Toward Traceable and Biodiversity-Aligned Rubber Sourcing:

A Risk Assessment Approach for Downstream Companies

By: Ruchita Shinde

Supervisor: Michael Gilek
Södertörn University | School of Natural Sciences, Technology and Environmental Studies
Master's dissertation 30 credits
Environmental Science | Spring semester 2025
Master's Programme in Environment, Sustainability and Global Development

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ABSTRACT

This study examines how downstream companies can evaluate and respond to upstream biodiversity-related risks in complex supply chains that prepare for the upcoming sustainability reporting requirements under the Corporate Sustainability Reporting Directive CSRD and ESRS E4. The study uses a case study of a Northern European-based automotive servicing company and analyzes its four tire suppliers in its supply chain by applying TNFD's LEAP framework. The study explores the broad issue of how companies indirectly linked to biodiversity risks influence the upstream traceability, deforestation mitigation, and supplier transparency. A thematic analysis was conducted by using secondary data from the corporate sustainability reports, CDP reports, and biodiversity risk tools. The findings reveal varying levels of supplier preparedness with key gaps in limited traceability, lack of smallholder farmer engagement, and ecological exposure in Southeast Asian countries. The study recommends structured biodiversity risk criteria in a company's procurement strategies and aligning with supplier expectations with the TNFD and CSRD standards. The study also provides a biodiversity risk screening checklist to support the downstream company's efforts in strengthening nature-related disclosure.

Keywords: Biodiversity Risk, TNFD, LEAP approach, Natural Rubber, Sustainable Supply Chain, ESRS E4, Southeast Asia, Deforestation, Tire manufacturing, Traceability

Acknowledgement

I would like to begin by expressing my deepest gratitude to my professor and supervisor, Michael Gilek, for his insightful guidance, thoughtful feedback, and continuous support throughout the thesis period. My sincere thanks to Eva Maria Widlund Tedros, it was a great honor to work with you and for giving me this opportunity, and for generously sharing your knowledge in the field of sustainability reporting. I want to thank my entire Department at Södertörn University for fostering such a welcoming environment and making the entire learning process meaningful and memorable.

I would also like to thank all the interview participants and everyone else who contributed their time, insights, and assistance in bringing this thesis together.

Lastly, I would like to thank my mother and Tanmay for their constant support and encouragement, it has been my greatest strength in achieving this milestone.

Ruchita Shinde

Abbreviations

TNFD – Taskforce on Nature Related Financial Disclosure

LEAP- Locate, Evaluate, Assess and Prepare

CSRD- Corporate Sustainability Reporting Directive

ESRS- European Sustainability Reporting Standards

CDP- Carbon Disclosure Project

WWF- World Wide Fund for Nature

GPSNR- Global Platform for Sustainable Natural Rubber

DMA- Double Materiality Assessment

ESG- Environment, Social and Governance

SBTN- Science Based Targets Network

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1 Introduction

Natural rubber (*Hevea Brasiliense*), which is a tropical plant, has been rapidly growing over the past two decades, especially in the regions of Southeast Asia, parts of Africa, and South America. The rise in rubber plantations is closely linked to environmental consequences and is one of the major driving forces for deforestation, soil carbon reduction, water contamination, chemical runoffs, and ecosystem degradation (Laroche 2024, Warren-Thomas et al. 2023). Studies have highlighted that due to the increase in forest land conversion into natural rubber cultivation has led to a substantial decline in plant and animal diversity as well as ecosystem functions (Seid et al 2022, Toriyama et al., 2022). Tire industries around the world are highly dependent on natural rubber in their tire production. This rise in global mobility and tire consumption continues the growth of the ecological footprint of rubber by emphasizing the need for traceability and sustainability measures.

Traceable and environmentally friendly natural rubber sourcing is becoming a big challenge for downstream companies that use rubber-made commodities but do not produce them. Many countries are now expected to report on environmental risks in their supply chains. New regulations like the Corporate Sustainability Reporting Directive (CSRD[1]) and ESRS are making this more important. This study focuses on a Company that is based in Northern Europe and specializes in car service and repair with outreach to eight countries. This study uses the Taskforce on Nature-related Financial Disclosure's (TNFD) LEAP framework to examine four tire suppliers in the company's supply chain to understand their initiatives to manage biodiversity risks in their rubber sourcing practices.

According to the case company's (*name of the company is not disclosed due to confidentiality as per ethical research guidelines*) supplier code of conduct, the company believes in responsible business conduct across its supply network, focusing on environmental protection, transparency, and legal compliance. Biodiversity and ecosystems are emerging material topics for many downstream companies, particularly in relation to the upstream impact of raw material extraction

[1] CSRD is an EU directive introduced by European Commission that mandates companies in European Union to release reports on their activities that have environmental and social impact.

and manufacturing. As noted in the company's 2024 Annual and Sustainability report, the company is at an early stage in understanding these impacts, with no prior data or structured work conducted on biodiversity related risks.

In response to evolving regulatory requirements under the CSRD, the company has developed a working group to address European Union Sustainability Reporting Standards (ESRS[2]). It plans to pilot a biodiversity risk assessment using the TNFD framework in the year 2025. This thesis directly contributes to this strategic direction by applying TNFD's LEAP approach to the company's tire supply chain by identifying risk hotspots, recommending actionable supplier screening and traceability strategies that can support the company's preparation for biodiversity risk mitigation and disclosure.

An increasing recognition of the material financial risks posed by biodiversity loss has resulted in the establishment of frameworks that help in assisting companies in evaluating and disclosing nature-related risks. TNFD provides structured steps to incorporate biodiversity and ecosystem considerations in business decision-making. Through TNFD's LEAP framework, companies can identify nature-related dependencies and impact across their value chain, especially when they are at risk of land use change and deforestation (Smith et al. 2024, First Sentier MUFG, 2024). Particularly, downstream companies that have an indirect relation to biodiversity risks through their involvement in tire-related business operations that rely on natural rubber (Anderson et al., 2023, Mei et al., 2021).

Many downstream companies, like the case company, are in their initial stages of incorporating biodiversity risks into their sustainability reporting. This study addresses a gap in the academic literature by examining how biodiversity risks in natural rubber sourcing are assessed within downstream supply chains, an area of study that remains underexplored. By applying TNFD LEAP framework, the research offers a case study based study on how voluntary biodiversity risk assessment tools can be implemented to evaluate upstream supplier practices in the downstream corporate context. Through a thematic analysis of public disclosures, the thesis studies supplier

[2] ESRS adopts a double materiality approach where companies are required to report on how their activities affect socially and environmentally, and report how they affect their financial performance.

traceability initiatives, risk exposure, and alignment to CSRD ESRS E4 expectations. As most of the natural rubber comes from Southeast Asia, where rubber plantations have caused some serious environmental harm, this study pays special emphasis to the sourcing regions when assessing supplier disclosure and risk hotspots. The study concludes by offering recommendations on how company that are indirectly linked to upstream nature-related risks can strengthen their preparedness for forthcoming biodiversity reporting requirements.

1.1 Research Problem:

The TNFD was launched in 2021 as a global initiative to help companies identify, assess, and report nature-related risks and dependencies in their business operations. As companies are dependent on nature's assets and services, companies need to adopt strategies in their operations that conserve and restore nature. Therefore, TNFD guides companies to align their strategies with emerging global expectations for environmentally focused business practices. The TNFD considers nature as the foundation of the world's economy and cannot be separated from each other (www.tnfd.global).

The TNFD framework has attracted the attention of the forestry, paper, and pulp industries, which depend on natural resources. These industries are highly vulnerable to climate change and biodiversity loss, making TNFD an important tool to evaluate financial risks and sustainability goals. Companies have adopted assessments that align with TNFD to measure their dependencies, financial risks and environmental impacts corresponding to biodiversity degradation, climate change and deforestation (First Sentier MUFG, 2024). However, gaps remain in incorporating nature-related assessment in corporate decision-making. Though TNFD disclosure complies with sustainable forest management, there is a need for greater determination to advance biodiversity outcomes in the long run.

TNFD is widely used in high-risk forest commodities like soy, palm oil, and the mining sector. Many companies that work in this industry are under major scrutiny, and TNFD frameworks help these companies to measure and mitigate the nature-related risk linked to supply chain traceability

and transparency (Mei et al., 2021). For instance, in the mining and extraction sector, companies are trying to adopt the TNFD framework to evaluate their risks related to water contamination, biodiversity loss, and land degradation. Companies in this sector are working on sustainable environmental strategies but often struggle to report on issues like air and soil pollution (Irvine-Broque & Dempsey, 2022).

Rubber cultivation has been observed to be a contributor to deforestation, soil erosion, and land use change, especially within Southeast Asian countries. TNFD implementation is still in the initial stage of adoption across the rubber industry to incorporate nature-related risks and promote traceability in the supply chain. Some companies that are dependent on rubber supply are adopting mitigating strategies similar to those used by the palm oil supply chain by introducing sustainability standards and certifications to prevent illegal land conversions. However, these companies face challenges due to the involvement of numerous smallholder farmers and a complex supply chain (Mei et al., 2021:49).

This results in a lack of understanding of how downstream companies, such as those sourcing tires that rely on nature, can apply the TNFD framework to assess and respond to biodiversity risks in their supply chain. Therefore, this thesis addresses the gaps by applying the TNFD LEAP framework and highlighting the risk hotspots, evaluating traceability methods, and supporting strategic alignment with biodiversity-related disclosure requirements.

1.2 Research Aim:

This study aims to assess biodiversity-related risks associated with natural rubber sourcing in companies that are indirectly linked to biodiversity risks through the tire supply chain. By applying the TNFD LEAP framework, the study evaluates the tire suppliers based on their traceability, environmental exposure, and risk mitigating strategies. The goal is to develop a strategic approach, including a biodiversity risk screening checklist for the Case company to identify and identify tire suppliers that are committed to nature-related disclosure, risk mitigation, and transparent rubber procurement.

1.3 Research Questions:

1. How do tire manufacturing companies in the Case company's supply chain manage biodiversity-related risks in their natural rubber sourcing practices, and to what extent do their disclosure align with the TNFD's LEAP framework?
2. What strategic measures, including a biodiversity risk screening checklist, can the downstream companies adopt to enhance traceability, reduce upstream biodiversity risks, and prepare for alignment with emerging sustainability disclosure regulations such as TNFD and CSRD/ ESRS E4?

2 Literature Review:

This section gives an overview of literature that explores how environmental sustainability has become increasingly important in global supply chain management, with particular attention to biodiversity-related risk. It begins by defining key concepts such as supply chain and environmental accountability then moves on to examine the challenges companies face in implementing sustainable sourcing practices, especially in relation to biodiversity. The review then narrows its focus to the natural rubber industry, where issues like deforestation, soil degradation and limited traceability are central concerns. By outlining both the broader academic context and the specific risks associated with rubber sourcing, this review provides the foundation for understanding the role of downstream companies like the Case company in biodiversity risk governance.

2.1 Environmental Risk and Accountability in Supply Chain:

The supply chain refers to the interconnected journey that raw materials, components, and goods take before their assembly and sale to customers. Whereas the value chain looks at all the steps that add value to a product beyond just its physical parts. Understanding both concepts is important as they are central to the focus of this study (McKinsey & Company 2022).

The recent literature emphasizes that supply chain has evolved beyond being merely a system for moving goods efficiently and cost-effectively, instead, it has now been recognized as a critical area for addressing environmental and social responsibilities. As people have become more aware, it has become clearer that many environmental issues like deforestation, climate change, labor exploitation, and pollution have occurred due to the early stages of a product's life, even before reaching the store shelves. This has led to growing expectations that companies should take responsibility not only for their own operations but also for their suppliers. Public pressure from consumers, NGOs, and regulatory bodies has pushed companies to be more open about where and how their products are made. In response, supply chain transparency has gained importance. It allows both businesses and the public to check the things sourced and whether these practices align with environmental and ethical standards. In this way, transparency has become a major part of the supply chain and has become a link between sustainability goals and real-world actions, also by helping companies better understand and manage their impact from the ground up (Schäfer 2023).

The evaluation of corporate supply chain, particularly in maintaining sustainable sourcing, still remains a complex task due to the lack of standardized metrics, the multifaceted nature of biodiversity, and the inherent challenges of incorporating environmental concerns into corporate decision-making. One of the top challenges is the lack of a mandatory, globally accepted biodiversity risk assessment framework that can compel companies to disclose their true sourcing practices (Wardell et.al, 2021). When it comes to calculating carbon emissions, which can be quantified in terms of tons of CO_2. However, in the case of biodiversity condition calculation, it involves multiple habitat qualities, species variations, and ecosystem services, making the process challenging due to the absence of standardized biodiversity risk framework. There are assessment methods and metrics that exist to assess biodiversity risks, but they focus on distinct biodiversity components that lead to variations in risk assessment in companies and other industries (West et.al, 2022).

Further, data availability and accuracy remains a key obstacle, as many organizations lack access to valid and location or region-specific data. Especially in Southeast Asian countries like Malaysia, Cambodia, and Laos, natural rubber expansion has led to an extensive amount of

deforestation. Yet, the extent of biodiversity impact is understudied when compared to palm oil plantations, additionally due to lack of strong governance and limited monitoring capacity, which contributes to more hindrance to biodiversity assessment (Warren-Thomas et.al,2018). In the rubber and timber industries, there is a major hindrance to biodiversity risk assessment that comes from the complex and lack of traceability in the supply chain. In these industries, companies rely on the opaque supply chain, where tracking the raw material is difficult and violates sustainability norms (Warren-Thomas et. al,2018:8).

2.2 Why companies struggle with traceability and transparency in sustainable reporting:

Major Southeast Asian countries like Vietnam, Thailand, Malaysia, Indonesia, and Laos have rubber industries as important economic sources. Due to the continuous demand for rubber, there is concern over serious environmental issues like deforestation and biodiversity loss. Industries that depend on rubber struggle to maintain transparency and treatability, which is crucial for sustainability reporting. Finding legitimate and sustainable sources of rubber is difficult because of the weak regulatory control and multiple smallholder farmers (Fripp et al., 2023). Initiatives like the Global Platform for Sustainable Natural Rubber (GPSNR), traceability initiatives, and Eco-friendly certification have formed to address these issues. Though these initiatives are helpful for responsible rubber sources, they face challenges due to inadequate technology, and economic and logistical hindrances (Kennedy et al., 2017).

For the rubber industry, the most difficult task is to ensure traceability because of its complex supply chain. Compared to other forest commodities like oil and timber, which are easy to trace as they are mostly owned by massive corporations. The world's largest rubber plantations are owned by multiple smallholder farmers who own not more than two hectares of land, making it tough for the companies to confirm their sustainable sources (Smit et al., 2020). For instance, In Laos, the government grants certain land for rubber cultivation, and companies grow rubber in that specific allotted area with permission from the authorities. Due to unreliable documentation, legal uncertainties over land ownership emerge. This creates uncertainties that force companies to stay

away from sustainable and communal risk that accompanies rubber cultivation (Bouahom & Kono, 2022).

In countries like Vietnam and Indonesia, smallholder farmers sell their rubber to a mediator, who then sells it to the big manufacturing companies. When a mediator is involved, it is very challenging for the manufacturers to trace whether the rubber is sourced from deforestation-free land. Making it extremely difficult for the companies to deliver accurate sustainability reports on their upstream supply chain process, although some manufacturers have started using traceability tools that can make progress in the coming years (Kennedy et al., 2017). Many voluntary certifications have been introduced to improve traceability and maintain transparency, such as the Forest Stewardship Council (FSC) and Sustainable Natural Rubber Initiative (SNR-i). The issue here is that the scheme does not include smallholder farmers as the process is expensive and complex. A study conducted in Indonesia highlighted that the large plantation owners complied with FSC requirements, but the smallholder farmers struggled because of economic challenges. Consequently, very few smallholder farmers adapt to the schemes, making it difficult to ensure supply chain traceability (Smit et al., 2020).

Rubber monitoring is difficult to track using satellite, companies use satellite monitoring and tracing websites like blockchain to enhance their supply chain transparency. In Cambodia, a similar initiative was introduced where blockchain was used to trace rubber cultivation, but exercising this process was expensive and faced criticism from the local traders who acquired benefits from a dubious system (Ingram et al., 2020). In Vietnam, national sustainability standards were introduced, but industry players are in disagreement as these are incompatible with the international certificate requirements. They feel that these certifications create confusion among the producers and create complications to sustainability reporting norms (Smit et al., 2020).

In some Southeast Asian countries, the implementation of sustainable regulation has faced severe constraints due to an incapable institutional capacity and regulatory inconsistency (Ingram et al., 2020). In Laos, the government allocated lands for rubber plantations are found to be associated with illegal deforestation and the displacement of local people (Smit et al., 2020). In Indonesia, the government has control over land use decisions, which results in inconsistent

enforcement of sustainable regulations. Companies that have good reputations with the government have taken advantage of it, as well as the fragmented rubber plantations that do not abide by the national sustainability laws (Bouahom & Kono, 2022).

In rubber plantations, smallholder farmers play a crucial role, and regardless of that, they are excluded from the sustainability programs since they face financial and technological limitations (Kennedy et al., 2017). Several smallholder farmers are unaware of the certificate requirements and struggle to gain access to the training on sustainable rubber cultivation management (Wang et al., 2020). In Thailand, efforts have been made to include smallholder farmers to include them in the sustainable supply chain, but lacked support because of extra expenses and administrative burdens. Corporate sustainability is failing as farmers are reluctant to follow sustainable practices and demand financial subsidies (Kennedy et al., 2017).

The rubber supply chain's structural, legal, and technological limitations are deeply rooted in Southeast Asia. The continuous absence of transparency in sustainability reporting is caused by multiple factors, like a lack of data, fragmented land ownership, disinterest in participation by stakeholders, and complex bureaucracy. It is important to address these issues and strengthen legislative intervention, improve monitoring tools, provide financial subsidies for smallholder farmers, and encourage collaborative teamwork by local authorities and corporate entities. The current literature only focuses on upstream actors in nature-related risks, and often, the downstream actors who shape the supplier behaviors have been understudied.

2.3 Biodiversity Risk in Rubber Sourcing:

2.3.1 Deforestation and Land Use Change:

The material composition in a tire consists of 41-48 % of rubber, 22-28% of Black Carbon, 13-16% textile, and 10-12% additives like other chemicals (Mohamad Syamir Senin et al. 2016). The main material source for producing a tire is natural rubber, and due to the emerging demand in vehicles, the production of tires has gone up to more than 1 billion tires per year. The automotive

industries consume 70% of the global rubber production and the rest goes to other industries like marine and electronics. Most of the rubber tree plantations are grown on the replaced forest lands and on the existing farmland which leads to direct deforestation (Wang et al. 2023).

There has been a significant expansion in the rubber tree plantations in Southeast Asia, which has led to deforestation and land use change due to continuous demand for natural rubber, especially in the tire manufacturing industries (Warren-Thomas et al. 2023). The rubber cultivation in Southeast Asia is not recent but has a long history, which has made it the world's leading rubber-producing region. Initially, rubber was introduced to Malaysia, Indonesia, Vietnam, Myanmar, and Cambodia as a government-led initiative. The small farmers began cultivating rubber, often mixing it with the rest of the crops in agroforestry methods. The rubber tree is a tropical tree that needs warm temperatures, ample amounts of sunshine, and considerable rainfall. But in the 1950s, China discovered a new variant of rubber that could continue growing in dry and colder regions. This further led to the expansion of rubber plantations northwards towards the tropical territory. In the past few decades, rubber farming has occasionally eliminated other crops like cocoa and coffee trees (Warren-Thomas et al. 2015).

The rubber driven deforestation is probably underestimated as the datasets received from the remote sensing data are commonly misunderstood as rubber plantation resembles natural forests which makes it difficult to distinguish between the two while using satellite imagery (Wang et al. 2023). Most of the studies based on deforestation apply models rather than real satellite images. These models assess deforestation based on government data and assumptions over land use and not assessing the high-resolution satellite images (Gitz et al. 2022). Approximately 75% of the rubber plantations are owned by small farmland owners, they expand their plantations into forests as they do not have that much space. For these farmers, rubber plantations can be their only source of income and they continue growing their plantations as the demand and cost of rubber increase. The issue is that these farmers are not registered in the national statistical data, which becomes difficult to monitor the deforested land. These farmers usually have less than 5 hectares of fragmented lands, which are difficult to trace through satellite assessment (Warren-Thomas et al. 2015). One such example is Cambodia, where more than 40% of rubber plantations are found in deforested areas, which is also known as an extreme case of rapidly expanding rubber farming.

More countries like Indonesia, Thailand, and Vietnam have observed a similar trend. (Wang et al. 2023, Gitz et al. 2022).

It is noted that from the year 1996 to 2016, around 4.1 million hectares of forest have been demolished for rubber plantations. The rubber plantations have significantly affected the key biodiversity Areas (KBA), whereas more than 1 million hectares of land are important ecological zones that have been converted into rubber plantations (Wang Y et al.2023). Due to the global demand for rubber, countries like Vietnam, Indonesia, Thailand, and China produced natural rubber from Hevea Brasiliensis trees, which caused major land use conversion. There have been great land use changes where farmers altered primary and secondary forests to monocultural plantations, which is closely connected to rubber expansion. The monocultural rubber plantations induced biodiversity loss, altered hydrological cycles, and disturbed the soil composition. Studies have proved that fertilizers and pesticides used in rubber plantations have resulted in soil erosion and impacted aquatic ecosystems (Gitz V et al. 2022).

2.3.2 Soil degradation and Ecosystem loss:

In Southeast Asia, the rapid growth of rubber plantations has considerably disrupted tropical ecosystems. Vast areas of land have been converted from primary and secondary forests to monocultural plantations (Panda & Sarkar, 2020). As rubber plantations replace natural forests, it results in a decrease in the soil organic carbon (SOC) pools and distorts hydrological cycles, all of which are responsible for long-term environmental degradation. In the first decade of forest conversion, the SOC level was reduced by 33%. A study conducted in Cambodia showcased that as new plantations are grown, the quality of the soil degrades faster and the ability to carry carbon diminishes (Toriyama et al., 2022).

Due to the land conversion into rubber forest, the organic matter in the soil declines, which impacts the fertility and increases the vulnerability to erosion. Research shows that on sloped terrain, mechanical terracing, and land preparation amplify soil compaction and runoff (Gitz V et al. 2022). The rubber tree needs plenty of water, which means that water resources in the region are also affected. The groundwater in the regions near the rubber plantations significantly reduces,

and the changes in the river discharge pattern are especially in the summer season (Mattsson et al. 2023). When the forest ecosystems are converted into monocultural plantations like rubber, it destabilizes the hydrological cycles, increasing the risk of droughts and affecting water availability for the surrounding ecosystems. On top of that, rubber plantations have a high consumption of chemical pesticides and fertilizers that lead to nutrient runoff and eventually pollute nearby rivers and lakes and damage marine life (Warren-Thomas et al. 2023). For rubber trees to produce latex, they need an ample supply of nutrients, phosphorus, and nitrogen. Repeated tapping eventually depletes necessary soil nutrients and reduces the soil fertility for future farming (Panda & Sarkar, 2020).

The forests are also home to endangered plant and animal species, by converting forests into rubber plantations abolishes the habitat of these plants and animal species, especially those that rely on structurally complex forests for existence (Singh et al., 2021). The rubber plantation considerably lowers the species richness and declines the population of birds, mammals, and invertebrates. The conversion process from forests to monocultural plantations compromises biological interactions such as seed distribution, pollination, and nutrient cycling (Warren-Thomas et al. 2015). Especially in Southeast Asia, the evolution of rubber plantations has directly impacted the key biodiversity areas (KBAs), forcing wildlife corridors to become broken and threatening the population of endangered species like large predators, gibbons, and hornbills (Toriyama et al., 2022).

The extensive development of rubber plantations has culminated in a loss of biodiversity, extreme soil degradation, and disturbance of ecological functions. Environmental strain has also increased as a result of rubber-based deforestation, which has extensively damaged crucial habitats, limited carbon sequestration capacity, and altered hydrological cycles.

3 Analytical Framework:

The section outlines the analytical foundation used to guide this study. Instead of using a classical theoretical framework, this study adopts two sustainability frameworks that are highly relevant to corporate biodiversity risk assessment and disclosure. This section explains the working of TNFD and its LEAP approach as well as ESRS E4 under the Corporate Sustainability Reporting Directive (CSRD). These frameworks are not abstract theories but are treated here as applied frameworks that offer methodological as well as analytical tools that companies can apply to identify and assess biodiversity-related risks. Through this context, they serve as a theoretical framework that guides the study's design, shapes criteria for assessing supply chain risk preparedness, and ensures alignment to emerging sustainability regulations. The section begins with an overview of TNFD, later it explains the four phases of the LEAP approach, and ends with introducing ESRS and E4.

3.1 Taskforce on Nature-related Financial Disclosure (TNFD):

Taskforce on Nature-related Financial Disclosure (TNFD) was officially launched in July 2020, with the support of founding partners and funders who received global endorsements from G7, G20, and other leaders (www.tnfd.global.org). It is a voluntary disclosure framework for organizations (companies, both large corporations and small to medium enterprises) to address dependencies and nature-related issues concerning the global sustainability reporting regulation (TNFD 2023a:4). The four pillars that support TNFD disclosure recommendations align with the Task Force on Climate-Related Financial Disclosure (TCFD) and the International Sustainability Standard Board (ISSB). They align with the goals and targets of the Kunming-Montreal Global

Biodiversity Framework and consider the various approaches to the materiality that are already in use (TNFD Disclosure Recommendations).

Figure 1 TNFD recommended disclosures/ four pillars TNFD 2022 (TNFD 2023a:8)

This framework has published some initial steps that a company must consider when preparing to assess and disclose its data using its four disclosure pillars. It is suggested that the organization, depending on its size, sector, and current sustainability, has different starting points. It highlights that organizations should adopt a systematic approach, initially beginning with evaluation of their nature-related impacts and dependencies, then integrating risk management, and then gradually broadening their disclosure over the years. TNFD falls into Target 15 of the Global Biodiversity Framework, which directs companies to disclose their dependencies on natural resources and biodiversity (TNFD 2023a:5).

When getting started with TNFD, it is important to understand the fundamentals of nature in detail and its relation to the company's business strategies. It is important to understand the characteristics of biodiversity, the components of nature, and the concepts of nature-related impact, dependencies, risk, and opportunities (TNFD 2023a:11). A business case within the organization must be made to identify nature-related issues. The organization can start by looking into the topics that come under nature-related issues, and once the business case is strong, it becomes easy for the company board to commit to TNFD. The next step is to start with the data that already exists within the company instead of creating new data. The company needs to focus on the material nature-related risks that are linked to its business and value chain (TNFD 2023a:13).

The company has to plan the implementation of TNFD. It is not mandatory to disclose all recommendations at once, they can start small and expand slowly. For continuous progress, they can plan for the long term by including clear goals, by collecting more data as it becomes available. The company can collaborate with stakeholders who are associated with it. Companies that are financially invested or indirectly reliant on nature through their operations are encouraged to promote sustainability among their sourcing partners. These organizations should support the adoption of sustainable practices that align with TNFD standards across their value chain. (TNFD 2023a). Companies are encouraged to evaluate their progress over time and align their internal strategies with nature-related standards. Registering as a TNFD adopter can also publicly demonstrate their commitment to managing and disclosing nature-related risks (TNFD 2023a:15).

3.2 LEAP Approach:

TNFD has developed a mixed approach, called the LEAP approach, that is executed on the existing data, which incorporates the nature-related frameworks like SBTN and the Natural Capital Protocol as well as other tools and methods developed by scientific organizations that are aligned with TNFD's standards and processes (TNFD 2023b). The TNFD recognizes that companies may have their own setup of risk management, but the LEAP approach is for all companies, regardless of their size and industry type to identify their nature-related issues. It is not mandatory to follow the LEAP approach, but it can be helpful for the organization to be aware of its impact on nature and report about it for the stakeholders (TNFD 2023 b:71).

LEAP is an acronym for locate, evaluate, assess, and prepare. Each phase has a purpose, such as determining the organization's location of interface with nature, evaluating dependencies and impacts on nature, assessing nature-related risks and opportunities, and preparing reports about material nature-related issues that are related to TNFD's recommended disclosures (TNFD 2023c:3). TNFD recommends all the organizations that before starting with LEAP they go through scoping phase as this can help organization set boundaries before they begin with their detailed nature related risk assessment (TNFD2023c:32). The importance of scoping phase is to bring the LEAP assessment team together, establish assessment parameters by drafting terms of reference

(ToR) document and to prepare a quick evaluation of the internal and external data to form a hypothesis. This phase also identifies any gaps that the organization can work on and decides if any external or additional help is needed with the process. It aims to make the assessment process efficient and seamless for later stages (TNFD 2023c).

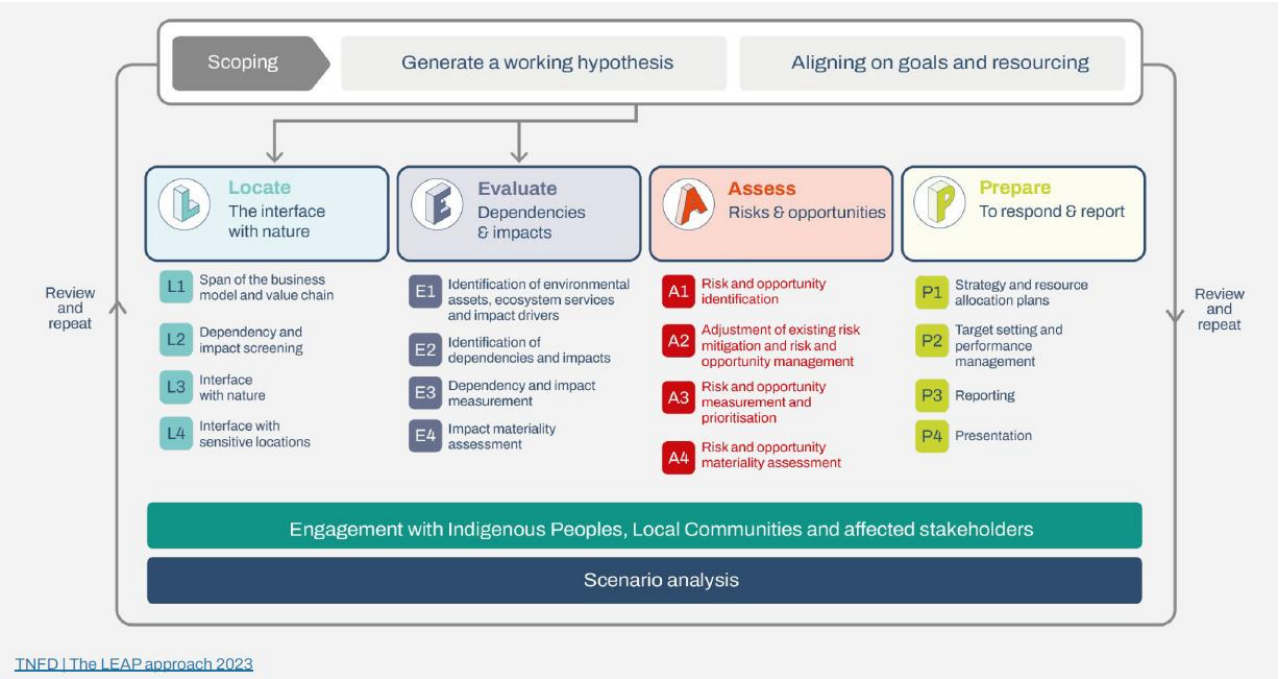

Figure 2 Structure of LEAP framework (TNFD 2023c:4)

3.2.1 Locate (Interface with Nature):

This phase works on three key areas: the sector in which the organization works in, the supply chain of the organization, including the upstream and downstream, and the geographic region where the organization supplies material and conducts its operations (TNFD 2023c:41). The objective of this phase is to pinpoint significant areas of an organization's business that affect or rely on nature that will help organizations in the later stages of LEAP assessment. The location phase is important to determine the environmental impact of the particular area of operations. It can be a challenge to distinguish specific areas of operations as large corporations have multiple areas of operations, which can be tough to analyze at each location. In this phase, it is not necessary to analyze each location, whereas organizations need to narrow down the most critical areas with

high to moderate nature-related risk. Some areas may be extremely sensitive that are prone to ecological loss, such as soil erosion, deforestation, or water pollution (TNFD 2023c).

3.2.2 Evaluate (Dependencies and Impact):

The evaluation phase helps organizations to realize their nature-related dependencies in detail. The organization has to find out on which components of nature (e.g., clean air, fertile soil, or water) they rely on for their operations. Also, they need to be aware of the impact they are causing to nature (e.g., land use change, pollution, or soil erosion) through their business operations. For instance, a tire manufacturing company depends on natural rubber sourced from rubber plantations, which rely heavily on fertile soil and stable climate conditions. However, the cultivation of rubber can degrade soil quality, contribute to deforestation, and affect local water systems through land use change and chemical inputs (TNFD 2023c).

3.2.3 Assess (Material Risks and Opportunities):

In the third phase of LEAP, the organization needs to determine and prioritize the risks and opportunities from their dependencies and impact on nature from the previous steps. This phase helps the organization to systematically analyze the risks arising from the financial decisions and opportunities through the business operation. It involves reporting the likelihood and enormity of risks by using the existing risk management framework, tools, and guidelines (e.g., International Organization for Standardization (ISO) 31000 Risk management guideline. The organization can shortlist the risks that need to be disclosed and given priority in the financial and sustainability planning (TNFD 2023c:100). The significance of this stage in LEAP is that it helps companies identify material risks, and their impact on finances, so they can incorporate them in their decision making and risk disclosure.

3.2.4 Prepare (Respond and Report):

Prepare is the finale phase in LEAP where organizations decide about their strategies on the findings from their previous phases, from locate, evaluate, and assess. In this phase, the organizations need to decide their action plan based on the findings from the previous phases, setting specific targets and goals for their sustainability efforts, and decide on what needs to be disclosed to the stakeholders, investors, and regulatory bodies. This phase ensures that organizations make strategic decisions based on the outcomes received from the earlier phases. Organizations have to prepare measurable and effective goals using science-based targets (SBTs) and present their sustainability strategies as TNFD recommended disclosure, by deciding on the style and presentation that aligns with the voluntary disclosure standards like GRI and ISSB (TNFD 2023c:139). An organization can use data-enhancing tools and visuals to enhance clarity in its financial and sustainability reports. To maintain consistency and credibility in their sustainability communication, organizations should align their disclosure with GRI, ISSB and TNFD standards (TNFD 2023c).

3.3 ESRS E4- Biodiversity and Ecosystem:

The inclusion of ESRS E4 in this study is based on its growing relevance for companies like the Case company, as companies will soon be required to report on biodiversity-related risks and impact under the CSRD. On 31 July 2023, the European Commission approved the delegated act on the first series of European Sustainability Reporting Standards (ESRS). The EFRAG was mandated by the CSRD to publish sustainability reporting guidelines outlining the obligations of businesses concerning sustainability reporting. Therefore, EFRAG released 12 ESRS standards in 2023 and additional standards to follow soon (EFRAG.org).

As per the CSRD, many large companies in the EU are required to report on their sustainability impacts. Since 2024, this rule has had to be followed by more than 50,000 companies and 10,000 non-EU companies, which is necessary for them to disclose Environmental, Social, and Governance (ESG) information. Specific to environment, the ESRS directs CSRD to report on

Climate mitigation and adaptation (E1), Pollution (E2), Water (E3), Biodiversity and Ecosystem (E4) and resource use and circular economy (E5) (Planet Labs Pbs 2024c:7). This study will only be focusing on biodiversity and ecosystem (E4) as time constraints did not allow for a broader assessment of the other ESRS environmental standards.

Many companies are directly or indirectly dependent on and impact biodiversity through their operations. For instance, companies working in agriculture, energy, manufacturing, or service sectors display biodiversity-related risks. The risks may include land use change, species depletion, deforestation, or failing to meet environmental standards. Due to growing recognition from international standard regulations and the government, biodiversity has gained immense importance and strict biodiversity-related reporting requirements. In ESRS, it is required for the organization to evaluate their material impact, risks, and opportunities on biodiversity and ecosystems within their entire value chain with the help of Double Materiality Assessment (DMA).

For a company to comply with ESRS E4, it must conduct a DMA where the organization has to assess and report how its operation affects biodiversity and how biodiversity impacts the business. In DMA, there are two assessments, the first is Impact Material Assessment, where the organization evaluates its business operation's impact on biodiversity and ecosystem, e.g., habitat destruction, deforestation, or soil erosion. The second is Financial Materiality Assessment, here the organization evaluates biodiversity-related issues and risks that can affect the company's performance and financial wellbeing, for instance, loss in biodiversity can lead to legal fines, increased costs on raw supplies, disturbance in the supply chain, or negative impact on business reputation (KPMG 2024:2). DMA helps create a holistic understanding regarding the organization's environmental risks and opportunities.

Companies use four indicators under E4 in their sustainability reporting. The first is impact driver accounting, where companies identify the factors that are affected by their operations. The company focuses on detecting in which areas its operations contribute to environmental degradation, e.g., deforestation, pollution, greenhouse gas emissions, or water contamination. The second indicator is Ecosystem Accounting, which evaluates how nature is changing or in transition due to the negative impacts of the company's actions. Here, the condition of the environment,

biodiversity loss, and habitat change are assessed. The third indicator is dependency accounting, where the focus is shifted from the impact of the company's operation on nature to the company's dependency on nature for their survival. Ecosystem services are very important for the company's workflow, and if that is hampered, then it could affect their supply chain and even financial costs. The final indicator is nature-related risks and opportunities accounting, where the environmental risks and opportunities are translated into financial risks and business opportunities. It analyses how the changes in biodiversity can impact the business performance and decision making (Grunewald 2024: 19).

4 Methodology:

This chapter explains the methodology used to evaluate biodiversity risks in the Case company's supply chain, applying TNFD's LEAP approach framework. The case company that was examined serves as a critical case (Gerring & McDermott, 2007) as it offers insights into how downstream companies are exploring biodiversity-related risks in its tire supply chain. The case company studied is an automotive service and repair company that has its operations across Northern Europe across eight countries. It does not produce tires but is indirectly linked to them as it distributes and installs them as a part of its services, making it indirectly linked to biodiversity-related risks in the upstream tire supply chain. The company aligns its sustainability efforts with the CSRD and expresses interest in piloting TNFD-based biodiversity assessment. The methodology identifies the company's interface with nature, evaluates dependencies and impacts, and identifies nature-related risks by analyzing its associated tire manufacturing company's initiatives in sourcing sustainable natural rubber.

For this study, a qualitative case study method has been adopted to review how tire manufacturing companies are transparent about their natural rubber sourcing locations. The geographic scope of this study focuses on Southeast Asian countries such as Thailand, Indonesia, Cambodia, and Malaysia. The reason for focusing on these countries is due to their significant contribution to the large-scale cultivation of natural rubber globally. Additionally, these regions thrive on rich biodiversity, smallholder farmers, and clear evidence of natural rubber cultivation

that has often led to deforestation, land use change, and hindrance to the ecosystem. The focus on Southeast Asia also matches the sourcing information shared by the tire manufacturing companies studied in this research.

To analyze and distinguish between the operations of tire manufacturing companies associated with Case company's supply chain, the study uses secondary data that is disclosed by the respective tire companies, also the data from Carbon Disclosure Project (CDP), GPSNR and (World Wildlife Fund) WFF's biodiversity risk filter to analyze the rubber sourcing locations. As the primary data was unable to source, this study is based on secondary data that is used to identify the dependencies on the nature and gain information on nature related risks as well as trace gaps in tracing data in value chain (TNFD 23c:90). This study uses TNFD's LEAP approach to structure and guide thematic assessment of biodiversity related risks and sustainability performance of tire manufacturing companies. The study explores five sustainability criteria based on the relevance to TNFD's framework to identify nature-related risks and opportunities, those are the location of rubber sourcing, alternative rubber investment, zero deforestation policy, smallholder farmers engagement, and risk mapping initiative. This study analyzes data published by tire manufacturing companies, which are referred to as Supplier 1, Supplier 3, Supplier 2, and Supplier 4.

4.1 Research Design:

This study uses the qualitative case study method, which is an empirical inquiry that investigates a phenomenon in its real-life context using multiple sources of evidence. The case study is more than just a method, it is also a research strategy that involves a detailed study of a particular unit of analysis within its natural setting (Priya 2021:95). This is an appropriate methodology for this study as the research is based on the situation in its real context (Case company's tire supply chain) making it a case study methodology. In this study, the researcher examines documents such as corporate sustainability reports, publicly published data from the tire manufacturing companies, and third-party data. This study is an explanatory case study as it investigates why and how tire manufacturing adopts sustainable steps to source natural rubber and manage biodiversity.

The research utilizes TNFD's LEAP approach, as it is a tool to analyze the appropriate risk management process. By using the LEAP approach, this study aims to find out how tire manufacturing companies disclose their dependencies on nature and their mitigating efforts related to biodiversity loss. The biodiversity risks that are connected to the sourcing of sustainable natural rubber in the company's supply chain are carefully evaluated in this study by using TNFD's LEAP approach method. This method supports a structured way to monitor corporate sustainability commitments and disclosure about biodiversity risks (TNFD 2023a). In addition to meeting company risk management requirements, this framework aligns with international sustainability standards (CSRD & ESRS) to ensure methodological rigor.

In this study, the researcher conducted a traceability assessment by evaluating how transparent each tire supplier is by analyzing the disclosed geographic origin of their natural rubber. The tire suppliers were categorized as high, moderate, and low traceability depending on whether the sourcing was reported at the sub-national, national, or no geographic level. Apart from that WWF Biodiversity Risk Filter was used to assess the environmental risk level in the disclosed geographic sourcing locations. Five ecological risk categories- provisioning services, regulating & supporting services, enabling, regulating services, mitigating services, pressures on biodiversity, and environmental factors were reviewed in the regions of Thailand, Malaysia, Indonesia, and Cambodia. The regions were scored low, medium, and high biodiversity risk based on their environmental conditions. The results and analysis section key areas such as supplier's reports on nature-related risks, tools to track natural rubber sourcing regions, initiatives to work with smallholder farmers, and alternative rubber material investment. This approach helped evaluate how suppliers are prepared for the future biodiversity reporting and how well their actions match what is expected under CSRD and ESRS E4.

4.2 Sampling Strategy:

To select specific tire manufacturing companies for analysis, this study applies the purposive sampling method. The purposive sampling method is used in qualitative research to help in the identification and selection of detailed cases while making the best use of limited resources. In this sampling method, a particular group or individuals are selected because they possess prior

expertise and knowledge related to the phenomena of interest (Palinkas et al 2015:2). The Purposive sampling method aligns with this study, as the tire manufacturing companies are specifically chosen to analyze the Case company's supply chain. The tire manufacturing companies are selected based on three criteria: they are part of the Case company's supply chain, they are registered as a company and have published sustainability reports publicly. This approach allows for a thorough and systematic analysis of corporate biodiversity risk in the natural rubber supply chain.

4.3 Secondary Data Collection:

The secondary data is used in qualitative research when it is difficult to conduct interviews and collect first hand data due to its feasibility, confidential materials, limited time and resources (Cheong et al, 2023:2). This study uses secondary data such as corporate sustainability reports, their publicly disclosed data on rubber sourcing locations, initiatives and certifications. Cheong et al. (2023) state that in order to maintain methodological rigor, secondary qualitative research can access publicly available data. The author also highlights that, secondary data can also broaden the scope of research and deliver useful information without the need to collect first-hand data.

This study has analyzed publicly disclosed corporate reports from four tire manufacturing companies, which are referred to as Supplier 1, Supplier 2, Supplier 3, and Supplier 4 for the purpose of anonymity. In addition to that, three expert interviews were conducted with professionals working within one of the tire manufacturing companies included in this study. These interviews took place in April 2025 and were conducted remotely via Microsoft Teams. Due to confidentiality agreements, no company names, individual identities, or interview content are disclosed in this study. These interviews were only conducted to support the researcher's understanding of current corporate practices and were not directly cited or quoted in the analysis.

4.4 Ethical Consideration:

In this thesis researcher had to take into account a few ethical considerations. Whichever data and sources used to compile this research are referred to at the bottom of the document. While working with secondary data, the study has only used the publicly available data, such as corporate sustainability reports, CDP reports, and regulatory disclosures that can be accessed online to ensure ethical compliance with research ethics guidelines. The study follows a strict data validation procedure by conducting cross-referencing resources to check the validity of the information and also by avoiding selective interpretation of the disclosed sustainability data. Additionally, three interviews were conducted under confidentiality agreements. In full respect of the signed NDA, no names of case company, their associated tire manufacturers or individual participants are disclosed, and no direct interview content is cited in this study.

4.5 Limitations to the study:

Due to the confidential agreements, the names of the case company and tire manufacturing companies analyzed are not disclosed. While it protects privacy, it may limit transparency for readers. The study relies on publicly disclosed reports and other data, which means that the internal data or on the ground verification was not possible. Although researcher validate sources, the analysis is still dependent on what companies have chosen to publish, which may not fully capture the realities of their operational practice. The research primarily focuses on Southeast Asian countries, where environmental risks such as deforestation are more prominent, while other regions not covered may face different challenges. Due to time constraints broad analysis of ESRS was not possible, so the study focuses on ESRS E4 biodiversity and ecosystem. The three interviews conducted during this study period were intended to enhance the researcher's understanding, which remains confidential and is not directly cited, which also limits the depth of primary insights included.

4.6 Data Analysis:

This study has used TNFD's LEAP approach to identify the Case company's interface with nature by examining the tire manufacturing company associated with the Case company's supply chain and analyzing their sourcing procedure of natural rubber. The TNFD is usually used by organizations to identify their dependencies and assessment of nature-related risks (TNFD 2023a:4). To manage and identify the Case company's interface with nature, the LEAP framework is applied. However, only the first three phases are used as a part of analysis while the last phase is incorporated as a recommendation section. In Locate, the study filters and prioritizes its interface with nature. The evaluate phase examines the dependencies and impact on nature by the organization's operations. The Assess phase studies the strategies and certifications of the tire manufacturing companies on their sustainable natural rubber sourcing procedure (TNFD 2023c).

The study has conducted a thematic analysis to understand the themes related to corporate sustainability linked to sourcing natural rubber. Clarke & Braun (2017:297) define thematic analysis as a process of identifying, studying, and interpreting patterns in the qualitative data. In thematic analysis, it helps in identifying specific themes that are very important for the study. The reason for considering thematic analysis is that it is flexible in regard to sample size, data collection method, and approaches. Similarly, to understand specific themes in this study, the research uses a deductive approach based on TNFD's LEAP approach by studying the data sourced from corporate reports, certification systems, and biodiversity disclosure. The diverse nature of corporate and third-party data provides a foundation for identifying sustainability commitments and strategies for managing and disclosing biodiversity risks in the Case company's supply chain.

4.7 Methods Summary Table:

Table 1 Summary of analytical tools and their application in the study

Method/Tool	Purpose in Study	How it was used
WWF Biodiversity Risk Filter www.riskfilter.org/	To assess biodiversity risk levels in the natural rubber sourcing regions (Church et al 2022:46)	By entering the country name and its sub-regional location to evaluate regional environmental risks
TNFD's LEAP Framework	To structure biodiversity risk assessment (TNFD 2023c)	Used locate, evaluate, and assess phases to examine tire suppliers and the prepare phase as recommendations to the case company

Table 2 Overview of Analyzed Documents and Data Sources

Supplier	Document Type	Year	Pages	Source Type
Supplier 1	CDP Disclosure	2023	84	Corporate webpage
	Annual Report	2024	340	Corporate webpage
	Rubber Sourcing Policy	2022	10	Corporate webpage
	Value Chain Report	2023	18	Corporate webpage
Supplier 2	CDP Disclosure	2024	547	Corporate webpage
	Corporate Responsibility Report	2023	101	Corporate webpage
Supplier 3	CDP Disclosure	2024	434	Corporate webpage
	Global Sustainability Procurement Policy	2024	40	Corporate webpage
	Integrated Report	2024	114	Corporate webpage
Supplier 4	ESG Report	2024	95	Corporate webpage
	CDP Disclosure	2023	161	Corporate webpage
All Suppliers	WWF Biodiversity Risk Filter	-	-	Online Platform
	GPSNR Membership Statement	-	-	Online Platform
Case Company	Annual and Sustainability Report	2024	112	Corporate webpage
	Supplier Code of Conduct	2023	8	Corporate webpage

5 Results and Analysis:

This section presents results as well as analysis, which evaluates tire suppliers (manufacturers) that are linked to the company's supply chain using the TNFD LEAP framework. The findings show significant variations in how the suppliers disclose their nature-related risks and engagement with sustainable rubber sourcing practices. Some suppliers have demonstrated high levels of traceability, risk mapping initiatives, and investment in alternative rubber material, whereas some suppliers demonstrate moderate to weak levels of location data and a lack of direct engagement with smallholder farmers. The results are based on five key criteria: transparency in rubber sourcing regions, investment in alternative rubber material, smallholder farmer engagement, zero deforestation commitments, and use of biodiversity risk mapping tools. These themes highlight TNFD's focus on nature-related dependencies, risks, and opportunities and provide a framework for evaluating supplier compliance with the evolving biodiversity disclosure requirements under CSRD and ESRS E4.

5.1 Locate:

The first phase in the LEAP framework is to locate where the Case company's interface is with nature. As the company's supply chain is involved in the downstream segment of the tire industry, this section will analyze the upstream operations, specifically the rubber sourcing practices and initiatives of tire manufacturing companies that are linked to the company's supply chain. Rubber is classified as a tropical tree, and over 90% of natural rubber is cultivated in tropical regions of Southeast Asia, and these areas have been vulnerable to deforestation and biodiversity loss (Warren-Thomas et al. 2023). Therefore, estimating the company's exposure to biodiversity risks such as ecological degradation and deforestation requires identifying the locations where natural rubber is sourced.

5.1.1 Rubber Sourcing Locations:

Table 3 Rubber Sourcing Locations by Manufacturers

Manufacturers	Disclosed sourcing regions	Own Plantation	Publicly Disclosed Quality	Traceability level
Supplier 1	Indonesia, Malaysia, Thailand	No	Detailed disclosure via value chain report	High
Supplier 2	Vietnam Indonesia, Malaysia, Thailand	No	Detailed disclosure via CDP questionnaire	High
Supplier 3	Indonesia, Thailand	Yes (Kalimantan Plantation/ Sumatra Rubber Estate)	Partial Disclosure via CDP questionnaire and Website	Moderate
Supplier 4	Indonesia, Thailand, Vietnam, Cambodia	No	Country-level disclosure via ESG report and CDP Questionnaire	Moderate

As per the Table 2, Supplier 1 and Supplier 2 have disclosed their location of rubber sourcing either in their corporate sustainability report, CDP questionnaire, or a separate publicly disclosed document on the natural rubber value chain, making them rank high in the traceability levels. Whereas, Supplier 3 only disclosed the natural rubber plantation it owns in Indonesia, and no other sourcing locations. Supplier 4 has disclosed just the countries of rubber sourcing, which lack sub-national or sub-regional details in their CDP questionnaire, as well as in sustainability reports. Both Supplier 3 and Supplier 4 indicate a moderate level of traceability. According to TNFD, it is difficult for every business to track their location of operations when it comes to a complex value chain; however, not knowing the specific location makes it tough to assess risk (e.g., deforestation zones) effectively. Lack of specific rubber sourcing location from Supplier 3 and Supplier 4 limits

the company's ability to identify and manage nature-related risks, and stands in contrast to the TNFD's recommendation for location-based assessment (TNFD 2023c:41).

5.1.2 Traceability Initiatives:

Each tire manufacturing companies have its sustainable natural rubber sourcing policy through which they plan and strategies on sourcing responsible natural rubber. Through these policy documents, it was revealed how these companies are using digital tools, third-party assessments and surveys to trace and increase transparency in their supply chain.

Table 4 Rubber Sourcing Tacking Tools used by tire companies

Company	Trackability Tools
Supplier 1	Agridence and RubberWay
Supplier 2	RubberWay
Supplier 3	Not specified
Supplier 4	Blockchain based

Supplier 1 and Supplier 2 both use RubberWay which is a web based mobile application that is used to trace natural rubber as well as creates surveys that are filled by smallholder farmers or intermediary dealers. Apart from tracing sustainable rubber, it also works as a risk assessment tool in the whole upstream supply chain process (Rubberway.tech). Similarly, Agridence is an online trading platform which also works as a tracking tool to trace sustainable natural rubber that can be used by smallholder farmers, companies, and dealers (Agridence.com). Supplier 3 in their CDP questionnaire has not stated the exact name of the tool to trace natural rubber but they have mentioned that they have introduced a digital internal tracing system that is implemented in Liberia and will soon introduce it to countries like Indonesia or Thailand to improve their supply chain traceability. On the other hand, Supplier 4 uses Blockchain technology by participating in the

Project Tree initiative. This technology helps to record every transaction and movement of rubber from the upstream to the downstream value chain in an authorized and transparent process.

5.2 Evaluate:

To evaluate specific nature-related risks, the WWF Biodiversity Risk Filter tool was chosen to study the environmental impact and dependencies related to the geolocation of natural rubber sources for Supplier 1, Supplier 2, and Supplier 3. In this section supplier's initiatives to manage deforestation, smallholder farmer training to cultivate sustainable natural rubber, and risk mapping actions are evaluated. In this study, two types of risks are examined- physical risk which includes four subcategories, and reputational risk with one subcategory. The reason to analyze these two risks is that suppliers that are directly dependent on nature, such as forests, water and soil, which come under physical risk. This risk occurs due to a decline in ecosystem services. for instance, deforestation brings harm to natural functions that support production. Reputational risk arises when a company directly or indirectly is linked to environmental or biodiversity loss. The company may face the risk of damaging the company's public image, which can also lead to criticism from consumers and loss of trust among its stakeholders (Church et al. 2022: 32).

Risk Type	Risk Category	Key	Indicator name
PHYSICAL	1. Provisioning Services	S1_1	Water Availability
		S1_2	Forest Productivity and Distance to Markets
		S1_3	Limited Wild Flora & Fauna Availability
		S1_4	Limited Marine Fish Availability
	2. Regulating & Supporting Services - Enabling	S2_1	Soil Condition
		S2_2	Water Condition
		S2_3	Air Condition
		S2_4	Ecosystem Condition
		S2_5	Pollination
	3. Regulating Services - Mitigating	S3_1	Landslides
		S3_2	Wildfire Hazard
		S3_3	Plant/Forest/Aquatic Pests and Diseases
		S3_4	Herbicide Resistance
		S3_5	Extreme Heat
		S3_6	Tropical Cyclones
	5. Pressures on Biodiversity	S5_1	Land, Freshwater and Sea Use Change
		S5_2	Forest Canopy Loss
		S5_3	Invasives
		S5_4	Pollution
REPUTATIONAL	6. Environmental Factors	S6_1	Protected/Conserved Areas
		S6_2	Key Biodiversity Areas
		S6_3	Other Important Delineated Areas
		S6_4	Ecosystem Condition
		S6_5	Range Rarity

Figure 3 WWF Biodiversity Risk Indicators used for the analysis of the natural rubber sourcing regions

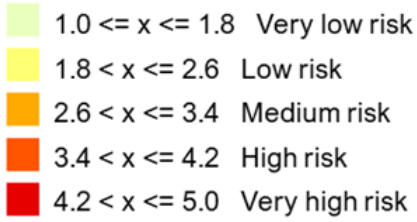

Figure 4 WWF Biodiversity Risk scores

5.2.1 WWF Biodiversity Risk exposure by region:

To use the WWF Biodiversity Risk Filter, first, an account was created, then three company portfolios were formed with the supplier's name. Then, manually rubber sourcing locations that were identified with the use of the CDP questionnaire, sustainability reports, and supply chain reports were uploaded under each supplier's name. Since rubber is classified as a plant-based commodity, the parameters in the tool were selected as the 'Plant Products' category within the tool. The tool then generated risk profiles for each supplier and provided risk scores as per Figure 4, indicating which location comes under low environmental risk and which comes under high

environmental risk. These scores are based on an existing environmental database, indicating the types and severity of nature-related risks specific to geographic regions.

Table 5 Supplier 1 Biodiversity Risk Scores derived from WWF Biodiversity Risk Assessment Filter

Country	Land or Seascape	1. Provisioning Services	2. Regulating & Supporting Services - Enabling	3. Regulating Services - Mitigating	5. Pressures on Biodiversity	6. Environmental Factors
Indonesia	Java (542)	3.6	2.25	2.88	2.58	2.5
Indonesia	Java (541)	3.6	2.5	2.5	2.58	2.5
Indonesia	Sumatra (535)	3.25	1.5	2.88	3.25	2.5
Indonesia	Sumatra (535)	3.25	2.5	2.88	3.29	3.5
Indonesia	Java (542)	3.6	2.25	3	2.58	3
Indonesia	Sumatra (535)	3.55	2.75	3.25	3.29	3
Indonesia	Sumatra (535)	3.55	3	2.88	3.29	2
Indonesia	Sumatra (535)	3.65	2	2.88	3.29	2.5
Indonesia	Sumatra (535)	3.55	3	2.88	3.38	2.5
Indonesia	Sumatra (535)	3.55	2.5	2.88	2.92	2.5
Malaysia	Pahang	3.25	2.25	3	3.35	3.5
Malaysia	Perak	3.25	2.75	2.88	2.96	3
Malaysia	Kelantan	3.25	3	3.38	3.31	2.5
Malaysia	Malay Peninsula (526)	3.25	2.25	2.88	2.98	3
Malaysia	Pahang	3.25	2.25	2.88	2.94	3.5
Malaysia	Perak	3.35	3.25	2.88	3.35	3
Thailand	Mekong	3.75	2.75	3.5	2.75	2.12
Thailand	Andaman Sea	3.35	2.25	3	3.27	3
Thailand	Mekong	3.65	2.25	3.5	2.38	2.5
Thailand	Gulf of Thailand	3.4	3	2.88	3.31	2.5
Thailand	Mekong	3.65	2.25	3.5	2.38	2.5
Thailand	Mekong	3.45	3	3.5	2.75	2.5

Supplier 1 sources its natural rubber from multiple regions across Southeast Asian countries- Indonesia, Malaysia, and Thailand. The sites studied in the WWF biodiversity risk filter consist of smallholder farmers as well as estates and industrial plantations. The WWF biodiversity risk filter shows moderate to high-risk scores across all regions. Especially in the regions of Sumatra (Indonesia), Pahang (Malaysia), and the Andaman Sea (Thailand), are observed to be higher in

environmental scores. This suggests that these areas are vulnerable to impacting ecosystem services and are located near biodiversity hotspots.

Table 6 Supplier 2 Biodiversity Risk Scores derived from WWF Biodiversity Risk Assessment Filter

Country	Land or Seascape	1. Provisioning Services	2. Regulating & Supporting Services - Enabling	3. Regulating Services - Mitigating	5. Pressures on Biodiversity	6. Environmental Factors
Indonesia	Sumatra (535)	3.55	2.5	2.88	3.25	3
Indonesia	Sumatra (535)	3.45	1.5	2.38	1.92	2
Indonesia	Java (541)	3.8	2.25	2.88	2.58	3
Indonesia	Sumatra (537)	3.55	2.25	2.88	3.29	2.88
Indonesia	Borneo (534)	3.45	2.25	2.88	3.25	2.5
Indonesia	Sumatra (535)	3.3	4.5	4	4.5	4
Indonesia	Sumatra (536)	3.55	2.75	2.5	3.33	2.5
Indonesia	Sumatra (535)	3.55	2.5	2.88	2.92	2.5
Indonesia	Sumatra (535)	3.25	2.25	3.25	2.92	3
Indonesia	Sumatra (535)	3.55	3.25	3.25	3.29	2.75
Indonesia	Borneo (534)	3.35	2	3.38	2.92	2.62
Indonesia	Borneo (534)	2.95	2.5	3.25	3.25	2.5
Indonesia	Java (541)	3.5	2.25	2.88	2.96	3
Malaysia	Malay Peninsula (526)	3.45	2.25	2.88	3.31	3
Malaysia	Pahang	3.45	3.25	3.38	3.31	3
Thailand	Andaman Sea	3.5	2.25	2.88	3.27	3
Thailand	Gulf of Thailand	3.65	2	3.25	2.94	2.5
Thailand	Gulf of Thailand	3.5	2.25	2.88	2.9	3
Thailand	Gulf of Thailand	3.45	2.25	3.38	3.33	3.5
Thailand	Gulf of Thailand	3.7	2	3.38	2.9	3.5
Thailand	Gulf of Thailand	3.4	3	2.88	3.31	2.5
Vietnam	Dong Nai & Vaico	3.45	2.25	3.25	2.98	3

According to Supplier 2's CDP corporate questionnaire, across Southeast Asia countries, the sources of its natural rubber are Indonesia, Malaysia, Thailand, and Vietnam. The WWF biodiversity risk assessment scores highlight that these regions come up at moderate to high environmental risk levels. Particularly, Sumatra (Indonesia) and the Gulf of Thailand (Thailand) score high in all risk indicators, which indicates that these areas are under threat to the availability to natural resources and ecosystem conditions.

Table 7 Supplier 3 Biodiversity Risk Scores derived from WWF Biodiversity Risk Assessment Filter

Country	Land or Seascape	1. Provisioning Services	2. Regulating & Supporting Services - Enabling	3. Regulating Services - Mitigating	5. Pressures on Biodiversity	6. Environmental Factors
Indonesia	Borneo (534)	2.6	3.5	3.88	3.58	4.25
Indonesia	Sumatra (537)	3	3.5	3.88	4.12	4

Supplier 3 has only disclosed the location of its owned rubber plantation in Borneo and Sumatra, Indonesia. The WWF biodiversity risk filter results highlight that both locations are high in all risk indicators, which indicates that these locations could be vulnerable to serious environmental degradation, close proximity to biodiversity hotspots, weak soil conditions, and possible challenges to ecological functions.

Supplier 4 was excluded from the WWF biodiversity Risk Filter analysis due to the lack of detailed geolocation disclosure except for the countries of natural rubber sourcing. When comparing the biodiversity risk scores of the other three tire manufacturing companies- Supplier 1, Supplier 2, and Supplier 3, it was observed that all three rely heavily on Indonesia for sourcing natural rubber. The analysis shows that even though using traceability tools, many rubber cultivation regions are located in close proximity to biodiversity hotspots, and are highly vulnerable to environmental degradation and fragile ecosystem conditions.

5.2.2 Corporate Policies and Biodiversity Commitments:

In this section, the supplier's initiatives are analyzed regarding their mitigating efforts against biodiversity loss, deforestation, alternative materials used instead of natural rubber, and public commitments. This information is reviewed using their ESG reports, corporate sustainability reports, CDP Corporate questions, and other publicly disclosed information.

Table 8 Measures to adopt sustainable natural rubber by tire companies

Tire Supplier	Zero Deforestation Policy	Smallholder Farmers Engagement	Alternative Rubber Investment	Risk Mapping Initiative
Supplier 1	Sustainable Natural Rubber Sourcing Policy / GPSNR member	Training courses in Indonesia	Yes	RubberWay analysis tool
Supplier 2	Natural Rubber Procurement Policy/ GPSNR member	Capacity building training	Yes	Tire Industry Project/Third-party risk assessment
Supplier 3	GPSNR member/ WWF/ ETRMA	Capacity building in collaboration with WWF Japan/ supporting GPSNR initiatives	Yes	Third-Party Assessment by EcoVadis and Varisk Maplecrot
Supplier 4	GPSNR member/ EUDR/ Sourcing rubber with sustainability certified sources (FSC, ISCC)	Provides eco-friendly supplies to farmers through Project Tree	Not specified	National Level supply chain risk screening

Supplier 1 has adopted Sustainable Natural Rubber Policy into its operations to mitigate on risk that may be caused to the stakeholders, forests, and other environmental components. Through this policy, Supplier 1 is following on four commitments- respect for people, minimizing environmental impact, fair and equitable value chain, and responsible sourcing. Under minimizing environmental impacts, Supplier 1 intends to align with GPSNR's framework to source natural rubber that does not come from deforested land. In addition to adopting the Sustainable Natural Rubber policy to mitigate risk management, it also uses the RubberWay platform as a risk mapping tool, which helps in identifying sustainable rubber sources and the risk of deforestation linked to rubber in the upstream process. To encourage the usage of sustainable natural rubber, Supplier 1 in collaboration with another international organization, has been training Indonesian smallholder farmers to adopt sustainable farming methods in cultivating natural rubber. In 2011, Supplier 1

came up with a Project, where they are researching an alternate rubber that can be extracted from Russian dandelion. This plant can lessen the burden of Southeast Asian countries for growing natural rubber, as this type of Dandelion is a low-maintenance plant and does not need a tropical climate for cultivation. In 2018, Supplier 1 introduced bicycle tires to the market that are made from dandelion rubber.

In 2022, Supplier 2 introduced the Natural Rubber Procurement Policy, which follows GPSNR's frameworks that aim to source raw materials like natural rubber sourced from deforestation-free land. This policy also aims to promote the betterment of smallholder farmers. Supplier 2 collaborates with GPSNR and funds its capacity-building initiatives, especially for farmers in Indonesia. To promote sustainable tires, in 2023 Supplier 2 introduced tires that are designed with 70% sustainable raw materials that include sustainably sourced natural rubber, soybean oil and ash silica obtained from rice husk. Similar to Supplier 1, Supplier 2 also uses RubberWay tool to trace sustainable natural rubber and tools like WWF biodiversity risk filters, ENCORE and SBTN to identify nature-related impact from their operations.

Supplier 3 has come up with a Global Sustainable Procurement Policy, which states that the company will not source raw materials that may lead to deforestation. The company is a member of GPSNR and adheres to the guidelines of the organization. To facilitate the cultivation of natural rubber, Supplier 3, in alliance with WWF Japan, offers training to smallholder farmers in Indonesia on plantation techniques to grow strong yields and other practices. The supplier has been researching an alternate rubber source that is extracted from the Guayule shrub, which is found in arid regions of the Arizona deserts. In 2022, by using the rubber from Guayule shrubs, the supplier introduced a new range of race tires. It aims to use 100% sustainable raw materials in its tires by the year 2050. To identify environmental and social risks, the company has conducted third-party risk assessments through EcoVadis and Verisk Maplecroft. They even conducted audits on selected natural rubber suppliers using a self-assessment questionnaire, which was created in collaboration with WWF Japan.

Supplier 4 is committed to following sourcing guidelines that align with the European Union Deforestation Regulation (EUDR) and encourages suppliers to provide FSC or International

Sustainability and Carbon Certified (ISCC) natural rubber. The supplier, in collaboration with ITOCHU, works on a project where they work on a blockchain traceability tool and provide smartphones, tapping knives, and formic acid, an eco-friendly coagulant, to smallholder farmers for cultivating high-quality natural rubber. Supplier 4 has not specified about its alternative rubber material initiative instead, it states that it is diversifying its sourcing location and not relying on any one country for its rubber, as it can create pressure on the region's ecosystem. In 2018, the supplier introduced the Sustainable Natural Rubber policy, which aligns to the GPSNR frameworks and helps monitor risk in addition to that it also conducts national-level supply chain assessments on suppliers.

Overall, Supplier 1 and Supplier 3 are spontaneously investing in alternative sources of natural rubber, such as dandelion and guayule, which highlights their efforts to reduce the environmental burden on Southeast Asian countries to produce natural rubber. Although Supplier 4 has not disclosed any specific alternative rubber initiatives, the supplier acknowledges its efforts to diversify sourcing locations and reduce the dependency on biodiversity-sensitive regions like Southeast Asia. All four suppliers are members of GPSNR and commit to its frameworks, which also include supporting a deforestation-free rubber supply chain. Each supplier has established its sourcing policies, which aim to incorporate sustainability principles in their supply chain operations. Additionally, all of them collaborate with NGOs and associations to support and train smallholder farmers in cultivating sustainable rubber plantations. Even environmental and social risk assessments are conducted by all suppliers, either by third-party online tools or internal audits, which shows their recognition of the importance of responsible upstream operations.

5.3 Assess:

In this phase most relevant nature-related risks and opportunities are identified within the Case company's upstream supply chain process by using the WWF biodiversity risk filter, corporate disclosure, and risk mitigating efforts that were studied in the earlier stages of Locate and Evaluate. In this section, qualitative analysis is carried out to analyze the issues of sourcing from a particular region and its environmental and operational challenges.

5.3.1 Identifying Material Related Risks by Regions

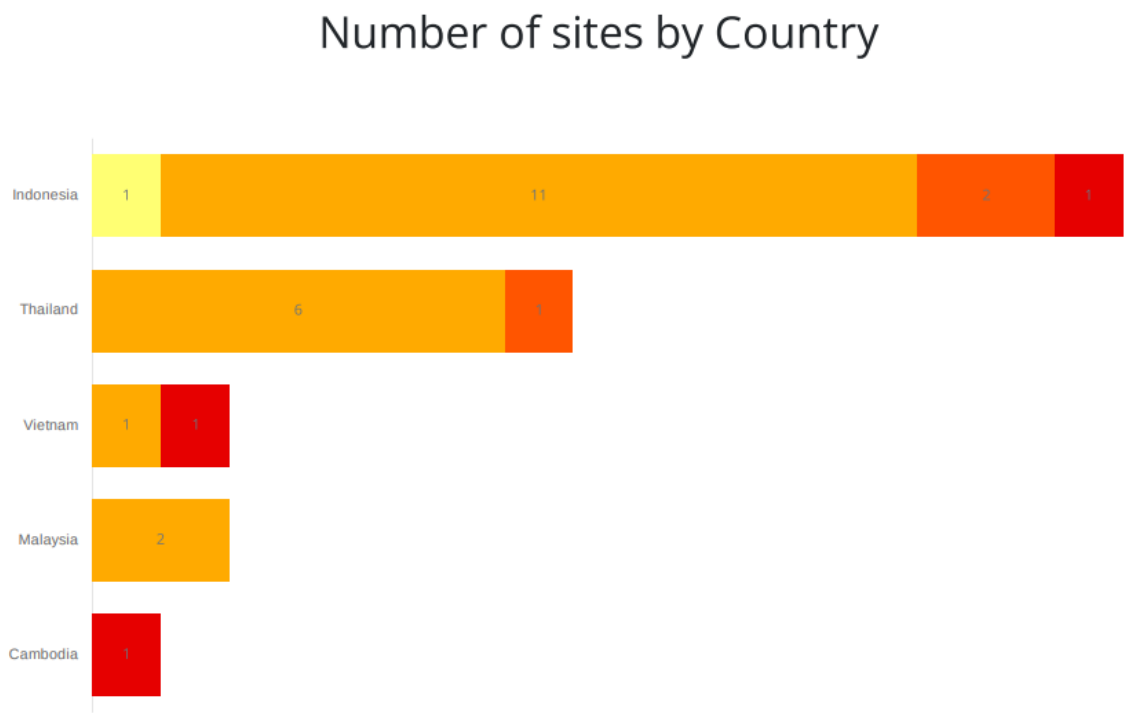

Figure 5 Country-specific risk level distribution- accessed through Biodiversity Risk Filter

It is observed that all four tire manufacturing companies reviewed for this study have been sourcing their natural rubber from Indonesia. Though Supplier 4 has not disclosed specific sub-regions, but highlights in its CDP corporate questionnaire that it sources its rubber from Indonesia (44.8%), Cambodia (1.4%), Vietnam (0.04%), and Thailand (25.5%). The figure 8 clearly indicates that most of the sourcing regions are in Indonesia, which comes under moderate to very high biodiversity risks.

Figure 6 Risk indicator specific risk level distribution- accessed through Biodiversity Risk Filter

Most of the natural rubber sourcing regions face biodiversity pressures, which could relate to forest canopy loss and land use change. WWF biodiversity risk filter data indicates that these regions fall under high to very high levels for provisioning services, suggesting potential threats to water availability, wild flora and fauna. Moreover, all sourcing sites show some level of exposure to pollution, establishing a conclusion that biodiversity pressure is a common risk factor across all sourcing geographies.

5.3.2 Supplier initiatives to mitigate identified risks and their prioritization:

The assessment phases require recognizing the connection between ecological risk exposure in sourcing regions that are studied in the Evaluate phase, with how well Case company's potential suppliers are prepared to address those risks. The aim in this phase is to examine which nature-

related risks are material to the company and find areas where tire suppliers' readiness gaps could expose the company to potential environmental, reputation, or regulatory concerns.

All four tire suppliers have publicly declared to source their raw material, including natural rubber, from deforestation-free sources by aligning with GPSNR's framework to their operations and transparency levels that vary considerably. Supplier 1 demonstrates the strongest alignment with TNFD expectations. It has adopted advanced traceability through the RubberWay tool, trained smallholder farmers in Indonesia by partnering with another organization that works on sustainable development, and also invests in alternate rubber production through their in-house project by using dandelion-based rubber. This shows high readiness to reduce dependency on biodiversity-sensitive geographies and to manage long-term ecological risk. Similarly, Supplier 2 provides detailed sourcing location in its CDP corporate response 2024, when compared to its corporate responsibility report. It uses assessment tools like RubberWay, WWF Biodiversity Risk Filter, and ENCORE to monitor and evaluate environmental risks. However, the supplier only states in its corporate responsibility report that it funds GPSNR's capacity-building project for farmers, which indicates its lack of direct engagement with smallholder farmers. Additionally, while the Supplier 2 mentioned ongoing research on alternatives to their raw materials, it does not specify alternatives to natural rubber, which may limit its adaptive capacity in high-risk regions.

Supplier 3 has developed progress through a collaborative initiative with WWF Japan by conducting training for smallholder farmers in Indonesia. Furthermore, it also discloses its research on alternative rubber material from the Guayule shrub. In its CDP 2024 corporate questionnaire, it only discloses information about its company-owned plantation and does not provide into other sourcing locations across its broader supply network. This lack of traceability represents a gap in its assessment capacity and limits alignment with TNFD guidance. Supplier 4 discloses only country-level sourcing data and has not reported any engagement in alternative rubber research. However, it compensates for this limitation through its project, which is a blockchain-based initiative to trace its upstream process. The supplier also supports smallholder farmers with suitable farming inputs and aligns its scoring policies with the EUDR and encourages its suppliers to provide raw materials with FSC and ISCC certifications.

The company's capacity to control upstream sustainability performance and risk exposure related to biodiversity is directly impacted by these variations in supplier preparedness. Relevant risk factors for the Case company's natural rubber supply chain include ecological degradation in high-risk sourcing regions, especially in Indonesia, Malaysia, and Thailand, where tire suppliers operate in or near biodiversity-sensitive landscapes. Insufficient sourcing transparency, particularly among suppliers such as Supplier 3 and Supplier 4, limits the ability to perform effective risk mapping and align with emerging regulations like the EUDR. Another issue is the limited investment in alternative rubber materials, which prolongs dependence on ecologically vulnerable regions and increases long-term sustainability risks. Lastly, inconsistent engagement with smallholder farmers poses reputational, social, and environmental risks and reduces the resilience of the supply chain (TNFD 2023c).

Considering these difficulties, the analysis shows that the Case company has room to improve its approach to supplier interaction and selection. Suppliers such as Supplier 1 and Supplier 2 exhibit relatively stronger traceability, utilization of risk assessment tools, and alignment with TNFD principles. These companies could be given preference for future procurement partnerships or collaborative sustainability projects. Conversely, tire suppliers with inadequate risk management or disclosure procedures may require targeted dialogue or capacity-building interventions to minimize their exposure to biodiversity-related risks. Incorporating these findings into the Case company's supplier assessment and procurement procedures will enhance alignment with risk frameworks and contribute to long-term value chain adaptability.

6 Discussion & Recommendations:

This section interprets the results generated by the TNFD's Locate, Evaluate and Assess phases and presents practical recommendations for the company. As the company's indirect exposure to upstream biodiversity-related risks through its downstream operations plays a critical role in shaping sustainable practices through its procurement and supplier engagement processes. The four tire suppliers that are chosen in this study showed notable differences in sourcing location traceability, smallholder participation, and risk mitigation for deforestation. The analysis is based on location-based risk mapping, assessment of nature-related dependencies, and mitigating efforts on deforestation risks.

The analysis revealed a significant difference among the four tire suppliers reviewed. The Suppliers 1 and 2 demonstrated high traceability levels, they disclosed sub-national sourcing locations and also disclosed their use of risk mapping tools such as RubberWay in their CDP disclosure and in Sustainability reports. Both suppliers also reported stronger involvement with sustainability initiatives, such as investment in alternative rubber materials and engagement with smallholder farmers through NGOs and other environmental organizations. Despite owning rubber plantations, supplier 3 only showed limited transparency about its natural rubber sourcing locations and only disclosed information about its own plantations. Supplier 4 only disclosed its rubber sourcing country locations with limited involvement with smallholder farmers or investment in alternative rubber materials.

These differences can be linked to several factors that Frippe et al. (2023) and Smit et al. (2020) mentioned. Traceability in the rubber industry is often hindered by weak governance, involvement of a large number of smallholder farmers, and limited adoption of traceability technology. Suppliers with the greater exposure to EU markets or active participation in international organizations like GPSNR are more likely to disclose sourcing details and adopt sustainability practices (Smit et al., 2020). However, this relationship is not consistent, as supplier 4, despite being a member of GPSNR, has not disclosed its sub-regional rubber sourcing locations, which indicates that membership does not always guarantee transparency. Meanwhile, companies

sourcing from regions with limited institutional capacity, such as Southeast Asia, may face additional barriers to transparency and biodiversity reporting (Bouahom & Kono, 2022).

This study supports previous findings that rubber sourcing presents serious environmental risks particularly in biodiversity hotspots such as Southeast Asia (Warren-Thomas et al. 2023, Wang et al. 2023). As mentioned by Wang et al. (2023), rubber driven deforestation is often underestimated due to poor traceability and smallholder farmer dominance, with rubber plantations expanding into forests in unmonitored areas. The findings also support Panda & Sarkan (2020) and Toriyama et al. (2022), who addressed how rubber, a monocultural plant, degrades soil and disturbs the water cycle. This study also tries to highlight how downstream companies that are often excluded from environmental accountability can play a major strategic role in upstream risk governance through procurement influence and supplier engagement. As noted by Schäfer (2023), supply chain transparency is not just an obligation but a tool for real-world sustainability transformation. By applying the TNFD framework to a downstream company, this study demonstrates how such companies can influence procurement, traceability demands, and nature-related disclosure expectations across their value chain.

It is a contribution to the contemporary research on biodiversity risk governance by shifting the focus to downstream companies. The TNFD LEAP framework serves as a structured analytical tool in the qualitative research that demonstrates new directions for further academic research on sustainability reporting related to forest commodities. The findings also encourage social pressure on tire manufacturing companies, on responsible natural rubber sourcing, especially from Southeast Asian countries. As some tire suppliers do not fully disclose their rubber sourcing regions, there is a need from the public and government to push for strong rules and clear reporting for companies to improve their supply chain. The customers and investors need to understand which tire suppliers are truly working towards protecting the environment and which ones are not acting responsibly towards the nature.

The findings also show how the TNFD LEAP approach can be used as a tool in scientific research to evaluate nature-related risk in organizations working in diverse and complex fields. This approach can help in analyzing environmental hotspots, environmental risks, and how

organizations respond to those risks. This study adds scientific knowledge to downstream companies that are not often studied in biodiversity research. This also suggests future research in detailed on-the-ground studies with smallholder farmers to understand their perspective on changing regulation in natural rubber sourcing. Additionally, future research could also look into how efficient blockchain-based rubber tracing tools are for natural rubber sourcing and other forest commodities like timber or cocoa. Lastly, the study shows that there are advantages as well as disadvantages to using publicly available company reports for research purposes. Although it provides access to useful information, it also indicates the need for field research or using third-party data to verify that the company's actions align with what they report.

The discussion now shifts from risk identification to response formation. The Prepare phase is referred to as recommendation in the TNFD LEAP framework (TNFD 2023c) that emphasizes the importance of organizational alignment, target setting, and disclosure planning in light of material ecological risks. The case company could strategically position itself as a responsible participant in the tire supply chain through its use of global frameworks like TNFD, SBTN FLAG, and CSRD/ESRS E4, as explained in this section.

6.1 Recommendations to downstream companies:

Based on the findings from the case study, several strategic recommendations are formulated that assist downstream companies, particularly those working in the automotive sector, who indirectly rely on natural rubber through their supply chain. These recommendations will help the companies be prepared for the upcoming biodiversity-related reporting requirements. While these recommendations are drawn from a specific company context, they are relevant for other companies with indirect exposure to biodiversity risks in the upstream supply chain. The following points provide a generalized approach to improve supplier engagement, traceability, and alignment with frameworks like TNFD, CSRD, and ESRS E4.

Firstly, the companies can integrate traceability expectations in their procurement strategy for suppliers to disclose their sourcing locations (i.e., regions and sub-regions). TNFD emphasizes that to understand the nature-related risks, it is important to determine the locations based on risk

identification (TNFD 2023c). Even EUDR[3] (European Union Deforestation Regulation) mandates companies to disclose granular details of the geolocation that is essential to disclose data for deforestation-linked commodities (European Commission). While the downstream companies are not directly subject to EUDR, the regulation has implications for their upstream partners. Encouraging EUDR-aligned sourcing criteria among suppliers would help the companies mitigate indirect reputational and regulatory risks.

The companies can add biodiversity-related performance criteria into their supplier evaluation process. Such as the biodiversity risk screening checklist that has been developed as a part of this study. This checklist will help identify how tire suppliers meet the downstream company's biodiversity expectations based on traceability, transparency, and proactive risk management initiatives. A complete checklist is available in the Appendix. The performance criteria may include time-bound zero deforestation commitments, evidence of engagement with smallholder farmers, memberships in associations like the Global Platform for Sustainable Natural Rubber (GPSNR), and use of biodiversity assessment tools similar to the WWF biodiversity risk filter. This strategy aligns with CSRD's ESRS E4 reporting standard, which requires disclosure of biodiversity and ecosystem-related risks and opportunities throughout the value chain (Grunewald 2024). The companies could give priority to those suppliers who exhibit leadership in sustainable innovation. Relevant examples are Supplier 1's project that produces rubber from dandelions and Supplier 3's creation of Guayule-based rubber that reduces the burden on the tropical ecosystem. By supporting such projects, the company can advocate for circular and regenerative product design while transitioning away from vulnerable sourcing regions.

The downstream companies could request evidence for farm-level tracking and capacity-building programs from their suppliers. This can include blockchain-based rubber tracking platforms, smartphone distribution to smallholder farmers so they can fill real-time traceability data, offering eco-friendly inputs similar to formic acid, or training smallholder farmers on sustainable land use practices. These suggestions are in accordance with the inclusive data-driven risk management strategy advocated in the SBTi's Forest, Land, and Agriculture (FLAG)

[3] EUDR was launched in June 2023, it requires companies to disclose certain commodities, including rubber tires in the EU market, that are not linked to deforestation or forest degradation. This regulation will apply to companies from 30 December 2025 for large and medium-sized companies.

guidance. Through this, it provides sector-specific criteria for land-intensive sectors like rubber production. FLAG is not the primary framework used in this study, but it emphasizes on traceability, farm-level initiatives, and zero deforestation goals that highlight the strong significance of supplier engagement in upstream natural rubber sourcing (Anderson et al., 2023).

Finally, the Case company referred to in this study can begin prepping for voluntary alignment with CSRD and TNFD disclosure. Although not currently required to report under CSRD, the company has identified biodiversity and ecosystems as material due to their impact on the upstream supply chain. By aligning to its reported structure with ESRS, the company has treated 2024 as a transition year, and in 2025, it plans to conduct a pilot study utilizing the TNFD framework. This proactive strategy reflects the Case company's dedication towards safeguarding its disclosure and enhancing its ability to meet new regulations set forth by the European Union.

6.2 Strategic Alignment with TNFD Reporting Standards:

Aligning future reporting practices with the TNFD's disclosure framework enables downstream companies to enhance the transparency and consistency of their strategic sustainability initiatives. The TNFD framework has four pillars: Governance, Strategy, Risk & Impact Management, and Metrics and Targets. Each of them serves as the foundation for nature-related reporting for companies and offers guidance for future ESG communication.

Under the Governance pillar, the companies could report how their leadership manages biodiversity and environmental risks. This includes stating the boards and management roles and responsibilities in evaluating nature-related risks. The companies can provide information on how biodiversity and environmental risks are included in their supplier governance and procurement decision-making procedures under the governance section. Given the company's indirect relationship with upstream activities, the company's response can include setting specific sustainability requirements for its tire suppliers, such as expectations on traceability, smallholder support programs, and commitments to deforestation-free natural rubber sourcing (TNFD 2023b).

As a downstream company, it can use its supplier relationship to influence upstream sustainability outcomes. According to the TNFD's strategy pillar, the companies need to disclose how their procurement strategies, value chain dependencies, and long-term business resilience are affected by nature-related risks and opportunities identified in their suppliers' sourcing regions. Instead of addressing specific initiatives, the company can explain how it aligns its procurement strategy with more general objectives for biodiversity and ecosystem protection through supplier assessment, traceability data, and risk mapping tools to guide sourcing decisions (TNFD 2023b, Grunewald 2024).

A vital element in the company's risk management strategy is to incorporate supplier biodiversity risks into its supply chain risk assessment and monitoring procedures. The companies can disclose the methods they implement to assess supplier practice in terms of upstream sourcing transparency, smallholder participation, and environmental risk mitigation as a way to identify and prioritize nature-related issues within the frameworks of TNFD's risk and impact management. Although downstream companies do not have a direct relation with the upstream plantations, it can manage risk exposure by setting procurement standards, applying risk filter such the WWF Biodiversity risk filter to regions suppliers source their natural rubber from and by collaborating with suppliers on sustainability improvement (TNFD 2023b, Church et al 2022:46).

Following metrics and target pillar, the companies can develop and disclose specific metrics that monitor their suppliers' sustainability performance with respect to biodiversity-related requirements. These metrics can provide information on sub-national sourcing locations, their commitment to sourcing from deforestation-free locations, and the tools they use to identify and assess biodiversity-related risk (e.g., Rubberway). Even though the company's operations function indirectly, setting these types of specific goals, for example, 80% traceability and deforestation-free sourcing across tire suppliers by 2027, would show a proactive approach to nature-related risks management and setting measurable and time-bound targets for biodiversity and land use risk that align with recommendations outlined by TNFD and SBTN FLAG standards and ESRS E4 reporting requirements under the CSRD framework (TNFD 2023b, Anderson et al., 2023).

7 Conclusion

This study assesses how downstream companies that are linked to indirect exposure to upstream biodiversity-related risks through the tire supply chain. The study used a Northern European-based car service and repair provider as a case example, by evaluating four tire suppliers linked to the company's supply chain. By referring to the results and findings, the study develops strategic recommendations and a screening checklist to help downstream companies evaluate whether their tire supplier's source of natural rubber is sustainable. Particularly focusing on tire supplier's rubber sourcing locations, smallholder farmer engagement, and investing in alternative rubber materials. The results showed that although some suppliers have made progress through their initiatives, there are significant gaps in traceability, geographic specificity, and disclosure of nature-related dependencies and impacts. These gaps represent not only environmental and ethical concerns but also business and regulatory risks, especially in the context of developing frameworks like the Corporate Sustainability Reporting Directive (CSRD).

Downstream companies, though not directly involved with raw material extraction, are still exposed to its environmental and regulatory consequences, need to actively manage biodiversity risks that are becoming more important to the business. As sustainability regulations expand and stakeholder expectations rise, companies must move beyond passive compliance towards a more collaborative strategy. This involves embedding biodiversity considerations into procurement policies, strengthening supplier due diligence, and enhancing internal capacities to evaluate environmental risks across the value chain.

This study also provides a biodiversity risk checklist and supplier screening criteria that contribute to the process as practical tools that the companies can incorporate into their supplier engagement and reporting systems. This checklist intends to help downstream companies become CSRD E4 ready and to provide a foundation for future alignment with TNFD. By using the insights from this study, companies can better manage biodiversity risks in their supply chain and show leadership in being open and responsible about how their products are sourced.

To conclude, addressing biodiversity concerns is no longer a choice in the global value chain, it is a strategic necessity. Companies have the opportunity to strengthen their operational resilience and contribute to a broader transition towards a nature-positive business practice through informed and responsible risk assessment and targeted engagement.

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Appendix

Based on the results developed through TNFD's LEAP, WWF Biodiversity Risk Assessment Filter, sustainability polices, and supplier risk mapping, here is a checklist that the Case company could use as a procurement and risk screening tool.

Biodiversity Risk Checklist For Downstream Companies		
Tier 1: Contracting Party (Direct supplier)		
Criteria	What to check	Why it matters
Sub National sourcing disclosed	Suppliers provide exact location of sourcing like country and sub-regions	Enables biodiversity risk mapping (TNFD Locate)
ESG Reporting and risk assessement participation	Supplier can submit CDP reports, thirdparty risk assessment report (eg. Rubberway/ EcoVadis reports)	Shows proactive nature related risk identification
Deforestation free commmitment	Public deforestation free sourcing policy alinged with GPSNR and TNFD	Minimizes reputational or ecological risks
Tier 2: Manufacturer (Production)		
Criteria	What to check	Why it matters
Country of manufacturing disclosed	Disclosed location where rubber is processed into tires	To track environemntal regulations in production areas
Participation in Risk mapping tool	To check if Suppliers uses tools like RubberWay	Demonstrate understanding of upstream biodiversity and regulatory risks
Member to associations on mitigating sustainable natural rubber	Member of GPSNR or similar organizations to show support on sustainable natural rubber	Confirms adherence to global sustainability frameworks
Tier 3: Material Provider (Rubber Matrial Supplier)		
Criteria	What to check	Why it matters
Sub national production regions disclosed	Sourcing regions for rubber sheets, compunds etc	Indentifies proximity to biodiversity hotspots
Smallholder Supports & Engagement	Participation in initiatives like trainaing and capacity building	Strengthens social sustainability and long-term ecosystem resilience
Investment in alternative rubber souces	R&D projects those can be shared	Reduces dependency on biodiversity and natural resources
Tier 4: Raw Material Origin (Plantation or Farm Level)		
Criteria	What to check	Why it matters
Detailed Geo-location of the rubber plantation disclosed?	Sub-regions of farm areas and plantation ownership data if available	To understand land use change monitoring, pollution impact assessment
Blockhain or farm level tracability adoption	Use of blockchain tools similar to RubberWay and Agridence	Verifies sourcing integrity and builds farm level compliance evidence
Biodiversity conversation initiatives	Supplier engaged in reforestation, soil protection or nature restoreation	This indicates nature positive contribution beyond compliance

Figure 7 Biodiversity Risk Checklist for Downstream Companies