers may export their goods with forged or reused export permits, for instance, by reusing the same export permit once the uninspected cargo has left Brazilian grounds (UNEP & INTERPOL, 2012, p. 48). Brazil has also been involved in schemes where wood is laundered through complex trade routes: For instance, illegal loggers may export timber to another country (country B), which is then re-imported as "legal" product to country A or re-sold to a third country (country C), disguising its true source (from country A) by assuming an alternate origin from country B (UNEP & INTERPOL, 2012, p. 47; UNEP-WCMC, 2018, p. 4). This trade may occur in reverse as well, as Brazil has acted as a conduit for illegal timber sourced from elsewhere, such as Peru or West Africa, by re-exporting the imported timber to the EU after re-labelling them as Brazilian origin (UNEP-WCMC, 2018, p. 4). In the last step, illegal loggers may falsify certifications or use legitimate certifications for illicit timber (UNEP & INTERPOL, 2012, p. 7).

Note that malicious actors may use different illicit measures based on the funds, manpower, and network available to them (Noor et al., 2020, p. 610). Organised crime groups mainly act through the falsification of forestry credits and misstatement of data in Brazil's timber tracking systems and also infiltrate state agencies by bribing and recruiting public officials (Perazzoni, 2018, p. 24; Teixeira, Rodrigues, & Maryudi, 2018, p. 3167). Small-scale producers, on the other hand, may not have the required funds and network to engage in such practices (Noor et al., 2020, p. 610). Overall, the PMFS and its approval form the first weak link in the timber control system since they enable loggers to generate thousands of cubic meters of fraudulent forestry credits, which are assumed to be legitimate from their creation onwards (Greenpeace, 2018, p. 6). Research suggests that generating a "surplus" of forestry credits to legalise illicit timber is likely to be widespread (Brancalion et al., 2018, p. 3). The various forms of fraud present in the later stages of the supply chain highlight the difficulty in distinguishing between legal and illegal wood and effectively implementing certification schemes, as noted by the UNEP and INTERPOL (2012, p. 23) (Greenpeace, 2018, p. 3). According to Greenpeace (2018), "it is almost impossible to guarantee if timber from the Brazilian Amazon can be assumed to have originated from legal operations, let alone from operations that do not violate human rights or environmental laws" (p. 6).

3.3 Causes of Illegal Logging

The identified illegalities in the logging supply chain are enabled by the interplay of multiple factors rather than the dominance of one single factor (Lin, Lee, & Liu, 2021, 2021, p. 2; Ortiz, 2019, p. 4). These factors can be found in deficiencies of the licensing, control, and monitoring system as well as in issues in the overarching socio-economic and political-legal environment (Lin et al., 2021, p. 2; Ozinga & Mowat, 2012, p. 203; WWF, 2021, p. 78). Note that these factors are not independent of each other but may be intertwined and mutually reinforcing (Lin et al., 2021, pp. 10–11; Noor et al., 2020, p. 609). Additionally, the following elaborations should not be understood as comprehensive since other

contributors of illegal logging exist. Instead, the focus will lie on examining the most important factors that emerged from the literature review. Note that this paper will not address factors related to consumer countries, such as insufficient import regulations on illegal logging, given the scope of the paper and the fact that the discourse around the causes of illegal logging in Brazil has been marked by a strong national character (Greenpeace, 2021, ¶10; Kleinschmit et al., 2021, p. 10).

3.3.1 Timber Licensing, Control, and Monitoring Systems

Various weaknesses in Brazil's timber licensing and tracking system, which the UN Environment Programme and WCMC (2018) have acknowledged as "dysfunctional" (p. 4), facilitate the commission of illegal acts. Examples include the ease of obtaining approval for permits (e.g., Brancalion et al., 2018, p. 4, Carvalho et al., 2019, p. 127), the lack of field inspections (e.g., Greenpeace, 2018, p. 3; UNEP-WCMC, 2018, p. 4), and the insufficient use of scientific and technical parameters (e.g., Carvalho et al., 2019, p. 127; Greenpeace, 2018, p. 10). In the Brazilian Amazon, approvals for logging permits are granted nearly automatically, and the ease of obtaining a permit might even increase further under the Bolsonaro Administration, which is seeking to speed up and simplify the environmental licensing process (Borges, 2018, ¶1; Brancalion et al., 2018, p. 4). Additionally, some licensing authorities are accepting the CAR as the property owner's right to convert or harvest forests within the legal boundaries despite the unverified and self-declared nature of CAR information – estimates number the percentage of fraudulent CAR registries at 30 percent (Aguiar & Torres, n.d., ¶14; Carvalho et al., 2019, p. 127; Ferguson, Sekula, & Szabó, 2020, p. 13). Information found in sustainable forest management plans is also rarely verified by authorities due to a lack of field inspections, leaving room for overestimation and other illegal practices (UNEP-WCMC, 2018, p. 4). In the cases where field inspections are carried out, they may be poorly executed as evidence of a Greenpeace study (2018) suggested "that technical and scientific parameters are not being used in evaluations for licensing by PMFSs" (p. 10). This has been exacerbated by the fact that Brazil's Ministry of the Environment replaced technicians with environmental expertise with people lacking the experience or training (Carvalho et al., 2019, p. 127).

Beyond that, the existence of "petty" corruption (e.g., Pokorny et al., 2016, p. 70; Noor et al., 2020, p. 612) facilitates the occurrence of illegal logging. Petty corruption can be defined as "the exchange of small amounts and normally takes place in the implementation and enforcement of laws and regulations by mid- to low-level government employees" (Pokorny et al., 2016, p. 70). A corrupt forestry official accepting a bribe to allow illegal timber to pass a checkpoint is an example hereof (Noor et al., 2020, p. 612). In Brazil, petty corruption is a well-known and much-reported issue in issuing logging permits and has also been observed in other stages of the supply chain, such as transportation (NEPCon, 2017, pp. 17, 19, 36, 53). Lastly, the interpretation concerning the implementation of forestry law varies between different states and has resulted in incoherencies between different systems (Hoare, 2015, p. 29). Specifically, the inadequate integration of databases contributes to the existence of loopholes in the timber licensing and control system (e.g., Brancalion et al., 2018, p. 4). For example, the SISFLORA system used in Mato Grosso and Pará is not wholly integrated with the SINAFLOR system used in other regions, leaving room for incorrect bookkeeping on forestry credits (Greenpeace, 2018, p. 6).

The monitoring systems also have certain weaknesses that facilitate illegal logging (Tacconi et al., 2019, p. 5). The use of the systems DETER, DETER-B, and PRODES (see Chapter 3.1) for detecting deforestation and forest degradation brings temporal limitations, as data is published on a monthly (DETER), trimonthly (DETER-B) or annual (PRODES) basis (Kalamandeen et al., 2018, p. 7; Klingler & Mack, 2020, p. 424; Perazzoni, 2018, p. 34). There may be a considerable time lag between the occurrence of the deforestation or forest degradation activity and the dispatch of law enforcement

personnel if sent out: "During the period from 2008 to 2013, 45% of deforestation in the Amazon was not detected in time for law enforcement agents to act" (Tacconi et al., 2019, p. 5). Additionally, the systems exhibit technical limitations as they have difficulties with detecting small-scale forest degradation (e.g., Assunção & Gandour, 2019, p. 5; Perazzoni, 2018, p. 35). While DETER-B was developed to counteract this problem and has improved the monitoring system's ability to capture small-scale logging, forest loss of less than one hectare is not detected by all three systems (Assunção & Gandour, 2019, p. 5; Perazzoni, 2018, p. 35). If degraded areas remain undetected, they will not trigger an alert, making it is less likely for law enforcement teams to visit them (Assunção & Gandour, 2019, p. 5). Other factors weakening monitoring efforts include the lack of technical expertise to interpret data (e.g., Carvalho et al., 2019, p. 127; Cerbaro, Morse, Murphy, Lynch, & Griffiths, 2020, p. 14) and the shortage of personnel and equipment to conduct field operations, transit inspections, and export controls (e.g., Cerbaro et al., 2020, p. 14, UNEP-WCMC, 2018, p. 5) (see Chapter 3.3.2).

3.3.2 Socio-economic and Political-legal Environment

Beyond the deficiencies in the licensing, control, and monitoring system, factors of illegal logging are rooted in the socio-economic and political-legal environment in which the supply chain and associated tracking and monitoring efforts are embedded (Ozinga & Mowat, 2012, p. 203). An often-named factor in the socio-economic environment is the maximisation of profits in the short term (e.g., Condé, Higuchi, & Lima, 2019, p. 2; Lin et al., 2021, p. 2; Malamud, 2018, p. 37; Noor et al., 2020, p. 611). When illegal logging occurs, short-term economic gains are prioritized over environmental and social aspects, which depend on maintaining an appropriate level of extracted timber and using sustainable practices (Condé et al., 2019, p. 2). Revenues are maximised by disregarding sustainable harvesting limits, removing wood from non-authorised or prohibited lands, and extracting high volumes of valuable timber (de Lima et al., 2018, p. 2; Perazzoni, 2018, p. 5). One single trunk of the species Ipe, for instance, yields between USD 500 and 1,500 (HRW, 2019, p. 30). Costs are minimised by foregoing sustainable felling techniques, profiting from lower transaction costs, and evading customs and tax payments (de Lima et al., 2018, p. 2). Given the revenue potential and cost savings, illegal logging is highly profitable: Carvalho et al. (2018, p. 403) found the profit margin of illegal logging to be approximately 67 percent, making this business financially rewarding, especially considering the low probability of fines or prosecution. In fact, "illegal logging is the most profitable natural resource crime, outpacing wildlife trafficking, illegal fishing, illegal mining, and crude oil theft" (May, 2017, p. 69). Lentini from IMAFLORA says: "In summary, it's too easy, low risk, and high profits" (Interview Lentini).

Other socio-economic factors, mainly concerning small-scale producers, are poverty (e.g., Goncalves et al., 2012, p. vii; Kleinschmit et al., 2021, p. 7; Lin et al., 2021, p. 2; McDermott et al., 2015, p. 137; WBCSD Forest & WRI, 2014, p. 52) and difficulties to comply with forestry regulations (e.g., Hoare, 2015, p. 2; Kleinschmit et al., 2021, p. 7; Noor et al., 2020, p. 610; Tacconi et al., 2019, p. 5; Wellesley, 2014, p. 25). For people living in economically underdeveloped regions with few job opportunities, illegal logging may provide an essential source of income and fuelwood for private use (Azevedo et al., 2017, p. 7656; Lin et al., 2021, p. 2). An illegal logger from the Peruvian Amazon voices: "I was jobless in Pucallpa for years until I came here. I have a family to feed. It's not that I don't care about our future, I just had nothing else to do" (Tali, 2016, ¶7). The region of the Brazilian Amazon is also affected by poverty: "The region suffers from the highest rates of poverty in Brazil, with nearly 40% of the population below the poverty line in some Northeastern states" (Guedes et al., 2011 as cit. in McDermott et al., 2015, p. 137). Furthermore, small-scale producers may face difficulties to abide by the law: On the one hand, they may face disproportionate temporal and financial costs of compliance, for instance, resulting from lengthy bureaucratic procedures or excessive fees (Hoare, 2015, p. 2; Kleinschmit et al.,

2016a, p. 18). On the other hand, Brazil's complex myriad of regulations has made adherence to legal requirements burdensome, exacerbated by unclear legislation, lacking governmental support, and limited access to information (Hoare, 2015, pp. 2, 14; Tacconi et al., 2019, p. 5; Wellesley, 2014, p. 25).

Furthermore, lacking consumer awareness on timber legality facilitates illegal logging (e.g., EFI & Proforest, 2014, p. 7; Gonzales, 2018, ¶35; UNEP & INTERPOL, 2012, p. 21; Wallen, 2018, ¶1). When purchasing furniture, panels, floors, or other wooden products, few consumers think about where the wood came from (Wallen, 2018, ¶1). Jeanicolau de Lacerda, from the Brazilian Coalition on Climate, Forests, and Agriculture states: "The problem is that certified wood is little known, even among final consumers in rich countries. As long as the [public] doesn't know what they are buying, and do not take a stand, the situation will remain exactly the same" (Gonzales, 2018, ¶35). While B2B consumers are more likely to be aware of the risk of illicit timber, they may still unknowingly purchase illegal timber, for instance, because they did not conduct a thorough assessment of its origin beforehand (WWF, 2015, p. 16). A study conducted by WWF (2015, p. 4) found that from all UK companies, 17 in total, the WWF team had purchased wooden products from, none were able to present evidence of having undertaken due diligence on the timber's legality. The European Forest Institute and Proforest (2014) found that while many businesses "did not actively support illegal production, few had ever sought information on the legality of the timber that they used" (p. 2). Instead, the criteria commonly considered for purchasing decisions were price, quality, and availability (EFI & Proforest, 2014, p. 2). Strong B2C demand for cheap wood suggests that price also played an important buying criterion for end consumers (Hoare, 2015, p. 7; Lin et al., 2021, p. 2). "If consumers are interested only in quality, price and delivery dates and pay no attention to deforestation or degradation involved in the creation of a product, then producers will have no incentive to stop destroying forests" (EFI & Proforest, 2014, p. 7).

National and international demand were named important socio-economic drivers of illegal logging (e.g., Fern, 2021, ¶2; Lin et al., 2021, p. 2; Kimbrough, 2020, ¶2; Kleinschmit et al., 2021, p. 6; UN & Environment & WCMC, 2018, p. 3). Massive demand for timber, plywood, pulp, paper, and other wooden products fuels illegal logging to the extent that "the legal timber trade is reported to be insufficient to meet demands, meaning harvest is supplemented by the illegal trade" (UNEP-WCMC, 2018, p. 3) (Kleinschmit et al., 2021, p. 6; Wellesley, 2014, p. 12). Demand for commodities, such as soy, beef, cacao, and palm oil, represents an indirect driver of illegal logging, as these commodities require cleared land for cultivation or livestock farming and the preceding step of forest conversion entails timber removal (see Chapter 2.2) (Ortiz, 2019, p. 4). Continued population growth worldwide and rising per capita income are expected to accelerate demand for such commodities (Aguiar & Vieira, 2016, p. 1823; UN, 2017, p. 3). Growing demand provides legally and illegally operating producers an incentive to expand their activities in the rainforest (Amazon Watch, 2019, p. 17).

Illegal logging is also driven by Brazil's economic development strategy (e.g., Fearnside, 2017, p. 1; Haupt, Bebbington, & Bebbington, 2020, p. 88; Pokorny et al., 2016, p. 62; Moutinho, Guerra, & Azevedo-Ramos, 2016, p. 4; Ortiz, 2019, p. 4). The country's economic development has depended on forest exploration in the past and will continue to rely on it in the near future since the government has locked in what Carlos Nobre calls a "deforestation-based model of development" (Volckhausen, 2019, ¶19) (Haupt et al., 2018, p. 88). This model builds on driving economic expansion in the Amazon and promoting large-scale infrastructure projects that open up untouched forest areas (Klingler & Mack, 2020, p. 425; Phillips & Briso, 2020, ¶19). For example, in April 2021, the Ministry of Infrastructure received authorisation for reconstructing highway BR-319, which would split the Brazilian Amazon in half and give access to vast areas that had remained intact due to lacking access (Fearnside, Ferrante, &

de Andrade, 2020, ¶6; Ministério da Infraestrutura, 2021, ¶1). Philip Fearnside, a research professor at INPA, warns this is "the beginning of the end for Brazil's Amazon forest" (Fearnside, 2020, ¶1). Transport infrastructure in the form of roads and highways have a massive impact on forests as they serve as entry points for new economic actors, large transportation vehicles, and heavy industrial machinery, enabling the expansion of both legal and illegal activities that further forest degradation and conversion (Fearnside, 2017, p. 1; Pokorny et al., 2016, p. 67; Kleinschmit et al., 2021, p. 7). Moreover, new roads promote the construction of illegal roads: Haupt et al. (2020, p. 17) estimate that in Brazil, three kilometres of illegal roads are built for every kilometre of legal road.

One of the most-named factors in the political-legal environment is the current government in power (e.g., Carvalho et al., 2019, p. 127; Kleinschmit et al., 2021, p. 9; HRW, 2019, pp. 9–11; Londoño, Andreoni, & Casado, 2020, ¶6; Observatório do Clima [ODC], 2021, pp. 18–19). The Administration that took office in 2019 "has a markedly anti-environmental stance both in rhetoric and practice" (Carvalho et al., 2019, p. 127): Both the President and until recent Minister of Environment Ricardo Salles have been accused by environmentalists of supporting illegal loggers (Camargo, 2020, ¶3; Harris, 2021, ¶10; ODC, 2021, p. 18). In fact, Salles resigned from his position in June 2021 amid two criminal investigations on his alleged ties with illegal logging (Stubley, 2021, ¶1). All former Ministers of Environment alive – eight in total – accused the current government of promoting a "política sistemática, constante e deliberada de destruição das políticas meio ambientais[8]" (Gortázar, 2019, ¶1). An example hereof is the reversal of timber export regulations: While most wood exports previously required IBAMA's authorization before receiving an export license, only a few exceptions need it after the change, ensuring all future unauthorized shipments – once perceived as illegal – became legal, opening a plug for large-scale illegal timber exports (Borges & Branford, 2020, ¶12, 13; Spring, 2020a, ¶4, 19, 25). Furthermore, the Bolsonaro Administration has weakened environmental agencies by removing 21 of 27 IBAMA directors, slashing the budgets of IBAMA and ICMBio by over 30 percent in 2019 and 2020, and proposing a cut of 27.4 percent in the 2021 federal budget set aside for environmental inspections and forest fire response (Harris, 2021, ¶10; HRW, 2019, p. 2; Müller, 2020, p. 24). The President has publicly criticized Brazil's environmental agencies, referring to them as "industries of fines" and promising to end the "festival" of environmental sanctions (HRW, 2019, p. 10). "Bashing government agencies is like music for illegal economic actors. Loggers understand Bolsonaro's statements as authorisation to act" (HRW, 2019, p. 132).

The Bolsonaro Administration has implemented measures that exacerbate existing power asymmetries between powerful economic groups on the one hand and indigenous people and other small-scale actors on the other hand (Kleinschmit et al., 2021, p. 7). These power disparities have been acknowledged as an important political-legal factor contributing to illegal logging (e.g., Carvalho et al., 2019, p. 127; Kleinschmit et al., 2021, p. 7; Kröger, 2017, pp. 28–29; Lin et al., 2021, p. 1; Moutinho et al., 2016, pp. 4–5). Due to their resources, privileges, and connections with decision-makers, many economic players have the power to lobby for their interests, often at the cost of smaller actors (Pokorny et al., 2016, p. 64). The extractive industries' lobby has been pushing to open up large parts of the Amazon, including indigenous lands and protected areas, for large-scale extractive activities (Miranda, 2021, ¶2). Supported by the Administration, they developed multiple bills, which would restrain the demarcation of indigenous lands, allow extractive activities on indigenous territories, pardon land grabbing, and ease environmental constraints for certain actors, if approved (Miranda, 2021, ¶2, 6). For instance, Bill 3729/2004 ratified by the Senate exempts certain business activities, including extensive cattle farming and semi-intensive agriculture, from environmental licensing and allows a form of self-declaration,

[8]English translation: systematic, constant and deliberate policy of destruction of environmental policies.

where companies can assess and verify the impacts of their business activities themselves (Dantas, 2021, ¶3, 8; Miranda, 2021, ¶12). Given the power imbalances, small-scale actors may find it challenging to resist these developments (Haupt et al., 2020, p. 60; WWF, 2021, p. 35).

"Grand" corruption, like its counterpart petty corruption (see Chapter 3.1.1), contributes to illegal logging in Brazil (e.g., Blarel, 2019, ¶5; Kleinschmit et al., 2021, p. 6; Perazzoni, 2018, p. 24; Schipani, 2019; Wellesley, 2014, p. 23). Grand corruption occurs when substantial amounts of money are used to obtain an illicit advantage and commonly involves high-ranking politicians, judges, civil servants, police or military officers in connection with awarding concession licenses, influencing bureaucratic processes, or receiving protection from legal procedures (NEPCon, 2017, p. 11; Noor et al., 2020, p. 612; Schipani, 2019). Large-scale illegal loggers are more likely than small-scale actors to be involved in grand corruption due to their power, widespread networks, and available means (Noor et al., 2020, p. 610). In 2010, the Federal Police exposed a scheme in which a total of 1.5 million cubic metres of timber were illegally extracted from the Amazon, affecting an area the size of Spain, and resulting in around USD 500 million in damage to the rainforest (Perazzoni, 2018, pp. 23–24). Over 90 people were arrested, ranging from private landowners to high-level government officials, such as the then governor of Mato Grosso, a former Deputy Secretary of Environment, and the then deputy secretary of the State Rural Development Agency (Neme, 2010, ¶4; Perazzoni, 2018, p. 24). Similarly, an investigation in 2015 revealed the involvement of high-ranking officials at the federal (e.g., IBAMA, INCRA), state (e.g., SEFA, SEMAS), and municipal level (Tacconi et al., 2016, p. 28).

Corruption undermines effective law enforcement, which is critical for punishing present offenders and deterring future ones from engaging in illegal activities (European Commission [EC] 2014, p. 2; Goncalves et al., 2012, p. 8). Brazil's current law enforcement system is characterized by several weaknesses that have promoted illegal logging (e.g., Chen et al., 2021, p. 1; Kleinschmit et al., 2021, p. 7; Malamud, 2018, p. 38; Wellesley, 2014, pp. 6, 10; WWF, 2021, p. 79). During the investigation phase, law enforcement teams struggle to conduct proper investigations partially due to poor coordination between the involved institutions and departments at the federal and state level and, since recently, the missing support of IBAMA and ICMBio, which suffered large budget cuts (Hanbury, 2021, ¶13; Tacconi et al., 2019, p. 5). The probability that illegal loggers in Brazil are penalized for harvesting illegal timber was numbered at less than 0.08 percent in a UN study (NEPCon, 2017, p. 10). Penalties, when imposed, are often inadequate in relation to the committed forest crime and are rarely collected (Wellesley, 2014, p. 26; Schipani, 2019): Estimates for the percentage of fines imposed that were ultimately paid range from five to ten percent depending on the source consulted (Eaton, 2018, p. 20; Tacconi et al., 2019, p. 5; UNEP-WCMC, 2018, p. 4). Even perpetrators of serious crimes may not suffer the legal consequences of their actions since "Brazil's legal system is both notoriously slow and allows for a virtually endless succession of appeals, with the result that for environmental infractions a violator with money for legal defence can avoid punishment almost indefinitely" (Carvalho et al., 2019, p. 127). Overall, the current law enforcement system does not constitute a significant deterrent but instead contributes to the perception of high levels of impunity among illegal loggers (HRW, 2019, p. 12; Klingler & Mack, 2020, p. 433; Londoño et al., 2020, ¶23; Schipani, 2019). "Law enforcement has reached its minimum effectiveness in a decade" (Nobre, 2019 as cit. in Sandy, 2019, ¶7).

One field that is negatively affected by weak law enforcement is the enforcement of property rights (Faria, Júnior, & Montenegro, 2019, p. 1961). Issues around land tenure have been recognised as a contributor to illegal logging in the Brazilian Amazon (e.g., de Lima et al., 2018, p. 13; Faria et al., 2019, p. 1961; Fernandes et al., 2017, p. 497; Kleinschmit et al., 2021, p. 7; UNEP-WCMC; 2018, p.

4). Undesignated public lands are particularly vulnerable to land grabbing, especially when ownership rights are not adequately protected (de Lima et al., 2018, p. 1). Simulations run by de Lima et al. (2018) found that "up to 69 and 40% of the baseline timber volume from Federal and State Undesignated Lands, respectively, could be subject to illegal logging in 30 years" (p. 14). On the other hand, ownership rights of designated lands in many parts of the country remain unclear, insecure, or hard to prove (Magalhaes & Trevisani, 2020, ¶21; Sparovek et al., 2019, p. 1). The existing legislation on land tenure has been perceived as "dysfunctional" (NEPCon, 2017, p. 10), partially due to lacking regulation and improper recording of property registers, which has led to land disputes between settlers, farmers, indigenous people, and other groups (Faria et al., 2019, p. 1961). These conflicts are exacerbated by forged ownership documents and Bolsonaro's refusal to recognize additional indigenous lands, of which 246 are still awaiting demarcation (Ennes, 2021, ¶12; NEPCon, 2017, p. 10). The President stated that "Não demarcarei um centímetro quadrado a mais de terra indígena[9]" (Hirabahasi, 2018, ¶1).

The capability to enforce environmental law, manage public lands, approve licensing requests, track timber shipments, and monitor logging activities is weakened by limited institutional capacity (Lin et al., 2021, p. 3; Paiva et al., 2020, p. 32; UNEP-WCMC; 2018, p. 3), an often-named factor facilitating illegal logging (e.g., Brancalion et al., 2018, p. 1; Paiva et al., 2020, p. 32; Piotrowski, 2019, p. 9; UNEP-WCMC, 2018, p. 3; Wellesley, 2014, p. 16). Many illegal timber shipments go unnoticed due to limits in resources, which have become even more pronounced in light of the recent budget cuts (Piotrowski, 2019, p. 9). An analysis by the Climate Observatory [ODC] (2021, p. 11) revealed that the expected total governmental budget allocated for environmental affairs in 2021 reached the lowest levels in two decades, leading to a reduced number of staff. For instance, IBAMA, the main environmental enforcement agency, has 681 agents at disposal to enforce the law in the entire country, signifying a decrease of 48 percent of its agents in 11 years (Sassine, 2019, ¶1; Shalders, 2021, ¶24; Spring, 2021, ¶1). Shortages in personnel already existed in the past: In 2018, the state environmental agency in Pará, for instance, had 55 officers available to evaluate requests for logging licenses, conduct field inspections to verify data, and approve applications – when deemed duly – for an area nearly the size of Peru (Brancalion et al., 2018, p. 1). In 2018, IBAMA had four officers available for patrolling over 17 million hectares of forests in Mato Grosso, roughly the size of Austria and Portugal combined (Piotrowski, 2019, p. 9). Given the vastness of the Brazilian Amazon, equalling the size of Europe, and the comparatively low number of agents available, "[there] are places where the state's power, judicial power doesn't reach" (Cutrim, 2019 cit. in Sullivan, 2019, ¶20) (Filho, 2019, p. 11).

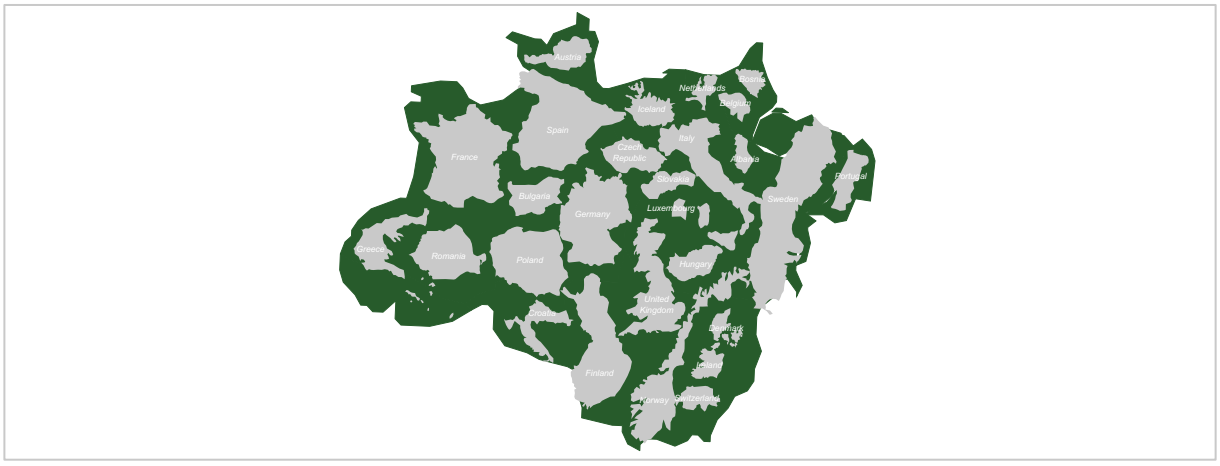


Image 5: Comparative size of the Brazilian Amazon vs. Europe (own image based on Filho, 2019, p. 11)

[9]English translation: I will not demarcate one more square centimetre of indigenous land.

3.4 Repercussions of Illegal Logging

Not all impacts from illegal logging are negative, especially when taking a short-term view (Kleinschmit et al., 2016b, p. 134). Certain stakeholders, such as consumers who benefit from lower prices caused by illicit timber may reap the benefits (Sheikh et al., 2019, p. 1; UNEP & INTERPOL, 2012, p. 7). Additionally, individual small-scale loggers, indigenous people, and local communities may profit from illegal logging by gaining an additional source of income (Kleinschmit et al., 2016b, p. 134). However, from a broader perspective, illegal logging is associated with serious negative environmental, societal, and economic implications, which are closely intertwined and multifaceted (Kleinschmit et al., 2016b, p. 134; Noor et al., 2020, p. 608). These negative repercussions outweigh the positive ones, as private gains – often relatively short-lived – mostly accrue to a few at the detriment of the many, undermining national and international commitments to climate change mitigation, sustainable development, and environmental conservation (see Chapter 2.2) (Lovejoy & Nobre, 2019, p. 1; Ozinga & Mowat, 2012, p. 203; The World Bank, 2019, p. 8; WWF, 2011, p. 3).

3.4.1 Environmental Repercussions

On the environmental level, illegal logging results in the degradation and the loss of the rainforest: An analysis conducted by the NGO Imazon showed that for each tree felled without sustainable forest management – as is typically the case with illegal logging – another 27 trees are damaged (Hoare, 2015, p 1; Müller, 2020, p. 19). The more degraded forests become, the less resilient they are to natural or induced forest fires, acting as "fire bridges" to intact forests nearby (Müller, 2020, p. 17). Fires rarely occur naturally but are typically set by loggers after felling trees to clear the area for agricultural or other purposes (see Chapter 2.2) (HRW, IPAM, & IEPS, 2020, p. 9; Sullivan, 2019, ¶9). In fact, according to Alberto Setzer, a scientist at Brazil's space agency INPE, "99% percent of the [Amazonian] fires result from human actions 'either on purpose or by accident'" (Yeung, 2019, ¶6). These fires contribute to the erosion of Brazil's natural resource base and the destruction of habitats for flora and fauna (EC, 2014, p. 2; Hoare, 2015, p. viii). Beyond the extractive ecosystem services, illegal logging also negatively affects non-extractive ones (The World Bank, 2019, p. 8).

Illegal logging causes loss of biodiversity, which jeopardizes the balance of the entire ecosystem since biodiversity represents an integral part of a healthily functioning ecosystem (Lovejoy & Schmitz, 2020, ¶4, 10; Perazzoni et al., 2018, p. 23). Furthermore, as a major driver of degradation and deforestation in the Amazon (see Chapter 2.2), illegal logging also advances changes in the hydrological and climate system: On deforested lands, more than half of the rainwater runs off, which is problematic since the rainforest usually generates its own rainfall through recycling mechanisms (Lovejoy & Nobre, 2018, p. 1; Lovejoy & Nobre, 2019, p. 1). Extreme climate swings[10] in the Amazon are intensifying as both record dry and record wet events have been observed (Hanbury, 2020, ¶15). The rainforest experienced heavy floods in the years 2009, 2012, and 2014, and severe droughts in 2005, 2010, and 2015 (Hanbury, 2020, ¶15; Nobre et al., 2016, p. 2). In addition, illegal logging influences the role of the Amazon as a carbon sink: A study led by INPE researcher Luciana Gatti discovered that around 20 percent of the Amazon rainforest is releasing instead of storing carbon emissions (Davidson, 2020, ¶1). Other studies provide further evidence of the reduced capacity of the Amazon as a carbon sink (see Baccini et al., 2017; Brienen et al., 2015). Beyond that, illegal logging also undermines other ecosystem services, such as water filtration and soil erosion prevention (The World Bank, 2019, p. 8).

If the destruction of the Amazon rainforest continues, "(…) today's environmental problems become tomorrow's catastrophes" (Serkez, 2020, ¶1). Carlos Nobre and Thomas Lovejoy, who coined the term

[10]These extreme climate swings are not only driven by illegal logging activities, but also other factors, such as climate change (Hanbury, 2020, ¶13).

biodiversity, found that the Amazon is approaching a tipping point after which the forest commences a self-destruction process that humankind will be unable to halt (Dennehy, 2016, ¶15; The Economist, 2019, ¶3). Trees would dry out and die during this process, advancing the conversion of large parts of the landscape into tropical savanna (Carvalho, 2020, ¶8; The Economist, 2020, ¶1). The consequences of this forest dieback, which include the extinction for tens of thousands of animals and plant species and the release of 80 to 100 billion tonnes of carbon into the atmosphere, would be dire (Nobre, 2019, ¶2; The Economist, 2019, ¶3). It is estimated that the tipping point will be transgressed at 20 to 25 percent, factoring in global warming and increased vulnerability to fire (Lovejoy & Nobre, 2018, p. 1). Deforestation was estimated at 17 percent across the entire rainforest in 2019, with an upward tendency considering the current deforestation rates (Lovejoy & Nobre, 2019, p. 1). The heightened frequency of extreme floods and droughts, the extended dry seasons, and the increased mortality rates of certain species may represent the first flickers of this tipping point (Lovejoy & Nobre, 2019, p. 1). Though some arguments suggest that forest dieback in the Amazon may be less probable or occurs at a higher rate than the one suggested by Lovejoy and Nobre, it is still premature to rule out this scenario (Amigo, 2020, ¶12–13; IPCC, 2014, p. 309; Lapola et al., 2018, p. 11671).

3.4.2 Societal Repercussions

Illegal logging not only negatively affects the environment, but also societies on the local, national, and global levels (Ortiz, 2019, p. 4). The parties involved in illegal logging activities may generate profits from timber that does not rightfully belong to them: Each time illegal logging occurs on private lands, the local inhabitant loses out on income (UN, 2017, p. 3). The inhabitant and his community may also lose access to foods, construction materials, fuelwood, and medicine, since illegal logging results in the loss or degradation of forests (Ding et al., 2016, p. 1). In turn, food insecurity, unemployment, and poverty may increase since many communities depend on the rainforest for subsistence, employment, and livelihoods (Gray et al., 2015, p. 1; Gutierrez-Velez & MacDicken, 2008, p. 249). In extreme cases, illegal logging may also result in the displacement of local communities to the detriment of their cultural and ancestral heritage (Ortiz, 2019, p. 4). To'o from the Awà tribe in the Brazilian Amazon remarks: "We live in the depths of the forest and are getting cornered as the outsiders close in. We are always fleeing. Without the forest, we are nobody and have no way of surviving" (UNEP & INTERPOL, 2012, p. 51). As a last resort, indigenous communities may completely abandon living in the rainforest and migrate to cities instead (Yirka, 2018, ¶2). When indigenous communities decide to stay and defend their territory, they often put themselves into danger as illegal loggers often threaten, attack, and sometimes even murder the people standing in their way: This danger not only applies to indigenous people but also to government officials, environmentalists, and other land defenders (HRW, 2019, pp. 1–2; Londoño, Andreoni, & Casado, 2020, ¶38). In 2019 Brazil ranked third among the world's deadliest countries for land defenders (Global Witness, 2020, p. 9). Overall, illegal logging may contribute to the violation of several human rights, such as the right to own property (Article 17), the right to an adequate standard of living (Article 25), and even the right to life (Article 3) (Hoare, 2015, p. viii; UN, 1948, pp. 2, 5, 7).

The negative social repercussions reach far beyond the local communities and also concern the Brazilian population. Whenever loggers illegally fell timber on public lands, the Brazilian government is deprived of fiscal revenue, which in turn reduces its investment capacity for public education, healthcare, social welfare programs, and other areas of public expenditure (de Lima et al., 2018, p. 1; Schatz & Jenkins, 2020, ¶3). Moreover, the man-made fires in the Amazon may not only adversely influence the local population but also people throughout the country (HRW, 2020, ¶1). In 2019, the fires in the rainforest-covered areas as far away as São Paulo – a city situated over 3,000 km away from many blazes – with

smoke, poisoning the air which millions of Brazilians breathe (HRW, 2020, ¶3; Woodward, 2019, ¶3). According to a report by the Human Rights Watch, the Amazon Environmental Research Institute, and the Institute for Health Policy Studies (2020, p. 1) the exposure to harmful air population resulted in 2,195 hospitalisations attributable to these fires. They believe that the health impact goes beyond these cases since many people may have limited access to healthcare institutions and the number does not encompass people with respiratory problems, which – though serious – did not require treatment in the hospital (HRW et al., 2020, p. 2).

Besides the local and national impact, illegal logging also entails implications for society on a global level. The negative impact of illegal logging on biodiversity, hydrological systems, carbon storage capacity, and other non-extractive ecosystem services reduce human well-being for the present and future generations (Lovejoy & Nobre, 2019, p. 1). Additionally, human intrusion into the rainforest increases the risk of zoonoses, defined as infectious diseases transmitted from animals to humans (The World Bank, 2019, p. 16; WHO, 2020, ¶1). For example, Thomas Lovejoy suggests that human's excessive intrusion into nature is partially responsible for the emergence of the COVID-19 disease, which is causing countries unprecedented economic and social costs and affecting the vulnerable and poor disproportionally (Ahmad, 2020, ¶1; Troëng, Barbier, & Rodríguez, 2020, ¶5; Weston, 2020, ¶12). The risk of future pandemics materialising increases with rising deforestation and degradation activities: "Every hectare of the Amazon that is cleared takes us closer […] to the next pandemic," (Harris, 2020a, ¶5) according to Tanya Steele, CEO of WWF in the United Kingdom.

3.4.3 Economic Repercussions

In terms of economic repercussions, illicit activities create an unfair disadvantage for legally operating companies in the timber industry (Schatz & Jenkins, 2020, ¶4). First, illegal loggers make reduced or no forestland payments since they may unlawfully seize free timber from public or private lands (Azevedo-Ramos, Silva, & Merry, 2015, pp. 4–6). Second, legally operating companies typically have limits regarding the total timber harvested due to their interest in sustainably harvesting the forest over the long term and the limitations defined in the PMFS or concession agreement (Greenpeace, 2018, p. 5). In contrast, wood is abundant for illegally operating companies (Perazzoni et al., 2020, p. 3). Third, these companies do not pay any royalties, taxes, and other fees to the government on the illegally harvested timber, undermining legitimate companies that are subject to tax and other expenses (Azevedo-Ramos et al., 2015, p. 3; WWF, 2020, ¶4). Fourth, illegal loggers do not bear the costs of paying fair wages, covering employee benefits, and managing forests sustainably, while legal loggers must often provide for employee well-being and adhere to sustainable practices, such as reduced impact harvesting techniques (Kleinschmit et al., 2016b, p. 135; Ozinga & Mowat, 2012, p. 182; Azevedo-Ramos et al., 2015, pp. 4–5). Though illegally operating companies may carry other costs, such as payments for bribing officials, their total additional savings exceed their additional expenditures, making it a highly profitable business (see Chapter 3.3.2) (Hoare, 2015, p. 30; UNEP & INTERPOL, 2012, pp. 6–7). This secures them a competitive advantage, which, in turn, distorts the wood market and punishes honest timber companies that are operating in a low-margin environment (Goncalves et al., 2012, p. 2; Ozinga & Mowat, 2012, p. 182; Šulyová & Koman, 2020, p. 8). Swiss timber company Precious Woods, for instance, states: "That [illicit] production does not pay taxes, does not bear the costs of a proper forest management [plan], so it is 30 percent to 40 percent cheaper. Our company, for instance, cannot compete with the illegal timber sold in the Brazilian market" (Gonzales, 2018, ¶35).

Due to their leaner cost structure and their ability to harvest high volumes of free timber, such companies significantly increase the wood available in the market, pushing prices down (Brancalion et al., 2018, p.

4). It is estimated that the world prices of timber prices are 7 to 16 percent lower due to illegal logging (Sheikh et al., 2019, p. 1). This price reduction, in turn, decreases the profitability of legally operating companies and increases the incentives for them to follow illicit practices, starting a vicious cycle in the industry (WWF, 2020, ¶4). Besides depressing market prices, illegal logging also undermines consumer confidence in legal and sustainable wood, making them question whether wood classified as sustainable was harvested in an environmentally and socially responsible manner and whether the timber available in the market was logged in accordance with the law (Guertin, 2003, p. 7). The recent deforestation developments in Brazil have shaken consumer confidence even further and set off calls to boycott Brazilian products, which concerns the timber and other industries in Brazil (Londoño et al., 2020, ¶33; Magalhaes & Trevisani, 2020, ¶18). The developments also triggered a response from corporate clients: In 2020, over 40 European companies warned they would boycott products made in Brazil if the government did not act on deforestation (Harris, 2020b, ¶12). Overall, these aforementioned points discourage legitimate companies from investing in legal and sustainable practices as they suffer a competitive disadvantage in global markets, and their efforts to invest in legal and sustainable forest management may not be rewarded (Goncalves et al., 2012, p. 2).

The informal timber sector also brings about numerous negative economic consequences for the Brazilian government. The shortfall in government income stifles Brazil's economic development: On the one hand, illegal logging results in foregone revenues in the form of corporate taxes, royalties, and other fees and creates considerable costs associated with uncovering and prosecuting illegal logging (The World Bank, 2019, pp. 8, 16; WWF, 2020, ¶3). On the other hand, the government loses out on taxes since people employed in the informal sector work unofficially (The World Bank, 2019, p. 16). Moreover, the informal sector contributes to unemployment since activities, such as extensive land-use planning and sustainable forest management, are typically avoided, while these would create new jobs in the formal sector (de Lima et al., 2018, pp. 2–3). Lastly, illegal logging may deter foreign investors from investing, banking institutions from providing financial services, and international organisations from offering aid (Contreras-Hermosilla, 2002, p. 12). In 2020 a group of 29 global investment companies managing USD 3.7 trillion wrote, "the escalating deforestation in recent years, combined with reports of a dismantling of environmental and human rights policies and enforcement agencies, are creating widespread uncertainty about the conditions for investing in or providing financial services to Brazil" (Spring, 2020b, ¶3) and demanded the Brazilian government to act (Spring, 2020b, ¶1).

The repercussions of illegal logging on the ecosystem services have adverse effects on the economy. The loss of extractive resources and biodiversity may result in the disappearance of undiscovered medicine, impacting the pharmaceutical industry (Lovejoy, 2019, ¶5). Alterations in the hydrological system concern industries heavily dependent on water, such as the hydropower sector, while extreme climate changes adversely affect sectors that are particularly vulnerable to natural hazards, such as the agricultural sector (Hanbury, 2020, ¶18; Harris, 2020a, ¶13). The transgression of the tipping point – driven by illegal logging and other factors – would exacerbate the adverse effects: The transformation of large areas of the Amazon rainforest into savanna-like conditions would significantly reduce the rainforest's ability to provide resources, such as foods, timber, and medicine, which many sectors depend on (The Economist, 2019, ¶3). Local economies would suffer too since many communities rely on forest products for their livelihoods and rivers for travel, fishing, and drinking water (Hanbury, 2020, ¶6). Reduced generation of hydroelectric power, decreased crop yields, and diminished fish stock are only some of the many consequences: Rammig et al. (2018, p. 3433) estimate the long-term losses of a large-scale Amazon dieback to be between USD 1,367 and 6,928 billion.

4 Corporate Action to Combat Illegal Logging

Given the high levels of illegality in the Brazilian Amazon and its severe environmental, social, and economic consequences, action is required. Although substantial progress has been made in the past years, illegal logging remains prevalent (Kauano et al., 2017, p. 2). The contribution of all actors – the private sector, the Brazilian government, international governments, intergovernmental organisations, civil society organisations, consumers, and other stakeholders – is required to target illegal timber at its root causes (Interview Professor; WWF, 2021, p. 38). Due to the research focus, the thesis will centre on the role of the companies at every stage of the supply chain, namely loggers, processers, importing and exporting companies, and retailers (European Forest Institute [EFI], 2014, p. 1). Corporate action for other private sector players, such as certification companies or auditing companies, will not be outlined, though some of the insights gained and measures developed may also apply to them. The following chapters will discuss the corporate responsibility of tackling illegal logging and subsequently describe the set of actions that companies can take.

4.1 Corporate Responsibility

With its extensive resources, investment potential, and wide business network, private sector companies have a critical role in preventing, detecting, and prosecuting illegal logging (EC, 2018, p. 12; The World Bank, 2019, p. 32). "For companies in the timber and paper products value chain, what is considered 'business as usual' has changed drastically over the last few years with heightened global policy attention on deforestation and forest degradation" (WWF, 2017, p. 8). Due to the adverse impact of illegal logging (see Chapter 3.4), stakeholders are increasingly demanding assurance that timber products are produced legally and sustainably while respecting fair labour practices (WRI, 2018, p. 6). Many governments have announced policies on purchasing sustainable and legal timber and tightened regulatory requirements for the industry to protect forest resources (EFI & Proforest, 2014, p. 8; Hoare, 2015, p. 49). Some investors have developed investment criteria to exclude illegal logging and deforestation, while environmental advocacy groups have launched campaigns against companies to provoke action against illegal logging and deforestation (EFI & Proforest, 2014, p. 8). Beyond that, public concern about forest degradation, climate change, and biodiversity loss has grown alongside calls for companies to assume their corporate responsibility (Lambin et al., 2018, p. 1).

Corporate responsibility has been discussed in Europe since the beginning of the millennium under the heading of "Corporate Social Responsibility" [CSR], though its roots go back as far as 1953, the year where Harold Bowen published his book "Social Responsibilities of the Businessmen" (Ramasastry, 2015, p. 239). Though there is no universally recognised definition of CSR, it can be understood as an umbrella term for the discussion of "responsibilities of business and its role in society, including categories such as business and society, business ethics, or stakeholder theory" (Scherer & Palazzo, 2007 as cit. in Ramasastry, 2015, p. 239). CSR goes beyond philanthropy and volunteerism and involves improving a company's business activities to avoid harmful effects on people and the planet and thus, concerns the manner of how profits are generated (Bader, 2012, ¶6). Besides moral reasons, timber companies can take up their responsibilities and implement measures against illegal logging for a myriad of reasons (Hoare, 2015, p. 49). For example, benefits could include higher employee satisfaction (e.g., WWF, 2017, p. 4), an increased competitive advantage (e.g., Lima et al., 2020, p. 13), and a strengthened company brand (e.g., Lambin et al., 2018, p. 1). Moreover, reputational, financial, legal, and boycott risks can be mitigated (WRI, 2018, p. 6; WWF, 2021, p. 44). Given the increasing pressure from stakeholders, moral reasons, associated benefits, and risk reduction, timber companies are encouraged to assume their responsibility and adopt measures to address illegal timber.

4.2 Corporate Strategies to Address Illegal Logging

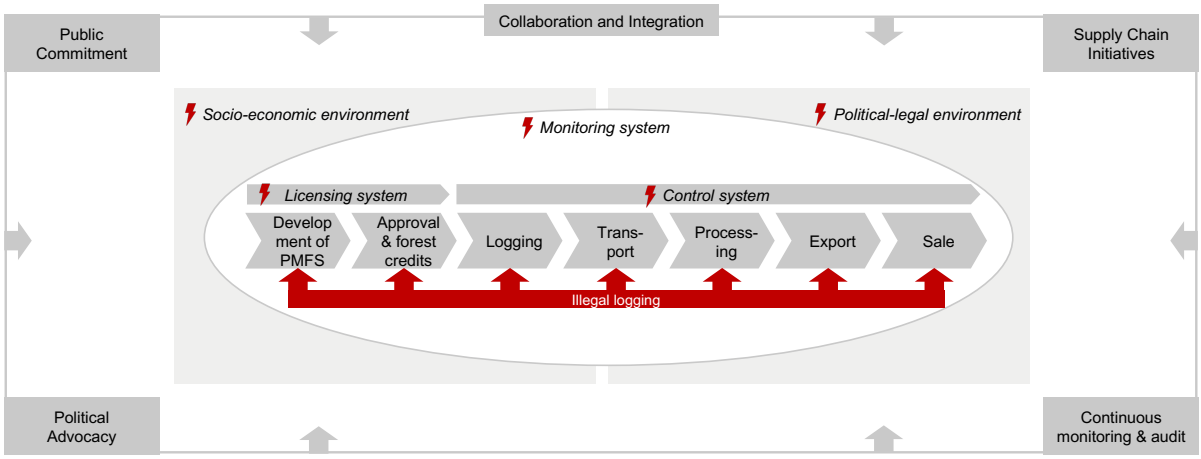


Image 6: Framework of corporate action (own image)

The analysis of the causes revealed that factors concerning the licensing, control, and monitoring systems and issues in the socio-economic and political-legal environment contribute to illegal logging. So far, the private sector response has been perceived as insufficient since many companies are lagging on implementing actions after having committed themselves to preventing illegal logging (Piotwroski, 2019, p. 9; Wellesley, 2014, p. 2). Mobilising the private sector, particularly companies only serving the domestic market, will be critical given that the vast majority of forest products in Brazil are destined for the domestic market (Cashore et al., 2016, p. 126). Overall, all timber companies serving both domestic and international markets need to further strengthen their efforts in tackling illegal logging if the ambitious forestry goals are to be achieved (see Chapter 2.2) and illegal logging eliminated.

An extensive literature review was conducted to identify the strategies that companies can implement to address illegal logging. Interviews with experts on the Brazilian Amazon and timber supply chains were conducted to fill knowledge gaps and complement findings with practical perspectives. The following areas of corporate action against illegal logging emerged (see Image 6):

1. Company pledge to remove illegal logging and deforestation (e.g., EC, 2016, pp. 64–65; EFI & Proforest, 2014, p. 2; Greenpeace, 2018, p. 27; Hoare, 2015, p. 49; Interview Professor; Lambin et al., 2018, p. 2, WRI, 2018, p. 12; WWF, 2017, p. 17)
2. Supply chain initiatives (e.g., Brancalion et al., 2018, p. 4; de Lima et al., 2018, p. 15; EC, 2018, p. 12; Hoare, 2015, p. 49; Interview Horowitz-Burdick; Interview Lentini; McDermott et al., 2015, p. 134; WBCSD Forest & WRI, 2014, p. 30; WRI, 2018, p. 5)
3. Monitoring efforts and periodic audits (e.g., Azevedo-Ramos et al., 2015, p. 7; EC, 2016, p. 64; Greenpeace, 2018, p. 27; Interview Horowitz-Burdick; Interview Lentini; Lowe et al., 2016, p. 992; WBCSD Forest & WRI, 2014, p. 35)
4. Political advocacy for government action (e.g., Brancalion et al., 2018, p. 4; EC, 2018, p. 12; Greenpeace, 2018, p. 27; Hoare, 2015, p. xii; Interview Lentini; Lambin et al., 2018, p. 5)

Due to the complex and interconnected nature of the identified causes, the measures undertaken by different stakeholder groups must be harmonized and multi-stakeholder collaborations formed to effectively tackle illegal logging, which represents the fifth category that links together the other four areas of corporate action (e.g., Castilla-Rubio & Nobre, 2016, ¶11; Hewitt, 2020, ¶9; Lambin et al., 2018, p. 6; Müller, 2020, p. 9; The World Bank, 2019, p. 38; WWF, 2021, pp. 52, 55). Kleinschmit et

al. (2021, p. 8) note that even though companies and the Brazilian government were identified as responsible parties for illegal logging, they are also equally seen as part of the solution in the scientific debate and the discourse held by international organisations and NGOs. Both discourses suggest "that those who are responsible for illegal logging can also act as solvers" (Kleinschmit et al., 2021, p. 8). However, it is important to acknowledge that despite the growing number of companies interested in tackling illegal logging and other environmental and societal challenges, many remain unconcerned about their adverse effects on forests and have no interest in changing their practices (EFI, 2014, p. 11). Lastly, it is important to note that the ability to implement the defined corporate strategies varies: For instance, for political advocacy, large, powerful companies may be able to exert a certain influence on the government, while smaller actors might find it challenging to have their voices heard. Therefore, the presented framework of corporate action may need to be adapted on a case-by-case basis and tailored to the respective company's needs, capabilities, and capacity. Given the scope of the thesis, the following elaborations will focus on actions that timber companies at the later stages of the supply chain can take, such as processing companies, importers, exporters, and retailers, though certain insights may equally apply for actors operating at the early- and mid-stages of the supply chain.

4.2.1 Commitment to Removing Illegal Logging and Deforestation

The first area of corporate action entails pledging to comply with all the relevant environmental, forestry, and human rights legislation and exclude illegal logging and deforestation from the company's own operations and supply chain (Lambin et al., 2018, p. 2; Ozinga & Mowat, 2012, p. 197). A company may decide to expand this pledge by including social and environmental criteria that go beyond the law, thus committing to sourcing not only legal but also sustainable timber (Lambin et al., 2018, p. 2). It is important that the pledge is backed by top management, encompasses measurable goals, and has a clear time frame (WWF, 2015, p. 17). The scope of the pledge varies depending on the company's business model and may cover a range of regions and commodities, such as timber, beef, and soy, or be limited to a specified industry and region, such as timber from the Brazilian Amazon (Lambin et al., 2018, p. 2). Furthermore, the commitment may be communicated solely internally or also to other stakeholders, such as the public, investors, and NGOs. Public disclosure is recommended since the pledge is perceived to be more authentic and benefits related to responsible sourcing, such as a positive brand impact, are greater than in cases where commitments are not publicized (WWF, 2017, p. 5). Additionally, a company may also decide to participate in collective commitments, such as the 2014 New York Declaration on Forests, (see Chapter 2.2) (Haupt et al., 2020, p. 14; Lambin et al., 2018, p. 1). It was endorsed by over 190 entities, including 62 companies, 41 governments, and 40 NGOs (New York Declaration on Forests, 2021, ¶1).

Company pledges to combat illegal logging and deforestation are typically operationalised by conducting a supply chain audit and developing purchasing policies and/or a code of conduct (EC, 2014, p. 10). Such an audit could detect potential violations and identify suppliers with an increased risk of illegality due to, for instance, discrepancies in their environmental register, and give crucial insights for risk prioritisation and budget allocation (Nikolakis, John, & Krishnan, 2018, p. 3; WBCSD Forest & WRI, 2014, p. 27). Furthermore, a code of conduct guides people who are acting on the company's behalf by outlining principles that must be followed: For example, a company code of conduct may prohibit employees from engaging in illegal activities throughout the supply chain (WWF, 2016a, pp. 10, 25). In purchasing policies, companies might commit to only sourcing legal or certified timber from suppliers who abide by the Forest Code and other legislation and meet stringent environmental and social standards (Azevedo et al., 2017, p. 7657; EC, 2016, p. 65). A policy may consider price aspects: For instance, one timber company refrains from purchasing particularly cheap timber "because they

know timber can't be that cheap" (Interview Daniel). On the same note, companies may stop sourcing timber from suppliers who cannot provide reliable documentation on timber legality or meet the purchasing policies' requirements (Greenpeace, 2018, p. 27). Beyond that, action plans, chain-of-custody initiatives, supplier audits, transparent reporting, and smallholder support represent other elements of operationalisation (EC, 2014, p. 10; Lambin et al., 2018, p. 2; WWF, 2017, p. 9).

As a result of the adapted purchasing policies and supplier code of conduct, suppliers may be required to change their practices to comply with the new policies (EFI, 2014, p. 7). However, some suppliers, mainly small-scale loggers, may struggle with compliance as they do not have the knowledge or means to adapt their practices (see Chapter 3.3.2): It is recommended that companies provide information, guidelines, training, and guidance to support suppliers' transition towards the desired forestry practices (Lambin et al., 2018, p. 5; WWF, 2016a, pp. 25–26). Increased costs resulting from changes in purchasing policies or the code of conduct, may need to be addressed with incentive instruments, such as recognition or price premiums (Nikolakis et al., 2018, p. 3). Especially acquiring forest certifications may prove challenging for smaller players as they are costly and entail stringent conditions for forest management and supply chain verification (WWF, 2016a, p. 34; WWF, 2017, p. 27). Therefore, companies seeking to become certified could consider providing financial assistance or facilitating group certifications (EFI, 2014, p. 9; WWF, 2016a, p. 34). IKEA, for instance, partnered up with WWF to support over 20,000 small-scale loggers in achieving FSC certification in China (WWF, 2017, p. 27).

Overall, many companies in the forestry sector – especially those with global reach – have adopted public pledges to tackle illegal logging and deforestation, which has been encouraging (WRI, 2018, p. 12; WWF, 2017, p. 4). However, understanding the effectiveness of these pledges is challenging due to the variety of actors and supply chains involved, the lack of transparency on measures and progress, the recent nature of many pledges, and the interaction of corporate measures with those implemented by the government, NGOs, or other players (Lambin et al., 2018, pp. 1–2). These points contribute to the difficulty of isolating and assigning responsibilities for observed changes, exacerbated by vague formulations of commitments and the absence of time-bound interventions (Lambin et al., 2018, p. 1; WWF, 2017, p. 4). Furthermore, a disconnect between the company pledges and the reality of the actions carried out on the ground may exist (EFI, 2014, p. 11).

4.2.2 Supply Chain Initiatives

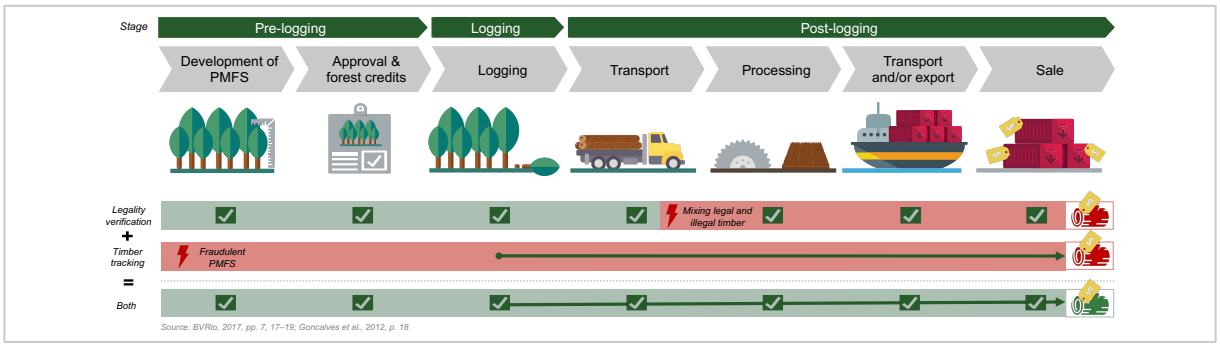


Image 7: Importance of combining legality verification and timber tracking (own image)

The second area includes putting measures in place to ensure the timber's legality until it reaches the end consumer, which is done with two components: Legality verification and timber tracking (see Image 7). It is critical to acknowledge that the combination of both is required to ensure legality to the best extent possible. On the one hand, legality verification at the source and each supply chain step is critical

to ensure that all actors comply with the relevant laws and possess the required documentation. However, strong legality verification efforts could be undermined since legally harvested timber could, for instance, be mixed with illicit timber during the transportation stage due to inadequate timber tracking efforts (see Chapter 3.2.2). On the other hand, only relying on tracking systems leaves room for illegal activities since tracking only traces an individual piece of timber often from the forest to the end consumer. If fraud occurs at the initial stages of the supply chain during the creation of the sustainable forest management plan, the entire tracking system would be based on tracking fraudulent timber if thorough legality checks do not complement the system. Consequently, strong efforts in both legality verification and timber tracking are required to reduce the risk of illegality in the timber supply chain. Forest certifications build on legality verification and tracking efforts and represent another supply chain initiative companies can adopt. (Interview Daniel; Interview Lentini; Mutz, 2019; UNEP & INTERPOL, 2012, p. 7)

4.2.2.1 Legality Verification

At the source, legality verification aims to evaluate whether logging was conducted in forest areas where harvesting is permitted while respecting the requirements defined by the PMFS and legislation of Brazil and the importing country, if applicable (WRI, 2018, p. 14). Along the supply chain, legality verification includes examining whether legality was respected during transport, processing, import, export, and sales. To demonstrate legality, the primary documents required are the timber extraction permit, so the AUTEX or AUTEF, as well as the respective transport authorisation, the DOF or GF (see Chapter 3.1.2) (Costa et al., 2016, p. 61). Further documentation may be required depending on the product type and destination. However, "given the high probability of fraud in logging permits" (Brancalion et al., 2018, p. 4) and the self-declaratory nature of much of the information the permits are based on (see Chapter 3.3.1), solely relying on documentation issued by the government's licensing system is not considered sufficient to ensure legality by the Amazon Watch (2019, p. 37) and Greenpeace (2018, p. 27). During an interview, Sam Daniel, a senior international research coordinator at Greenpeace, said: "It looks like it's legal. But obviously the [forestry] credits are actually based on a falsehood. The whole system is based on something which is not correct." Several interviewees recommend companies to go beyond solely collecting required documentation (Interview Daniel; Interview Lentini; Interview Horowitz-Burdick).

Additional measures companies could adopt to decrease the risk of illegality represent carrying out surveys among supply chain actors, examining potential ownership issues (e.g., the company owner has a history with corruption), organisational structures (e.g., supplier runs cattle business in addition to logging), and organisational history (e.g., labour record) (Greenpeace, 2018, p. 27; Interview Horowitz-Burdick). Further potential measures include conducting physical timber inspections, on-site visits in the forest, sawmills, and other processing facilities, and comparing information from the collected documentation to other data sources (e.g., historical and current management plans of similar forests) (Greenpeace, 2018, p. 27; Interview Horowitz-Burdick; Lowe et al., 2016, p. 992). "The key is that you're comparing pieces of information against each other right, from different document claims," (Interview Horowitz-Burdick) says Maxwell Horowitz-Burdick, Director at supply chain consultancy Double Helix Tracking Technologies. Overall, these measures are deemed helpful for determining whether the issued number of forestry credits is accurate, estimating the risk of illegality, and identifying discrepancies, particularly over a longer time period (Interview Horowitz-Burdick). "The way that you catch that [illegal logging and laundering] is long term data collection," (Interview Horowitz-Burdick) explains Horowitz-Burdick. Naturally, the sophistication of the verification measures is dependent on a

company's resources, its capabilities, motivation, and risk exposure, which is determined by the type and source of the timber purchased (Interview Horowitz-Burdick).

Implementing these verification measures and collecting, evaluating, and reconciling data from these different documents is linked with considerable effort, especially when conducted for every transaction (Leong, Viskin, & Stewart, 2018, p. 6). Technologies, such as big data analysis and machine learning, which could cross-validate and triangulate data to support the identification of irregularities are typically not applied by timber companies (Ferguson et al., 2020, p. 12). Ensuring legality is rendered more difficult by differences between the state and federal systems SINAFLOR and SISFLORA (see Chapter 3.1.2), in addition to constantly moving document requirements for export, which vary from product to product (Interview Horowitz-Burdick). For example, exporting plywood from Brazil requires different documentation than exporting wood decking (Interview Horowitz-Burdick). Beyond that, the reality in the Brazilian Amazon is that many businesses operating in the timber industry still only rely on the collection of basic documentation, which is considered proof of legality in Brazilian law (Interview Lentini). The DOF, for instance, "is the legal document that proves that your timber is legal" (Interview Lentini). Many companies assume legality upon receipt of documentation issued by government bodies. Lentini from IMAFLORA, states: "Brazil lives in, at least in the forestry area, in an assumed legality environment" (Interview Lentini). Daniel from Greenpeace observes: "The thing is, everyone knows what's going on, everyone knows that the documents don't really prove what's happening. […] Even the companies in Europe also know. […] They have a document, but it's all meaningless ultimately, and companies know that" (Interview Daniel).

4.2.2.2 Timber Tracking

Timber tracking is closely connected with legality verification, as companies commonly wish or are required to transfer certain claims throughout the supply chain, typically from the forest to the consumer (EC, 2016, p. 66). Without traceability, all that was verified was that someone, somewhere, at some point harvested timber while respecting legal requirements (Mutz, 2019). The aim is to collect, store, manage, and disseminate data associated with the timber product and production processes and provide information on the timber's identification, history, and location in all stages of the supply chain retrospectively or in real-time (Hunt, Mirowski, Smith, & Turner, 2014, p. 11). Traceability solutions in the timber industry can include paper-based documentation, IoT technology, scientific methods, or a combination of these (Costa et al., 2016, p. 13; Seidel, Fripp, Adams, & Denty, 2012, p. 13). These approaches have their advantages and disadvantages, and, similarly to legality efforts, their suitability depends on the company's budget, risk exposure, and timber product (Costa et al., 2016, p. 13).

When using a paper-based approach, traceability is established by assigning documentation to the respective timber shipments (Lowe et al., 2016, p. 992). "A supply chain can be regarded as a chain of legally binding contractual relationships" (WBCSD Forest & WRI, 2014, p. 27), also known as the "chain of custody." Businesses can track their products along the chain of custody to determine the journey of the timber by examining and verifying certain documentation (Lowe, Wong, Tiong, Iyerh, & Chew, 2010, p. 264). Documentation commonly includes forest inventories, logging licenses, production reports, sales invoices, transportation documents, and export documents, some of which already need to be collected to verify timber legality (Lowe et al., 2016, p. 992; WBCSD Forest & WRI, 2014, p. 27). Timber needs to be marked in the harvesting stage to establish the link between the documentation and the physical product to ensure its identification and traceability along the whole supply chain (Mutz, 2019). In paper-based traceability systems, timber is commonly marked with conventional methods, such as paint, where numbers and letters are painted on the individual log, or

plastic tags, where each tag has a unique identification number (Lowe et al., 2010, p. 263; Seidel et al., 2012, p. 15). While both options are attractive due to their low costs, they are prone to inefficiencies, forgery, and wear over time due to weather exposure (Picchi, 2020, p. 1; Seidel et al., 2012, p. 15; The World Bank, 2019, p. 36). Plastic tags tend to be less durable than paint markings, as they may get damaged or detached from the timber (Seidel et al., 2012, p. 15). In cases where the markings are removed due to the physical transformation of wood, for instance, from log to sawn wood, timber is tracked with the mass balance method, which includes the comparison of input and output volumes as well as the examination of efficiency and conversion rates of processing facilities based on information from the collected documentation (Interview Horowitz-Burdick; Seidel et al., 2020, p. 13). A downside to this approach is that illegal timber could potentially be mixed with legal timber if the indicated efficiency and conversion rates are inaccurate (see Chapter 3.2.2) (Seidel et al., 2012, p. 14).

Beyond that, timber companies can use IoT devices to track timber along the supply chain, which can be attached to timber products, processing facilities, or transport vehicles (Šulyová & Koman, 2020, p. 1). IoT can be defined as a "network of physical objects or things […] embedded with electronics software and sensors which are provided or unique identifiers and possess the ability to transfer data across the web with minimal human interventions" (Kshetri, 2021, p. 141). These objects can record information on aspects, such as location, humidity, temperature, product information, vehicle speed, and status (e.g., hard braking of the vehicle) (Basole & Nowak, 2018, p. 352). The use of IoT enables almost real-time tracking of timber along the supply chain, which represents an advantage compared to paper-based evaluations that are usually carried out retrospectively (Basole & Nowak, 2018, p. 353; Kshetri, 2021, p. 142). In addition, real-time tracking increases supply chain visibility and serves as a basis for swift decision-making at the operational, strategic, and tactical levels (Kshetri, 2021, p. 142; Šulyová & Koman, 2020, p. 1). Other reported benefits of IoT devices include reduced operating costs, lower error rates, and decreased risk of forgery and illegal timber entering the supply chain, which is why they are considered reliable traceability tools (Lima et al., 2020, p. 15; Picchi, Kühmaier, & Marques, 2015, p. 173; Seidel et al., 2012, pp. 7, 15, 17; Šulyová & Koman, 2020, pp. 1, 15).

IoT devices used by some timber companies in Brazil represent barcodes, QR codes, RFID tags, and GPS trackers (Costa et al., 2016, p. 32; Ferguson et al., 2020, p. 12). Barcodes and QR codes function similarly: Workers can attach them to logs and sometimes sawn timber, after which the codes containing product information are scanned with readers during every step of the supply chain (Harvey, 2020, ¶10; Seidel et al., 2012, p. 17). The data is collected and transferred electronically to the company's database, meaning businesses can monitor the product flow and take prompt action if irregular activities occur (Seidel et al., 2012, p. 17; WBCSD Forest & WRI, 2014, p. 28). The Brazilian federal government, for instance, has adopted QR codes for timber harvested in federal concession areas (Costa et al., 2016, p. 32). RFID tags have similarities to barcodes and QR codes, as they can also be attached to each log and are scanned at each processing step (Costa et al., 2016, p. 32). However, RFID tags can store more information and be automatically read at long distances of up to four metres (Björk et al., 2011, p. 831; Picchi, 2020, p. 2). Automatic readability, enabled by radio frequency signals, reduces the processing time since a transportation truck can have the entire shipment scanned by driving past the RFID scanning device as opposed to having someone unload the truck, scan each log individually, and re-load it (Björk et al., 2011, p. 830; Picchi, 2020, p. 1). However, RFID technology is considered more expensive than other wood identification options (Seidel et al., 2012, p. 17). All three IoT tools require the staff to undergo training to operate the reading devices and often need an internet connection or access to mobile phone networks to function (Seidel et al., 2012, pp. 15, 17). Lastly, companies can attach GPS trackers to vehicles, allowing the tracking of transportation routes, and thus, identification of any detours of the

defined route (Costa et al., 2016, p. 32). Note that IoT devices are not immune to fraud, though some have made fraud extremely expensive for malicious actors (Kshetri, 2021, p. 197; Thakker, Patel, Tanwar, Kumar, & Song, 2021, p. 8671). For instance, to replicate legitimate QR codes to masquerade illegal timber, such actors would need to have access to large quantities of legitimate products to generate sufficient genuine codes, making such business models less attractive (Kshetri, 2021, p. 197).

The use of scientific wood technologies further reduces the risk of illegality (Seidel et al., 2012, pp. 3, 13). Different scientific approaches to identify, track, and verify timber have emerged, which can complement tracking efforts (Kleinschmit et al., 2016b, p. 135; WRI, 2018, p. 14). These wood identification methods can be categorised into visual methods (e.g., wood anatomy and dendrochronology), chemical methods (e.g., mass spectrometry, near-infrared spectroscopy, stable isotopes, radiocarbon), and genetic methods (e.g., population genetics and phylogeography, DNA barcoding, DNA fingerprinting) (Dormontt et al., 2015, pp. 793–795). These methods deliver the most reliable identification compared to identification methods relying on non-inherent wood characteristics, as they are based on inherent features, such as chemistry, anatomy, and genetics (Dormontt et al., 2015, p. 793). "The best tools are the scientific ones, because those can still be traced throughout production," (Interview Horowitz-Burdick) says Horowitz-Burdick. In other words, scientific methods are effective even after timber has undergone several stages of physical transformation, which is not the case for IoT tools and other wood identification methods, such as paint and tags (Worm, 2020b). For instance, an isotope analysis of a wooden table can confirm whether the declared region within country A is accurate if a reference database for that country exists (Worm, 2020b). The degree to which these different methods can identify the timber's genus[11], species, geographic origin, and match the product to the original tree varies depending on the method (see Appendix Chapter 1.3).

Of these scientific methods, DNA fingerprinting – the matching of samples of the timber product (e.g., furniture) with samples of the forest where it allegedly originated from – is found especially promising for supply chain verification (Campion, 2011, ¶3): "It is the only forensic timber identification technology with the potential to independently trace timber products as they travel along the often convoluted global supply network" (Dormontt et al., 2015, p. 795). Therefore, it has the potential to deter fraudulent activities and increase actors' confidence in the chain of custody (Seidel et al., 2012, p. 22). In law enforcement, DNA testing proved to be key in prosecuting an illegal logger for the first time in 2015 after scientists matched samples from the suspected timber with specimens from the national forest where trees had been illegally felled (Lowe, 2020, ¶10; Mason & Parker-Forney, 2018, ¶3). Since then, the use of DNA testing has evolved extensively in that field, also seen in the development of UN guidelines on DNA forensic identification for law enforcement personnel, prosecutors, and the judiciary (Clausen, 2016, ¶4; UN, 2016, p. 4). Despite the potential of DNA fingerprinting for linking products to their original tree, the technology has not reached large-scale industry application for supply chain verification (Clausen, 2016, ¶9). Selected supply chain consultancies, such as Double Helix Tracking Technologies, and forestry companies, such as Bunnings, make use of this technology, but they remain in the minority (Campion, 2011, ¶10; Dormontt et al., 2015, p. 795; Double Helix Tracking, 2021, ¶1).

Dormontt et al. (2015) note that "there is currently a substantial gap between the potential and realised application of most of the [scientific] methodologies" (p. 796), as many are still in their infancy (Dormontt et al., 2015, p. 793). Especially the chemical and genetic methods still face limitations, such as lacking reference databases containing species-specific chemical or genetic information of timber

[11]Cambridge Dictionary (2021a) defines genus as „a group of (...) plants, more closely related than a family, but less similar than a species."

from a known geographic location and require further research until they can be effectively deployed against illegal logging on a large scale (Dormontt et al., 2015, pp. 782, 794; van Solinge, Zuidema, Vlam, Cerutti, & Yemelin, 2016, p. 92). While large-scale application in supply chains is not yet possible, it can be used as an additional layer to the existing tracking solution (Worm, 2020b). For instance, retailers could periodically test samples provided by suppliers who are aware of them doing these tests but unaware of when they will do them (Worm, 2020b). Additionally, the scientific methods can be used for high-risk situations and cases where provided documentation is deemed untrustworthy or the risk of fraud to be high (Double Helix Tracking, 2021, ¶2; Seidel et al., 2012, p. 31; Worm, 2020b). If these methods are used, it is important to have a broader traceability system in place to contextualise the results, especially the alarming ones, so that companies can estimate the magnitude of products affected and which suppliers should potentially be reviewed for non-compliance or inconsistencies (Interview Horowitz-Burdick; Worm, 2020b).

Many timber companies operating in the Brazilian Amazon base their traceability efforts on the paper-based approach, including mass-balance analyses (Interview Lentini). Paper-based systems are considered difficult to oversee and subject to tampering (Nikolakis et al., 2018, p. 5; Seidel et al., 2012, p. 47). Lentini from IMAFLORA notes that many companies "don't really have traceability, what they have, it's a bunch of documents coming in and a bunch of documents coming out. And at the end, what you need is roughly […] volumes to be consistent" (Interview Lentini). Yet, timber companies in the Brazilian Amazon have not taken up IoT tools on a large scale, a practice that has been observed in the wider timber industry (Interview Horowitz-Burdick; Šulyová & Koman, 2020, p. 1). Nonetheless, it is important to acknowledge that depending on the product type, IoT devices may not represent the ideal solution as physical timber may undergo several processing stages, where the devices would need to be removed, undermining the devices' purpose (Interview Horowitz-Burdick). Moreover, IoT tools incur high establishment costs (e.g., initial set up, training, purchase of infrastructure) and moderate recurring costs (e.g., maintenance, unit prices), which should not be underestimated in an industry marked by low margins (Costa et al., 2016, p. 33; Interview Horowitz-Burdick). In cases where timber companies decide to use IoT devices, a broader system should be developed to ensure it provides a comprehensive picture of timber legality and traceability, given that each tool only addresses specific aspects. For example, GPS trackers attached to transport vehicles focus on fraud occurring in the transportation phase. This is equally important for the adoption of scientific methods, as some methods can only achieve identification on one of the aspects of the continuum of timber identification, so the genus, species, provenance, or individual level. (Costa et al., 2016, p. 33; Dormontt et al., 2015, p. 792).

4.2.2.3 Forest Certifications

Forest certifications build on legality verification and tracking efforts but have their own particularities (SGS, n.d., p. 3). They were initially created to determine whether wood originated from forests that were managed according to specified environmental and social standards and have evolved to consider the legality of timber products and forest operations (WRI, 2018, p. 14). The two most common certification schemes are the Forest Stewardship Council [FSC] and Program for the Endorsement of Forest Certification [PEFC] labels, with the former being "more detailed and prescriptive in nearly all aspects considered for forest certification" (Garzon et al., 2020, p. 1) (McDermott et al., 2015, p. 139). In the Brazilian Amazon, FSC represents the main certification scheme, while PEFC certification is still in the initial stages of adoption (Interview Lentini). For both schemes, two types of certifications exist: The forest management certification, which asserts that wood was sourced from well-managed forests that fulfil economic, environmental, and social requirements, and the chain of custody certification, which verifies that certified timber was kept separate from non-certified products throughout the supply

chain after having left the forest (EC, 2016, p. 66; SGS, 2017, ¶4). If a forest owner wishes to sell the final product as certified, both types of certifications are required (FAO, n.d., p. 2). Overall, forest certifications go beyond just verifying legality and include social and environmental aspects at the source to assure buyers the purchased timber originated from well-managed forests and fair labour conditions (WRI, 2018, p. 14). However, given the nature of the claim, legality verification is mainly limited to the forest and harvesting practices and does not focus on legality aspects along the supply chain, as pointed out by Christian Kobel, forestry auditor at SGS: "At the moment, there is no legality verification of the chain of custody" (Interview Kobel). Instead, the supply chain evaluation centres on traceability criteria, such as, segregating certified from non-certified timber (Interview Kobel).

Relatively few timber companies have adopted forest certifications: FSC certifications account for less than 3 percent of total wood production in the Brazilian Amazon, and PEFC certified forests have an even smaller share (Costa et al., 2016, p. 24; Ferguson et al., 2020, p. 11; Interview Lentini). Plantations account for most certifications, leaving large areas of natural forests, which are characterized by an increased risk of illegal logging, uncertified (see Chapter 3.1.1) (McDermott et al., 2015, p. 139). On the other hand, some have pointed out limitations inherent to certifications, including the costly, lengthy, and difficult process, the limited uptake by small-scale loggers, and unclear land rights in the Brazilian Amazon, which are problematic since undisputed rights are a prerequisite for certification (EC, 2016, p. 69; McDermott et al., 2015, pp. 135–136; WWF, 2017, p. 27). The World Resources Institute (2018) points out that "voluntary third-party certification bodies cannot and do not guarantee that certified products are legal" (p. 14). Even Loa Worm (2019), a director at FSC, admits that "certification is primarily based on paper and trust that the companies involved in a supply chain is *[sic]* truthful" (¶4). In the current trust-based system, the recorded transaction volumes of certificate holders are not verified by default – Instead, only random samples are tested by the certification body during the annual audit, leaving room for fraud (Worm, 2019, ¶6–7). On several occasions, illegal timber was confiscated that had been FSC or PEFC certified or handled by companies that had certified other timber products (Earthsight, 2020, ¶14; WRI, 2018, p. 14). Despite these drawbacks, certifications mitigate the risk of illegal timber, and many NGOs continue to encourage the adoption of certifications (McDermott et al., 2015, p. 139; WRI, 2018, p. 5). The European Commission (2016) considers certification as "the most successful (…) initiative so far, for sourcing legal/sustainable timber" (p. 67) while acknowledging the limitations inherent to certifications (p. 69).

Overall, the presented supply chain initiatives are not meant to cover the entire spectrum of measures companies can take but are intended to capture the most important ones. It is recommended that companies analyse their current systems, company needs, prevailing conditions, risks, and markets they wish to serve to subsequently determine the ideal mix of supply chain initiatives based on inputs of experts (Seidel et al., 2012, p. 20). Based on the insights gained, timber companies can build robust systems (e.g., digital mapping with forest polygons) and procedures (e.g., sample testing on a batch basis), which operate on an ongoing basis and are specific to the identified risks (Interview Horowitz-Burdick). Which set of measures should be pursued depends on factors, such as resource availability, supply chain complexity, existing legality requirements, type of timber product, specific customer needs, and other factors (Seidel et al., 2012, pp. 19–20).

4.2.3 Monitoring Efforts and Periodic Audits

After adopting such systems and procedures, an audit should be conducted to assess whether they are functioning properly and, if necessary, improvements undertaken (EC, 2016, p. 43). Monitoring efforts are important to identify inconsistencies and risks along the supply chain and to take appropriate

mitigating action (EC, 2016, p. 53). Companies should keep in mind that in some cases, the reduction of illegal timber is not only dependent on the identification of illegal timber in the supply chain but also on the corporate measures taken as a result of the detection (Nogueron, Cheung, & Kaldijan, 2016, ¶12). Cutting business relations to suppliers involved in illegal logging after mitigative measures failed represents one way of how companies can translate data into action (Nogueron et al., 2016, ¶12). Additionally, it is recommended that continuous monitoring efforts and periodic audits are undertaken after the initial assessment since excluding illegal timber from the supply chain is an ongoing process (Lowe et al., 2016, p. 43). Audits can be conducted internally, externally through an independent party, or as a combination of both (Lowe eta l., 2016, p. 991; WWF, 2017, p. 16). Moreover, it is essential that audits, including field inspections, can be undertaken unannounced since the audited party may conceal illegal practices before an announced audit (Lambin et al., 2018, p. 4). For example, in the supplier code of conduct, IKEA states that audits may occur announced or unannounced and will be undertaken by both the company and third parties (IKEA, 2021, ¶10).

Several authors, environmental groups, interviewees, and trade organisations agree (EC, 2016, pp. 64, 66; Greenpeace, 2018, p. 27; Interview Lentini; Interview Daniel; WBCSD Forest & WRI, 2014, p. 35) that independent, third-party audits are desirable, particularly in areas perceived as high risk, which is the case for timber sourced from the Brazilian Amazon (see Chapter 3.2.1). Interviewee Horowitz-Burdick explains that independent, third-party audits may receive access to critical information that timber companies may not have access to. For instance, if a sawmill sells wood to ten different companies, each of these companies will only have a view on the respective share they purchased, limiting their ability to conduct analyses on volume reconciliation (Interview Horowitz-Burdick). “It’d be really hard […] to tell if they’re cheating or not, because you have a really small sample and visibility of claim material” (Interview Horowitz-Burdick). One of the main advantages of contracting third parties is that they can look at the bigger picture within the mill or other supply chain players since they hold the information confidential on their behalf (Interview Horowitz-Burdick). Consequently, they might have access to a larger data set for conducting analyses on legality and verification, compared to the cases of internally conducted audits, which helps identify inconsistencies among all the provided documents (Interview Horowitz-Burdick). Other advantages of independent third-party auditors include increased assurance, reduced bias associated with self-reporting, and decreased risk of illegality (BVRio, 2017, p. 4; Ferguson et al., 2020, p. 3; WBCSD Forest & WRI, 2014, p. 35).

The European Commission (2016, p. 65), Amazon Watch (2019, p. 37), and Greenpeace (2018, p. 27) recommend publishing the results of the audit to ensure transparency towards external stakeholders and allow public scrutiny. Companies can use transparent reporting to their advantage by educating customers, environmental groups, and the public on their efforts in combating illegal logging, which could positively impact their reputation and brand, in addition to improving consumer awareness, a contributor of illegal logging (see Chapter 3.3.2) (WWF, 2017, p. 6). Besides publishing audit results, companies could integrate elements of these reports as well as insights from legality verification, tracking, and monitoring efforts to promote customer engagement and responsible decision-making (Mutz, 2019). This could be done by telling the timber’s story via the website, social media channels, and sales channels, where curious consumers could, for instance, scan a QR code that is attached to the final timber product (Šulyová & Koman, 2020, p. 14). Other tools, such as DNA technology, which enables the identification of a product’s origin (see Chapter 4.2.2), have the potential of turning the tap to illegal logging at the retail end and getting consumers interested (Worm, 2020b).

The scope and ambition of monitoring efforts and periodic audits undertaken in the Brazilian Amazon vary strongly, from nearly non-existent measures to sophisticated investigations undertaken by third-party auditors (Interview Lentini; Interview Horowitz-Burdick). Some companies remain reluctant to commit resources to carry out and improve their due diligence beyond what is legally required of them, citing costs and weak consumer demand as reasons (Costa et al., 2016, p. 30; WWF, 2017, p. 10). Additionally, audits are time-specific, meaning they may potentially be limited to only detecting non-conformities during specific points in time (Costa et al., 2016, p. 30; Worm, 2021a). Kobel from SGS points out that "we [auditors] are not all the time on site, and we can't guarantee 100% legal compliance" (Interview Kobel). Research has revealed cases of suppliers concealing violations during visits, highlighting the challenge of sustainably changing supplier practices (Lambin et al., 2018, p. 4; Ozinga & Mowat, 2012, p. 197). In the cases where non-conformances are identified, the questionable product may have already been sold and the damage already caused. The gap between the occurrence of the transgressions and their detection might be extensive and hinder the implementation of effective measures in response, such as product recalls (Costa et al., 2016, p. 30).

4.2.4 Political Advocacy for Government Action

"Introducing tracking systems alone will not be a panacea to resolve all associated issues with illegal logging" (Seidel et al., 2012, p. 32). Timber tracing systems and other corporate measures only represent one component of the wider response to illegal logging, given that many of the identified causes go beyond companies' direct reach (see Chapter 3.3) (Piotrowski, 2019, p. 9; Seidel et al., 2012, p. 32). In fact, evidence suggests that the effectiveness of legality verification and traceability systems seems to be linked to the producer's country – in the present case Brazil's – governance capacity and quality (EC, 2016, p. 42; Lambin et al., 2018, p. 5). The Brazilian government plays a key role in creating a level playing field for legal and sustainable timber by introducing adequate legislation, supportive incentives, appropriate sanctions, and comprehensive safeguards to prevent perverse effects on small-scale loggers (Lambin et al., 2018, p. 6; Wellesley, 2014, p. 26; The World Bank, 2019, p. 33). For instance, the government could facilitate legal compliance for smallholders by providing capacity building and supportive services, in addition to removing disproportionate hurdles in bureaucratic procedures (see Chapter 3.3.2) (Hoare, 2015, p. xiii; McDermott et al., 2015, p. 138). Additionally, the government shapes areas, such as law enforcement, trade policies, anti-corruption efforts, and information sharing (Lambin et al., 2018, p. 6). Companies, especially those with considerable influence, can exert pressure on the Brazilian government[12] to act (Lambin et al., 2018, p. 5). "Political advocacy is crucial, as there are still a lot of areas where the government can take action" (Interview Lentini).

Among others, success in reducing illegal logging depends on firm political will to maintain proven approaches and implement measures to tackle the root causes of illegal logging (Assunção & Gandour, 2019, pp. 2, 8; The World Bank, 2019, p. 9). As current political will has been markedly lacking (see Chapter 3.3.2), companies could demand a change of the Administration's stance in rhetoric and practice through the reversal of policies relaxing forest legislation, redoubling of efforts to combat illegal logging, and strengthening of environmental agencies and their budgets (Arnold, 2020, ¶46; Canineu & Chávez, 2021, ¶5; HRW, 2019, pp. 13–14). For example, in an open letter in May 2021, 36 companies from the retail, agriculture, social, and financial sectors, wrote: "We have noted that the targets to reduce these levels [of forest fires and deforestation], as well as the enforcement budgets available to deliver them, are increasingly inadequate. […] However, if this or other measures that undermine these existing protections become law, we will have no choice but to reconsider our support and use of the Brazilian

[12]Foreign companies can exercise influence on their own government, as consumer-country governments can also implement measures to reduce illegal logging (Hoare, 2015, p. viii). However, due to the defined focus on the national level (see Chapter 3.3), the paper will not address this area.

agricultural commodity supply chain" (Agricultural Industries Confederation et al., 2021, p. 1).

Beyond that, the analysis of causes of illegal logging revealed deficiencies in the Brazil's licensing, control, and monitoring systems employed to govern logging in the Brazilian Amazon (see Chapter 3.3.1). "Smarter licensing processes is what we need" (Brancalion, 2018 as cit. in Kugler, 2018, ¶15), says Pedro Brancalion, professor at the University of São Paulo. Companies could encourage the government to reform the current licensing and control system to a fully transparent system that integrates the SINAFLOR and SISFLORA systems, cross-references declared information with other databases, and flags information perceived as suspicious (Brancalion et al., 2018, p. 5; Greenpeace, 2018, p. 27; Kugler, 2018, ¶15; Wellesley, 2014, pp. 15, 26). Furthermore, including more field inspections and technical and scientific parameters could prove essential for preventing fraudulent forestry credits: In the Peruvian Amazon, field inspections led to the cancellation of nearly half of the inspected forest concessions after the detection of major violations (Brancalion et al., 2018, p. 4; Greenpeace, 2018, p. 27). Lastly, investments in monitoring, including detection systems, communication infrastructure, personnel, and vehicles, are required to tackle illegal logging (Kleinschmit et al., 2021, p. 9; Noor et al., 2020, p. 615; Wellesley, 2014, pp. 2, 15).

Law enforcement improvements are linked to the clarification and enforcement of laws related to land tenure and management (Kleinschmit et al., 2021, p. 8). Attaining clear, secure, and enforceable land rights lies in the interests of companies seeking to establish legal supply chains as they need to verify that timber was harvested in areas where logging is permitted (Hoare, 2015, p. xii). Additionally, "secure tenure underpins a broad range of human rights and is at the foundation of economic development, social equity, poverty reduction, women's empowerment, environmental sustainability, peace, and stability" (Gray et al., 2015, p. 8). Companies can exert pressure on the Brazilian government to promote clear land tenure by clarifying land rights, respecting the rights of indigenous people, and removing hurdles to the recognition of community and indigenous lands awaiting demarcation (Ding et al., 2016, n.p.; Fern, 2021, ¶10; WWF, 2016a, p. 31; WWF, 2016b, p. 8). This would include withdrawing government support for the bills driven by the extractive lobby (see Chapter 3.3.2), which seek to open up indigenous territories for extractive activities (Canineu & Chávez, 2021, ¶5). In May 2020, 43 supermarkets and investors wrote an open letter to the National Congress of Brazil: "We are deeply concerned about the Provisional Measure 910 […] which would legalise the private occupation of public lands, mostly concentrated in the Amazon. Should the measure pass, it would encourage further land grabbing and widespread deforestation which would jeopardise the survival of the Amazon and meeting the targets of the Paris Climate Change Agreement and undermine the rights of indigenous and traditional communities. We believe that it would also put at risk the ability of organisations such as ours to continue sourcing from Brazil in the future" (AB Agri Ltd et al., 2020, p. 1). The proposal was withdrawn before it was brought to the floor (AIC et al., 2021, p. 1).

Overall, the presented government measures only represent a selection of the whole set of measures that the Brazilian government can implement to tackle illegal logging under the encouragement of the private sector. However, currently, timber companies in Brazil are rarely present in politics and display a low level of engagement (Interview Lentini). Companies may find it challenging to advocate for government action and progressing political change on their own (EFI, 2014, p. 5). It may be worthwhile to align objectives and efforts with other economic players, associations, NGOs, civil society groups, and concerned individuals as political pressure exerted by multiple parties is more likely to materialise into government action. For example, when the UK government proposed to reduce environmental standards under the pretext of improving the business environment, over 10,000 companies united to lobby against

the proposed relaxation of legislation, which significantly influenced subsequent government action (EFI & Proforest, 2014, p. 10). Additionally, it is important to acknowledge that some companies may use their influence to lobby against changes that curtail their economic freedom, even if these changes would contribute to the reduction of illegal timber (EFI & Proforest, 2014, p. 9). This political behaviour has been observed in the agriculture industry in the Brazilian Amazon, where powerful players representing the industry's conservative fraction have been supporting Bolsonaro in driving his Amazon agenda (see Chapter 3.3.2) (Amazon Watch, 2019, pp. 3, 7).

4.2.5 Alignment of Approaches and Multi-stakeholder Collaborations

Eradicating illegal logging requires the efforts of multiple stakeholders as it cannot be achieved single-handedly (Ozinga & Mowat, 2012, p. 204; World Bank, 2019, p. 38). Different stakeholders at the local, national, and international level need to be mobilized to act, with increased efforts made to include local communities and their needs as they are typically disproportionately affected by the repercussions of illegal logging and face challenges in making their voices heard (see Chapter 3.4) (EC, 2016, p. 38; World Bank, 2019, p. 8; WWF, 2021, p. 52). The stakeholder's roles in the fight against illegal logging differ: The Brazilian government needs to play the role of establishing a level playing field for legal timber and strengthening law enforcement efforts to reduce the profitability of illicit activities (see Chapter 4.2.4) (Interview Daniel). The private sector's role lies in abiding by legislation and taking appropriate measures to exclude illegal timber from their supply chains, thus contributing to the provision of legal timber (see Chapter 4.1). Consumers, on the other hand, are encouraged to proactively seek information on where and how timber was harvested, processed, and transported, in addition to including legality and sustainability considerations in their purchasing decisions (Muniz & Pinheiro, 2019, p. 139). In addition, they can exercise pressure on governments and the timber industry, together with NGOs who play an important role in actively investigating the occurrence of illegal logging and raising awareness (Costa et al., 2016, p. 13; UNEP & INTERPOL, 2012, p. 23). International governments and intergovernmental organisations could tackle illegal logging by developing a global agreement[13] on combatting illegal logging where the same rules apply to all participating countries, reducing the risk of leakages that can be defined as "the shifting of illegal logging activities to other countries with lower standards" (Kleinschmit et al., 2016a, p. 15) (Interview Professor).

Since some actions undertaken by one stakeholder may be offset by adverse effects of measures taken by other actors, approaches need to be aligned and public and private policies complemented to create reinforcing effects, avoid perverse effects, and address critical constraints (Lambin et al., 2018, p. 6; WWF, 2021, p. 55). For instance, the adoption of forest certifications by the private sector may criminalise smallholders unless they are accompanied by supportive policies implemented by the Brazilian government (Lambin et al., 2018, p. 5). Beyond aligning different approaches, collaborations between different stakeholders are important for developing solutions tackling illegal logging (Castilla-Rubio & Nobre, 2016, ¶11; Interview Daniel; Interview Professor; Müller, 2020, p. 9). Companies could work together with the Brazilian government to foster sustainable development in the region, given that some forestry businesses in the Amazon have supported health, education, and other social programs before (Ding et al., 2016, p. 1). Together they could develop alternative income opportunities given that poverty was identified as a cause of illegal logging, and felling timber illegally may be the only income source in some regions (see Chapter 3.3.2) (Kröger, 2018, p. 585; The World Bank, 2019, p. 33). A forestry technician, for instance, acknowledged illegal logging as "the only available option passed on to the new generation" (Kröger, 2018, p. 585) in communities living along the Maró River in the

[13]Some countries, such as the US, EU, and Australia have implemented consumer policies but at the time of writing, no global agreement on illegal logging existed.

Brazilian Amazon. Solutions such as income transfer programs, community support systems, and socio-environmental business opportunities that conserve the forest could be explored (Carvalho, 2020, ¶13; EFI & Proforest, 2014, p. 9; Faria et al., 2019, p. 1977). For example, the indigenous community Nova Esperança in the Brazilian Amazon produces and sells handicrafts made from wood collected from the ground, meaning individuals refrain from felling a tree solely to extract raw materials. By promoting local development, empowering communities to use their forests sustainably, and developing socio-environmental business opportunities, livelihoods can be improved, and alternative income opportunities accessed, discouraging the participation in illegal activities (EC, 2016, p. 40).

Collaborations can also include partnerships between the private sector, governmental, and research institutions. For instance, Double Helix Tracking Technologies, together with the University of Adelaide and the Australian Centre for International Agricultural Research, developed a DNA map exhibiting unique genetic clusters for the high-value species teak for four Southeast Asian countries and managed to accurately trace 99 percent of the blind samples to their reported origin and match them to their individual tree stump in the planted or natural forest (Gallou, 2021, ¶11, 14; Hickson, 2021, ¶1, 20). Similarly, a consortium of actors, namely FSC, WRI, US Forest Service International Programs, Royal Botanic Gardens, Agroisolab, and Kew, have started the World Forest ID project with the objective to build a global timber database, which is required for the large-scale deployment of scientific wood identification methods (see Chapter 4.2.2.2) (Worm, 2020b). Collaborations could also revolve around developing sector-wide commitments within the timber industry, a sector that currently does not have such goals in Brazil (Interview Lentini). Discussions on establishing industry-wide commitments are being held by timber companies and IMAFLORA, a non-profit organisation, but are still in the early stages (Interview Lentini). Additionally, collaborations could be formed between private sector actors of the timber industry and other industries that are linked to forest degradation in the Brazilian Amazon, such as the cattle ranching, soy, and infrastructure sectors (see Chapter 2.2, 3.3.2) (Hoare, 2015, p. xii). Alison Hoare (2015), a senior research fellow at Chatham House, notes: “There is an urgent need for coherent cross-sector strategies that extend efforts to tackle illegal logging beyond the forest sector” (p. xii). Timber companies and other stakeholders are encouraged to explore other types of collaborations than the ones presented. Barriers to collaborations may include lacking financial, temporal, and human resources and lacking motivation to drive measures beyond companies’ core business activities. Additionally, orchestrating and integrating the efforts of different stakeholders may be challenging, given the vast array of actions undertaken and the complex nature of interactions between them (WWF, 2021, p. 52). Alignment of measures and multi-stakeholder collaborations are further complicated by conflicting views, competing perspectives, and differing interests and may be subject to lengthy processes seeking to build consensus and concert actions (EC, 2014, p. 11; WWF, 2021, p. 55). This is especially relevant for developing a global agreement on combatting illegal logging since countries may have diverging agendas and different perceptions on the agreement’s scope, obligations, and targets.

5 The Potential of Blockchain to Complement Corporate Action to Combat Illegal Logging in the Brazilian Amazon

Some companies have recognised blockchain's potential to address illegality in different industries and first movers have begun to adopt blockchain-based solutions (Askew, 2020, ¶23; Kshetri, 2021, p. 191–192; Shapshak, 2018, ¶1). In the fishing industry, for instance, solution providers OpenSC, TraSeable, and Provenance have advanced blockchain solutions together with incumbent companies (Herweijer, Combes, Swanborough, & Davies, 2018, p. 22; Kshetri, 2021, p. 193; Whiting, 2020, ¶19). In contrast, the timber industry is marked by comparably few blockchain applications as most of the existing solutions are still being developed (e.g., Double Helix Tracking Technologies), tested (e.g., FSC), or in the early stages of implementation (e.g., WTP) (Interview Horowitz-Burdick; Interview Fabing; Worm, 2021a). Many companies are unfamiliar with blockchain use cases, and there is a general lack of awareness and understanding of the technology (Shelkovnikov, 2016, p. 10; Upadhyay, 2019, p. 23). The following chapters will explore blockchain's potential to address illegal logging by outlining the methodological approach, examining its applicability in the corporate framework of action, and evaluating an end-to-end blockchain solution for the Brazilian timber industry.

5.1 Methodology

Though the literature on blockchain technology is growing, it represents a nascent research field due to blockchain's relatively recent emergence and complexity (Nikolakis et al., 2018, p. 2; Vilkov & Gang, 2019, p. 391). Beyond that, "the emergence of Blockchain publications in leading academic journals has shown a substantial time lag in comparison to industry adoption" (Treiblmaier, 2020, p. 2), one reason being lengthy review cycles preceding publications (Treiblmaier, 2020, p. 2). As a result, "existing Blockchain case studies are rare" (Treiblmaier, 2020, p. 3). While research on blockchain applications and the development of case studies have progressed in industries such as the mining, pharmaceutical, and financial services industries (e.g., Kshetri, 2021, pp. 216, 260; Subramanian, Chaudhuri, & Kayikci, 2020, p. 31; Thakker et al., 2021, p. 8749), blockchain-related research has remained sparse in the timber industry as evidenced by the scarcity of published research in this field (see Appendix Chapter 1.1). Therefore, this thesis will examine blockchain's application in the timber industry. The analysis will centre on blockchain's potential to reduce illegal logging, a focus derived from blockchain's recognised potential in curbing illegal business practices and criminal activities (Hastig & Sodhi, 2020, p. 942), particularly in the timber industry (Vilkov & Gang, 2019, p. 390). Additionally, given the defined research scope, the evaluation will centre on the applicability by companies operating along the timber supply chain. Therefore, the potential use of blockchain by other players, such as the government and certification bodies, is not examined. Lastly, the geographic focus will lie on the Brazilian Amazon. A geographic focus is critical given that the causes of and solutions to illegal logging vary from country to country, and intercountry differences in forestry regulation and the forestry environment exist (Kleinschmit et al., 2016a, p. 14). Despite these restrictions, insights gained may still be valuable to other regions affected by illegal logging. Overall, the following sub-chapters seek to answer the research question: "How can blockchain technology complement corporate action to combat illegal logging in the Brazilian Amazon?"

To answer this research question, a qualitative approach was selected. Qualitative research methods are considered most helpful in answering "how" or "why" questions and "addressing unchartered questions and terrains" (Bettis et al., 2015, p. 3) (Ridder, 2017, p. 282). While plenty of literature on qualitative research methods exists, their applicability to blockchain has not been thoroughly explored yet, given the technology's nascency. In this research field, "case study research provides many useful tools to

systematically generate knowledge on which future research can build, be it theory-based or practically oriented" (Treiblmaier, 2020, p. 27). However, the literature review on qualitative research approaches in blockchain and case studies revealed widely varying approaches, an observation confirmed by Treiblmaier (2020, p. 14). He notes that "hardly any of them [blockchain case studies] apply the suggested procedures for case studies that can be found in the academic literature" (p. 14) and that "there exists a dearth of theory-based academic papers on the topic [of blockchain] following robust methodologies" (p. 1). After reviewing the extant case study literature, he, therefore, developed suggestions and guidelines for structuring case studies that further the research agenda and add value to the industry (Treiblmaier, 2020, pp. 1, 27). The methodological approach is based on his proposed case study structure after following his recommendation of selecting the parts deemed most useful to answer the research question (Treiblmaier, 2020, pp. 22, 24, 26). Additionally, the approach draws on elements of the blockchain evaluation approaches suggested by Accenture (Leong et al., 2018, p. 40), PWC (Herweijer et al., 2018, p. 3), and BCG (Bender, Burchardi, & Shepherd, 2019, ¶28) – consulting companies that have developed and implemented blockchain use cases for their clients.

The defined methodological approach (see Image 8) draws from BCG's two-step approach consisting of an ideation and a validation phase (Bender et al., 2019, ¶28). In the first step, a definition of blockchain is provided, followed by an overview of its key features and how they differ from traditional databases (Treiblmaier, 2020, p. 24). The depiction of the blockchain characteristics provides the foundation for analysing how the technology could create meaningful value and complement corporate strategies against illegal logging (Treiblmaier, 2020, p. 21). Afterwards, one use case is defined and analysed in-depth for its validity in the second step (Bender et al., 2019, ¶29). Feasibility plays a critical role: "If a use case does not meet a minimum level of feasibility and potential return, then companies do not even have to consider the second step of which blockchain strategy to adopt" (Carson, Romanelli, Walsh, & Zhumaev, 2018, ¶35). Accenture proposes four key criteria, namely technical, market, operational, and financial feasibility, to assess a blockchain use case (Leong et al., 2018, p. 40). After the feasibility evaluation, the results of the analysis are put into context and blockchain's relevance for illegal logging is discussed followed by the limitations and future outlook (Treiblmaier, 2020, p. 24).

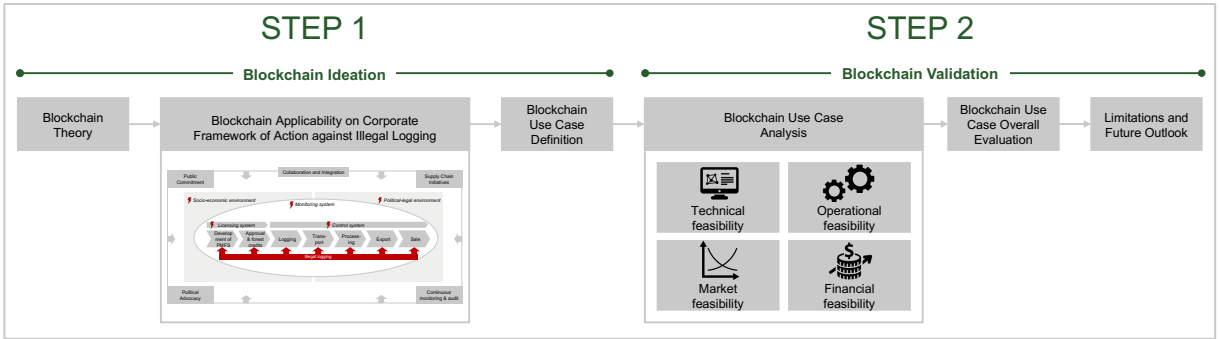


Image 8: Visualisation of the methodological approach (own image based on Bender et al., 2019; Herweijer et al., 2018, p. 3; Leong et al., 2018, p. 40; Treiblmaier, 2020, p. 22)

A combination of primary and secondary sources will be used to answer the research question (Treiblmaier, 2020, p. 24). Secondary sources include consulting reports, media articles, published company information, and literature on blockchain technology, supply chains, the timber industry, and the Brazilian Amazon. Furthermore, given the lack of blockchain-related research in the timber industry, different blockchain solutions of companies will be considered, three of which will be developed in-depth as case studies. Such case studies represent an adequate method to transfer industry experiences into the research agenda and to further theory development (Treiblmaier, 2020, p. 1). Considering that

blockchain-related research in responsible sourcing is still under development and information on existing blockchain solutions is often limited to media articles and company websites, interviews were conducted. They are considered useful for "examining unchartered territory" (Adams, 2015, p. 494) and understanding "how" or "why" certain events occur (Adams, 2015, p. 493).

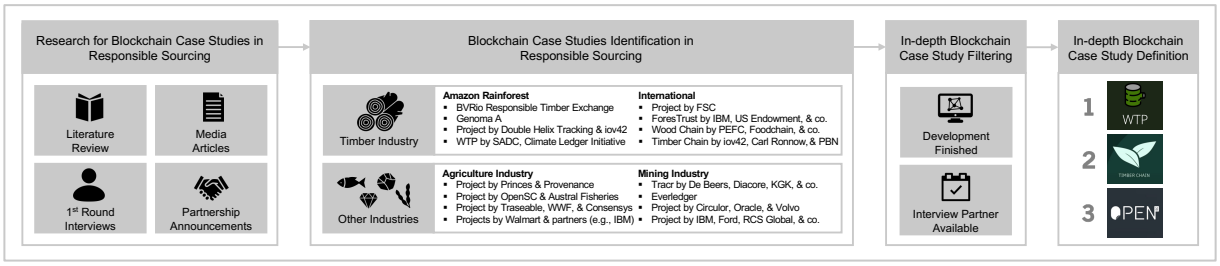


Image 9: Selection process of the in-depth case studies[14] (own image)

To determine which case studies should be developed in-depth, several information sources were consulted to identify the current landscape of blockchain applications in responsible sourcing (see Image 9). Given the relatively recent emergence of blockchain in the timber industry, applications in responsible sourcing from the agricultural and mining sector were consulted due to the industries' similarity to the timber sector in terms of challenges, processing stages, and illegality issues. A literature search with relevant key words was conducted to identify relevant papers (see Appendix Chapter 1.1). Given that the scientific discourse requires time for publishing, media articles and partnership announcements were examined, which provided up-to-date announcements of blockchain projects. Additionally, some experts on the timber industry and Brazilian Amazon were asked to name blockchain projects during the first rounds of interviews. Through these efforts, 16 blockchain projects were identified. In the next step, the identified blockchain projects were filtered based on two criteria: The first criteria – completion of development – sought to exclude early-stage projects where the solution was still being developed and, therefore, the generation of insights on the technical, operational, market, and financial feasibility was limited. Bakker (2018) observed that "blockchain in Brazil is still in its early stages" (p. 1), meaning that cases outside of Brazil were examined. The second criteria concerned the availability of interview partners, which was critical given the low availability of secondary sources and limited level of detail in available sources. Summarising, the filters applied were the use of blockchain, application of responsible sourcing in the timber, mining, and agriculture industry, completion of the development stage, and availability of interview partners. This resulted in the selection of the Wood Tracking Protocol [WTP] project, Timber Chain, and Open SC as in-depth case studies.

The Wood Tracking Protocol [WTP] project was launched by the Swiss Agency for Development and Cooperation in partnership with the Climate Ledger Initiative (Jaggi, 2019, p. 30). The project seeks to create a new way of tracking wood with a tamper-proof digital system based on digital verification protocols and blockchain technology in the Peruvian Amazon (WTP, 2021b, p. 4). An objective of their system is to tackle illegal logging and be recognised as a tool that can enable companies to meet forestry laws and determine the origin of timber (Fabing, 2021a, pp. 1–2). WTP has concluded the system's development phase and has initiated the pilot stage with companies in the Peruvian Amazon to evaluate its viability and scalability (Jaggi, 2019, p. 31). This case is relevant due to its geographic proximity to Brazil and its focus on the Amazon rainforest, the timber industry, and illegal logging. Furthermore, there are numerous similarities between the Peruvian and Brazilian Amazon, as both are marked by widespread corruption, high timber illegality, and challenges with fraud in provided documentation and along the timber supply chain (see Chapters 3.2, 3.3) (Interview Fabing).

[14]This overview may not be comprehensive. Instead, it captures a selection of blockchain projects that are used by companies for responsible sourcing.

Timber Chain is the result of a collaboration between technology provider iov42, timber trader Carl Ronnow, and certification company Preferred by Nature (Interview Kealoha). Timber Chain allows timber companies to digitise data recording processes and currently focuses on timber exporters (Interview Anning). The inclusion of other actors in the industry, such as upstream suppliers, could present an option in the medium to long term (Interview Anning). The solution seeks to minimise the risk of illegality, foster data-driven decision-making, and provide transparent audit trails (iov42, 2021c, ¶4). The partners have concluded the development and testing stage and Timber Chain has gone live in June 2021 with Carl Ronnow as the first timber company to implement it for exports of Malaysian timber, mainly to the EU and UK. This case study provides valuable insights on how blockchain-based solutions can overcome some of the challenges that exist in the current certification and auditing process, such as falsified documents and double-use of legitimate certified documents (Interview Kealoha). These challenges are also common to the wood sourced from the Brazilian Amazon (see Chapter 3.2.2).

OpenSC is a technology venture founded by WWF-Australia and BCG Digital Ventures (WWF-Australia, 2018, ¶1). The venture combines blockchain with machine learning and IoT to track products from the source to end consumer for a wide range of commodities, such as tuna, prawns, coffee beans, and palm oil (Kshetri, 2021, p. 192). It jointly co-innovates on a solution with industry partners, such as Nestlé and Austral Fisheries, and creates an offering that can be used by these partners and sold to other industry players (WWF-Australia, 2018, ¶1). The venture is considering expanding to timber, but the development of initial concepts is still at an early stage, so no information on timber applicability was provided during the interview (Interview Lange). This case study will focus on the source-to-bait solution in the fishing industry, which has passed the development and testing phase and is being implemented in fishing companies since 2019 (Mutz, 2019). The solution addresses illegal fishing, which has various parallels to illegal logging since fish can be harvested in prohibited marine areas (vs. protected forest areas), overfished (vs. over logged), and laundered in the fish supply chain (vs. laundered in the timber supply chain) (see Chapter 3.2.2) (Fox, Mitchell, Dean, Elliott, & Campbell, 2018, p. 946). The key learnings gained from the case studies are weaved into the following chapters. The detailed approach used to conduct the interviews and develop the case studies, the comprehensive case study results, and the interview transcripts can be found in Appendix Chapters 2 and 3.

5.2 Blockchain Ideation

To ideate on how blockchain could complement corporate strategies to tackle illegal logging, the key terminologies of the technology and differences towards traditional databases are outlined. Based on the theory, potential applications on the corporate framework of action are derived before a blockchain use case for the timber industry is defined.

5.2.1 Blockchain Theory

Different definitions of blockchain exist, but no universally recognised definition has emerged (Treiblmaier, 2020, p. 4). Bender, Burchardi, and Shepherd (2019) define blockchain as “a database infrastructure that is distributed and shared among network participants. Blocks of data entries and transactions are chained together and stored in an immutable form” (¶4). According to de Filippi and Hassan (2018) “Blockchain is a digital distributed ledger system where transactions and records are verified by community consensus” (as cit. in Nikolakis et al., 2018, p. 6), while Düdder and Ross (2017) define it as “a distributed database that is characterized by decentralization, consensus, validity, immutability, and authentication” (p. 2). Examining these definitions, blockchain at its most basic level

represents a digital database that is distributed among several parties. Further commonalities among the definitions are decentralisation, consensus, and immutability, characteristics that have also been recognised by other authors (Kshetri, 2021, p. 31; World Bank, 2017, p. 5; Treiblmaier, 2020, p. 6).

In blockchain, no central authority controls the distributed ledger and its history, unlike traditional databases, where typically one single entity governs the database (Bender et al., 2019, ¶5; Iansiti & Lakhani, 2017, ¶3). Multiple or all network participants own a complete, identical, and up-to-date copy of the ledger and can access the database at any point in time, though the degree of decentralisation and data accessibility depends on the type of blockchain used (The World Bank, 2017, p. 5). This ledger is automatically updated in all participants' computers each time a new transaction is added (Kouhizadeh & Sarkis, 2018, p. 3). To add a new transaction, the relevant network parties need to agree on its validity, which differs from traditional databases where commonly one central party validates transactions (Higginson, Lorenz, Münstermann, & Olesen, 2017, p. 2; Treiblmaier, 2020, p. 6). The network participants need to specify the consensus protocol, which includes defining rules, such as parties involved and mechanisms used, in the algorithmic design of the ledger beforehand (The World Bank, 2017, p. 6). While different consensus mechanisms exist and new ones keep emerging, three important ones include Proof of Work [PoW], Proof of Stake [PoS], and Proof of Authority [PoA] (Herweijer et al., 2018, p. 14; Kshetri, 2021, p. 30). In a PoW consensus model, all network participants can compete to validate a transaction, while in a PoS protocol, only a specified group of users can verify transactions in proportion to their stake (Kshetri, 2021, p. 30). For instance, one participant who owns five percent of all coins in a specific cryptocurrency can only validate five percentage of blocks (Kshetri, 2021, p. 30). A modified version of the PoS protocol represents the PoA consensus model, where a group of preapproved users who are perceived as trustworthy validate transactions, meaning the validators' identity rather than their stake is decisive (Hinckeldeyn, 2019, p. 16; Kshetri, 2021, p. 30). Note that the consensus mechanisms vary in terms of confidentiality, security, and processing times, and their applicability is dependent on the blockchain type (Hinckeldeyn, 2019, p. 12).

Once transactions are validated, they are stored in the database in a "permanent, immutable, tamper-proof and transparent manner" (Subramanian et al., 2020, p. 12). To alter records, consensus is required among the network participants, and a new transaction with the adapted information is added, given that blocks are linked to the preceding block, ordered chronologically, and stored permanently (Iansiti & Lakhani, 2017, ¶3; Kouhizadeh & Sarkis, 2018, p. 3). This mechanism is different from traditional databases, where data transactions may be non-transparent and vulnerable to fraud and misuse (Subramanian et al., 2020, p. 11). Besides the consensus mechanism, cryptographic techniques, such as hashes[15], data encryption, and unique digital signatures, prevent the alteration of transactions and ensure data integrity (Subramanian et al., 2020, p. 15). An exception to the data immutability in all types of blockchains, especially public ones, exists: The "51 percent attack" (Ganne, 2018, p. 7). In such a scenario, a group of validators who control more than 50 percent of the network's blockchain could alter the content in the ledger (Ganne, 2018, p. 7; Upadhyay, 2019, p. 14). However, it is considered a complicated and computationally time-intensive procedure and regarded as "almost impossible" (Upadhyay, 2019, p. 13), even more true in light of the recently proposed consensus algorithm that would require malicious actors to attain control of 99 percent of the validators (Ganne, 2018, p. 6).

After establishing the blockchain characteristics decentralisation, the consensus mechanism, and data immutability, a closer look at the blockchain is taken. The technology involves storing transactions, which are called blocks, in the database, which is referred to as the chain – hence, the name blockchain

[15]A hash is used to identify one specific transaction. From the hash value it is not possible to infer the input of the hash function (Hinckeldeyn, 2019, p. 6).

(Subramanian et al., 2020, p. 12). The first entry in the blockchain is known as the "genesis block," and each new transaction once validated via the consensus protocol, is added to the previous block in chronological order (Ganne, 2018, p. 6; The World Bank, 2017, p. 9). Each block contains the hash of the preceding block, the transaction data, the corresponding time stamp, and the respective digital signature of the participants (Urban, 2020, p. 19). Similar to signatures on a contract, these digital signatures bind the participant to the block's content (The World Bank, 2017, p. 8). "Network participants each have a private key, which is used for signing digital messages and only known by the individual user, and a public key which is public knowledge and is used for validating the identity of the sender of a digital message" (The World Bank, 2017, p. 9). Additionally, the ledger can be programmed to automatically trigger transactions, with so-called "smart contracts," once the defined rules are met (Hinckeldeyn, 2019, p. 21). Lastly, it is important to be aware of the differences between blockchain types, namely public permissionless, public permissioned, and private permissioned blockchains (see Image 10) (Mulligan, Scott, Warren, Rangaswami, 2018, p. 5). "Each version is useful to achieve different objectives and meet different requirements" (Mulligan et al., 2018, p. 5). Given the concerns companies may have regarding confidentiality, permissioned blockchains are often preferred for supply chain applications since the owners of the blockchain have control of who can access the network and which users have the permission to read, validate, and write data (Ganeriwalla, Casey, Shrikrishna, Bender, & Gstettner, 2018, p. 2; Kshetri, 2021, p. 40; Subramanian et al., 2020, p. 16). According to Ganeriwalla et al. (2018), "Most industries are heading in this direction [of public permissioned and private permissioned blockchains]" (p. 2).

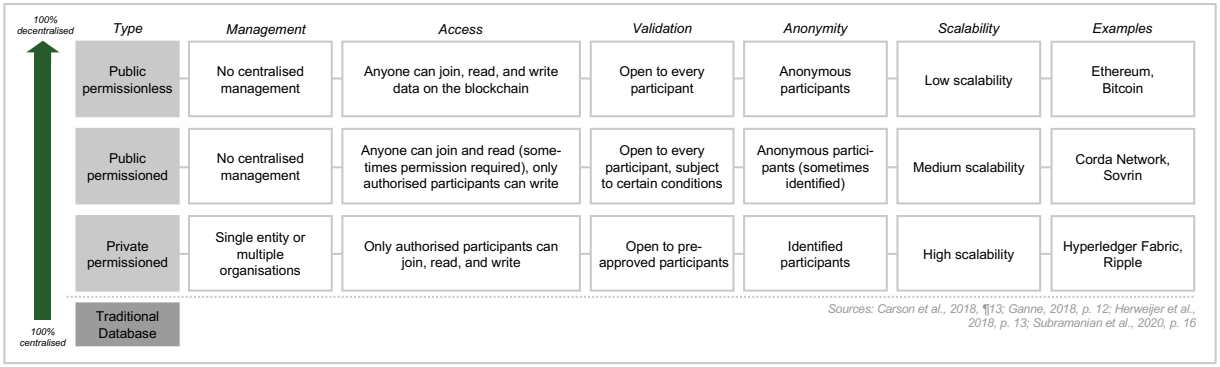


Image 10: Overview of blockchain types (own image)

5.2.2 Blockchain Applicability on Corporate Framework of Action

The presented blockchain characteristics – decentralisation, consensus, and data immutability – could promote transparency, traceability, security, and reliability (Figorilli et al., 2018, p. 11; Ganne, 2018, p. 77). In the timber industry, actors are often suspicious that others are not as transparent as they ought to be (Interview Anning). Beyond that, the blockchain characteristics could reduce fraud, opacity, and illegality in the timber supply chain (Kshetri, 2021, p. 20; The World Bank, 2017, p. 15). Vilkov and Gang (2019) remark that "to reduce illegal logging and modernise timber trade, blockchain is a new technology which could be a candidate solution and system" (p. 390). Several companies have developed and implemented blockchain-based solutions to address illegal logging in supply chains, such as WTP and Timber Chain (iov42, 2021c, ¶4; WTP, 2021, ¶4). Beyond that, blockchain-based solutions have emerged in other industries to address illegality in cattle farming, soy production, fishing, and mining (Leong et al., 2018, p. 45; Varriale, Cammarano, Michelino, & Caputo, 2020, p. 9; WWF-Australia, 2018, ¶1). Lastly, blockchain is considered advantageous for supply chains characterized as complex and involving numerous stakeholders, as is the case for the timber industry (Interview Lange). Companies using blockchain-based solutions often work with specific claims that assert a product's

origin, legality, sustainability, or other claims (Ganne, 2018, p. 80). For instance, OpenSC verifies the claim "fished outside protected areas" (OpenSC, 2021d, ¶3), Timber Chain "FSC certified [timber]" (Interview Anning), or Provenance "sustainably sourced and slavery-free [tuna] products" (Ganne, 2018, p. 80). The following sub-chapters will examine how blockchain-based solutions could complement the corporate strategies outlined in Chapter 4.2. Note that the materialisation of the opportunities presented will depend on the exact solution and blockchain architecture.

5.2.2.1 Commitment to Removing Illegal Logging and Deforestation

Blockchain represents a way for companies to transform their pledges to combat illegal logging into tangible reality by integrating the technology into existing systems or developing new blockchain solutions (US Endowment, 2020, ¶2). Additionally, the technology could help companies meet legal, social, and environmental claims by storing them on the ledger in an unchangeable manner (Kshetri, 2021, p. 106). Currently, it is difficult for external stakeholders to verify company claims effectively: For example, "Apple argues that it has been mapping its cobalt supply chain to the mine level since 2016. However there is currently no way to determine the truth or falsity of such a statement" (Kshetri, 2021, p. 19). Depending on the supply chain steps covered by the blockchain solution, the technology could support upstream suppliers in fulfilling supplier code of conducts or meeting purchasing policies. Companies may even require suppliers to join the blockchain platform: For instance, after completing an 18-month testing phase Walmart set a deadline for its direct suppliers of spinach, lettuce, and other greens to join its food-tracking blockchain solution. The company also mandated its indirect suppliers to join but gave them an additional eight months to comply. (Nash, 2018, ¶1).

A timber company may give other parties, such as auditors, authorities, consumers, and the public, access to view data stored on the blockchain, creating increased transparency around the timber supply chain and insights on how the company is acting on its commitment to exclude illicit timber from its supply chain (Hastig & Sodhi, 2020, p. 940; Kshetri, 2021, p. 31). As a result, other benefits could materialise, such as increased credibility, higher trustworthiness, and improved company reputation (Kshetri, 2021, pp. 20, 106, 197). Furthermore, given the relatively recent emergence of blockchain in the timber industry, companies could gain a competitive advantage by being one of the first movers and providing end consumers and other stakeholders unparalleled transparency into the actions the company is taking to meet its commitment to removing illegal logging and deforestation (Interview Lange). Once the blockchain solution is created, the company could scale it to an industry-wide solution to address illicit timber, multiplying the company's positive impact (Interview Lange).

5.2.2.2 Supply Chain Initiatives

Blockchain could increase transparency within the timber supply chain and help prevent illicit timber from entering supply chains (Hastig & Sodhi, 2020, p. 938; Leong et al., 2018, p. 10). However, the technology alone cannot verify timber legality and correctness of the data entered by the network participants (Carson et al., 2018, ¶11). "Blockchain cannot assess whether an external input is accurate or truthful – this applies to all off-chain assets and data digitally represented on blockchain" (Carson et al., 2018, ¶11). Therefore, the technology typically complements existing company efforts to verify legality and data validity: Carl Ronnow, for instance, uses Timber Chain in addition to its legal source certification and other due diligence measures (Interview Anning).

Though the technology alone cannot guarantee legality and data correctness, it is characterised by certain features that may promote legal business activities and support legality verification: First, transactions in the blockchain are validated by other network participants via the consensus protocol (see Chapter

5.2.1), discouraging participants from entering false information (The World Bank, 2017, p. 6). For example, in Timber Chain, the certification organisation Preferred by Nature has the role of a validator, meaning the organisation authenticates the origin, species, or other claims made (Interview Roberts). Second, given the immutability of data once uploaded in the blockchain and visibility on who uploaded it, transactions of illegal timber, once uncovered, can be easily traced to the respective participant, who can be held accountable. Thus, data immutability creates a strong disincentive for actors to insert fraudulent information (Kshetri, 2021, p. 26). Third, the blockchain solution can be linked to external data sources, such as government databases containing companies' legal status or environmental and tax infractions (Costa et al., 2016, p. 83). A change from legal to illegal for a network participant would be flagged in the system in real-time, allowing other actors to take action by stopping business relationships, not accepting shipments, or returning orders. For instance, WTP connected the blockchain system to OSINFOR's database, which records the legal status of Peruvian timber companies, to have an up-to-date view of the legal status of its network participants. (Interview Fabing)

Blockchain can support timber tracking efforts, such as paper-based evaluations, IoT devices, and scientific wood identification methods, mainly by recording the data generated by these tools in the blockchain. However, blockchain cannot replace these efforts since its role is limited to data storage, management, and sharing, meaning it does not generate information on the timber or its journey (Varriale et al., 2020, p. 2). Michael Marus, Chief Innovation Officer at FSC, says: "Blockchain technology can help with compliance, can help with understanding what happens day to day with handling materials, could be something that complements or fortifies chain of custody but it's not going to replace chain of custody" (Worm, 2021a, minute 8:03). Even in the case where blockchain helps a company transit from storing documentation in paper form to recording them in a digitised format, the type of information collected remains the same unless the decision is made to include additional data points (Interview Anning). Richard Anning, Environmental Manager at timber company Carl Ronnow, explains: "We're not giving any different information that we would have given without the blockchain. We're just putting it on the blockchain" (Interview Anning). Beyond data storage, management, and sharing, blockchain offers several other benefits for tracking timber.

Blockchain could support companies in recording transactions at every step of the supply chain, thus increasing end-to-end traceability from stump to store (Herweijer et al., 2018, p. 6). By allowing blockchain to record timber-related data permanently, companies can demonstrate their commitment to transparency and data integrity, as they cannot change data retrospectively, which in turn can increase other actors' trust in the company and the supply chain (Subramanian et al., 2020, p. 4). Additionally, in an end-to-end solution, blockchain may facilitate or automate the documentation of the chain of custody since each actor records information after a change of ownership occurred, meaning timber companies do not need to recreate the entire chain of custody based on collected documentation, which is often the case in paper-based approaches (Worm, 2019, ¶34). Instead, information can easily be accessed in almost real-time, as illustrated by Walmart: In 2016, when the VP of food safety picked up a package of mangoes from a store and asked his team where it had originated from, it took them six days, 18 hours, and 26 minutes to answer the question (Kshetri, 2021, p. 187). After Walmart trialled a blockchain-based traceability system, where each actor in the supply chain recorded product and transaction data, it took only 2.2 seconds to trace the mangoes back to the source (Duan, Zhang, Gong, Brown, & Li. 2020, p. 9). Beyond increased efficiencies, a constantly updated ledger allows companies to increase their response rate to issues as soon as they occur (Kshetri, 2021, p. 101).

Increasing visibility of the entire production chain via blockchain technology can help companies streamline administrative components of the certification process and fulfil FSC and PEFC chain of custody requirements (PEFC Italy, 2019, ¶2; Worm, 2019, ¶18). "If set up properly, Blockchain will ensure that these certificates cannot be copied, double-counted, or illegally sold" (Babich & Hilary, 2018, p. 22). Also, FSC director Worm acknowledges the potential of blockchain in automating transaction verification to address the time-consuming verification process and address issues, such as double counting certified timber (Worm, 2019, ¶8, 10–11). By including certification organisations in the blockchain solution as validators or linking the blockchain solution to their databases of certified companies, companies could reduce the risk of purchasing illegitimate timber masqueraded as certified.

5.2.2.3 Monitoring Efforts and Periodic Audits

The potential of real-time timber tracking could support companies in monitoring their supply chains and product-related information, such as price, quality, location, and date, on an ongoing basis (Montecchi, Plangger, & Etter, 2019, p. 284; Varriale et al., 2020, p. 8). If the blockchain solution includes satellite imagery as a data source and is combined with technologies, such as image recognition algorithms and machine learning, the system could be programmed to automatically trigger alerts when events of selective logging or deforestation are identified (Kshetri, 2021, pp. 174–175). Furthermore, by recording transactions at key steps of the supply chain, blockchain provides an immutable audit trail in addition to storing auditor's findings in a permanent manner (The World Bank, 2017, p. 15). Horowitz-Burdick says: "You have this secure record of what was claimed, which can be used super usefully as an auditing tool, because you have this immutable ledger of what was claimed by the mill and what was verified by the importer" (Interview Horowitz-Burdick). This ledger can easily be shared with auditors, regulators, and authorities for verification and generate time and cost savings (Bender et al., 2019, ¶9; Kshetri, 2021, p. 32; RCS Global, 2017, p. 14). Generally, data collection supports companies in conducting risk assessments, evaluating risk mitigating strategies, and identifying inconsistencies over time (Interview Horowitz-Burdick; PEFC Italy, 2019, ¶3). According to Michael Fabing, co-founder of WTP, insights for optimising operations could be gained, which could result in efficiency and financial gains, respectively bottom-line benefits (Interview Fabing).

The information captured by the blockchain solution can also be shared with end consumers (Leong et al., 2018, p. 10). Currently, consumers have difficulty determining the legality and sustainability of timber products as commonly no central database exists, which they can access (RCS Global, 2017, p. 9). Blockchain, in combination with IoT tools (e.g., QR codes), can provide the means for consumers to access information about the product, its origin, and journey on the blockchain, improve their knowledge, and thus, make responsible purchasing decisions (Kshetri, 2021, p. 152; Montecchi et al., 2019, p. 286). "Undoubtedly, blockchain guarantees a standard of authenticity and security to the final consumer that no other system is able to provide in such a precise and verifiable manner" (Varriale et al., 2020, p. 11). Benefits that could accrue are the acquisition of new customers, favourable reputation as well as increased customer loyalty, trust, and transparency (Galvez, Mejuto, & Simal-Gandara, 2018, p. 226; Hastig & Sodhi, 2020, p. 941; Varriale et al., 2020, p. 3). Providing valuable information on legality and sustainability might enable timber companies to position their products in the premium segment, and thus, to reap the benefits of higher prices and top-line growth (Interview Lange).

5.2.2.4 Political Advocacy for Government Action

Blockchain has limited applicability in helping companies advocate for government action. Nonetheless, the Brazilian government could evaluate its applicability for its licensing, control, and monitoring systems that are currently marked by several weaknesses (see Chapter 3.3.1). For example, the

government could explore the use of blockchain to address petty corruption – a well-known issue in the licensing process of logging permits – since the technology has been recognised for its potential to reduce fraud and corruption (NEPCon, 2017, pp. 17; The World Bank, 2017, pp. 15, 33). Beyond that, "distributed ledger technologies have the potential to help governments to collect taxes, deliver benefits, […] record land registries, assure the supply chain of goods and generally ensure the integrity of government records and services," (The World Bank, 2017, p. 33) according to Mark Walport, the UK's Chief Scientific Advisor. Therefore, the Brazilian government could examine how the technology could potentially address challenges such as unclear property rights (see Chapter 3.3.2) and the use of the CAR registry, where information is often self-declared and unverified, as sole evidence of property ownership (see Chapter 3.3.1). However, given the defined research scope, the thesis will refrain from examining the potential use cases of blockchain by the Brazilian government in further detail.

5.2.2.5 Alignment of Approaches and Multi-stakeholder Collaborations

Though blockchain's potential in aligning approaches is limited, it bears great potential in strengthening collaboration between different parties, such as supply chain actors. "It represents a better, more secure and viable way to collaborate and conduct business among various members of a supply chain ecosystem" (Subramanian et al., 2020, p. 12). Parties, such as auditors and regulators, can be given access to key information or play a more active role in the blockchain as validators (see Chapter 5.2.2.3) (Kshetri, 2021, pp. 25, 32). For instance, Anna Roberts, Head of Business Development at iov42, mentioned that they are currently considering making the UK competent authority for timber regulations an additional validator on Timber Chain (Interview Roberts). Furthermore, timber companies can decide to include government agencies or authorities as collaborators in their blockchain solution: For example, WTP is collaborating with police, who can add transactions, and the government agencies OSINFOR and SERFOR, who oversee companies' legal status and approve submitted forest management plans (Interview Fabing). As of now, WTP's platform is notified as soon as authorities flag a shipment as illegal, given the linkage to the respective database (see Chapter 5.2.2.2) (Fabing, 2021a, p. 1). WTP is exploring the potential to pass on information of transactions marked by strong inconsistencies to law enforcement for closer examination. Moreover, Fabing expressed that they see potential in pursuing partnerships with certification organisations or technology providers, such as drone surveillance and wood identification technologies, to complement their blockchain solution since such fields do not represent WTP's area of expertise. (Fabing, 2021a, p. 2; Interview Fabing)

Beyond that, blockchain can be a project for multiple stakeholders to collaborate on. Ganne (2018) states: "Given the potential of Blockchain, companies, civil society organizations, software developers, academics, governments and intergovernmental organizations should work hand-in-hand to assess the practical and legal implications of the technology and to develop collective solutions to existing challenges" (p. 112). Collaborations between the private sector and government can be pursued, as in the case of WTP, where they are working with the Peruvian government towards providing the blockchain solution free of cost for timber companies (Interview Fabing). According to Fabing, the Peruvian government may be interested in doing so since the widespread adoption of WTP's solution helps increase the attractiveness of Peruvian timber to international buyers and formalise the timber sector, which is currently marked by a high percentage of informal workers (Interview Fabing). Timber Chain is an example of a blockchain collaboration between a timber company (Carl Ronnow), technology provider (iov42), and certification company (Preferred by Nature) (Interview Kealoha). Another example of a multi-stakeholder collaboration represents the blockchain project by IBM (technology provider), Walmart (incumbent company), and Tsinghua University (academia), which pursues the objective of improving food traceability for Chinese consumers (Kshetri, 2021, p. 179).

5.2.3 Blockchain Use Case Definition

An end-to-end blockchain solution from the forest to the end consumer may allow timber companies to realise many of the aforementioned benefits. This thesis will examine the use case of an end-to-end blockchain solution to evaluate the feasibility of implementing blockchain technology to complement corporate strategies and address illegal logging.

5.3 Blockchain Validation

As outlined in the methodology, the defined use case is validated by appraising four feasibility criteria, namely the technical, operational, financial, and market feasibility, which include the discussion of important aspects and risks involved with blockchain in the respective areas. Key insights of the feasibility analysis and potential of blockchain to combat illegal logging are drawn before the outlook, limitations, and areas for future research are presented.

5.3.1 Blockchain Use Case Analysis

Technical feasibility examines technical aspects, including the blockchain architecture, the feasibility of end-to-end supply chain tracking from stump to store, and technical limitations. Operational feasibility covers data requirements, educational processes, and infrastructural challenges, while market feasibility investigates the prevailing market conditions in the Brazilian Amazon. Lastly, financial feasibility discusses cost and revenue implications. (Leong et al., 2018, pp. 22–23, 25–26, 29) Though all four areas are important, the focus of the analysis will lie on technical feasibility given the defined research scope of evaluating the potential of blockchain technology to combat illegal logging in the Brazilian Amazon. Insights are drawn from the literature review, conducted interviews, and case study analysis, mainly from the three in-depth case studies WTP, Timber Chain, and OpenSC but from time to time from other blockchain solutions (see Image 9). Note that the feasibility aspects discussed in the following sub-chapters should not be considered exhaustive as non-mentioned aspects may play an essential role in the decision to employ blockchain. For example, company-specific factors, such as top management support, organisational readiness, and capabilities to bring about change, may influence this decision (Hastig & Sodhi, 2020, p. 935; Subramanian et al., 2020, p. 5).

5.3.1.1 Technical Feasibility

The analysis of the 16 blockchain solutions in the timber, agricultural, and mining industries revealed that blockchain typically represented only one part of the solution for combating illegal trade, given the technology's limitations. On the one hand, companies undertook parallel efforts to verify product legality and ensure traceability, efforts deemed critical due to blockchain's inability to verify the correctness of inserted data and to generate information on the product and its journey (see Chapter 5.2.2.2). Roberts from iov42 emphasized that blockchain does not replace companies' existing legality and tracking efforts and commitments to due diligence but rather adds an extra layer of security (Interview Roberts). On the other hand, companies typically implemented blockchain alongside other technologies, such as IoT and machine learning. "Blockchain should not be viewed as an all-encompassing platform. Its value and significance lie in combination with other technologies" (Kshetri, 2021, p. 130). Both practice and literature suggest that IoT devices support companies in capturing real-world information on the product, its location, and supply chain conditions, while machine learning facilitates the analysis and synthesis of data collected on legality and sustainability to detect inconsistencies in an automated manner (Catalini & Gans, 2016, p. 12; Costa et al., 2016, p. 40; Subramanian et al., 2020, p. 22). For example, OpenSC employs blockchain, IoT, and machine learning to collect, analyse, and store data on tuna to verify whether it was caught outside of marine protected areas in a data-driven, automated way. Raw data is stored on the blockchain to ensure immutability, IoT

devices are attached to the fish, and machine learning combines, analyses, and cross-checks multiple data sources that influence a vessel's ability to fish (Interview Lange). OpenSC uses both primary data, including vessels' GPS coordinates, speed of the fishing vessel, historical data on fishing trips duration, and secondary data, including weather data, sea level depth, GPS coordinates of protected zones, and data from governmental vessel monitoring systems for the machine learning model (Interview Lange). Machine learning could prove particularly valuable for analysing large datasets and identifying patterns over time and, thus, useful for the Brazilian Amazon where inconsistencies in wood production are typically not detected in one audit but rather over time (Interview Horowitz-Burdick; Interview Lentini). Furthermore, Brazil is characterised by relatively high availability of digitised data in the timber sector compared to other countries, which often work with paper-based control systems, meaning numerous digital systems, such as SISFLORA and SINAFLORA, could be linked to the solution and form the basis of the machine learning analysis (see Chapter 3.1.2) (Interview Horowitz-Burdick). Overall, any of the technologies used in identifying illegal logging can form one piece of a broader control system that companies have in place (Interview Horowitz-Burdick). For such systems, blockchain can add value by bringing together the best technologies and integrating the entire set of collected data for synthesis and analysis in one place (Interview Kealoha; Subramanian et al., 2020, p. 22).

The decision to adopt a certain blockchain type (see Chapter 5.2) depends on the participating actors, the pursued objective, the shared data, defined business policies, and other factors (Leong et al., 2018, p. 56). Data visibility was named a concern for timber companies in two interviews (Interview Kobel; Interview Roberts). Private blockchains may be more suitable for such companies, since access to the network is restricted, and companies remain in control of which users read, validate, and write data (see Chapter 5.2.1). This was the case for FSC: Worm (2019) explains that business-sensitive data is withheld in their blockchain solution and only shared between direct trading parties and – when required – auditors (¶28–29). Very few timber companies in the FSC system would be interested in a public blockchain setup where trading volumes of all parties in a supply chain would be visible in the blockchain network (Worm, 2019, ¶27, 29). On the other hand, public blockchains – depending on their setup – can also be built to maintain data confidentiality. For instance, WTP opted for a public blockchain, where the transaction's hash is uploaded, in combination with IPFS, where transaction data is stored and only accessible with the respective hash (Interview Fabing). With such a blockchain architecture, companies remain in control of the type of data that is shared and with whom, while parties in possession of a hash value can verify the validity of the data (Interview Fabing; Urban, 2020, p. 21). As seen in these examples, blockchain solutions differ case by case: "Organizations that are building a blockchain-based solution should consider what type of data should be on-chain, what data need to be accessed by whom, for how long and for what purpose, and what data should be limited to one-to-one transactions" (Leong et al., 2018, p. 49). Additionally, the consensus protocol of how data in the blockchain solution is verified and by whom needs to be defined (see Chapter 5.2.1).

Implementing a blockchain solution does not necessarily entail collecting new data points since existing data is typically saved in the blockchain network (see Chapter 5.2.2.2). Independent of blockchain, companies may make the decision to collect additional data points, such as employee wages, to comply with certain environmental and social standards (Worm, 2021b). Leveraging existing data systems saves resources associated with the collection and recording of new data points. OpenSC, for instance, examined what data was already being collected by fishing vessels, governmental vessel monitoring, and weather monitoring systems, and with minimal effort, linked the relevant data, such as weather data collected by weather monitoring systems, to the OpenSC solution. (Interview Lange) Developing a blockchain solution in the timber industry could therefore include reviewing and leveraging extant data

sources of supply chain actors, Brazil's licensing, control, and monitoring systems, and forestry data on the Amazon, such as density, biodiversity, and species occurrence. Sawmills, for instance, may already have robust systems in place to track the conversion rates of logs to sawn wood (Interview Anning). The data collected in WTP's blockchain solution represents an example of the type of data that could be recorded in a timber blockchain: In the initial stage, information on the logger's location, the tree's location, timber height, diameter, volume, species, and the wood identification number is collected. Other data may be required for subsequent supply chain steps: For example, the license plate of the transport vehicle is requested during transportation but omitted in other supply chain steps. (Interview Fabing)

Blockchain solutions can be deployed without employing devices or reading hardware in the timber supply chain, exemplified by Timber Chain (Kshetri, 2021, p. 94). However, research and other blockchain solutions suggest that blockchain is typically complemented by IoT devices to establish the link between the physical object and its virtual counterpart, also known as the "digital twin," to provide real-time visibility on the product and its journey to the end consumer and reduce the risk of fraud (EC, 2019, p. 1; Kshetri, 2021, p. 147; RCS Global, 2017, p. 3). Catalini and Gans note (2016): "In the absence of a strong link between offline and online events, asymmetric information and moral hazard will be an issue in these markets" (p. 12). How this link is established depends on the industry, objectives, and product type: While RFID tags work relatively well in the fresh tuna supply chain, given the limited processing, they are not suitable for palm oil since the end product is liquid (Kshetri, 2021, p. 195; Leong et al., 2018, p. 41). Lastly, user-friendliness is central to the acceptance and adoption of new technologies: "Technology always needs to be user friendly. You have to always think about the people that are involved," says Marus from FSC (Worm, 2021a, minute 23:52). For supply chains, this converts to minimally disrupting existing work processes through blockchain, IoT devices, and other technologies (Interview Lange). OpenSC's guiding philosophy states: "Make technology invisible to the people using it in order to automate and accelerate operations rather than disrupt workflow with additional steps" (OpenSC, 2021c, ¶9). Tom Lange, Transparency Innovation Lead at OpenSC, remarks that leaving existing workflows undisrupted is not always possible, but that wherever possible, implementation would proceed as cost-effectively as possible (Interview Lange). User-friendliness should be reflected in the design of additional workflows, such as mobile applications used to scan IoT devices (Düdder & Ross, 2017, p. 5). In the following paragraphs, numerous ways of how the physical product and the digital counterpart can be connected will be discussed. Note that timber companies may not have the resources or the need to implement the following solutions but may opt for only one of them based on their risk exposure. For instance, if the supply chain risk is highest in the logging step, a company is more likely to focus its risk-mitigating strategies on this supply chain step.

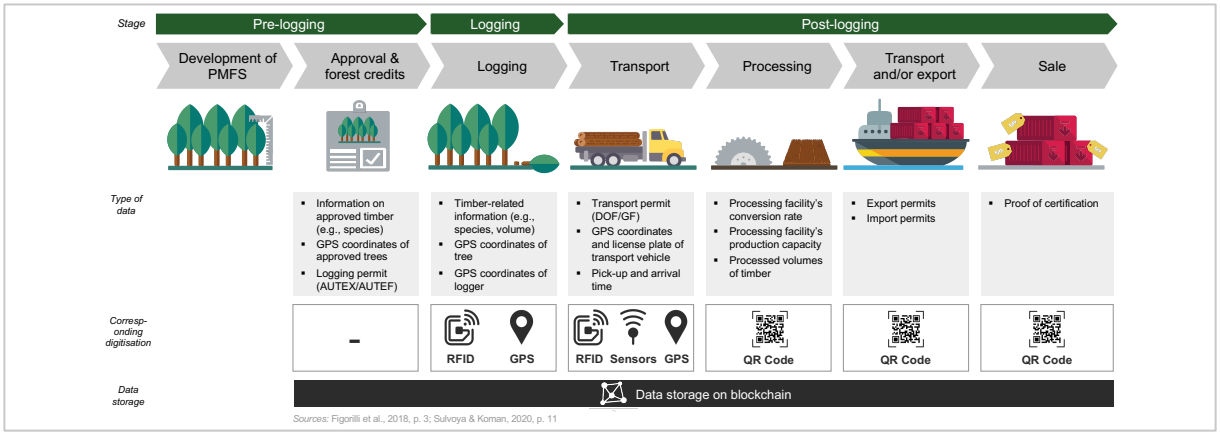


Image 11: Example of a possible blockchain solution in the timber supply chain (own image)

In the pre-logging phase, data on timber from the PMFS can be extracted, serving as a basis for establishing timber legality in the logging phase, where the GPS coordinates of the tree and those of the logger are recorded by taking pictures before and after the tree has been felled, similar to WTP's solution and Vilkov and Gang's proposition (Interview Fabing; Vilkov & Gang, 2019, p. 392). Additionally, governmental databases on the GPS coordinates of prohibited zones could be accessed and linked to the solution (Interview Fabing). By checking the GPS coordinates of the harvested tree against the GPS coordinates of approved and prohibited trees, one can determine whether the tree was logged inside or outside the permitted logging area (Vilkov & Gang, 2019, p. 392). After the tree has been felled, it can be marked with RFID tags to record product information and scanned at critical points in the supply chain until the wood is being processed (Chen et al., 2017, p. 173). A pilot study conducted by Figorilli et al. (2018, p. 9) tested the use of RFID tags for stages leading up to the timber's processing and QR codes for subsequent stages in combination with blockchain technology. They suggest that "the use of such technologies for wood traceability is already feasible and economically sustainable" (Figorilli et al., 2018, p. 11). However, practical applications of RFID in combination with blockchain are currently lacking in the timber industry: In at least five of the eight[16] timber blockchain solutions reviewed (see Image 9), none employed RFID tags in their solution. WTP, for instance, is using QR codes in early stages of the supply chain but sees potential in employing RFID tags in the future for the steps leading up to processing (Interview Fabing). Fabing remarks: "RFID will be very useful in these […] stages […] because we're talking about trees that are like 20 metres long, or five metres long" (Interview Fabing). Contrasting, Horowitz-Burdick states: "I don't see RFID […] as super useful, purely for the reason that you're dealing with a product that is immediately cut up […] and that's where fraud happens" (Interview Horowitz-Burdick). These opposing views suggest that the use of IoT tools, such as RFID tags, needs to be explored on a case-by-case level to determine its suitability.

During the transportation stage, illegally harvested timber can be mixed with legal timber by making a stopover at an illegal logging site and loading illicit timber on transportation vehicles, such as trucks, boats, and planes (see Chapter 3.2.2). Sensors can determine the vehicle's status, so whether the vehicle is being loaded, standing still, or moving, while GPS tracking allows transportation routes to be precisely tracked (Basole & Nowak, 2018, p. 352; Costa et al., 2016, p. 32). The data points extracted from these IoT devices in combination with other data, such as journey time, allow the blockchain network to determine whether transportation vehicles are following the planned route and flag suspicious movements, delays, or stops with predefined algorithms or machine learning analysis (Chen et al., 2017, p. 174; Kshetri, 2021, p. 84; Vilkov & Gang, 2019, p. 392). For example, Princes' blockchain solution in the tomato industry in Italy includes an installed GPS system in transportation vehicles to attain complete visibility on the movement of tomatoes (Askew, 2020, ¶19).

In the processing stage, logs are cut into large wooden boards or processed further into wood chips, paper, or other timber products (Interview Kobel). Due to the physical transformation that timber undergoes, employing IoT devices may not be feasible depending on the degree of processing: QR codes can be relatively easily affixed to large pieces of wood, as illustrated in Figorilli et al.'s pilot study (2018, p. 10), and scanned during transport, export, and sales, whereas attaching them to smaller wooden chips requires disproportionate efforts and costs (Interview Fabing). However, neither the RFID tag nor QR code can accompany the timber through the processing stage, meaning there is room for fraudulent activities by mixing illegal with legal timber (Interview Fabing). "The honest and accurate transference of information from RFID tag to QR code relies on the manufacturer" (EC, 2019, p. 1). Fabing remarks that the only way they make sure mixing does not occur at WTP is through mass-balance calculations:

[16]Based on publicly available information and interviews. In three timber blockchain cases, no data on the specifics of the solution was available.

"If you have 100 cubic meters of wood, you cannot have 150 cubic meters of wood coming out. So, the volume and the weight is [sic] the only thing that we can have as a tangible" (Interview Fabing). Mass-balance checks are widely used throughout the timber industry during the processing stage, particularly by certification companies and third-party auditors who typically have greater insights into the processing facilities' conversion rates and quantities processed due to their independent nature (see Chapter 4.2.3) (Interview Horowitz-Burdick; Interview Kobel). On-site audits and DNA fingerprinting represent other measures that help maintain the link between physical timber and its digital counterpart.

Nevertheless, with QR codes end consumers can easily access information on the timber product, its origin, and its supply chain journey, allowing companies to tell powerful stories around their traceability efforts (see Chapter 5.2.2.3) (OpenSC, 2021c, ¶2). Using QR Codes, OpenSC developed a series of interactive digital experiences tailored to different customer journeys: Consumers dining in a restaurant, for instance, are presented a summary of key facts on when, where, and how fish was caught rather than an extensive description of the fish and its journey (Mutz, 2019; Whiting, 2020, ¶4). Similarly, timber companies could create tailored customer experiences by differentiating between customers purchasing wooden furniture online, in furniture stores, or home improvement stores. Fabing from WTP mentioned that QR codes are currently not attached to the final wood product but will be incorporated in the future so end consumers can access the entire product history (Interview Fabing). Overall, the presented digital twins only cover some of the possible illegal activities exhibited in Image 4, namely logging in non-authorized and prohibited areas, and mixing illegal with legal timber during the transportation stage (see Chapter 3.2.3). This finding underlines the need for timber companies to engage in parallel legality verification and traceability efforts to cover other forms of illegality, such as overestimating volumes, logging protected species, and overstating conversion rates of timber, to ultimately exclude illicit timber from their supply chains. Though data on volumes, species, and conversion rates – typically recorded in the blockchain – could, in theory, rule out such scenarios, they rely on actors entering the respective data truthfully, which may be unlikely for malicious actors.

Similar to how fraud occurring during the creation of the PMFS undermines trackability efforts for subsequent supply chain steps (see Chapter 4.2.2), manipulating the first data entry in the blockchain negatively affects all blocks thereafter since they are based on the Genesis block (see Chapter 5.2.1). Lentini from IMAFLORA remarks: "Using blockchain technology only makes sense if you have a good source. […] You can have the best traceability systems and blockchain solution, but if the originating point is fraudulent, then there is little use for blockchain" (Interview Lentini). This challenge common to other data management systems is known as the "Garbage in, Garbage out" problem and is more pronounced in blockchain due to its characteristics of consensus, validity, and immutability resulting in the perception of integrity for data blocks post-validation, which may have serious negative consequences (see Chapter 5.2.1) (RCS Global, 2017, p. 4; Tucker & Catalini, 2018, ¶6). "Even though the data stay immutable, the blockchain does not have a verification mechanism to prove whether the raw data were correct" (Galvez et al., 2018, p. 230). Ganne (2018), senior analyst at WTO, notes that "while blockchains can help prevent fraud on the ledger, the tamper-resistance of the technology cannot prevent false information from being fed into the ledger" (p. 6). Therefore, blockchain cannot determine whether perhaps the most critical step of data collection is happening correctly or whether entered data truly reflects the actual situation (Hastig & Sodhi, 2020, p. 947; Tucker & Catalini, 2018, ¶5). For instance, malicious actors could withhold information on unsustainable practices used during the logging process. Daniel from Greenpeace remarks: "That first part of the [verification] process would really be key for success" (Interview Daniel). Consequently, when developing blockchain solutions, appropriate safeguards need to be incorporated to ensure data veracity in the blockchain, especially in

the context of the Brazilian Amazon, where thousands of fraudulent forestry credits are already generated in the initial stages of the supply chain (see Chapter 3.2.2) (Nikolakis et al., 2018, p. 6).

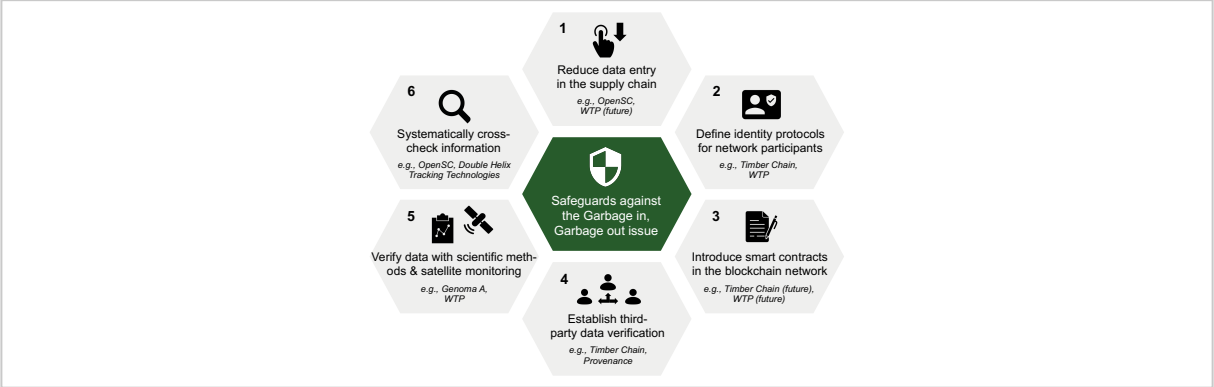


Image 12: Safeguards against the Garbage In, Garbage Out issue (own image)

Several potential safeguards emerged from the blockchain literature review, case study analyses, and conducted interviews (see Image 12). First, opportunities for data manipulation and human error can be reduced by automating the data capture process with IoT tools (Babich & Hilary, 2018, p. 6; Montecchi et al., 2019, p. 291). Though IoT tools are not infallible, they considerably reduce the risk of manipulation since strenuous efforts are required to manipulate IoT devices, and safeguards can be put in place to prevent tampering (see Chapter 4.2.2.2) (Carson et al., 2018, ¶30). Circulor, for example, integrated mechanisms in their blockchain solution to prevent GPS spoofing where actors project a false location to the GPS receiver (Hyperledger, 2020). WTP has recognised the potential of IoT devices to reduce the risk of fraud or human errors and thus, in the future, seeks to integrate different technologies into its blockchain solution, which is currently characterised by manual data capture (Fabing, 2021a, p. 2). Fabing from WTP remarks: "The less user input is in a system, the less manual work, the better it is. […] the more we can automate the system using sensors, GPS, photos, RFID tags, the better" (Interview Fabing). OpenSC already employs IoT in its solution by attaching an RFID tag to the fish after the catch, which is replaced with a QR code during the filleting stage (Kshetri, 2021, pp. 191–192).

Second, establishing identity protocols for the blockchain network may deter illegal activities. For instance, the identity-centric focus of Timber Chain, which includes authentication of personal data, such as date of birth, nationality, address, or employer information, means that only verified participants can join the blockchain network (Interview Kealoha; iov42, 2021b, ¶3). Kealoha from iov42 states: "That holds people accountable for whatever they're doing on the platform. So, […] if there is somehow faulty data, whether it's just accidental, or perhaps not accidental, it can be traced back to that person. And that kind of disincentivizes, [...] illegal or dubious behaviour in the system" (Interview Kealoha). Also, WTP has identity protocols for their network participants in place, namely checks of companies' legal status and user authentication with mobile phones (Interview Fabing; Jaggi, 2019, p. 30).

Third, the use of smart contracts may provide an incentive for participants to engage in honest behaviour (see Chapter 5.2.1). Via smart contracts, actors can define certain conditions that need to be in place before a data block is validated: In the logging step, the GPS coordinates of the timber load could be checked against those of protected and permitted trees before being accepted by the blockchain solution (Vilkov & Gang, 2019, p. 392). Another example of a prerequisite could be a defined transportation time range and planned transportation route, meaning transactions would not be validated in cases where the delivery time is exceeded, or the planned transportation route deviated from (Vilkov & Gang, 2019, p. 392). Based on publicly available information and interviews conducted, none of the reviewed timber

blockchain solutions currently use smart contracts in their solutions. However, to reduce the risk of data manipulation, WTP plans to handle payments through smart contracts in the future, where the money would be transferred to the seller when certain conditions are met (Interview Fabing). “So, if someone is lying, and making false allegations, or the information is a mismatch, that can be reported, and the money might not be transported,” (Interview Fabing) explains Fabing. Besides WTP, iov42 is actively exploring the use of smart contracts for their technology (Interview Roberts).

Fourth, the blockchain solution could include verifying critical pieces of data by third parties (Duan et al., 2020, p. 12). “Third parties may still be required to check off-chain processes and confirm that they meet the asserted claims. Ethical and social claims via a blockchain, for example, are only as good as the offline verification processes that guarantees [sic] that relevant ethical and social requirements have been met off-chain” (Ganne, 2018, p. 81). The same holds for legality claims, given that malicious actors are unlikely to record illegal activities they engage in off-chain. Data authentication could be carried out by actors such as the government (Duan et al., 2020, p. 12), indigenous people (Nikolakis et al., 2018, p. 6), certification organisations (Vilkov & Gang, 2019, p. 392), or auditors (Babich & Hilary, 2018, p. 28). At WTP, the government agencies OSINFOR and SERFOR help with data verification (see Chapter 5.2.2.5), while in Provenance’s blockchain solution for tuna, NGOs support the registration process of fishermen and verify social and environmental standards at the point of capture (Leong et al., 2018, p. 49). In the timber industry, third parties could conduct unannounced on-site visits to the logging site and check whether the data recorded mirrors the off-chain situation (Kshetri, 2021, p. 25). Furthermore, they could randomly request proof for specific pieces of information, as is planned for Double Helix Tracking Technologies’ blockchain solution (Interview Horowitz-Burdick). Lastly, these third parties could be named validators in the blockchain network and thus, be responsible for validating data (see Chapter 5.2.1) (Nikolakis et al., 2018, p. 6). For example, in Timber Chain, the main validator is Preferred by Nature, who authenticates the origin, species, permits, and certifications (Interview Roberts). “Effective governance of the blockchain (i.e., who decides what is put on, when and how) is essential to maintaining the integrity of the records” (Nikolakis et al., 2018, p. 13).

Fifth, the blockchain solution could encompass scientific testing, particularly DNA fingerprinting (see Chapter 4.2.2.2), as an independent method of verifying data veracity (Herweijer et al., 2018, p. 22). DNA fingerprinting is particularly promising since it overcomes the challenge of the physical transformation that timber undergoes in the processing stage, which is marked by difficulties in securely linking the physical timber to the digital counterparts (Worm, 2020b). Genoma A, for example, matches timber DNA extracted during later supply chain steps with the sample collected from the tree stump and captures the results in the blockchain (Interview Lentini). Düdder and Ross (2017) note: “A Blockchain entry (transaction) can be linked to physical evidence, e.g., its DNA profile in digital form as cryptographic hash” (p. 4). However, Anning draws attention to the costs involved: “With DNA, if you wanted to get down to the stump where the tree actually came from, then that would just be hugely expensive. But it could work for very, very high-value species” (Interview Anning). To mitigate costs, DNA fingerprinting could be used for blind samples of timber shipments (Seidel et al., 2012, p. 23). Additionally, parallel efforts could be undertaken to generate data that is not captured by the supply chain actors but collected independently of them (Herweijer et al., 2018, p. 22). For instance, satellite monitoring could be used to flag events of selective logging or deforestation in logging sites and help determine whether overlogging or other illegal activities took place (Kshetri, 2021, p. 25). WTP, for instance, seeks to incorporate satellite monitoring in its future blockchain solution (Interview Fabing).

Lastly, data entered by supply chain actors, extracted from secondary sources, and collected by IoT devices, satellite imagery, and scientific methods can be cross-checked to identify inconsistencies in the timber supply chain. “The key is that you’re verifying pieces of data against other pieces of data that have been supplied” (Interview Horowitz-Burdick). Information matching represents one part of the solution at Double Helix Tracking Technologies and WTP (Interview Fabing; Interview Horowitz-Burdick). Big data analytics and machine learning could support data reconciliation and pattern identification, especially when data accumulates over time if historical data is included, as is the case at OpenSC (Interview Lange; Kshetri, 2021, pp. 174–175). OpenSC employs machine learning to cross-check primary and secondary data, some of which is historical, and determine whether illegal fishing occurred (Interview Lange). Overall, these aforementioned safeguards against the Garbage in, Garbage out problem may not completely eliminate illegal timber from the supply chain since loopholes may continue to exist (Babich & Hilary, 2018, p. 28). However, incorporating several safeguards reduces the risk of illegal logging and increases the economic cost of carrying out illicit activities, potentially to the point where it does not make financial sense to engage in such activities.

5.3.1.2 Operational Feasibility

To set up a blockchain solution, the type of data collected by supply chain actors must be defined and standardised in terms of using the correct certificate codes, vocabulary, product groups, and measuring units (Ganne, 2018, p. 96; Worm, 2021a). “Both upstream and downstream players have to decide on a set of input data for identification and align registration points” (Hastig & Sodhi, 2020, p. 937). Kealoha from iov42 mentions that “[in] an industry like timber, which has been around for a while, there might be some hesitation [concerning blockchain] because there’s an expectation that a lot of systems have to be retrofitted” (Interview Kealoha). Fabing remarks: “The problem is really when all the different companies use different systems” (Interview Fabing). At WTP, for instance, some timber companies used the American customary measurement systems based on feet and mass, while companies serving the European markets resorted to imperial units, such as centimetres and kilograms (Interview Fabing). Therefore, network participants may need to align data structures. However, Marus from FSC believes it is “not [a] huge obstacle to overcome” (Worm, 2021a, minute 20:58).

Data availability, interoperability, and information disclosure play a role when multiple actors in a supply chain are involved (Interview Lange). Data availability refers to the type of data sources available in existing systems, while interoperability pertains to the way technical interfaces of different actors speak to each other (Ganne, 2018, p. 94). Additionally, interoperability refers to the compatibility of the blockchain solution to existing company systems for supply chain management as well as other blockchain ledgers (Hastig & Sodhi, 2020, p. 950; Herweijer et al., 2018, p. 22). “Organizations need to ensure there is flexibility built into their application architecture to enable applications to operate across different platforms in the future” (Leong et al., 2018, p. 57), for instance, by applying open protocols and standards (Worm, 2020a). Information disclosure relates to finding the right balance between transparently sharing information and disclosing business-sensitive information: For instance, one challenge that fishing companies using OpenSC’ solution faced was determining to what extent a shipping vessel’s fishing route should be shared with end consumers, given that these routes represent sensitive information and competitors could start fishing in that area (Interview Lange). Additionally, the acceptable error rate of data inputs needs to be established (RCS Global, 2017, p. 12). Errors are not always human-induced but might be caused by the timber’s properties: During the logging phase, forestry workers may unintentionally overestimate the volume of a log attributable to a large hole on the inside of the tree that becomes apparent in the processing stage but had previously not been visible, a phenomenon that may be particularly relevant in the Brazilian Amazon given its massive diversity of

trees (Interview Fabing). Volume variations may result from physical changes that timber undergoes throughout the supply chain, for instance, during transport in rivers, where the volume increases due to water absorption, or during processing, where logs are processed into sawn timber (Interview Fabing).

Studies have reported that many people working in the supply chain management field have difficulties fully understanding the technology's potential (Duan et al., 2020, p. 11; Varriale et al., 2020, p. 4). Therefore, developing a blockchain solution may require employees of timber companies to undergo an educational process. For example, at Carl Ronnow, employees had to obtain knowledge on blockchain technology, how it works, and how it could be applied in the respective supply chain (Interview Anning; Interview Kealoha). On the other hand, the technology provider who is supporting the development and installation phase might need to deepen their knowledge on industry specifics, as was the case for iov42, for whom the timber industry was relatively new (Interview Anning; Interview Roberts). In cases where timber companies seek to develop the blockchain in-house, they may need to recruit people equipped with the right skillset and expertise on blockchain and potentially other technologies, such as machine learning and big data analytics (Bender et al., 2019, ¶32). Depending on the specificities of the blockchain solution, such as the novel introduction of IoT devices, forestry workers and other supply chain actors may need to undergo training to adopt new work processes and develop their technological skills (Hastig & Sodhi, 2020, p. 947; Interview Fabing). Lastly, in instances where timber companies plan to share data from the blockchain with consumers, timber companies may need to educate consumers on blockchain technology as many may not be familiar with it.

Infrastructural challenges could hinder the deployment of blockchain solutions in the Brazilian Amazon, particularly if they use IoT devices (Kshetri, 2021, p. 206). Some IoT devices, such as QR codes, require an internet connection to synchronise to the blockchain network (Figorilli et al., 2018, p. 7; Interview Fabing). Internet connection may be limited or completely unavailable in the Amazon rainforest, as was the case for WTP in the Peruvian Amazon: "One of the biggest issues that we have is not a blockchain problem, it's really about the lack of internet connection in Peru," (Interview Fabing) says Fabing. They discovered that around 80 percent of the country did not have an internet connection and thus, needed to develop an application that worked with neither internet connection nor cell phone reception and that synchronised the information to the blockchain network once the user returned to the city after several days (Interview Fabing). This application is currently being tested in the Peruvian Amazon (Interview Fabing). Beyond internet and cell reception, acquiring devices and other infrastructure for all actors might represent a hurdle: "Additional enabling technologies may be required to help ease reliable data input, such as smartphones, tablets, scanners, sensors and geospatial technologies, and electronic payment systems. The cost of participation may be prohibitive to key actors who will require additional investment, support, and incentives" (Leong et al., 2018, p. 55). Another major challenge WTP faced was "the fact that people don't use smartphones, especially in the forest" (Interview Fabing). Many forestry workers they worked with did not own a phone due to the inadequate cell phone reception and, therefore, were often not willing to purchase one due to the low perceived value of having a mobile phone in the jungle. Additionally, lacking electricity in parts of the Amazon may present a further hurdle since electricity is vital for charging smartphones, tablets, and other devices. (Interview Fabing)

5.3.1.3 Market Feasibility

Developing and implementing a timber blockchain solution from stump to store requires collaboration and coordination amongst all actors, which may be difficult to achieve (Duan et al., 2020, p. 12; Montecchi et al., 2019, p. 291). For example, some upstream players in Brazil might be unwilling to participate due to insufficient infrastructure and limited financial resources (Leong et al., 2018, p. 39),

given that "sophistication of Brazilian operations varies from […] one cutting line in the middle of the jungle through to […] really sophisticated giant flooring mills" (Interview Horowitz-Burdick). Those suppliers willing to participate may need implementation support or otherwise may find themselves excluded from market access and affected by increased power asymmetries (see Chapter 3.3.2) (Lambin et al., 2018, p. 5). Moreover, the high percentage of illegality in the Brazilian Amazon (see Chapter 3.2.1) may represent a hurdle: "The whole system is a problem. If you're a timber company in Brazil […] you're stuck in a system that's rife with illegality and corruption. So, even if you want to do the right thing, it's very difficult, unless there's a level playing field" (Interview Daniel). Anning acknowledges the benefits of involving upstream suppliers in Timber Chain but recognises that "the time isn't right for it yet. They're not open to doing things a new way" (Interview Anning), which is why they did not opt for a stump-to-store blockchain solution but instead focused on timber exporters. He continues: "So, kind of what we're hoping is that our buyers will buy into it, and then would prefer it and once that gets some traction, we can go to suppliers and say, 'Well, this is now what we're doing. If you want to be part of this, you know, we've got to be doing this, this, and this'" (Interview Anning). Furthermore, the blockchain solution can face opposition by other supply chain actors, for instance, due to an unwillingness to share information or a perceived threat to their competitive advantage (Hastig & Sodhi, 2020, p. 948). "This is not an industry that readily changes," remarks Anning.

To establish a stump-to-store solution, a timber company may need to assume a leading role to mobilise the actors in the timber supply chain to align diverging interests, coordinate efforts, and potentially develop an industry-wide solution (Bender et al., 2019, ¶31; Hastig & Sodhi, 2020, p. 948). Such companies typically tend to be large industry players who, in some cases, cover costs for other actors that arise from using the solution (Kshetri, 2021, p. 415). For example, De Beers, which supplies around 30 percent of the world's diamonds by value, initiated the development of a mine-to-consumer blockchain solution for the whole diamond industry (Bender et al., 2019, ¶23). Outside the blockchain realm, some of the most effective measures against deforestation in the Brazilian Amazon, such as the Soy Moratorium, were led by major soy companies who agreed not to buy soybeans grown on areas deforested after 2006, resulting in a drastic decline in soy-driven deforestation (Lambin et al., 2018, p. 4; WWF, 2021, p. 48). "[In] the Soy Moratorium, we had a few companies who controlled the majority of the soy. […] With the timber industry, it's not like that you have thousands of timber companies. You don't have the big few soy companies that had a lot more power. So, it's different" (Interview Daniel). Consequently, the timber industry may not necessarily have a natural leader for initiating an industry-wide timber blockchain solution and attracting other players by leveraging its market position, financial resources, and business relationships (Bender et al., 2019, ¶23). Therefore, several players in the timber industry may take up the development of end-to-end blockchain solutions, as already evidenced by the start-up Genoma A and Double Helix Tracking Technologies, which might lead to the development of multiple timber solutions in the Brazilian Amazon, potentially presenting another hurdle (Hastig & Sodhi, 2020, p. 948). "The emergence of multiple traceability systems in the same industry sector can make suppliers resistant to adopting any of these systems" (Hastig & Sodhi, 2020, p. 948).

Brazil distinguishes itself from other tropical timber-producing countries concerning the digital availability of timber-related data from governmental licensing, control, and monitoring systems (Interview Horowitz-Burdick). "The problem with timber is it's really archaic. […] There's not a ton of digital platform for nodes of information to be tied into a blockchain system, with the exception of Brazil, which is why we're trying to pilot it with Brazil supply chains […]. There already are digital interfaces for document requests and issuance, through SISFLORA and SINAFLORA online systems, […] which is super rare in the tropical world" (Interview Horowitz-Burdick). For example, blockchain

solutions could link to historical and current PMFS of other logging sites in the region, which are publicly available, to cross-reference data entered by supply chain actors concerning timber volume, species, and density (Interview Horowitz-Burdick). Another benefit of the Brazilian system is the breadth of documentation that timber companies are required to collect to legally move timber shipments (see Chapter 3.1.2) (Interview Horowitz-Burdick). "The [Brazilian] system is extremely robust, in terms of the amount of data generated from production, transit material, [and] harvest […]. There's far more information produced than even we would see in America for similar products" (Interview Horowitz-Burdick). The BVRio Responsible Timber Exchange, a tool to screen Brazilian timber products for their legality status, makes use of the data availability by extracting information on forest management activities, transportation, and timber trade from government systems (Costa et al., 2016, p. 10). However, a downside of some of the accessible data may be the information's fraudulent (see Chapter 3.2.2) or self-declaratory nature (see Chapter 3.3.1), as pointed out by Lentini from IMAFLORA. Systematically cross-checking information helps address this challenge (see Chapter 5.3.1.1).

"The wide-scale deployment of Blockchain requires […] frameworks that not only ensure the interoperability of networks, but also clarify the legal status of blockchain transactions, and regulate responsibilities and the way data can be accessed and used. Without this regulatory layer, blockchain technology could well be confined to pilot projects" (Ganne, 2018, p. 97). Particularly global supply chains, where blockchain solutions extend beyond national borders, questions around jurisdiction, commercial rules, applicable laws, data governance, and other topics must be resolved (Hastig & Sodhi, 2020, p. 949; The World Bank, 2017, p. 19). Due to the relatively recent emergence of blockchain technology, the current legal and regulatory framework on blockchain and cryptocurrencies is lagging behind technological developments (Treiblmaier, 2020, p. 9; The World Bank, 2017, p. 19). In Brazil, "fierce debates and discussions are ongoing as to whether and how the technology should be regulated" (Costa, 2020, ¶19). Lawyer Luciano Costa (2020) expects regulation of public blockchains in Brazil to increase, while private blockchains will be subject to less regulatory scrutiny since a control system is already in place and existing instruments, such as courts, could help resolve legal disputes (¶8–9).

5.3.1.4 Financial Feasibility

Developing and implementing a blockchain solution incurs fixed and variable costs, which vary depending on factors, such as the sophistication of the blockchain solution, make-or-buy decisions, and the company's existing degree of data digitisation (Costa et al., 2016, p. 33; Varriale et al., 2020, p. 9). More sophisticated blockchain solutions that combine blockchain with IoT devices will incur higher costs than a solution that does not employ such devices (Galvez et al., 2018, p. 228). "Automatic data capture techniques is [sic] often costly, hard to implement and difficult to apply to volumes and bulk items" (Galvez et al., 2018, p. 228). However, if supply chain actors already had IoT integrated into their tracking solution prior to employing blockchain, costs are relatively marginal (Kshetri, 2021, p. 94). Make-or-buy decisions refer to the decision to develop an in-house blockchain solution or partner with technology providers, such as iov42 (Subramanian et al., 2020, p. 17). Fabing from WTP remarks: "Usually it's much, much cheaper to rent a piece of software than building the software for you. […] So, from a cost point of view, it doesn't really make sense for a company to do it by themselves" (Interview Fabing). Lastly, a company that is currently mainly relying on paper-based documentation will need to invest additional resources to digitise the data, which is not the case for a company that already has strong electronic data capture processes in place (RCS Global, 2017, p. 18).

Fixed costs include costs associated with the initial set-up of the technological infrastructure, mobile application development, training, infrastructure investments (e.g., smartphones), implementation, and

operations (e.g., marketing, staff, facilities, accounting, legal) (Costa et al., 2016, p. 33; Paton, 2018, ¶14; RCS Global, 2017, p. 18; Varriale et al., 2020, p. 9). Fixed costs typically become lower after initially high establishment costs of the blockchain solution since many of the aforementioned costs are one-off (Costa et al., 2016, p. 33). Recurring fixed costs may include maintenance, operational, and licensing fees, in cases where companies use technology provider's blockchain solution (Costa et al., 2016, p. 33). Transaction costs, unit costs of IoT devices used, scientific testing, and field visits represent examples of variable costs. Fabing from WTP acknowledges that sophisticated technologies, such as IoT, always come at a price, as seen with RFID chips: "There's a cost of USD 1. So, what's a dollar? But here in Peru it might be a lot of money" (Interview Fabing). Scientific methods come at an even higher cost and can be priced up to USD 400 per sample, depending on the diagnostic methodology used (see Appendix Chapter 1.3) (Dormontt et al., 2015, p. 792). Also, on-site field visits incur high costs as personnel is typically required to travel large distances, and there are few, if any, economies of scale (Costa et al., 2016, p. 30). "In many cases, maintaining a robust link between offline events and distributed ledgers is still expensive" (Ganne, 2018, p. 81). It becomes evident that "blockchain systems are expensive to implement and manage. For this reason, blockchain is out of reach for many organisations" (Kshetri, 2021, p. 203). Small-scale loggers as well as small and medium-sized companies, may be disproportionally affected by the relatively high costs involved with blockchain technology (Varriale et al., 2020, p. 4). Large companies could help other supply chain actors absorb some of the costs involved with blockchain solutions (Kshetri, 2021, p. 415). However, generally speaking, even relatively small costs can already affect a company's willingness to adopt a blockchain solution, given the industry's low margins (Šulyová & Koman, 2020, p. 8). "Timber is hard in that regard because the margins for these people are super small. […] You have to make a really good business case for them to spend money on this stuff," says Horowitz-Burdick.

The potential upside of a blockchain solution are potential cost savings (e.g., faster recalls), efficiency gains (e.g., automatic data capture), and revenue growth (e.g., premium positioning with legality and sustainability criteria) (Leong et al., 2018, p. 52). Timber companies in the Brazilian Amazon could improve their access to the international timber market and premium prices, as was the case for WTP (Interview Fabing). During conversations with international timber buyers, Fabing found that buyers currently do not purchase wood from the Peruvian Amazon because they perceived it as illegal and preferred to buy wood from other countries and pay a 20 to 30 percent higher price instead. However, they expressed interest in buying Peruvian timber if companies could present reliable proof of legality and trackability. (Interview Fabing) Lastly, financial benefits may be more easily reaped for high-value timber (Leong et al., 2018, p. 34). Anning remarks that the combination of blockchain, with DNA fingerprinting could be particularly interesting for high-value timber since "it could absorb the cost then of doing the DNA fingerprinting at every link in the supply chain. And if you coupled that with uploading this information, and the other information that you gather onto a secure database, such as blockchain, that could be quite a good marriage" (Interview Anning). To determine the financial feasibility, timber companies are encouraged to conduct a cost-benefit analysis of a blockchain solution on a case-by-case basis and compare them to other measures that can be taken against illegal logging (Hastig & Sodhi, 2020, p. 947). Note that some benefits (see Chapter 5.2.2.1), such as improved reputation, may be difficult to quantify but nevertheless important to consider (Interview Lange).

5.3.2 Blockchain Overall Evaluation and Discussion

As emerges from the preceding chapters and the presented case studies, blockchain bears considerable potential in complementing corporate action against illegal logging in the Brazilian Amazon. The technology can strengthen a company's pledge to remove illegal logging, complement supply chain

initiatives, monitoring efforts, and periodic audits, help align multi-stakeholder efforts and strengthen multi-stakeholder collaborations (see Chapter 5.2.2). Blockchain adds an additional layer of transparency, security, and trust since uploaded data is validated through a predefined consensus mechanism, after which it is unalterable and undeletable (Interview Kealoha). Certain blockchain characteristics, such as consensus and immutability, as well as the possibility to include external databases on companies' legal status, environmental, tax, and labour legislation infractions create a strong disincentive for malicious actors to enter fraudulent data and engage in illegal activities (see Chapter 5.2.2.2) (Costa et al., 2016, p. 83). Blockchain can represent a powerful tool in timber supply chains, which can be characterised by complexity, multiple stakeholders, conflicting interests, and trust issues (Figorilli et al., 2018, p. 11; Interview Lange; US Endowment, 2020, ¶2). A large part of blockchain's value lies in its combination with other technologies, such as satellite imagery, IoT, and machine learning, which can support legality verification and identification of inconsistencies in an automated and data-based manner (see Chapter 5.3.1.1). Another value-add is its ability to integrate data from different technologies and external databases into one place for synthesis, analysis, identification of irregularities, and sharing of information (Interview Kealoha). For example, blockchain technology facilitates information sharing with stakeholders, such as end consumers, which could help address lacking consumer awareness, an identified contributor of illegal logging (see Chapter 3.3.2). Lastly, implementing a blockchain solution may increase the economic cost of engaging in illegal activities, another contributor of illegal logging (see Chapter 3.3.2).

Developing a blockchain solution with end-to-end traceability is deemed technically complex due to timber's physical transformation in the processing stage (see Chapter 5.3.1.1). In the initial stages of the timber supply chain, blockchain, together with RFID, GPS information, and sensors, can significantly reduce the risk of logging in prohibited and non-authorised zones since the data collected can be protected against manipulation. Similarly, IoT devices can help prevent the mixing of illegal with legal timber during the transportation stage. However, the use of IoT alone cannot completely remove the risk of illegality due to the nature of other types of illegal logging, where critical data, such as timber volume and species, cannot reliably be captured by the actors themselves since it is not in the interest of malicious actors to report such data truthfully. Additionally, the link between the physical timber and its digital counterpart cannot be fully maintained during the processing stage: There is space for fraudulent activities once the RFID tag is removed during the processing stage, even if a QR code is attached to larger pieces of wood after processing. To maintain timber trackability, measures such as mass-balance checks, field audits, and DNA fingerprinting can be introduced with DNA fingerprinting producing the most accurate results (see Chapter 4.2.2.2). Establishing a strong link between the physical timber and its digital twin is crucial but can become expensive, adding to high establishments costs and moderate recurring fixed and variable costs of blockchain technology (see Chapter 5.3.1.4). For this reason, implementing such measures may only be financially feasible for high-value timber, random samples in a timber shipment, or large timber companies with access to extensive resources (Ganne, 2018, p. 81). Operational challenges related to lacking internet, devices, and electricity in the Brazilian Amazon remain. Other operational aspects, such as data standardisation, availability, interoperability, information disclosure, and educational needs are largely dependent on the stakeholders involved (see Chapter 5.3.1.2). Similarly, timber players' willingness to cooperate will vary depending on the involved parties (see Chapter 5.3.1.3). The emergence of multiple timber blockchain solutions and the future development of the regulatory and legal environment remains uncertain. Timber companies interested in exploring blockchain technology are encouraged to conduct their own feasibility studies, including cost-benefit analyses, to tailor the analysis towards the respective companies, partners, and supply chains and include non-mentioned factors in the assessment.

It should be noted that blockchain technology should not be perceived as a panacea for the problem of illegal logging in the Brazilian Amazon (see Chapter 4.2.4), given the multitude and complexity of contributors to illegal logging (see Chapter 3.3). Many of these contributors, such as insufficient institutional capacity, poverty among small-scale holders, and the lack of governmental field inspections, remain unaddressed by blockchain and require government action and multi-stakeholder coordination (see Chapters 4.2.4, 4.2.5). Particularly the prevalence of illegality in the Brazilian Amazon (see Chapter 3.2.1) and the high profitability of the illicit timber trade (see Chapter 3.2.2), create an unfair competitive advantage (see Chapter 3.4.3). These factors amount to a strong disincentive for companies to engage in legal activities and spend resources on curbing illicit timber, for instance, through blockchain solutions (see Chapter 5.3.1.3). Even in the scope of corporate action to address illegal logging, blockchain has its limits since it does not represent an all-encompassing technology (Kshetri, 2021, p. 130). In its simplest explanation, it represents a shared database, meaning it cannot directly contribute to legality verification or generation of tracking data since its role is limited to collecting, synchronising, storing, and sharing data in addition to flagging inconsistencies if programmed (see Chapters 5.2.2.2, 5.3.1.1). However, whether companies act upon such alerts is not upon the blockchain solution to decide since it only provides the basis for decision making (Interview Fabing). Moreover, blockchain is marked by the Garbage in, Garbage out problem since it does not entail a data verification mechanism and thus, does not protect against deliberately falsely inserted information, calling for companies to put appropriate safeguards in place to identify illicit practices that are occurring offline but not recorded on the blockchain (see Chapter 5.3.1.1). Researchers Nikolakis et al. (2018) remark: “It is critical to understand that the blockchain is a means to an end, rather than an end in itself, and without supportive governance safeguards, the blockchain could be misused, or become meaningless” (p. 13). Identified safeguards entail automating data capture, establishing identity protocols, introducing smart contracts, and third-party data verification. Other identified safeguards include verifying data with scientific methods and satellite monitoring, and systematic cross-checking of information, particularly with the aid of machine learning and additional data sources. Overall, blockchain can form one part of the overall solution that a company has in place to curb illegal logging, thus complementing rather than substituting existing company efforts (see Chapter 5.2.2.2).

Despite the weaknesses, blockchain solutions, if set up properly, can help prevent illegal timber from entering supply chains (Hastig & Sodhi, 2020, p. 938; Paton, 2018, ¶10). For instance, it could help ensure that certifications are not copied, double-counted, or illegally sold (see Chapter 5.2.2.2). If appropriate safeguards are put in place to secure the initial stage of data entry, data after it has been validated, becomes highly tamper resistant due to its immutability (see Chapter 5.2.1) (Nikolakis et al., 2018, p. 10). Additionally, if a timber blockchain solution becomes universally adopted in the Brazilian Amazon, it may reduce the illegal trade, as “all the remaining harvested timber bypassing the use of blockchain could, and probably would, be considered contraband” (Vilkov & Gang, 2019, p. 392). Fabing from WTP explains that the widespread adoption of the blockchain solution could lead to a situation where timber buyers would not purchase wood unless suppliers are using the respective blockchain solution (Interview Fabing). However, until that point is reached, implementing such a solution within a timber company can reduce the risk of illicit activities being laundered within the respective supply chain but is unlikely to considerably impact illegally operating timber companies outside of the respective supply chain (Interview Fabing). To address these players and achieve a large-scale reduction of the illegal timber trade, different stakeholders need to take action and strong collaborations need to be formed (see Chapter 4.2.5).

5.3.3 Future Outlook, Limitations, and Future Research

In terms of blockchain adoption, Nikolakis et al. (2018) expect "blockchain to gradually become the foundational standard adopted by all firms" (p. 13). To drive blockchain forward in the timber industry, early movers are required to take the lead to create coalitions, forge partnerships, and explore blockchain applications in the supply chain (Bender et al., 2019, ¶33). "Really long term, […] the companies that […] invest in new technologies are the ones who are smart, they're the thought leaders," (Interview Horowitz-Burdick) says Horowitz-Burdick. Leadership both within each company as well as externally with other stakeholders is needed to evaluate the opportunities and limits of blockchain, define the particularities of the blockchain solution, overcome technical, operational, market, and financial challenges, and address risks associated with such a solution (Bender et al., 2019, ¶16; Hastig & Sodhi, 2020, p. 948; Herweijer et al., 2018, p. 30). Risks include but are not limited to energy consumption issues, particularly for public blockchains, insufficient understanding of security threats, and vulnerabilities resulting from programming errors (Ganne, 2018, pp. 4, 90; Higginson et al., 2017, p. 5). For example, statistics have revealed that between 15 and 50 bugs occur per 1,000 lines of code, potentially leaving companies vulnerable to hacking attacks (The World Bank, 2017, p. 18). Lastly, it is important for companies to keep track of the development of blockchain and other technologies: Drones, wood identification technologies, and other solutions are appearing on the horizon and may form part of companies' blockchain solutions (Interview Fabing). Applications of blockchain in the timber supply chains are currently focused on legality aspects. FSC director Worm (2021a, minute 33:20) and Roberts (Interview Roberts) see future potential for blockchain in offsetting carbon or documenting social aspects. At iov42 they are looking into "capturing that there's no modern slavery involved in the supply chain, and that people are paid a fair wage, and that people are qualified and have the skill sets to be operating the machinery that they're operating" (Interview Roberts).

This thesis has several limitations. First, it had an explicit focus on timber legality. Though sustainability aspects are often included in legislation, future research could explore whether current Brazilian timber legislation could be extended to include sustainability criteria and how blockchain could address social challenges, such as human rights abuses. Second, the focus was laid on causes and solutions to illicit timber in the Brazilian Amazon and less on the implications of the inter-country timber trade. The role of consumer countries and global agreements as well as the application of blockchain in international timber supply chains could be the subject of a future paper. Third, the thesis centred around strategies that companies could adopt to address illegal logging and focused on using blockchain in timber supply chains. A future paper could investigate other stakeholders' role in combating illegal logging, develop measures they could undertake, and evaluate how blockchain could complement such strategies. For example, the use of blockchain in the Brazilian government's licensing, control, and monitoring systems could be examined. Fourth, the blockchain ideation and validation analysis in this thesis were kept at a general level due to the focus on determining the broader potential of blockchain for addressing illegal logging. Further studies could partner with timber companies to tailor the blockchain ideation and validation analysis. Fifth, the analysed use case focused on blockchain's potential to complement end-to-end supply chain traceability, given the focus on illegal logging. Other application areas of blockchain in timber companies, such as operational efficiency gains (e.g., Hastig & Sodhi, 2020, p. 944), reduced delivery times (e.g., Varriale et al., 2020, p. 8), and automating repetitive processes (Ganeriwalla et al., 2018, p. 1), could be explored. Lastly, the normative nature of this paper could be complemented by empiric or quantitative research. For instance, the B2B and B2C demand for legal timber could be quantified, helping companies evaluate the financial feasibility of implementing a blockchain solution.

6 Conclusion

Following a comprehensive investigation on the problem of illegal logging in the Brazilian Amazon, solutions in the corporate sphere, and the potential of blockchain in addressing these solutions, the key findings are summarised, and the research questions answered. The first research question dealt with the main causes of illegal logging, a widespread phenomenon in the Brazilian Amazon (see Chapter 3.2.1). The analysis of the supply chain of illegal timber showed the various ways of how the legal logging process can be thwarted and illicit timber laundered on its way to the end consumer (see Chapters 3.1.2, 3.2.2). The occurrence of illegal logging can be ascribed to multiple factors of interrelated and reinforcing nature, related to deficiencies in Brazil's licensing, control, and monitoring system (see Chapter 3.3.1) and issues in the socio-economic and political-legal environment (see Chapter 3.3.2). Various weaknesses in Brazil's official timber tracking system enable illegal logging, including the ease of obtaining approval for permits, the lack of field inspections, the insufficient use of scientific and technical parameters, the existence of petty corruption, and the inadequate integration of government databases. Additionally, factors of illegal logging are rooted in the overarching environment: Short-term maximization of profits, poverty among small-scale producers, difficulties to comply with legislation, Brazil's economic development model, national and international demand for commodities, and lacking consumer awareness were identified as socio-economic factors. On the political-legal side, the following contributors were determined: The Bolsonaro Administration's stance towards the environment, the disproportionate distribution of power, the existence of grand corruption, weak law enforcement, land tenure issues, and limited institutional capacity.

The second research question concerned strategies timber companies can pursue to combat illegal logging. A framework containing five areas of corporate action was developed to answer this question. First, timber companies can pledge to comply with relevant environmental, forestry, and human rights legislation and exclude illegal logging from their supply chains (see Chapter 4.2.1). This pledge can be operationalised through several measures, such as supply chain audits, adapted purchasing policies, and an action plan. Second, legality verification and tracking efforts are important to verify legality at the source and along the supply chain, and track legality claims from the forest to the end consumer (see Chapter 4.2.2). Verifying legality could entail conducting field visits, carrying out surveys, and examining suppliers' ownership set-up, organisational history, and company structure, while timber tracking entails the use of paper-based documentation, IoT technology, scientific methods, or a combination of these. Forest certifications, which build on legality verification and tracking efforts, represent another option for timber companies. Third, continuous monitoring efforts and periodic audits can be undertaken, the results of which can be transparently shared with internal and external stakeholders (see Chapter 4.2.3). Fourth, timber companies can use their influence to encourage the Brazilian government to address illicit logging through several measures, such as creating a level playing field, introducing adequate legislation, and reforming the current tracking system (see Chapter 4.2.4). Aligning company actions with those carried out by other stakeholders and forming multi-stakeholder collaborations represents the last category, which links together the other four areas (see Chapter 4.2.5). This area is key for addressing illegal logging, given the phenomenon's complexity, the interrelated nature of the causes, and stakeholders' differing spheres of influence.

The third research question addressed the potential of blockchain technology in complementing corporate action to combat illegal logging and was answered in two parts, namely the blockchain ideation and blockchain validation phases. The blockchain ideation phase outlined several ways of how the technology can complement corporate strategies. It can help timber companies transform their pledge to tackle illegal logging into tangible reality by storing information on timber legality in an

unchangeable manner and granting other stakeholders access to this data, creating transparency around how they act on their commitments (see Chapter 5.2.2.1). Concerning supply chain initiatives, the technology cannot guarantee legality and data correctness, yet certain features, such as the consensus mechanism and immutability, may promote legality throughout the supply chain (see Chapter 5.2.2.2). Similarly, while the technology cannot generate information on the timber and its journey, it can integrate the data recorded by other technologies, such as IoT and machine learning, in one place for synthesis, analysis, storage, and subsequent sharing. Additionally, blockchain can help prevent forest certifications from being copied, double counted, or illegally sold if set up properly. Furthermore, companies can permanently record auditors' findings and maintain an immutable audit trail by employing blockchain technology (see Chapter 5.2.2.4). Linkage to external databases, such as those overseeing companies' legal status, and information sharing with other stakeholders, such as government or police authorities, can promote multi-stakeholder collaborations (see Chapter 5.2.2.5). The technology's application for aligning efforts undertaken by different stakeholders and as a tool to drive government action is limited (see Chapter 5.2.2.4), though the use of blockchain by the Brazilian government could be the subject of future research (see Chapter 5.3.3).

The blockchain validation phase evaluated the use case of an end-to-end blockchain solution from the forest to the end consumer. The technical feasibility analysis established that timber can be effectively traced from the forest up until the processing stage with a combination of RFID, GPS trackers, and sensors (see Chapter 5.3.1.1). However, given timber's physical transformation process, technical devices need to be removed, leaving room for fraudulent activities. Mass-balance checks, scientific methods, and field audits can help maintain the link between the physical timber and its digital twin. Additionally, several safeguards can be taken to address the Garbage in, Garbage out problem, such as automated data capture, smart contracts, and third-party data verification. Operational challenges related to data standardisation, availability, interoperability, information disclosure, and education may exist depending on the actors involved while lacking internet, mobile network, and electricity pose probable operational challenges (see Chapter 5.3.1.2). Similarly, supply chain actors' willingness to participate in a blockchain solution may vary (see Chapter 5.3.3.3). Other market aspects, such as the emergence of multiple timber blockchain solutions and the future development of the regulatory environment in Brazil, remain uncertain (see Chapter 5.3.3.4). Considerable establishment costs and moderate recurring fixed and variable costs are expected, which may deter small and medium-sized timber companies from adopting blockchain solutions unless used for high-value timber or on a sample basis. Companies are encouraged to conduct their own feasibility analyses to consider company-specific aspects, capabilities, resources, and other factors, tailoring the analysis to the respective case. Overall, if set up properly, blockchain technology can help reduce illegality in timber supply chains by forming one part of the broader system that a company has in place, thus complementing rather than substituting existing company efforts. Yet, given its relatively recent emergence, there is a need to further explore the potential of tackling illegal logging in future research (see Chapter 5.3.3).

In light of the Amazon's importance to mankind (see Chapter 2.1), the persistence of illegal deforestation and logging (see Chapter 2.2), and the grave repercussions of illegal logging (see Chapter 3.4), action must be taken to meet the COP26 pledge, Paris Agreement, NY Declaration on Forests, and other forest-related goals. It is critical that all stakeholders – the private sector, the Brazilian government, international governments, intergovernmental organisations, civil society organisations, and consumers – assume their role in tackling illegal logging. Through joint efforts, the tipping point can be averted, and a global environmental disaster prevented. "Together, we need the will and imagination to tip the direction of change in favor of a sustainable Amazon" (Lovejoy & Nobre, 2019, p. 2).

Bibliography

Adams, W. (2015). Conducting semi-structured interviews. In K. E. Newcomer, H. P. Hatry, & J. S. Wholey (Eds.), *Handbook of practical program evaluation* (4th ed., pp. 492–505). Hoboken, NJ: Jossey-Bass.

Aguiar, A. P. D., Vieira, I. C. G., Assis, T. O., Dalla-Nora, E. Toledo, P. M., Santos-Junior, R. A. O., … Ometto, J. P H. (2016). Land use change emission scenarios: Anticipating a forest transition process in the Brazilian Amazon. *Global Change Biology, 22*(5), 1821–1840. http://dx.doi.org/10.1111/gcb.13134

Amazon Watch. (2019). *Complicity in destruction II: How northern consumers and financiers enable Bolsonaro's assault on the Brazilian Amazon.* Washington, DC: Amazon Watch. Retrieved from https://amazonwatch.org/assets/files/2019-complicity-in-destruction-2.pdf

Assunção, J., & Gandour, C. (2019). *Combating illegal deforestation: Strengthening command and control is fundamental.* Rio de Janeiro: Climate Policy Initiative. Retrieved from https://www.climatepolicyinitiative.org/wp-content/uploads/2019/04/white-paper-Combating-Illegal-Deforestation-Strengthening-Command-and-Control-Is-Fundamental.pdf

Assunção, J., McMillan, R., Murphy, J., & Souza-Rodrigues, E. (2019). *Optimal environmental targeting in the Amazon Rainforest* (Working Paper 25363). Cambridge, MA: National Bureau of Economic Research. http://dx.doi.org/10.3386/w25636

Azevedo, A. A., Rajão, R., Costa, M. A., Stabile, M. C. C., Macedo, M. N., Reis, T. N. P. d., … & Pacheco, R. (2017). Limits of Brazil's Forest Code as a means to end illegal deforestation. *Proceedings of the National Academy of Science of the United States of America, 114*(29), 7653–7658. http://dx.doi.org/10.1073/pnas.1604768114

Azevedo-Ramos, C., & Moutinho, P. (2018). No man's land in the Brazilian Amazon: Could undesignated public forests slow Amazon deforestation? *Land Use Policy, 73*(2018), 125–127. http://dx.doi.org/10.1016/j.landusepol.2018.01.005

Azevedo-Ramos, C., Silva, J. N. M., & Merry, F. (2015). The evolution of Brazilian forest concessions. *Elementa, 3*, 1–8. http://dx.doi.org/10.12952/journal.elementa.000048

Babich, V., & Hilary, G. (2018). OM Forum – Distributed ledgers and operations: What OM researchers should know about blockchain technology. *Manufacturing & Service Operations Management, 22*(2), 223–240 https://dx.doi.org/10.1287/msom.2018.0752

Baccini, A., Walker, W., Carvalho, L., Farina, M., Sulla-Menashe, D., & Houghton, R. A. (2017). Tropical forests are a net carbon source based on aboveground measurements of gain and loss. *Science, 358*(6360), 230–234. http://dx.doi.org/10.1126/science.aam5962

Bakker, E.-J. (2018). *Brazil's beginning blockchain business.* Netherlands Enterprise Agency. Retrieved from https://www.rvo.nl/sites/default/files/2018/02/brazils-beginning-blockchain-business.pdf

Basole, R. C., & Nowak, M. (2018). Assimilation of tracking technology in the supply chain. *Transportation Research Part E: Logistics and Transportation Review, 114*(2018), 350–370. http://dx.doi.org/10.1016/j.tre.2016.08.003

Baur, N., & Blasius, J. (2014). Methoden der empirischen Sozialforschung. In N. Baur & J. Blasius (Eds.), *Handbuch Methoden der empirischen Sozialforschung* (pp. 41–61). Cham: Springer. http://dx/doi.org/ 10.1007/978-3-531-1893900

Bettis, R., Gambardella, A., Helfat, C., Mitchell, W., Anteby, M., Lifshitz, H., … Suddaby, R. (2014). Primer: Qualitative research in strategic management. *Strategic Management Journal,* 1–11. Retrieved from https://www.strategicmanagement.net/pdfs/qualitmanagement.pdf

Björk, A., Erlandsson, M., Häkli, J., Jaakola, K., Nilsson, Å., Nummila, K., … Sirkka, A. (2011). Monitoring environmental performance of the forestry supply chain using RFID. *Computers in Industry, 62*(2011), 830–841. http://dx.doi.org/10.1016/j.compind.2011.08.001

Brancalion, P. H. S., de Almeida, D. R. A., Vidal, E., Molin, P. G., Sontag, V. E., Souza, S. E. X. F., & Schulze, M. D. (2018). Fake legal logging in the Brazilian Amazon. *Science Advances, 4*(8), 1–7. http://dx.doi.org/10.1126/sciadv.aat1192

Brazilian Forest Service [BFS]. (2019). *Brazilian Forests at a glance 2019.* Ministry of Agriculture, Livestock and Food Supply. Retrieved from https://www.florestal.gov.br/documentos/publicacoes/4262brazilian-forests-at-a-glance-2019/file

Brienen, R. J. W., Phillips, O. L., Feldpausch, T. R., Gloor, E., Baker, T. R., Lloyd, J., … Zagt, R. J. (2015). Long-term decline of the Amazon carbon sink. *Nature, 519*(7543), 344–348. http://dx.doi.org/10.1038/nature14283

BVRio. (2017). *Practical guide to conducting due diligence of tropical timber products: Brazil.* Rio de Janeiro: BVRio Institute. Retrieved from https://www.bvrio.org/publicacao/173/practical-guide-to-conducting-due-diligence-of-tropical-timber-products-brazil.pdf

Carvalho, A. V., Silva, F. M., Carvalho, R. A. F., Guimaraes, J. L. C., Carvalho, A. C., Almeida, R. M., … Santos Filho, M. B. (2018). Legislação ambiental e economia do crime na BR-163 e PA-370: Análise do mercado madeireiro illegal. *RICA, 9*(6), 391–408. http://dx.doi.org/10.6008/CBPC2179-6858.2018.006.0036

Carvalho, W. D., Mustin, K., Hilário, R. R., Vasconcelos, I. M., Eilers, V., & Fearnside, M. (2019). Deforestation control in the Brazilian Amazon: A conservation struggle being lost as agreements and regulations are subverted and bypassed. *Perspectives in Ecology and Conservation, 17*(3), 122–130. http://dx.doi.org/10.1016/j.pecon.2019.06.002

Cashore, B., Leipold, S., Cerutti, P. O., Bueno, G., Carodenuto, S., Chen, X., … Zeitlin, J. (2016). Global governance approaches to addressing illegal logging. In D. Kleinschmit, S. Mansourian, C. Wildburger, & A. Purret (Eds.), *Framing illegal logging and its governance responses in Brazil – A structured review of diagnosis and prognosis* (pp. 119–132). Vienna: International Union of Forest Research Organizations. Retrieved from https://www.iufro.org/fileadmin/material/publications/iufro-series/ws35/ws35-high-res.pdf

Catalini, C., & Gans, J. S. (2016). *Some simple economics of the blockchain* (Working Paper 22952). Cambridge, MA: National Bureau of Economic Research. http://dx.doi.org/10.3386/w22952

Cerbaro, M., Morse, S., Murphy, R., Lynch, J., & Griffiths, G. (2020). Information from Earth observation for the management of sustainable land use and land cover in Brazil: An analysis of user needs. *Sustainability, 12*(2), 489. http://dx.doi.org/10.3390/su12020489

Chen, B., Peng, K., Parkinson, C., Bertozzi, A. L., Slough, T. L., & Urpelainen, J. (2021). Modeling illegal logging in Brazil. *Research in Mathematical Sciences, 8*(2), 29. http://dx.doi.org/10.1007/s40687-02100263-6

Chen, S., Shi, R., Ren, Z., Yan, J., Shi, Y., & Zhang, J. (2017). A blockchain-based supply chain quality management framework. In *Proceedings of the 14th International Conference on e-Business Engineering (ICEBE)* (pp. 172–176). http://dx.doi.org/10.1109/ICEBE.2017.34

Condé, T. M., Higuchi, N., & Lima, A. J. N. (2019). Illegal selective logging and forest fires in the northern Brazilian Amazon. *Forests, 10*(1), 61. http://dx.doi.org/10.3390/f10010061

Contreras-Hermosilla, A. (2002). *Law compliance in the forestry sector. An overview* (Working Paper 28617). Washington, DC: World Bank Institute. Retrieved from http://documents1.worldbank.org/curated/en/232581468763471728/pdf/286170Law0Forestry0WBI0WP.pdf

Costa, P. M., Costa, M. M., & Barros, M. (2016). *Using big data to detect illegality in the tropical timber sector.* Rio de Janeiro: BVRio Insitute. Retrieved from https://www.bvrio.org/publicacao/160/using-big-data-to-detect-illegality-int-the-tropical-timber-sector.pdf

de Lima, L. S., Merry, F., Soares-Filho, B., Rodrigues, H. O., Damaceno, C. d. S., & Bauch, M. A. (2018). Illegal logging as a disincentive to the establishment of a sustainable forest sector in the Amazon. *PLOS ONE, 13*(12), 1–21. http://dx.doi.org/10.1371/journal.pone.0207855

Ding, H., Veit, P. G., Blackman, A., Gray, E., Reytar, K., Altamirano, J. C., & Hodgdon, B. (2016). Climate benefits, Tenure costs. *The Economic Case For Securing Indigenous Land Rights in the Amazon.* Washington, DC: World Resources Institute. Retrieved from https://files.wri.org/s3fs-public/Climate_Benefits_Tenure_Costs_Executive_Summary.pdf

Dormontt, E. E., Boner, M., Braun, B., Bruelmann, G., Degen, B., Espinoza, E., … Lowe, A. J. (2015). Forensic timber identification: It's time to integrate disciplines to combat illegal logging. *Biological Conservation, 191*(2015), 790–798. http://dx.doi.org/10.1016/j.biocon.2015.06.038

Duan, J., Zhang, C., Gong, Y., Brown, S., & Li, Z. (2020). A content-analysis based literature review in blockchain adoption within food supply chain. *International Journal of Environmental Research and Public Health, 17*(5), 1784. http://dx.doi.org/10.3390/ijerph17051784

Düdder, B., & Ross, O. (2017). Timber tracking: Reducing complexity of due diligence by using blockchain technology. *CEUR Workshop Proceedings, 1898,* 15. http://dx.doi.org/10.2139/ssrn.3015219

Eaton, S. (2018). A climate tipping point in the Amazon. *The Nation.* Retrieved from https://www.thenation.com/article/archive/tropical-forests-are-flipping-from-storing-carbon-to-releasing-it/

European Commission [EC]. (2014). *Combating illegal logging: Lessons from the EU FLEGT Action Plan.* Retrieved from http://www.euflegt.efi.int/documents/10180/72377/Combating+illegal+logging++Lessons+from+the+EU+FLEGT+Action+Plan/

European Commission [EC]. (2016). *Evaluation of the EU FLEGT Action Plan (Forest Law Enforcement Governance and Trade) 2004-2014.* Retrieved from https://ec.europa.eu/environment/forests/pdf/FLEGT%20Eval%20Consultant%20Report%20EN.pdf

European Commission [EC]. (2018). *Work Plan 2018-2022 for the Implementation of The Forest Law Enforcement, Governance And Trade Action Plan.* Retrieved from https://ec.europa.eu/environment/forests/pdf/FLEGT_Work_Plan_2018_2022.pdf

European Commission [EC]. (2019). *Science for environmental policy. Blockchain technology could improve traceability of wood through the supply chain.* Retrieved from https://ec.europa.eu/environment/integration/research/newsalert/pdf/blockchain_technology_could_i_prove_traceability_of_wood_through_the_supply_chain_527na1_en.pdf

European Forest Institute [EFI]. (2014). *Working with the private sector on REDD+.* EU REDD Facility. Retrieved from http://www.euredd.efi.int/documents/15552/154912/Working+with+the+private+sector+on+REDD2B/f7c02847-ebd9-4656-aafc-3a2857d905e9

European Forest Institute [EFI], & Proforest. (2014). *Mechanisms for reducing deforestation.* EU REDD Facility. Retrieved from https://redd.unfccc.int/uploads/2_89_redd_20150619_eureddfacility_working_with_the_private_sector_on_redd_2B.pdf

Fabing, M. (2021a). Insight from Michael Fabing: IT lead, wood tracking protocol. *Climate Ledger Initiative.* Retrieved from https://climateledger.org/resources/Michael-Fabing_Interview-WTP.pdf

Fabing, M. (2021b). *Wood tracking project* [PDF file]. Received from Michael Fabing

Faria, W. R., Júnior, A. A. B., & Montenegro, R. L. G. (2019). Multidimensional characteristics and deforestation: An analysis for the Brazilian Legal Amazon. *Quality & Quantity, 53*(2), 1959–1979. http://dx.doi.org/10.1007/s11135-019-00850-4

Ferguson, B., Sekula, J., & Szabó, I. (2020). *Technology solutions for supply chain traceability in the Brazilian Amazon: Opportunities for the financial sector*. Rio de Janeiro: Igarapé Institute. Retrieved from https://www.jstor.org/stable/resrep26938

Fernandes, A. P., Hoeflich, V. A., Viana, G., Amendola, E. C., de Oliveria, F. E. M., & Ansolin, R. D. (2017). Destination of public forests in Brazil: An analysis of forest concessions. *Nativa, 5*(Especial), 497–503. http://dx.doi.org/10.5935/2318-7670.v05nespa06

Figorilli, S., Antonucci, F., Costa, C., Pallottino, F., Raso, L., Castiglione, M., … & Menesatti, P. (2018). A blockchain implementation prototype for the electronic open source traceability of wood along the whole supply chain. *Sensors, 18*(9), 3133. http://dx.doi.org/10.3390/s18093133

Filho, F. J. B. (2019). *Combating deforestation in the Brazilian Amazon* [PowerPoint Presentation]. Washington, DC: World Bank. Retrieved from http://pubdocs.worldbank.org/en/876051574452638489/pdf/Webinar-Deforestation-Brazil-05-26-19.pdf

Food and Agriculture Organization of the United States [FAO]. (n.d.). *Forest Certification: Basic knowledge.* Retrieved from http://www.fao.org/sustainable-forest-management/toolbox/modules/forest-certification/further-learning/en/?type=111

Food and Agriculture Organization of the United States [FAO]. (2019). *Global forest products facts and figures 2018.* Retrieved from https://www.fao.org/3/ca7415en/ca7415en.pdf

Fox, M., Mitchell, M., Dean, M., Elliott. C., & Campbell, K. (2018). The seafood supply chain from a fraudulent perspective. *Food Security, 10*(1), 939–963. http://dx.doi.org/10.1007/s12571-018-0826-z

Galvez, J. F., Mejuto, J. C., & Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. *Trends in Analytical Chemistry, 107*(2018), 222—232. http://dx.doi.org/10.1016/j.trac.2018.08.011

Ganeriwalla, A., Casey, M., Shrikrishna, P., Bender, J. P., & Gstettner, S. (2018). Does your supply chain need a blockchain? *Boston Consulting Group.* Retrieved from https://imagesrc.bcg.com/Images/BCG-Does-YourSupply-Chain-Need-a-Blockchain-Mar-2018_tcm81-187053.pdf

Ganne, E. (2018). *Can blockchain revolutionize international trade*? Geneva: World Trade Organisation. Retrieved from https://www.wto.org/english/res_e/booksp_e/blockchainrev18_e.pdf

Garzon, A. R. G., Bettinger, P., Siry, J., Abrams, J., Cieszewski, C., Boston, … Yeşil, A. (2020). A comparative analysis of five forest certification programs. *Forests, 11,* 863. http://dx.doi.org/10.3390/f11080863

Global Witness. (2020). *Defending tomorrow. The climate crisis and threats against land and environmental defenders.* Retrieved from https://www.globalwitness.org/en/campaigns/environmental-activists/defending-tomorrow/

Goncalves, M. P., Panjer, M., Greenberg, T. S., & Magrath, W. B. (2012). *Justice for forests. Improving criminal justice efforts to combat illegal logging.* Geneva: The World Bank. Retrieved from http://documents1.worldbank.org/curated/en/139031468337139570/pdf/676190PUB0EPI0067882B0780821389782.pdf

Gray, E., Veit, P. G., Altamirano, J. C., Ding, H., Rozwalka, P., Zuniga, I., … Ussami, K. (2015). The economic costs and benefits of securing community forest tenure: Evidence from Brazil and Guatemala. *World Resources Institute*. Retrieved from https://files.wri.org/s3fs-public/15_WP_CLUA_Forest_Tenure.pdf

Greenpeace. (2018). *Imaginary trees, real destruction. How licensing fraud and illegal logging of ipe trees are causing irreversible damage to the Amazon Rainforest*. Retrieved from https://www.greenpeace.org.br/hubfs/Greenpeace_Report_Imaginary_Trees_Real_Destruction_March_2_18.pdf

Guertin, C.-E. (2013). *Illegal logging and illegal activities in the forestry sector: Overview and possible issues for the UNECE Timber Committee and FAO European Forestry Commission* [Conference session]. UNECE Timber Committee Market Discussion, Geneva, Switzerland. Retrieved from https://www.unece.org/fileadmin/DAM/timber/docs/tc-sessions/tc-61/presentations/guertin-paper. pdf

Gutierrez-Velez, V. H., & MacDicken, K. (2008). Quantifying the direct social and governmental costs of illegal logging in the Bolivian, Brazilian, and Peruvian Amazon. *Forest Policy and Economics, 10*(4), 248–256. http://dx.doi.org/10.1016/j.forpol.2007.10.007

Hastig, G. M., & Sodhi, M. S. (2020). Blockchain for supply chain traceability: Business requirements and critical success factors. *Production and Operations Management, 29*(4), 935–954. http://dx.doi.org/10.1111/poms.13147

Haupt, F., Bebbington, A., & Bebbington, D. H. (2020). Progress on the New York Declaration on Forests. Balancing forests and development. Addressing infrastructure and extractive industries, promoting sustainable livelihoods. *New York Declaration on Forests.* Retrieved from https://forestdeclaration.org/images/uploads/resource/2020NYDFReport.pdf

Herweijer, C., Combes, B., Swanborough, J., & Davies, M. (2018). Building block(chain)s for a better planet. *PwC.* Retrieved from https://www.pwc.com/gx/en/sustainability/assets/blockchain-for-a-better-planet.pdf

Higginson, M., Lorenz, J.-T., Münstermann, B., & Olesen, P. B. (2017). The promise of blockchain. *McKinsey*. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Industries/Financial%20Services/Our%20Insights/The%20promise%20of%20blockchain/The-promise-of-blockchain.pdf

Hinckeldeyn, J. (2019) *Blockchain – Technologie in der Supply Chain. Einführung und Anwendungsbeispiele*. Wiesbaden: Springer.

Hoare, A. (2015). Tackling illegal logging and the related trade: What progress and where next? *Chatham House*. Retrieved from https://www.chathamhouse.org/sites/default/files/publications/research/20150715IllegalLoggingHoareFinal.pdf

Human Rights Watch [HRW]. (2019). *Rainforest mafias. How violence and impunity fuel deforestation in Brazil's Amazon.* Retrieved from https://www.hrw.org/sites/default/files/report_pdf/brazil0919_web.pdf

Human Rights Watch [HRW], IPAM [Instituto de Pesquisa Ambiental da Amazônia], & IEPS [Instituto de Estudos para Políticas de Saúde]. (2020). *'The Air is unbearable'. Health impacts of deforestation related fires in the Brazilian Amazon.* Retrieved from https://www.hrw.org/sites/default/files/ media_2020/08/brazil0820_web.pdf

Hunt, M., Mirowski, L., Smith, A., & Turner, P. (2014). A review of systems and technologies for timber traceability [Contract Report]. *National Centre for Future Forest Industries*. Retrieved from https://www.researchgate.net/publication/311425127_A_review_of_systems_and_technologies_for_timber_traceability_National_Centre_for_Future_Forest_Industries

Intergovernmental Panel on Climate Change [IPCC]. (2014). *Climate change 2014 impacts, adaptation, and vulnerability part A: Global and sectoral aspects.* Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_ FINAL.pdf

Jaggi, F. (2019). The Wood Tracking Protocol – combining the benefits of blockchain with the capacities of mobile devices in Peru. In F. Jaggi (Ed.), *Navigating blockchain and climate action:*

2019 state and trends (pp. 30–31). Climate Ledger Initiative. Retrieved from https://www.goldstandard.org/sites/default/files/documents/cli_report-2019_state_and_trends.pdf

Kalamandeen, M., Gloor, E., Mitchard, E., Quincey, D., Ziv, G., Spracklen, D., … Galbraith, D. (2018). Pervasive rise of small-scale deforestation in Amazonia. *Scientific Reports, 8,* 1600. http://dx.doi.org/10.1038/s41598-018-19358-2

Kauano, E. E., Silva, J. M. C., & Michalski, F. (2017). Illegal use of natural resources in federal protected areas of the Brazilian Amazon. *PeerJ, 5*(2017), 1–20. http://dx.doi.org/ 10.7717/peerj.3902

Kehl, T. N., Todt, V., Veronez, M. R., & Cazella, S. C. (2015). *Real time deforestation detection using ANN and Satellite images. The Amazon Rainforest study case*. London: Springer.

Ken, S., Sasaki, N., Entani, T., Ma, H. O., Thuch, P., & Tsusaka, T. W. (2020). Assessment of the local perceptions on the drivers of deforestation and forest degradation, agents of drivers, and appropriate activities in Cambodia. *Sustainability, 12*(23), 9987. http://dx.doi.org/10.3390/ su12239987

Kleinschmit, D., Leipold, S., & Sotirov, M. (2016a). Introduction: Understanding the complexities of illegal logging and associated timber trade. In D. Kleinschmit, S. Mansourian, C. Wildburger, & A. Purret (Eds.), *Framing illegal logging and its governance responses in Brazil – A structured review of diagnosis and prognosis* (pp. 13–22). International Union of Forest Research Organizations. Retrieved from https://www.iufro.org/fileadmin/material/publications/iufro-series/ws35/ws35-high-res.pdf

Kleinschmit, D., Mansourian, S., Wildburger, C., van Solinge, T. V., Cashore, B., Cerutti, P. O., … Tacconi, L. (2016b). Conclusions. In D. Kleinschmit, S. Mansourian, C. Wildburger, & A. Purret (Eds.), *Framing illegal logging and its governance responses in Brazil – A structured review of diagnosis and prognosis* (pp. 133–138). International Union of Forest Research Organizations. Retrieved from https://www.iufro.org/fileadmin/material/publications/iufro-series/ws35/ws35-high-res.pdf

Kleinschmit, D., Ziegert, R. F., & Walther, L. (2021). Framing illegal logging and its governance responses in Brazil – A structured review of diagnosis and prognosis. *Frontiers in Forests and Global Change, 4,* 624072. http://dx.doi.org/10.3389/ffgc.2021.624072

Klingler, M., & Mack, P. (2020). Post-frontier governance up in smoke? Free-for-all frontier imaginations encourage illegal deforestation and appropriation of public lands in the Brazilian Amazon. *Journal of Land Use Science, 15*(2–3), 424–438. http://dx.doi.org/10.1080/ 1747423X.2020.173976

Kouhizadeh, M., & Sarkis, J. (2018). Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability, 10*(10), 3652. http://dx.doi.org/10.3390/su10103652

Kröger, M. (2017). Inter-sectoral determinants of forest policy: The power of deforesting actors in post-2012 Brazil. *Forest Policy and Economics, 77,* 24–32. http://dx.doi.org/10.1016/ j.forpol.2016.06.003

Kröger, M. (2018). The new 'sustainable communitarian' logging schemes and their critique inside multiple use conservation areas in the Brazilian Amazon: Preliminary notes. *Globalizations, 15*(5), 581–592. http://dx.doi.org/10.1080/14747731.2018.1474032

Kshetri, N. (2021). *Blockchain and supply chain management.* Amsterdam: Elsevier, Inc. http://dx.doi.org/ 10.1016/C20200-02868-9.

Lambin, E. F., Gibbs, H. K., Heilmayr, R., Carlson, K. M., Fleck, L. C., Garrett, R. D., … Walker, N. F. (2018). The role of supply-chain initiatives in reducing deforestation. *Nature Climate Change, 8,* 109–116. http://dx.doi.org/10.1038/s41558-017-0061-1

Lapola, D. V., Pinho, P., Quesada, C. A., Strassburg, B. B. N., Rammig, A., Kruijt, B., … Nobre, C. A. (2018). Limiting the high impacts of Amazon forest dieback with no-regrets science and policy action. *Proceedings from the National Academy of Sciences of the United States of America, 115*(46), 11671–11679. Retrieved from https://www.pnas.org/content/pnas/115/46/11671.full.pdf

Leong, C., Viskin, T., & Stewart, R. (2018). Tracing the supply chain. How blockchain can enable traceability in the food industry. *Accenture*. Retrieved from https://www.accenture.com/_acnmedia/PDF-93/Accenture-Tracing-Supply-Chain-Blockchain-Study-PoV.pdf

Lima, K. S., Castro, A. C. M., Baptista, J. S., & Silva, U. (2020). Wood-logging process management in Eastern Amazonia (Brazil). *Sustainability, 12*(18), 7571. http://dx.doi.org/10.3390/su12187571

Lima, R. Y. M., & Azevedo-Ramos, C. (2020). Compliance of Brazilian forest concession system with international guidelines for tropical forests. *Forest Policy and Economics, 119,* 102285. http://dx.doi.org/10.1016/j.forpol.2020.102285

Lin, J.-C., Lee, J.-Y., & Liu, W.-Y. (2021). Risk analysis of regions with suspicious illegal logging and their trade flows. *Sustainability, 13*(6), 3549. http://dx.doi.org/10.3390/su13063549

Lovejoy, T. E., & Nobre, C. (2018). Amazon tipping point. *Science Advances, 4*(2), eaba2340. http://dx.doi.org/10.1126/sciadv.aat2340

Lovejoy, T. E., & Nobre, C. (2019). Amazon tipping point: Last chance for action. *Science Advances, 5*(12), eaba2949. http://dx.doi.org/10.1126/sciadv.aba2949

Lowe, A. J., Dormott, E., Bowie, M. J., Degen, B., Gardner, S., Thomas, D., … Sasaki, N. (2016). Opportunities for improved transparency in the timber trade through scientific verification. *BioScience, 66*(11), 990–998. http://dx.doi.org/10.1093/biosci/biw129

Lowe, A. J., Wong, K.-N., Tiong, Y.-S., Iyerh, S., & Chew, F.-T. (2010). A DNA method to verify the integrity of timber supply chains; Confirming the legal sourcing of Merbau timber from logging concession to sawmill. *Silvae Genetica, 59*(6), 263–268. http://dx.doi.org/10.1515/sg-2010-0037

Malamud, M. (2018). Economías ilícitas en la Amazonia: desafío para la gobernabilidad en Perú, Brasil y Colombia. *Revista de Globalización, Competitividad y Gobernabilidad, 12*(1), 34–47. http://dx.doi.org/10.3232/GCG.2018.V12.N1.01

May, C. (2017). Transnational crime and the developing world. *Global Financial Integrity*. Retrieved from https://secureservercdn.net/45.40.149.159/34n.8bd.myftpupload.com/wp content/uploads/2017/03/Transnational_Crimefinal.pdf?utm_source=google&utm_medium=google&utm_term=(not%20provided)&utm_content=undefined&utm_campaign=(not%20set)&gclid=undefined&dclid=undefined&GAID=1296893601.162348345

McDermott, C. L., Irland, L. C., & Pacheco, P. (2015). Forest certification and legality initiatives in the Brazilian Amazon: Lessons for effective and equitable forest governance. *Forest Policy and Economics, 50,* 134–142. http://dx.doi.org/10.1016/j.forpol.2014.05.011

Medvigy, D., Walko, R. L., Otte, M. J., & Avissar, R. (2013). Simulated changes in Northwest U.S. climate in response to Amazon deforestation. *Journal of Climate, 26*(22), 9115–9136. http://dx.doi.org/10.1157/JCLI-D-12-00775.1

Montecchi, M., Plangger, K., & Etter, M. (2019). It's real, trust me! Establishing supply chain provenance using blockchain. *Business Horizons, 62*(3), 283–293. http://dx.doi.org/10.1016/j.bushor.2019.01.008

Moutinho, P., Guerra, R., & Azevedo-Ramos, C. (2016). Achieving zero deforestation in the Brazilian Amazon: What is missing? *Elementa, 4,* 1–11. http://dx.doi.org/10.12952/journal.elementa.000125

Müller, C. (2020). Brazil and the Amazon Rainforest. Deforestation, biodiversity and cooperation with the EU and International Forums. *European Parliament*. Retrieved from

https://www.europarl.europa.eu/RegData/etudes/IDAN/2020/648792/IPOL_IDA(2020)648792_EN.pdf

Mulligan, C., Scott, J. Z., Warren, S., & Rangaswami, J. P. (2018). Blockchain beyond the hype: A practical framework for business leaders. *World Economic Forum*. Retrieved from https://www3.weforum.org/docs/48423_Whether_Blockchain_WP.pdf

Muniz, T. F., & Pinheiro, A. S. O. (2019). Concessão florestal como instrumento para redução de exploração ilegal madeireira em Unidades de Conservação em Rondônia. *Revista Farol, 8*(8), 12–142. Retrieved from http://www. revistafarol.com.br/index.php/farol/article/view/123

NEPCon. (2017). *Timber legality risk assessment: Brazil.* Retrieved from https://preferredbynature.org/sites/default/files/library/2017-06/NEPCon-TIMBER-Brazil-Risk-Assessment-EN-V1.pdf

Nikolakis, W., John, L., & Krishnan, H. (2018). How blockchain can shape sustainable global value chains: An evidence, verifiability, and enforceability (EVE) framework. *Sustainability, 10*(11), 3926. http://dx.doi.org/10.3390/su10113926

Nobre, C. A., Sampaio, G., Borma, L. S., Castilla-Rubio, J. C., Silva, J. S., & Cardoso, M. (2016). Land-use and climate change risks in the Amazon and the need of a novel sustainable development paradigm. *PNAS, 113*(39), 10759–10768. Retrieved from https://www.pnas.org/content/pnas/early/2016/09/13/1605516113.full.pdf

Noor, M. N. H. M., Kadir, R., & Muhamad, S. (2020). Timber theft: Examining the factors of illegal logging. *International Journal of Innovation, Creativity and Change, 13*(12), 608–620. https://www.ijicc.net/images/vol_13/Iss_12/131256_Noor_2020_E_R.pdf

Observatório do Clima [ODC]. (2021). *Pushing the whole lot through. The second year of environmental havoc under Brazil's Jair Bolsonaro.* Retrieved from https://www.oc.eco.br/wp-content/uploads/2021/01/Passando-a-boiada-EN-1.pdf

Ometto, J. P., Aguiar, A. P. D., & Martinelli, L. A. (2014). Amazon deforestation in Brazil: Effects, drivers and challenges. *Carbon Management, 2*(5), 575–585. http://dx.doi.org/10.4155/CMT.11.48

Ortiz, E. (2019). Introduction. In M. Piotrowski & E. Ortiz (Eds.), *Nearing the tipping point: Drivers of deforestation in the Amazon region* (pp. 3–6). Washington, DC: Inter-America Dialogue. Retrieved from https://www.thedialogue.org/wp-content/uploads/2019/05/Nearing-the-Tipping-Point-for-website.pdf

Ozinga, S. & Mowat, H. (2012). Strategies to prevent illegal logging. In F. Wijen, K. Zoeteman, J. Pieters, & P. van Seters (Eds.), *A handbook of globalisation and environmental policy* (2nd ed., pp. 439–466). Northampton, MA: Edward Elgar Publishing, Inc. Retrieved from https://www.fern.org/fileadmin/uploads/fern/Documents/strategies%20to%20prevent%20illegal%20logging.pdf

Pacheco, P., Cerutti, P. O., Edwards, D. P., Lescuyer, G., Mejía, E., Obidzinski, K., … Sist, P. (2016). Multiple and intertwined impacts of illegal forest activities. In D. Kleinschmit, S. Mansourian, C. Wildburger, & A. Purret (Eds.), *Framing illegal logging and its governance responses in Brazil — A structured review of diagnosis and prognosis* (pp. 9–118). International Union of Forest Research Organizations. Retrieved from https://www.iufro.org/fileadmin/material/publications/iufro-series/ws35/ws35-high-res.pdf

Paiva, P. F. P. R., Ruivo, M. de L. P., da Silva Júnior, O. M., Maciel, M. de N., M., Braga, T. G. M., de Andrade, M. M. N., … Ferreira, B. M. (2020). Deforestation in protect areas in the Amazon: A threat to biodiversity. *Biodiversity and Conservation, 29*(6), 19–38. http://dx.doi.org/10.1007/s10531-019-018679

Perazzoni, F. (2012). *SIG, Amazônia e polícia federal. Geointeligência no combate ao desmatamento ilegal na Amazônia* (Publication No. 202252736) [Master's Thesis, Universidade Nova]. Repositório Universidade Nova. Retrieved from http://hdl.handle.net/10362/10538

Perazzoni, F. (2018). Amazonia, organized crime and illegal deforestation: Best practices for the protection of the Brazilian Amazon. In M. Undar (Ed.), *The 21st century fight for the Amazon: Environmental enforcement in the world's biggest rainforest* (pp. 21–55). Cham: Macmillan. http://dx.doi.org/10.1007/978-3-319-56552-1_2

Perazzoni, F., Bacelar-Nicolau, P., & Painho, M. (2020). Geointelligence against illegal deforestation and timber laundering in the Brazilian Amazon. *International Journal of Geo-Information*, *9*(6), 398. http://dx.doi.org/10.3390/ijgi9060398

Picchi, G. (2020). Marking standing trees with RFID tags. *Forests, 11*(2), 150. http://dx.doi.org/10.3390/f11020150

Picchi, G., Kühmaier, M., & Marques, J. de D. D. (2015). Survival test of RFID UHF tags in timber harvesting operations. *Croatian Journal of Forest Engineering, 36*(2), 165–174. Retrieved from http://www.crojfe.com/archive/volume-36-no.2/survival-test-of-rfid-uhf-tags-in-timber-harvesting- operations/

Piotrowski, M. (2019). Drivers of deforestation in the Amazon Region. In M. Piotrowski & E. Ortiz (Eds.), *Nearing the tipping point: Drivers of deforestation in the Amazon region* (pp. 3–6). Washington, DC: Inter-America Dialogue. Retrieved from https://www.thedialogue.org/wp-content/uploads/2019/05/Nearing-the-Tipping-Point-for-website.pdf

Pokorny, B., Pacheco, P., Cerutti, P. O., van Solinge, T. B., Kissinger, G., & Tacconi, L. (2016). Drivers of illegal and destructive forest use. In D. Kleinschmit, S. Mansourian, C. Wildburger, & A. Purret (Eds.), *Framing illegal logging and its governance responses in Brazil – A structured review of diagnosis and prognosis* (pp. 61–80). International Union of Forest Research Organizations. Retrieved from https://www.iufro.org/fileadmin/material/publications/iufro-series/ws35/ws35-high-res.pdf

Ramasastry, A. (2015). Corporate social responsibility versus business and human rights: Bridging the gap between responsibility and accountability. *Journal of Human Rights*, *14*(2), 237–259. http://dx.doi.org/10.1080/ 14754835.2015.1037953

Rammig, A., Lapola, D. M., Pinho, P., Quesada, C. A. N., Brown, I. F., Krujit, B., … Nobre, C. A. (2018). Estimating the likelihood of an Amazon forest dieback and potential socio-economic impacts. *Geophysical Research Abstracts, 20,* 3433. Retrieved from http://mtc.m21c.sid.inpe.br/col/sid.inpe.br/mtc-m21c/2018/04.09.13.08/doc/ramming_estimating.pdf

RCS Global. (2017). *Blockchain for traceability in minerals and metals supply chains: Opportunities and challenges.* Retrieved from https://www.rcsglobal.com/wp-content/uploads/2018/09/ICMM-Blockchain-for-Traceability-in-Minerals-and-Metal-Supply-Chains.pdf

Ridder, H.-G. (2017). The theory contribution of case study research designs. *Business Research, 10*(2), 281–301. http://dx.doi.org/10.1007/s40685-017-0045-z

Seidel, F., Fripp, E., Adams, A., & Denty, I. (2012). Tracking sustainability: Review of electronic and semi electronic timber tracking technologies. *International Tropical Timber Organization*. Retrieved from http://www.itto.int/direct/topics/topics_pdf_download/topics_id=3145&no=0&disp=inline

SGS. (n.d.). *Is your timber legal?* Retrieved from https://www.sgs.com/~/media/Global/Documents/Brochures/SGS-Governments%20And%20Institutions-Is%20your%20timber%20legal-A4-EN-10-V1.pdf

Sheikh, P. A., Bermejo, L. F., & Procita, K. (2019). International illegal logging: Background and issues. *Congressional Research Service*. Retrieved from https://sgp.fas.org/crs/misc/IF11114.pdf

Shelkovnikov, A. (2016). Blockchain. Enigma. Paradox. Opportunity. *Deloitte.* Retrieved from https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/Innovation/deloitte-uk-blockchain-full-report.pdf

Sparovek, G., Reydon, B. P., Pinto, L. F. G., Faria, V., de Freitas, F. L. M., Azevedo-Ramos, C., … Ribeiro, V. (2019). Who owns Brazilian lands? *Land Use Policy, 87,* 104062. http://dx.doi.org/10.1016/j.landusepol.2019.104062

Strand, J., Soares-Filho, B., Costa, M. H., Oliveiera, U., Carvalho, Pires, G. F., … Toman, M. (2018). Spatially explicit valuation of the Brazilian Amazon Forest's ecosystem services. *Nature Sustainability, 1*(11), 657–664. http://dx.doi.org/10.1038/s41893-018-0175-0

Subramanian, N., Chaudhuri, A., & Kayikci, Y. (2020). *Blockchain and supply chain logistics evolutionary case studies.* Cham*:* Springer.

Šulyová, D., & Koman, G. (2020). The significance of IoT technology in improving logistical processes and enhancing competitiveness: A case study on the world's and Slovakia's wood-processing enterprises. *Sustainability, 12*(18), 7804. https://dx.doi.org/10.3390/su12187804

Tacconi, L., Cerutti, P. O., Leipold, S., Rodrigues, R. J., Savaresi, A., To, P., & Weng, X. (2016). Defining illegal forest activities and illegal logging. In D. Kleinschmit, S. Mansourian, C. Wildburger, & A. Purret (Eds.), *Framing illegal logging and its governance responses in Brazil – A structured review of diagnosis and prognosis* (pp. 23–36). International Union of Forest Research Organizations. Retrieved from https://www.iufro.org/fileadmin/material/publications/iufro-series/ws35/ws35-highres.pdf

Tacconi, L., Rodrigues, R. J., & Maryudi, A. (2019). Law enforcement and deforestation: Lessons from Indonesia and Brazil. *Forest Policy and Economics, 108,* 101943. http://dx.doi.org/10.1016/j.forpol.2019.05.029

Teixeira, M. A. D., Lima, R. M., & Ferreira, J. C. S. (2018). Crimes Verdes e Colarinho Branco – A mafia da madeira na Amazônia Ocidental, uma violação aos direitos humanos. *Quaestio Iuris, 11*(4), 3148–3172. https://doi.dx.org/10.12957/rqi.2018.37444

Thakker, U., Patel, R., Tanwar, S., Kumar, N., & Song, H. (2021). Blockchain for diamond industry: Opportunities and challenges. *IEEE Internet of Things Journal, 8*(11), 8747–8773. http://dx.doi.org/10.1109/JIOT.2020.3047550

The World Bank. (2017). *Distributed Ledger Technology (DLT) and blockchain*. Retrieved from https://olc.worldbank.org/system/files/122140-WP-PUBLIC-Distributed-Ledger-Technology-and-Blockchain-Fintech-Notes.pdf

The World Bank. (2019). *Illegal logging, fishing, and wildlife trade: The costs and how to combat it.* Retrieved from https://openknowledge.worldbank.org/handle/10986/32806

Treiblmaier, H. (2020). Toward more rigorous blockchain research: Recommendations for writing blockchain case studies. In H. Treiblmaier & T. Clohessy (Eds.), *Blockchain and distributed ledger technology use cases: Applications and lessons learned* (pp. 1–32.). Cham: Springer.

Tritsch, I., Sist, P., Narvaes, I. d. S., Mazzei, L., Blanc, L., Bourgoin, C., … Gond, V. (2016). Multiple patterns of forest disturbance and logging shape forest landscapes in Paragominas, Brazil. *Forests, 7*(12), 1–15. http://dx.doi.org/10.3390/f7120315

United Nations [UN]. (1948). *The Universal Declaration of Human Rights*. Retrieved from https://www.un.org/en/universal-declaration-human-rights/

United Nations [UN]. (2015). *Paris Agreement*. Retrieved from https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

United Nations [UN]. (2016). *Best practice guide for forensic timber identification*. Retrieved from https://www.unodc.org/documents/Wildlife/Guide_Timber.pdf

United Nations [UN]. (2017). *Resolution adopted by the Economic and Social Council on 20 April 2017*. Retrieved from https://documents-dds-ny.un.org/doc/UNDOC/GEN/N17/184/62/PDF/N1718462.pdf?OpenElement

United Nations Environment Programme [UNEP] & International Criminal Police Organisation [INTERPOL]. (2012). Green carbon, black trade. In C. Nellemann (Ed.)., *Illegal logging, tax fraud and Laundering in the world's tropical forests. A rapid response assessment*. Arendal: INTERPOL Environmental Crime Programme.

United Nations Environment Programme [UNEP]- World Conservation Monitoring Centre [WCMC]. (2018). *Brazil.* Retrieved from https://ec.europa.eu/environment/forests/pdf/Country_overview_Brazil_ 03_10_2018.pdf

Upadhyay, N. (2019). *UnBlock the blockchain*. Gateway East: Springer.

Urban, N. T. (2020). *Blockchain for business. Erfolgreiche Anwendungen und Mehrwerte für Netzwerkteilnehmer identifizieren.* Wiesbaden: Springer.

van Solinge, T. B. (2014). Researching illegal logging and deforestation. *International Journal for Crime, Justice, and Social Democracy, 3*(2), 35–48. http://dx.doi.org/10.5204/ijcjsd.v3i2.179

van Solinge, T. B., Zuidema, P., Vlam, M., Cerutti, O., & Yemelin, V. (2016). Oragnized forest crime: A criminological analysis with suggestions from timber forensics. In D. Kleinschmit, S. Mansourian, C. Wildburger, & A. Purret (Eds.), *Framing illegal logging and its governance responses in Brazil – A structured review of diagnosis and prognosis* (pp. 81–98). International Union of Forest Research Organizations. Retrieved from https://www.iufro.org/fileadmin/material/publications/iufroseries/ws35/ws35-high-res.pdf

Varriale, V., Cammarano, A., Michelino, F., & Caputo, M. (2020). The unknown potential of blockchain for sustainable supply chains. *Sustainability, 12*(22), 9400. http://dx.doi.org/10.3390/su12229400

Vilkov, A., & Gang, T. (2019). Blockchain as a solution to the problem of illegal timber trade between Russia and China: SWOT analysis. *International Forestry Review, 21*(3), 385–400. http://dx.doi.org/10.1505/146554819827293231

Walker, J., & Kemp, L. (2019). Blockchains are diamonds' best friend: The case for supply chain transparency. In J. Barberis, D. W. Arner, & R. P. Buckley (Eds.), *The RegTech book: The financial technology handbook for investors, entrepreneurs and visionaries in regulation* (pp. 250–254). Hoboken N.J.: Wiley.

Wellesley, L. (2014). Illegal logging and related trade: The response in Brazil. *Chatam House.* Retrieved from https://www.chathamhouse.org/sites/default/files/publications/research/20141029IllegalLoggingBrazilWellesleyFinal.pdf

World Business Council for Sustainable Development [WBCSD], & World Resources Institute [WRI]. (2014). *Sustainable procurement of wood and paper-based products.* Retrieved from https://files.wri.org/d8/s3fspublic/wri_report_4c_report_ legalityguide_final320.pdf

World Resources Institute [WRI]. (2018). *Sourcing legally produced wood.* Retrieved from https://files.wri.org/d8/s3fs-public/sourcing-legally-produced-wood.pdf

World Wide Fund For Nature [WWF]. (2011). *Timber and wood products*. Retrieved from http://assets.wwf.org.uk/downloads/timber_briefing_280611.pdf

World Wide Fund For Nature [WWF]. (2015). *Do timber products in the U.K. stack up? A report on the results of testing selected retail products that aren't covered by the EU timber regulation.* Retrieved from http://assets.wwf.org.uk/downloads/timber_testing_report_may15.pdf?_ga=1.244146183.368477186.432800215

World Wide Fund for Nature [WWF]. (2016a). *Brazil's new Forest Code: A guide for decision-makers in supply chains and governments.* Retrieved from http://assets.wwf.org.uk/downloads/wwf_brazils_new_forest_code_guide_1.pdf?_ga=2.175500258.160566498.1603976319-1385818356.1603976319

World Wide Fund For Nature [WWF]. (2016b). *Tackling illegal logging, deforestation and forest degradation: An agenda for EU action.* Retrieved from https://wwfeu.awsassets.panda.org/downloads/wwf_joint_briefing_deforestation.pdf

World Wide Fund For Nature [WWF]. (2017). *Responsible sourcing of forest products. The business case for retailers.* Retrieved from https://www.wwf.org.uk/sites/default/files/201705/WWF%20Business%20Case%20responsible%20sourcing_0.pdf

World Wide Fund For Nature [WWF]. (2021). *Deforestation fronts. Drivers and responses in a changing world.* Retrieved from https://www.wwf.ch/sites/default/files/doc-202101/Deforestation%20fronts%20%20drivers%20and%20responses%20in%20a%20changing%20world%20-%20full%20report.pdf

Internet Sources

AB Agri Ltd, Agricultural Industries Confederation, Ahold Delhaize, ALDI SOUTH Group, AP7 (Sjunde AP-fonden), Asda Stores Ltd., … Wm Morrison Supermarkets Plc (2020). *An open letter on the protection of the Amazon.* Retrieved from https://www.retailsoygroup.org/wp-content/uploads/2020/05/Letter-from-Business-on-Amazon.pdf

Agricultural Industries Confederation, Ahold Delhaize GSO B.V., ALDI Einkauf SE & Co. oHG, ALDI SOUTH Group, AP7 (Sjunde AP-fonden), Asda Stores Ltd., … Wm Morrison Supermarkets Plc. (2021). *An open letter on the protection of the Amazon*. Retrieved from https://www.proterrafoundation.org/wp-content/uploads/2021/06/Letter-from-Business-on-Amazon_2021.pdf

Aguiar, D., & Torres, M. (n.d.). Deforestation as an instrument of land grabbing: Enclosures along the expansion of the agricultural frontier in Brazil. *Agro é Fogo*. Retrieved from https://en.agroefogo.org.br/deforestation-as-an-instrument-of-land-grabbing/

Ahmad, P. (2020, June 30). Impacts of COVID-19 disproportionately affect poor and vulnerable: UN chief. *UN News.* Retrieved from https://news.un.org/en/story/2020/06/1067502

Amigo, I. (2020, February 25). When will the Amazon hit a tipping point? *Nature*. Retrieved from https://www.nature.com/articles/d41586-020-00508-4

Arnold, C. F. (2020, October 2). Captain chain saw's delusion. *The New York Times.* Retrieved from https://www.nytimes.com/2020/10/02/opinion/amazon-rainforest-conservation.html

Askew, K. (2020, September 21). Princes adopts blockchain as part of its proactive approach to illegal labour in Italian agriculture. *The Food Navigator.* Retrieved from https://www.foodnavigator.com/Article/2020/09/21/Princes-adopts-blockchain-as-part-of-its-proactive-approach-to-illegal-labour-in-Italian-agriculture

Austral Fisheries. (2021, April 27*). Glacier 51 toothfish wins delicious produce award*. Retrieved from https://www.australfisheries.com.au/news/2021/glacier-51-toothfish-wins-delicious-produce award

Bader, C. (2012, February 2). Apple sweatshops & Twitter censorship: A defining moment for CSR. *TriplePundit.* Retrieved from https://www.triplepundit.com/story/2012/apple-sweatshops-twitter-censorship-defining-moment-csr/88471

Baretto, P., & Muggah, R. (2019, August 23). The Amazon is reaching a dangerous tipping point. We need to scale solutions now if we have any chance of saving it. *World Economic Forum*. Retrieved from https://www.weforum.org/agenda/2019/08/amazon-dangerous-tipping-point-forest-fires-brazil/

Bender, J. P., Burchardi, K., & Shepherd, N. (2019, April 9). Capturing the value of blockchain. *Boston Consulting Group*. Retrieved from https://www.bcg.com/publications/2019/capturing-blockchain-value

Blarel, B. (2019, October 29). The real costs of illegal logging, fishing and wildlife trade: $1 trillion–$2 trillion per year. *The World Bank.* Retrieved from https://blogs.worldbank.org/voices/real-costs-illegal-logging-fishing-and-wildlife-trade-1-trillion-2-trillion-year

Borges, A. (2018, December 21). Novo chefe do Ibama quer licenciamento ambiental automático. *Terra.* Retrieved from https://www.terra.com.br/economia/futuro-presidente-do-ibama-quer-licenciamento-ambiental-automatico,a8b3d565bc174aeeb35da55ae8653c3c3oxcjdku.html

Borges, T., & Branford, S. (2020, March 11). Brazil drastically reduces controls over suspicious Amazon timber exports. *Mongabay.* Retrieved from https://news.mongabay.com/2020/03/brazil-drastically-reduces-controls-over-suspicious-amazon-timber-exports/

Camargo, S. (2020, July 8). Prosecutors target Brazil's environment minister over dismantling of protections. *Mongabay*. Retrieved from https://news.mongabay.com/2020/07/prosecutors-target-brazils-environment-minister-over-dismantling-of-protections/

Cambridge Dictionary. (2021a). *Genus*. Retrieved from https://dictionary.cambridge.org/dictionary/english/genus

Cambridge Dictionary. (2021b). *Logging*. Retrieved from https://dictionary.cambridge.org/us/dictionary/english/logging

Campion, J. (2011, July 12). Tree fingerprinting helps track illegal logging. *Australian Geographic*. Retrieved from https://www.australiangeographic.com.au/news/2011/07/tree-fingerprinting-helps-track-illegal-logging/

Canineu, M. L., & Chávez, L. T. (2021, April 22). Bolsonaro's empty promises to protect the Amazon. *Human Rights Watch*. Retrieved from https://www.hrw.org/news/2021/04/22/bolsonaros-empty-promises-protect-amazon

Carson, B., Romanelli, G., Walsh, P., & Zhumaev, A. (2018, June 19). Blockchain beyond the hype: What is the strategic business value? *McKinsey & Company.* Retrieved from https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/blockchain-beyond-the-hype-what-is-the-strategic-business-value

Carvalho, B. (2020, May 27). The Amazon will soon burn again. *The New York Times.* Retrieved from https://www.nytimes.com/2020/05/27/opinion/amazon-bolsonaro-deforestation.html

Carvalho, B., & Nobre, C. (2020, October 2020). We're turning the Amazon into a savannah. *The New York Times*. Retrieved from https://www.nytimes.com/2020/10/02/opinion/amazon-rainforest-climate-change.html

Castilla-Rubio, J. C., & Nobre, C. (2016, September 30). Could the digital revolution save the Amazon? *World Economic Forum.* Retrieved from https://www.weforum.org/agenda/2016/09/could-the-digital-revolution-save-the-amazon/

Clausen, L. (2016, May 18). Scientists can now track stolen timber using DNA profiling. *SGS*. Retrieved from https://www.sbs.com.au/topics/science/nature/article/2016/05/18/scientists-can-now-track-stolen-timber-using-dna-profiling

Correa, P. (2020, June 15). Brazil drives increase in worldwide forest loss. *PhysOrg.* Retrieved from https://phys.org/news/2020-06-brazil-worldwide-forest-loss.html

Costa, L. (2020, May 15). Brazil: Blockchain comparative guide. *Mondaq.* Retrieved from https://www.mondaq.com/brazil/technology/935288/blockchain-comparative-guide

Dantas, C. (2021, May 13). Nova lei do licenciamento ambiental: entenda os próximos passos e o que está em jogo. *G1.* Retrieved from https://g1.globo.com/natureza/noticia/2021/05/13/nova-lei-do-licenciamento-ambiental-entenda-quais-sao-os-proximos-passos-e-o-que-esta-em-jogo.ghtml.

Davidson, J. (2020, February 12). Amazon deforestation is causing 20% of forests to release more carbon than they absorb. *EcoWatch.* Retrieved from https://www.ecowatch.com/amazon-deforestation-carbon-emissions-2645127492.html?rebelltitem=2#rebelltitem2

Dennehy, K. (2016, February 17). Lovejoy, 'godfather' of biodiversity, reflects on 50 years in the Amazon. *Yale School of the Environment*. Retrieved from https://environment.yale.edu/news/article/thomas-lovejoy-on-biodiversity-habitat-fragmentation-and-50-years-in-the-amazon/

Double Helix Tracking. (2021). *Scientific testing* [Webpage]. Retrieved from https://www.doublehelixtracking.com/scientific-testing

Earthsight. (2020, December 16). *Europe awash with wood from billion-dollar Russian illegal logging scandal*. Retrieved from https://www.earthsight.org.uk/news/press-release-europe-awash-with-wood-billion-dollar-russian-illegal-logging-scandal

Einhorn, C. & Buckley, C. (2021, November 1). Global Leaders Pledge to End Deforestation by 2030. *The New York Times*. Retrieved from https://www.nytimes.com/2021/11/02/climate/cop26-deforestation.html

Ennes, J. (2021, June 2). Land conflicts in Brazil break record under Bolsonaro. *Mongabay*. Retrieved from https://news.mongabay.com/2021/06/land-conflicts-in-brazil-break-record-in-2020-under-bolsonaro/

Farias, E. (2019, September 13). Amazônia em Chamas: 90% da madeira exportada são ilegais, diz Polícia Federal. *Amazonia Real.* Retrieved from https://amazoniareal.com.br/amazonia-em-chamas-90-da-madeira-exportada-sao-ilegais-diz-policia-federal/

Fearnside, P. M. (2017, April 18). Business as usual: A resurgence of deforestation in the Brazilian Amazon. *Yale Environment 360.* Retrieved from https://e360.yale.edu/features/business-as-usual-a-resurgence-of-deforestation-in-the-brazilian-amazon

Fearnside, P. M. (2020, November 3). BR-319: The beginning of the end for Brazil's Amazon forest (commentary). *Mongabay.* Retrieved from https://news.mongabay.com/2020/11/br-319-the-beginning-of-the-end-for-brazils-amazon-forest-commentary/?utm_medium=Social&utm_source=Twitter#Echobox=1604772203

Fearnside, P. M., Ferrante, L., & de Andrade, M. B. T. (2020, March 27). BR-319 illegal side road threatens Amazon protected area, indigenous land (commentary). *Mongabay.* Retrieved from https://news.mongabay.com/2020/03/br-319-illegal-side-road-threatens-amazon-protected-area-indigenous-land-commentary/

Fellet, J. (2020, January 29). The 5 main points of conflict between the Bolsonaro government and the indigenous. *BBC*. Retrieved from https://www.bbc.com/portuguese/brasil-51229884

Fern. (2021, March 1). *Why is it important to fight illegal logging? – FAQ.* Retrieved from https://www.fern.org/publications-insight/why-is-it-important-to-fight-illegal-logging-faq-2303/

Gallou, S. L. (2021, June 22). DNA tracing of timber to increase forest sustainability and integrity. *Faculty of Sciences. The University of Adelaide*. Retrieved from https://sciences.adelaide.edu.au/news/list/2021/06/22/dna-tracking-of-timber-to-increase-forest-sustainability-and-integrity

Gandour, C., Menezes, D., Vieira, J. P., & Assunção, J. J. (2021, March 9). Forest degradation in the Brazilian Amazon: Public policy must target phenomenon related to deforestation. *Climate Policy Initiative*. Retrieved from https://www.climatepolicyinitiative.org/publication/forest-degradation-in-the-brazilian-amazon-public-policy-must-target-phenomenon-related-to-deforestation/

Gonzales, J. (2018, May 24). Illegal loggers 'cook the books' to harvest Amazon's most valuable tree. *Mongabay.* Retrieved from https://news.mongabay.com/2018/05/illegal-loggers-cook-the-books-to-harvest-amazons-most-valuable-tree/

Gortázar, N. G. (2019, May 8). Uma inédita frente de ex-ministros do Meio Ambiente contra o desmonte de Bolsonaro. *El País.* Retrieved from https://brasil.elpais.com/brasil/2019/05/08/politica/1557338026_221578.html

Greenpeace. (2008, December 12). *Hackers help destroy the Amazon rainforest*. Retrieved from https://storage.googleapis.com/gpuk-archive/blog/forests/hackers-help-destroy-amazon-rainforest-20081212.html

Greenpeace. (2021). *Fighting against deforestation and illegal logging* [Webpage]. Retrieved from https://www.greenpeace.org.au/what-we-do/protecting-forests/threats/

Hanbury, S. (2020, February 24). Amazon Tipping Point puts Brazil's agribusiness, energy sector at risk: Top scientists. *Mongabay.* Retrieved from https://news.mongabay.com/2020/02/amazon-tipping-point-puts-brazils-agribusiness-energy-sector-at-risk-top-scientists/

Harris, B. (2020a, May 20). Brazil faces international backlash over Amazon land reform bill. *Financial Times*. Retrieved from https://www.ft.com/content/ca84017c-94c5-48ca-80c6-2ac31ea20cd9

Harris, B. (2020b, June 23). Investors warn Brazil to stop Amazon destruction. *Financial Times*. Retrieved from https://www.ft.com/content/ad1d7176-ce6c-4a9b-9bbc-cbdb6691084f

Harris, B. (2021, May 11). Doubts linger over army mission to save Brazil's rainforest. *Financial Times*. Retrieved from https://www.ft.com/content/66393e86-5965-4e79-850f-d1d52916135f

Harvey, F. (2020, February 13). UK to lead global fight against illegal logging and deforestation. *The Guardian.* Retrieved from https://www.theguardian.com/environment/2020/feb/13/uk-lead-global-fight-illegal-logging-deforestation-cop-26

Hewitt, D. (2020, July 30). Legal and sustainable timber trade is essential to COVID-19 economic recovery. *International Institute for Sustainable Development*. Retrieved from http://sdg.iisd.org/commentary/guest-articles/legal-and-sustainable-timber-trade-is-essential-to-covid-19-economic-recovery

Hickson, K. (2021, February 3). Innovations helping smallholder farmers & forest-owners add sustainability & integrity to their enterprise. *Double Helix Tracking Technology.* Retrieved from https://www.doublehelixtracking.com/news/innovations-helping-smallholder-farmers-forest-owners-sustainability-integrity-enterprise

Hirabahasi, G. (2018, December 12). 'Não demarcarei um centímetro quadrado a mais de terra indígena', diz Bolsonaro. *Época*. Retrieved from https://oglobo.globo.com/epoca/expresso/nao-demarcarei-um-centimetro-quadrado-mais-de-terra-indigena-diz-bolsonaro-23300890

Human Rights Watch [HRW]. (2020, August 26). *Brazil: Amazon fires affect health of thousands*. Retrieved from https://www.hrw.org/news/2020/08/26/brazil-amazon-fires-affect-health-thousands

Hyperledger. (2020). *Sustainable supply chain tracking for Volvo cars' electric vehicle batteries on hyperledger fabric blockchain - Douglas Johnson-Poensgen, Circulor & Mark Rakhmilevich, Oracle* [YouTube Video]. Retrieved from https://www.youtube.com/watch?v=PlXkLvQnsHU&t=48s

Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. *Harvard Business Review*. Retrieved from https://hbr.org/2017/01/the-truth-about-blockchain

IKEA. (2021). *IWAY: The IKEA code of conduct.* Retrieved from https://about.ikea.com/en/work-with-us/for-suppliers/iway-our-supplier-code--of-conduct

iov42. (2021a, July 1). *iov42 solution demo: Timber chain* [Video File]. Retrieved from https://www.youtube.com/watch?v=vnUVG4j-mZU

iov42. (2021b). *An identity-centric platform built on pioneering technology* [Webpage]. Retrieved from https://iov42.com/our-technology/

iov42. (2021c). *Timber Chain: Securing sustainable supply chains* [Webpage]. Retrieved from https://iov42.com/our-solutions/timber-chain/

Jezequel, M. (2019, August 25). Global appetite for beef, soy fuels Amazon fires. *PhysOrg.* Retrieved from https://phys.org/news/2019-08-global-appetite-beef-soy-fuels.html

Khadka, N. S. (2019, August 28). Amazon fires: Forest loss challenges Paris climate ambition. *BBC.* Retrieved from https://www.bbc.com/news/science-environment-49484530

Kimbrough, L. (2020, March 5). Versace, Amazon, Samsonite among companies listed as deforestation 'laggards'. *Mongabay.* Retrieved from https://news.mongabay.com/2020/03/versace-amazon-samsonite-among-companies-listed-as-deforestation-laggards/

Kugler, H. (2018, August 31). Scientists pin down fraud that fuels illegal Amazon logging. *SciDevNet.* Retrieved from https://www.scidev.net/global/environment/news/scientists-pin-down-fraud-that-fuels-illegal-amazon-logging.html

Levis, C. (2020, October 2). The grandmother trees. *The New York Times.* Retrieved from https://www.nytimes.com/2020/10/02/opinion/amazon-rainforest-giant-trees.html

Londoño, E., Andreoni, M., & Casado, L. (2020, June 6). Amazon deforestation soars as pandemic hobbles enforcement. *The New York Times.* Retrieved from https://www.nytimes.com/2020/06/06/world/americas/amazon-deforestation-brazil.html

Lovejoy, T. (2019, May 22). Why the Amazon's biodiversity is critical for the globe/interviewer: The World Bank [Transcript]. *The World Bank*. Retrieved from https://www.worldbank.org/en/news/feature/2019/05/22/why-the-amazons-biodiversity-is-critical- for-the-globe

Lovejoy, T., & Schmitz, O. (2020, August 17). Yale experts explain biodiversity. *Yale University.* Retrieved from https://sustainability.yale.edu/news/yale-experts-explain-biodiversity

Lowe, A. (2020, September 17). *If a tree falls in a forest…* [Blog Post]. Retrieved from https://andylowe.org/2020/09/17/if-a-tree-falls-in-a-forest/

Macedo, M. N., & Pereira, V. P. (2020, October 2). We know how to stop the fires. *The New York Times*. Retrieved from https://www.nytimes.com/2020/10/02/opinion/amazon-rainforest-fire-prevention.html

Magalhaes, L., & Trevisani, P. (2020, September 4). Brazil's vice president admits mistakes in fighting Amazon deforestation. *The Wall Street Journal.* Retrieved from https://www.wsj.com/articles/brazils-vice-president-admits-mistakes-in-fighting-amazon-deforestation-11599211803

Mason, J., & Parker-Forney, M. (2018, June 11). DNA testing can save trees from illegal logging – and you can help. *World Resources Institute.* Retrieved from https://www.wri.org/insights/dna-testing-can-save-treesillegal-logging-and-you-can-help

Mattoso, C., Serpaião, F., & Seto, G. (2021, April 14). PF diz ao STF que Salles atrapalha fiscalização Ambiental e pede que ministro seja investigado. *Folha de São Paulo.* Retrieved from https://www1.folha.uol.com.br/colunas/painel/2021/04/pf-diz-ao-stf-que-salles-dificulta-fiscalizacao-ambiental-e-pede-que-ministro-seja-investigado.shtml

McCarthy, N. (2019, August 27). Deforestation helped make Brazil the world's top soy producer [Infographic]. *Forbes.* Retrieved from https://www.forbes.com/sites/niallmccarthy/2019/08/27/deforestation-helped-make-brazil-the-worlds-top-soy-producer-infographic/#655718c1869e

Mendonça, E. (2019, September 22). Bolsonaro's Brazil unlikely to achieve Paris Agreement goals: Experts. *Mongabay*. Retrieved from https://news.mongabay.com/2019/09/bolsonaros-brazil-unlikely-to-achieve-paris-agreement-goals-experts/

Ministério da Infraestrutura. (2021, April 7). *BR-319/AM: DNIT recebe autorização para as obras de reconstrução do Lote C* [News Release]. Retrieved from https://www.gov.br/dnit/pt br/assuntos/noticias/br-319-am-dnit-recebe-autorizacao-para-as-obras-de-reconstrucao-do-lote-c

Miranda, R. (2021, June 17). Rise for the Earth! *Amazon Watch*. Retrieved from https://amazonwatch.org/news/2021/0617-rise-for-the-earth

Mortimer, E. (2019, April 25). Brazil's tropical rainforest is a huge economic asset. *Financial Times.* Retrieved from https://www.ft.com/content/ff052b4c-65c9-11e9-a79d-04f350474d62

Muggah, R. (2021, April 2). Exposing organized crime in the Amazon: Q&A with Robert Muggah of the Igarapé Institute. *Mongabay.* Retrieved from https://news.mongabay.com/2021/04/exposing-organized-crime-in-the-amazon-qa-with-robert-muggah-of-the-igarape-institute/

Mutz, M. (2019, September). How supply chain transparency can help the planet [Video File]. *TED.* Retrieved from https://www.ted.com/talks/markus_mutz_how_supply_chain_transparency_can_help_the_planet?language=en

Nash, K. S. (2018, September 24). Walmart requires lettuce, spinach suppliers to join blockchain. *The Wall Street Journal*. Retrieved from https://www.wsj.com/articles/walmart-requires-lettuce-spinach-suppliers-to-join-blockchain-1537815869

Neme, L. (2010, July 8). Top officials busted in Amazon logging raids, but political patronage may set them free. *Mongabay.* Retrieved from https://news.mongabay.com/2010/07/top-officials-busted-in-amazon-logging-raids-but-political-patronage-may-set-them-free/

New York Declaration on Forests. (2021). *Endorsers of the New York Declaration on Forests* [Webpage]. Retrieved from https://forestdeclaration.org/about/nydf-endorsers

Nobre, C. (2019, October 1). The path to a profitable and protected Amazon. *Scientific American.* Retrieved from https://blogs.scientificamerican.com/observations/the-path-to-a-profitable-and-protected-amazon/

Nobre, C., & Castilla-Rubio, J. C. (2012, November 29). Why we should fear the Amazonian tipping point. *World Economic Forum.* Retrieved from https://www.weforum.org/agenda/2012/11/why-we-should-fear-the-amazonian-tipping-point/

Nogueron, R., Cheung, L., & Kaldijan, E. (2016, May 25). 5 technologies help thwart illegal logging by tracing wood's origin. *World Resources Institute*. Retrieved from https://www.wri.org/insights/5-technologies-help-thwart-illegal-logging-tracing-woods-origin

OpenSC. (2021a). *Case study: Austral fisheries* [Webpage]. Retrieved from https://opensc.org/case studies.html

OpenSC. (2021b). *For certifications. Strengthen your certification with the latest tech* [Webpage]. Retrieved from https://opensc.org/certifications.html

OpenSC. (2021c). *How it works: We create traceability & transparency technology* [Webpage]. Retrieved from https://opensc.org/technology.html

OpenSC. (2021d). *OpenSC for business and the planet* [Webpage]. Retrieved from https://opensc.org/business.html

OpenSC. (2021e). *Your Patagonian toothfish ID b36ac724-fbf6-43f3-a985-7fd27fc87162* [Webpage]. Retrieved from https://opensc.org/product-example

Paton, E. (2018, November 30). Will blockchain be a boon to the jewelry industry? *The New York Times.* Retrieved from https://www.nytimes.com/2018/11/30/fashion/jewelry-blockchain-de-beers.html

PEFC Italy. (2019, April 26). Wood-chain: The technology for strengthening traceability and PEFC certification. *MedForest.* Retrieved from https://medforest.net/2019/04/26/wood-chain-project-the-technology-for-strengthening-traceability-and-pefc-certification/

República Federativa do Brasil [RFB]. (2006). *Lei Nº 11.284, de 2 de marco de 2006.* Retrieved from http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2006/lei/l11284.htm

República Federativa do Brasil [RFB]. (2012). *Lei Nº 12.651, de 25 de maio de 2012*. Retrieved from http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm

República Federativa do Brasil [RFB]. (2013). *Lei Nº 12.850, de 2 de agostos de 2013.* Retrieved from http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2013/lei/l12850.htm

Romero, S. (2019, August 30). Where is the Amazon Rainforest vanishing? Not just in Brazil. *The New York Times*. Retrieved from https://www.nytimes.com/2019/08/30/world/americas/amazon-rainforest.html

Sandy, M. (2019, December 5). 'The Amazon is completely lawless': The rainforest after Bolsonaro's first year'. *The New York Times.* Retrieved from https://www.nytimes.com/2019/12/05/world/americas/amazon-fires-bolsonaro-photos.html?searchResultPosition=1

Sassine, V. (2019, September 16). Número de fiscais do Ibama cai pela metade e PGR recomenda autorização de concurso em 30 dias. *O Globo*. Retrieved from https://oglobo.globo.com/sociedade/numero-de-fiscais-do-ibama-cai-pela-metade-pgr-recomenda-autorizacao-de-concurso-em-30-dias-23952424

Schatz, B., & Jenkins, M. B. (2020, January 15). Deforestation can't be stopped by voluntary action alone. *World Economic Forum*. Retrieved from https://www.weforum.org/agenda/2020/01/deforestation-voluntary-action-regulation/

Schipani, A. (2019). How crime drives deforestation in Brazil's Amazon. *Financial Times.* Retrieved from https://www.ft.com/video/a2082c03-41e2-493b-8e63-0556f4f79d90

Serkez, Y. (2020, October 2). Every place under threat. *The New York Times.* Retrieved from https://www.nytimes.com/interactive/2020/10/02/opinion/amazon-under-threat.html?searchResultPosition=6

SGS. (2017, December 6). *The origin of timber, paper and other forest products* [News Article]. Retrieved from https://www.sgs.com/en/news/2017/12/the-origin-of-timber-paper-and-other-forest-products

Shalders, A. (2021, February 5). Com Bolsonaro, área ambiental do governo já perdeu 10% dos servidores. *BBC.* Retrieved from https://www.bbc.com/portuguese/brasil-55849937

Shapshak, T. (2018, May 10). Blockchain used to track gems to counter blood diamonds and fakes. *Forbes.* Retrieved from https://www.forbes.com/sites/tobyshapshak/2018/05/10/blockchain-used-to-track-gems-to-counter-blood-diamonds-and-fakes/?sh=ee23c0f18f67

Spring, J. (2020a, March 4). Exclusive: Brazil exported thousands of shipments of unauthorized wood from Amazon port. *Reuters*. Retrieved from https://www.reuters.com/article/us-brazil-environment-lumber-exclusive-idUSKBN20R15X

Spring, J. (2020b, June 23). Global investors demand to meet Brazil diplomats over deforestation. *Reuters*. Retrieved from https://uk.reuters.com/article/us-brazil-environment-investors/global-investors-demand-to-meet-brazil-diplomats-over-deforestation-idUKKBN23U0L8

Spring, J. (2021, January 12). Brazil environmental fines fall 20% as deforestation soars. *Reuters*. Retrieved from https://www.reuters.com/article/us-brazil-environment-idUSKBN29H1Q7

Stubley, P. (2021, June 24). Brazil's environment minister Ricardo Salles resigns over Amazon logging inquiries. *The Times.* Retrieved from https://www.thetimes.co.uk/article/brazils-environment-minister-ricardo-salles-resigns-over-amazon-logging-inquiries-5psntv7x3

Sullivan, Z. (2019, August 26). The real reason the Amazon is on fire. *Time*. Retrieved from https://time.com/5661162/why-the-amazon-is-on-fire/

Tali, D. (2016, August 22). Illegal Amazon loggers: 'Anyone who buys the wood is as guilty as I'. *The Irish Times*. Retrieved from https://www.irishtimes.com/news/world/illegal-amazon-loggers-anyone-who-buys-the-wood-is-as-guilty-as-i-1.2763706

The Economist. (2020, June 11). *How big beef and soya firms can stop deforestation*. Retrieved from https://www.economist.com/the-americas/2020/06/11/how-big-beef-and-soya-firms-can-stop-deforestation

The Economist. (2019, August 1). *The Amazon is approaching an irreversible tipping point*. Retrieved from https://www.economist.com/briefing/2019/08/01/the-amazon-is-approaching-an-irreversible-tipping-point

The Economist (2021, November 4). Covering the ground: trees and COP26 [Audio podcast]. *The Intelligence from the Economist*. Retrieved from https://podcasts.apple.com/au/podcast/covering-the-ground-trees-and-cop26/id151230264?i=1000540736309

Troëng, S., Barbier, E., & Rodríguez, C. M. (2020, May 21). The COVID-19 pandemic is not a break for nature – Let's make sure there is one after the crisis. *World Economic Forum.* Retrieved from https://www.weforum.org/agenda/2020/05/covid-19-coronavirus-pandemic-nature-environment-green-stimulus-biodiversity/

Tucker, C., & Catalini, C. (2018, June 28). What blockchain can't do. *Harvard Business Review*. Retrieved from https://hbr.org/2018/06/what-blockchain-cant-do

US Endowment. (2020, October 13). *ForesTrust, LLC and the future of the global wood supply chain* [Press Release]. Retrieved from https://www.usendowment.org/forestrust-llc-and-the-future-of-the-global-wood-supply-chain/

Volckhausen, T. (2019, December 19). Paris accord 'impossible to implement' if tropical forest loss not stopped. *Mongabay*. Retrieved from https://news.mongabay.com/2019/12/paris-accord-impossible-to-implement-if-tropical-forest-loss-not-stopped/

Wallen, K. (2018, May 11). You've probably got no idea how big the problem of timber trafficking is. *World Economic Forum.* Retrieved from https://www.weforum.org/agenda/2018/05/global-timber-trafficking-harms-forests-and-costs-billions-of-dollars-here-s-how-to-curb-i

Weston, P. (2020, April 25). 'We did it to ourselves': Scientist says intrusion into nature led to pandemic. *The Guardian.* Retrieved from https://www.theguardian.com/world/2020/apr/25/ourselves-scientist-says-human-intrusion-nature-pandemic-aoe

Whiting, K. (2020, February 12). Blockchain could police the fishing industry - here's how. *World Economic Forum.* Retrieved from https://www.weforum.org/agenda/2020/02/blockchain-tuna-sustainability-fisheries-food-security/

Wood Tracking Protocol [WTP]. (2021). *WTP* [Webpage]. Retrieved from https://wtp-project.com

Woodward, A. (2019, August 22). Amazon fires created a smoke eclipse in the skies above Brazil's largest city, 2,000 miles away. *Business Insider.* Retrieved from https://www.businessinsider.com/amazon-fires-eclipse-sun-above-sao-paulo-brazil-2019-8?r=US&IR=T

World Health Organisation [WHO]. (2020). *Zoonoses* [Webpage]. Retrieved from https://www.who.int/topics/zoonoses/en/

World Wide Fund for Nature [WWF]. (2020). *Illegal logging* [Webpage]. Retrieved from https://wwf.panda.org/our_work/our_focus/forests_practice/deforestation_causes2/illegal_logging/

World Wide Fund for Nature-Australia. [WWF-Australia] (2018). *WWF-Australia and OpenSC* [Webpage]. Retrieved from https://www.wwf.org.au/get-involved/panda-labs/opensc#gs.6sfose

Worm, L. D. (2019, March 11). *Blockchain in FSC* [News Article]. Retrieved from https://www.linkedin.com/pulse/blockchain-fsc-loa-dalgaard-worm/

Worm, L. D. (Host). (2020a, June 2). How blockchain can help FSC - Interview with CIO Michael Marus (No. 4) [Audio podcast]. *Forest For The Future*. FSC. Retrieved from https://open.fsc.org/handle/resource/442?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+forestforthefuture-podcasts+%28Forest+For+The+Future+-+Podcasts%29

Worm, L. D. (Host). (2020b, August 6). Can wood samples help save our forests and improve due diligence? Interview with Roger Young, Agroisolab, and Phil Guillery, FSC (No. 8) [Audio podcast]. *Forest For The Future*. FSC. Retrieved from https://open.fsc.org/handle/resource/455?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+forestforthefuture-podcasts+%28Forest+For+The+Future+-+Podcasts%29

Worm, L. D. (Host). (2021a, May 10). How blockchain can help FSC - Interview with CIO Michael Marus (No. 19) [Audio podcast]. *Forest For The Future*. FSC. Retrieved from https://open.fsc.org/handle/resource/482?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+forestforthefuture-podcasts+%28Forest+For+The+Future+-+Podcasts%29

Worm, L. D. (Host). (2021b, June 1). Making data from the ground a reality – An interview with Joanna Nowakowska, Deputy Director, FSC Technology and Information Unit (No. 20) [Audio podcast]. *Forest For The Future*. FSC. Retrieved from https://open.fsc.org/handle/resource/483?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+forestforthefuture-podcasts+%28Forest+For+The+Future+-+Podcasts%29

Yeung, J. (2019, August 23). Blame humans for starting the Amazon fires, environmentalists say. *CNN.* Retrieved from https://edition.cnn.com/2019/08/22/americas/amazon-fires-humans-intl-hnk-trnd/index.html

Yirka, B. (2018). Analysis suggests economic losses due to Amazonian dieback more than mitigation efforts. *PhysOrg*. Retrieved from https://phys.org/news/2018-11-analysis-economic-losses-due-amazonian.html

Zia, M., Hansen, J., Hjort, K., & Valdes, C. (2019, July 1). Brazil once again becomes the world's largest beef exporter. *United States Department of Agriculture.* Retrieved from https://www.ers.usda.gov/amber-waves/2019/july/brazil-once-again-becomes-the-world-s-largest-beef-exporter/

Cover image: Eucalyptus Plantation Macapa Brazil from https://media.greenpeace.org/archive/Eucalyptus-Plantation-Macapa-Brazil-27MZIFJJ105MP.html

Appendix

1 Tables

1.1 Overview of Blockchain Studies in the Timber Industry

#	Authors	Journal / University	Location	Title	Overview of Approach and Content
1	Vilkov, A. & Gang, T. (2019)	International Forestry Review	Russia and China	Blockchain as a solution to the problem of illegal timber trade between Russia and China: SWOT analysis	The authors conduct a SWOT analysis on the applicability of blockchain for the Russian Chinese timber trade, which is characterised by high illegality. After discussing the market characteristics and causes of illegal logging in these markets, the strengths, weaknesses, opportunities, and risks of blockchain are outlined and applied to the Russian Chinese timber trade.
2	Nikolakis, W., John, L., & Krishnan, H. (2018)	Sustainability	Not defined	How Blockchain Can Shape Sustainable Global Value Chains: An Evidence, Verifiability, and Enforceability (EVE) Framework	The authors develop a conceptual framework named "Evidence, Verifiability, and Enforceability," to illustrate how blockchain could enhance sustainability. The framework can be applied in any industry and the authors use the timber industry as an example of the framework's application. Illegal logging is briefly mentioned as a potential application area (largely focused on application by certification organisations), but not elaborated in detail. The focus of the discussion lies more on sustainability.
3	Figorilli, S. et al. (2018)	Sensors	Italy (location of simu-lation)	A Blockchain Implementation Prototype for the Electronic Open Source Traceability of Wood along the Whole Supply Chain	This paper represents the first work that introduces the use of blockchain for electronic traceability in the timber industry. The authors conducted a simulation for which they implemented a blockchain architecture and tracing system based on RFID sensors with ten trees in Italy. The paper mostly describes the prototype and concludes with a short discussion on implications for practice and theory. Illegal logging is briefly mentioned as a potential area of application but not elaborated in detail.
4	Düdder, B. & Ross, O. (2017)	Department of Computer Science, University of Copenhagen	Not defined	Timber Tracking Reducing Complexity of Due Diligence by using Blockchain Technology	The authors briefly outline issues inherent to the current chain-of-custody system used in timber supply chains. The discussion on illegal logging focuses on the trade between (non-defined) countries. They propose a blockchain solution and continue with a brief description of the solution, the requirements for its implementation, and the impact. Elaborations are kept very brief and the blockchain solution is not described in detail.

Source: own table

The scarcity of research became evident in the conducted literature search via the University of St. Gallen research tool with relevant key words, which resulted in the finding of only four papers related to the coverage of blockchain in relation to illicit industries or the timber. The keywords "blockchain" or "block chain" were used together with "timber," "wood," "illegal," "Amazon," and "Amazonas."

1.2 Overview of Required Documentation in the Brazilian Timber Supply Chain

System	DOF	SISFLORA Mato Grosso	SISFLORA Pará
Region covered	All states in Brazil, except Mato Grosso and Pará. Managed by IBAMA.	Mato Grosso state. Managed by SEMA Mato Grosso.	Pará state. Managed by SEMA Pará.
Forest	**PMFS:** For the whole logging area to support multi-year operation. Must be prepared by a forest engineer and authorised by the state's Secretary of Environment (SEMA/OEMA).		
	Annual operational plan: Provides a more detailed inventory of the area to be logged, including individual trees, logging roads, and log decks.		
	AUTEF: Logging permit issued by the SEMA for a period of 1 year, stating the species and volumes authorised to be extracted during the period.		**AUTEX:** Logging permit issued by the SEMA for a period of 1 year, stating the species and volumes authorised to be extracted during the period.
Transport	**DOF:** A license for the transportation of timber products issued by the logging company via the online official system.		**GF:** A license for the transportation of timber, differentiated by type of product. GF1: Transportation of logs. GF3: For other timber products.
Sawmill	**LO:** Operational license. System of stock control and conversion rates associated with the DOF system. Sawmills must record input and output, and conversion rates associated with different products.	**LF:** Forestry license. **LA:** Operational license. System of stock control and conversion rates associated with SISFLORA. Sawmills must record input and output, and conversion rates associated with different products.	**LAU:** Environmental license. System of stock control and conversion rates associated with the SISFLORA. Sawmills must record input and output, and conversion rates associated with different products.
Sales	**Nota Fiscal Electrônica:** Federal digital invoice/receipt of the Brazilian revenue department, to record all sales in the country and the amount of taxes due.		

Source: BVRio, 2017, p. 23

1.3 Overview of the Different Scientific Methodologies

	Wood anatomy	Machine vision	Dendro-chronology	Mass spectrometry	Near infrared spectroscopy	Stable isotopes	Radio-carbon	DNA barcoding	Population genetics/phylogeography	DNA fingerprinting
Identify genus	Yes	Yes	No	Yes	Yes	No	No	Yes	No	No
Identify species	Occasionally	Occasionally	No	Yes	Yes	No	No	Yes	Occasionally	No
Identify provenance	Occasionally	Unknown	Occasionally	Yes	Yes	Yes	No	Occasionally	Yes	No
Identify individuals	No	No	Yes	No	No	No	No	No	No	Yes
Determine age	No	No	Yes — where growth rings are present	No	No	No	Yes	No	No	No
Approximate cost per sample including expertise	<$100	<$1	<$100	<$1–$100 — depending on the mass spectrometry method used	<$100	$100–400	$300–400	$100–$300	$100–$300	$100–$300
Speed of process	Minutes–days	Seconds–minutes	Hours–days	Minutes–days depending on the mass spectrometry method used	Seconds–minutes	Several days	Several days	Several days	Several days	Several days
Prior information requirements	None — but suspected region of origin can be helpful	None — but suspected region of origin can be helpful	species	Suspected genus	Broad region of origin	Species	None	None — but suspected taxa can be helpful	Genus for species ID, species for regional ID	Species
Equipment requirements	Microscopy preparation and observation tools	Machine vision camera and database link	Macroscopy equipment	Mass spectrometer and equipment for isolating extractives (if required)	Near infrared spectroscopy machinery and database link	Light gas isotope ratio mass spectrometer and elemental analyser	Liquid scintillation counting and accelerator mass spectrometry equipment	Molecular biology laboratory	Molecular biology laboratory	Molecular biology laboratory
Reference material requirements	Access to microscopic wood anatomy examples through microscope slides and electronic databases	Central database of scientific reference images processed for automated classification	Tree ring series data derived from reference tree cross-sections from specific areas	Heartwood samples from multiple individuals of the desired taxa and potential lookalikes	Regional specific database loading of reference spectra obtained from wood specimens	Wood samples from the desired species with various tree rings	None	Leaf, cambium or wood samples from the desired taxa and potential lookalikes	Leaf, cambium or wood samples from multiple individuals from across the range of the species	Leaf, cambium or wood samples from multiple individuals from across the range of the species
Current use	The most commonly and extensively used method for genus ID	Used predominantly in a research context and in pilot implementation projects	Used occasionally to match wood coming from same tree or to determine antique verses modern origin of timber	Used extensively for identification of some taxa (e.g. *Dalbergia*)	Used extensively for assessment of wood properties Currently used in pilot studies for identification	Used extensively for origin check in agricultural products and used in proof of concept studies and pilot tests for timber	Used extensively for age determination in a wide range of materials, limited application to timber at present	Used extensively for species identification in a wide range of taxa, limited application to wood at present	Used predominantly in a research context and in pilot implementation projects	Used extensively for individual identification in humans and other taxa, limited application to wood at present
Obstacles to implementation	Training of sufficient numbers of wood anatomists, maintenance of reference collections	Incorporation of reference material into database, classification models robust for global context vs. regional models	Collection of tree ring series data for important taxa in areas of interest	Development of reference databases for additional taxa of interest	Development of reference databases for additional taxa of interest	Development of reference databases for additional taxa/areas of interest	No significant obstacles to implementation	Development of discriminating barcodes that work on DNA extracted from wood	Development of genetic markers and reference databases that discriminate areas and taxa of interest	Development of genetic markers and reference databases that discriminate individuals in taxa of interest
Research needs	Discrimination between closely related taxa, forensic validation of methods	Development of global scientific image reference collection, uncertainty quantification and probabilistic model development	Accuracy of dating, provenancing and individual ID, forensic validation of methods	Forensic validation of methods for additional taxa	Development of reference databases, forensic validation of methods	Development of reference databases, forensic validation of methods	No specific research needs with regards to timber	Development and forensic validation of DNA barcoding methods	Development and forensic validation of discriminating genetic markers and reference databases	Development and forensic validation of discriminating genetic markers and reference databases

Source: Dormontt et al., 2015, p. 792

2 Case Studies

2.1 Case Study Overview

#	Name	Type of Organisation	Case Study	Company Representative (Interview)
1	Wood Tracking Protocol	Timber tracking solution provider	Timber	Michael Fabing
2	Timber Chain	Timber tracking solution provider	Timber	Richard Anning (Carl Ronnow), Anna Roberts and Kiara Kealoha (iov42)
3	OpenSC	Technology venture	Fish	Tom Lange

2.2 Case Study Results

2.2.1 Wood Tracking Protocol

2.2.1.1 Overview of Solution

Illegal logging in Peru has adverse environmental, social, and economic effects, similar to illegal logging in Brazil (see Chapter 3.4) (WTP, 2021b, p. 2). It negatively affects forests, strips local communities of their livelihoods, and creates dishonest competition for responsible timber companies (WTP, 2021b, p. 2). WTP seeks to address illegal logging by providing a tool for companies to track timber, which guarantees that the tracked wood is legal with a high probability. This tool consists of a smartphone application and web platform that supply chain actors can access to insert and verify data at each step of the entire supply chain (Fabing, 2021a, p. 1). Supply chain actors have access to a smartphone application and web platform to capture and manage data during the supply chain (Interview Fabing). Additionally, the web platform includes other functionalities, such as key facts on forest inventories, forecasted wood production, and cost information, meaning it can also be used both as tracking and accounting software (Interview Fabing; WTP, 2021, p. 22). Note that the interface of both smartphone application and web platform, respectively the data requirements, varies depending on which supply chain steps the user covers: For example, entering the license plate of the transportation vehicle is required for the transportation stage, while for an actor in the logging phase it is not necessary to enter this information (Interview Fabing). In these applications, actors can view the entire history of the tracked wood, respectively, where it came from, which companies handled it, and who has legal custody over it (Interview Fabing).

WTP uses three databases to store data on the back end: A centralised database, IPFS, and the Ethereum Main Net (Interview Fabing). Sensitive data, such as telephone numbers, addresses, and names, is stored on a private, centralised database, accessible only by WTP (Interview Fabing). WTP does not release personal information on any blockchain network to protect its users since indigenous people in the Peruvian Amazon who took action against illegal logging have been killed by malicious actors before (Interview Fabing). Timber-related data, on the other hand, is stored in hashed values in the IPFS network and Ethereum Main Net, which is accessible to everyone who has the required access information (Interview Fabing). WTP uses IPFS to store pictures and more complex data, while the Ethereum Main Net is used to store simple data (Fabing, 2021a, p. 2). Most of the data is stored in IPFS, given the lower energy consumption and costs compared to the public ledger Ethereum, where storage of one Gigabyte cost several million dollars after the gas price spiked in July 2020 (Fabing, 2021a, p. 2; Interview Fabing). In the future, WTP sees potential in using the Ethereum Main Net to program smart contracts that would automatically transfer payments between the supply chain actors after specified conditions are fulfilled and the transaction is validated (Fabing, 2021a, p. 2). Overall, blockchain adds value by mitigating the risk of illegality and "storing […] information in a public book, tamper proof and accessible to all, allowing the consumer to verify the legal origin of the wood he acquires" (WTP

Project, 2021a, ¶10). Furthermore, the technology creates added value with its smart contracts functionality, which enables the system to program transactions to be performed automatically in the future (Interview Fabing).

Companies in the Peruvian Amazon have four main advantages by using the WTP system. First, timber companies can access digitised information on timber products, their locations, and suppliers from the first stage of the supply chain onwards. Currently, in Peru, almost all documentation in the timber supply chain is paper based, where "people are doing everything with a piece of paper" (Interview Fabing). Documentation is scanned and uploaded on databases, but in many cases, the information remains non-searchable since data is only available in the scanned format and not entered manually into systems. By adopting the WTP system, companies have increased transparency on their products, the supply chain, and their finances. Second, companies can use the system to extract valuable, data-driven insights for their business operations, forming the basis for process optimisation, productivity gains, and financial gains. Additionally, timber companies can identify which suppliers have consistently delivered high-quality wood and met all legal, social, and environmental requirements. Third, timber companies can obtain access to the international timber market to profit from premium prices. Fabing, co-founder of WTP, remarked that Peruvian timber companies could improve their access to the international timber market and premium pricing with WTP since it allowed them to present proof of legality and trackability. Currently, many buyers refrain from purchasing wood from the Peruvian Amazon due to the high percentage of illegality and prefer buying wood from other countries at a 20 to 30 percent higher price. Lastly, companies using the WTP system receive real-time notifications when the government agencies OSINFOR, Peru's forest inspection agency, and SERFOR, Peru's national forest and wildlife service, flag companies as illegal since the WTP system established a direct link to the agencies' database of illegal companies. (Interview Fabing)

2.2.1.2 Technical Aspects

In Peru, OSINFOR and SERFOR are responsible for conducting field inspections, issuing logging licenses, and carrying out audits typically once a year. WTP works in close partnership with these agencies that provide important input on companies operating illegally, trees approved for harvest, and GPS coordinates of forest areas allocated for harvesting. To ensure up-to-date information on companies' legal status, approved trees, and protected zones, WTP established a connection via an API between the company's and agencies' databases. Changes in the agencies' databases will be automatically reflected and, if necessary, flagged in the WTP system. (Interview Fabing) For companies seeking to join the WTP network, OSINFOR needs to give green light on their legal status, meaning the agency carries out the due diligence on WTP's behalf (WTP, 2021b, p. 8). Approved companies are required to set up their identity verification process, which includes connecting the user account with a phone number required for two-factor authentication (Interview Fabing; WTP, 2021b, p. 8).

In the pre-logging phase, a forest engineer needs to create an inventory of the trees allocated for harvest in a forest management plan, known as the *Plan de Manejo Forestal*, similar to the PMFS in Brazil (see Chapter 3.1.1) (WTP, 2021b, p. 6). To do this, the engineer needs to enter key data in the mobile application (e.g., timber volume and species), upload a picture of the tree, and record GPS data on the tree's location (WTP, 2021b, p. 6). After the forest management plan has been submitted, SERFOR gives its approval or disapproval, a decision that will be stored on the blockchain (WTP, 2021b, p. 6). This information, together with data on other approved trees and the locations of protected zones, is reflected in WTP's mobile application, which shows loggers whether the tree they are standing in front of can be harvested or not (Interview Fabing).

During the beginning of each supply chain stage, physical verification and authentication of the tree occur (WTP, 2021b, p. 13). In the logging stage, the logger is required to take a picture of the tree via the mobile application before and after cutting it and enter data concerning the GPS location, the company, and other information, all of which is stored in the databases (WTP, 2021b, p. 6). After the tree has been felled, a unique QR code is created, printed, and attached to each individual log to ensure its identification during subsequent supply chain steps (Interview Fabing). In the post-logging stage, actors need to follow similar procedures in the transport, processing, and export steps, including scanning the QR code for identification, taking a picture of the timber shipment and entering data relevant to the respective stage of the supply chain (WTP, 2021b, p. 6). To ensure legality during the processing stage, WTP relies on mass-balance checks: "The volume and the weight is the only thing that we can have as a tangible. So, if someone has like 100 cubic meter [sic] of wood, he cannot sell more than 100 cubic meter wood on the market," (Interview Fabing) remarks Fabing. In such cases, where the output exceeds input volumes, an algorithm would reject the inserted data and show a mismatch in real-time (interview Fabing). Common throughout all stages of the supply chain is data matching: "So, what we try to do is to try to connect the dots based on the information that people are entering," though Fabing notes that this currently is done manually or through simple formulas, such as input and output relationships, which can be programmed with an algorithm (Interview Fabing). Overall, the WTP system lowers the risk that the same tree is double counted along the supply chain (Jaggi, 2019, p. 30).

Currently, the entire workflow for capturing data encompasses a series of manual steps, including taking a picture, checking the GPS data, and inserting data in the mobile application (Interview Fabing). Fabing notes that the initial priority for the WTP project was to digitise the paper trails in the Peruvian timber industry, to enable data-driven insights and optimise timber tracking (Interview Fabing). They are currently examining ways to automate data entry process to improve accuracy and reduce the risk of human error (Fabing, 2021a, p. 2; Interview Fabing). In this context, the WTP team developed a platform vision for the future that includes the use of IoT devices, such as satellite imagery, drones, sensors, cameras, and QR codes, at the final stage (see image) (WTP, 2021b, p. 6). By attaching QR codes to the final product, WTP could spark B2C demand since buyers can access information on the product's history and origin (Interview Fabing). Satellite imagery is useful for monitoring forest cover and identifying the occurrence of selective logging and deforestation events. However, Fabing acknowledges the limitations of satellite imagery, namely the limited detail level and the update rate, since images are refreshed only every month or biannually, depending on the provider (Interview Fabing). Drones can overcome this weakness since they can capture information on the type, species, and size of trees while flying over forest areas (Interview Fabing). In the future, they could complement or even replace field inspections to some extent (Interview Fabing). Sensors can support volume measurement and wood identification by measuring the heat that trees emit, which differs from species to species (Interview Fabing). Similarly, high-tech cameras can support the wood identification process, though Fabing believes that this type of technology still needs five to ten years to develop before it can be widely used (Interview Fabing). Fabing sees considerable potential in partnering with companies driving these IoT solutions for the coming years (Interview Fabing). Besides partnering with technology providers, collaborations with non-state actors, such as the FSC organisation, represent another possibility (Fabing, 2021a, p. 2). Moreover, WTP seeks to integrate the payment processing system in its platform, where transactions could be programmed to be automatically executed if pre-defined conditions are met and the information required for timber tracking is registered (WTP, 2021a, ¶11; WTP, 2021b, p. 4). (Interview Fabing)

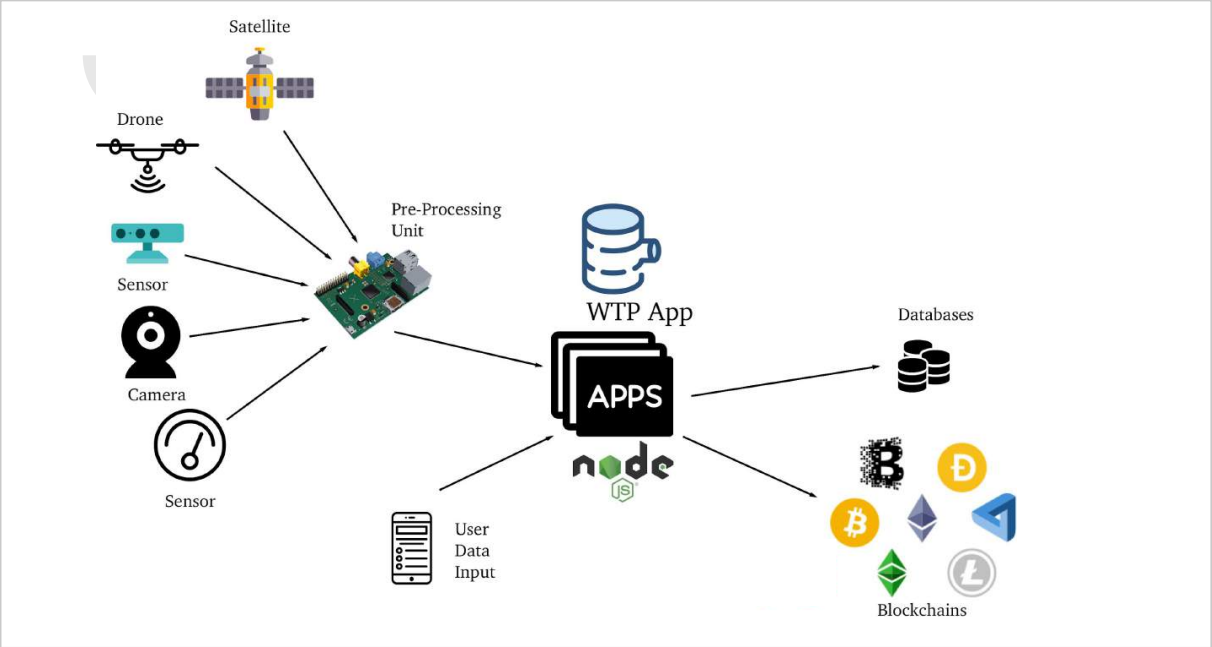


Image: WTP platform vision for the future (WTP, 2021b, p. 6)

While the WTP system considerably decreases the risk of illegal logging occurring along the supply chain, Fabing acknowledges that limitations still exist. First, the system currently allows network participants to import data since some actors may have already recorded the data beforehand and thus, do not want to repeat the data entry process. In such cases, Fabing states that WTP does not have GPS data along the entire supply chain and would trust people to perform their work correctly. Second, the WTP system does not include procedures to verify other forms of illegal logging, such as the occurrence of overlogging and the possession of required operating licenses among processing facilities. Though these application areas could become relevant in the future, for now the WTP solution focuses on verifying whether logging occurred in authorized zones. Third, while GPS tracking increases the transparency of the timber's journey, Fabing notes that actors can still tamper with GPS data, for instance, by using a VPN, which can disguise the actor's actual location. Lastly, given that the current process still largely depends on actors capturing data manually and actors "have to trust the user with the form to go to the woods and do the work" (Interview Fabing), the risk of human corruption and manipulation exists. (Interview Fabing)

WTP decreases the risk of human manipulation and illegal logging through several mechanisms. By capturing each network participant's identity, address, and phone number in the set-up phase, each transaction can be linked to a specific participant. Additionally, the platform's partners OSINFOR and SERFOR play an important role in mitigating the risk by verifying the legal status of network participants and approving forest management plans. In the future, this risk will further be mitigated by reducing user input and automating the data entry and payment process. Fabing comments, "the more we can automate the system using sensors, GPS, photos, RFID tags whatsoever, the better, the more accurate because they're less corruptible" (Interview Fabing). Lastly, blockchain, through its characteristics, may act as a deterrent since actors do not want mistakes or proof of illegal practices to be permanently recorded on a ledger accessible by everyone. (Interview Fabing)

2.2.1.3 Other Aspects

On the operational side, WTP faced several challenges, which can be categorised into data-related and non-data-related ones. On the one hand, they faced difficulties aligning the different methods companies used to calculate timber volume and determining an adequate error rate for volume calculations. Wood is subject to physical changes, for instance, during transport in water where the volume increases due to water absorption or during the processing stage where logs are processed into sawn wood, complicating volume calculations. Additionally, trees vary in shapes, especially in the Amazon: For instance, one tree may have a large hole on the inside, which only becomes apparent in the processing stage, but only after the logger has already entered the estimated volume. However, mistakes may also occur in species determination and other data entered, which the WTP team also needed to consider when defining an acceptable error rate. Additionally, WTP needed to align data entry requirements since companies, for instance, used different measurement systems: Timber companies supplying US customers often used feet and inches, while companies supplying EU customers worked with metres and centimetres. (Interview Fabing)

Other operational challenges included the lack of internet connection in the Amazon and the entire country, as they discovered that around 80 percent of Peru did not have any internet connection. Therefore, the WTP team had to develop a mobile application that could function without an internet or cell phone reception for several days, reliably capture data entered by the user, and transfer the information to the database once internet is accessible. Another operational challenge WTP faced was that most forestry workers did not own a phone due to the non-existent cell phone reception and may not be willing to purchase one, given the low perceived value of having a cell phone in the jungle. Lastly, Fabing notes that some forestry workers need to undergo training to adopt the new data capture process. Here, they worked together with the institutions Cite Florestal and Cite de Madera that educate people on new technologies and teach them how to use them. (Interview Fabing)

From the financial perspective, Fabing acknowledged that sophisticated technologies always come at a cost, as seen with RFID chips: “There's a cost of USD 1. So, what's a dollar? But here in Peru it might be a lot of money” (Interview Fabing). Therefore, it is important for WTP to carefully determine the cost and benefits under the consultation of timber companies when evaluating the application of different technologies in the tracking system. Additionally, if WTP were to integrate the payment process in the application, an education process would need to occur for some supply chain actors, especially in the upstream stages. This education process would need to occur for both cryptocurrencies and fiat currencies: “The problem is that people don't like banks, because of the simple reason that they will have to start to pay tax. And that's why they prefer cash because it's untraceable” (Interview Fabing). Lastly, in terms of fees incurred by WTP, Fabing mentions that they are looking into options that would allow them to offer the tracking functionalities of the WTP system for free. To achieve this objective, they are currently working with the government to attain funding for their tool. Incentives for the Peruvian government include improved access to international markets for the timber industry and formalising the timber industry, which is currently marked by a high percentage of informal workers. If timber companies seek to use functionalities beyond the tracking system, such as the accounting and supply chain management features, they need to pay a monthly fee. (Interview Fabing)

2.2.2 Timber Chain

2.2.2.1 Overview of Solution

Timber companies' efforts to verify legality and track timber can be undermined by malicious actors who, for instance, falsify paperwork or reuse legitimate documentation. Additionally, since regulations, such as the EUTR, leave the exact due diligence requirements open to interpretation, information requested by international buyers may vary case by case. Richard Anning, environmental manager at Carl Ronnow, says: "That makes it really quite complicated […] for us to be preparing different types of different levels of due diligence documentation for different buyers and it also confuses suppliers" (Interview Anning). Timber Chain addresses these challenges by granting timber companies access to a secure, digital platform where they can upload the entire set of information that may be required by subsequent supply chain actors (Interview Anning). Anning mentions: "If we gather every single bit of information that we would give to the buyer that wants everything, and we put it onto the blockchain, and then when we ship to any of these [other] buyers, we give them an encryption key for their particular shipment, they can go in and take as little or as much as they want" (Interview Anning). In the case of Carl Ronnow, the uploaded information represents information that the timber company is already collecting and has already verified. "This means that rigorous due diligence has already been applied to information uploaded for shipments on Timber Chain which is recognized by the fact that it is covered under our LegalSource certification. Therefore, uploading shipment information onto Timber Chain enhances the credibility of wood that already has credible third party certification, which demonstrates adherence to the due diligence requirements of the EUTR, and Timber Chain is an additional, rather than a standalone, tool to provide Buyers confidence that the wood they are purchasing will not be in contravention of the requirements of the EUTR" (Interview Anning). Anning notes that Timber Chain could also store information generated by IoT devices or results from scientific wood identification methods if other timber companies sought to combine Timber Chain with such methods. (Interview Anning)

In terms of system architecture, Timber Chain is built on top of the iov42 platform (Interview Kealoha). It is important to understand that this platform is not based on conventional blockchain technology itself but is inspired by the blockchain: For instance, the platform does not "block" transaction records together like traditional blockchains do. Instead, each transaction goes through individually, which helps with processing efficiency. And instead of recording a linear sequence of events from block to block, they have developed a system called Proofmesh® which weaves together multiple, immutable lines of actions for greater security that scales with the network (Interview Kealoha). Kiara Kealoha, marketing and communications manager at iov42, explains: "We've developed our own technologies from the ground up to kind of make the application of blockchain in organizations faster, scalable, and more secure" (Interview Kealoha). In other words, iov42 identified and re-created key blockchain features in their platform, such as consensus, decentralisation, cryptographic encryption, and data immutability, meaning the advantages typically associated with blockchain, such as security and transparency, still apply (Interview Kealoha; iov42, 2021b, ¶3). Additionally, iov42 leverages digital identification features to ensure that all network participants have verified identities to promote trust between users and, if necessary, hold users accountable for their actions (iov42, 2021b, ¶3). Identity verification may include authenticating information, such as date of birth, nationality, address, and employer information (iov42, 2021b, ¶3). Overall, the blockchain-inspired features are not meant to replace existing legality verification and tracking efforts undertaken by timber exporters and other actors but instead seek to add an extra layer of trust, transparency, and security amongst the network participants (Interview Kealoha). Additionally, blockchain enables companies to put the entire set of data collected by different devices

in one database, where it can be analysed and synthesised quickly: "It's about […] bringing together all of the best technologies out there in one place," says Kealoha (Interview Kealoha).

Timber companies have several advantages by using Timber Chain. First, they can digitise their data records and collect information in a "single source of truth," where requested information can easily be shared with the respective buyer or other parties, optimising the auditing process and removing the labour-intensive process of preparing individual due diligence packages for each buyer (Interview Kealoha; iov42, 2021c, ¶6). Timber Chain, therefore, addresses pain points associated with paper-based processes, such as the risk of human error and corruption (iov42, 2021c, ¶6). Second, companies can demonstrate their commitment to transparency and data integrity by uploading all information onto Timber Chain, where data cannot be changed retrospectively, and documents cannot be reused, potentially increasing buyers' trust in the uploaded data (Interview Anning). Transparency is key in the timber industry, as "there's quite a lot of suspicion that people are not as open and transparent as they should be" (Interview Anning). Third, companies adopting Timber Chain may gain a competitive advantage over other timber companies that do not provide the same level of transparency into their data records (Interview Anning). Other advantages could manifest in increased regulatory compliance, the ability to share data with consumers, and bottom-line benefits resulting from reduced due diligence costs (Interview Kealoha).

2.2.2.2 Technical Aspects

Timber Chain's platform currently focuses on timber exporters and does not include upstream actors and buyers. "We do hope, at some point to involve those upstream in Malaysia in this but the time isn't right for it yet. They're not open to doing things a new way," says Anning (Interview Anning). He sees potential in approaching these upstream actors after attaining the buy-in from Carl Ronnow's buyers, which would create a greater incentive for upstream suppliers to participate in Timber Chain. Until then, they need to upload information they collected from the upstream suppliers, either manually or by importing data. Note that timber exporters typically already collect such information from suppliers, meaning this step does not represent an additional data collection process. To verify the correctness of the data, Carl Ronnow relies on legality verification and timber tracking procedures that were already in place before implementing the blockchain-based platform. In other words, Timber Chain complements existing due diligence efforts and does not substitute them. (Interview Anning; iov42, 2021a)

Timber Chain distinguishes between two types of users: Normal users and endorsers (Interview Roberts). Normal users, such as timber traders, use the system to prove certain claims made on their timber to buyers or regulators (Interview Roberts). Claims could be made on the timber's legality, sustainability, volume, origin, and species (Interview Roberts). On the other hand, endorsers represent third parties that validate the claims made and are selected by the network participants (Interview Roberts). In Timber Chain's case, the main endorser is Preferred by Nature, though the platform is open to include other third parties or certifiers in the future (Interview Kealoha). Anna Roberts, head of business development at iov42, remarks that given the decentralised nature of the platform, "people have to agree on who are those reputable parties that they want to be part of this broader network. So, it will be a decision made by existing parties as to who else would be involved in it" (Interview Roberts). After the endorser verifies the information, it is encrypted and the hash of this data is uploaded onto the platform, meaning the timber exporter remains in full control of which actors receive access to hashes of the uploaded information (iov42, 2021a). Selected pieces of information can be shared with other parties by providing them with password protected links, which allows them to view a specific set of

information (Interview Kealoha). Currently, the information collected on Timber Chain is not shared with end consumers (Interview Kealoha). However, some timber companies have expressed interest in including this feature in the future (Interview Kealoha).

Summarising, Timber Chain addresses the "Last Mile Problem" through several mechanisms. First, the identity-centric focus of the platform means that only verified participants can join the network (Interview Kealoha). Kealoha says, "that holds people accountable for whatever they're doing on the platform. So, you know, if there is somehow faulty data, whether it's just accidental, or perhaps not accidental, it can be traced back to that person. And that kind of disincentivizes, […] illegal or dubious behaviour in the system" (Interview Kealoha). Additionally, endorsers and timber companies play an important role in verifying specific claims or the correctness of data (Interview Anning; Interview Kealoha). For instance, Anning mentions that Carl Ronnow verifies data in the same manner as they always have, namely by identifying risks, developing risk-mitigating measures, and implementing them (Interview Anning).

Given that Timber Chain currently only focuses on the timber exporter, the platform does not store information collected by upstream supply chain actors in real-time, for instance, through RFID devices. However, iov42 is currently examining how tracking and monitoring tools could complement the data collection process in the future. Kealoha sees potential in using scientific testing methods, such as DNA mapping and stable isotope testing (see Chapter 4.2.2.2), to verify the reported species at later stages of the supply chain. A weakness of such wood identification methods is that they are often limited to one aspect of wood identification, as is the case for DNA mapping where the species can be confirmed, but not necessarily the origin (Interview Roberts). Anning highlights a different weakness of DNA mapping, namely the missing timber databases, but sees considerable potential in combining Timber Chain with DNA fingerprinting, which does not require such a database (see Chapter 4.2.2.2) (Interview Anning). This combination could be particularly interesting for high-value timber since "it could absorb the cost then of doing the DNA fingerprinting at every link in the supply chain. And if you coupled that with uploading this information, and the other information that you gather onto a secure database, such as blockchain, that could be quite a good marriage" (Interview Anning).

Beyond scientific methods, iov42 is exploring potential use cases of IoT devices, such as RFID, drones, and satellite imagery. For example, Roberts points out that satellite imagery could be applied in cases where results from scientific testing methods cannot provide a conclusive answer on the timber's legality: "Stable isotope testing can tell you that within a particular, I don't know, one kilometre radius […]. But what happens if that area is next to an endangered forest? Or what happens if it's next to an area that doesn't have a quota for logging?" (Interview Roberts). In such cases, satellite imagery could be used as an additional tool to analyse whether illegal logging occurred within the radius established through isotope testing and may bring more clarity on the timber's origin, potentially providing a better basis for decision-making for timber companies (Interview Roberts). Regarding the future direction of the iov42 technology itself, Roberts mentions three points. First, they are analysing the technology's applicability in carbon markets, where it could secure data on carbon capture and offsetting, representing a direct link to timber. Second, iov42 is examining how the technology could cover social aspects, so "that there's no modern slavery involved in the supply chain, […] that people are paid a fair wage, and that people are qualified and have the skill sets to be operating the machinery that they're operating" (Interview Roberts). Lastly, the team is exploring the applicability of smart contracts to automate transactions between network users (Interview Roberts).

2.2.2.3 Other Aspects

In the timber industry, "there might be some hesitation because there's an expectation that a lot of systems have to be retrofitted" (Interview Kealoha). Roberts notes that the degree of data adaptation depends on how advanced companies are in digitising their existing data collection process (Interview Roberts). Low to moderate efforts may be required by a timber company that has structured, digitised data in place (Interview Roberts). Another operational aspect concerns education: A two-sided education process needed to take place, where Carl Ronnow employees learned more about how blockchain and the iov42 platform worked and how they could benefit their business, while the iov42 team had to get familiar with the particularities of the timber industry, its pain points, and its supply chain (Interview Anning; Interview Kealoha).

To use Timber Chain, a set-up fee, licensing, and transaction costs are charged. The exact cost depends on the company, its needs, and its resources. For example, a company with an in-house software development team may face little to no external development costs. The level of sophistication also influences costs: A timber company seeking to integrate Timber Chain with its existing customer-facing traceability app and IoT devices may face higher costs than a company requesting a simpler solution. Beyond these financial aspects, timber companies may face market resistance in implementing such a solution along the entire supply chain. Anning, for instance, recognises the benefits of including upstream suppliers in Timber Chain, however, acknowledged that "the time isn't right for it yet" (Interview Anning). He explained that "they're not open to doing things a new way. So, kind of what we're hoping is that our buyers will buy into it, and then would prefer it and once that gets some traction, we can go to suppliers and say, 'Well, this is now what we're doing. If you want to be part of this, you know, we've got to be doing this, this, and this.'" (Interview Anning).

2.2.3 OpenSC

2.2.3.1 Overview of Solution

Illegal, unregulated, and unreported fishing poses a threat to marine biodiversity and ecosystems worldwide (Whiting, 2020, ¶11). A significant part of illegally sourced fish is caught by unlicensed vessels or in protected zones (OpenSC, 2021d, ¶3). OpenSC developed a solution that allows fishing companies to track fish from the moment it is caught to the end consumer, making it difficult for illegal fish to enter the market and helping consumers avoid purchasing illegal or unsustainable products (Whiting, 2020, ¶3; WWF-Australia, 2018, ¶1). OpenSC always works with specific ethical or sustainable production claims for their solutions in different industries (Interview Lange; Mutz, 2019). Examples of claims include "produced by legally registered workers," "farmed on deforestation-free land," and, in the case of fish, "fished outside protected areas" (Interview Lange; OpenSC, 2021d, ¶3). To verify and secure the claim throughout the entire supply chain, workers tag the individual fish directly after being caught to assign a unique ID at its origin that links the product to the claim on its subsequent journey (WWF-Australia, 2018, ¶2). Other information is collected at the source and stored in an immutable blockchain ledger, after which a machine learning model determines the validity of the claim, respectively, whether the fish was caught outside of marine protected areas (Interview Lange). The tag allows the company to oversee where the fish was caught, where it travels to, who handles it, and which supply chain actor has legal custody (OpenSC, 2021b, ¶4; Whiting, 2020, ¶16). With this information, OpenSC increases bait-to-plate transparency in the supply chain and links the tracked fish to the promised claim (WWF-Australia, 2018, ¶1).

Overall, blockchain represents only one of multiple technologies in the solution provided by OpenSC. Blockchain's main purpose in the company solution is to record raw data and verified legal,

sustainability, or ethical claims in an immutable database, where information is impossible to falsify or manipulate (see Chapter 5.2.1) (Interview Lange). This generates trust among the stakeholders who receive access to view or confirm the data, especially those questioning the information (Interview Lange). Tom Lange, Transparency Innovation Lead at OpenSC, notes that "when you have supply chains that are complex, and multiple stakeholders are involved and where you have a potential trust issue, then blockchain is quite a powerful tool" (Interview Lange). Additionally, blockchain can be a useful tool for companies seeking to raise consumer awareness and encourage responsible consumption patterns. Markus Mutz, CEO of OpenSC, mentions that "it can help mitigate some of the trust issues that are inherent to giving people information and then asking them to change their consumption behaviour because of that information" (2019, 7:26).

Companies, across all industries, have five main benefits from using Open SC's solution: First, they can promote legal and sustainable production while solving sustainability challenges specific to their industries (Interview Lange). In the case of fishing companies, they can support the recovery of depleted fish stocks and contribute to the exclusion of illegally sourced fish from their supply chains (Whiting, 2020, ¶15). Second, they can improve their ability to manage strategic and regulatory risks resulting from increased visibility into product movement and operations along the supply chain (Interview Lange). Third, companies may secure financial gains, both on the top line and bottom line. On the one hand, they can strengthen consumer confidence and meet consumers' increased demand for transparency by providing information on the product's journey and production processes (Interview Lange; WWF-Australia, 2018, ¶9). Granting access to this information and generating trust may enable companies to raise product prices and position their products in the premium segment (Interview Lange). On the other hand, bottom-line benefits can result from optimised operations, targeted product recalls, and efficiency gains (Interview Lange; OpenSC, 2021a, ¶11). Fourth, companies can gain a competitive advantage by offering a unique selling proposition and establishing themselves as forerunners to legality and sustainability efforts in their industries (Interview Lange). Lastly, companies can improve their ability to meet investor requirements on environmental and social standards by granting them access to an immutable database (Interview Lange).

2.2.3.2 Technical Aspects

For each solution, OpenSC jointly co-innovates with industry partners to identify the most important challenges in the respective supply chain and develop a risk-mitigating solution that addresses these challenges and is specific to the industry, region, and product (Interview Lange). In the fishing industry, OpenSC partnered with Austral Fisheries, a fishing company that was looking for a way to increase transparency in its Patagonian Toothfish operations in Africa, Europe, Asia, and the Americas (OpenSC, 2021a, ¶1). Together they co-innovated a solution that verifies the claim "fished outside protected areas" in four steps: Tag, check, trace, and share (see Image) (WWF-Australia, 2018, ¶4). In the first step, each Patagonian Toothfish is tagged with an RFID tag and temperature monitoring sensors right after the catch (Kshetri, 2021, p. 191). The tag contains a unique serial number that identifies the fish throughout the entire chain (the QR code that replaces the RFID tag at a later stage contains the same number) (Mutz, 2019). The sensors monitor temperature levels to guarantee an unbroken cold chain throughout its supply chain (OpenSC, 2021a, ¶8).

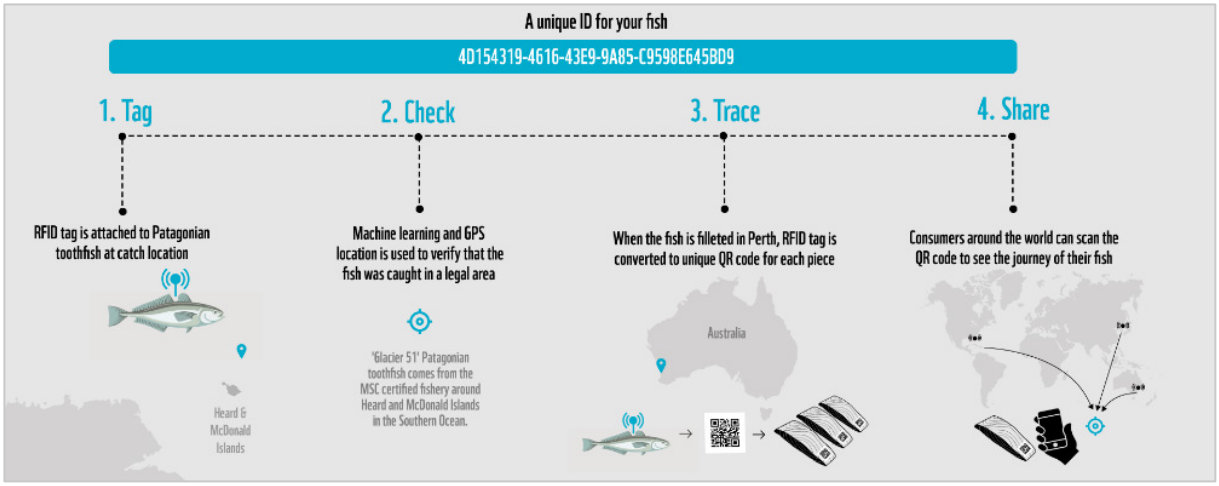


Image: OpenSC solution in the fishing industry (WWF-Australia 2018, ¶4)

In the second step, a machine learning model is applied to the combined data sources "in an automated, real-time and ongoing manner" (Mutz, 2019) to determine whether the fish was caught in a legal zone, where enough fish are present to ensure healthy fish populations (Kshetri, 2021, pp. 191–192; Mutz, 2019). Lange remarks that the type of data collected depends on the specific commodity (Interview Lange). In the case of fish, the machine learning model draws on both primary and secondary data: Primary data, so the collected raw data, includes GPS coordinates, speed of the fishing vessel, and historical data on fishing trips duration (Interview Lange). The collected raw data is hashed and stored in almost real-time on the Ethereum Mainnet, a public blockchain, so it remains uncorrupted and accessible to other stakeholders, such as regulators, at a later point in time (Interview Lange). Note that the companies have complete control over their data since hashes only work one way, and it is not possible to infer the input based on the hashed value (Hinckeldeyn, 2019, p. 6; Interview Lange). Additionally, secondary data, namely sea depth, weather data, the GPS coordinates of protected zones, and governmental vessel monitoring systems, which monitor national and foreign fishing vessels, are included in the data basis (Kshetri, 2021, p. 192). To verify the claim of whether fishing occurred outside protected areas, respectively detecting when the vessel is fishing and when not, the model evaluates the time the vessel spent in one location and the speed it was moving while taking into account secondary data sources, all of which impact the vessel's ability to catch fish (Interview Lange, OpenSC, 2021c, ¶6). Consequently, OpenSC can provide specific, data-backed assurances that the fish has not been caught in prohibited areas (WWF-Australia, 2018, ¶6).

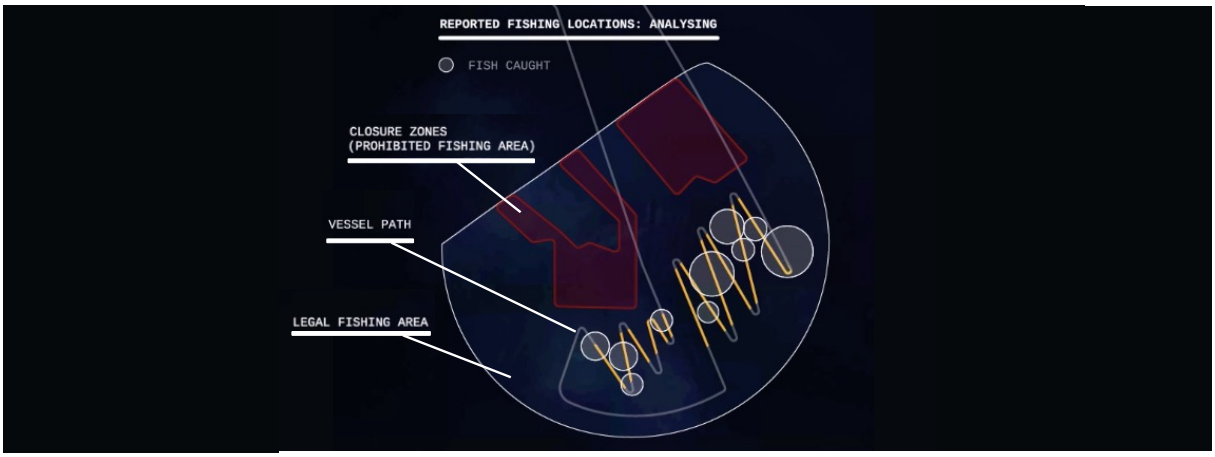


Image: OpenSC Machine Learning Model (own image based on OpenSC, 2021e)

After the claim has been verified, the fish is traced throughout the supply chain in the third step to ensure that the verified claim can be linked to the individual fish that the consumers have in front of them. "Without that level of traceability, all that we've really verified in the first place is that somebody, somewhere, at some point caught a fish in a sustainable way," (Mutz, 2019) says Mutz.

Lange notes that OpenSC' ambition is to create a solution where technology is made invisible to the people using it and does not impact existing processes or workflow (Interview Lange). This is only possible to a certain extent since the adoption of IoT devices, such as RFID tags or QR codes, requires an additional step where the product is tagged and scanned (Interview Lange). In such cases, they seek to identify the most cost-effective and least disturbing solution (Interview Lange). Which IoT device is most suitable for tracking the product along the supply chain depends on the commodity (Interview Lange). Mutz mentions that "depending on the type of product that we're working with, we may use QR codes, bar codes, RFID tags or other tag technologies" (2019, 7:26). To record traceability information on fish, OpenSC opted for RFID tags, QR codes, and sensors (OpenSC, 2021a, ¶8). Note that actors along the supply chain have access to a mobile application to scan RFID tags and QR codes at key supply chain stages (Interview Lange; Open SC, 2021a, ¶7). During the filleting phase, workers remove the fish bones and the RFID tag, after which a QR code is attached to each fillet package since QR codes are more easily readable by end consumers (Kshetri, 2021, p. 192; Mutz, 2019).

In the last step, the information is shared to end consumers. Mutz notes: "How to share this information is really different from product to product. And different from where you buy it. You behave differently in those situations. You are stressed and time-poor in the supermarket. […] Or you are critical and inquisitive when researching for a larger purchase online" (2019, 8:24). In the case of fish, OpenSC developed a range of interactive digital experiences tailored to specific situations. For consumers having dinner in restaurants, for instance, a summary of the key facts is provided rather than an extensive description of the fish and its journey (Mutz, 2019). WWF Australia states that "by using OpenSC, consumers can also be confident about what they are eating, where it came from, and how it got to them" (WWF-Australia, 2018, ¶9). Furthermore, sharing information on the fish and its claim enables consumers to learn more about their product and gives them the choice to make responsible consumption decisions (Mutz, 2019).

Image: B2C information sharing via QR code
(own image based on Austral Fisheries, 2021; OpenSC, 2021e)

It is important to note that the OpenSC machine learning model cannot 100 percent guarantee that the fish was caught outside marine protected areas, given that it relies on the honesty of the workers attaching the RFID tag to the fish. In a hypothetical scenario, a non-monitored boat could illegally fish in a marine protected area, drive to a monitored boat, and transfer its catch where the workers proceed with tagging illegally sourced fish, making it appear legal from the first stage onwards. Lange notes: "There will be always a solution or a situation where you can actually cheat the system despite us verifying something, but our ambition is that we want to make it impossible or non-economically *[sic]* so that it does not make sense and from an economic perspective to cheat the system at scale" (Interview Lange). In the presented scenario, the economic attractiveness of illegal fishing decreases because increased efforts are involved with driving to the monitored boat, storing the illegal catch, and de-freezing the catch to attach the RFID tag. Besides reducing the profitability of illegal fishing, the machine learning model can, with high accuracy, determine when fishing is taking place and when not. After it has detected whether fishing is taking place, there is a defined time frame allocated for attaching the RFID tag to the fish. Based on the total volume of fish tagged and the total time when fishing could have occurred, the model can evaluate whether the reported volume is appropriate. Lastly, the OpenSC solution includes mass-balance checks where harvesting volumes are compared to volumes from past fishing trips for cross-checking purposes. This way, inconsistencies can be identified, for instance, when reported volumes are suddenly twice as high as usual. (Interview Lange)

2.2.3.3 Other Aspects

In terms of finances, OpenSC charges a one-off fee for the initial set-up of the solution and a recurring fee for using the platform. The exact fee depends on the specific commodity, the total product volume, the number of claims verified, the operating region, and the product's margin structure. However, Lange notes that it may not make economic sense to co-innovate on a solution for a new commodity with only low volumes as a starting point, given the investment costs. Once a solution is developed, the venture seeks to provide it to other industry players, including small-scale producers. Therefore, OpenSC seeks to offer its product at an affordable price for smaller actors that is cheaper than the fees charged by certification schemes. One challenge that Lange sees, lies in quantifying the benefits of increased transparency and risk mitigation, especially compared to corporate projects like digital transformations, where efficiency gains can be calculated relatively accurately. (Interview Lange)

A challenge companies face when developing an OpenSC solution is establishing the trade-off between transparently disclosing information and protecting their business interests when sharing their results with end consumers. This challenge also applies to fishing companies, as "the fishing path where they actually fish is quite sensitive information, and the companies do not want to disclose that to competitors" (Interview Lange). Therefore, companies need to strike a balance between communicating relevant, compelling information to the end consumer and not disclosing commercially sensitive data. Determining data availability and reliability represents another operational challenge, especially when numerous actors in the supply chain are involved. When establishing data availability and defining the data sources, Lange recommends reviewing what internal or external systems are already in place that companies could leverage since this could decrease the costs and efforts associated with setting up and operating new data collection systems. For instance, OpenSC' solution in the fishing industry draws on existing data already collected by vessels, such as GPS coordinates and vessel speed, meaning that the venture solely needs to establish the link between the existing data source and the new traceability system, after which data extraction occurs automatically. (Interview Lange)

Lastly, OpenSC typically partners with the market players that distinguish themselves from their competitors through their sustainability practices and seek to take the next step to establish automated legality verification and tracking systems. “You need to have someone who's really believing in the long-term value of such like, of transparency overall, of sustainability,” Lange remarks. Additionally, it is helpful if companies that are willing to co-innovate on transparency solutions have strong, supportive supply chain partners, respectively manage to form “a coalition of the willing” (Interview Lange), since developing and implementing a verification and traceability solution will become noticeably easier than when only one actor wants to innovate. In the latter case, the actor may face high barriers since incentive structures to convince supply chain partners might need to be developed. (Interview Lange)

Company	Technologies	Blockchain Architecture	IoT devices	Key Data collected
Wood Tracking Protocol	• Blockchain • IoT • Digital identification	• IPFS • Ethereum Main Net	*Current* • QR code (timber) • GPS *Future* • RFID tags • Infrared sensors • Satellite imagery • Drones • Wood identification technology	*Primary data* • GPS data • Timber data (e.g., species, volume) • Personal data *Secondary data* • List of illegal companies from OSINFOR and SERFOR • List of trees approved for harvest from OSINFOR and SERFOR • GPS coordinates of protected areas from OSFINOR and SERFOR
Timber Chain	• Blockchain • Digital identification	• Iov42 (blockchain-like)	• None in case of Carl Ronnow • Possible for other timber companies	• Personal data (e.g., name, birthdate, employer, address) • Timber data (e.g., volumes, origin, species) • Certifications
OpenSC	• Blockchain • IoT • Machine learning	• IPFS • Ethereum Main Net	• RFID tag (fish) • QR code (fish) • Sensors (fish) • GPS (vessel, fish, each supply chain step)	*Primary data* • GPS data • Vessel speed • Past data on fishing trips duration and harvested volume • Temperature sensors *Secondary data* • Sea depth • Weather data • GPS coordinates of protected zones • Governmental vessel monitoring systems

2.3 Overview of Cross-case Patterns

Area	Topic	Interviewee & Company	Direct Citation
Role of blockchain	Combination with other technologies	Lange (OpenSC) Kealoha (iov42) Horowitz-Burdick (Double Helix)	• "We are a technology company that uses blockchain is one of the multiple technologies to create a solution" • "But we have, we leverage different technologies. And we've developed our own technologies from the ground up […]" • "For any of these technologies, they can be pieces of a puzzle of a really robust system […]"
	Blockchain complements existing legality verification and tracking efforts	Roberts (iov42) Kealoha (iov42) Anning (Carl Ronnow)	• "That's the really important point. It is not replacement of legacy efforts to do this. It is sitting below lots of different efforts around traceability already […]" • "Timber chain doesn't necessarily replace or get rid of kind of all of the good work that these organizations are doing, and their commitments to due diligence and sustainable sourcing and all of these things." • Carl Ronnow checks correctness of data "as we normally would for anything, you know, so you identify where the risks are, and you mitigate those risks."
Advantages	Financial gains	Lange (openSC) Roberts (iov42)	• "So, yes, top line benefit, but you have also multiple bottom-line benefits" • "And, you know, by reducing time and cost on due diligence, then that impacts their bottom lines […]
	Competitive advantage	Anning (Carl Ronnow) Lange (OpenSC)	• "It's always good to be ahead of these things because you can get an advantage in the market." • "But also when you enter new markets, you can basically have a unique selling point and unique advantage and providing this transparency to the end consumer."
	User Identity verification	Kealoha (iov42) Fabing (WTP)	• "So, everybody that's participating in the system has to have a verified identity. So, that holds people accountable for whatever they're doing on the platform." • "And so in order for us to make sure that the people are not scamming the system, we ask the user to login […] using the telephone number."
Data verification	Data comparison	Fabing (WTP) OpenSC Website (OpenSC, 2021a)	• "And the idea is we are matching the information that you're giving us" and "so what we try to do is to try to connect the dots based on the information that people are entering." • "We developed a machine learning algorithm that combined multiple data sources to verify that Austral's vessels had only fished in legal areas."

	Verification by third parties	Roberts (iov42) Fabing (WTP) Horowitz-Burdick (Double Helix)	• "That's the role of the endorser. […] The endorsers are third parties who authenticate or validate the origin, the species." • "It's OSINFOR, and the other one is SERFOR. And so these are the institutions that are giving, that are making sure that this wood is illegal or not illegal and giving the authorization to the company to go into the forest and cut the trees." • "That's our job as a third party, right. There's these like critical pieces of information that need to be verified."
Digital Twin	Mass Balance Checks	Lange (OpenSC) Fabing (WTP)	• "Lastly, the OpenSC solution includes mass-balance checks where harvesting volumes are compared to volumes from past fishing trips for cross-checking purposes." • "So, the volume and the weight is the only thing that we can have as a tangible. So, if someone has like 100 cubic meter of wood, he cannot sell more than 100 cubic meter wood on the market."
Data privacy	Companies have full control of data visibility	Lange (OpenSC) Kealoha (iov42)	• "Our client have full control over their data and needs to then say, for example, if they have a regulator, or a customer, questioning the information, we then can provide them the information on the hash and basically, they can just close whatever information they like […]" • "So, the people who use the service so like, let's say, an exporter, they control and own the data that's being put into Timber Chain or to the system and they can decide, for example, if they want their clients to be able to see a shipping record […]"
Data sharing	Share data with B2B consumers	Lange (OpenSC) Fabing (WTP)	• "So, we basically match a specific information claim with a product and then in the end, have also capability to share this information, either in a B2B context. So, for example, in internal dashboards, for example, a particular producer can provide it to the customers that they are selling to the information on the sustainable ethical production." • "So, in accounting software, we would give you the tool to the company to see how much wood they are gonna produce."
	Share data with B2C consumers	Lange (OpenSC) Fabing (WTP)	• "We actually have an end consumer experience, basically, where you can scan your QR code on a product and can see the information on the product basically, to create and consume experience around that." • "And in the future, because it's not the case currently, is that the buyer who wants to buy the wood can just scan a QR code for example, and have all the information about where the wood is coming from."

3 Interviews

3.1 Interview Partner Selection

	#	Name	Organisation	Organisation type	Position	Duration
Round 1	1	Marco Lentini	IMAFLORA	NGO	Senior Project Coordinator and Forest Engineer	1h 25m
	2	Christian Kobel	SGS	Verification, testing, and certification company	Global Business Manager in Forestry, Timber and Paper	40m
	3	Sam Daniel	Greenpeace	NGO	Senior International Research Coordinator	45m
	4	Professor	University	Academia	Professor of Forest and Environmental Policy	28m
	5	Maxwell Horowitz-Burdick	Double Helix Tracking Technologies	Timber supply chain consultancy	Director Americas	56m
Round 2	6	Michael Fabing	Wood Tracking Protocol	Timber start-up	Co-founder and Forest Engineer	52m + 1h 09m
	7	Tom Lange	OpenSC and BCG	Technology venture	Transparency Innovation Lead	1h 06m + 30m
	8	Anna Roberts and Kiara Kealoha	Iov42	Technology provider	Roberts: Head of Business Development; Kealoha: Marketing and Communications Manager	52m
	9	Richard Anning	Carl Ronnow	Timber company	Environmental Manager	1h

Given the research questions, the relevant areas for interviews were identified as the Brazilian Amazon, timber supply chains, and blockchain. Interviews with a focus on the Brazilian Amazon and timber supply chains were held in the first round of interviews. To ensure a wide range of opinions was represented, interviewees from different types of organisations, namely academia, NGOs, and certification companies, were selected. Insights from these interviews formed the basis for the second-round interviews. For example, the importance of data veracity in blockchain solutions was raised during the first round of interviews by Sam Daniel and Marco Lentini. Therefore, in second-round interviews, ways of how the companies verify data and implement safeguards to prevent fraudulent data in blockchain solutions were discussed in-depth. The second-round interviews were held with representatives of the companies selected for the development of blockchain case studies (see Chapter 5.1). Overall, candidates were screened for both their area of expertise and type of organisation they were working for. Potential interviewees or organisations were identified through mentions in literature or LinkedIn searches and approached via LinkedIn or email. An outreach to 35 people was made.

3.2 Interview Guidelines and Approach

"if SSIs [semi-structured interviews] are going to be conducted with different groups, a guide will have to be tailored to each group" (Adams, 2015, p. 496). Therefore, three different guidelines were developed to accommodate for the differing backgrounds of the interviewees and objectives of the conducted interviews. Interviews conducted in the first round aimed to address gaps that emerged during the literature review, receive on-the-ground insights on aspects discussed in the literature (e.g., use of IoT tools), and complement the theoretical perspective with practice-oriented perspectives. Interviews conducted in the second round of interviews had the objective of developing blockchain case studies to draw insights for a potential timber blockchain solution in the Brazilian Amazon. During these second-

round interviews the technical, operational, market, and financial aspects of the respective blockchain solution were discussed to mirror the methodological approach set out in Chapter 5.1. Similar to the methodological approach, the interviews centred on the technical aspects of the blockchain solution. Overall, the guidelines employed a mix of closed- and open-ended questions (Adams, 2015, p. 493).

Note that the interview guidelines were tailored to the background of each interviewee and information from secondary sources – for some interviews, some clarifying questions were added. For instance, for OpenSC, the following question was added: "In an article, Markus Mutz mentions: 'Some of the commodities that we are currently working on are well below the price point of the more exclusive fish like the Patagonian toothfish". What is the approximate price point/range below which such a traceability solution does not make sense?' Another example of customisation is the following question for iov42: "In a YouTube video of iov42, you explain that the focus lies on the exporter and certifier. Has the platform been extended to other supply chain actors?" Lastly, the interview guidelines served as an orientation for the interview, meaning that the order of questions may have been switched depending on the interview flow and certain questions may have been skipped due to time limitations and the emerging discussion. At the beginning of each interview, the interviewees were asked for permission to record for interview transcription and the matter of confidentiality was addressed (Adams, 2015, p. 501). One interviewee, the professor, preferred to remain unnamed in this report. During the interview, clarifying questions were asked – when needed – and discussed points synthesised and summarised for confirmation from time to time.

The interviews were transcribed, contrasted with literature findings, and reviewed for any unclarities (Baur & Blasius, 2014, p. 51). In cases where discrepancies or unclarities were identified, follow-up questions were sent or a follow-up interview conducted, which were subsequently included in the transcripts. For first-round interview partners, statements that were consistent across different interview partners were generalised, for instance, in the following manner: "Several authors, environmental groups, interviewees, and trade organisations agree (EC, 2016, pp. 64, 66; Greenpeace, 2018, p. 27; Interview Lentini; Interview Daniel; WBCSD Forest & WRI, 2014, p. 35) that independent, third-party audits are desirable, particularly in areas perceived as high risk, which is the case for timber sourced from the Brazilian Amazon" (see Chapter 4.2.3). Another example is the following: "Several interviewees recommend companies to go beyond solely collecting required documentation (Interview Daniel; Interview Lentini; Interview Horowitz-Burdick)" (see Chapter 4.2.2.1). To ensure that such statements were in line with the interviewee's opinions, approval was attained from the respective interviewees before submitting the thesis.

The interview results from the first round provided valuable insights to open questions concerning illegal logging in the Brazilian Amazon (see Chapter 3) and strategies that timber companies could undertake to address illegal logging (see Chapter 4). Additionally, they raised important points that were taken into account during the evaluation of the potential of blockchain technology (see Chapter 5). For instance, during the interview with Christian Kobel, the concern of data visibility in blockchain solutions was discussed, which was taken into consideration for the technical evaluation of blockchain in Chapter 5.3.1.1. The interview results from the second round of interviews were consolidated into case studies, which can be found in Appendix Chapter 2.2. For comprehensiveness, the case studies were complemented by secondary sources, such as company websites, newspaper articles, and other sources containing information on the blockchain solution of the case study companies. After the case studies were written, they were circulated to the respective interviewees for approval and feedback to ensure they were in line with their expectations and accurate in the description of the solution. The results of

the case studies were mainly relevant for evaluating the potential of blockchain technology in Chapter 5.

3.2.1 Interview Guideline for Brazilian Amazon Experts

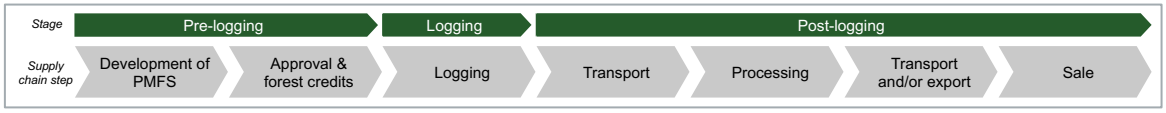
A) Causes of illegal logging

Causes of illegal logging can result from different areas and can be caused by different stakeholders (e.g., government, companies, consumers etc.).

1. From your perspective, what are the causes of illegal logging in the Brazilian Amazon?
2. Which stakeholders need to play what role in fighting illegal logging?
3. What potential do you see in collaborative efforts between different stakeholders (e.g., government, companies, consumers, NGOs, public)? How could they look like and who would play which role?

B) Measures companies can take against illegal logging

Timber companies throughout the supply chain (e.g., those active in the harvesting phase or retailers) can take action against illegal logging.



4. In your opinion, what measures can timber companies take against illegal logging? Have you observed best practices in the timber industry?
5. Based on your observations, are there any differences in the level of intensity of action taken (e.g., small-scale loggers vs. large-scale loggers, domestic vs. international companies)?
6. Are companies engaging in political advocacy efforts against illegal logging?
7. What do you think of the use of forest certifications (e.g., FSC or PEFC) by timber companies? Do you see any strengths and/or weaknesses in certifications?
8. One source mentioned that most certification holders in the Brazilian Amazon are plantations and that certifications are not as common in natural forests. Is this something you have also observed?

C) Legality verification and traceability efforts of companies

Timber companies can verify the legality of the timber and/or trace the timber throughout the supply chain with traceability systems. Traceability systems collect, store, manage, and disseminate data associated with the timber product and production processes and provide information on the timber's identification, history, and location in all stages of the supply chain retrospectively or in real-time.

9. The US Lacey Act and other countries require legality verification to import timber. How can a company comply with the legality requirement?
10. How do logging companies in the Brazilian Amazon commonly trace or track their supply chain? Do they use paper-based systems (where they track the chain-of-custody through documentation) or electronic systems (e.g., RFID technology, or electronic barcodes)?
11. Where do you see weaknesses in the different systems used by these companies?
12. Are the legality verification and traceability efforts undertaken in one instance of time (e.g., retrospectively during an annual audit) or on a continuous basis (e.g., automatically through systems)?
13. Do you see an area where blockchain could be implemented to support company efforts?

3.2.2 Interview Guideline for Timber Supply Chain Experts

A) Legality Verification in the Brazilian Amazon

1. What challenges in verifying legality and tracing timber in the Brazilian Amazon do you currently see?
2. Is it currently difficult to trace logs along the supply chain to the source?
3. What systems do companies that operate in the Brazilian Amazon or source wood from that area have in place to verify legality and/or trace timber (if any)? For example, is it mainly paper-based, meaning only documentation is collected and evaluated?
4. Is the legality of timber verified with every shipment or only at certain points of time (e.g., when setting up new supplier relationship, during the yearly audit)?
5. Do you evaluate whether illegality occurred along the supply chain (e.g., sawmills don't have required license, missing transport or export documentation etc.)?

B) Traceability Efforts in the Brazilian Amazon

6. Do companies trace timber with technologies, such as QR codes, barcodes, RFID tags? If yes, is timber mainly tracked on a batch or individual level?
7. Literature states that RFID, QR codes, and other IoT technology are not 100% tamper-proof. How could they be tampered with?
8. How do traceability efforts/systems deal with the physical transformation of timber (e.g., from log to pulp)?
9. To what extent can scientific methods be implemented in a company's supply chain?
10. Do some timber companies use satellite systems to monitor their forests? If not, do you know of an organisation that would provide this service to timber companies?

C) Blockchain Solutions

11. What is your view on blockchain's potential in addressing illegal logging? Are you aware of any blockchain projects that are currently being implemented?
12. How do you believe blockchain will develop in the future?

3.3.3 Interview Guideline for Blockchain Case Study Interviews

A) General Aspects of Company X

1. What problem(s) does Company X seek to address? How does Company X address this problem compared to the situation beforehand?
2. What supply chain stages are covered by the solution?
3. Where do you see the added value by blockchain, especially compared to other traceability systems that use IoT tools (but no blockchain)?

B) Blockchain solution (Technical Aspects)

4. Description of blockchain solution
    a. What data is visible to the supply chain actors and consumers?
    b. By whom and with what consensus mechanism is data validated?
    c. Where do you see the added value by blockchain, especially compared to other traceability systems that use IoT tools (but no blockchain)?
    d. Where do you see the added value by the solution compared to existing systems timber companies have in place?
5. Verifying timber
    a. What claims do you verify (e.g., legality, certification)?

   b. How do you ensure that the data entered in the first step is correct? In other words, how do you solve the "Garbage in, garbage out" Problem?
6. Tracing timber
   a. How is the link between the physical timber and digital timber established (e.g., use of IoT devices)? How do you address the physical transformation of timber in the processing phase (e.g., sawmill)?
   b. Have you considered the use of DNA technology?
7. Future potential
   a. Is there an area or application that is not included but could be explored in the future?

C) Operational, Financial, and Market Aspects

8. How was the feedback from the participants?
9. What are the challenges that companies faced when they implemented your traceability solution?
10. One aspect mentioned by literature when it comes to implementing blockchain is the cost aspect. How costly is it for companies to implement your traceability system (one-off costs and recurring costs)?
11. Are the costs offset reduced costs or increased revenues (either due to increase in volumes sold or price increase made possible by tracking efforts)?
12. What measures did companies need to take to ensure smooth implementation (e.g., training, purchasing of devices etc.)?
13. What is your opinion on the future prospects of blockchain?

3.3 Interview Transcripts

3.3.1 Interview Marco Lentini

The first question is actually on the timber legislation in the Brazilian Amazon. So, I read that there are differences in terms of legislation. For instance, natural forests that are privately or publicly owned have different legislation depending on whether it's native or planted forest. And my first question is quite technical. So, basically, I know that for privately owned natural forests, that they must comply with the Brazilian Forest Code and that publicly owned natural forests need to comply with Public Forest Management Law. Do you know what legislation applies to plantations, like whether it's also those or wherever they have a different type of legislation?

Okay. So, just to have a basis, I mean, at least, for the last two decades, but I mean, mostly, for the last 15 years, we have very specific legislation about producing timber from natural forest. So, that probably started in the middle 90s. But the most actual legislations are from 2008 or 2009. There are a few points from the National Council for Environment. So, I probably can send some of these materials by email. Just remind me. So, there's a basic really set of laws, saying basically, you can exploit or harvest timber from the Amazon. But to do that, you need to do forest management. And there's a lot of regulations about what is the minimum standard for forest management. Of course, that is inconsistent, because you can also have a [unclear] from the first stage, right? Okay, so that's one. And then the Forest Code in Brazil is pretty old. It was from 65. And it passed by a review in 2012. So, that's the version that you have there. And you're correct. It goes into several directions. It talks a little bit about Forest Management, Natural Forest, but also talks a little bit about plantations. It has a few articles on plantations as well. And, of course, between these two pairs that I described, you have Public Forest Management Law from March 2006, which really started this movement of taking control of public lands in Brazil, mostly in the Amazon because at least 9% of the public forests in the Amazon. And besides this process of forest concessions in Brazil, which is very new, we are very excited about that,

because we are doing a reflection on what is going on with concessions in Brazil now, because this is a 15-year anniversary of the law.

Of the concessions law?
The public concession law, yeah. The Public Forest Management Law. And of course, the Forest Code also talks a lot about planted forests. There is not a large concern about planted forests in Brazil. The understanding is that natural forests are more regulated in terms of saying to the property owner what he or she should do, and planted forests approach it in an informative approach, right? So, the owner of the plantation has to inform the agencies about what he or she is doing, but that is not really a licensing process going on. You just need to say, well, I'm planting these trees, I intend to have this by that year, and most of this process doesn't have a licensing ideal.

So, just to confirm. So, basically, the Brazilian Forest Code also partially applies to plantation. So, we have like some articles in there.
Yeah.

What exactly do you mean with there's not much concern for plantations? Is Illegal logging not a big issue in plantations or is it more that regulations are not that strict for plantation owners?
It means that basically, you can plant. If you do forest plantations, you don't need a license to do that. You just can do.

I mean, isn't there like an official process where you have to submit a plan?
Not really.

Not really?
If you're talking about exotic species, just do it. If you're talking about native species, yes, you can plant without restrictions. But if you want to harvest it, there's a process of informing the agency that you are planting those trees. Let's say that I want to do mahogany planting. And 30 years from now, someone will say, well, but how do you prove that you planted this timber rather than harvesting from natural forest. So, I should have done a process of informing the agency that I was doing that planting to be able to have this in future. But again, it's much less regulated in the sense that if they want to plant, just plant, and you don't need license to do it.

Then how does the Brazilian Government then ensure that certain minimum standards are being respected in plantations? Or is this not really something that they want to check?
There are regulations about the land use of the property. For example, you have to have the property, you have to have the registry, you have requirements in relation to [unclear] zones. And depending on the size of property, you have requirements about the proportion of the forest that needs to be on the property, we call legal reserve, which is weird. But I mean, for example, if you are in the Amazon, you are required to maintain 80% of the area in forest. Now it becomes more messy because before 2012, it was required to be native forest. It is not anymore, necessarily. You can have some exotic species in your legal reserve. So, that's what you need to require to do. But what do you do with outside legal reserve is your problem. So, if you want to go there, and plant mahogany, that's your problem, you don't need a license for that.

Okay. But then as a follow up question, so I know that for timber from natural forests we basically need to do a sustainable forest management plan. And then we get forestry credits based on

information provided in the plan. And then it's entered into the SINAFLORA or SISFLORA system. And we basically check that the chain of custody is always correct, that another buyer gets the credits from a seller etc. And is it the same process for wood from plantations? Do they also need to register it in the systems?
No. There are a few states that if you are talking about planted timber from native species, they will require to do the registration in SISFLORA for example. Let's say them planting mahogany and I want to circulate mahogany timber, a few of the agencies would say: "Okay. So, you should register that in SINAFLORA, DOF to circulate the timber to prove that it was planted rather than harvested in nature forest." So, that would be required for very specific cases. Most of the plantation timber in Brazil does not even require a DOF. If you're talking about exotic species, they're not required at all. You can just harvest it.

Okay. And what's your opinion on this? So, on the one hand you have the issue of illegal timber in the Brazilian Amazon. And then on the other hand, you have the thing that most planted wood doesn't require any transportation, documentation or governmental approval. Do you see this as a problem?
Well, maybe becoming in future. I mean, because right now, what we have is that we have very few plantations in the Amazon, really. We have a few and most of the exotic species plantations comes from South Brazil. So, it is a very different reality. Of course, it does not mean there is not illegal logging. It is possible. For example, if you do a pinus plantation in a riparian zone, it would be illegal to have the standard, but should be protected. But it is a much smaller problem than we have in the Amazon. So, I think it is okay, if the system to show compliance of the rural properties with the law works. So, I think I'm okay with that. What is really the complex issue could become in the future is if native species populations start to expand in the Amazon. That could become a problem indeed in the future.

Okay, perfect. And so maybe as a follow up question on the process of the wood from natural forests. Do you know, during any of the steps, if they need to rely on paper-based documentation or is it a system that is completely electronic? So, for instance, at the border points can officials check online, whether they have the forestry credits or is this something that they need to bring in the printed form?
Well, at least all the states in the Amazon already have electronic systems, at least for the transactions. Transactions, I mean, between the forest management plan, the log plan until the final destination in the industry. So, it's all electronic, and also actually all self-declaratory which is one of the problems, in my opinion. But it's all electronic. So, I mean, you have a very few process that is still running on paper, for example, some of the agencies is, you have to submit a paper copy or the forest management plan or the annual forest plan or even the post-harvest report and things like that, but all the transactions are now electronic.

Okay. And what do you mean with self-declaratory nature, is it just something that you need to fill out online, but isn't necessarily double checked?
For example, if you got the credits, let's say that you have a forest management plan. So, when you're loading the truck, it's up to you to put in the guide, whatever you want, in terms of species volumes, etc. So, you're declaring how much that person is transporting. So, that's part of the problem.

And then, I guess, like, there isn't enough manpower to check every truck for a specific volume.
Rarely.

Okay, and do you see like any potential for making fraudulent documents in this process? Or is it...?
Wow - That's an industry!

It's an industry?
Oh, yeah, the fraud, there's so many ways of doing that.

Can you elaborate on this - like give an example?
So, first of all, let's say that you are Lynn, you have a forest in Pará. Well, first thing is to say, "Well, I do want to do harvesting. So, I will hire an engineer," so hire me. And you say, "Please Marco say there's more... Ipe it's very expensive. So, please say, there is more Ipe then I actually have," so I will fraud the forest management plan so your forest has more Ipe or Camaro or more whatever species than it actually has. So, I'm inflating the credit, so when I get credits, they're inflated. They bring a much richer stock, valuable timber can actually have so that's one. Second one, I can do a lot of things in DOF, as I said, I can since it's self-declaratory, you can say that your trucks have a slightly smaller volume in transport than they actually have, so that you create a surplus of credits at some point. You can use, depending on the operation, you can use the DOF twice by the way.

But isn't it like, if it's like electronically, can't they see that?
You are in the forest, you enter the internet, you need the guide, you print it, you give it to the truck driver, the truck driver comes back and uses the same one for the same transportation event, what's the problem.

Oh, okay so but this only works if they don't check the same truck or like two different trucks have it license in both cases when it would be uncovered? No?
You can do two travels with the same truck because you need to put the plate on the trip and the guy, he will do, two travels with the same document. The sawmill has several mechanisms that hides that timber well. So, I mean, you can transport like 40 cubic meters and declaring in the DOF 20 or you can since you're inflating the DOF, you can transport, let's say a few of the Ipe stocks of your area. You can go to indigenous land, harvest a bit of Ipe there and you have enough credits to do it because you inflated your forest management plan so it's undetectable.

Okay, so, if I understand it correct the DOF system runs electronically, but usually like truck drivers still have a printout?
Right, you have an invoice. About the timber that is going out, plus a printed copy of the DOF, just printed to give it to the truck driver. If it is not enforced and if you do the scheme with the sawmill the truck drivers come back with the same DOF, sometimes the same invoice and use it twice and who will say that you were wrong?

Okay interesting. That was everything for the timber legislation and the Brazilian Amazon. Now I would like to move on to legality verification. So, an area that have quite the expertise in are traceability efforts of companies. So, as I understand it, like also for certifications, sometimes they see it as two different things. In the first one, we first want to see, is it legal? Is the timber legal? And then for the chain of custody verification, we basically want to see that the timber that is legal was transported throughout the supply chain to sort of verify that timber was sourced from that forest. Basically, so what I'm not quite clear on yet, is a connection between companies' efforts to verify the legality and then the efforts from the Brazilian government on tracing the wood, like, for instance, through the SISFLORA system, in the DOF documentations. So, when companies basically need to verify the timber, do they need to rely or check the documentation that is provided by the Brazilian government?

Well, that's tricky, because you see, we're describing certification, forest certification, it's a voluntary mechanism and you're right. So, what it does is give one additional guarantee that the risks along the supply chain are being mapped. So, as you said, well, pretty much try to evaluate the risk of timber going to point A to B. That's statement to be correct from B to C. So, we are talking about very long chains, some cases we have like 15, 20 points until the final destination. So, it goes to the first sawmill, second sawmill, third sawmill. So, until going to the final destinations, really challenge is maintaining the minimal level three sub-dealer alongside the chain. So, but is a voluntary mechanism. If you take companies that are not certified what do they do? It's pretty much nothing really, you just collect a bunch of documents. So, what you have to do as a sawmill, is to prove that you are... The level of inputs that you are receiving are consistent with the level of outputs that you're selling and that is the conversion rate, let's say, by law, actually, the conversion rate is stated in 35%. So, it means that I found some new order, I can buy 1,000 cubic meters of logs. And if I get 1,000, I can sell 350 cubic meters. And that is a lot of ways to fraud, several ways. And depending on accountability, or my sawmill, I can manage that I can sell without fiscal invoice. Also, which makes me able to get more logs. And as a third mechanism that there is in law that I can do specifically studies to say that my conversion efficiency is above 35%. So, if I can get that approved it so my room for fraud, the chain is still larger. So, you'll see these guys don't really have traceability, what they have, it's a bunch of documents coming in and a bunch of documents coming out. And at the end, what you need is roughly is volumes to be consistent. There's no traceability.

So, this means that the Brazilian government doesn't have very strict requirements on companies verifying the legality at all, or tracing the timber, they just need to provide the documentation?
The Brazilian government takes for granted that if you're receiving a DOF it's because your timber is legal. That's what DOF means. It is the legal document that proves that your timber is legal. And goes all along the chain. I'm not saying the due diligence process don't do a slightly better job, they do. But basically, what the importer in let's say the Netherlands is receiving it's a DOF. So, DOF takes for granted that you are following Brazilian law. Which is not true.

So, that's like the legality assurance that the companies have to provide when they for instance, want to export timber from the Brazilian Amazon. Okay, that's interesting.
We have a sentence for them. We say that, I used to say that Brazil lives in, at least in the forestry area in an assumed legality environment. It's pretty much what's going on, if you receive the DOF you assume that it's legal. There's a lot of fraud. Both in the forest management plan and in the sawmill. You're not required to show precisely from where it comes. So, remember, the sawmills are receiving logs from everywhere. So, you have a bunch of sources, and you have a bunch of buyers. So, what you do is these two piles have to be balanced around a certain conversion rate. But there's no traceability because you can say, "Well, this is specific timber where it comes from, which forest measurement plan, I have no idea, it's a mix." So, that's not very traceable to the point.

Okay, interesting. But then if I understand correctly, basically, most companies that log timber rely on the documentation of the Brazilian government for legality verification. And do you see any difference between companies that only sell goods to the Brazilian market, and compare it to companies that export the wood would have higher requirements, because they know that like the US Lacey Act, at least has some stricter requirements in terms of legality verification or is this not something that you were able to observe?
Well, there is, at least for exportation markets, you are one step further, you start in a process of risk assessment and mapping your supply chains. So, it does require for the due diligence idea. I think it goes

into the direction of at least making your operators more aware of where the timber is coming from. So, I think it's an interesting movement. But at the end, in terms of legality, I don't think that makes no difference.

I also read there are like efforts to use electronic traceability systems? So, for instance, with RFID tags or electronic barcodes? Do you feel they are more secure? Or what's your opinion on both systems?

I'll say something very strong. I'm sorry for that. Again, I think traceability is about showing from where the timber comes from. So, if you get a trader that is selling to a company in the Netherlands, what traceability shows is where that specific timber comes from which forest measurement plan. So, that's one improvement, I guess. But it has nothing to do with illegal logging, it is not solving anything, it's two different subjects. One fact is one thing. Another thing is a very different issue. So, you're sure that traceability is a system that certainly can help to assess risks. I am sure and to map these chains in a more elaborate way, I think it's a necessary tool. But I don't believe it's a silver bullet by far. It has no connection with the illegal logging problem at all.

Then in your opinion, what can timber companies do to reduce illegal logging in their supply chains?

Get certified by FSC.

But getting certified by FSC includes legality verification and traceability efforts.

Sure, it goes above the law. So, certification is not only law, it is above law. So, in our view, when we are saying that we have, so the situation is very bad. You have no alternative. Okay, so we do, I have to say that. I used to talk to journalists, and they say, "So, well..., everything is lost..." So, no, come on. We have what we call proven responsible management. It's the conjunction of enterprises that suffered third-party verifications. So, to me, the whole idea is that the only way to decrease risk is to do a verification by a third party. We have two types for verification in the Brazil. One is for FSC enterprises and second one is for concessions, that will be concessions in Brazil had been developing in an environment of very high, very strong verification processes. So, to me these are the only two sources there are to derisk.

Okay, one quick question. So, there's no PEFC certification in the Brazilian Amazon?

It's starting. Well, most of the enterprises certified by FSC are certified by PEFC. So, they can choose, so they have double certification. But as I know, most of them prefer to sell FSC rather than PEFC. But it's a big debate now because FSC, well, with your sole IFL issue, I can tell you later about that, a lot of companies are considering to switch to PEFC certificate.

Actually, before you tell me more about it, I have a follow up question. So, I'll just quickly share the screen. What certifications do is they basically, verify the legality of the timber in the beginning, like in the source. But as we both know, there are multiple ways that illegal timber can still go into the supply chain or workers' rights disrespected. So, how do they ensure that this doesn't happen, if they only check it from the source?

When we are saying certification, at least most important standards, first of all, there is not only legality check. So, it goes a bit beyond. In the case of FSC, you see a lot of the issues related to the workers, customer rights and things like that. So, I want to extend on that. But you'll see a lot of things that go heavier into the social agenda as well. Plus, the performance of the forest management plan. So, we used to say the certifications go in the direction of improving performance and not only compliance. So, what do you expect from a source which is certified is to have much smaller risks of illegal logging. Why?

Because you have checked all that points that are susceptible to fraud, you will look into the procedures, you will look into the implementation practices. And most importantly, you are looking, for example, in things like the forest inventory, which you see, for example, was this trying that, idea that, you know, as a logger where you could be inflating, your forest inventory, there should be control and bias verification systems by the agencies. That's one thing. So, you know that source is good. So, along the supply chain, yeah, so a long supply chain going to point A, you see logging, transport processing, process here, you can have in Brazil like 5, 6, 7 companies in a sequence. So, it's a long chain until the final trader, let's say. So, all these guys sell FSC, for example, they have to have a minimum traceability system, what we call chain of custody. So, that's what actually guarantees, not guarantees, but gives you a very low risk of having contamination along the chain. So, the relation to your last question, traceability makes a lot of sense, as I said, is interesting, too, as I said, but again is a tool that only makes sense if you are sure that the source is good. So, in that case, I would say low risk, because you know that the source is good.

Okay. So, basically, in the case of a certification, they would not only check the conditions in the forest but they would also check, for instance, that the processing facilities they have the licenses? But then, for instance, can we really check if during the transport, nobody was bribed. Because that's something that's very difficult to check, right? But it would also constitute illegal logging.
Well, not no, I would say, as an answer, but I can't see why you need to bribe something that is proven to be legal.

Well, during the process, you could for instance, have a batch of legal timber that's certified and then you could try to launder it with illegal timber, and then bribe the officials that then sell that as the legal batch.
You still could do it. I mean, for me, the idea of the chain of custody and traceability systems is that at the end over time, you would create inconsistences that would become detectable. So, the whole idea of a chain of custody, I'll not say that zero is, is not. But for example, over time, if you have a company that has a strong traceability system and procedures, it would become very difficult to hide. For example, illegal timber, it would not be impossible, would be that you as an auditor of chain of custody companies that are starting to see inconsistencies and these certificates are suspended. I have participated in this year, two audits where we suspended both certificates because it starts to show things that are inconsistent, volumes that are inconsistent, right. So, I would say that not immediate, maybe but most of the traceability systems over time, is the Monte Carlo Testing at the end is difficult to hide illegal logging.

Okay. I see. And during these certifications, when they verify the legality or also other conditions, do they also rely on the documentation like DOF documentation etc.? Or do they do additional checks?
Let's say indicate for, let's take an example a sawmill. So, of course, the basic documentation continues to be DOF and the invoices. So, I'm not defending specifically here, the certification systems, but the third-party verifications, that's key, this independent body, going to that place and doing an audit. That's what makes the difference in my mind. But there's not government, there's not a consultant hired by the company, but is somebody independent who looks at that. To me, that's the division between what can be better low risk or worse high risk? So, even if the documentation is the same, let's say, what the company needs to do is to have first of all a very strong control systems everything coming in, everything come out all conversion rates. Second of all, if you were talking about the certified company, it had to do a separation of materials that comes from certified forests from non-certified forests, they have to start to process the timber that was certified in a separate way than the non-certified timber, that they

start to have conversion registers for certified and non-certified, you know where I'm going? At some point, any inconsistencies in conjunction when you're using a control system you show if something's wrong. It's different for say, "Well, I'm a logger processing 1,000 cubic meters 350, I have no grades, I have no control, I have not one spreadsheet. I just do it like a crazy guy doing whatever I want." So, it's the lack of a control system verified by someone, in my opinion, that allows illegal logging to prevail along the processing chains.

And these audits, like where someone comes to check and checks, the documents, etc., that independent third party, I guess, does it in the beginning and then maybe every year or so, after they receive a certification?

At least every year. Yes, that's a common practice for certification systems. Of course, there is verification systems as well. We have several systems designed to look on specific case alongside the chain. So, most of these big certification bodies had their own standards for verification. IMAFLORA for example, has the legal source as we call, it is also a third-party independent verification that goes but it goes much more focusing on legality. So, not much worried about some of the social or environmental plus agenda. So, it's simpler, but again, it's third-party verification. So, SGS has one, I mean, my point is that the only way to start to cleaning, I guess, this supply chain is by increasing the number or parts of the chain under independent verification.

Is there always someone who's checking the information? Or does someone only check if they're suspicious about something? Or is there always someone who needs to check it in every shipment that the documentation is correct?

Again, I'm not saying that it's good or bad. But again, at least suspicious in the sense that you know, when you say third party, because you want someone to be really independent with this, this type of mechanism that you were discussing, we used to call it second party. So, what you do is, let's say that you and I, we are on, and we say, "Hey, listen, let's do a system ourselves, and let's apply it." Maybe we can apply well, maybe we cannot apply well, we'll hire a consultant to go there and check. And this consultant might be more independent, or might say, "Well, I want to write a report about things that Marco and Lynn want to hear." So, it's difficult to say. I would say that is not as trustworthy as independent verification by any chance. There is largely to show that second party certification tends to give results that are favourable to the company.

But the third-party verification is only done once. And then like my question is, if you do it once, but don't have any other traceability systems in place or legality verification, how do you make sure that after the forest was checked or your other suppliers or sawmills were checked, that they engage in illegal activities after the check?

Well, first of all, whenever we say a third-party verification should have monitoring, verification. So, it's not only once, it should be regular. How regular? I don't know, at least once a year. You have come back and go to these companies, most of these third party anyways, do a sample. Let's say if you have a very large supply chain, you're not visiting all sawmills, you have like a sample. Secondly, you have to come back and do another sample. And of course, the way that we see third parties that you could ask, "Well, but if the auditor is bribed?" well, there's a reason why in second year you go to different auditor and a third auditor, but over time, you're trying to control the risks of corruption. Corruption is a big point here, by the way, when you talk about illegal logging in Brazil. So, I mean, it is a process of exposing, I guess these companies, that makes a difference over a given period of time. The process of trying to make all parts of all checkpoints in the supply chain, to have better procedures, to have

registered, to have filing of the documents, to have their conversion rates exposed over time. Yeah, that I believe that.

Interesting. I see that our time is running out. Do you have another 10, 15 minutes or do you need to run? [interviewee nods] Okay, perfect. Because it's so nice to talk to someone who's very knowledgeable about this area.
Yes, of course. But I'm probably the most the grumpy side of the issue so I hope you are able to find more optimistic people.

How regularly are audits conducted in your experiences?
Usually once in a year. But during most audits only a sample is taken.

Besides that I also read about efforts of scientific methods to trace timber. What is your opinion on such methods?
I think they are very useful. But they are tough to implement because of their costs and because you need to develop the databanks. There is one company, called Genoma A, that is currently working on combining blockchain and DNA technology. They basically extract a sample from the individual tree, secure it with blockchain, and at a later stage in the supply chain validate the extracted sample with the newer sample.

It is interesting that you mention the Genoma A project. Are you aware of any other blockchain projects that are currently being pursued in the Brazilian Amazon?
Yes, there is another project called embrapa.

Thank you. And what potential do you see in using this technology against illegal logging?
To be very open with you. I think it's a bit too much. There are other low risk traceability systems that can trace the tree from the source to the supplier at relatively low risk and reasonable costs. Using blockchain technology only makes sense if you have a good source. Because if the forest inventory is fraudulent, what is the point? You can have the best traceability systems and blockchain solution, but if the originating point is fraudulent, then there is little use for blockchain. Third party validation is crucial.

Interesting to know. Now that we have discussed traceability systems and legality verification, what can companies do against illegal logging in your opinion?
I see four areas of action for companies:

1. Proof of enforcement with certifications or legality verification .
2. Increase of third-party verification.
3. Convincing the domestic market to give a difference since there is very little conscience about legal and sustainable timber now.
4. Create sector-wide commitments. At the moment, the timber sector in Brazil does not have any goals. The discussions on creating such sector-wide commitments is only starting now.

What do you think about timber companies engaging in political advocacy efforts?
Political advocacy is crucial, as there are still a lot of areas where the government can take action, for instance, in strengthening law enforcement or also in increasing agencies' budgets.

Do you see a lot of companies engaged in political advocacy efforts?
None. Not that I am aware of. Currently, there is very little engagement of timber companies. Other sectors, such as the agricultural sector are much more present in politics and they also have members represent in the congress. This is not the case for timber companies, they don't engage in political efforts.

I see, moving on to my last question: Why do you think illegal logging occurs?
It's too easy. And very profitable. If you look at IPE it's sold for around $3,000 per board. Not even illegal drugs make that much money. And it is also very unlikely that you will get caught. In fact, if you look at statistics, less than 2% of environmental crime in Brazil is punished. In summary, it's too easy, low risk, and high profits.

What exactly do you mean with it's too easy? Is it easy in Brazil's control system?
Yes exactly. There are many ways how loggers can misuse the current system.

3.2.2 Interview Christian Kobel

Perfect. So, you mentioned the FSC certifications. So, if I as an importing company would want to get a certification, would all the players in the supply chain before me also need to be FSC certified?
Yes.

Okay. And then you also mentioned that you have auditors all around the world. And so I'm trying to get a better understanding of how FSC or certification processes in general work. So, do you as a third-party organization always carry out field inspections to verify the legality requirements or is this not something that is always done?
So, if we talk about forest management certification, yes. If you talk about chain of custody, so, this is then the timber flow. So, at the moment, there is no legality verification of the chain of custody, so that means, in the timber production and processing.

Okay. So, you do not check legal requirements or for instance, sawmills or paper mills?
No.

Okay. But you can still ensure to the best of possibilities that the legality of the woods sourced from the forest.
So, the forest management includes social and environmental and, yes, also legal aspects if you certify forest. But then when the timber... So, the chain of custody certification, that means to assure that there is no mixing in the production chain. So, there are some commitments which have been signed by the companies, but it's not the focus on the certification. So, the focus on the chain of custody certification is that it comes from a well-managed forest. That's also what the label is saying at the end. But not that the sawmill is legally verified or something like that.

And then maybe as a follow-up question, so I saw that for the legality verification of forest, certain employment legislation or working conditions of workers need to be respected. But then you also don't check if this is the case for middlemen. So, for instance, at the sawmill.
We check it in the forest, but not the sawmill. The sawmill is only a commitment from the company, if required. We check if this commitment is there. What is new at the moment is the introduction of ILO or labour requirements. So, FSC introduced this year, social requirements for a chain of custody. So, that means that in the audit of social requirements, we are now a step ahead and also verify legal

requirements relating the labour rights. That's new. That's coming. That's implemented by the end of next year.

Also, in the supply chain or only in the forest?
Also in the supply chain, yes. So, that means that very [unclear] in the legality verification of labour requirements. So, we have here, some additional requirements, which is coming in. So, it's not only the traceability, it goes further now. Until the end of next year, also FSC labour requirements must be verified.

But if I understood correctly, this is not the case for the PEFC certification.
For PEFC is similar. So, PEFC has also already some labour requirements, which apply along the supply chain.

Okay. The same holds for PEFC, but you don't check the legality of the timber along with supply chain, but only like from the forest.
So, in both cases, we verify in the forest. And PEFC has already developed some requirements for legality in the supply chain. And FSC now, at the moment, introduce also requirements for legality respectively for social labour requirements in the supply chain. FSC is usually more detailed. Therefore, this has also, I think, a significant implication these new FSC labour requirements for the supply chain.

Okay. Very good. Okay. I would now move on to some specific questions on legality verification and traceability efforts to understand this process a bit better. So, you mentioned that you carry out legality verification and chain of custody verification. This is done in the beginning. But then afterwards, is this done on a regular basis or is this done once a year?
Usually, once a year. It can also be more often, but at least once a year.

And you mentioned that this certification process or monitoring process by you is enough to comply with the EU regulations.
Maybe something which is important for all these legality verifications, so what we check is always a system of the company to be in compliance with the legislation. So, we can verify or confirm that the company is always in compliance with all the laws, because we do only once a year check, and we check the system of the company, that means we check if they have a system to register all the legal requirements, what they do to comply with it, and also how they implement it. But we are not all the time on site, and we can't guarantee 100% legal compliance. It just kind of confirm that the system is in place for the company to manage the legal compliance. That's maybe one thing when we talk about certification, when we talk about timber due diligence, which is EUTR. So, this is another system. Timber due diligence system is a system to mitigate the risk of purchasing illegal timber. That's always also a risk-based system. That's again, the system which we are verifying. That's just important to understand that the obligation to be legal compliance has always remained with the company, because that cannot be verified with only one audit per year. So, we are checking the system.

That timber due diligence system, this is different from the systems that companies have to check legality or to trace the chain of custody?
So, the timber due diligence system is applied by an importer to the EU or somebody who is importing. So, it's an obligation for all importers of timber to the EU, because the EU want to prevent that illegal timber is placed on the market. And therefore, with the timber due diligence system, so the companies are looking at its supply chains and its origin of timber, it's looking at its suppliers, it's looking

backwards down the supply chain and try to identify the risk depending on the complexity of supply chain, depending on the risk of origin from some countries, which are more high risk or low risk, and depending on all that information. That's the due diligence system where a company try to look back at the supply chain and assess the risk of illegality. And if you're in the forest, so then it's the company itself, right? So, the company, the forest manager, must comply with the legal requirements, that's maybe a little bit simpler, because it's normally the own activities which are mainly in the focus of the legality verification. That's from my point of view. If we just check a company itself or if we do due diligence system, we look down the supply chain.

So, with timber due diligence system, it doesn't necessarily have to be a system that is in place of a company, it's just an analysis that you do of your suppliers.
Yeah. We help the companies do that. We usually only do verification. If the company wants to be certified, there is a standard, that is FSC standard, saying what the company must do to comply with this legality requirements, or to comply with the environmental requirements, or with the social requirements. So, we check if the company is doing it. And if it's not good, we raise nonconformity. The company has to address it. The same is for the timber due diligence system. So, for the timber due diligence system, there are set of rules, which are defined by the European Union. And so we specify that we have an approved system from the European Union, a checklist. We just go to the company and check if they do comply with this due diligence requirement. If they gather the information that they must have to, if they are doing the risk assessments on the aspects they have to, if they do risk mitigation when there is a risk. So, that's what we check.

Okay. Perfect. Okay, I have another question. So, you mentioned that you look at the company's system to check whether they are in place? And do the companies usually have two different systems for verifying legality and verifying the chain of custody, or is this all in one?
If the companies have two different systems in place? Is that the question?

Yeah.
Good question. So, I don't want to make it too complicated, but in the FSC and CoC system, so we have also a view, it's possible to apply also due diligence system, similar like EUTR. And that's particularly for the chain of custody. Maybe you heard that there are also FSC mix products, for instance. So, these are products, so they've efficacy 100% products, where timber must come from certified sources. All timber and the FSC mix for that. So, the FSC mix product is product which can contain timber from certified sources, and timber from so named controlled sources. And for the control of not certified timber, timber due diligence system must be conducted. And then it can be accepted as an additional component.

Okay.
Yeah. Maybe you must study the FSC, similar PEFC system. And therefore, the question is yes. So, company can have a CoC certification, which includes the timber due diligence system, which includes also timber from not certified sources, but from control with the timber due diligence system.

Okay. But then how exactly do... Okay. So, just to get a better understanding. So, companies do they also check the legality requirements of their suppliers? And you could do this with a paper trail of documentation. And so we check that they have all the transportation documents required by the government, etc.?

It is... I take the FSC system again, because it's goes more deeper, it's more elaborated. In FSC System, FSC develops the risk assessments in the due diligence system. That is for most of the countries - you can go to the FSC website - there is a risk assessment about the country and the FSC has five main categories requirements, which is legality, which is species legality, which is GMO, which is transition of forests to other use, which is not allowed, etc. So, these are high conservation value forests. So, this is hundreds of pages. In some cases, with a lot of control measures, which must be implemented. And this can be in some countries more the legal part. It can be more the high conservation value forests or more environmental parts. So, this is quite detailed system that the company has to do to verify to make sure that the timber is from acceptable sources, but it includes also legality aspects.

So, if I understand correctly, with legality verification from a company side, is it just done together with FSC once in the beginning, but then afterwards, just with the audit. And they don't do it like on a regular basis with every timber shipment.

Yeah. Maybe I try to summarize. So, the principle is that the forest management certification, it includes also legality aspects, legality system of forest management, which must be considered. For the chain of custody, at the moment, the labour requirements are now included and at least for that prospect, you will see by end of next year, that also some legality verification, must occur in the chain of custody. For timber, which enters the chain of custody, which is not certified, but used in certified products, so, due diligence system, FSC control system or PEFC control sources are implemented which includes also some legality aspects of the supply chain, for the forest of origin. Yes, and then is the EUTR system. So, there is a system which is only a separate due diligence system, which is required, or there is an obligation to do that for the imports of timber in the EU. They just must do it, if they do not have to use us, SGS, so it's voluntary to let this verify by SGS for the certification. It's a requirement that each company that is purchasing or selling FSC timber must be certified by a certification body. For the EUTR, it's voluntary. Most of the company also don't do it. So, we have just a few clients for EUTR.

Okay. Perfect. And from the companies that you've audited, so I've read about electronic systems for tracing the timber for the supply chain like GPS tracking or RFID technology. Are there also efforts that you see among the companies that you audit, or is it more simple than that?

Yes, I think this will certainly be the future that more technology will come in, particularly in the supply chain. So, the chain of custody certification, because there is so much for certification. So, there are about, I don't know, 30,000 or 40,000 companies. And yes, that's much high amount of work and also costs, which is used for that control. And it's also a bit questionable in the past, and how far this is really efficient with these annual audits. And I can't imagine that some digital system will replace parts of that control or will be used for that control. I think it will not completely replace the audits, but it can help to have more accuracy, in general.

You mentioned... Like, what is the approximate cost for timber company to get certified? Maybe the setup cost?

Yes, the costs for everybody, for the companies, for the certification bodies, I mean, it's not only traceability, there are also local use, social aspects, as we said before, but yeah, I think with the technology, the system can be made more efficient.

Do you also see potential for blockchain in this entire picture? Because I guess, from my perspective, it's very still in the beginnings in the timber industry, like I haven't seen many companies use these efforts. But do you see potential behind this technology?

I mean, I'm not specialist for IT, for blockchain. I think for me, it's just technology. And I believe that technology will be there. The problem is more whether the company really accept this until this status is implemented. There is some concern about the confidentiality of information, because for the companies, that's the core of what they do. And so they must be sure that this information is not just published and available to everybody or to anybody that you will not trust... Maybe you make some research about OCP, so this is something which FSC intended to introduce five years or more ago. This was their intention to monitor all trades with FSC. But this has not been accepted by the industry at that time. And the technology was already there for five years ago. But yes, maybe I think the one of the main points what the company said is it'll be too complicated to put it in a uniform structure. The information, that's maybe one of the... Also when we talk about future, so the companies must use all the same system, exactly the same structure of data, so that it can be entered. So, that is must be harmonised. And the second thing is that, yes, the company must collaborate, and also trust in the system. Maybe the mistake with OCP was that this was maintained by FSC, so FSC was the owner of this OCP. And maybe the companies would more participate with blockchain, as I understand blockchain, so the company remain the owner of the information. They keep the ownership of the information, and they just say, "With whom it will be shared." So, it's not a central body who is then owning all the data. I don't know that's what I understand from blockchain. But that could be an argument that is not a long body, who owns all our power so that there is a very clear explanation?

So, you're basically saying maybe another approach would be to make private companies themselves owner decider of structure of who gets to have information?

I don't know. Yes, I think it's difficult to convince the companies to participate one system for all timber flows. And yes, therefore, there must be a clear system that they understand who is owner. And that also the status information is not shared with other. That confidentiality is assured. So, maybe a third point is that you must also consider that there is also some processing, which occurs in the company. So, if there is a log, then in the company, in the sawmill it is cut, and you then have boards. So, it's not possible to just trace it. So, somebody must also control in the company, what happens physically, because he can't trace from a log to the board or to the board, or from the log to the pulp. So, there must be also a traceability system in place in the company itself, where the processing happens. For trading, it's simpler. For trading, the product is not changed, but when we have processing, so there must be some process in place, which cannot be traced by a digital system.

Yeah, you mean...

This is physical - a physical transformation happens. So, it's difficult. And then the next point is SGS has also a system of transparency model. That can go on our website where we map, we have a system, where we offer companies to map their supply chain. So, this is them coming from maybe producers, retailers, who want to know the supply chain. This is used for food products. We have also been forestry system, we just see that for forestry, the supply chains are longer than for other supply chains, like food. Like food, it's usually the producer, then its transformation and then it's going to the store. For timber there can be that there is a logger, then there is a sawmill, there are traders between and when it comes to... That's also another point, which is a challenge for the trader, for the forest chain of custody.

From your efforts also, that SGS conducts, where do you still see weaknesses, where illegal logging could enter the supply chain despite all the auditing efforts?

Yes, so I think, I don't know if you go to the FSC website, I just received today, again, a report from China. Yes, I think, FSC, it's difficult to control everything. That's clear. For me, if the certified timber still has a high level of assurance, but also barely happens. There are 40,000 companies from all

countries. And if there are really frauds, there is a lot of efforts to prevent and try to detect fraud. That's always a fight. But that happens. Yes, certainly we try to address this. We have a lot to go because of this. We also suspended or withdrawn a lot of companies already because we detected fraud. But that must be, it's clear that this happens, it's a stuff that must be investigated. That's maybe the advantage. There's a certain transparency that this can be also subject in FEC system for instance. For EUTR it's difficult to say for me because it's less transparent. I think there are cases they are monitored in the FSC certification system. So, there is a lot of effort to address this and suspend these companies or exclude these from the systems.

Well, thank you so much for taking the time to talk to me. All the topic, like everything around certification got so much clear after this conversation, so a huge thank you for my side.

Follow-up Email:
The following follow-up question was sent per email: "In the beginning you confirmed that all players in the supply chain (e.g., sawmills) would need FSC certification if a new company is seeking to get certified. Later in the interview, you mentioned that legality requirements are just checked at the source (and not in other steps of the supply chain). From my understanding, supply chain players therefore, do not need legality verification but only need CoC-verification. Did I understand this correctly?"
I can make following Points:

- The Forest is certified against Forest Management Criteria which cover the compliance with legislation (FSC FM and PEFC FM, e.g. look for FSC Principals and Criteria)
- For being able to label a product and the end of the chain, all processing and trading companies with legal possession of the material between the forest and the end product must be certified FSC COC, PEFC COC). The companies are assessed against traceability criteria and legal compliance is not in the focus. however, the company must commit themselves to some additional fundamental requirements which also include compliance with legislation (e.g., look for FSC Policy of Association). PEFC already and FSC newly introduces additional social requirements, which cover fundamental social rights, which will have to be assessed in the future.
- There is an exception that also not certified material can enter the supply chain and be used for certified products (e.g., look for Controlled Wood in FSC Mix, FSC Percentage products). For this material Due Diligence must be conducted which covered also requirements to mitigate the risk of using timber from illegal logging. Look for Categories of the FSC Controlled Wood System.

3.3.3 Interview Sam Daniel

So, I know in your report today, you did quite some analysis on the control and licensing system with the Brazilian government and you saw that a bit as one of the main causes of illegal logging. Are there other factors that you consider important to contribute to this problem?
Yeah, Brazil has quite good laws. But there's a real lack of governance with the laws so that's one major issue. I guess, I mean, depends on like, how deep you kind of go with this thing. Because basically, the Amazon is characterized by a huge amount of illegality and crime and violence, and so on, it's not everywhere, but in different parts it's different. And it's very hard, even for timber companies and whatever companies who want to be acting legally, it's actually very difficult when you're working in an area where everyone is acting, not everyone, but there's a massive illegality happening. I remember

once we were campaigning against a timber company in the UK. And it's a big deal in tropical timber. And he said, "If we only sold legal timber, we would be out of business because everyone was selling illegal tropical timber, we wouldn't be able to compete." So, I think that the lack of governance is a really big issue. Without a clear level playing field. It's very difficult for companies to act in a good way.

What do you understand, governance is it like the presence of a government or is it governance in the sense of not enough law enforcement efforts happening?
Not enough law enforcement, yeah. Also, there is massive corruption there as well, which is being dealt with.

I read some articles about corruption cases and saw that's an issue. And moving on to the next question, maybe. So, now, we sort of discussed a bit the causes, where or who exactly like, which stakeholders do you see or which stakeholders need to contribute to solving illegal logging? And what role do you see them playing?
I think you need the collaboration between the business, civil society, and government. Do you know about the Soy Moratorium?

Yes.
So, that was like a great success. But you had government, NGOs and business all coming together with the disagreement. And I think that was really key to have all those different parts in agreement and working together. And I think that's also what's needed within the timber trade, you need the industry, you need the NGOs, you need the government, all to come together to work on a solution. Because, once one of those parts is missing it's very difficult to get enforcement, to get support that the agreement needs to get, resources and so on. So, I think you need all those key three parts together to really get an effective agreement, and potentially even international companies in order to back that. Also, the Soy Moratorium, a lot of that, in the end, one of the driving forces behind a moratorium was actually McDonald's. Because for years, they've been accused of rainforest destruction, but no one had ever proved it. And when we proved that they don't want to be the only company who had to deal with these problems. They wanted the whole industry to move with them. They really lobbied quite hard within the industry to implement this moratorium. So, that was quite effective.

But so I read about this Soy Moratorium and I read that it was quite effective. But I also read some articles from other authors, but they don't believe that the same, like a type of moratorium for the timber industry would be the right approach. Do you agree with them?
Yeah, it might not be the right approach. But I think you need those different sectors to come together in agreement. The Soy Moratorium, we had a few companies who controlled the majority of the soy. I think, I don't know, the exact percentage but it was a lot. With the timber industry, it's not like that you have thousands of timber companies. You don't have the big few soy companies that had a lot more power. So, it's different. It's going to be a harder deal to enforce that and come to what we have soy industry.

Yeah. Do you see any other areas or specific topics where you stakeholders could take on collaborations or invest for efforts in? Or do you have a best practice or an example that you saw throughout your research?
Not really, I mean, I think there's pockets of good governance in the Amazon. But it's quite small, relatively and huge amount of logging. So, the question is, like, can you upscale that and maintain the

standards. The problems is, you might have a good scheme, but once you start making it bigger, it starts to get watered down, and so on. Right, so can you have like federal forest concessions in the Amazon, which is seen as like the gold standard and I'm not hugely familiar with them. By now, they have very good reputation. And they're seen as like the best there is. But can that standard be replicated on a much larger scale? I don't know if that's possible. But that would be the kind of thing that would be needed. We have logging problems to log in area. It was like state concessions and federal concessions.

Is this the same as like, the concessions that are given to companies in this competitive process?
Concessions run by the federal government.

Perfect. Cool. The second topic is more about measures that companies specifically can take against illegal logging. In your opinion, what can timber companies that are operating in the Brazilian Amazon or sourcing from Brazilian Amazon do against illegal logging? And have you observed any specific best practices?
Yeah, so there's a lot of timber companies operating that can do. We've worked with some companies kind of informally on what they've been doing and so on in the past and one company in particular, like they brought in a whole, basically all the thoughts and then like, make up new plans and how they deal with all these issues and so on. They certainly still have problems. But they make a lot of effort into the timber where it comes from visiting the logging areas. I have not worked on logging for a while so things really changed since I'm working on it. But a forest engineer gives the state its logging plan. Each logging plan, they show each tree is they're going to log, which trees they are, the density and they put a tag on each log, on each stump, this kind of stuff. Sometimes they go there, they check everything, they check the stump, they check the tags, they go through the plans, they check the density, because one of the common things is companies often overestimate the density of high value timbers, they check all this stuff. The things that companies can really do like maybe not 100%, but really like people are sure it is more likely to come from good logging place. One timber company, they told me if people come up with cheap timber, they won't buy it because they know timber can't be that cheap. It's illegally logged and all this kind of stuff. So, those simple things that companies can do. So, yes, it's not fool proof, because the corruption in the Amazon can be really quite clever and really quite smart to circumvent the regulations and stuff. There's only some things companies could do that lower the risk.

And so I read about the requirement importing companies need to demonstrate or like fulfil. So, if I need to show due diligence, or verify their legality, are you familiar with how companies do that with timber sourced from the Brazilian Amazon?
So, that's a big problem with that, because basically, the credits themselves might be based on falsehood, so a lot of time a lot of logging licenses, they overestimate the amount of valuable trees they've got, or they don't log it, or log somewhere else, or whatever it is. So, they get their credits. For instance, you probably read this already, to log so many Ipe trees, but actually log in from a protected area, once they've got the credits, companies importing timber can show the credits on the timber all along the chain. It looks like it's legal. But obviously, the credits are actually based on a falsehood. The whole system is based on something which is not correct. So, they do the due diligence and the getting the transport documents and all this kind of stuff. It still doesn't show what's legal, basically.

So, basically, companies mostly verify legality based on the documentation that's provided by the DOF system?
Yes, DOF system. Most of the credits are not accurate, the original credits that are done. Because when a company submits a logging plan, they're supposed to go and check it, most of the time they don't, we

always need to know that. We had a bunch of reports in 2014, there was one case, if I get the name, I'll find it for you. They had 100,000 cubic meters of credits, which they logged and when they did to fly over, nothing had been logged in this forest area, they sold 100,000 cubic meters of timber from somewhere else. And that was like an extreme case, obviously, that's quite a huge amount of timber. It was submitted that forest management plan, when they checked, none of the forest was logged.

Wow.
Sort of 100,000 kilometres of timber from the credits they got. They didn't log any of the areas they said they were going to log. They just logged timber from, who knows where? So, that's kind of like, the level of illegality going on there...

Absurd. I mean, like, the Brazilian Amazon is also so huge in dimension. It's literally like the size of Western Europe. It's just so difficult. And I'm trying to think from the perspective of timber companies like what can they do, if they can't trust the credit system or the Brazilian government? I mean, they can also do some field inspections themselves. But beyond that, do you see any area where or measures that we could take in addition to that?
Good question. I mean, if they have.... Even with the forest inspection; it can be quite difficult to tell what the stump of the tree is? Some species are quite similar. So, we can get quite difficult, but these things you could start doing with like testing, isotope testing, for instance, and DNA testing. And I guess, that's kind of the way things are going to go eventually, I know, I think in Europe they're quite in the idea of isotope testing, you can see, if you have a big enough database and enough samples you can start to really define where a sample came from. But you need to acquire like massive database for that, it's going to take a long time to put together. I guess the testing thing is like something which even then I'm sure they'll find a way to corrupt it. There's always another way to circumvent it. The system that's actually quite amazing. If you look at how the system is? It sounds quite incredible. But there's so many different ways that they managed to corrupt the system. And ways to corrupt systems, even hack into the system and create credits. So, there's always like another way of the corruption, that can least lower the risk and lower the illegal logging.

And have you also worked together with companies that use, like technologies like RFID tags or electronic barcodes to sort of track the timber within the supply chain?
I think, again, it's the same problem. Once the first credit is laundered into the system at the start of a process, it doesn't matter what the rest of the process is because the trees were illegally laundered somewhere else and laundered in. So, you can have all that, but right now the biggest problem is the first step that the trees are being laundered into the system.

I mean, I guess there are other ways that you can also launder timber throughout the supply chain, for instance, like in the transport phase that you like, drive to another facility to get the illegal logging. But yeah, of course, the main problem is the source. And that's what it very interesting, because I also talked to other people. And they also said that actually, like traceability efforts in itself don't matter that much if the source isn't good.
That's the problem. Yeah, that's the problem right now is the initial laundering of the timber into the system in the first part of the chain.

So, if I would ask you, where you see potential for blockchain, your answer would be similar?
I mean, I think blockchain could help. But I'd be curious to hear like, how it could work? And also like how we could really verify blockchain? That first part of the process would really be key for success. I

think it's something to explore. I don't know if we could.... Obviously, when blockchain came out, we're really excited. Maybe this would be something that could work for us. But...

I think like, so from what I've read, and also heard from other people, it has the same problem like the traceability technologies, but it's a first step that is really the key. I think, somewhere the solution will probably lie between thoroughly checking the source and combining traceability systems to ensure that during the supply chain, that nobody sort of mixes certified or legal timber that you checked at the source. Then this would probably have to be combined with DNA technologies, maybe sample wise to really check that it wasn't sort of switched out during the process. I'm still figuring it out, where, and to what extent it could be applied. Because, as of now, I'm also not sure what players would need to be involved for such a big project, because of course, also a lot of costs are involved in setting this up. During the work that you did, I mean, you work together with some companies, did you see or did you observe any differences in the level of intensity of action taken by companies, so for instance, for between Brazilian and international companies or small scale loggers and large scale loggers?

It depends on the company. Some companies, they really wanted to try and deal with the situation. Some companies are more, they genuinely want to be no not dealing with any illegally logged timber and they've been even trying to preserve the Amazon and so on. I think, ultimately, the Amazon, these timber companies. It's also their livelihood, but also they're kind of destroying their livelihood. Just like with the fishing industry, they know they're overfishing, but they're kind of stuck in the system. Some timber companies were definitely I felt were generally genuinely trying to work harder to weed out illegality in their chain and get a good source of timber and so on. One company in particular, I think, really spent a lot of work, really trying, they wanted to sell themselves as the best company out there. But they had two sides to their business, one was like a factory, one was like, just a general timber trading business. So, for the factory, I think they did pretty good in terms of sourcing, really upping their game. But for their just regular import / export business, it was just the same, just buying on the open market. So, they'll also deal a lot with illegal timber. So, half of business was kind of like fairly good, half was also a massive problem. So, it's a mixed bag. Some good companies, I mean, really shocking to me, like stuff that they were doing. And the companies that they were trading with, and these are some of the better companies, so wasn't many companies were I had a lot of respect for in terms of their efforts.

Okay. And what do you think of the use of certifications among companies, do you see that as a potential solution?

Well, I think Greenpeace did, I think we wanted certification. Greenpeace was on the board of FSC for a long time. But for places like in the Amazon FSC is not really working anymore. A lot of, the group has had quite good relations with some FSC concessions, like a long time ago in the Amazon. But there's been a lot of problems with FSC in the Amazon. FSC in Canada, for instance, all Canadian offices were really happy with FSC in Canada, right? They work, we think it's a good standard, and so on, and it works. But in the Amazon, I don't think FSC is working that well. And I think they've got a lot of problems. All those big timber certifications FSC was definitely the best one, much better than a PEFC and so on. I think standards were good. But I think the enforcement became a problem. And things got watered down. I don't know enough about it, but I saw a lot of reports of problems with FSC concessions. Dealing with illegal timber, and so on, and even having problems with land issues, who owns it? Being accused of, not land grabbing, but yeah, being on other people's land, and so on. And the Amazon FSC became a problem. And Greenpeace pulled out of FSC, a few a couple of years ago, I guess it was now two, three years ago, we came off to the board. We didn't make a big deal about it.

But we didn't feel we could really be there anymore. We were seeing a lot of problems with it. And yeah, we also just released a report about certification. If you saw it.

Yes, I saw it.
Yeah. So, I think we invested a lot in certification for a long time. And I think we've come to the point where we needed an urgent action for a long time, but it's becoming really more and more critical every year. And certifications are not delivering, and a lot are really weak, there's a few good ones. FSC was definitely one of the better ones, even that's not delivering in a lot of places. So, it's really a shame. But it's a big problem. Now we're looking to legislation to try and meet that gap. But even that is going to be difficult.

So, you feel like legislation. So, you see the Brazilian government playing a role?
They need to play a role. But not in this administration obviously, I don't see them playing a role. And I don't know what will come after Bolsonaro. I say, Bolsonaro is bad, but it's been bad in the Amazon for a long time. I mean, illegal logging and deforestation actually got better for a long time. But it's been on the up for quite a while even before Bolsonaro and obviously under him it's getting much worse. And I think, my opinion, any effective solution you need the Brazilian government involved. I think, legislation in Europe in the US, in other countries can help. But to really solve the issue you need collaboration between the Brazilian government, the timber industry, between NGOs, maybe between foreign governments as well. I don't see, how they can really make it work significantly without the government being involved and playing a positive role.

You mentioned legislation, do you maybe know whether legislation in terms of requirements or timber companies, whether that's a bit weaker in Brazil, compared to the core requirements of importing countries, such as the US or Europe, have for timber companies.
Say that again.

Wherever, basically, have a legislation, or requirements for companies that sell timber domestically, only within Brazil is less strict than companies that want to export the timber?
So, not sure if it's any weaker? I just think there's less enforcement. It also comes down to the... The issue is the logging itself. Brazil, in many ways has quite good laws but its enforcement, that's the problem. But the thing is, everyone knows what's going on, everyone knows that the documents don't really prove what's happening. It's not like companies are surprised that, "Oh, this was illegal timber. We have the documents but it turned out to be illegal," everyone knows that it's a problem. It's not like a secret. Even the companies in Europe also know. So, it's a well-known problem that even though everyone has the documents, they can trace that back. They still saw massive illegality in the trade. I've done a lot of undercover work in the past. And that was like, really key from meeting companies. So, yeah, it goes, they have a document, but it's all meaningless ultimately, and companies know that. And sometimes companies... The whole system is a problem. If you're a timber company in Brazil, or whatever it is. You're stuck in a system that's rife with illegality and corruption. So, even if you want to do the right thing, it's very difficult, unless there's a level playing field, that everyone's playing by the same rules. There's still things you could do. But it's very hard, I think, companies to really step out there and make a change. I mean, it's not so easy.

Do you see consumers playing a role in this entire picture?
Yeah, definitely. I think consumers have played a role in the past. I think, when the issue of Amazon deforestation first came on the scene, I guess, 30 years ago, whatever it was, that people didn't want to

be invested in that. And we still see that now, companies don't want to be linked to deforestation in the Amazon. I mean, that's clear. And especially in Europe, I think, probably the US as well, companies, they care about that. And they care what people think. But there's only so much consumers can do, without asking for a boycott. So, consumers can try, they can buy certified timber, but even that is still sort of problem. So, yeah, they have a role to play. I think their role is.... I guess I'll see, maybe using this, I don't know what their role is right now. Our commercial work has been on corporates, basically, we don't really target consumers that much with our work, we're really looking at corporates to try and change the behaviour.

And then what do you recommend companies like do you see or do you believe it's better for them to do independent third-party monitoring as opposed to for them doing it themselves?
Yeah, having independent monitoring, when no one's really ever independent because you're paying them. If you start independently monitoring them, potentially they're going to see things bit more objectively than you would yourself. I think that's only going to take company so far, without the government really enforcing the laws. And I'm checking what's going on. I think they're always going to have problems. There are some people who do independent market monitoring, and I've not worked with them. I haven't heard such great things about their level of checking, for instance, and really like weeding out illegality. A lot of time when assembled, it's kind of greenwashed. I think it's hard if you're being paid by another company, it's also hard to say what you need to lose all this money and get by only this timber from this area. But you also like, a difficult role to play. I think for people who play that role, if that makes sense.

You still believe it's better than the companies themselves doing the check?
Potentially. I think companies who are in the Amazon, for instance, have a pretty good idea what's going on. So, if they really want to weed out the illegal trade in timber and deforestation, they may not achieve 100%. But they can make a pretty good go of it. And I think that's down to intention and desire. And I think that's not an easy thing to do because it's a lot of work. Potentially, lowering your profits, but you could also have opportunities, you can sell yourself as a better company and show what you're doing. So, it's a lot more work. It's a lot more putting yourself out there within the trade and potentially lowering your profits. But it has its opportunities, you have to really want to do it. I think there are some companies out there who do want it, but it's a lot of work for them.

Have you observed or during your research did or did some companies come up that really shone through your efforts that they took or invested in fighting illegal logging or measures that they took?
Yeah. I think so we didn't all agree on the team, whether how good these companies are, to be honest with you. I thought, there were one or two companies that were really making sincere efforts to combat illegal logging.

Are you allowed to name these companies?
No. Because we have a very kind of undercover confidential, kind of informal working agreement and it wasn't really public but some of my colleagues didn't have same opinion as me. They weren't so convinced. Because they felt because even though I thought they were quite sincere, they still had problems in their supply chain. I think they are making quite a lot of effort. But they still had problems. And I was pretty open with them about it, then they they agreed. Some of my colleagues like, "They should definitely be dealing with this problem," but depends on how you're looking at things.

Okay. Yeah, I think those were all my questions. Do you have any last comments or perspectives on the future that you want to share?

I think, one of the challenges is to find a new way forward. I think there has been progress over the years. All the systems in place, definitely probably would reduce illegal logging, but there's still a huge amount of problems and we do need to find a new way forward. And hopefully with a positive role by the Brazilian government, but I don't know whether that's going to happen or not going to happen. Basically, you're looking at this thing from a purely, from a different point of view, because it's good to find like, think about the ways that we can make a difference and try and solve these problems because time is running out. And these are major issues. Illegal logging is the first part in the chain of deforestation, and it's a really key part in that cycle. It's a really big issue.

3.3.4 Interview Professor

Which stakeholders do you see playing a role in combating illegal logging? And what specific role do you believe they play?

I guess there is many stakeholders who play a role. And if we look into what scientific studies say, and what media says, and everyone else says, it's very much politics, that should play a role. So, political decision makers should have a key role in changing things. And in particular, when we look into Brazil, and it seems that of course, because of the changes in government some years ago, things have changed. And people would like to see changing back. So, doing more about monitoring, doing more about in the end about implementation of specific finds and something like that. So, that will be important. But of course, it's as well the local stakeholders who play a role. So, it's as well the industry playing a role, the consumers at the end play a role as well. While the retailer, actually the whole supply chain could take a role in that. So, it's not only up to politics, but of course, we can imagine that politics plays a role. But if this doesn't happen as we wish, or as people think it would be acceptable. It might be good to involve more private actors more societal actors, so NGOs**.**

And you mentioned the Brazilian Government, do you also see a role in international governments in this entire context?

Can you repeat the question, please?

You mentioned the Brazilian Government that they have a role to play in fighting illegal logging. Do you see a role for the international governments?

Well, yeah, absolutely, absolutely. It absolutely is. Thanks for reminding me. I think that's very important. Because I think that at the moment, we do not really have international rules there. And this is why everybody, every country can do what they do. And then we do have consumer policies. So, we do have in Europe, we do have in Australia, we do have in the US consumer policies saying that, we don't want illegally harvested wood in our countries. But most of what happens stays in the country. So, it doesn't really come to the international market. For this reason, it doesn't matter in all cases. And of course, as long as we do not have similar regulations and rules and standards in every country, there is always a question of leakages. So, if I have very strong rules and one consumer countries saying that we don't want that, we don't want illegally logged wood and we want to prevent it. Well, you can easily export it to another country.

And what do you exactly mean with international rules that we don't have them at the moment like how exactly would these rules be or like what would they cover, for instance, due diligence by companies?

Yeah, it all kinds of forms could be assumed, but it should be something where there are involved as many countries as possible. So, something like at the UN level. So, it could be an UN issue to do that. And of course, we have some organizations who play a role in that. UN is quite involved in these issues. And of course, we have other organizations as well who are involved in trying to do that. But we do not have really rules or we do not have a combating illegal logging agreement or something, which would be something which is multilateral agreement, but it could be something as well, which is more privately, more from the private sector. Of course, we do have forest certification. But this is always a question then because it's voluntary. You don't need to.

And you mentioned consumers also, what do you see in or what do you see their role in?
Well, the question is, what kind of consumer do we mean? So, do we really mean us personal human beings buying some wood and trying to identify where it comes from and whether it's a legal source or not, it becomes really difficult. But it might be interesting as well to have these consumer country perspective of course to say okay, we need to go one step beyond that and say, okay, we don't as it is already in place, and we do have the EUTR saying, okay, we only want to have legally logged timber on the European market.

Yeah. Okay, perfect. Do you see potential in collaborative efforts between different stakeholders? So, for instance, the government with companies or NGOs? And if yes, do you have any idea what these collaborations would need to target? Like, if it's specific topics or something like that?
Yeah, I guess they need to, I think it's very valuable to have that to have a governance system rather than a governmental system. So, not only this multilateral public policy agreements, but as well, including other actors were quite involved in that. And I think it's important to first of all, discuss the dimensions we have there. And then about the opportunities and possibilities to really track to really monitor what kind of finds and what is the problem? And what are the solutions? I think it needs to be discussed. And it's really hard to discuss that on a high level, because the situation the context is always very different. So, whether we go into the Amazon or somewhere else. And of course, what is important is as well, then there are equal situations that and I think that's what I like about a global agreement, that we have the same rules everywhere and not only in a few countries which means like that as well. So, it should be not something like a northern idea, blamed to the global south but it should be something that is commonly agreed or agreed upon, and the regulation should be true than for everybody.

So, have you seen best practices of timber companies both within Brazil for domestic wood in the domestic market, and then also for international companies that source wood from the Brazilian Amazon?
What do you mean by best practices then?

Best practices in for instance, measures that they took in the supply chain, or commitments or partnerships?
Oh, I have no exact example in front of me. I'm sorry for that.

No worries at all. Do you, or what do you see the role in, or what do you generally think can timber companies do to fight illegal logging?
Well, if they admit to certain standards, which are not only ecological standards as well, social standards, that would be fantastic. But of course, it's difficult for them as well, because what you do is you, first of all, you admit you adapt to the rules in the countries. And so it's hard to say, well, you should stick with the rules, that's fine. They do that because they do that in one country. But that might be not the

rules, which are socially acceptable all around the globe. So, it should be, maybe having a little bit of a higher standard would be nice. But of course, I know that it is a bit optimistic and naive, because it's always, it costs more than if you can if you sell the wood more expensive than your neighbour because he or she is only adapting to the national rules or to look up to different situation. But of course, in the Amazon, we can see as well that some of those, some of the industries are, well not even adapting the local or the national rules. So, that would be of course a first step.

And do you see any potential in the companies, for instance, engaging in political advocacy or political lobbying activities to influence the government or Brazilian Government?
You mean, in which direction to well to?

To for instance, improve law enforcement or…?
You think the companies go there and to improve law enforcement? I think it's rather optimistic. Well in Brazil, the problem is that while there is a, there are regulations and there are regulations against illegal logging and have do have a strong monitoring as well. But the problem might be that in the end, the fines collected are not that money. So, are you really going there and say, "please collect more fines," of course you could do that, that some countries will have a higher standards will of course benefit from standards where everybody takes the same level. So, that will be good. In the end, it would be nice if there are some countries, some companies standing up and saying, okay, "we want a higher standard", and we want others to really take that as well. So, that would be of course fantastic but I'm not sure whether this is realistic.

Yeah. Well, I mean like, there have been some companies, more international companies or like investors who signed agreements for instance, 30 or 40 companies to encourage the Brazilian government to take effort. So, maybe not necessarily the timber company, but also other private sector players could play a role.
Of course, and I think that has been done already earlier when it comes to other forest issues. While in Europe what we have seen that the pressure comes from the consumers. So, we are not going to consume. But that only works if you are a strong consumer, and there is no leakage effect. So, if there is no chance that some other countries say "Oh, we don't care, just well import the wood to us. And we are happy about it, we don't care about these standards." So, but the pressure could work, if it is more general maybe more universal, and this is what I meant was a global issue that we if it is just a part of the global and part of the international scene, then it will not work. So, if Europe says "we don't care, oh, we want higher standards, and we want you to want to take care of that. Otherwise, we don't take your wood anymore" than Brazil says "okay, yeah, good I'll send the wood to China is no problem."

Yeah, okay. And also China is currently importing a lot of wood from Brazil.
Oh, absolutely. So, the market has really exploded, and there was so much need of wood as well in China, and the market is really immense.

And then maybe back again to company measures, you briefly mentioned for certifications in the beginning, do you see or what do you think of the use of forest certifications?
What kind of certifications?

Forest certifications for instance FSC or PEFC?
Yeah. Well, it's very good that we have that. And I really would support that, these initiatives not coming from governmental actions but private governance or collaborative governance, where different

stakeholders play a role. And it's important as well, that there are different standards for different countries because situations are very different. But of course, what we can see as well as that the certification standards, the starting goal or the initial goal of these certification processes was to exactly go into tropical forests, and so on. And what we can see now is, certification takes place in Europe and in the global north, and not so much in the tropics. So, that's a bit it's a bit difficult because you can choose whether you like to be certified or not. And then yeah, well, if it will not benefit you, you will not do that. And so, this is why many areas, and in particular, those areas where it's really problematic will not certify. It's a voluntary thing. So, there needs to be rules as well, governmental rules. So, it can just be both working together in a collaborative manner, but only the one well, at least until now. And we have already some years behind us to forest certification.

So, you feel like it would improve the situation if for instance, forest certifications would be mandatory for companies?
I've never thought about that because I think it doesn't work. Because then it's not it. No, it would be absolutely against the rules, because it's a governance system. It's a collaborative governance system, nothing to do with the government and this is one of the first examples, we have in FSC is, that it is not linked or not well, not linked is not true, but it is not. The need is not in and who can otherwise make things mandatory, is only the state. So, it would absolutely contradict the idea of sort of voluntary certification to say this is a global standard, we need to do that. What you can do as a consumer say, "Oh, we only buy it if it is certified." So, that is an option. Even there problematic maybe, if we look at the World Trade Organization agreement, but anyways, it works. So, you can say we only well as a standard, we need certified wood and if every country does that, then it's okay. But you can't press that on the enterprises or the wood industry or whatever to say, "You'll have to certify", because who would say that? It's only the government. So, then it's not a governance system anymore.

Okay. But then, if it won't come through market side, it would need to include many players who put this pressure on the companies because as of now, I think only 3% of the wood in the Brazilian Amazon is certified. So, it's really like nothing.
Yeah, but there is no chance on saying you have to, who should say that?

Okay, so the next category covers a bit more the specific actions that companies can take. So, for instance, verifying the legality of timber, or tracing the timber throughout the supply chain. I'm not sure how much expertise you have in this area, but just let me know if…
I'll just let you know if I have no idea.

Okay. So, I don't know if you've worked or talked to timber companies, throughout your research and also throughout your career, and your work as a professor. But how timber companies typically trace the timber through their supply chains? Is it that they're mainly using paper-based documentations? So, they're just collecting the documentation and then saying, "Okay, now we did the work" or do they also use a lot of electronic systems such as RFID tags or electronic barcodes to make the system more secure?
So, I have no idea whether they really use it a lot. But from my perspective, what I would say just that is an assumption and not real knowledge is that it is very much paperwork. So, that's at least what is asked for as well, when you want to show the diligence in Europe for example, for the EUTR regulations, you need to show the paper and this is what is done. And we know that there's of course, DNA tracking and things like that has been rather expensive as well, at least in the past. So, that you hardly could do that. It would be too expensive to trace it back.

And do you see any more potential, maybe with this DNA technologies or scientific methods, if it became more or cheaper in the future, do you see this as a potential solution? Or what's your opinion on such methods?
The solution to what.

Illegal logging?
Yeah, but that is only if we do that, then you would need someone who really want to do that. So, who wants to apply these kinds of methods, we can do that in Europe, or in the US or in Australia. Because the regulations say that we only let timber on the market, which has been sustainably managed and so on. And then we have good reason to do so. But for the timber that nationally stays in the country, and that is most of the timber. So, most of the timber is nationally marketed and maybe in the surrounding countries as well. There, it doesn't matter and so it will not solve the whole problem. And it doesn't solve the problem because if we still have markets that do not apply the same system. It's not solving the problem. The only thing is what we do is, we prevent these kinds of wood from [entering] the European market if at all because well, the paperwork is, you can buy that as well. So, it's not honourable, always a question on whether it is really right or not, or whether it's a real paperwork or it's just a copy one or something? So, you can buy that, that's not so problematic.

But then, so if I understand correctly, so if a lot of paperwork isn't trustable also because in Brazil, you have problems with the licensing and control system, which is like a system with the government. Where they generate forestry credits which are basically seen as legal. So, the company can say, we have the paperwork for these credits. This is basically proof of legality. But the problem is already that a lot of these credits are fake or fraudulent. And if companies can't rely on this paperwork, I'm just wondering, what can they do to ensure that or to the best extent possible, ensure that they are not buying illegal wood?
Yeah, I guess they can trace back, but it's expensive, or it was expensive. I'm not so much into this technology issue. So, I have no idea. Maybe they have now less expensive versions but it's quite complicated. So, what in Europe is done, you only look into those really risky countries, when you want to really, even paperwork, we're still really controlling there as we are looking into those countries that are really risky. And the others, we say, "okay, we assume that there are safe spaces, because there is not." Well, imagine how many people should work there to control whether everything is correct. It's not well, it's not possible.

And when you say the company can trace back the wood, do you feel it's easy today to trace it back to the source?
I think it's doable, but it's too expensive. And in particular, when it comes to the resources, not only the technology but it needs people to do that. And you want to buy wood and you want to use it and you don't want to go back and try to find where it is. And even if you know where it is from, then you don't know exactly whether this is the tree that is maybe in an environment where tenure rights are not really accepted or not. So, it's really complicated. It's hard for companies, I guess to do so. It's not impossible, but it's very cost sensitive, expensive, I guess.

Yeah, that's true. We briefly also talked about RFID tags before. And basically in the ideal world, in the use of, if you use RFID tags you would track or tag each log individually to ensure traceability. Do you see, do you think this is feasible to tag each lock individually? Or do you think this would need to occur on a sample basis?

I have no idea of this very technical question. I have no idea. I just know that many of the trees are well that are logged. And then there is what laundering in some countries and changed with well, legally logged in illegal logged, and it's not as easy. But I've no idea about that. So, the technical questions better asked someone else.

Okay. And then I'm not sure how familiar you are with blockchain. But there has been some talk in other industries such as the beef industry, or soy industry, or diamond or cobalt mining, where they are basically implementing solutions to track the product from the source to consumer. Do you see any potential for this application in the timber industry as well?
Yeah, I guess it might be an opportunity. It is already supposed to be done by some enterprises. I think they already claimed that they do that or that they go or they are going to use it in future. So, it seems to be already an option which is on the market.

Yeah, yeah. There have been some smaller projects that are currently in development, also by the FSC certification body and with some players, but it's still very in the beginning of the development because we're still developing the solutions and making sure it's feasible in the market. I don't know if you want to dive deeper into this topic. But do you see any challenges in implementing such a technology? So, for instance, that it might be difficult to educate the people that actually do the forestry work to implement such a system.
Now, I'm not concerned about the people and the education. I think people can learn the question is whether the technology is too costly, the whole process might be too costly, too complicated. The machines you use or the technique you use, the whatever you need there might be very sophisticated for some countries in a way that it is might be expensive as well to have that and might be expensive to read or sell to make to ensure that it is always on track and that it works. And so I'm not so much concerned about the people but more about the technology and whether that might be feasible and too expensive in the end, if everything comes together because you need to educate the people you need to have the technology, you need to use it as well.

3.3.5 Interview Michael Fabing

Also in terms of confidentiality. Do you probably how is it like do you mind if I then write these things in my paper or do you prefer to talk about the information that you provide me, and these between us?
Well, this information is nothing confidential. If you want to, we have many reports about that talks about the different illegality problem that we have in Peru. So, in many, many reports, even on one of the big problem that we have in Peru is corruption as well, that people are receiving money for allowing the illegal good to go on it to be sold. And so there's a lot of documentation you can find on the internet that talks about a problem that we have in Peru. It's a bit similar to Brazil, because 50% of the country of Peru has the Amazonia. So, 50% are countries that Amazonia and so they have a lot of problem of respecting that.

And I read on the website that your blockchain solution is on a public ledger. So, I was just wondering like how do you or companies that are participating in this solution worried about aspects such as confidentiality? And how do you sort of address this?
So, we don't put everything on the public blockchain. We use a centralized database system and a public blockchain. The reason why we use that is because we have an entire system that actually will help the people, especially the company to get an overview and accounting kind of software, on how the business is run. And the only information that we put on a blockchain is an information about the good. But the

project that the product that we have is basically an application and people have to log in for example, with the telephone number and a password. And these information are not put on a blockchain at all. These are still like everything that is private information will be stored on our private server, as well, because there are worse cases for example, with indigenous that are going against this illegal wood. And during the pandemic, they just got killed. So, some information, so you don't want to have personal information release in the public. Because after that, maybe some bad people will go after the people. So, some information, especially when your information is about personal people. No telephone number, address, name of the person that's stored on a private server, and the information about the wood itself, not the traceability the supply chain per se, it's put on a public blockchain.

What exactly like what type of information is then stored and verified and the blockchain?
We use mostly IPFS currently, because of the energy that you use on, we were thinking to use Ethereum at the beginning for pretty much everything. But then we moved everything to IPFS because of the energy consumption. So, most of the information is stored on the IPFS and the IPFS record is stored on the Ethereum blockchain.

Okay, so this IPFS platform is basically the private server but you use?
No, the IPFS stands for interplanetary file system. So, it's a decentralized system that allows the storage of information on multiple servers. It's not the blockchain per se, in a way like Ethereum does it. It is just a decentralized storage management system. And you store the information on multiple computers and you get a hash of the information that you have stored, especially because we want to store image files that can be up to a megabyte files. And as well, complete data sets of the process of the wood that has been done directly on the IPFS network.

Okay.
I can go more in details of the technicality if you want to continue some documentation about that.

Maybe at a later stage. But so basically, but then like who is sort of involved in this blockchain? So, you're mainly trying to bring more transparency also for the consumers. But then I guess, like the main group that's participating are the companies right?
Currently, because it's a step-by-step process, because one of the issue so we started with having everything on blockchain. But then we discovered that 80% of the country of Peru doesn't have internet connection. So, at this moment as we speak, we have a group of people that are testing the application in the forest and there is no internet connection, there is no cell phone reception for several days. So, we needed to build an application where basically that works offline, where people can document the work, take pictures and everything. And once they connect, once they go back to the city, they have an internet connection, they can send all the information back to the platform. So, one of the biggest issues that we have is not a blockchain problem, it's really about the lack of internet connection in Peru. And the idea after is to put all the information about the wood on the blockchain. And in the future, because it's not the case currently, is that the buyer who wants to buy the wood can just scan a QR code for example, and have all the information about where the wood is coming from. What's the company that deal with it, all the information about the origin of the wood will be available, not only on our platform, but on any blockchain.

Okay, so you basically have an app and this app is on an iPhone, or like a phone?
Yeah, it's so basically, what we have is an app that is to 92% of the people that have a smartphone in Peru, use Android. So, iPhones are not very popular here. And especially when you go to the to the

forest industry, many people don't even have a phone, because there's no cell phone [network]. So, we work with people like the manager of a company to bring a smartphone or a tablet, like an Android tablet because they're cheaper on the field and do the documentation. So, basically yeah, consider some more documentation about, but that's basically our app. So, to make it easy for them, we give them a different stage of where they are. Now, if they want to cut the tree, if they want to do the transportation, the transformation, so there are different models, and they just have to click on it, and do recodification ID. So, they have an entire identification system that exists in the system that they have. Then after that, if they have internet connection that will be able to see the entire history of the tree. So, that's just for demo purpose. And then all they have to do is to ask a question that based on the model now, if you're censoring, if you're cutting the trees that will be different question than if you're transporting. For example, if you transport the wood, you will need to get the license plate of the truck. But the license plate of the truck when you cut the tree, you don't have it. So, the question are a little bit different. And all these information that we collected, which is tax information, and pictures and GPS data are actually stored on the blockchain using IPFS.

Did you just say tax information?
I don't know.

Like the taxes that a company pays?
No, all the information about the tree.

Okay, and then in terms of the data that is collected, you mentioned that you take pictures, what are the pictures of?
The pictures of the tree. So, basically, when they cut a tree, we want to take a picture of before the tree's cut and after the tree's cut.

Okay.
And the reason why we say we take pictures for the documentation purpose as well. And we use as well a GPS data on where the picture was taken.

Okay. So, this isn't, it's a possibility to sort of like, implement fraudulent activities at this point, because you combine it with GPS and pictures, or is there like a way where I don't know I mean, like you have these a VPN, but you can sort of put yourself in a different location, or is this also something you considered in your solution?
No, it is always a possibility. For example, the time where Pokémon GO came online, now people were getting an application that were faking the GPS data. So, people were able to collect the Pokémon Go without actually walking. But it's not, of course everything is hackable. But at least it gives the information about, now it's a step forward because at the moment, people are doing everything with a piece of paper. And so, if you have a GPS that will use, they will enter a system that we call the UTM. So, it's a number that they have to add to that is given by the GPS, if they have a GPS device with them or what they say is "Okay, this is my parcel, this is my field." Now I'm a company, I have a concession and this is my field, and I'm cutting the tree labelled 123 at 50 meter west from the end of my field. So, that's how they measure it.

But then, I mean, you mentioned that obviously, like cutting trees from a location where you're not allowed to cut a tree is one aspect of illegal logging. But in Brazil for instance, you also have the case that you have these forest management plans that allow you to say, maybe cut 10 trees but then instead

you cut more than, like more than the 10 trees. But how do you sort of check that these things don't happen?

We can't really do it. So, what we work, we work with the local authority, which is OSINFOR and SERFOR here in Peru, and they give us a list of all the trees that are approved to be cut. And then using the application, when the person goes online, when the person goes to the field, the application would say, well, this tree, you're too far away from the tree that can be cut. So, we give the information to the people have what they can do what they cannot do. But if someone wants to cut the tree and sell it, not via our app, but to someone else. So, we don't forbid the person if someone wants to do something illegal they were able to do. But what we want to do is, the main purpose of this project is we we're not currently fighting illegal wood logging, what we're doing is we're giving an incentive for the people to do the right thing. So, for example, in Peru many companies, big companies that sells furniture and stuff like this, they don't buy wood in Peru because it's "illegal". So, they prefer to buy the wood in China or not necessarily China but Chile, Colombia, or actually importing woods from North America and Europe. And so if we can convince the big buyers of wood to say, look, you can trust that the wood that you're buying via our platform is 100% legal, that it will be a more formal market. There will be an incentive for people to use our application because at the end, they will make more money because it will have access to the international market, which at the moment they don't have access to.

Okay, but then like, okay, let's say that somebody buys wood from the forest where you have a person taking a picture, but then that wood is processed in a sawmill. And depending on what type of definition you take for illegal logging like where the sawmill also needs to fulfil certain requirements, such as having the required license to operate, do you also check if this is there or do you just basically trace that wood to the buyer, but don't really analyse the legality of players in between?

That's not our job. But we connect directly with the big institution here in Peru that say this company is illegal. And then it will be marked on the application that this guy, this company is doing illegal activity. And then it's up to the buyer to say, "Okay, I'm buying this piece of wood or not". But we are flagging, basically working with the institution to mark some of the. So, first of all, only the companies that are legal will have access to the platform. And if they get in the middle or they get flagged as doing illegal activity, the buyers in real time pretty much in real time working directly with the API from the institution will know that this wood is from illegal origin.

So, wait, so you basically said that companies have to apply to participate? But how do you check, so if you do like a due diligence on the company before accepting them as a member of your blockchain solution?

Correct, but it's not us we do that we have an institution in Peru that is OSINFOR. We have two institutions that is OSINFOR and SERFOR and they are doing the work already.

What are the names of institutions?

It's OSINFOR, and the other one is SERFOR. And so these are the institutions that are giving, that are making sure that this wood is illegal or not illegal and giving the authorization to the company to go into the forest and cut the trees. And as well, they are the ones doing the audit with the police and stuff like this, to make sure that wood is actually really legal. So, they are the one responsible for making that in place. And so we work directly with them.

But when you say audits that they do audits, do they do this like regularly, every month or is it every year or did they?

They do some control where they go to the site and they see “Okay, what are the paper? Are you doing everything you, is every tree getting marked.” So, they're making check audits on a regular basis, I think it would be at least once a year. But then as well, here, we'll have some stories that auditors are getting corrupted and stuff like this. So, there are stories about that as well.

Corruption is a big issue also in Brazil.
Corruption is a big issue. Because now someone's like, “Okay, I have illegal wood, but I have you here give you USD 100 and you close your eyes.” So, it's a big problem here. So, using our application, we cannot fight because we have limited technology, we cannot fight illegal logging, because it's like an accounting software. So, in accounting software, we would give you the tool to the company to see how much wood they are gonna produce. And so it gives you an entire transparency on the accounting software. But if someone has a double bookkeeping, like a black, whatever money box, that is not reported in the accounting software, we cannot do much with that. So, the only thing we can do is using image satellite to say, “Okay, this zone, is this some activity happening, that should not happen. Maybe we should look into that.”

Okay, and then on the website, I also read that you sometimes you track one tree, and then sometimes a batch, make a load of wood. And are there any differences in terms of maybe like digital twins, I don't know if you also use like technologies like RFID, or if it's only like GPS, or what's like the difference from your perspective.
So, the idea of using RFID, or NFC is there because sort of the status that we have at the moment, we have an application and a web application. But that means that there's a lot of manual work that is involved with it. Which means for example, I am doing the wood cutter, I go to the forest, I see a tree, I take a picture, I add to some information, cut the tree, take a picture and add some information and done. But it's still manual work to do. And one of the questions that we ask is what's the species of the wood that you're cutting? There might be some mistakes, what's the volume of wood? There might be some mistakes happening. So, and we still have to trust the user with the form to go to the woods and do the work. So, there are better technology that exists using RFID, or our camera system, that you can actually detect the piece of wood, I have an entire on our blog, I have entire article about the different ways of identifying a piece of wood. But upon that we have here in Peru is, they are currently using paper and pencil to identify the activity. So, the first phase is to digitize this process. And ideally will be to use IoT device that you know that will do the work without the human interference with it. So, using QR code technology will be one of the solution that is simple to use. Currently, we are trying with this ID tag.

Okay, it's an RFID tag?
That's a QR code tag. So, this QR code tag, they just have to put it on the piece of wood, scan it and add information. And then as long as he goes along the wood, people will be able to identify it very quickly. But the problem happens when you have to transform the wood, because you go from a big trees to small pieces of wood. And then the question is like, well, how do you track all the different pieces of wood? So, from a software point of view, it's not a problem. But from a human point of view, you're not expecting someone to scan and print 100000s of QR code on each wood. So, they have a system in Peru where they say “okay, this is the wood that came with this identification number. And then it was cut in 100 pieces of wood. And these 100 pieces of wood will have a unique identification number that is ABC for example. So, they have different way of identifying a piece of wood.

But then wait, so then if you have 100 pieces of wood, there's not really a digital twin or a box with a QR code and then you have like those 100 pieces inside. How do you make sure that it's not like mixed in this process?
The only way we make sure is about the volume. So, if you have 100 cubic metres of wood, you cannot have 150 cubic meters of wood coming out. So, the volume and the weight is the only thing that we can have as a tangible. So, if someone has like 100 cubic metre of wood, he cannot sell more than 100 cubic metre wood on the market. Yeah, more or less 10% because now the wood can get water as they become wet. But that's the idea actually.

Okay. But then if I understood correctly, you usually for logs, you do tag or are trying to tag each individual log?
Correct, for the big pieces of wood, yes.

And I mean like, that's quite a lot of manual work now, is this something that's being accepted by companies? But we have to tag each or like make this process with each tree.
While for the trees itself, yes, is not a problem. So, currently at the moment they are marking, they're putting a number. And then for example, so they have an entire nomenclature that exists. So, let's say we have a tree, which is called so they have actually a logic. So, each tree has three numbers, the first number is the numbers of the parcel of the field. The second one is the part of the section of the field, and the third one is the tree number. And after that when it gets cut, it will become for example, you have a tree called 511. And when you get cut, the first trunk that would be cut would be called ABC, so they use letter in that case. I can send you some documentation, if you want to talk about the identification, because it becomes quite complex.

Yes, it would be great if you could send me some additional information.
So, they have already a system in place in Peru, where they you know, just by knowing the numbers of the wood, you know exactly where is it from. And like it's part of, now three other one that exists, they have an entire system that exists for that. The information I have is in Spanish.

No worries, I can use online translators.
Okay, so they have an entire system that exists in place to identify a piece of wood. But then when it goes to the transformation, and it gets cut in small pieces, then is a bit more you can't face exactly each piece because it will be too complicated. Or in that way, but there will be an investment from the company is to have an RFID process because an RFID reader can read up to 100 pieces or 100 tags per minute. So, then you will be able to do something like this. But there's a technology, an investment that you have to do to identify each single piece of wood.

And I guess, like the RFID tags need to be attached, right?
Correct.

And also when the pieces are really small, it doesn't really work, right?
Well, there is different technology that exists in the RFID tag, some of them work without internet, without electricity, some of them need electricity, but all of them need to be programmed. So, these are learning curve, now from someone who is trained to cut wood. Now he has to learn how to program an RFID tag.

And then maybe back to the point that you mentioned that you sort of need to trust that person in the beginning to enter correct data. I mean, like this is also a point that I found in literature and referred to as the first mile or "Garbage in, garbage out" problem.
Correct.

Besides that audit that your partner organizations do on a regular basis, is there anything else that you can do or are doing, or maybe you want to do in the future to address this problem.
So, what we do is so for example, when you have a company, they say because they work with you a lot on stage, because of the season, I think it is very similar to Brazil. So, they go to the forest, and as a company, they go to a forest and they start cutting the wood. And they do the work and do the documentation of the work. Then you have another company that comes in, they take the wood out of the forest, and then they bring it to the sawmill. And all of them have to do the documentation. And the idea is we are matching the information that you're giving us. So, for example, if someone say "I have a tree of 50 cubic meter of wood" and the guys transporting is like "Well, I don't have 50 cubic meter of wood, I only have 40 cubic meter of wood." So, then you can say "okay, there's like someone is lying in this history." So, what we try to do is to try to connect the dots based on the information that people are entering.

And in this scenario, what would happen with the blockchain? I guess they wouldn't enter that or like create a new block for that transaction. If it's 50 and 40 cubic meters.
No, we there, we don't have a smart contract in that case for example, for the payment transfer, but we record every single information So, if someone makes a mistake is like, "Damn, I made a mistake that's not this type of wood, it's another piece of tree." It's not a problem, you just create a new record of the information. And that will be seen on a blockchain that you made a new record that was a mistake. But we record every single transaction on the blockchain.

If this occurs, do you as a team automatically get a notification that something doesn't add up? Or do you only see this problem when you go and check the transaction?
No, we see it in real time, when something happened which is the mismatch. At the moment we are not making we are not the police but that's something that we can transfer directly to the authority. "Look, this is something that just happened. Maybe you should investigate, how come someone say he receive a piece of wood of this and the other guy say receive something else." And the idea is well is the payment system. But that's more in the future that we want to automate the payment system. If the information is matching, automatically the money will be paid to the person. But that's only when a case is matching, and we're still learning about how much mistakes can we allow? Because things can happen on just calculating a volume of wood. They have different formula to calculate the volume of wood. So, the estimation that you have the first time is very different than the one that you receive coming out of the forest. So, we'll still be learning in that way to understand what's really happening, and how we can actually solidify the information.

If such a situation occurs, do you say to the company, "hey, like something doesn't add up, can you check with each other?"
Correct, that's the idea. Yes.

Perfect.
Because that's what a company wants to know is like, who are the good provider? Who are the bad provider? Who are the ones that are trying to scam me? And who are the ones who are doing a good

job? So, if the person is doing a good job, he should be rewarded more than someone who's trying to scam me. Now if someone said, "Oh look, I'm sending you plywood 100 cubic meter," and that was the guy receive it. It's like, yeah, "but 100 cubic meter of plywood is actually garbage, we can just use it for paper. I don't want to pay the same price." So, because they have a history trail of everything that has been done, they can follow up about who are the bad apples and who the good ones. Which at the moment, they have no oversight at all.

So, I see that our time is up. So, I'm not sure like, is this like an introduction call and you want to schedule another call or do you have time for more questions in this call?
I have more, a little bit more time as well. If you want, I will send you some information if you're interested. We have a blog on the WTP project where you can get a lot of information about different identification system that we have, which is the one of the biggest problem, because now identifying 100 pieces of wood will be manually very difficult or 1,000 for example. So, the technology that exists, and I can send you as well, the nomenclature that we use in Peru that tells us how should wood be identified based on which stage they are.

Yeah, perfect. I happened to look into more information about this project. That's very helpful too, because I think it's a very similar case, illegal logging in Peru and I think solutions will probably lie in a similar direction.
It is a big problem. And it's a bit sad for example, in Peru that 3.50% of the world forest is based in Peru. But Peru only exports 0.05% of the wood. There is a huge loss between what they could make in terms of money and resource and what actually happened in because of the corruption and the illegal wood logging.

Yeah I mean, it's also the same case in Brazil. I mean, like not exact the numbers of course, but similar kind of.
Chile a bit different because Chile use mostly plantations. So, they know what they're producing. So, Chile is a bit different.

Okay, perfect. So, you mentioned the payment system that you wanted to put this in the solution at one point in time. And as of now, like how willing are companies to participate in this blockchain solution provided by you? Do you see some resistance or do you see a lot of willingness to participate?
Depend on who you're talking to. But so far, the feedback that we receive was pretty welcome. Because one of the things that they want to do is to improve their productivity that they have, but they don't have currently in Peru. The big companies, they want to have access to international market, which currently they don't have access to. So, it's like I can sell the product, if I will be able to sell my wood in the United States, Europe, or even to big companies in South America. I'm all in. But currently, I can't because I don't have access because nobody wants to trade with me. So, that would be a big advantage for them. The biggest problem that we have is the technological, it's not a technological but the adoption problem. For example, 70% of the people in Peru don't have a bank account. So, we talk about cryptocurrency, Bitcoins and stuff it is how about we can transfer the money directly to them using cryptocurrency. Well, people love to have cash, so the adoption to transfer them to say, "Look, you're not getting cash in paper anymore, but you receive it directly on your phone, because you've done your work." There's still an education process that need to happen.

But it doesn't necessarily have to be via cryptocurrencies, the payment process, can't you still keep the same payment processes before?
No, we work as well with banks. So, we have a local bank here, BCP. But the problem is that people don't like banks, because of the simple reason that they will have to start to pay tax. And that's why they prefer cash because it's untraceable.

So, basically, currently the payment in the forest industry in Peru is basically they get cash directly. And they don't even want to do a bank account.
Correct.

Okay,
Well, I cannot say, no, not everyone works like this.

From your experience.
Yeah, there are people like this. So, who has a lot of cash based economy, where they basically just knock people off to get their money, because it's money that they have in hand, and the government doesn't have any access to any of it.

But then how do you educate people or like, show them that this is also a solution?
Well, it's like Peru has about 100,000 company that work in wood industry, and we will not be able to have the 100,000 companies using the software tomorrow. So, we work with the company that are actually interested in that, the companies that do the thing according to the law and respect everything. So, and then we will want to do is like, "if you use our application, and you get all the certification from the authority by using our application, you will be able to sell your wood to international market at a higher price" and that will be the incentive.

Is that really possible that we can sell it at a higher price? If from your experience?
Yeah, we talked to a few buyers of wood. And they say, they pretend to buy wood from foreign country up to 20 to 30% more expensive than what that wood that they could get in Peru. But they don't buy in Peru because of illegal wood logging. As well, international buyer, because we have beautiful pieces of wood in the Amazonian and Peru, international buyer would pay a lot of money for having access to these pieces of wood.

Are there other incentives that companies have, besides being able to sell it at a higher price?
The transparency, so they will be able to see how well the company is getting operated. Now once you have an accounting software, you know how much money you make, how much money you spent, who is your best provider, who is the worst provider. So, they will have a better overview on how the business is run. So, just having this overview will be better for them. It was like implementing an accounting software for them.

Okay, but then basically like we don't really have a lot of additional costs, because we don't need to because you're providing the blockchain solution, so they don't have any development costs on their side?
Correct. So, we're still working with the government because the government ideally would be that there will be a program that will be funded by the government. And the government will give this tool for free. So, just to have clarity on it. But for reports, company will be able to pay for it because they will

have an oversight on how well the business is run. And if they can improve the efficiency and productivity that means more money in the pocket for them.

But then, do they have any costs or like what cost factors do they or like what do they need to provide, or are there any costs that are incurred for them to participate except maybe getting like the smartphones and tablets required to sort of read the QR codes?
So, at the moment, we will doing the testing with them to understand a user experience, what are the issues now, the fact that they don't have internet connection for weeks. Also, we're still figuring out that, but the idea is to go to a Software as a Service [SaaS] model, where basically they will pay like a monthly fee to have access to the software and get training and stuff like this. So, similar to Salesforce or other big companies to have like a SaaS model where they pay for a monthly fee, depending on how many users they have.

Users so?
So, a bigger company will pay more than a smaller company.

So, you mean people who are able to register?
Correct.

Okay, interesting.
So, what we want is to have the tool for that will help the traceability of the wood that will be showing the origin of the wood for free. But the entire, how well you're operating your company will be based on a monthly fee. That's what we're looking for. It's not 100% done yet.

Okay, and then, but if a company were to develop a blockchain solution for their own supply chain, do you have any idea how much that would approximately cost for such a company?
It depends on how complex your product will be. But so of course, like DFSC is working on a blockchain technology as well. The idea is just like if you hire a company to build a software just for you, or if you went to software, usually it's much, much cheaper to rent a piece of software than building the software for you. And as while we use a lot of open source project behind it. So, from a cost point of view, it doesn't really make sense for a company to do it by themselves. Especially if after we are getting approved by the government. And the government of Peru say, this is the solution we should use in the future because we trust the platform.

Interesting, but then this would only work if you have the willingness of the government to collaborate.
There are initiatives. So, the government has to do something in that way because of the international market demand, so they didn't set up on what technology they will use. But they are kind of mandated by the international organization to provide us a framework for the traceability of wood. It will that be only software I don't think so, but the software will be a piece of it.

And that you mentioned before, let's take a few steps back that you had that adoption problem that people don't really want to accept the money. Did you have any other problems or challenges that you faced when you developed and implemented the blockchain solution?
The blockchain itself, well, of course people are scared about the fact that if they do mistakes, it will appear on a blockchain. Because once it's stored in the blockchain, you can't change it. So, that was a worry for them. But basically, the blockchain is not really the problem. The problem that they have that

we are facing is mostly the fact that there is no internet connection, the fact that people don't use smartphones, especially in the forest. So, this education that needs to happen, like money to transfer by paper money. So, that's the kind of stuff that still need to be happen, the education process needs to be done.

But then who is responsible for this education process? Is it you or is it your partner or is it you together?

So, we work with different institution here in Peru. One of the institution Cite Florestal. So, Peru has a centre of competencies where their job is to teach the best technologies and new technology and a new way of doing things to the people. So, they teach people how to do furniture in a proper way, I would say. What technology they can use to build furniture property. And as well, we have Cite Florestal which is there to teach basically the people about how to do the job properly. So, we have set of excellent stuff out there and that we're working with to teach people how to use the application and we work directly with them in order to develop the system. I should put you on a team, so you can learn a lot of things.

Yeah, I love like, this is like an area I didn't really know much before I started my thesis on, so it's a lot to learn. But yeah, it's very interesting. So, basically you mentioned that companies are participating to also increase productivity? In what sense can they increase productivity?

In a way to say for example, like so for example in Peru, you don't have one company that can own all the land. So, they have to work with local producer, because they have an agricultural reform that was done in the 80s, 90s, where basically they were giving like, because before they had like some kind of a feudal system, where you had like one guy that was owning all the land, and the worker that was working for them didn't own the land at all. So, then they had like an agro reform that happened, the 80s where you say, everyone who is working the land will be able to get his ownership of the land. And so now, a company who wants to buy wood, will need to work with many, many different partners that will cut the wood and provide to them. And so one of the plan that they have, they receive the wood, but they don't necessarily know the quality of the wood. So, there's a lot of information that they don't have, a lot of transparency that they don't have. So, one of the ideas, one of the advantage of our tool is that they will be able to see who are the suppliers that are providing them good wood, good quality, and who are the one that are not providing good wood.

But then only their direct, we can only see our direct suppliers, or can they also see the suppliers before their supplier?

Yeah, that's the beauty of supply chain of blockchain, you can see the entire history.

Yeah, but it depends on how you program it, right? Because like, depending on that blockchain solution, you can only, companies can only see from where it came from, but they don't see or know the names of the companies that were in between.

That's what we use the hybrid system, where someone, I will have to do a demonstration of the application another time. Where basically, the person will be able to see all the company that involve and they can see which company are illegal or not illegal. So, they will be able to see the entire history of the wood, but as well from all the companies that are intervening in that. So, we are mixing information that is coming from our centralized database that are private information, such as your name, your company, address, and so on. But as well, the information of the piece of wood itself will be on a blockchain.

Yeah, quick, when you say database, do you mean the IPFS system or is this another database?
No, we have an almost a MySQL database for managing user account and company profiles.

That this is on, like only you guys have access to this I guess?
That's the advantage of our platform.

Okay, so can I maybe have like a short summary of the different databases or servers that you have? So, you have the app that's on the phone of a smartphone of the people?
Correct. So, the app can be downloaded on the Google Play store. And the app is mostly for people who have no internet connection.

Yeah, and then you have the IPFS system. And they also store data?
Correct. So, we have a native application that is available as an application for Android that you can download from the Google Play Store. We have a web application, which is a PWA, which is a progressive web application that people can use on the form without installing anything, but they just need an internet connection. All of it are connected to a centralized MySQL Database. And MySQL Database is just making sure that the people like for the entire authentication on based on my telephone number and my password, know who I am or about my telephone credential, I know who I am. So, the entire authentication is done by a centralized server, MySQL Database and then the information about the wood is copied over to an IPFS network. And as well as the Ethereum blockchain.

How many databases do you have in total?
Three Databases.

Three databases, okay.
So, one centralized, one is IPFS and one is an Ethereum.

Okay. Thanks for clarifying that.
The reason is because we try to use the best technology for what we need to do know like, yes, people can start an Ethereum wallet. But teaching people how to use an Ethereum, how to insert an Ethereum wallet would be very complicated. So, we want to make it simple for the end user.

Okay, but then if I understand correctly as a company, I would have access to that the app that you can download on the phone, it's specifically for the cases where you don't have internet. And then you also have that app but from the IPFS system, but you can also download access for your smartphone. So, you can access two different things?
Correct, the IPFS is a decentralized system. So, anyone who has access to the IPFS network will have access to the information, whatever, you just need to know the hash. So, it's basically like the Ethereum network. As long as you know the hash, you can retrieve the information that you're looking for.

Okay, but what information can everybody access to then? So, supplier, wood information?
The wood, yeah. So, the wood industry, picture of the tree, and other information, the data concerning the wood will be accessible on the IPFS network.

Okay, perfect.
But the private information is on a centralized database.

Yeah, but only you have access to.
Yeah, that's something we can work with the institution with an API and stuff. So, these are the kind of stuff and that's where basically, the incentive of the person is like, well, I can use only IPFS or but if you use our application, you will have access to the information, the private information of the company, that we work in collaboration with the public institution. So, it's a bit complex.

Okay, and then quickly, also to summarize again, but I understood correctly. So, as of now, the digital twin that you have is basically image with a smartphone and GPS tracker. But you don't use RFID tags, or barcodes or QR codes. Those are things that you're looking into for a future.
Yeah, the only thing that we use is this QR code. I can take it out of the plastic.

And this is attached to the tree?
Correct.

And it gets detached once it gets processed, I guess.
Correct. And then that can be reused as an easy identification system. There are different identification system that exist, there's a technology that still needs to happen. I've listed on the blog, there's a big list of all the different identification system, because the idea is to be able to identify a piece of wood without human interaction. So, the less human interaction, the better it is. But when you have no internet connection, and the cost of these tools or maybe will be more expensive. No, you have to see what makes economical sense.

And did you ever hear or consider using scientific methods like DNA technology?
Yeah, it's on our radar. If you have someone in a DNA technology, that would be great. So, we're using like, so there is a company that exists using high-definition camera that they can see for example, the quality of the wood. And that gives us some kind of a fingerprint of what the wood is, and they could basically identify to a certain extent, to identify the piece of wood actually. But they are, it's very expensive that works in labs. So, not in the field, currently. The drone system, they're using infrared technology as well. There's different markings that exists, but at the moment we work with what they currently use in place. But for sure, DNA technology will be great. It is just, we're not there yet.

Yeah, I think like the technology itself, isn't there yet, because it's still very expensive. And you can only do it on sample base, but I think it's getting cheaper and cheaper.
So, in RFID there are nails that exist with an RFID chip that you just put on under the tree, and then you program it, and that's all you have to do. But they have a cost you know, there's a cost of $1. So, what's a dollar? but here in Peru it might be a lot of money. So, now there's a lot of things that there's a lot of work that needs to be done in the future. I agree with that. There's a lot of technology that are really to cool to work with. But the reality of living here in Peru, where people don't have internet connection, there's no cell phone reception in many, many places. It's a little bit different you know.

Absolutely.

Follow-up Interview
[Michael Fabing offered to present the company presentation of WTP]
So, basically, to do the architecture that we have is basically the user, either there was the original application. So, the user connects to a web application or native mobile application, then it goes to a node JS server. And for node JS, it stores information into, we used to use big chain DB before. It was

an interesting project that was coming out of Berlin. But basically, the project is different. And so we're using Ethereum and IPFS currently, for storing the information on the block chain. That's the current architecture that we use now. So, we have all the users are connected to the system, using either a web application or a native Android application. The system has a centralized database for managing all of the user credential, username, password private information, company names. And then it gets stored into an Ethereum blockchain and IPFS. For all the information that is about the wood itself, the traceability of the wood.

Okay. Wait, but then where is this user's company management system?
No. So, we use a we call it we call it a multi-user, multi-tenant system. So, basically, it's like a Facebook or LinkedIn, you connect on LinkedIn profile, but LinkedIn managing billions of users. So, to make it easy for the user, because, for example, if you work with an Ethereum block chain, you need to set up wallets. And teaching people in Peru who don't have a bank account how to set up an Ethereum wallet will be a little bit complicated. So, we decided to go with a centralized system first, that manage all the identification system. So, basically, the people when they have to log in, they will just have to use a telephone number that is validated by the SMS. As well in Peru, for example, we have a lot of people that do spoofing and scamming. So, they can create hundreds of 1000s of fake email address. But a telephone number is at least here in Peru telephone number is registered to your name using your identification number. So, to avoid, for example, to fight crime, that people steal phone and then buy a cell phone that are actually stolen, the government is actually requiring every company that sells cell phone, especially cell phone numbers, that the number of the telephone number has to be linked directly to your what we call here, to DNI which is like your identification number. And so, in order for us to make sure that the people are not scamming the system, we ask the user to login with other telephone number using the telephone number.

Okay.
And that management system is managed by a centralized database. In that case, we're using My SQL that is connecting to different service provider to send the SMS to verify that my name Michael Fabing, belongs to this telephone number and no one else. So, it's just to make sure that the user is who they are. Like in Peru we have a lot of problems that people try to scam, especially if you can there's a lot of history, a lot of stories during the pandemic that people were saying like I need oxygen balloon of oxygen and people were selling them for $5,000. And they're just giving back a bottle. Those are completely empty, not have any oxygen. And so, there's a lot of people scamming. A scam is a big problem here in Peru. So, that's what we're using the telephone number to verify that the user is who they are and they cannot create a fake email address.

Okay. But is this also a problem in the timber industry, scamming? Or is it more like a general problem, and you're trying to tackle with using this identification over the telephone?
No, it is a big problem in the in the wood industry. So, I've seen reports and I talked to people that says, for example, that you are allowed to cut 1,000 cubic meters of wood, and people will be able to produce exactly 1,000 cubic meters of wood. Why? Because you're just putting wood from different places to gather paper, in on the traceability system that they have currently will be tampered or modified. So, tampering of information is a very big thing here in Peru. That's why they have a very difficult organization or the government has a lot of checks. For example, if you sign a contract, when I bought my house, I needed to put my signature my fingerprint signature on each page when signing.

My gosh.

And in my contract, I have to put the name, my full name, birth name, where I was born, my passport number and my fingerprint. So, they do a lot of checks. If you signed a contract is the same, like basically anytime you have to sign something, you have to put your fingerprint you have to provide your DNI, you have to have a document that is certified by a notary, that this document was not forged and stuff like this. So, there's a lot of information tampering, it's a big problem here.

Okay.
And that's the vision on the long term. So, we have a principal platform in the centre that currently works with a web application and a mobile application. From the centralized application we connect some information to a centralized database, everything that is private information, and everything that is related to the wood itself will be stored directly on block chain. In our case, we use IPFS and Ethereum. We are thinking in the future as well connecting with satellite images. So, we have a contract with the European Space Agency to get satellite images know when to get precise information to see if this zone can be for example deforested or not.

More, because I mean, like in logging, you sometimes have a problem that it's not deforestation, but like illegal logging of selected trees. Can this also be identified?
The ideal will be like this, yes, we collect the information reported on the field by the user. And we are basically using the Google Maps, the Google street view, from the car view. But we can integrate with space agency, satellite images. So, currently, we use Google Images, but they're not as accurate, and not as up to date. So, we're working with the European Space Agency to get more up to date satellite images. One of the thing is using RFID. So, we use these kind of metal tags, currently for an easier identification of a piece of wood. But we can use as well RFID that you can programme, put it in directly into the piece of wood. And then using a machine, you don't necessarily need to have like an input from the user with a cell phone. But using an RFID machine like an Arduino, an ESP 32, you can actually collect information automatically and faster than people doing a photo of it.

Okay. And then drones, how are you thinking of using drones?
So, we talked to a companies that do auditing about drones, so satellite images are great, but they're still far away. So, there's a company that do drone flying over certain spaces, and they do images, but the images that they will have is much more accurate and much more precise. And so, we want to integrate not only the satellite images, which come with the GPS, but as well, working with a local company that do drone imagery from different sector to get more defined information about, you know, what's their species of the tree. How high are the trees to get more information about that. The Google or the satellite images will give us information about what zone should be protected, from what zone has been illegally logged. But the drone images will give us information about what kind of trees, the type of trees, the size of the trees, things that you can't get from satellite images.

And what's his company called? But does this drone take images?
I don't have it. We talked to them like two weeks or two months ago, I can give you the information of them. There are a few companies actually to do drone images for preservation of forestry.

But this is, is this affordable for company?
No, we try to work with the government to integrate this technology directly with the government. So, the government because at the end, the government has to make a decision about what trees can be cut, what trees should be protected. And that will help them to make a better-informed decision. Now, if they can say, "Okay, this is a satellite images, and as you can see, there was illegal logging happening

in this region." And then you can send a drone that will cover different surfaces as like, "Okay, this company wants to cut the trees in the next three months. So, how about we send a drone over the field, and he will make an imagery of the field and you know, what kind of species exist without sending someone on site and verifying every tree." So, we want to work with the government to make that in place.

Okay, I see. Then, you just mentioned that the government basically knows which tree is legal and which tree isn't? Is it the individual trees or a zone? Because also last time, basically, you told me that OSINFOR gives you basically a list of trees that are approved?

Yeah, so basically, So, the way it works is, so people have a field, like a forest field. And they do an inventory based on auditing, so they send people on the field to make an audit, but as well, they have they call it Censo de Florestal, which are basically call it engineers, basically people going through the field and making an inventory of the trees that they have, that is in the field and the trees that they want to cut. And based on this report, that can be falsified as well, that's why the drone, image will be better. But based on this report, they make a decision about "Okay, for this year, because you have a surplus of this kind of tree, so you can cut these amount of tree of these pieces. But based on this report, we should protect these trees because they are no, we need to keep the ecosystem up and running." So, they have an entire system and entire policies that they have in place. That is based on a report made on the field. And so having drone imagery will give them a faster overview of what's actually happening. And as well, the documentation and the report that they are doing will not be tampered.

I see. Okay.

So, it is complex. It is a highly procedural and a complex system to have an understanding and oversight on what's the forest looks like. And based on this report, they will make a decision about what tree should be cut. Because they want to keep sure that the ecosystem will be up and running. And that the trees they are cutting are of age and not the young one. And so, this entire I don't know, it details, all this information. But that's basically the overall work of OSINFOR to give you the green light for the wood cutter to cut a certain amount of trees.

Okay.

So, all these tools are there to make better informed decision. And because they are made by machines know when a drone fly over, that he sends in information. And so there's no middleman or person that will be like, "Hey, how about I give you USD 1,000 for falsifying the report, and I can cut more than I should?"

Yeah.

Because these are things that are kind of current here in Peru. So, that's basically the vision in the future. So, we just want to integrate with different technology solution to do as much automatic processing of the information and not relying on the people on the site to do the work.

Quick question about the new satellite systems: Would they be something that's ongoing? Or would they just be used like in specific points of time?

So, the European Space Agency, they have satellite that goes over the region all the time, so every month or something like this, so we will update the image automatically to the latest version of it is as google satellite images by Google satellite can be a six month or a year old but when you use the European Space Agency they have more up to date data. And so, we will always use the most up to date data. So,

that means that people can make a decision based on the data that is three months old. And a week after that we received the ultimate version that was just scanned a week ago.

Then okay, let's say this is, automatically updated after each month. And then let's say that during January, like during mid-January, illegal logging happened, and it's caught on satellite. So, basically, you can see it, will this be automatically flagged or only if somebody analyses this data?
So, the automatic is a bit tricky at the moment, because we need to use machine learning. So, at the moment, we were not thinking about automation of it. But I know there's a company that is trying to do that automatically. And they use machine learning, to identify the risk of deforestation in the future.

Which company does that, do you know that?
I don't know I will, I can send you the information about that. We were talking a few years ago with a Brazilian company that tried to predict the deforestation that will happen in the future, based on satellite images that they have currently. So, they have a prediction algorithm. So, for example, what they predict is like, deforestation happens a lot, when, for example, they can see that was a camp of mining camp was built recently. And for example, if someone will decide, we'll build for a farm or a house, then deforestation will happen in this neighbourhood very quickly after. So, based on different events, they can predict where the deforestation will happen in the future.

Yeah, because actually, I talked to a company they're called OpenSC, but they don't have anything in the timber industry yet. But they basically use machine learning to combine all the data and to sort of verify or like increase the accuracy, and in their case of tuna, whether it's fished legally or not, by combining different data sources, and just trying to understand if this would also be possible for the timber industry.
Yeah, that's, there's definitely company working with this. And so collecting working with them and collecting this information with them will help basically the local government to make a better informed decision. That is not relying on the people outside making reports. But basically getting information from satellite images, not only that it will be cheaper as well, because flying a drone will be cheaper than sending a team of people going to the forest and making a marking, but as well the information will not be tampered, because well you could but it's like you know, it's less likely to tamper this information. And so, we want to work with these different providers and integrate this information with our application to give an options to the regulator, and the institution that we have here to make a better informed decision about what tree to be cut. And from that, the user because currently one of the problems that they have, we were just doing a test two weeks ago, that people when they go on site, they have absolutely no internet connection at all. Which means as well that they don't even use Google Maps because there's no internet connection, so they don't know where they are. So, what we want to do is to give them with a GPS because everyone has a mobile phone. So, with a GPS data, you can actually find a tree that you want to cut easily. And get all the information about can you cut the trees or not. So, they are we're building a little bit the application to be able to work completely without any internet connection.

So, then, okay, so basically, if we have a logger who's going to cut a tree with an app in the future, if you solve these issues with like the internet connection, he could walk around the forest and then stand in front of a tree and the know if he's allowed to harvest that tree or not.
Correct.

You overlap it with I guess a GPS coordinates that you get from the government that says "Okay, here, this is this area's legal or here you can legally harvest."
Correct. So, that's the idea of, for example, we use a system that we call geo fencing. So, because at the moment, for example, when people want to cut the tree, they have it on an Excel spreadsheet. It will be written while the tree is about 150-meter east of the end of your field, 120-meter north of the end of the field. So, that's how they guess, are they use another system, if they have a GPS system, they use a UTM meter. So, they give you like the GPS coordinate, and they have to go there. But they still have to find a way and finding a way is actually a little bit of a complicated route. So, we want to do that everything inside of the application itself. And as soon as, for example, the company say so because at the moment, the way it works is that people are going outside and making all the reports, send the Excel spreadsheet then they receive a feedback back. So, all of it could be done directly via the application.

Perfect. And I see that here you also mentioned sensors and cameras, how would this be used?
So, the cameras are basically at the moment of people using the photo of the trees, but they are technology. One of the biggest problem that we have is the identification of a piece of wood, that is complex. So, at the moment, we rely on a lot on the people using the nomenclature, where basically a tree that is cut has to have a number. And then when he gets cut, he has different number, and so on. So, basically, they have an entire system of like, the tree belongs to the company one, in the field number five in the section number three, that's the tree, tree number five based on the Excel spreadsheet, and then what is cut, it's to the cutting number A. And so they have a number that that only goes longer based on how many times to cut the tree get cut. But people can make mistakes. And as well, they have to specify what kind of species of the tree can be done, it will be cut, and people can make mistakes. So, they are a company that use complex cameras to be able to figure out what species of the tree they're doing based, for example, on the leaves, shapes and the tree shapes. It works a little bit more in North America and Europe because the trees are a bit more homogeneous. When South America the trees will be different, it will be more complex. But basically the idea is having an application that when you see it on your phone, you can recognize your tree based on the pictures.

Okay.
So, it might be that people will have to take a leaf of the tree, and then a piece of the tree and the software will be able to recognize the species of the tree.

And this software already exists or is it in development?
That is early development. So, there are few companies that work mostly in North America and Europe because the species of the tree are very different and very unique. South America is bit more complex. So, that's we're talking about software that with cutting edge technology that might actually be used in production in five or 10 years.

Okay. And the sensors.
So, that will be the kind of sensor then the other one is using infrared system where you can actually detect everyone, so they are like infrared sensor that can actually measure based on the heat that a tree emit, and can identify basically, what kind of tree do you have to deal with. It's like a facial recognition. So, people can recognize, or I can identify you just based on the heat that you emit from your face. They are more or less accurate because here we want more to see what kind of volume they have and what's the species of the trees, each tree can emit a different radiation system or radiation map that can help to identify the species of a tree. But this is more in the future because that means investment in technology and are so technology exists it needs to be developed. We need to work with partnership. I know for

example, IBM in Switzerland was working on something called a crypto anchor that can define basically the origin of a piece of gold based on high density camera. It's IBM crypto anchor, there's a guy from Switzerland that is working on it. And so these are the kind of technology that we want to work with partner with companies, if they have technology that can help it, that's great. We are not necessarily the guy doing it. Because our technology and our expertise is not into building this kind of stuff. But these are the companies that we want to partner to bring you all in platform to help basically the automation of recognizing of trees, and making sure that the trees are getting cut, or actually legal. So, that's the long-term platform of it. The current platform, what we have is basically different platform. So, we have a platform that is used by the company itself, we have a platform that is used, for example, for the end user. So, the idea is, if an end user sees a furniture, you will scan a QR code, and you can see the entire history of the furniture and from where the tree is coming from. So, that's the end customer, the admin is the part of the company that can actually manage the employees and who can do reporting for them. But as well have an oversight about how efficient the company is getting run into in terms of production of trees. And then we have integration that works directly with public institutions such as OSINFOR and SERFOR, where SERFOR and OSINFOR can feed us information directly. Now, for example, this is the list of all the trees of all the company that are considered legal. And these are the lists of the company that are considered illegal. So, it's a list that they publish every month, that can be integrated directly with our platform. And so when a buyer wants to buy wood from a farmer provider, he can see more or less in real time that one of the member of the producer of the tree is considered illegal based on the authority feedback.

Who is the authority? It's basically your, your company, or is it? Or is it defined within the members of the supply chain?

So, what do we do we work with institution of Peru. So, one of the institutions is called SERFOR therefore, and sell for is the one that is publishing a list of illegal, has a list of the company that they consider legal and the list of company that they considered illegal, based on different criteria, one of them could be what we discovered that this company is using kids for doing the work, or they're not paying the employees or whatsoever. So, they make a list every month of the company that are listed, legal, and the list of companies that are considered illegal. And, and we integrate this list directly in our application. So, when the buyer wants to buy wood, from a specific provider, he can see that all the people all the company that are involved into the supply chain, are considered legal by the institution. And as well, we have a sensor, which is basically helping is a media application that help the government and in a company to know what to make an inventory of the potential of the trees that they have currently. And that can be working in partnership with a drone company. It's a big, big system that we're building in place.

Definitely.

So, that's the entire workflow that we have. So, the workflow starts from the organization that is actually making the inventory of the forest, I can send you a high definition of it if you want to. So, it started with the people that are doing an inventory of what's happening in the forest, how many trees and what kind of trees and what's the volume of the tree based on the different parcel of wood, to the people actually doing the cutting, getting the authorization of it to the actual entire supply chain of cutting the tree, transporting the tree, transforming the tree, and so on. So, that's the entire supply chain that we have in our platform. So, the platform itself, we try to make it as simple as possible. So, it is actually in Spanish. So, everyone can have a system where they can scan a QR code if they have a security a QR code, as well. To make it simple. I would just log in. To make it simple. If people need to generate an identification system, we have an Identification System generator. So, all they have to do is like we have

a new tree, I need to generate an identification system. So, I'll just pick a button, I get a QR code with a number. And I can print this information directly on the tree below the piece of wood.

You can print it on the tree?
Of course you need a printer. But basically the idea will be to print it or to generate a QR code that you can print it and stick it on the QR code on the tree. That's what we do as well. If people don't want to print it, they can use these metal tags that are pre implemented. And then they just have to activate them by telling like this number, what's the number, 141 belongs to this tree in this forest. So, the person that goes into the forest to cut the tree, just have to scan the QR code and they have the entire information, are they able to be cut, and so on.

And do you use this instead of identification marks that you can paint on the trees or in addition to them?
It, an addition, So, it's an alternative. We have as well like a volume calculator based on different so based on the step on where you are, you have different formula of calculating the volume of wood. So, these are a quick tool that we gave to our user to be able to calculate a piece of wood, a volume of wood based on the different steps that they're in. But basically what they have to do so. So, the application, what you can see is a workflow here. And what we do is basically something that is very similar to the workflow. So, the first thing that we have is a sense of just putting my Wi Fi on so you have a better precision. So, basically, they have to say what's the status of the operation that you're in. So, it starts by the first status is about making the inventory. So, when someone makes an inventory, they just have a list, the company has a list of all the trees that they have in the inventory. And they can add a tree directly to the inventory. And then they enter the GPS. So, they're just going to click on a button to get the GPS address. So, they know exactly where they are. They add a picture. And they enter some information about the tree itself. Yeah. So, we so we work directly with the organization that we have here in Peru about all the questions that they have to enter. And the question that are nice to have, but not necessarily required. And once that's done, they just send the information. And it's stored into the system. Once they go to the next stage, they go to, for example, cutting the tree. So, that's where the system becomes a little bit complex. So, we give the opportunity as a user that belongs to a company to have an oversight of all the trees that they have in the inventory. So, they just have to say, "Okay, I'm in front of the tree 5-57-15. It's a species of Tornillo, and he has a volume of 16,717 cubic meter." So, if I am in front of this tree, I just have to click on a button. And I can see the entire history of the tree. And everything that was made about it, that's a demo version. So, most of the information is not relevant, but just for demo purpose. So, the idea, is that when people can click on the button on the tree identification, they can see the entire history of the tree and what happened to it, all the information, who did what so for example, in this first stage, I can see the name of the user, the name of the company, the volume, and all the information that they have entered into the system. Once I want to cut the tree, I just have to click the button, get my location I get my GPS address with the satellite images. So, that's where with better satellite images, you can get more relevant and more up to date information if that zone would be dangerous to cut a tree or not. And then just enter information into the system. Like what's the name of the tree? What's the species of the tree, what's the identification system and how many pieces you want to generate. So, if I say, "okay this piece of wood this tree will be cut in three pieces," then I have to add to this information that gives me the diameter at the bottom, the diameter at the top and the length of the tree, of the of the pieces of wood and so on.

Okay.
So, the system itself is quite complex because every single step has different question. So, if I did the question that we have in Censor Forestal are a bit different than cutting the trees which is different than making it in pieces, which is different than cutting, than transporting, for example, when you transport a tree, you need to identify the vehicle with the license plate number. But the license plate number is completely irrelevant when you want to cut the tree. So, the different information that are asked to the user based on the stage that align.

But then I have a question. So, let's say you have a company for each of the different steps. If a company for instance, at the processing stage wants to implement your solution, that requires everyone in their supply chain to also use your solution?
Yes, ideally, yes. So, at the moment, we allow the importation of Excel spreadsheet directly into the system. So, we have the people to get on board. But the idea is that people use the application from the beginning to the end. But for making them easier to begin, especially is like, "well, I already did that stage. And I have all the information that I need in my Excel spreadsheet, I don't want to go back to the forest and do the work again." So, we do the importation. Knowing that when we import the data, we're not necessarily have the GPS, we would trust a person to do the right work. No, it's not, we don't have necessarily GPS coming directly from the phone.

But does that always work just importing the data, or do you need to make some data standardization, because I think like every company has like different values and different columns and stuff like that.
So, the organization that we work with, they have a models that everyone tries to work with. So, they have like some kind of a standard, but it's not a requirement that every company needs to use that. But basically, we work with Cite Florestal and Cite de Madera, which are organization, which are institution that are helping and teaching the people on site, how to do the work basically. And they have standardization. They have some standards, they have templates of Excel spreadsheet that is sent to the user. And one of the template is like you need to have the GPS data. But then for sure, we have some issues that for example, some companies that work mostly with American customer will use unit based on feet and inches. Some other company that we're where the customer mostly from Europe and then somewhere else are mostly using centimetre and metre. So, sometimes we have just to deal with information are given to us in feet and inches. And some other places they give information in centimetres and meters. So, we need to do some conversion on that, as well. Based on experience, we receive information with people they don't have GPS data they have UTM measure. So, we need to convert the UTM system that they have into a GPS that we can use on while using GPS longitude and latitude. So, yes, the conversion that is required. But most of it are kind of standardized in the doing away that they have a model and template that company follows. And usually that works well.

But then, like companies usually do need to invest some effort to structure their data into the same format so it fits into your solution?
Yeah, what we do, because database is like MySQL so it's very, we can import pretty much any kind of data. But to make sense. For example, what we do we try to know for example, the volume of wood, how you compare volume of wood, if someone is measuring in feet cubic and the other one is measuring a cubic meter, and the other one will be centimetre. So, the problem is not the company itself. If the company is only using feet and inches, it's not a problem. But then the company is calculating the volume based on feet and inches. And then the next company is giving information based on centimetres and meters. And then another one that might decide to give the information in decimetre. So, you need to have a standardized on the system itself to compare the information between the different players. If the

company itself only use inches, no big deal if they only use centimetres, no big deal. The problem is really when all the different companies use different systems. So, that's why the application that we have is way to standardize everything to using meter as the only unit and then we can convert anything into whatever information that you want to. But yeah, the application itself, we try to keep it as simple as possible. So, in that case, you see the entire options. But the user and the company will not see all of it. If I am, my company is doing transportation, I don't care about the Censo Florestal, I don't care about cutting the trees, because that's I'm not involved with that. So, if I log into as another profile, I will see only the things that are allowed to do it. And that can be integrated to the user system as well. So, for example, when you have a big company that say, we have people that are responsible for cutting the trees, then we have people that are responsible within the same company that are responsible for transporting the tree. So, as a user, I will see different elements into my platform. And the idea is simply you can identify, for example, they have different system of identification, you have identification that is made about the Código del Árbol, which is the tree identification system. But then you have an identification that is based on the contract of taking the wood out of the forest. So, they give you a different number. And then you have the Guia de Transporte Forestal, which is basically the transportation number authorization. And as a company, you will see, we give you the opportunity to use any of them. And when you for example, add the Guia de Transporte Forestal, you will see the history of all the pieces of wood that you have, all the way from the beginning.

In Brazil, we have it as well. But in Brazil actually, like a big issue is that sometimes these transportation permits are based on fake or fraudulent credits. Is this also the case in Peru?
Correct. We have good players and bad players. Bad players say "okay, I don't have this wood, but I have these illegal wood that was harvested in a place, I should not have done it. But just put it in here. I give you USD 100, here the USD 100 there." Yeah, it's a very common. Corruption is a big problem. So, if we do this kind of information, the information will not be if when people use the application, the information will not be relevant, will be not based on piece of paper that has 50 signatures on it. But it will be based on information that is stored on a platform. And all the information is stored on a blockchain and that's where the blockchain becomes very relevant is that no one else, nobody can tamper this information. So, we cannot say that for example, a company can enter bad information or manipulate the information. For us, what is stored on a blockchain is not in our control, nobody can change this information.

Okay.
So, we understand that people can make mistakes, and if they make a mistake is like correction, the application will allow them to make a correction, but it will appear in the blockchain as a correction.

Okay, but then there's no aspect that you have in your solution that could sort of cross verify whether the data from like, for instance, the Guia de Transporte Forestal is like, legit.
But basically, using RFID identification, we can actually kind of know make it more difficult for people to tamper the information. For sure, at the moment, we're relying on what people use currently, which is people entering data manually. So, in order for us to solve the problem, there's two ways. So, one of the way is to minimize the user input. So, the less user input is in a system, the less manual work, the better it is. So, we can, the more we can automate the system using sensors, GPS, photos, RFID tags whatsoever, the better, the more accurate because they're less corruptible. The other way that we want to do it as well, is to give the incentive, for example, we want to automate the transfer of money directly. So, for example, if someone say, "I just cut at a cent 100 cubic meter of Pinewood" and the transportation companies say, that's correct, "we receive 100 cubic meter of Pinewood", automatically the money will

be transferred, using smart contract. So, if someone is lying, and making false allegations, or the information is a mismatch, that can be reported, and the money might not be transported by smart contract. So, that's why Ethereum is very interesting in that way.

But I mean, that only works if the buyer detects that in the moment, or where he still has a product, right? Because if he only figures that out, maybe after a year, when he gets complaints from the end consumer that he sold the product to, then it doesn't really solve this issue, right?

While it's, it will be a transparency. So, of course, there's still work to be done to, to get it implemented and used by everyone. But that's the idea that one of the what the incentive is to say, "okay, know, if everyone is playing by the same rules, and if everyone is entering the information properly and accurately, then the system works, no problem." The problem becomes when someone's like: "I received 100 cubic meter of wood but it's not 100 cubic meter, I'm sorry, it's only 80. So, why would I pay for 100 cubic meter if I only receive 80?" But the other person is like: "No, you're lying!" So, someone is lying? So, then you can send auditors to say: "Okay, who is lying in that case?" And so that's where you can figure out where are the bad people? Or someone say, "I'm sending 100 cubic meter of shihuahuaco is an expensive tree, expensive wood, but the other person is like: "No, that's not shihuahuaco that you sent me that's like garbage." So, someone is lying. And so that's what we can raise flags is like: "Okay, someone is like, let's send an auditor on place and, and figure it out, because somebody is not playing by the rules." But at the moment, what we're doing, so that's more the long-term vision to have a system that can integrate. So, we work with different [inaudible] and a different organization from Africa that was implementing something in Africa, for pay for the automation of payment. And that will be a way of formalizing as well the people, because 70% of the people in Peru are informal, are paying cash by money. So, we want to formalize it. And so that's where the incentive of the government would be very useful to saying "okay, we want to promote this application, because it can help to formalize our entire wood industry as well the buyers, because one of the issues that we have in the EU is that buyers don't buy would from Peru, for a simple reason is they don't know where the origin of the word is coming from. So, the incentive will be like if you can prove that the wood was cut decently and all of it is actually legal.

You know if this is the same issue in Brazil?

I suspect is very similar. I think there's a lot of similarity. Because what are we talking here as well, because I don't think that the Amazonia in Brazil and the Amazona in Peru are very different. I think they're very similar. There might be some differences, but I think there's a lot of similarity.

Perfect. And then you mentioned is basically one of the ways that reduces risk of, you know, human error. And human corruption is a tool such as IOT, we briefly discuss it the last time already. But I basically also talked to other people. And a lot of people say that they don't really see a lot of potential in RFID, or RFID tags, because basically the problem with wood is that it's often cut up immediately after harvest. So, if you attach an RFID tag to the wood, you have to detach it again. And then it goes into a sawmill, which has maybe 10 other different sources of forest. So, they basically said that here, we only see volume reconciliation as a solution. Do you tend to agree with this?

Yes, the RFID piece of wood has limitation. But it's very useful, for example, for identifying a tree in the forest itself. So, for example, when I go back to my workflow, the complex workflow, or let me go here, so you see better. So, the RFID will be very useful in these in these 1, 2, 3, 4, 5 stages (Censo Florestal, Tala de árboles, Arrastre y almacenamiento, Trozado, cubicación, Transporte Terrestre interno), because we're talking about trees that are like 20 metres long, or five metres long. So, everything that is before transformation, RFID is useful, because it will help the people to discover

where the tree is located and get all the information from the tree inside of the forest, then the tree is cut, then it will be a cut in big pieces, but there will still be transport. By big trucks. So, we are talking about pieces of wood that will be a few meters long, and weighing 100 kilos something like this. So, for that an RFID will be useful. But once you go to you have a trunk of a tree, and then it will be cut in small pieces no for being used in the furniture, then the RFID is useless, because you go from five pieces of wood to something that will be 500 and transferring 5 to 500 RFID will be useless. But it will be very useful for as long as you have big pieces of wood. Yes.

Okay and I mean, like the main advantage of RFID is just that, if you have like a setup, right, but it can be read from a distance and it doesn't need to be scanned individually.
As well. One of the information that we have is we rely a lot on people entering information manually on the application. Well, the RFID you just have to scan it and have all the information automatically, and it will work offline. So, currently, what we do inside of the application, we uploading all the information directly into the application. That means that people will have to download megabyte of information that they might or might not use at all. But just because they have no internet connection. And when they go into the forest, they need to have access to this information. So, if you load this information directly into the RFID, people with a smartphone with any smartphone, don't need to download information prior. And it can just scan the RFID and get all information that automatically. And then they can reprogram the RFID by adding information to it. So, the RFID works really well for places that have no internet connection because you can program them. And as long as you don't have to go from one piece of wood to 500 after.

Is there like another advantage from an RFID compared to for instance, a QR code because a QR code you could also scan for information, right?
The QR code is useful just for identification. But you can only put up to 64 characters of information. Yeah, it's just a question of, there's a website called QR stuff, the more info let me say, let me check. So, the more information you add into a QR code, the more complex it becomes, it is a limit. So, for example, that's a simple one. But let's make the text something like this. Well, let's see, the more add information, the more complex the QR code should become. But anyway, the QR code is only limited by a certain amount of characters, I think is 64 and after 64 characters or 128 characters, I don't know. That's pretty much it. So, you cannot add. For example, if I take as an example, this, this piece of wood. Now just one stage will be the volume, the Tornillo, all the data that will not be able to fit in one QR code. But that information could be fitting into an RFID.

Okay.
And as well, the QR code, you know, if you have a piece of paper, but then a piece of paper is ripped, or it's maybe difficult to read might be difficult to scan, while an RFID code you just has to pass in front of it. That's pretty much it.

Okay, and I guess it's the same with the barcodes. So, it's a similar concept like QR codes where you can't have that much information.
Yes, so barcode and QR code are the same thing. The only difference is, is that a QR code is a three-dimensional barcode. So, barcode is just one line. And it has black and white and the size of the bars that are black and white makes a code. But a QR code is not only one, it's not two dimensional, but it's three dimensions. So, it's a barcode that has a different dimension. So, the QR code is just a more sophisticated, more elaborated version of a barcode that can allow to integrate more information into it.

So, the barcode will be just an identification number of products. That's pretty much it. The QR code, you can have more information on it.

Yeah.
And then RFID would be even more information.

Perfect. Okay. So, there are some cases where RFID tags can be useful, especially for tracking the timber before the transformation.
Correct. Especially it works really well offline because the QR code is great, but you need an internet connection to be able to read anything. Where if you can't read your ID, you can read the QR code, but you cannot download information. So, do you know if it works really well, because you can get the information directly from the RFID chip without requiring an internet connection. But the other stuff, you know, like with chemical marking, and but I think the future is really about the camera where basically people will be able to identify a piece of wood, or the species of the wood directly based on the shape of the leaves, the shape of the trees. But that's in the future maybe five years. 10 years? I don't know. Okay. Anything else?

Yeah, but I…
You're running out of time.

It's always so much information. And it's very interesting. Do you still have a bit of time? Or do you need to jump?
No, I have a half a bit of time.

Okay, perfect. So, last time, you mentioned that you store GPS data as well from the tree? Is there any other GPS data that you store for instance, like from processing facilities or trucks? Or is it just the tree?
No, we take the GPS of every single input that our user is doing. So, we know for example, where the tree has been logged? Where has it been deposit. When the company when the truck took to the wood, the person has to document the work, and then when he deposits to the companies. Because we don't want for examples, like I gave 100 cubic meter of wood to this company at this location. But in between, there might be some falsification of information. So, we asked people to document the work every time they do something, and at the time where they take a pictures of the document or work with a GPS.

Okay, but the sensors are not used for trucks, right?
No, no, not currently.

Do you see any potential for using it for trucks as well?
So, for example, company use GPS to know where the trucks are located. So, for example, to know for example, the efficiency of a truck driver. And if in the middle, for example, they because what can happen as well is that someone will drive to a concessionary of would, collect the wood and they and then go somewhere else to collect wood from an illegal logging, and then give it to the company. Yeah. So, to avoid that people use GPS tracking. But again, people can deactivate it. So, it's a product management system. So, company use it to monitor the people to optimize the route. And to make sure that people are not collecting wood that they should not collect.

And then in terms, I mean, we briefly mentioned it before, like with machine learning. They basically said that the idea is basically to match the information that you receive against each other, and then identify discrepancies. Is this currently done manually, so does a person need to sit in front of the laptop, look at the data and then figure that out, or you have any algorithms or database comparison or Big Data Tools that help you?

No, but what we currently have is, we measure everything. And then we can flag for example, when a company say I have 100 cubic meters of wood, and the other person will see 120 cubic meters of wood. So, then we notice a discrepancy. And that can be done by a simple algorithm. If the machine learning is really well used, for example, when you have to deal with images and stuff like this, that's something that is not like the image sets, satellite images, machine learning will be very useful for that. But for us at the moment it's just an algorithm. Of course, we're still working about how much tolerance now for example, the wood will be cut, for example, in the wood is coming from the forest from the jungle, and then the transportation will be done on water. So, they go into the forest, they cut the trees, they take the trees out of the forest, and they put it into the water. And then a lot of transportation will be done on water. And what happened when the wood is in water, he began volume and weight, because you collected a bit of water, the water will be going into the wood. So, what happened at the end, is that the volume and the weight of the wood at the reception might be bigger than what they send it. But that's normal, that's part of the operation. So, we need to allow mistakes or a certain percentage of that to happen.

Yeah, there I guess you just use past information to compare?
Correct.

Then the algorithms sort of put the information together or like how can I understand this.

So, what we do, we just measure the volume of wood. So, the volume of wood is basically everything for us. In the best way we can. So, for example, if someone say "I sent 100 cubic metres of wood", then it went through the water, and then the other person was receiving only 20 cubic meters, like, okay, it's 20%. It's in the tolerance. But if someone said no, "I receive 200 cubic meter wood," okay, that's a mistake. There's something wrong with that. So, that's why we can enter. One of the issue as well is the volume of wood is very difficult to calculate. So, the volume of wood is very precise once it's cut in pieces, and you have something that is square. But for example, when someone goes into the forest, and say this is the tree, so they're measuring the circle of the tree at the beginning, like the diameter at the bottom, the diameter in the centre and the diameter at the top. And then they say, as well what's the height of the tree. But what they don't know is inside there might be a big hole. And so they make an approximation on what the volume of wood they can come out of it. Knowing that the reality might be very different because the tree, in Europe it's a bit different because all the trees they don't have a hole in the centre. But in the jungle, you can have massive trees. And then you discover that 80% of the tree is useless because of the hole that they have inside of the tree. And that's something that they only discover after they cut it. So, that's why they have different formats of cutting the tree and then when you cut the tree in Germany, they call it sterholz, which basically is a German word, where basically you take the wood out and you put it together and he gives you an approximation of the volume of wood. Knowing that that's not exactly the volume of because there's still air now you have a piece of wood with another piece of wood and in between is air. So, it's an approximation of the volume of wood. Knowing what the real volume of wood will be once it's cut in pieces. So, even the calculation of volume of wood is not something that is highly accurate. Okay, so we have to work with this precision somehow.

Yeah, it sounds complicated. And then I know that you mentioned last time in Peru currently the process is very paper based of what exactly is your definition of paper-based? Is it really just having the printouts of a documents? Or is it in a digital system, but just based on documentation.
So, digitization the way works currently is that people scan, basically, because people in the Peru they don't have internet connection 80% of the country doesn't have internet connection. And when people go into the forestry, there's absolutely no reception at all. They might have a satellite images at a camp. But when they go into the field cutting the wood is absolutely nothing, no cell phone reception, nothing. I've seen it myself, you know, you walk in the middle of the jungle, and you don't have a cell phone. So, if something happened to you, well, that's it. Yeah. So, what they do, they rely on paper. And on the paper is, I can send you some example on the paper, there's like numbers written on it. And then it's signed with the thumbprint and a stamp of the company. But everything is based on paper. And what they do after they take this paper, they scan it as a PDF, and they upload it. Okay, so they have a digitization process, but it's still manually written.

So, you can search for data, or is it just the scan, because that's not searchable?
So, what they do, now they have a scan, which is not searchable at all. And then if they want, they can manually do some data entry into a system. So, we want to simplify all of it. Sometimes they enter information into the system. So, they have a system that is called Data Bosque, which is a system that works on Microsoft computer, where people can enter this information that is on a paper into an Excel spreadsheet type software. But what matters is really the piece of paper. That's what the authority is looking at. So, that's how it works.

So, one last question, or do you need to go? Last time, you mentioned that your software doesn't really help in fighting illegal logging. It's basically like an accounting software. But do you think if enough companies would adopt your solution in Peruvian Amazon that it could be used as a tool to maybe identify wood that is not in your software, let's say like 70% of the companies use your solution. But then it would be easier to address illegal logging.
I think it's more a tool that will give the opportunity for people to make more money using legal logging. And to say, for example, if the tool is used massively around the country, that people will refuse to buy wood that doesn't have our stamp. It's like the FSC. The FSC stamp is like, well, "if you don't, if you're not FSC stamp, I'm not buying the wood from you." So, we would like to work with the FSC. We are not working with the FSC at the moment. But one of the idea is that the FSC adopt this tool to say okay, using this tool, we can make sure that the wood that you're buying is legal. And company will buy only wood when they have the FSC stamp. And that way will be the same as like this application is wood that you're buying was using or the company that you're buying from was using our platform. Therefore, we can guarantee with 90% or I don't feel 100% it will be for sure. But with a high probability that the wood that you buy is legal. And therefore, if and therefore the people that buy that are doing illegal logging will not find buyer anymore. But the black market will always exist. So, we can't fight the black market like this. But at least we give an opportunity for the people to sell the product using legal method and buyers to be sure that the wood that you're buying is certified, that it's legal.

Perfect. Thank you so much for taking the time and presenting your project or your products in more detail it was super helpful.
So, at the moment we are testing it with different companies. So, we are still learning about what they need, what they don't need, where are the issues. The fact that there is no internet connection at all is a big problem. And what are the technological limitations and economical limitations or technology we can do a lot of things. But then it's like "I'm not buying a camera for USD 5,000 just especially not in

the forest." Now you will see people like "I'm not having a cell phone not in the forest. There's no cell phone reception. So, the cell phone is useless to me. So, why would I go into the jungle with my cell phone just to take pictures of wood, knowing that I don't have cell phone reception?" So, there are issues with that. So, we're working with companies that have more internet connection, knowing that some companies like yeah, "I'm sorry, we just have nothing here." Okay. If you have any questions, let me know. I can always answer your question for your report.

3.3.6 Interview Horowitz-Burdick

I would love to dive into the topic of legality verification that Brazilian Amazon.
Sure.

And so what challenges in verifying legality and tracing timber do you currently see?
So, those are kind of two different questions, right. I mean, they're tied together but defining legality of a timber supply chain has more to do has more than just the traceability of the material. So, challenges and legality verification are multitude, right. Because you have to look at things outside of traceability like, ownership and structure. You know, are there other issues with the ownership like, do they outside of their forestry do they run a soil business or a cattle business? What's their labour record? You know, are there other issues with just the ownership of the land that aren't tied to timber at all. And then legality also gets really complicated in Brazil, because of the state versus federal systems that are used in both traceability and legal verification of timber, right. So, the federal system, which is run by IBAMA is called, SINAFLORA, which was set up, by a German bank, like 10, 12 years ago is accepted by a handful of states. But you know, and then in Rondônia, in Pará and a bunch of places in Madoroso they use their own state systems, which is either IMAC or SISFLORA which operate very similarly, but with a few key differences, right. So, some of those states have outright tried to reject SINAFLORA, because it's kind of for administrative reasons. Like it's not operational all the time, because it's a government digital project, which I don't know about Switzerland but in the US it never turn out that great. So, you know, there's been this question of state versus federal legality of timber. And then there's kind of also a constantly moving target with particular document requirements with export, depending on from product to product like solid wood decking has different export document requirements than plywood has. And some of those requirements have been removed as under the new administration, which you know, isn't necessarily tied to the deforestation stories that you hear about. So, you know, legality is like this huge question. So, the challenge is (a) educating yourself well enough that you know, what is legality for this product in the place that it's being produced? (b) And what are the key points of verification within that, right? So, beyond challenges, the one benefit of working in Brazil is the system is extremely robust, in terms of the amount of data generated from production, transit material, harvest production transit material you know, what there's far more information produced than even we would see in America for similar products, right. So, the ability to collect and verify information is better than almost any tropical nation that we work in by a longshot. Traceability is an issue in the same way that it is kind of anywhere in the world, this largely just depends on the complexity of the supply chain and you know, there might be some very straightforward supply chains for something like veneer where you can you know, compare log measurements from forests that they own, vertically integrated so you could literally you know, just look through records, compare measurement of logs, do sampling in terms of what you're verifying, and track it back to the forest, right. By log tagging, and then there's other supply chains that are extremely muddled and they're buying off buyers and they have partner mills. So, you know, traceability is the same challenges that you would see anywhere in the world.

But then do you, it's sometimes difficult to trace a product back to its source?
Yeah, definitely. Again, it depends on the product. If you're looking at large volume export on a particular product that is multi-manufactured, so it goes through a couple different couple of mills that will all have maybe their own forest sources that they don't own themselves. And maybe there's a log trader too thrown in there as well. You know, they're not necessarily running their documentation on a strict basis of, "alright, this document, this transfer document is tied to this log", they're running it off balance. So, they say we have this number of logs for this volume, and they tie it together. And that way, it doesn't mean it's representative of that actual supply chain, or the material that's in that order, or in that container. So, what we work with companies to try to do is put systems in place where we can say, "Okay. This container material, we can tell you what forests contributed to the material in this container, right?" I think it's important to understand that kind of nowhere in the world, are you able to say this stick came from this log, that just isn't a reality of how timber manufacturing works, what you can say is for this particular batch, these are the forest sources that were used in this production, right.

How exact can you be with identifying the exact forest? Is it like more a region or could you…?
You know, you can definitely identify the exact forests, right. So, you should be able to otherwise you're exposed yourself to huge risk, right. Like you need to know exactly what forests are claimed to be being used for the production of this material. And then you need to have all of the management plan information associated with the annual operation of that forest, right. Because that's the only way that you can tell "Okay, so the annual plan of operation for this particular forest will have been you know, assessed by a forest engineer by either the state or federal government, which will calculate the volume of different species available for harvest and our sustainable management plan for that forest." But then you have to compare. "Okay, so it says, there's X amount of Ipe for harvest in this forest. And then we'll go around and look at a bunch of other historical and current year management plans for similar forests in the area and say, "okay, is that accurate number? Are they inflating the number? The cubic meters of Ipe are available for that forest." So, and then you look at you know, satellite imagery and see, okay, how much forest cover and species differentiation actually exists in this forest? Is that accurate? You know, because that's the core basis of where the claim is made you know, is the forest engineer being true to what's in the forest? If that's the case, then you have a good starting point, right.

Can I, so do I understand correctly that you and your role as consultants, or…
We're a service provider.

Service providers, that you check the forest, like sustainable forest management plans? And also the plan of the annual operations?
Yeah. So, we collect all this documentation and use it you know, as evidence to verify what's our starting point? Like, do we know that what they're claiming volume wise for, what they're planning on producing will be accurate, right? And then, but the issues get really complex, because even if that's the case, there's ways to launder material through the claiming forest. So, what you have to do is really look at their entire production, you can't just do it for one client, right. Because what one client is buying that you're doing the verification on that material might represent a very small percentage of what's actually happening in that mill. So, it'd be really hard for you to tell if they're cheating or not, because you have a really small sample and visibility of claim material. So, that's you know, one of the strengths we have as a third party is we can look at bigger pictures within the mill because we hold that information confidential on behalf of them. So, that we can get a better picture of what they're doing large scale for a particular product. Does that make sense?

So, basically, if you refer to a client, you're talking about, let's say a sawmill has products of ten different timber companies, and one?

Step forward, so our client would typically be the importer who's buying you know, plywood from a mill, but they're buying you know, this species of face back plywood, but that mill has ten other clients they're selling to. So, you're only seeing a 10th of the volume and so your ability to you know, audit through documentation claim, volume reconciliation of what they're producing versus the raw material as they're getting is really limited to what that client, what you're doing for that client, right? So, we try to get involved with these mills where we can look at you know, their total production, right.

Okay, interesting. And then, maybe back to the topic of legality verification, you mentioned that basically there are different definitions or like, it's difficult, they say that you can define the legality different, you can define it maybe in the logging phase, but then you can also define it further in the supply chain. So, checking that the sawmills have the licenses or export permits, you check all these different?

Yeah, so the way our service works, maybe this will be helpful to explain. We'll get contracted by an importer or someone to have a look at a mill or more specifically to have a look at a particular product that they're buying, right. And we'll get introduced to that mill, we'll learn about the product, and then we'll set up a date for an assessment, right. And the point of that assessment is to look at all of their legal registration throughout the entirety of the supply chain from you know, export license, mill registration, land ownership, corporate structure, who's involved in the funding and capital side of things, upstream suppliers in terms of sound material or whatever, and then forced assets right, so and who owns those and all the registration required for legal operation in a forest, legal transitive material, legal registration of the company, legal ownership of the land the company has on all of that, right? That's kind of the first block of documentation and an assessment that we do when we go and sit down with these mills. And we always go in person as much as we can, that's changed as COVID a bit. But as much as we can we do in person. And then you know, and then after we've looked at all that kind of legal documentation for the entirety of the supply chain, we'll go through the production of the material, and we'll walk through the mill, and we'll really try to understand, “okay, this is how you organize logs in your log yard. This is your process for receiving these logs. This is what information you're recording. This is what documentation you retain upon you know, logs being dropped off in your yard. This is how you organize them by species, or lot or forest or whatever. This is what's recorded when those logs are peeled. This is what's recorded when they're cut. This is what's recorded when they're dry. This is what's recorded when they're glued, this is what's recorded when they're put into stock. This is what how everything is then organized for shipment.” And then we'll test that right we'll say, “Okay, here's this container with these pallets, show me what logs contributed that.” So, back through that system. “Can you show me what logs contributed to that and then you can show me the transport information for those logs?” So, we can tie them to a particular forest, right. And then after we've kind of gone through that exercise, and a day and a half, two days, whatever with them on site and really understand their mill and their sourcing and their production will write a report to the client that says, “Okay, here's what we found. “Here's the gaps. Here's the risks, here's opportunities for improvement,” right. And then that involves a whole bunch of desk research to which is here's deforestation risk in Rondônia because that's where the mill is located in Brazil. Here's risks associated with the owners that are you know, partial owners of this entity that's part of the supply chain, had corruption issue five years ago, because we run it through those sorts of you know, different corporate risk tools you know, that sort of thing. So, here's risks associated with this species and species mixing and substitution. Here's risks associated with how much the US government and NGOs are paying attention to this particular region in trade, right. So, you

come up with them this huge risk profile picture that includes this detailed look at the supply chain as well, right.

And if I understood correctly, this is a hard requirement for these importing companies to import the wood from Brazil or does this go beyond what is required by importing law?
So, US Lacey Act and EUTR are very vague, right. There's this big differences between the two. A key component of meeting the criteria of Lacey and EUTR is having performed a risk assessment and then mitigated that risk, right. So, that's the second step of our service, is we'll say, here's what we found. Here's how we think we can implement systems to mitigate the risks that we found. Sometimes it's not even possible. Sometimes we say, there's too much crazy things happening here. "Here's some suppliers who are way more trustful, right. Maybe you should do business with them." But most of the time, we're able to say, "okay, you know, if we implement these procedures in the mill, and then if we're testing or you know, mapping your concessions and looking at deforestation layer over the top of that, and then for every consignment, we're collecting X documentation and verifying that documentation, then that mitigates the risks that we've found," right. Any number of those tools that I mentioned can be implemented in a risk assessment or risk mitigation system, but then that's carried out on an ongoing basis. So, we do that for every container or every container product that leaves that we're verifying. There's some amount of verification action that happens for that material.

Can you clarify what you mean, with systems to mitigate risk? Is that like, are those procedures within the company, or do you set up systems within the timber companies?
Yeah, so both, so wherever we find risk, we need to take steps to mitigate it, right. So, if that means there's, they're not collecting information that we need at the mill, then we'll have them collect that information and we'll verify pieces of that information, right. Or you know, we might have them taking samples on a quarterly basis or batch basis to test for origin or you know, we might do supply chain, digital mapping with forest polygons and deforestation risk layers layered over, right. So, it's, we build a system that's specific to the risks identified for that product right, that's how our service works. But in terms of the law, that's kind of a bit of what's prescriptive is, you need to identify what risks do exist for that product, and then you need to make sure that you've mitigated those risks.

And you mentioned, okay, so I'm trying to like understand better how this process of like auditing works. So, I guess you do this extensive risk assessment and a development of risk strategies at the beginning of maybe like developing or contracting a new supplier? Do you carry out audits, then on a yearly basis afterwards or do you also verify or support the companies in doing these checks?
Yeah. So, like I mentioned you know, that risk assessment stage, sometimes for companies, that's all they want, right, is to know what's going on in their supply chains. And then that's a hard stop in our service. And then we'll provide a proposal saying, "here's what it would take in our eyes to mitigate that risk on an ongoing basis." Which often will include us going back either quarterly, biannually, or annually to perform an onsite. But for any product that we are verifying yeah, there's verification performed on every single consignment of timber for that importer right, for that product. So, every time a shipment leaves for that product, to go to that importer, we're collecting information and verifying information on that particular batch of product, right. So, unlike certification, where you go into a mill, and you certify their procedures, and then everything that mill produces under that certification scope is certified. And that's it, and then there's an annual audit and that's the end of that. We're actually performing verification on every single batch of timber that leaves you know, for that product to the importer. So, the mill will have procedures in place for the mill will tell us here are our production outputs. Here's where we are in production, these containers and consignments are you know, finished

and getting loaded. We'll make requests for whatever documentation set or other information we need under the system we've designed, and then issue them a green light to export on behalf of the buyer. And that way, we're collecting information over time which is super useful, especially in the context of Brazil, because you can't you don't get to just like on an onsite audit find the problems. You find them over time. Yeah, it's an accumulation of data which becomes useful.

Okay, and then I'm just trying to understand then, do the timber companies also have systems in place, respectively do they also document the documentation?
Definitely. So, the importers is that we typically have longer relationships with and work with. A lot of people who already have pretty sophisticated due diligence or do care programs. And they use us as you know, a third party to augment their internal compliance programs right, because third-party risk assessment and oversight is also more in EUTR, the conscription of good due care system, right. And the way those laws are, it's not so much how they're written. It's more dictated by enforcement of what the requirements are. And but you know, anywhere in Europe, the competent authorities are going for a high-risk product, be looking that you've contracted a third party to overview the risk and mitigation of that product, right. So, we typically people we work with are already have pretty sophisticated compliance programs in place. And we'll help them build upon that. And then we also, we work with another partner called 11Foundry who has a product called fiber trace, which is a digital interface for risk tracking and product tracking. So, we'll use that to administer our verification from time to time, but we'll also then help companies that they're selling that software to, to set that software up in a way that makes sense for their product groups. So, that's like one of the technology partners we have. And then the way that's going to end up eventually overlying into blockchain is the information entered into their fiber trace system for product will be mirrored on to a private ledger blockchain, right. And so certain actors of third-party verification that would go into that software would be hashed inside of a private ledger, a blockchain system.

Okay, wait. So, how exactly does fiber tracing or analysis work?
Fiber trace is just the name of the software, it's just a software problem. You should look up a 11Foundry the name of the competing company and fiber trace, the name of the software that they use.

But then if I understand correctly, the information is entered manually, or do you have the timber connected to certain devices such as RFID tags or Barcodes?
Yeah. So, I guess we should probably move through your list a little bit. I get going on tangents. These are big questions that you listed here. So, no, all the information will be entered manually based on collected information and data, right. And the key is that you're verifying pieces of data against other pieces of data that have been supplied, right. And sometimes that's done directly by the mill, sometimes it's done by the importer, sometimes for really critical and high risk things. It's done by us like that's the point is we as a third party, were overlooking those pieces of data. The issue with barcode, which has been tried a bunch, RFID, which has been tried a bunch is it doesn't get around the issues of people who want to cheat because you've just moved material, right? They use barcodes in log identification in Brazil, and they use that in Indonesia as well, under SVLK. It works okay for kind of just volume tracing, but you can do the same thing with log lists like it doesn't. The addition of that technology doesn't really help in stopping fraud.

But it might, do you think it might reduce the risk of fraud occurring along the supply chain?
Not for someone who wants to commit fraud. The only thing these technologies really do, DNA included, is they have to be you know, there's no one silver bullet, right. For any of these technologies,

they can be pieces of a puzzle of a really robust system, but without context and you know, a strong document-based system, strong production tracking, strong third-party verification, strong forest, sustainable or forest use verification. None of these technologies are going to solve anything, right. Like it has to be within context of a broader system. And it's also the best way to get the use out of those technologies. Because if you don't, if you know, if you have DNA testing in place and you find out something's wrong, well, if you don't have a broader system in place, you have no idea how much product is affected by that one result, right? So, you need all of these needs, or all of these technologies are just tools that you use in building a broader system that meets the specific risk of that product. Does that make sense? And they all have different strengths and weaknesses, I don't see RFID or barcoding as super useful, purely for the reason that you're dealing with a product that is immediately cut up. So, and that's where fraud happens. And switching a tag or an RFID tag you know, once it hits the log yard is irrelevant, because it's going to be cut. And there's things like [inaudible] which are like chemical tracing isotopes that can be applied to things that are invisible to use for documents certification and money laundering, they've tried to implement into the timber industry, and it just doesn't make that much sense, right? I forget what the name of that company is, they make proprietary isotopes that can be applied invisibly to anything, right. And then you can by doing that, say this is this thing, right. But it faces the same problems that any technology in timber does is "Okay, what do you spray that on a tree? And then that tree gets made into lumber and you have no idea if it's related or not?" And who's applying it, right? So, yeah, the best tools are the scientific ones like, the ones inherent like isotope and genetics, because those can still be traced throughout production, right. But even then, without implementing them inside of a wider system, they're really quite useless. And that's why you don't see wide adoption of them. It will get better as the cost of doing it goes down, but again without contextualizing those sorts of technologies, they're not particularly useful. The same as is can be said of blockchain as well.

Okay, so maybe back to the topic of legality verification. I know one problem in Brazil especially is that, fraud can occur in the beginning of the entire supply chain, at the point where they generate these forestry credits based on the sustainable forest management plan. How do you tackle this aspect? Do you make additional analysis besides just collecting for instance, transportation documents?

Yeah, so DOF isn't really directly tied to forest management, right. A DOF is just a transit document, right, that says these logs took this route from this patio to this mill. What you have to look at is the POA and the management plan for that year, right. And again, as I mentioned earlier, the best way to look at if that's done accurately or not, to have forest engineers that work in the area that know, you know, they'll say like, "No, these volumes are all out of [inaudible] in this area." But then also to have enough data on file and know how to access publicly available information in Brazil to compare to other forest management plans, both historically and for that year, for that region, we can say is in line with those. What are the challenges in Amazon is just inherent to the Amazon, is there's a massive diversity of species within the Amazon compared to other tropical forests. And there's massive variance in what species grow and what density, depending on where you are in there, right. Because people say that Amazon, they think about the Amazon rainforest but that's like being like America. It's huge, its enormous, right. So, there's huge variation in what goes where and what density is. So, yeah, you have to have some local knowledge about what's happening and then be able to you know, demonstrate that anecdotal knowledge through document collection verification, or comparison to what's going on in the region.

And you also mentioned that you sometimes use satellite imagery to sort of verify the information. Is this something that you have seen timber companies also do or is this usually just something that service providers do?

It's more what service providers do. I mean, it depends what you mean by timber company, right? An importer's timber company, a sawmill is a timber company. So, Global Forest Watch is used pretty widely on the import side, especially in Europe, which has pretty good hotspot deforestation tools, as well as like fire alerts all the like University of Maryland deforestation data stuff. So, we'll use that, then we have another technology partnership with a company called source map. That does kind of supply chain visualization on a digital platform that can be done on like a consignment basis. So, you can watch material flow and a fairly live environment through a supply chain that you've mapped on their platform. And then we can overlay digital risk layers on top of those maps. So, we can draw polygons of the forests that are active for that supply chain, and overlay the Global Forest Watch deforestation and fire information of those polygons and set up alerts that if there's major deforestation events within those polygons, or near them, we'll know, right. So, but that again, is just another tool it doesn't get around the problem of laundering, it doesn't get around the problem of illegal logging and laundering is the main one, right, that's hard to catch. So, the way that you catch that is long-term data collection. And looking at patterns long term for the entirety of that mill's production.

And these tools, are they for free and accessible by all the companies?

Yeah, the Global Forest Watch ones are, there's better Landsat tools out there that are higher resolution that people can pay for. But that hasn't really been integrated that much into the timber industry yet, right. I think there will be a day where it is like, Earth Science and so many other ones. There's a bunch of them out there. And they'll do like pilot studies and stuff with the timber industry but it's fairly expensive. And timber is hard in that regard because the margins for these people are super small. So, you know, additional costs and risk is tough. And it used to be you know, even eight years ago or five years ago, when I started getting involved in this, like it was really hard to get companies to spend a couple of thousand bucks on the risk assessment stage. Now, that's not the case, because the cost of doing business is so much higher like that your risk exposures so much higher, and enforcement has been picked up. But again, these people are importing wise working on very small margins, so it's hard for them, you have to make a really good business case for them to spend money on this stuff, right.

Okay. But again, it depends on the type of timber, no? For instance high value timber?

It depends on the risk exposure, right? So, and that's dictated by the type of timber they're importing and where it's coming from. But really long term, if you're, the companies that spend the most money on this and invest the most in it, and invest in new technologies are the ones who are smart, they're the thought leaders, they're the bigger people, they're the people who are going to turn around and sell those efforts in the market, right. And say to consumers eventually, hopefully, this is what we want to see is for consumers to care about where their wood products come from as much as they would like their coffee or fast fashion or other things, right. But people don't really think about timber in that way. And they sure don't want to pay for it. So, if we can use these tools to demonstrate to consumers the value and traceability of active forest management as a social and environmental good. Hopefully, that will increase market share for these companies that are actually investing in these tools in this space, right.

And you're, so if I understood correctly, those thought leaders are the companies that are initiating these developments. Those are normally the bigger companies that have more resources available?

Yeah. Well, they have more resources available. And they have more to lose. Like they have more you know, brand reputation at stake. They have typically more interface with authorities because they're bigger targets, right.

Maybe moving on to traceability efforts I just wanted to quickly verify. So, if I understood correctly, not many timber companies are currently using technology such as QR codes or RFID, in the Brazilian Amazon from your experience?
No, not in Brazil. In general, barcoding was tried years and years and years ago and never really picked up because it's easy to defraud. RFID, I know is used to some degree in like finished product, but not so much through the production, right. But no you don't see it in Brazil that much. Sophistication of Brazilian operations varies from like you know, one cutting line in the middle of the jungle through to you know, really sophisticated giant flooring mills, right.

But then how is the timber tracked? Is it just basically tracked based on volume calculations and documentation such as sales invoices?
Yeah, so there's your question, right. So, the benefit of the Brazilian system is that there's required legal documentation for movement of material. So, there's you know, a wide breadth of documentation that you can look at, or should be collecting so to see material flow and then within the mill itself, this is why we do on-site assessments. You have to understand how they're recording their production, right? And good mills and mills in general, the better the mill, the better they're recording and specification and recording the production. Not for traceability, but so that they know their efficiencies, right. So, then you know, you collect that information as well. And then you're collecting all this bulk of information that you're auditing you know, annually or whatever. But in our case for every consignment of material. So, you're looking at you know, largely a document material supply chain flow. But you're looking at that and tracking it, both on a shipment basis and then on a total production basis. So, you're seeing if those things line up with the claims of material source line up with the amount that they're producing for these particular species. The greys lining up or the sizes lining up like this again, why like the big picture, long-term data collection and verification are what's important, right. And then for some materials, not in Brazil yet but for Indonesia, and some West African stuff, we'll do material testing as well. So, we'll do some amount of either DNA population verification or species verification, which is more about a species declaration issue than it is about traceability but we will do some population genetic verification as well as isotopic regional verification for like, Russian timber, and oak and stuff like that.

And if I understand correctly, if you are a main way of sort of tracing this chain of custody is through sales invoicing, then timber is mainly traced in like the shipment and not as individual timber?
No, not like stick perspective. But it's not sales invoicing. It's like a whole bunch of different types of documents. Sales invoicing would be one of them, but then you know, different types of transport documentation, log list, production information. It's not just sales invoicing, right. Like there's all sorts of different documentation information that you're collecting. And the key is that you're comparing pieces of information against each other right, from different document claims.

Yeah, now I was just trying to like understand if this is something that you do like for each sort of log or if it's more of a shipment in like one timber shipment?
Yeah, so it really depends on the product and the rates and what system we built. So, like for some Brazilian products will do every time they receive a consignment of logs, we know about it, right. And we have all the documentation behind that consignment of logs, right. And then every time they produce a batch of finished product, we know about it before it ships, right. And we tie it to this huge list of

information that we have related to their log receival right. So, there's like two rungs of verification happening there. For others where there's lower risk, if it's like a plantation species, we're just looking at like, what they bought mass accumulation and what their export make right and that they have all the documentation related to that. And there's less checks and verification. But you know, we'll build systems where we can rectify pieces of information against each other as soon as it's claimed. And we can build you know, immediately updated graphs on what's happening, or how many logs have been delivered of a particular species against, what the claimed availability and volume for their forest assets were, for each of those forests and we'll start to run totals against those, right. So, we can have an idea of where they are in their production year, or if they're producing more than what was claimed in the forest or if they're way under producing for a particular forest that also sets off a flag. So, you know, there's lots of different ways to use this data to identify potential issues in the supply chain.

And then in the case where you for instance, have timber that's processed into boards, and then maybe into pulp. How does this verification process work? Does it mainly work then over the volume calculations, or like efficiency calculations of how much that, sawmill or processing facility processes?

Yeah, so I mean, we don't do a ton of pulp and paper, which is a totally different question. But for example for like, sawmill, yeah, we looked at their efficiencies in the mill or for peeling, we'll look at efficiencies of what they're reporting because a mill, pretty much everywhere in the world. There's like caps on efficiencies for certain products for certain species. And if you are claiming that you produce more efficiently percentage wise, you have to have that certified by the government by an inspector that will come and look and say, “Okay, look at your production run over a period of time and say, you actually are reclaiming 70% of X log for peel”, right. So, those efficiencies are typically registered by the government, and there's caps on what you can claim you're doing. And then you know, wood is something that we verify on site as well. So, yeah, a lot of you know, calculations of production are done with that percentage efficiency in mind. But then also again, the time, data over time, you start to learn for each product, what's possible, how they improve, how the quality moves, because you'll look at invoicing for grade, and that'll have a different efficiency for a lower grade material than a higher grade material. So, you have to start to learn all these complexities of the timber trade itself right, to understand that stuff.

Okay. And then you briefly mentioned DNA technology before. So, this is something that companies don't currently implement in their own supply chains because it's quite costly.

There is couple of issues with DNA. So, you know, we work with our Chief Scientific officer, this guy named Andrew Lowe from the University of Adelaide, who is probably the leading forest geneticists department in the world. They're also building their own isotope lab as well. So, the issue is that people don't want to use it, it is a little bit cost prohibitive at this point, but that also depends on what species and what questions you're asking. So, DNA can answer questions about species, it can answer questions about one-to-one matching, and it can answer questions about population. But all of that is dependent on the reference data available for that particular species in that particular regional question, right. And whether the work has been done in snip marker identification to be able to use DNA for that question, right? Which is true of all of these same sorts of sciences, whether it's mass spec, isotope, wood anatomy, you have to have a robust sample population of reference material to be able to draw those markers out and know where this wood came from, or what species of it. So, that's kind of the main limiting factor is, have those tools been developed for this species and product and question, right? Which in the Amazon, there's been a lot of DNA species work done a little bit of population. But again, it's very difficult because even for the same species, regionally they might differ quite a bit. So, there's a lot of

work to be done in it and it's expensive to develop those tools specifically because of reference material collection. So, I might be in Cameroon in October doing a bit of that work for a couple of different species. That's for the pharmaceutical industry though.

And where do you see the potential of blockchain and all of this besides sort of collecting and verifying the information that you mentioned before?
So, that's the million-dollar question for blockchains. We have blockchain companies that always want to get involved. But the problem with timber is it's really archaic. You know, there's not a ton of digital platform for nodes of information to be tied into a blockchain system, with the exception of Brazil, which is why we're trying to pilot it with Brazil supply chains, is because they're already our digital interfaces for document requests and issuance, through SISFLORA and SINAFLORA online systems, right. Which is super rare in the tropical world. So, our goal is, we'll start piloting this stuff within our own systems, right. Show that there is benefit in having a superior hash data record of third-party verified information, as well as individual input information, as well as are important information, as well as mill input information. So, that you have this secure record of what was claimed, which can be super useful as an auditing tool, because you have this immutable ledger of what was claimed by the mill and what was verified by the importer, but also can be used you know to demonstrate deterrence, because you know, what mills are claiming being recorded, and immutable. So, again, it's the immediate value is piloting and showing that, and then if we can, our hope is that we can kind of integrate that at a state level with some of the larger forest collective and industry groups that we work with in Brazil to say, "Okay, do we want to implement this across SISFLORA for all of Rondônia", and start to have this massive accumulation of blockchain data for DOF requests or export requests or export requests or for GF 123, right. So, then you start to have digital nodes that you can mirror on to an immutable ledger that becomes valuable in the way that we think of blockchain data verification being valuable, right. But that's way down the road.

Yeah, but then like, if you're accessing these different databases, if I understood correctly, are like connecting it with those and you have different players entering data, how do you check if that data is correct or like what mechanisms do you have in place?
Yeah, so for ours, that's our job as a third party, right. There's these like critical pieces of information that need to be verified. So, that's our job. So, inside of the fiber trace software, we'll outline is just some for this product that says double helix has to check X, Y, Z documents against X, Y, Z pieces of data information that are entered in for each shipment for that shipment to be green lighted and exported, right. So, then that entire process and what was entered by the importers and entered by the supplier are all captured inside of fiber trace as a software platform, which is then mirrored on to iov42's immutable ledger platform essentially which is built. This is you've probably already read it if you're looking at blockchain inside of the timber spaces with preferred by nature had set up with iov42 and Carl Ronnow which is a European timber company, a piloted interface software system for a Malaysian timber product. But it doesn't go back to forests particularly far it was helpful for Carl Ronnow structuring their compliance program. But beyond that, I don't see a ton of value in it. So, we're working with that same company and trying to bring more about marketable value to how that works right. By integrating easy to use software that helps manage compliance and ERP, third party oversight of critical data, and then marrying that onto an immutable ledger that can be used for auditing and presenting information to competent authorities.

What do you consider critical data?
Depends on supply chain, depends on the product.

Okay, but then how could you maybe walk me through the process of at what point in time what stakeholder would enter this information, so we can have a better understanding of your solution?
Sure. So, again, not our solution, it's one thing that we're trying out as we start to look at new technologies, right. So, for example, like we went and did a risk assessment on an eBay product. That decking supplier had three partner mill sub suppliers, and ten different forests that are supplying for this harvest year and that's the base claim. We go into each of those entities on the ground with our contractors that we work with in Brazil, verify the information that was supplied, looking at how they're producing, what documentation should be available, what documentation is currently collected, what is not. And then write them a plan that says, "okay, each of you are going to produce this information for every consignment of timber that you trade between each other, which eventually becomes the product for export", right. So, we have an accumulation of documentation and data at the final mill that's producing the deck, right from all of its suppliers, and forests. All that information has been on a forest level verified and continues to be verified. And then we're running tallies of volume against the logs as they arrive to the other mills. Key checks you know, some of that information is going to be input by the mills themselves into this software platform. And some of it is going to be collected and verified by us. Some of it will be randomly requested by us, even though they're just inputting it themselves or you know, we'll ask to see the information that they've input where that came from on a random basis, because that's part of the prescriptive plan that we've written for this product. Meanwhile, we also have you know, all of these polygons mapped and trace, and are for each consignment of logs and putting that in a digital system that shows "Okay, this consignment log is arriving from this force to this mill," we have kind of a live view of what's happening for production inside of the supply chain on a claimed basis, right. Then all of that information is as it's being put into the software platform is being mirrored on to a hashed, immutable ledger platform as well. Both at the mill level, and at the import level, and that our verification point level, right. So, we might be looking at, "okay, these are the dots are so claim to be associated with this shipment." How do we know that? So, then we'll request information from the mills upstream to show that those are the DOFs they received, or the upstream DOFs that they received in their production. And we'll ask for the recording ledger for that day of production associated with that product. And we'll match it all up, right? And say, might be problem say, "okay, we've claimed X amount of material in this day was produced from these five, eight logs from this log. But that doesn't line up with this DOF. So, where does this material actually come from?", which usually is they'll just say, "Oh you know, it's a balance issue or recording issue" or whatever, and we'll figure it out. But that's flagged is one issue. If that keeps happening then we know, these guys are lying, or they're not having the right material or they're not following the procedure well, which is its own issue, right. So, does that make sense? I know it's really complicated. But that's kind of how, an example of how the system works.

Yeah, makes sense.

3.3.7 Interview Tom Lange

Perfect. So, why don't we start with a brief introduction of a product or service that OpenSC technology offers and what exactly the role of OpenSC is.
Yeah. So, we are OpenSC, a technology venture and so, blockchain is only a part of it. So, usually we do not define ourselves as a blockchain company, right. So, that just upfront, but we are a technology company that uses blockchain as one of the multiple technologies to create a solution. So, what are we doing? We have basically created a platform that enables businesses to verify sustainable production or verify, ethical, or sustainable production at source. So, for a specific product, when we have done that, we believe we have created value. And this value needs to be traced throughout the supply chain. So, we basically match a specific information claim with a product and then in the end, have also capability

to share this information, either in a B2B context. So, for example, in internal dashboards, for example, a particular producer can provide it to the customers that they are selling to the information on the sustainable ethical production on a B2C context, where we actually have an end consumer experience, basically, where you can scan your QR code on a product and can see the information on the product basically, to create and consume experience around that. So, this is basically what we are doing, because we believe that we have created, we believe that we are actually creating a new sector. So, really not so many companies, maybe no company has done this before. And so what we are always doing is, looking for leading companies in that space, who already are very advanced in sustainability, so as to sustainable practices, maybe have certifications and so on, and now want to go the next step and actually want to communicate in a data driven and automated by with the end consumers. So, this is where we are really specializing and to give companies the choice to generate data, and then communicate it also to the end consumer, it's a bit complex.

After you develop a solution, and you sell it to the company, is your role still active or automated, so you don't really do anything?

So, each project, we start usually, with a project that is always co-innovation. Because usually, the solutions we develop are not out there yet. So, this is what we are trying to achieve. So, when we start working, it always needs to involve some co innovation that we are jointly doing together with the client. And that is really developing proof of concept. Running initial implementations, pilots and so on. And based on that we create a product sizeable offering, that we can then sell to other players in the industry as well. So, that is the ambition but at that stage, we are like trying always to co-innovate and develop something. And once we have it, like developed in an initial solution, for example, and become, I can talk about the different examples we have there. But it's basically always capturing specific data at source, validating a specific ethical or sustainable production claim continuously for the whole of production. And then linking it to physical products. And this happens on our platform. And then basically we charge our clients an ongoing platform fee for using our services. So, it's always at the end of implementation to onboard people or companies on our platform. And afterwards, we basically charge a recurring fee for our platform service.

Okay, cool, then maybe let's move to the next category, the blockchain case study. Can you maybe like, give me a brief description of a platform especially like in terms of blockchain aspects. So, how exactly is blockchain integrated or like what type of blockchain is used here?

Yeah. So, we use the Ethereum Main Net. So, it's a public blockchain. And what we basically do is every day, so within 24 hours, we use the raw data of our clients so that we gather, for example, for example in the seafood example, we use GPS coordinates, it's just shipping trajectory of the vessel, and basically store that every 24 hours, and then storage, basically the whole thing on the Ethereum main net. And this is basically what we mainly do with that. So, basically conserve the information on the blockchain. Then, of course, in the end, the companies and also end consumers have the possibility to look it up. But we deliberately said we want to store the raw data and also as close like, as soon as we actually get access to the specific data, so directly, after we have captured that and we use Ethereum for that.

Okay, and then what data points are stored? You said GPS coordinates?

Yeah. So, this depends. Like, on the specific commodity, so what kind of data we actually gather there. So, for example, it's usually traceability data, right. So, for example, in the seafood example, we, I think you read it also on the website, we verify the claim around that no fishing has taken place inside of marine protected areas. So, all the fishing has taken place outside marine protected areas. So, that is the

claim. So, how we do that, we basically use the GPS information of each shipping vessel, ingest that into our platform, and then have a machine learning algorithm developed, that basically can detect when is fishing happening and when not. And so, this, all this data, basically not the analysis, but the raw data is basically ingested into our there's, like it's taken and just all byte data, there's a hash written over it. So, that if someone wants to validate some data at a later point, then he can just use the raw data. And there's no trust element that he needs trust in OpenSC. For example, what we are doing or in the client so that is the advantage of blockchain from our understanding, so we just use it in terms of generating trust. In a coffee example, I can have another one there. We, for example, verify payments to smallholder farmers, that we have, for example, back level traceability. So, how much coffee is actually collected in Africa from smallholder farmers, and we digitize documents there on the traceability. So, how much volumes and what date are actually coffee beans, been transported to collection points and so on. So, all this raw data is basically what we are storing on the blockchain.

Raw data that the client like the company collects.
Correct that we are gathering.

Okay. Perfect. Where do you see the added value of blockchain? Having IoT?
Yeah. So, this is exactly what many companies are actually contacting us and say, “yeah, we also want to have a blockchain solution.” And then we actually asking them, “okay, what do you actually want to achieve?” Right? And this is something really, adding blockchain always creates also some complexity. And that's why we also want to not be thrown into a blockchain company, as I mentioned at the beginning, right. So, we're, we always claim ourselves, we are a technology company, and usually only because you mentioned that in the interview guide. But usually in the first 15 minutes or so, the first 50% of a conversation, even we are not mentioning blockchain at all. So, this is, of course, our aim. But we have this capability. And I think the advantages of blockchain are always when you have supply chains that are complex, and multiple stakeholders are involved and where you have a potential trust issue, then blockchain is quite a powerful tool. So, you have to have some kind of data stored in a decentralized form that can be verified by external sources. And there'll be use it. But just for the specific use case.

Okay, but okay, for instance, I'm just curious to know what information different supply chain actors can see in the blockchain? Because you mentioned that it's basically safe for everyone to see. So, are you also saving information on volumes?
Yeah. So, okay, do I need to maybe correct. Of course, we always, our clients have full control over their data. So, we are basically, I think we are using there's a system we have a blockchain engineer, right. And but when he explained something on that, so I'm naturally I'm coming from consulting. So, I'm not the deepest blockchain expert, but what we are doing is basically using IPFS, maybe you have heard about it before. And I think with that, we are creating basically a hash of the data, we use it, and then store the information and the form on the blockchain, but still, only the hash is visible in the Ethereum main net. So, still, our client have full control over their data and needs to then say, for example, if they have a regulator, or a customer, questioning the information, we then can provide them the information on the hash and basically, they can just close whatever information they like, but we can prove for everyone that this data is tamper proof and just know and was stored like 24 hours after we have basically captured this data, but it's not that you can just look in some way or now and see externally and look okay for our key client, for example, Austral fisheries. You see, we have caught the fish and how much volume that is, just no customer will actually want to do that. But for example, for a regulator purpose, this is quite powerful to have this capability.

If I understand correctly, you basically only have a hash value that is visible to everyone.
Yeah.

Okay. So, then let's move on to the next category. So, you mentioned that basically, your solution has three components verify, trace, and share. In terms of verifying you can basically verify the claim fished outside protected areas. How do you make sure that the fish that is basically tagged during this initial stage is actually from that boat from that location? In case of the scenario were a boat, illegally fishes and then brings it to that boat.
Yeah, so, I think you can create, we can create multiple examples where you can always say what is in this particular case? And can you cheat the system and yes, there will be always a solution or a situation where you can actually cheat the system despite us verifying something, but our ambition is that we want to make it impossible or non-economically so that it does not make sense and from an economic perspective to cheat the system at scale. So, basically, when you increase the effort that another boat needs to fish then store the fish and then transport it back then defreeze potentially because you need to attach a tag to it it's a lot of effort right? And this economically doesn't make sense. So, this is my first answer to that. Second answer of course what we are doing is when we are seafood solution is we as I said we capture the GPS data, use machine learning algorithms to detect when are they fishing and when they're not fishing. Yeah, after we have detected fishing, there's a defined time frame when they're back basically harvest the fish again and then need to attach this RFID tag to each individual fish. So, if these and then each of our detectors have been scanned into our system so you can see basically from the time it divides and time difference you can allocate it to a specific fishing trip or not. So, this is another test how you can make sure that everything is happening as it's supposed to be and the last point is also around mass-balance checks, maybe answers also another question now. So, for example, if you have this amount of fishing trips, but suddenly, like double the amount of fish stacked, right, usually you can, for example, harvest from one fishing trip, X amount of tons and next time it's twice that amount right then something is awkward and this is also how you can check if everything was alright or not. So, there are multiple things how you can basically check that what you are verifying makes sense.

You basically have a benchmark of some kind in your data.
So, this is always of course on history. Yeah, some historic information for example, in the coffee supply chain where we work on now, we go away from seafood, but in the coffee supply chain, you can say, each farmer, we know the size of the plantations of each smallholder farmer and for each hector of coffee plantation, you know, what is actually feasible in terms of coffee yields, right you generate from one plantation. And then for this for this particular intent, 1000s of farmers basically bring their coffee. If you have now farmer who actually delivers ten times the coffee volume that is normally for his plantation size, then something is wrong, then you can do multiple things so that the claim is faked. Either you don't know what, because we are always right now working with high-quality sustainable products. So, usually you get a higher price. That's why there's some motivation for farmers or producers to maybe try to teach the system but then you say "no, you just get the regular price for it." Right. So, that doesn't make sense. So, we always try to make sure that you can monitor something in real time.

If I understand correctly, it also doesn't address other issues in illegal fishing industry, such as overfishing.
Yeah. So, no. So, definitely. So, our aim is for each if we work with a fishing company, they should and then we also do it for example, not only this is premium Patagonian toothfish that Markus for example, was talking about in his TED talk or also in the news articles and so on, we also work for example, for prawns, so, you cannot actually monitor or attach each individual prawn. So, what we are basically

doing is detecting, tagging each 10 kilograms of prawns that are harvested and giving all the products that are caught on the vessel an identity and you basically, just by the, if you know the processes on a fishing vessel, you can yeah, it doesn't make sense from a volume perspective to attach it also because you generate operational benefits, because they do not need to count to the vessel. So, basically, what I want to say is each product on the fishing vessel is tagged anyway. And what we are doing is we by monitoring the GPS coordinates, we can basically verify that no fishing has taken place outside so they basically cannot do a fishing trip without us noticing. And also they have no capacity actually to not tag any fish that is not there because that is not how we work together. So, basically, we put all the systems in place to monitor the whole catch and the whole fishing trip. So, for the whole batch, we can verify that what can happen is that another of course boat that we are not monitoring is actually fishing there and fishing beyond their quota. But for the specific vessel, if we validate or verify the whole catch, we can say this has specific quota because it can only like catch I don't know 2,000 tons. We have the full information and can actually attach the claim but complication is of course if you do that, you need to do it for multiple fisheries. But there we are working for example, with the government to identify systems where for example, in a long-term situation and create a system where all the fishing companies are basically need to work together. Solutions like OpenSc and where the whole catch is monitored. And then you can basically say yeah, because the whole catch is validated that no overfishing has taken place or illegal fishing.

And then maybe to the claim "produced by legally registered workers" on your website, this is also something that you can do for the workers on the boat?

Yeah, so as I mentioned before, so we are co-founded by WWF, and BCG digital ventures, right, as you have seen on our website, so because we are co-founded by the WWF, we have an environmental or conservation focus. That's where we started with. But two years from now, when we were initially founded, we had another investor, an impact investor, and our board and that is humanity united, or the working capital fund, which is part of the humanity united, which has more anti-slavery and workers rights focus. And so we do both, we look into sustainability claims, but also on workers' rights claims and fishery is definitely an aspect of that, right now we are working on solutions there. Nothing is yet like fully implemented. But the aim here is for example, to validate we are video monitoring on particular vessels, guaranteed level of rest, for example for the working crews, because actually, you can, yeah, if you just think about it, like these fishing vessels are outside in the ocean and there's basically no, like sometimes there are observers, but enforcement of regulations or which is hard to monitor. So, that's why we try for example, with sensors, with data to monitor specific elements and then can basically make the claim "Yeah, all the workers have at least had 12 hours of risk per day, right." So, this kind of claims we are working on. And for the worker's rights claims of course we also try to use existing data as we have done in the seafood industry, because these shipping vessels are sending GPS data anyway. So, for the workers' rights claims, you also of course, try to use existing video monitoring installed to get this data. But this is like initial concepts and not fully implemented. Because there's also some of course, data privacy topics we need to work around. But for example, in the coffee supply chain, this is another big example, I am coming back always, we verify premium payments to smallholder farmers. So, this is something more related to the social aspect or workers' aspects. And not really to the environmental aspect.

But then basically, if understand correctly, these boats need to install these video cameras on the boat?

Most of the camera, and most of the shipping vessels actually have already some kind of video monitoring equipment, because regulators request that for specific purposes. They are working for

specific fishing companies that have some internal policies to enforce these policies. Usually, these companies have video monitoring already installed, it's just a matter of accessing the data and then making use of it and using the right analysis and so on. So, that is the concept. So, wherever possible, we try to minimize actually the installations required to together create some data. But sometimes it's not possible and then we do it but as cost-effective as possible.

Perfect. Next category about tracing I read that you use RFID tags. Are you reusing them and if yes, how many times can they be ultimately reused?
Not yet. I think, so for the Patagonian seafood we use actually, we'll have real physical RFID tags that are basically to be put on each individual fish. And to my latest knowledge is that these are not these cannot be recycled yet. At least we do not reuse them. Sorry they are recycled but not reused. So, that is them. But for example, for the pawns, we use RFID ID codes. And of course, it's 2D codes, right? These are basically batches you can put on the packages. That's not backwards, it's also scannable from an advanced so there's also some metal in the labels, but it's basically an RFID label, let's say it like that. It's something similar to barcodes. We also know for another fishing company, because the process is actually so controlled we also use barcodes to trace that but it's just a matter of what works in each supply chain, you just need a method so that you can say you have full traceability of the product. And you can basically you just create an individual identity either for an individual product or for batch of product, so that we can attach the claim to it and what the use 2D, to RFID, barcodes. Yeah, but this is basically what we are doing for the coffee example, we are also using for example, tags RFID no QR codes, we use QR tags on the individual coffee bags and these are then scanned along the different supply chains, but basically they are QR codes attached to each individual coffee bag.

And have you considered using DNA technology?
Yeah, I was when looking into other commodities. So, we are commodity agnostic, right. So, it means that we do not limit ourselves to one particular commodity we have started in seafood and there's also the most public information, but I mentioned it again, we work in coffee, in palm oil, we also have done some work in dairy. And when I looked into cotton, I saw a number of other competitors I would not say them competitors because most of the active companies are really into traceability and our core value proposition is on verification. So, to verify specific ethical and sustainably production claims. I know that there is DNA available for some technology, for our commodities but it does not make sense so far. So, that's why we have not used it. For us the technology doesn't matter, we just want to verify something, make it available to the consumer. We are also very happy to partner with others, so it's not that we need to create everything on our own. We are basically a spider in the web orchestrating everything and using technology that is already out there and put it on our platform to verify something and make it available to the end consumer. For each commodity, for each supply chain, in each region, for each client the solution will potentially look a bit different.

And so, basically you mentioned or you describe the process of or like what type of data is saved. What data, if any at all, do the different actors need to enter, is it only scanning the tag or the QR code or do they need to do something else?
So, what we try to do is of course to create a solution that impacts that ideally does not impact the existing working processes and workflows. This is this is our ultimate ambition. But at some point, this is not possible, for example, in fishing vessels each individual fish needs to be then tagged anyway. So, this is an additional process that is sometimes needed also when you offload and particular stages into supply chain, yes, and have ID or QR code or whatever needs to be scanned. So, that we have full traceability and our system. So, this is on the operational side when it comes to what data actually did

our clients need to give us access to this really depends on the specific claim. And we want to verify jointly with the client in seafood, it's fishing outside illegal marine protected area so we just need the GPS coordinates and then at the end of course then the information on each end. Tagged fish, for example, or the QR code on the prawns like they have ID tags for the 10 kilo boxes of prawns at different stages of supply chain.

But if you see that you need the GPS coordinates can't you like put a GPS tracker on the vessel?
Yeah, so there is GPS sensors anyway sensing is this information for security reasons for regular because the regulator request that. So, this is what I meant with this in the seafood for example it's very easy because there are so many systems anyway sending in two different systems the GPS coordinates. And for us, it's only a matter of ingesting this data, basically say "yeah, we also want to get access to this data." And using that for our own methodologies. In coffee, because I make it more tangible here. It's for example, when each individual smallholder farmer delivers their coffee to a collection point, for example, in Africa, or in the Democratic Republic of Congo, where we are doing it there, basically this is all written by hand, right? So, we have handwritten documents. And what we do there is we use image recognition, to digitize this information. So, we have digitized supply chain information, and use it then to transfer traceability and attach the specific claim to it. On top of that we verify premium payments, using mobile money. We also saw, for example, that promise to farmers are paid in and the way that they do so that for the specific volume we have the information, you know, the payment that are due we verify that in a digitized form, because it's mobile money, we're also working on a cash solution. And then we basically can link that. So, there's always systems that are already out there and then try with minimal effort to digitize or extract the relevant data that we use or need to have for our solution. I know it's a bit complex, it's not a straightforward answer, but it's very individual for each supply chain we need to get the data to ensure traceability and verification and this is very individual for each commodity.

Can you confirm if I understood this correctly. So, for the tuna fish case, basically the only thing that the actors along the supply chain need to do after having granted you access to their systems is to tag the fish and then scan it at each transaction.
So, basically, the clients do not sometimes even I think actors in supply chain, do not even recognize that something is different now, right? So, that is really our ambition at the end, that management, or their potential clients can actually have then access in a continuous and data-based way for the whole production. But the process should not be interrupted. And in the beginning, of course, if we set up or design a solution, we of course work with the client and do a detailed supply chain mapping to gather all the information and yeah, so there's always some also strategic information about other regions we want to focus on in your supply chain, but as your supplier relationships and so on. That is just one-time information. And recurring information is usually then use this API's so that we can basically extract existing information or deploy sensors that can generate relevant data.

So, we don't also we don't really tell the actors along the supply chain, they don't have an app or something similar?
Oh, okay. Yeah. For example, to digitize the entire coffee example that I was just talking about, in order to digitize this solution, we have created an Android app. So, that the workers at the collection point can basically create an image of the paper records that they created at a collection point with all the volume information which farmers have delivered, or what kind of coffee, and that date and, and the exact volumes and so they are there, we have created an app and also, for example, the fish processing. We have used a solution and an app basically to scan the QR codes and then at some point, for example, the whole fish tank is split into fillets. And in order to support this process, the workers have also an app to

scan first the RFID tag of the fish and then after the filleting, on package, there's an app a QR code and it basically needs to be linked right. So, you need to preserve the identity. So, basically one RFID tag becomes x for example, if you just split it into fillets to QR codes or we also work with portions. So, then for example in 18 portions or something like it, depends what is the final end product. So, yeah, so definitely, if that is not automatically done by a system anyway, you also need to have systems in place or solutions in place to capture specific traceability information.

Okay, so I read that you also work on solutions such as wood.
Maybe that's somewhere written on the website. But just to be completely open. We have not done, have initial concepts, not at all. It's something we're looking into but so far, we were busy with other commodities.

[Part is omitted due to confidential information]

In an article I read, Markus mentioned that it doesn't make that much sense to implement your solution when it's a premium product or it's sold at a premium price. And you have like a reference price point where it doesn't make sense anymore.
Yeah so, I think I would not say just this. You cannot say at a specific price point, so, for example, palm oil is a very low margin product. But since it's such, like high volumes, it definitely makes sense for us. So, maybe what is behind that statement is, at the beginning we are like really building a category here. And it in the beginning always involves some innovation, you need to create a solution, and you need to find leading companies that basically already produce something sustainable and want to go to the next step. So, most of the time, when something for example, deforestation is detected in supply chains, like only the big companies are always then appearing on the newspaper articles, but the whole industry is basically doing it right. And then the big companies basically saying "no, I now deploy some systems. And now I can verify that for my whole of production, everything is sustainable for my thousands of mills where I'm procuring my palm oil from," and now second, third company and the ranking, you can see and if you don't want to, like appear on the newspaper, you can do it. So, what I want to say is that's why in the beginning, there's an advantage with working with leading companies and the sustainability is great because they want to actually benefit from that, want to go the next step, also want to address first is the increasing demand for transparency and supply chain by consumers. Want to really solve the sustainability challenge at scale. So, a digital solution makes really sense. But I will not say it's limited to specific commodities. Of course, we need in terms of just yesterday, someone reached out, an olive producer in Morocco, and I said yeah, for 20 tons of olive oil, it doesn't make really sense right for us to innovate on something. So, that is the initial like when we actually start a new commodity, but our aim as I said in the beginning is always try to productize something and then consecutively, like scale and scale the solution in the different industry, because we do not want to solve this challenge only for one particular company or have a solution, we want to really be an impact company. So, we want to create impact in the world. So, we are for profit company, but all our investors basically pledged that if they make a profit from their investment, just profits are going to, I don't know, foundations, or donated to social causes. So, that's why also we have an impact mandate with everything that we do. And that's why we create offerings that are affordable also for smallholders or for small-scale producers because it requires a bit of course, effort and investment.

Ok. And then quickly to the last bucket, we briefly discussed the financial aspects before and you mentioned that companies pay a recurring fee for using a platform. Are you allowed to say how much it costs?

Yeah. So, this is flexible. So, this depends of course on each individual commodity, we do there. So, I cannot give you a fixed number because it's very individual. It depends a bit on what kind of services, how many claims we verify, what is the overall volume and what commodity, which regions they're active and what is the margin structure of the commodity. What we basically use a bit as a guiding principle when determining the price, I think you will also get a new study the different models to derive to your platform pricing or pricing structure. Some idea would be competitor offerings, but they are building a category so it's hard for us. But what does maybe most related to us is some kind of certification scheme. So, for example in seafood MSC or inverted the FSC logo, or aquaculture ASC, so, there are all these kinds of Fairtrade logo and so on. So, these certification schemes, and they usually charge also an implementation fee in the beginning to set something up to get certified. And after that recurring fee, that is what you invest. And basically, we do in a similar way. So, we attach it to the volume and also to the services that we create. And our aim is to be much cheaper than fees that companies currently pay for the certification schemes.

Can companies usually offset the investment cost by reducing the costs or receiving increased revenues?

Basically, yes, definitely. So, we have basically four, five areas, I think, why companies basically work with OpenSC. Yeah, so now, our five benefits are, the one thing is solving sustainability challenges at scale, solve sustainability challenges is what I said, right, if you are a large company and already, like doing things like now moving into the digital space, it really has some benefits. And this is more around, yeah, for a company really increasing the impact that is also mandated, for example, from their supplier from their own employees, and so on. So, then the second one is build trust with consumers. So, this is definitely addressing the increased demand from consumers in terms of transparency. And that helps either increasing, for example, if you provide more information on particular products, you have the chance to increase prices. Often the products we are working with are already quite in the premium space. So, it's more a matter of making sure you can keep the existing market share, because like there's more and more increasing pressure from consumers. But also when you enter new markets, you can basically have a unique selling point and unique advantage and providing this transparency to the end consumer. And, yeah, and the database. Now this database communication, so not only depending on the law, but on a certification that you would then also need to trust, basically, but without, for us, it's not we do not verify practices that something is sustainable we verify actually outcomes, right? So, you can basically see, yeah, the fish must be caught in a sustainable form, and do not need as a consumer, you do not need to trust an institution that sends observers every two years to a fishing vessel and say, "Yeah, your policies look great. So, I trust you." So, this is how it's often done right. And yeah, so complete like new level of communication that you can enable. So, that is one thing then also, you will potentially have experienced that during your university time is around investor capital requirements. So, many investors request now that you need to be sustainable with your practices and so on. So, ESG requirements, for example. And this is also a form of having a database proof that you are operating sustainable. Last, or next point is managing strategic and regulatory risks. So, I was telling that before, right with palm oil, basically, it's very hard for a brand like a large producer of, for example of chocolate to verify that they are really only sourcing deforestation-free palm oil. And they are you need to have some kind of solutions to mitigate this risk. So, this is the next part. And then when it comes to benefits, this was your initial question. Bottom-line benefits would be also often through increasing supply chain transparency, you can create some operational benefits. For example, efficiency gains. One example I can give you is based on food waste, that's one example we are working with the company often has challenges that if something is small, errors are happening in the supply chain, because it's cold storage, for example, the temperature was not the right way. Some of the prawns turn black, you can still cook

them, but some of the prawns turn black. And then usually the supermarket call our client and say, yeah, "this is not like, we need to send it back to you." So, it's a product recall. And before they have worked with us, they didn't know that basically before they have to throw away all their production because of this one record, because they were not sure what was happening again, and what was the problem. And now with the traceability, they have very dedicated information on a product level and can have a very targeted records of the product. And so food waste is eliminated in this one example. Right. So, the loss is much more limited. So, yes, top line benefit, but you have also multiple bottom line benefits. Also. Sorry, another example is in coffee supply chain. For example, we just detected through the increased transparency, you have also some kind of fraud protection. So, that before coffee that was delivered in good quality to the collection points is maybe now was before delivered to someone else. And now it's not possible to actually send it someone else because you have fully traceability. So, this is also an example. So, yeah, operation of benefits. Definitely there.

Maybe one last question.
All good.

What were the challenges that companies were facing when they tried to implement your solution are co-developed or to co-innovate?
Yeah, so challenges are typically in terms of anything of increasing transparency and supply chain, they are, I think, three things that often appear, but I think you can also argue against it and find a solution that works for everyone. The first thing is, of course, always a bit of how much information do you want to disclose potentially, to consumers to competitors, also, especially in the fishing example, for example. The fishing path where they actually fish is quite sensitive information, and the companies do not want to disclose that to competitors. So, you need to find ways of verifying that and a sustainable form of communicating that to an end consumer, but not disclosing that in a too detailed form to an end consumer that can be then ultimately also competitor and then start fishing in this area. So, this is definitely one of the aspects. Then, of course, if you have the interaction of multiple actors in the supply chain, you always have the challenge of availability of data in general, is this data reliable? Is this data speaking to each other and so on? Right, so availability of data and yeah, and reliability of data when you work with multiple actors in the supply chain. So, you always need to reach always say, we need to create a coalition of the willing to do something like that also have basically a coalition of supply chain actors all one wanting to achieve something positive, and then it's much easier but if you only have one actor wanting to do something, you need to look into incentive structures or who has actually more power over what suppliers and last but not least, is also the benefits I just mentioned to you. Some of them you can quantify but some of them are also when it comes to risk mitigation, for example, it's very hard to estimate right? If you have a huge scandal, sometimes, it's a huge impact on your brand, reputation and so on and then like it's a huge turn, but it's very hard and compared to other projects like a transformation, digital transformation, you can calculate efficiency gains and so on. But for this transparency, it's very hard to really, in the beginning, define or calculate and return of investment. So, after one year, I will have that amount of benefits, right. So, this is really sometimes it challenged, so you need to have someone who's really believing in the long-term value of such like, of transparency overall, of sustainability. And usually top management has this ambition and, just perception already. But yeah, middle management sometimes is wrongly incentivized, right. They're only incentivized for some short-term cost benefits for example and then this is a bit challenging. So, yeah, to summarize, right, it's disclosing too much information, the risks, then not having actually access to information or reliability of information, and then just return of investment is a bit unclear in the beginning. You need some strategic visionary perspective.

Follow-up Interview

We can see if we have time for questions, but maybe let's start with the key questions. So, the first one is on verification. So, basically mentioned that OpenSC verifies claims at the source. Does this mean that you do not verify legality throughout the supply chain?

What do you mean by legality claims? Just my question, what is behind that? Like what do you expect?

I mean, like you basically want to sell legal fish right? And legality in the fish supply chain, it can be defrauded at different stages throughout the supply chain.

So, that no infiltration of like non-verified fish enters the supply chain, is that what you're looking for? okay, that is typically referred to... you can look into, for example, GS one standard, if you have not looked into that, that is then traceability or chain of custody, right? So, that you have digital traceability. And so, we did clearly differentiate between the verification of sustainable or ethical production claim at source. And then once you have verified that you need to ensure Chain of Custody of this physical product. So, it's not... Yeah, you can also call of course that you have a verified traceability. But yeah, we clearly differentiate what we mean by verify is more and the [inaudible] of the production claims that we are referring to. But definitely we have, like technology in place or systems in place and integrate with supplier systems. For example, to ensure that we have a segregated supply chain and ensures us chain of custody at the end. And infiltration of inferior products also swapping of products right, So, that would be claim product. So, I don't know if that answers your question, but...

Yeah for instance, let's say there are different actors throughout the supply chain and they need licenses to operate legally, would you also check that? Or is it sort of...

We could so... what we are like, it's not mandated to work with OpenSC because of regulatory purposes. So, we are focused on that things that are most important for the client of course, for our clients or customers. So, there is of course always a component that impact component we are an impact start-up. So, we do not want to engage in any greenwashing activities or whatsoever, but we do not define what is basically like sustainable or not right? We worked out together with the WWF and so, on, we do not we are not in that position to say they are only sustainable if that supplier has that license or that actor and the supply chain, then the fish is legal or not. So, we just asked like to collaborate, with WWF. And also ask our client what is like your requirements? What do you want to communicate to the end consumer or to your, like B2B stakeholders? And that'd be... do that because this is very important in sustainability of oil, right? There's not only not sustainable and sustainable there's a lot of like transition elements. And it's there's, it's not binary, right? There's not zero or one it's there's a lot of grey elements and we say especially in the transition not everyone can be fully sustainable on all dimensions from day one. So, we focus on the key elements that are most material to most relevant for the partners we are working with.

Okay, perfect. And then maybe like the next question number three is also linked to that, but I just wanted to clarify So, a machine learning model just basically integrates different data and then at the source verifies the legality of the fish?

Yeah. So, I think my initial answer to that question is the machine learning model only applied to verify data collected in the first stage of the supply chain was this model also applied to. Now yeah, So, the machine learning algorithms are only applied like we have set up is for the verification of this specific production claim. So, either as a social or official example it's a sustainable claim. Sorry, environmental claim. Yeah, there we use machine learning for the chain of custody is basically putting the measures in place. Of course, you can also put some kind of machine learning algorithms for example, if you look into chain of custody, there are multiple things how you can ensure chain of custody. You can either

have a fully like physical... What's it called? Basically that you have like we do it for the fish for example that we have an RFID tag on each individual fish. So, you can trace it everywhere. But you can also say the second level would be segregated supply chain. So, you have fish that comes from a verified source and fish that comes but it's not tagged and then you have fish that comes from a non-verified source. If you keep the fish if you never mix basically the fish during the day. Yeah, along the supply chain. So, then this is the segregate point. Then the third one would be then mass balances. So, if you have mixture of verified and non-verified, but this is also true for certifications, right? If you have a mixture of that, for example primer, it's often done in that way. Then you have a volume accounting. So, you say okay, you have you know, that like 100 kilograms of prime oil and that's a supply chain and 50 kilograms of non-verified prime oil enter the supply chain. So, then at the end you cannot claim 150% verified but only 100% right but you cannot differentiate now when the final product you don't know was it now 100% verified or not verified because it was mixed in the end. So, there's different stages of maturity but there's always also you cannot attach to a small prawn an RFID tag right? That makes no sense or when you have like, I don't know flour or soy or palm oil right how do you attach a physical text. So, you need to work with different measures.

Okay, perfect. Then the next one is concerning the IoT devices So, you mentioned the use of GPS data to track the journey of a tuna. And my question is how do you know the GPS coordinates of the fish once it leaves the vessel?

Yeah so, then like could be that I was too tired in the first conversation. So, we use the GPS data from the vessels. So, we do not attach like we only attach an RFID tag to a fish and not GPS tags. Would be way too expensive, I assume. So, now, the fish has an RFID tag and when the fish is offloaded from the vessel or then also entering the processing facility then you have an RFID antenna and then automatically the fish is scanned. So, that is how we detect it. But it's not and there'll be no like we do not know exactly the location of the fish, we just know it's caught. If you look into the GS one standard for traceability for example, you always talk about CTE and KDE. So, critical tracking events and key data elements and what we are what we need to make sure is that these critical tracking events are defined and at that point in time we want to have like full visibility that the product exists and no infiltration of other products have done but what happens in between or in the processing of course you cannot have like 100% visibility because also cost doesn't make sense right? That's true for temperature actually. So, temperature you say it's stated on the website. So, I'm not sure – I have not checked that our website but I assume if that statement is really there then it shows more the art of the possible. Right now we are not attaching any sensors but I think maybe for the prawns. I'm not so deep into our implementation. If you have cold chain supply chain, so, where the temperature really plays a role that we can also integrate with another data source. You always try we always try to find what the primary data... what primary data sources can be actually collected in a cost-effective way. And you can also think about the container where these prawns are transported. And you have like a temperature device that is connected to like to a cloud or something that we can integrate this data into our platform and also to run an automatic verification. So, check that the temperature of this prawn has always been like below, I don't know five degrees. So, we know that was always the case. That is definitely on our roadmap, but I'm not sure if that's live.

Okay but then you don't use any sensors in the fish supply chain?

So, you can always say like not IoT based or what do you say with IoT, right the IoT this RFID tags and then the sensors actually sensing the IoT. So, I would not agree with that statement but it's more and it's always at OpenSC we always try to limit the operational burden for any of our technology but still like achieve what we want to achieve. So, it's about for the fish since we can depend on the GPS data that

the battery is already sending out we can just use that right for our verification and the same is true we come to that data recording and sharing. So, weight for example we integrate with the scales on the vessel. So, when the fish is coming on board its weighed and it's put on a weight scale and this weight scales are digitized, so, we just integrate this data. So, it really depends what is the maturity of the supply chain we are operating in. So, if there's like access to good and right data we need to be just integrate with it, we do not need to apply additional sensors but in our supply chains for example in time oil, this is very remote and so, we need to integrate this with different kinds of sensors.

But when you say that like the so, you basically have the weight of a fish and it's digitally recorded, So, nobody needs to enter manually like the weight?
Yeah, so, that is always what we try to reduce any manual inputs right? We worked up as a client that has also other advantages of course but for us it's very important that if they release manual inputs, the less chances for data for either explicit or unfortunate later errors. So, if a client only has manual scales and tracks the date manually, which is about I think the fishing sector is also more advanced now. It could be that the fishing scales are usually they are all digital but this these fishing scales are not integrated to a cloud. So, they are we need to say okay we cannot get the API directly the data but basically get the CSV file from time to time from the ship and then integrate it into our platform but ideally we want to have it in almost real time. And usually when they from time-to-time data methods update their systems anyway. So, not only to fit our purpose but then we just use it for our systems as well.

Perfect and then towards data recording maybe quickly to weight since we touched upon it. The species of a fish is it usually only one type of?
Yeah correct So, usually but that is true almost for all fishing So, you have different kinds of catch methods and depending also where you fish. So, this is a longline fishing So, I think you have seen it like in the TED talk, you can see it. So, it's a long line, it's a kilometre long line, multiple lines with individual hooks, every couple of like, I don't, I don't know, maybe meter or so. With some like bait on it and then you get fish, these type of fish that we catch the Patagonian tooth fish that live lives like I don't know a couple of 100 meters below sea level. So, they are you typically catch because of the bait of the of the hooks catch the same species. If there are other species then they are not weighed or they are differently process than they do not get the RFID tag. So, usually, you do not have a lot of bycatch on that and species. But species detection of oil especially for the bycatch is another claim that we would like to explore. You have already for example, video monitoring on some methods where you have when the fish is landed on deck, especially this is in real light, they're already like cameras, some methods have already camera detection. And then this is another like idea we want to next year we'll explore that we automatically do image recognition and detect what kind of species for kind of other species were there. Because that's of course important also from a sustainability aspect.

So, for instance to ensure that no dolphins were caught?
Correct. But as I said like in that regions where especially because it's so deep under the water and also the types of hooks you use and so on and bait. Dolphins, I think is not a not a real issue, right. Also like the fish they catch, I think it's around 60 or 80, up to up to a meter or something. So, it's. So, there are different measures in place already to limit bycatch. So, I think there's a long line generally, there's more birds when the line is coming to the surface, that for example, try to catch the fish and then of course also get hooked. So, that is always a claim, but there are current measures in place to reduce it.

And then to question number 10. So, you basically talked about the IPFS?
I think I was super tired when explaining to that. So, let me explain the block chain how we use blockchain again, in like a structured form. So, basically, we use blockchain to provide the tamper-proof auditability of our supply chain, So, basically, that you can or that someone, if they want, can audit our, our data, and that we can prove that it's tamper proof. So, how we do it, the data we receive this primary data points, we always call like, especially that, that we need for the verification at source, we are archive that. So, basically, storage at the central data, but before even processing, right, So, we store it. And then I don't know if you are familiar, but otherwise read Wikipedia article on a hash. So, basically, you take that archive and create a hash. So, which means all the data that is stored in there has a fingerprint, and this and if you want to change, after you have archived it, if you change something of the data, the fingerprint would be not the same. So, you have really an individual hash and you cannot like tamper with the data. And then these hashes of these archives, they are basically published to IPFS. And the manifest file, and this manifest the hash then, ultimately, is then published to the Ethereum main net. So, what we are not storing just because of you will see it like potentially also in other conversations or something you have to really store more data on the blockchain is very expensive and very cumbersome process. So, and there's always a balance between, of course independent auditability of supply chain, but also transaction costs, and also environmental concerns or energy consumption. So, we do not store raw data, which we basically do a hash and write this raw data to ensure this auditability. Maybe that's now a bit clearer, but we...

Yeah definitely. So, basically, you only store the hash on the public block chain?
Yeah. Correct.

Okay, great, then question 11. So, if I understood correctly, for instance, companies can sell to B2B companies, and also to B2C. And for instance, if you have Austral fisheries serving fish to B2B consumers, what type of information is shared with them?
Yeah, so, theoretically, that this could be the same. So, what we are always like, what we do, what the role of OpenSC is to verify in a database by an automatic and for the whole of production, specific environmental or social production claim. And this is of course, like, there's no institutional trust required. So, this is based on data. And this data, depending on the client we are working with, can be either shared in an end consumer experience. So, imagine you have a QR code, and then scan and get considered consumer journey. But could be also we have, for example, a platform dashboard, where the client itself can access the data but he is also free to share this dashboard or exports of the dashboard of the captured data or processed data and verify data with B2B customers. So, that they can prove also that the fish they are selling to the B2B, for example, to retailers is really sustainable. Then the retailer itself can also create an end consumer experience for example, for their clients. So, if you are at the fish selling place in the supermarket, for example, you can imagine it's not a packaged product. So, that you have for example, a QR code then on the counter that you can basically scan or some kind of information. And so, yeah. So, it's basically the same information. So, data and the client has full control over the data. So, he decides basically, because all some things are also commercially sensitive. So, the client decides what they want to share, either to consumers or to their B2B customers.

And this dashboard that you're talking about, I guess, it's like a website that they can access?
Yeah, that's all there is to the usual, like, platform, like how do you say, yeah, platform. Like, of course, you can access this via browser and log in and see like, it's all on the cloud, of course. And you can, we have done multiple analysis, and you can track everything from the data we have captured and by things are verified, and maybe some things are not verified, So, that everyone has full visibility.

Maybe then quickly to question 9. So, basically, then the companies have access to this platform that is accessible through like the browser. And then, like workers along the supply chain, they have access to a mobile app to scan the tag?

So, yeah, correct. So, this is what I was talking about in the beginning, this chain of custody element right? At multiple, like you define this key critical data. Sorry it's called critical tracking events, CTEs. And there you need to know how do you basically capture that data. So, one critical tracking event when is the fish basically offloaded from the vessel to the port. So, you can either have someone with a scanner and scanning into each individual fish, what are the advantages that you have a RFID tag, So, you need to have an RFID antenna and ultimately, when the RFID comes close it senses the existence of it, and then it's uploaded to our platform. Whereas then, for example, when the fish is processed, so, in the processing factory, when basically one fish tank is put into two fillets, or portions, then the workers have an own app that we have programmed. So, that they can scan the fish, filet it, put it in packages that have a serialized QR code, and then scan the QR codes. And we basically have the full traceability along the processing step. So, always need to see what are the critical tracking events are where things can, where we need to have control over things and visibility. And then ideally, we find an automatic way because you otherwise create an additional task for the workers. And they are busy right with other stuff. So, you need to find ways to do it in an effective way.

Perfect. Do you think we have time for one last question?

Yeah. All good.

Okay maybe then to Question two. So, you mentioned or your website mentioned, but you can you issue claims to products? And certification companies also play an active role? Or how is the certification claim verified?

Yeah. So, we are generally open to work with certification schemes. And we are we either have or are or have ongoing discussions with that. But we are really independent and focus on key claims. So, certification schemes have really a very holistic view on sustainability. For example, MSC is I think, checking against, don't quote me on that, but checking on that against 150 criteria or something. And it will be not possible to automatically database way audit these 150 criterias in a data-based way. So, that's why we say we do not want to replace them and we do not want to automate and we want to focus what is the most concerning part that consumers are concerned or that our customers are proud of, they want to commit like. Or from a risk mitigation perspective where they say, like if this is not like. If our fisherman are really catching and marine protected areas we have a huge risk as a company. So, you identify what are these key topics, and then we develop solutions to focus on that one. The long-term strategy is of course that the overtime more and more integrate into that, that it becomes also potentially like the standards evolve and require some automatic audits through a solution provider as OpenSC and then also regulatory changes. So, right now we are really building on certification schemes and not trying to replace them and we are definitely open for collaboration but there's nothing public to announce yet.

Okay, perfect. Well, thank you so much for taking the time to answer these follow up questions. It was really helpful.

3.3.8 Interview Anna Roberts and Kiara Kealoha

So, maybe we can start with a brief introduction from your side, the work that you do and basically the products or services that you provide to other companies.

Kiara Kealoha: So, Iov42 it's an identity centric platform that is designed for organizations to build trust into their operation. That's a very high-level explanation. It leverages the principles of blockchain technology, but it is not a blockchain. So, that might be confusing. But basically, the simplest way to understand it is that all of the benefits that are usually associated or are known to be associated with blockchain. So, things like security, transparency, immutability, all of these things we offer through our platform. But we have, we leverage different technologies. And we've developed our own technologies from the ground up to kind of make the application of blockchain in organizations faster, scalable, and more secure. So, our main technology is a platform that other organizations can use to build solutions like Timber Chain, which is the one that you've come across. And it's one of our first services that we've launched, in collaboration with some partners, so we're really excited about it. But yeah, the idea behind our technology is that other organizations like Preferred by Nature, and Carl Ronnow, who we worked with on Timber Chain, would be able to build their own solutions on top of our platform. So, in this case, it was a supply chain solution, but there can be other solutions around government identities, for example, or securing medical records for a healthcare system, there's all, you know, different applications that could be built on top of our platform, and Timber Chain and supply chain traceability just happens to be one of them. But Anna can hop in if there's anything that I missed.

But then basically, if I understood correctly, your work on the development side has already ended? Or is this something, like on a project base? You develop these platforms and then your work is basically done?

Kiara Kealoha: Yeah. Okay, so I think a good way to kind of envision is iov42 is like a kind of layer at the bottom, made up of different kind of technological Lego pieces, basically. So, one piece could be like identity things. One is, you know, digital assets. One is digital certificates, and they're all kind of in this bottom layer. And that's our company. And then other companies can come and build on top of that layer, just kind of using the foundation of our technology. In the case of Timber Chain, specifically, we helped develop the solution, because our partners don't have their own kind of in-house development teams, right. So, they wouldn't necessarily be able to build it themselves. So, we helped develop it for them. But the idea of the platform is that anybody really can come and use it and build on top of it. And we have other clients right now that are building on top of it without us because they are they have their own development teams. But in this specific case, we helped build it. And we still are working with the client to build out more functionality and work with them, to make sure that they understand how to use it, and also to keep kind of refining it and building on top of it so that it continues to be beneficial to them as the service kind of builds up.

Yeah, perfect. And within Timber Chain, what type of data is visible to the different actors of the supply chain? Is it just like the hashed value or do they also see other information?

Kiara Kealoha: So, the people who use the service so like, let's say, an exporter, they control and own the data that's being put into Timber Chain or to the system and they can decide, for example, if they want their clients to be able to see a shipping record or some other kind of document that they put into the system. They can share that information using basically password protected links. And so, they can see the actual data. Anna is there anything else to add to that?

Anna Roberts: Yeah, that's absolutely right. You're right. It's stored in hash an encrypted hash format, Lynn. So, you're right about that. A lot of the data visibility is a big, big concern for people. And I know

that there's, in Brazil, for instance, is a government distributed ledger that has a lot of data on it. But the government owns that data once somebody put it in there. And with our platform, the company's keep ownership of their own data, rather than it being able to be monetized by other parties.

And where do you see like, the big value-add of this platform compared to current systems that companies might have in place, but don't look wherever just keep it on their own record, and then share it.

Kiara Kealoha: So, I think the really big value add of a, well, I'll start with kind of like a blockchain-based solution, and then I'll add a little bit more about iov42 specifically, but using having the kind of security and the transparency and the immutability of blockchain in these kind of systems is the value-add, because we know, you know, in the kind of timber trafficking market, a lot of the problems come from misusing documents or falsifying documents, or, you know, double using, like, maybe there is a legitimate certified document, but they don't use it appropriately. So, there are all these kind of issues around that. And so, when you have a system where every kind of record is unalterable, and undeletable, basically, that kind of adds this layer of transparency. So, that's the kind of general blockchain use case with our, with Timber Chain, specifically, the value-add a big value-add comes from the fact that it's identity centric. So, everybody that's participating in the system has to have a verified identity. So, that holds people accountable for whatever they're doing on the platform. So, you know, if there is somehow faulty data, whether it's just accidental, or perhaps not accidental, it can be traced back to that person. And that kind of disincentivizes, I guess, illegal or kind of dubious behaviour in the system. Yeah, I'd say that's the kind of big value add, in general. And of course, as you mentioned, being able to share the documents and the data and having more or less one sort of single source of truth that all of the different actors in the supply chain can refer to. And it provides this kind of extra layer of trust and security amongst the organizations because we're really, Timber Chain doesn't necessarily replace or get rid of kind of all of the good work that these organizations are doing, and their commitments to due diligence and sustainable sourcing and all of these things. It's not replacing that it's trying to just add an extra layer of security so that the different actors across the supply chain can trust that their sort of co-supply chain, actors are acting in good faith.

Anna Roberts: That's the really important point. It is not replacement of legacy efforts to do this. It is sitting below lots of different efforts around traceability already, that can plug however, they're doing that into our core platform to secure it. Timber Chain happens to be something that we built. But there's another organization who have a timber blockchain, who are switching their timber blockchain to be on our blockchain instead, because it allows different systems to talk and communicate with each other across boundaries, which we think is quite different. The second thing that's really an added value, and this maybe doesn't relate specifically to, oh, maybe it does actually to your kind of Amazonian timber thing is we don't need separate instances of our blockchain. To be able to do the same thing for other commodities coming from the Amazon such as soy or leather or beef for instance, you'd be able to secure the same degree of traceability of those commodities on the same instance of the chain rather than having to have separate solutions for everything.

Okay, I see, but then, if I understand correctly, and it's more supposed to complement efforts from companies to verify the legality. So, then my question is, like, is there a specific claim that companies that use your platform can basically track through the supply chain, and then give it to the end consumer for as the timber was harvested in a good area?

Anna Roberts: Yeah, so it's not just for legality, it is able, the, I guess, five main claims, four of which we're already doing, and five, which we're building towards. One is legality. Two is sustainability. And

that sustainability standard is defined by different standards. So, you could have the claim being that we meet PEFC Chain of Custody standards, or the claim could also be that we meet FSC forest management assessment standards. So, there's legality, there's sustainability, there is volume, volume is something that I don't think a lot of other companies do, we're able to track and convert volumes throughout. So, that you can tell "Hang on a minute, there's a you know, there are many, more cubic meters of timber at the end point in the value chain and went into there something weird is going on." And the last is the behaviour. And those are the behaviours of sorry, the origin and the species are the other ones. So, the behaviour is the legality and sustainability, then you've got volume, then you've got origin, and you also have species.

Okay, so wait, did I understand correctly, but timber companies currently with older or other existing systems don't really track the volumes throughout the supply chain?
Anna Roberts: Other traceability solutions?

So, they don't do it at the moment, like re-conciliating the volumes?
Anna Roberts: This is, so, this is what we've heard by competent authorities and regulators and enforcees. We haven't looked in depth at every single solution that's out there, but from the ones that we're close to and talking with, that's correct.

Okay. But then, if you have these different claims, such as sustainability or legality, how do you or how do companies make sure that this data is correct? Or entered correctly in the beginning?
Anna Roberts: That's the role of the endorser. So, we've got two roles that participants in the system play. First is they are users. So, they're a timber company or they're a furniture manufacturer or they are a retailer, they are people who will use the system because at various points they need to prove those claims about their timber for their own customers or for the regulators for instance. The second parties who are part of it are what we call endorsers. They endorse like you mentioned DNA in the questions that you sent over. The endorsers are third parties who authenticate or validate the origin, the species, or they are somebody like PBN, who is authenticating the permits and the certificates and saying: "Yes, we granted this certificate for that particular shipment. And by the way, that certificate expires on 12th. December, so yeah." Does that make sense?

Definitely. And who are these third parties? Are they usually like auditors such as SGS? Or is this something like who defines who these people are? Is this something that for instance, that timber companies define together? Or how is this sort of handled.
Kiara Kealoha: So, I'll take a first stab at it and then Anna can hop on after so for now that the main sort of third-party body would be Preferred by Nature. They're the kind of one sort of founding partners for this service or they really helped us understand the kind of sort of certification piece of this service. Having said that, Preferred by Nature is not the like exclusive certifying body or third-party body that we would work with and they also are quite happy that the Timber Chain service expands to include other third parties and other certifiers because that is really how we attack a problem like illegal logging, right? You have as many people working together as possible with the same kind of goal. We also so that's the kind of the certification piece. But we're also in conversations now with more kind of scientific research, Anna can speak more about because she's had more recent conversations with these groups, but to kind of come from the other side, so to look at the kind of wood that's coming through the product and to test it, to see that, you know, the species matches what is claimed that it is. So, that being kind of endorsed, basically, again, the claims that are being made. Anna, did you have any additional...?

Anna Roberts: Your question around who decides and who the endorser is? The short-term answer is, we have clients who might have a different certifier. So, they currently could have a strict certifier, and they decide that SGS should be invited to endorse them into the platform. So, it's either us or it's the existing parties who want to be involved. Moving forward, because a decentralized system by nature of the word decentralized, people have to agree on who are those reputable parties that they want to be part of this broader network. So, it will be a decision made by existing parties as to who else would be involved in it. Because if you can imagine, so I know, for instance, some of the I don't know the names of them. But we were talking to an organization yesterday who mentioned that some of the Russian certifying bodies, their standards aren't accepted in other markets. And if we were to suddenly have Russian certifying bodies being the highest standard that we have in here, it wouldn't live up to expectations of other markets that we want to work in. So, they have to agree and define what are the standards of the policies that have bought into it.

Okay.
Anna Roberts: So, it's basically it's, I mean, I say, basically, it's incredibly complicated, we're still figuring out but it's all about the governance of it, right.

And was it challenging to define like minimum standard that need to be upheld throughout the entire supply chain?
Anna Roberts: We are not, so we are not saying this is the standard that you can trust, or this is the data that you can trust, we're creating a platform for people to have all of the information they need to make that decision about the standard or the trust that they have themselves.

Okay, and then I think Kiara you just mentioned that you're working on basically trying to test the product at the other end of the supply chain, or that you've been discussing with people or researchers that are basically doing some or have experiences with scientific testing? Do you maybe want to add something to that?
Anna Roberts: Yeah. And I'll link it to your question about DNA. Because DNA, and I think some of the IoT stuff, like sticking QR codes on timber, or NFT, or RFID tags is a route that a number of organizations have taken. And they definitely play an important role in this. But we don't see them as being infallible. So, DNA, for instance, can tell you a species, but it can't necessarily confirm what the origin is of that timber. The thing that we think and again, it's not without its flaws, but we think there are ways to help recover those flaws. And scientific testing, such as stable isotope testing, which we know the UK competent authority with EUTR is keen to be involved with that is the type of endpoint testing or actually whatever point along the chain, you want it to happen that would be appropriate for. So there, one, they will become one of the endorsers on our platform.

Okay.
Anna Roberts: I can see you thinking a lot about this. And it's probably we've only been working in this field for about six months. So, it's probably our clumsy way of articulating things. So, if anything is confusing, or you think not accurate, please, call us up on it then.

Okay. But then if I understand correctly, they basically only do it for certain samples, or what's the plan? Or did you decide to not use this because of the drawbacks that this technology has?
Anna Roberts: No, no we do we really, really want to do it. Their plan over the next five years, and they've got US and UK government funding is to create a world reference set of samples from

everywhere. I think they currently have samples from 60 countries, but I don't know what their global coverage is exactly.

Do you remember the name of this project, something with World Forest ID?
Anna Roberts: Yeah. That's the one. So, yeah, exactly. So, they are, we are talking to well with it indirectly through the organization that runs the testing labs. So, not the sample and the reference set itself but the actual people who do who called on the samples and the reference samples.

Okay, perfect. And then you also mentioned the use of IoT devices. What's your take on this? Are these technologies especially, are they applicable to the timber industry? Because the problem of wood is that in many cases, it's almost immediately cut up after being harvested. And a lot of these RFID tags or QR codes would need to be removed during the stage.
Anna Roberts: Yeah, we agree. I think we'd agree with you. So, we originally looked at some nanotechnologies. But again, because how much things are processed it's probably not going to work out too, soon. Stable isotope testing, we think is a better way of being able to do that. There are other IoT solutions that are really interesting, such as drones and satellite technologies. And yeah, so they're more they're more of the things. It's really interesting Lynn, because we chatted some months ago with Copenhagen Business School. There's a master's course there, I suspect quite similar to the one you're doing. And somebody is doing a master's in a very similar topic to yours but not super focused in on the Amazon. And they had come across a lot of research around IoT as well. So, it's, yeah, it's a hot topic. There's a ton of funding for it, where I think going down the route of stable isotope testing in the first instance, but I think we'd like to involve satellite, what it's called? I'm trying to remember the terminology that's used…

Remote sensing?
Anna Roberts: And yeah, like, yeah.

Okay. And then, but then how, like, I've seen companies or independent auditors actually use satellite images sort of to complement the efforts to verify the legality. Because nowadays, that technology can even identify like selected logging, and not only deforestation. But drones. I haven't read that much about or like heard that much about how would you see this being implemented? And I imagine that it's rather expensive, also, because they would need to fly around all the time.
Anna Roberts: Yeah. And the battery life isn't in the battery, and on a lot of them. We've spoken with the CEO of the drone company, actually about their timber traceability solution but it's more satellites that we've had more conversations with than the drones themselves. Although the UK competent authority did talk about drones as being important to them.

Kiara Kealoha: Yeah, they did mention that. But I think it's good it's worth noting that with lots of, like, complicated solutions, like in complicated supply chains, like timber supply chains, as a company that works kind of a, you know, in the blockchain space, we're very clear that blockchain itself is not, you know, a magic solution, right. So, when you're able to kind of integrate other technologies, whether it's IoT, satellite imaging, if it's, you know, smart water sensors, if you're doing more agricultural stuff like that's, you know, one of the big value-adds of blockchain is being able to kind of integrate all of this data and, and putting it in one place so that it can be synthesized and analysed quickly as well. So, just to kind of highlight that, although we deal in the blockchain space, we're not one of those companies that says, you know, blockchain is the magic solution to everything because it's not, it's about kind of bringing together all of the best technologies out there in one place. Yeah.

And then you briefly mentioned that basically, you see quite a lot of potential satellite imagery, and how do you see this being integrated into your system?
Anna Roberts: Yeah. So, in in two ways, and I think it's, it's really important to take a step back at this point and say, with, although the development project with PBN in Colorado finished. This is a project that will go on for years as industries evolve and technologies evolve. So, we don't have all the answers to the questions that you're asking. Yeah, so just to be really upfront with that, in terms of satellites, one way, two ways in which they can be used. One way is around a lot of the shipping side of things. So, shipping is a big point where corruption can happen. And so there are organizations, I don't know if you've come across purple track and their technology that's used. But there are organizations who help confirm status and customs clearance of shipments. We've chatted with them, I think we're a little bit closer to understanding how it can be used in a different situation, which is stable isotope testing can tell you that within a particular, I don't know, one kilometre radius, I don't know exactly, how much of timber originated from that particular area. But what happens if that area is next to an endangered forest? Or what happens if it's next to an area that doesn't have a quota for logging? That is where a satellite would be able to say, "well, you're saying it's from the legal area. But actually, we can see that there's a lot of illegal activity happening just on the border of it." So, whilst you're 99% sure that it's coming from the legal area, because of the isotopic testing, there is that 1% chance that has come from that illegal area. And that's what satellites can help with.

But then how, like in such a situation where it's not 100% clear, how do you proceed?
Anna Roberts: We are not proceeding. We are not telling companies that they can or cannot proceed. We're giving them the platform to make that decision, whether they have done enough due diligence and whether they are comfortable with the level of potential illegality in there.

Okay, I see.
Anna Roberts: So, we're not very, clear to say we are not a new standard or anything like that.

Okay. And then maybe again, once back to the physical transformation of timber. So, you mentioned you were looking into nanotechnology, but you didn't really see how this could solve the problem of a physical transformation. Did I understand this correctly?
Anna Robert: Yeah.

And so then, how is it verified within the platform or by the endorsers? Do they just do the volume reconciliations based on, like, percentage that facilities can basically convert into sawn timber?
Kiara Koheala: Yeah, I'll let Anna take this one, because I think she can explain this slightly better than I can.

Anna Roberts: I think you, well, I think you actually did a pretty good job already, Lynn! Yeah. So, the monitoring organizations are the ones who can who define what an acceptable conversion rate is for a particular sawmill based upon the technology that they have for a particular type of processing step. And for a particular species and volume. So, they might say that there is a 50% conversion rate of teak in sawmill A in Myanmar, for instance. And if we can see that more than that 60% conversion rate is coming out the other end, that's an indicator to the importer further down downstream, that something's not quite right. Or it's an indication that actually that sawmill has invested in great technology that's helped them increase their conversion rate but that would then be for the certifier to go and check and see actually, are we all comfortable with the higher conversion rate.

Okay, I actually have a quick follow up question on that. So, basically, you mentioned, okay, let's say that the output is 60% instead of 50%. With your platform, is this automatically flagged? Or would it only come up if somebody actually looked at the number?
Anna Roberts: No, it would be flagged. So, there would there is an error that pops up. And it would be so it's flagged in that sense. The other thing that we're trying to do, and this is probably 2022, by the time we get there is, you might be familiar with smart contracts.

Yeah.
Anna Roberts: So, we've taken that concept and looked at it a little bit differently and have come up with what we call smart assets. And that is one of the things that we're trying to build in a smart asset is basically an IF function that gives permission for something to proceed. And building in conversion factors and volumetrics into that smart asset functionality is something that's on the roadmap.

Cool, maybe let's move to the last bucket. So, this is more about operational, financial, market aspects are like just challenges that you're facing during the development and implementation phase. So, maybe starting off with feedback from timber companies. How did they perceive your solution?
Kiara Keahola: So, like Anna said, I mean, the service is still quite new. We've been working on it for a little less than a year. I mean, we'll be at least when we first started the conversations and the service itself actually went live back in June. So, the feedback is ongoing, basically. And in the case of Preferred by Nature, and Carl Ronnow, the two kinds of first partners that we're working with this project, we have a very open and collaborative relationship, which has been really helpful to get really candid feedback. But I mean, basically, it's, it's on-going. Having said that, there are partners who do kind of have expectations for what they hope Timber Chain will kind of add to their operations and, and kind of businesses, which is, you know, things like in streamlining due diligence, increased regulatory compliance, and being able to share data with their consumers and buyers. And, you know, by reducing time and cost on due diligence, then that impacts their bottom lines, hopefully, but these are all sort of things that are expected benefits, and hopefully we see them and we work with them to kind of make these things realizable, but yeah, it's kind of ongoing, basically. Yeah, that would be the kind of quick answer, but I think we are planning on doing a sort of prove impact study, right. And so, we can be able to actually look at some metrics and point to the actual impacts, not just us saying, like, it should do this, that you that we can sort of see the actual impact of Timber Chain on their operations. So, that is ongoing. It hasn't started yet, but it will kick off soon.

Okay, so basically, then, if I understand correctly, as of now, companies can't really share that data that easily with end consumers, but this is something that you want to explore in the future.
Kiara Keahola: So, if you mean end consumer, what do you mean, when you say end consumer? Do you mean like the kind of the retailer or the end consumer as in like me buying a wood of wooden shelf from IKEA? Or what do you mean by end consumer?

We can take both cases, so B2B, like if you have a business as the end consumer, and then maybe someone buying a table that's made out of wood in IKEA.
Kiara Keahola: So, I think I mean, our Timber Chain right now currently focuses mostly on export, the traders themselves and the data that they are interested in sharing with their direct buyers. So, kind of the importers based in Europe, mostly, that's our geographic focus at the moment. And they are able to share whatever data that they would like to share with those particular buyers. And that's often shipping information about the shipments that are coming into that relevant documents and certificates, and things like that, and they can share that information. Okay, basically, if I was to, you know, I'm the trader,

you're my buyer, and you say, "I'd like to see the documents for the shipment that came in this Monday," I send you it could be like an email, for example, but it has like a password that only you have, you put it in and you can access this data, that doesn't necessarily mean that you can go on to, you know, the platform itself and kind of add information, you can just sort of see it. If that makes sense.

And then for B2C consumers it's something that is shared via QR code or this hasn't really been explored yet?
Kiara Kealoha: So, that's not or Anna can add, but I don't that's not necessarily what our focus is on right now. We're looking at that part of the supply chain, that doesn't mean that it's not going to happen one day. Because that's definitely some companies are interested kind of in having that sort of traceability for their customers, B2C customers. I think right now, a lot of what we're trying to focus on is looking more upstream to supply chain as opposed to downstream to really sort of focus on building up the robustness and the integrity of the data that's going into the system. But that yeah, doesn't necessarily cut off a solution that does, you know, go really literally from stump to store, as they say, but that's not necessarily our kind short term, I think, roadmap for the service.

Anna Roberts: Yeah, I mean any organisation that has a B2C requirement or solution that they've already built. So, I know a number of stores have that already or retail organizations manufacturers have that, that can be secured. That can be linked up to all of the data that's gone before on our platform. We haven't built the Timber Chain solution as it stands at the minute to service, I guess, citizen consumers rather than business consumers.

Okay, perfect. And then in terms of challenges during implementation, I guess you piloted this with certain with a set of companies? What was the main challenge? Or what are the main challenges?
Kiara Keahola: So, I think they're the, I guess, so I have to preface it by saying that we were kind of lucky with the people that we were working with, because they were obviously very open minded towards working with blockchain, they were interested in innovating a kind of new solution for their supply chains. But having said that, they're oftentimes when it comes to developing a solution that deals with blockchain. There's a little bit of, there's a lot of education that has to happen, right? Because there can there's apprehension sometimes. And that can be because blockchain has can have a negative sort of connotation, depending on who you're speaking with. Maybe they think about Bitcoin and energy consumption, or maybe they think about other kinds of cryptocurrencies. And so there's a lot of education about, you know, what blockchain really can do, what our technology does, specifically, and how it's different from the sort of standard blockchain model. Just doing that kind of education piece. And I think also, with lots of industries, and especially like an industry like timber, which has been around for a while, there might be some hesitation because there's an expectation that a lot of systems have to be retrofitted. Or there's, you know, lots of like, there's a learning curve when it comes to this kind of new technology or new software. And, you know, if you were to speak with one of our first kind of client Carl Ronnow, they weren't super excited, I guess, from the very beginning, they were kind of like, "Yeah, we're interested, potentially. But we don't really know about blockchain, we're not super sure about it, if this is actually going to make a difference." And it was just a lot of spending time with them. Sitting down, I mean, virtually on meetings and stuff, speaking with them, trying to understand what their needs were, and trying and communicating to them how our technology can address those different challenges. So, it was it was just kind of a learning together kind of process. And that was just one of the first sort of things that we had to tackle. So, not too much of a challenge. But just I think with a lot of blockchain technology solutions, there's just a little bit of education that has to happen in the beginning. Yeah.

And in terms of like, regarding the costs? Because if you don't really need to invest in IoT devices, what areas did the companies or do companies sort of need to invest in to make this part of their own supply chain?
Kiara Keahola: So, I'm going to give a quick answer and then I'll let Anna hop in, because it basically depends, right? And that's not necessarily a super satisfying answer. But every company will have different needs, maybe they want it to only address a certain part of the supply chain, maybe they do want to have an IoT or maybe they do want to integrate it with their kind of, you know, customer facing traceability app. So, there's all kinds of different sorts of things that come into play when it comes to costing out building up a solution. But I that's the kind of quick answer and Anna can build on top of that.

Anna Roberts: Yeah, I think the main one is it depends how bigger how advanced companies already are in digitizing their existing processes. And that, like, digitizing can be as much as Carl Ronnow where they were using Microsoft forms beforehand, or yeah, I think it's Microsoft forms. Just digitizing can be ensuring that they're properly structuring their data collection rather than everything being very paper based. So, that isn't our cost. But it is a little bit of a cost of entry that they need to make. If they're already there, that is a bit easier for them. And then for a number of people, if they have their own software development teams, there's no cost. For us, there's maybe a little bit of setup fee, and depending upon how much hand holding they need, there's no cost to them for putting their solution on our platform, other than a licensing cost to use the intellectual property behind it, and a transaction cost. And we know that for instance, if there is transaction costs, however much one euro per cubic meter is far too much for some organizations. So, ours is a lot lower than that. We're still figuring out exactly what the commercials are, actually. But yeah, at the minute, it's not a barrier.

Sorry, I see that our time is running out. Do you still have five more minutes? Or do you need to drop?
We can hang on for five more minutes.

Where do you see the future heading in terms of technology? So, I mean, like you integrated or selected some of the elements that you consider important for the current blockchain? Do you see another technology coming up that would replace basically these elements? Or do you feel that this is a solution that will establish itself in the market?
Anna Roberts: And you do you want your answer to just be related to timber?

Ideally, yes, but you can maybe paint a bigger picture too?
Anna Roberts: That's fine. That's fine. Because I think we're timber is just one small application of what we're doing. But I think, where do we see it going? I think there are two areas. And this, honestly, Lynn like, this is why our job is really interesting, this advances and our goals every month or so like there's a new way that we think that we can help people. So, there are I'm so sorry about that. There are three main areas that we're looking to build out. And that's further than going up and downstream. The first is to include carbon in it. So, information around that would serve carbon markets better. So, information around carbon capture, and carbon offsetting which links directly to timber. The second is more, and this is something that we've been thinking of, but we just haven't done it yet, is around the social elements of ESG, which is a term I really love. But by that, I mean, alongside capturing the origin, the species, the volume, the behaviours, part of that behaviour is capturing that there's no modern slavery involved in the supply chain, and that people are paid a fair wage, and that people are qualified and have the skill sets to be operating the machinery that they're operating, etc. So, including the social bits. And then the

third is the smart asset functionality. That's where we would really see our technology. Like putting a bit of rocket fuel into what we've already done. And that's something that we're working on as well. Did I miss anything here, Kiara? I don't know if that's too narrow.

Kiara Keahola: No, I think you I mean, you highlighted the fact that yeah, that we're focusing mostly on the kind of certifying the wood product, that the goal is to incorporate other elements of what we consider, you know, part of sort of traditional sustainability. So, community resilience and employee rights and things like that. And that's kind of in the longer-term roadmap. But I think in general, again, because our platform is although, you know, blockchain is the thing, or the elements of blockchain or principles of blockchain is what makes our technology secure. So, that, you know, when new kinds of technologies come around, or a new partner comes in, it's easy to sort of integrate our technology with those technologies. So, you know, as new things come up, then we're able to kind of scale and adapt properly by integrating with new technologies. Right, Anna?

Anna Roberts: Yeah.

3.3.9 Interview Richard Anning

Perfect. So, you briefly mentioned before that you don't operate in the Brazilian Amazon, but you had quite a lot of experience in timber supply chains. There are a lot of similarities in different timber supply chains, so, it may not always matter where it's sourced from but the supply chain in itself is quite similar.

Yeah, I think most, you know, most countries, especially tropical countries, which tend to be the high-risk countries will have similar problems, whether that's or similar issues to deal with, whether that's a perception of how forestry is carried out. In those countries, the levels of corruption in the supply chain and the awarding of licenses. The forest that the wood comes from is it's got, you know, very high levels of you know, they're tropical forests. So, it's very important to conserve the biodiversity of areas is much more than say in a temperate forests. So, I think the, you know, the issues will be kind of very similar. And so, I'll tell you a little bit about Carl Ronnow, we're about 30 years old, the company and we're a timber trader, so we don't own forest, so we don't even own a sawmill but we buy mainly sawn timber and veneer, which is used to make plywood, the veneer. And traditionally, we started trading just from Malaysia. But over the years that's changed. And we have quite a presence in Gabon, in Central Africa or West Central Africa, really. And you know, also from Europe, we export timber as well. And I do the kind of certification environmental side of things for the company. So, we work a lot with our suppliers, encouraging them to become certified. Look at certification, educating them on the benefits of doing that, because it then makes their wood product easier for us to sell, you know, into many of our markets. You know, so although our company has the head offices here, I'm sitting in Borneo in Samara in Malaysia, but we kind of operate from quite a lot of places, but not South America, not at the moment.

Okay. Very cool. And can you maybe tell me a bit more about Timber Chain in itself? Like how did it start and maybe also a brief description of what problem that it tries to address?

So, we've been working, you know, we've been working with a company that are now called Preferred by Nature, but they used to be called NEPCon. And they incorporated Rainforest Alliance, about three or four years ago. So, they're a certification body, and we've been working with them since 2003, actually, when we first got FSC Chain of Custody certification. And so I know some of the people that

are quite well, and they know that we're always up for looking at something new. Trying out something new. It's always good to be ahead of these things because you can get an advantage in the market. You know, if with what we're able to sell is slightly better because we're doing something more transparent or whatever. So, Adam Grant from, Preferred by Nature approached me last about September: "Look, we've linked up with a blockchain service provider called Iov42. They're interested in doing a pilot project to see whether blockchain technology could be used in the timber supply chain. You know, would you be interested?" And initially I wasn't because I didn't know a lot about blockchain. And I didn't know how it would benefit us or how complicated it was. But we, you know, we went through the process, and the more I learned about it, the better, you know, the more I kind of bought into the idea. And, you know, so now we're sort of, we're really going live with it now. So, we're able to ship timber under the blockchain, but we haven't done so yet. Because shipping is very difficult at the moment, because of, there's a container crisis, a shipping crisis around the world, I think, due to COVID, really, you know, there's a shortage of ships and shortage of containers. So, we've started Timber Chain, from Malaysia for our Europe sales, Europe, UK sales, and we haven't shipped any since we went live a few weeks ago, but we will do quite soon. So, I mean, it's not doing anything ground-breaking, it's not incredibly technical, although the people that are set it up are very clever, and they know a lot of stuff that I don't, but all we're really doing is, you know, uploading information, documentation information onto this secure digital database. And at the moment, our supply chain is very short, just because the way it's set up but it could involve a lot of other players, eventually. And that's when you really get the benefits of something like Timber Chain. But one of the big advantages I could see is that we are demonstrating transparency with our buyers. So, if we're basically you know, there's, within our industry, there's quite a lot of suspicion that people are not as open and transparent as they should be. Possibly, you know, documentation is reused, or it's messed around with, you know, there's all kinds of issues with our industry. And I felt that by agreeing to upload and commit all of this information onto this digital database, that can't be changed, you know, once you put it up there, and documents can't be reused, once you put them up there is kind of giving a message to the buyers that are required to do, you know, due diligence to a degree that there's a negligible risk of illegality, then, you know, this would appeal to them. And the buyers that I've spoken to, we've got some pretty good feedback, anything that we can do to kind of make their job easier and to build confidence with them. And they're competent authorities in their countries, I'm really talking about Europe in the UK now. So, that's kind of why we went into it. So, it's not highly technical, really. Although it can be used with some of the new scientific methods like DNA and mixed isotope testing and RFID some of the things that you mentioned in your mail, there's no reason why that information can't be stored on this, you know, secure database.

And how was the process before you implemented Timber Chain? Did basically, each actor just collect the documentation for him or herself? And now can basically have it in one place and just share the link instead of having different electrical documentation.

Well, in the case of Malaysia, you know, we're not giving any different information that we would have given without the blockchain. We're just putting it on the blockchain. So, we're gathering the information and we're putting it onto the blockchain, but one of the, you know, so we're really concentrating on the EU countries now who have the EUTR, but also the UK that's no longer part of the EU and they have the UK timber regulation. So, one of the things about the EUTR and the UK timber regulation is it's very open to interpretation of what is required to do a certain level of due diligence. So, imagine if we've

got ten different buyers in different European countries who all require due diligence for the product that we're selling them, shipping to them, but they all require different types of due diligence documentation, because it's not specified what's really needed. And some need more than others. And suddenly, some need less. That makes it really quite complicated, you know, for us to be preparing different types of different levels of due diligence documentation for different buyers and it also confuses suppliers. Because for this buyer, you need this. And for that buyer, you need that, you know. So, what I realized with blockchain is that if we gather every single bit of information that we would give to the buyer that wants everything, and we put it onto the blockchain, and then when we ship to any of these buyers, we give them an encryption key for their particular shipment, they can go in and take as little or as much as they want. So, that's kind of quite an advantage.

And then if I understood correctly at the moment, this Timber Chain is only used at the later stage of the supply chain so only by traders, exporters, importers, and then the buyers.

Well, I mean Timber Chain is very new and we're the first people to do this. Well, Timber Chain is what iov42 and Preferred by Nature are calling it so we're the first ones to do it. And it's not a standalone thing because we have the product that is involved is PEFC Chain of Custody certified, which all comes from PEFC certified forest management units. Okay, so it's got the FSC certification anyway, on top of that, we've got something called legal source certification, which is a due diligence certification. That NEPCon sorry, PBN, Preferred by Nature like to be called PBN now, so PBN, offer this due diligence certification, whereby they look at how you gather your due diligence information, how you mitigate any risks of non-compliance with EUTR. And if you meet their standard, then you get legal source certification, which we've had since 2016. I think so, you know, we're coming on for five years now. So, at the moment, this Timber Chain is an addition to our legal source certification. So, it's not a standalone thing. So, all of that, that the due diligence and the checking and the documentation that we've looked at, to obtain legal source certification. And our legal source certifications already in place that is then uploaded to the blockchain. So, although we haven't involved anyone upstream in the Timber Chain thing, we gather the information from them and store the information and we put it on ourselves.

So, how do you check whether the information that the suppliers give you is correct?

Well as we normally would for anything, you know, so you identify where the risks are, and you mitigate those risks. So, I mean, something like legal source certification or due diligence certification is more in-depth than, let's say, FSC Chain of Custody certification. So, you're not expected to go into this degree of risk assessment, although FSC, PEFC are bringing in risk assessment, it's not kind of really the same. So, whatever we have do to obtain a due diligence certification would be by, you know, you look at the country risk, you look at the regional risk, you look at the, say for instance, the MTCS, which is the Malaysian timber certification scheme, which is aligned to PEFC, you look at that, the standard of that, what their standard and then you do a comparison of, where that doesn't address all of the risks as per what the EUTR would require. Then you show how you mitigate those risks. And once we start buying in product, once you've done all that, we need certain documentation from our suppliers to prove where the forest, where the logs came from. And we need documentation from them. Within their sawmill, we go and visit the sawmills. We've trained them, a lot of them, we've trained them to get the FSC, PEFC certified and stuff anyway. So, we've got a really kind of quite a good handle on, you know, well, we've reached the level where we've been awarded legal source certification, and not that many companies

have, of the due diligence of how we handle this wood. We do hope, at some point to involve those upstream in Malaysia in this but the time isn't right for it yet. They're not open to doing things a new way. So, kind of what we're hoping is that our buyers will buy into it, and then would prefer it and once that gets some traction, we can go to suppliers and say, "Well, this is now what we're doing. If you want to be part of this, you know, we've got to be doing this, this, and this." Because it would be preferable if they were, you know, actively involved themselves. Now, the next place that we're probably going to start is in Gabon. And in Gabon, we buy sawn timber, mostly from operators who have their own forests. So, there's a direct relationship with the forest owner. And we're already gathering, you know, lots of due diligence from them for the shipments that we do to the EU. So, you know, that's something that we're going to be looking at probably in the near future. And, again, if we could get sort of one or two of those to buy into this, and they agree to upload information onto a blockchain, rather than just sending for us to check and then upload, you know, which would be the case at the moment. And then that would make things easier, but these, it's early days for this, you see. And, you know, it's always getting the balance between having benefits to sell to either your buyers or your suppliers. This is not an industry that readily changes, you know, generally.

You mentioned, so basically that you have to fulfil the requirements for the chain of custody. So, I'm just trying to like understand this a bit better. Does this mean that you need to document the chain of custody from the source to your stage? Or is it just for instance three suppliers before you where you need to have this information on?

Well, I mean, you can, if you're looking at chain of custody, if you're looking to FSC, or PEFC chain of custody, you can just look at their standards, and their standards will tell you what they require. And this is probably why something like the EUTR, if you're purchasing if your product originates in a high-risk country, you are required to have documentation and information right back to the forest source. So, that, you know, if you were buying from the US or New Zealand and importing into the UK, you probably wouldn't require that just the fact that it's from New Zealand or the US. If the wood originated in the US and the product originated in the US, then that would probably be enough for your competent authority who implements EUTR to say, well, that's probably enough. When you're buying from a higher risk country that is perceived as high risk and that most of the equatorial countries, if not all of them, then you know, you would be required to go right back to the forest source. Whereas you're not really required to do that with FSC and PEFC to the same degree. And one of the weaknesses of FSC and PEFC Chain of Custody has always been I've seen that you only have to pass on your direct suppliers claim. So, if they say this is FSC certified, then that's kind of good enough for you. But with something like the EUTR it's not. You know, because if you're buying sawn timber from a supplier, and he says "Oh, it comes from an FSC certified forests or PEFC certified forests," that's probably enough under FSC and PEFC chain of custody, but under the EUTR it wouldn't be because it's from a high-risk country and you're really supposed to map the supply chain and get information, right the way back to the forest source. And that is why I mean, the industry is up in arms about it. Because they say, well, they're importing wood with FSC and PEFC certified claims into say, into European countries, and they say, well, it's FSC and PEFC certified, but for the competent authorities that implement the EUTR or the UKTR in those countries, they say, "No, it's not enough, you need to get information that will take you right back to the forest source." And it might even be from you it might be buying from a lower risk, what's perceived a low-risk country. But if there's a high likelihood that the origin of the wood was from

a high-risk country, you know, then, you are required to gather information all the way back to the region on the forest source normally the forest source.

Okay, but then. Okay, so let's say, you as a processor, rely on the claim that a previous supplier basically gives you that it's FSC certified. How do they check this? Is there, like a database of FSC certified companies? Or do they just obtain the documentation?

I mean, you know, one of the parts of, to get FSC or PEFC, Chain of Custody certified, in every audit, but one thing you do have to prove is, how can you verify that your supplier has a valid Chain of Custody certification. And they're either FSC or PEFC chain of custody, and you just go, you basically go to the FSC, or PEFC website, you put in the details for the supplier, and it'll come up, it'll tell you that they're certified or not, it'll normally tell you the species that they they've included under the scope of their certificate, the different types of products that they've included under the scope. So, you know, there has been cases where we've been offered something that's certified from a supplier. And when we checked the website, the species or the product isn't covered under their scope. And then we point this out to them, and they would just go back to FSC, or PEFC. And expand the scope of their certification. So, you know that's how it's basically done with FSC and PEFC. But I don't want to get in a whole conversation where I'm not, saying this there's anything remiss with FSC and PEFC. But the fact that you know that, it's very much a generalization, but you're almost able just to take the claim of your direct supplier, and not dig too deeply, doesn't really marry up with regulation, like the EUTR or even the US Lacey Act, you need to be able to dig deeper. So, FSC and PEFC is a very useful tool for due diligence. But it isn't the complete solution that people thought it would be.

And maybe back to Timber Chain. So, basically, you mentioned that you could see maybe in the mid-term, long-term future, but you can also bring upstream suppliers onto the platform. Is there any other potential that you can see in Timber Chain in terms of maybe additional functionalities that it could adopt?

Well, I mean, so it's just a vehicle to store information. So, you know, that information could you know, you could be doing DNA testing on a supply chain, and, you know, you could just have the documentation for that and send it to a buyer or an authority checking it or you could upload it onto a secure database such as, a blockchain, such as Timber Chain. So, you know, like I kind of said a little bit earlier, one of the big advantages of it is being able to demonstrate transparency, and saying, "We're not trying to hide anything, we are prepared to put all of this information onto this secure database. So, once we put it there, we can't change anything." And we will give an encryption key to the buyer, who it's being shipped to, so not anybody can look at that. I mean, we can choose who looks at this, but, you know, a buyer in in saying the UK wouldn't be very happy if we shared that information with one of his competitors, you know, so it you know, it's the security aspect, it's the proof of transparency, it's about sort of being open that I think is one of the major advantages. But I think you know, the people I mean, if you want to know more about the potential for expanding, maybe you should speak to somebody at iov42, you know, who are the blockchain provider.

I already actually had a conversation with them last Friday.

Right, right. Who did you speak to Anna?

Anna and Kiara.
Okay. Okay. So, you know, they would have much more of an idea of where they want to go with this, you know, beyond what they're doing now. But they I mean, it's, you know, I mean, one of the most amazing things that I've seen is. It's just like an Excel spreadsheet, you know, when that first came out that you can put all of this information, you can use formulas to link it together. And, you know, blockchain is, in very simple terms and I'm not technological, but it's kind of doing a similar thing. But unlike an Excel spreadsheet, you can go back and change things. Once you upload something to this blockchain, to Timber Chain, you can't, you know, so there's that. Again, it's that extra level of commitment of transparency.

And then basically, I guess you have the information on a specific timber shipment? And how is this connection to that timber shipment established? Is it wood identification marks on the timber because I think that you don't use IoT devices at the moment?
Look, some of our stock is in our warehouses is barcoded, but, as well as being barcoded, it's also written in paint on the timber. So, you know, supply and timber is all about giving identities. And when identities change, you have to link the original identity to the new identity. And so, you know, that's very much done, but it's more, it depends who you're talking to, you know, different companies do things differently. You know, many of the suppliers in Europe, once they receive timber, then they do use barcoding or whatever to keep track of it. And there'll be more and more and more of that in the future. You know, the timber industry in countries such as Malaysia is still quite old fashioned, you know, it was only in the last three or four years that we can we've gotten suppliers to email stuff to us, rather than fax it, you know, seriously, you know. And they've got these old fax machines, they got no ink in them and stuff, you know, you can't read the documents. So, that's kind of slowly changing. You know, it's, you know, it's not like you see these European sawmills that are all up to date, and they've got electronic machines, computerized software that run machines, it's all very much done, but it's very labour orientated still. So, you know, the way they record the information is slightly antiquated. But that doesn't mean to say that there's anything wrong with that, it doesn't mean to say that it's any less credible. Because if you know how to follow the documentation and follow the numbers and trace it through, you know, I can go into a sawmill and they'll cut a batch of logs, or they, you know, they'll supply some sawn timber, I can go into a sawmill and trace that back to the logs or the batch of logs it came from just by going through the recording mechanisms that they have, and very often it's done by hand, more often than not, you know, and it's written in books or on, you know, on scrap, not scraps of paper, but on sheets of paper, but then normally in an office, they'll input all of that onto their, you know, onto their, whatever system they're running. And that's when it becomes sort of electronically recorded. But, you know, in the manufacturing side, the physical side, that transformation side. In countries such as Malaysia, it tends to be still quite old fashioned. But that doesn't mean to say there's anything wrong with that. As long as the numbers add up, you know.

Do you feel it's maybe a bit more prone to falsification or manipulation if you only have everything written and basically handwritten on paper, instead of having it in a system where you can basically, quite easily link it back to the source?
Yeah, but I mean, you couldn't, you know, I mean, you can also record stuff digitally, and it doesn't really exist as well. I mean, the results you get is only as good as the information you put in. Yeah, of

course. I don't think it's ideal to be doing everything manually. But because it's more messy, and it's more labour intensive. And, you know, I mean, you know, for instance, there are different types of companies in our industry, and there are companies that, you know, most of them are very good, and they're very honest, and record them very well, and we can trust them. But some don't, but we find out who they are, and we don't deal with them anymore. You know, we just stopped dealing with them. So, you know, the checks and whatever that we carry out, will eventually catch people out. Because if you just keep asking questions, which due diligence is it, it's a conversation, you ask questions, and you get answers, then if you're not happy with the answers, you can ask another question, you know, until you make a decision, well, you know, have I mitigated this risk? Or have I not, and if you haven't, then you've got to leave that supplier alone. I mean, although most of the industry is fine, the industry doesn't have the name that it has, because everybody's an honest player, you know, so. And you know, I think, if we were having this conversation in ten or 20 years time, it would be very different, people will be recording information in very different ways. And that that has happened over the time that I've been working here in Malaysia 15, 17 years, it certainly changed. You know, when I first started, we didn't even have the iPhone, you know, and there was no such thing as Facebook and WhatsApp. And, you know, there was, so you know, without sort of an iPhone, you couldn't go. And now you can go in and actually capture information at forest level, record trees at the stump and link back to satellites to get GIS marks to prove exactly where that tree stands and stuff like that. So, that wasn't available then. And, you know, that will become more and more, than norm. But, you know, it won't work everywhere straightaway, because some places have lot less access to even electricity, you know, or, the internet or whatever.

And so, basically, briefly mentioned that you use barcodes and basically wood identification marks to identify the timber, do you see any potential in using RFID technology, or maybe also QR codes in the future?

I mean, it's possible. I mean, RFID, I've seen that used here in Sabah, and that that's more for a forest level, you know, I don't really know how, whether it would be necessary in a warehouse situation, you know, where barcodes or you know, QR codes or whatever. But sure, I mean, the technology is out there. What we're kind of doing works pretty well at the moment. It's been working, you know, quite well for many, many years. So, I think the technology is much more useful say at forest level, you know, where there are big areas of forest. And if you can, you know, get a better handle of where wood originates from, where trees are standing, of course they're looking at satellite imagery to look at deforestation now. A company's sort of says that they're cutting in this area, but you can see exactly where they're cutting and stuff, you know. So, sure, there's lots and lots of technology kind of out there. And now I you know, I just think with what we're doing with our sawn timber it's, working quite well, you know, and if we can use the documentation? Well, I mean, it's not even manual, because I mean, it's all put onto our system. So, it's all electronically recorded. But we don't necessarily need to change things too much. But other companies would, because they might be bigger, and they might handle wood in a slightly different way.

In the cases where you've seen companies use RFID tags, or forest owners, is it attached to each individual log, or more on like a batch, because I'm just trying to figure out how feasible it is to attach the RFID tag on each single log individually.

Well, I mean, it was done here in Sabah. And it didn't work, you know, but it was about 15 years ago, maybe it was just too early, I don't think that the coverage was good enough for it then, because RFID uses it uses satellites.

Yeah, it uses radio frequencies, so I guess it goes over satellites.

Maybe they didn't have the enough towers up and stuff, it was kind of a pilot project. But I really saw the benefits of it, because I'd spent a lot of time in the forest. And I would, see when you know, tree is cut down, that it's given an individual identification, so it's given a number. And that number in Sabah, is chiselled into the tree stump, and then it's chiselled into the tree as well. And then the tree might be dragged out to the side, one of the, you know, the logging roads, and it might be cut into three pieces. Because it's too long to carry. So, you know, with the individual number that's on the tree stump and on the tree, it would be that number slash one, slash two, slash three, you know. So, you know, even back then in fact, you know, I thought if that can be recorded electronically, of course, it would help, you know. So, I think that's going to be coming out. I know, there are programs out there now where, you know, you can have an app on your phone to record the tree at a stump. And that would ping up to a, you know, a satellite to actually verify that, you know, you'd get it would record the coordinates. And then you could give whoever wanted it further down the supply chain the coordinates to say, if you're saying where, you know, this forest area has been licensed, etc., etc. is here. You can show that the product you're selling did originate from my area rather than outside their area. And that technology is already you know, being used by some companies and being trialled by some companies. And that's only good you know, that's a really good thing.

How do you in your case sort of track the timber through the physical transformation phase? So, for instance, when it gets processed from log to sawn timber, because at that stage you'd need to detach, for instance, also RFID tags are also ever wood identification markings, and then it goes through the process.

Yeah, so you're absolutely right, even if it has some kind of digital marking, but once it starts getting transformed, it could lose that identity. So, I suppose the simplest way to know what, you know what we, what, if we're trading in sawn timber, it's really quite simple. It's first transformation, you know, it's from a log to rough sawn timber. And, you know, I spent many years here in Sabah, in Peninsular Malaysia, training sawmills to help them get certification to get Chain of Custody certification. And well, more often than not, one thing to kind of remember is that most of the people here in Malaysia that work in the industry that are doing the sawing, for instance, they work on basically on what they produce, you know, so they're not salaried, or on wages. They're on what we call an English piece work, I can't think of a better a better word in English, I can't remember a better term for it. But basically, they're paid on whatever they produce. So, you know, it's to their advantage to say, well, we inputted 100 cubic meters of logs. And we actually got 70 cubic meters of salt timber out of it, you know, because then they get paid more if they're paid on what they produce. And it's to them, the sawmill owners' advantage to really know how the inputs and the outputs really add up. That they don't overpay the people that are doing the sawing for them. So, you know, I mean, I discovered this many, many years ago, the sawmill owners have a very good idea on the recovery of log to sawn timber. And most sawmills tend to use kind of a batch system, you know, so they will have records that say, this volume of logs with these log numbers were put into production. And there's not many processes, it would go through what they call

a breakdown saw, which is a really big saw that can, you know, cut through the log into, into planks and then it goes into what they call bandsaws that cuts it nearly to size. So, it's only sort of two stages. So, they need to be able to link the batch of logs that they put into the sawn timber that's produced. And that varies as well. It's not all of a certain grade, you know. And the recovery from log to sawn timber does depend on the size of the logs, how good the logs are, what grade you're cutting, because some markets will accept wood with more defects. So, what we do really is when we're looking at, let's say the product in it, we buy in Peninsular Malaysia that's certified. So, as PEFC certified, we would be able to just take the supplier's word if we wanted to remain certified that this wood originates from those PEFC certified logs. But we do extra, we asked to visit the sawmills and we look at their records and stuff. But we always ask for records of logged to sawn timber and we would look at the recovery. So, for different grades in different markets, the recovery, the recovery will change. And if the recovery's particularly high, outside the parameters that we use, then we need to go back and ask further questions.

And what's your view on scientific methods such as DNA technology, you briefly mentioned it shortly at the beginning.

Well, I mean, DNA technology, I think it's a brilliant idea. But number one, there's not enough of a database of the DNA data for all the different species. I think it is very, very limited. And it depends what level you want to get down to, you know. With DNA, if you wanted to get down to the stump where the tree actually came from, then that would just be hugely expensive. But it could work for very, very high-value species. So, there kind of is a use for it. So, I think it's great. There was a lot of talk about it sort of ten years ago, but I don't think it's used to the degree that it could be. One of the problems is that the market don't put enough value on wood from tropical forests. So, they'll want to pay similar prices, for much inferior wood that comes from temperate forests. And this is the industry's fault, as well, they should be marketed as a high, very high value species that takes you know, maybe 100, 150 years that tree to grow, you know, and you know it shouldn't be sold for a similar price or not that much more than, you know, plantation fires are grown a lot quicker. And because of the values kind of not enough, then you don't really have the, you know, the margin isn't there to maybe to do things such as DNA. And if it's not being widely asked for then why would you do it? Because it would be hugely expensive, even, you know, like mixed isotope testing. I mean, I was chatting to one of our buyers in the UK the other day, and sometimes a common authority in the UK come and, you know, they do require it, but he says it costs like 170 pounds or something to just to get a test. You know that's a lot of money. And to kind of have to do that all the time. And I mean, I'll turn the question back to you, why would it be required DNA testing in a sawmill? And I mean, doing DNA testing in a sawmill on its own is not going to be that beneficial, you need to link it back to the forest source.

So, basically, what I read is that there is one area within the scientific method. It's called DNA fingerprinting, and there basically collect samples of a tree at different players of the supply chain. And then in the end, basically, you can match, like, analyse whether it's from the same tree, and from that specific stump. But as you mentioned, it's still quite expensive. And it cannot be applied as of now on a large scale.

Yeah, and you know, what will the market pay for that, you know, you can do anything as long as the market will pay for that. But if the margins are kind of tight anyway, with all the other costs, such as shipping and stuff that's involved, I think it could be very, very useful for high value species, there are

some high value species that are protected not because they're endangered or anything but because the authorities in certain countries don't have a mechanism whereby to control that. So, rather, they say is banned. And if they catch anyone with it, then they're being illegal, but they're missing out on potential huge royalties. You know, a way to control it would be to use new technologies such as DNA and maybe Timber Chain, you could combine the two together, if it was a very high value species, it could absorb the cost then of doing the DNA fingerprinting at every link in the supply chain. And if you coupled that with uploading this information, and the other information that you gather onto a secure database, such as blockchain, that could be quite a good marriage, you know. So, there are definitely definite benefits for it. But, you know, I mean, I know somebody that's been involved in DNA for quite a long time and they were running with it and it kind of, it's not a big thing that they do now. Just because it's so difficult to roll out and, you know, the DNA libraries don't have enough of a database for you to check against so you just can't randomly do that in place of import for somebody to come along and take a sample of that word and say, is it that species? Does it come from that country? Because the database isn't there to compare it against. But if you create a database on a high value species, taking it right from the forest stump and following it through, and the high value species could absorb the extra cost of doing that, then it is, you know, potentially a really good use for it.

So, you basically mentioned that consumers currently maybe aren't willing to pay for that. I mean, from what I've seen from timber companies, currently, like I haven't from my personal observations, seen that many marketing efforts from companies that for instance are certified.

I'm not really talking about the consumers so much, because the consumers don't get involved. You know, they, most people have a real opinion on how forests will be managed. But if, you know, there's a set of garden furniture, that costs, you know, 100 pounds, and there's a set that costs 200 pounds that may have come from, you know, a high value area and FSC certified, they won't, you know, they won't necessarily go for the more expensive one, and the retailers are not making enough of a noise about it. So, I just think I think it's us as an industry, we're not creating enough awareness, we're not adding enough value to what we're doing, that we're trying to compete with other not just timber products, but other sort of alternatives, you know. Wooden window frames, and plastic window frames, you know, double glazing and stuff like that, what you can do with double glazing and wooden window frames, but you know, what I'm saying or steel window frames, you know, we're not, we're not doing enough to create the story as a whole, to really make people aware of how valuable it is. So, that isn't really a general criticism of the consumer, because generally, the consumer doesn't know, you know.

You feel it, if I understand correctly, but timber companies and the industry should also increase their efforts to provide more information on the importance of legal wood, so that it flows back to the consumers, so they can also make more informed decisions?

Well, not really, that's what you're saying. You know, I'm not really saying that. What I'm saying is the consumer, isn't that aware of it at the moment. I think, and this is a personal opinion, that maybe wood from tropical forests doesn't have the correct level of value attached to it. And there are, you know, a number of reasons for that. And the timber industry would be one of the one of the reasons for some of the reasons I've mentioned, but you know, whether how and when that will change, I've not really given that much thought to it. Of course, it would be great to, you know, for the tropical timber to be more highly valued, but, you know, there's lots of market forces, you know, in play here, and, you know, it's

not a homogenous thing anyway, because wood from the Amazon or wood from the Congo Basin or wood from, you know, Southeast Asia, they're all competing for the same markets, you see. They're all trying with not the same species, but species that will do similar things. So, not everybody's working together, you know, Malaysia and Indonesia don't work together. Although the species are very similar in some cases, you know, it's a business so I suppose it's really up to the trade bodies to be sort of pushing this thing and raising the awareness of what's being done. I think, I mean, certainly the UK timber Trade Federation do a lot of that, I don't know if you checked out their website and stuff, but there's a lot of information there. They're really pushing for "wood for good" type of thing and you know, sort of comparing the environmental characteristics of wood, say for window frames rather than, you know, other materials that you know, wood's a better insulator, etc., etc., you know, wooden buildings instead of concrete buildings does, has a much lesser impact on, you know, CO_2 emissions and other things. You know, so that, you know, they're the ones that are trying to kind of raise the awareness. And, of course, different companies and different players within the industry have different levels of engagement involvement, some guys just want to go to work and earn their money, and others try and push through changes and think deeply about what they're doing. And so, you know, it's difficult to give, you know, kind of a final answer to some of the questions really.

And maybe one last question. So, maybe back to Timber Chain, what were like the main challenges that you faced, during setting up and implementing, or like uploading the information on the platform?

Well, there hasn't really been any challenges to be honest with you. Because basically, we're not doing a standalone thing. So, we have a certification on this anyway, legal certification. So, all the information that we that we have used for five years to obtain, and then keep that legal source certification, any information that an auditor ever wanted to look at, we're just now uploading that onto the blockchain. I suppose the challenges really was, well with the people of iov42. Because, and this is, I mean, they're, technically they're, you know, great and stuff. But, you know, this industry is very new to them. So, the type of things that we're talking about, it was kind of about getting their head around it. And, you know, and, maybe we do, I mean, we are the first company they're working with, and I've stressed with them, other companies will do things differently. So, you've just got to look at our system as a very generic type thing. And what we call things will be different to what others call things. But the, you know, the basic system should be the same, that you want to be able to follow wood, from when you receive it and back to where it's coming from, to when you let it go. For a number of reasons as well, not just wood tracking for Chain of Custody's sake, but you know, we need to make keep a very good handle on the wood that we buy and the wood that we prepare for shipping to make sure none of it goes missing, you know. So, you know, the chain of custody that I've done for many, many years, in sawmills in Malaysia and help people implement them at the beginning, colleagues said they'll never agree to do this and stuff. But when I started working with sawmills, as I mentioned earlier, they tended to have pretty good systems anyway, because they wanted to track the recovery from log to sawn timber. So, we were just able to piggyback on the back of that with a Chain of Custody system and help them create a quality management system manual and kind of those types of things and just organize things a bit better. But many, many of the companies had good accountability systems in place anyway. Because it makes good sense to do so. So, yeah, I think we're just about done now. I've got another call in about 10 minutes.

So, much for taking the time to speak. It was very informative and valuable insights from a conversation. So, thank you from my side.

Yeah, no, no problems at all. Good luck with what you're doing. And yeah, when you've done your thesis and stuff, yeah, we're good to have a look at it. But good it's great that clever young people like you are looking into these things and it will help us all you know, down the line, I think. So, all the best here.

Follow up clarification:

Carl Ronnow already have due diligence certification, ie Preferred by Nature's LegalSource certification, on the PEFC certified product that is uploaded onto the Timber Chain. This means that rigorous due diligence has already been applied to information uploaded for shipments on Timber Chain which is recognized by the fact that it is covered under our LegalSource certification. Therefore, uploading shipment information onto Timber Chain enhances the credibility of wood that already has credible third party certification, which demonstrates adherence to the due diligence requirements of the EUTR, and Timber Chain is an additional, rather than a standalone, tool to provide Buyers confidence that the wood they are purchasing will not be in contravention of the requirements of the EUTR. Kindly make this distinction before submitting

4 List of Aids

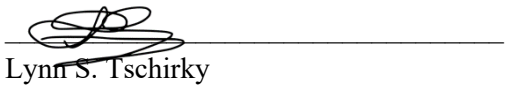
The services of freelancers from Fiverr and Upwork were used to support interview transcription and references.

Declaration of Authorship

"I hereby declare

- that I have written this thesis without any help from others and without the use of documents and aids other than those stated above;
- that I have mentioned all the sources used and that I have cited them correctly according to established academic citation rules;
- that I have acquired any immaterial rights to materials I may have used such as images or graphs, or that I have produced such materials myself;
- that the topic or parts of it are not already the object of any work or examination of another course unless this has been explicitly agreed on with the faculty member in advance and is referred to in the thesis;
- that I will not pass on copies of this work to third parties or publish them without the University's written consent if a direct connection can be established with the University of St.Gallen or its faculty members;
- that I am aware that my work can be electronically checked for plagiarism and that I hereby grant the University of St.Gallen copyright in accordance with the Examination Regulations in so far as this is required for administrative action;
- that I am aware that the University will prosecute any infringement of this declaration of authorship and, in particular, the employment of a ghost-writer, and that any such infringement may result in disciplinary and criminal consequences which may result in my expulsion from the University or my being stripped of my degree."

07.11.2021



Lynn S. Tschirky

By submitting this academic term paper, I confirm through my conclusive action that I am submitting the Declaration of Authorship, that I have read and understood it, and that it is true.