The biodiversity impact of global food value chains

Application and evaluation of the first two steps of SBTs for Nature on a Swedish fruit and vegetable wholesaler

Master's thesis in Industrial Ecology

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Cover: Glasswing butterfly (*Greta oto*) on tropical milkweed (*Asclepias curassavica*). Photography by one of the author's family members.

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Abstract

With the rate of biodiversity loss higher than any time in history and related upcoming legislative requirements, companies within all sectors must address their impacts and dependencies on biodiversity. One emerging framework for doing so is the Science Based Targets for Nature (SBTs for Nature). The aim of this thesis was to explore how the framework can be applied to a company in the wholesale food sector, in order to assess the biodiversity impacts in the upstream value chain. Further, the thesis aimed to evaluate whether the framework captures the main impacts on biodiversity in this context, and identify both challenges and opportunities connected to its application. The wholesale company Ewerman, part of Greenfood Group, was used as a case study, on which the first two steps of the SBTs for Nature were applied by following the technical guidance on SBTs for Nature and gathering both primary and secondary data. A literature study on how agriculture affects biodiversity was conducted, and its findings compared with the coverage of the SBTs for Nature methodology. Finally, challenges and opportunities were identified from meetings with company representatives, research articles and by reflecting on the work process throughout the project.

The application of the framework resulted in rankings of countries according to five pressure categories, based on where estimated pressures, and hence potential impacts, are the largest and where nature is the most sensitive. Some countries were frequently ranked high, which provides opportunities for multiple actions within one country. The SBTs for Nature framework captures some aspects of how agriculture affects biodiversity, but overlooks others, most importantly pesticide use. For companies within the food sector, the challenges of using the framework are related to the trade-off between accuracy and complexity. Data at a finer scale, and on impacts rather than pressures, would improve the precision of the assessment but can also be resource consuming or even impossible to obtain, at least currently. The framework does however offer opportunities in guiding the direction of companies' biodiversity strategy, both in terms of where to focus and on what, as well as for complying with regulative requirements such as CSRD and CSDDD. The SBTs for Nature are still under development, and hence needs continuous evaluation as companies within different sectors apply the framework.

Keywords: Biodiversity, Science Based Targets for Nature, Agriculture, Pressure, Impact, Value chain

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Louise Persson and Wilma Vidmark, Gothenburg, June 2024

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

BRF	Biodiversity Risk Filter
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSDDD	Corporate Sustainability Due Diligence Directive
CSRD	Corporate Sustainability Reporting Directive
DPSIR	Drivers, Pressures, State, Impact, Responses
EEA	European Environment Agency
ENCORE	Exploring Natural Capital Opportunities, Risks and Exposure
ESRS	European Sustainability Reporting Standards
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas
GRI	Global Reporting Initiative
HIC	High Impact Commodity
HICL	High Impact Commodity List
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ISIC	International Standard Industrial Classification of All Economic Activities
MST	Materiality Screening Tool
NCP	Nature's Contribution to People
NGO	Nongovernmental organisation
RISE	Research Institutes of Sweden
SBTi	Science Based Targets initiative
SBTN	Science Based Targets Network
SDGs	Sustainable Development Goals
$\mathrm{SoN_B}$	Biodiversity State of Nature Indicator
$\mathrm{SoN_P}$	Pressure-sensitive State of Nature Indicator
TNFD	Taskforce on Nature-related Financial Disclosures
WRF	Water Risk Filter
WWF	World Wildlife Foundation

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Introduction

Biodiversity is essential for the goods and services provided by ecosystems that are fundamental for human survival and well-being (Secretariat of the Convention on Biological Diversity, 2003). Despite our great dependency on biodiversity, human societal factors like consumption patterns, human population dynamics and trends, trade and technological improvements are today indirectly driving the deterioration of the natural ecosystems (IPBES, 2019). More directly, the biodiversity loss is mainly driven by changes in land and sea use, exploitation of organisms (particularly overexploitation), climate change, pollution and invasive species. The largest driver is changes in land use, where agricultural expansions are the primary reason for land use change. This has made agriculture the principal cause of biodiversity loss globally, and without changes to the system the decline is predicted to persist (Benton, Bieg, Harwitt, Pudasaini, & Wellesley, 2021). Already 2019, IPBES projected that around 1 million species risk extinction, and without actions to reduce the contribution to the drivers of biodiversity loss, the extinction rate will increase further (IPBES, 2019).

The rapidly declining biodiversity is however increasingly noticed, and many new regulations and frameworks to protect and promote biodiversity have been adopted in recent years. One example is the Kunming-Montreal Global Biodiversity Framework, adopted in 2022, that contains goals and targets that aim to achieve a world in harmony with nature by 2050 (Convention on Biological Diversity Secretariat, n.d.). Through new regulations, efforts on biodiversity conservation are also required from companies, like the EU Corporate Sustainability Reporting Directive (CSRD) where measurable biodiversity and ecosystem targets and action plans are required (EFRAG, n.d.). This development is increasing the demands on companies, of which many are used to reporting their greenhouse gas emissions but do not have experience in assessment of their biodiversity impact (Andréasson, 2023).

One such company is Greenfood Group. As a wholesale company with global value chains, they are dependent on biodiversity but also has large impact on nature from the agricultural activities in the first step of their value chain. Greenfood has recently added Biodiversity as a focus area within their environmental sustainability work, with the goal of formulating biodiversity targets and a strategy to achieve them. However, since wholesale companies often have many different actors and suppliers in their upstream value chain all the way down to farm level, it is challenging to gain and maintain control or influence of all suppliers. In order to comply with current upcoming regulations and to fulfil their environmental ambitions, they will nevertheless need to make demands on their suppliers. One of the affected subsidiaries within the group is Ewerman, which buys and sells local and imported fruits and vegetables from the whole world. Thereby they constitute an appropriate example for how companies within the food wholesale sector with global value chains can work with biodiversity assessment and will be the subject of study in this project.

A methodology for assessment of impacts on biodiversity, and in upcoming versions also target setting, with growing interest from companies is the emerging Science Based Targets for Nature. The method has been developed to relate to and complement existing frameworks and reporting standards like Science Based Targets initiative (SBTi), European Sustainability Reporting Standards (ESRS), Global Reporting Initiative (GRI) and the Greenhouse Gas Protocol (GHG-Protocol) (SBTN, n.d.-b), making it a potentially useful tool for companies. Considering that it is a completely novel method that has already gained some attention and interest from companies, it is interesting to see how it can be applied to companies in the food wholesale sector as well as explore its possible strengths and weaknesses.

1.1 Aim and Research Questions

The aim of the project is to perform a case study of the first two steps of SBTs for Nature on Ewerman, a subsidiary of Greenfood group. Moreover, the project aims to analyse if the framework captures the main impacts on biodiversity from wholesalers of fruit and vegetables with a global value chain, and identify the main challenges and opportunities of using the framework to assess their biodiversity impact.

The project will attempt to answer the following three research questions:

1. How can the first two steps of the SBTs for Nature, 1. Assess and 2. Interpret and prioritize, be applied to one of Greenfood's subsidiaries, Ewerman?
2. Compared with current science on the impact on biodiversity from agriculture, does the SBTs for Nature capture the impacts on biodiversity from wholesalers of fruit and vegetables with a global value chain?
3. What are the main challenges and opportunities of using the first two steps of the SBTs for Nature to assess the impact on biodiversity of a fruit and vegetable wholesaler with a global value chain?

1.2 Delimitations

In this project, only Step 1 and Step 2a and 2b of the Science Based Targets for Nature methodology are performed, due to time limitations and the fact that all steps have not yet been published. In situations where it has not been possible to follow the SBTN guidance exactly, this is clearly stated in the Methodology chapter. The literature study focuses on agricultural production of crops, and not animal farming, since Greenfood's subsidiary Ewerman only purchases fruit and vegetables. The value chain assessment only includes Ewerman's upstream value chain and not their own warehouse operations in Sweden or downstream activities.

2

Background

This chapter provides a background to the key concepts for understanding the context and contents of the report. It includes a definition of biodiversity, the main drivers of biodiversity loss, the connection between the food system and biodiversity, an introduction to the DPSIR framework, regulations and frameworks on biodiversity, an introduction to the applied framework Science Based Targets for Nature, and finally a presentation of the case study company Ewerman and the group it belongs to, Greenfood.

2.1 Biodiversity

According to the Convention on Biological Diversity, biodiversity, or biological diversity, is defined as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Secretariat of the Convention on Biological Diversity, 2011).

Due to the different dimensions of biodiversity, on a genetic, species and ecosystem level, biodiversity generally cannot be encapsulated in a single-metric approach (Marshall, Wintle, Southwell, & Kujala, 2020). This is illustrated by the review of Marshall et al. of commonly used measures of biodiversity, in which 9 categories and 24 sub-categories were identified. Some examples are the category Abundance with the sub-categories Species Abundance and Taxonomic Abundance, and the category Diversity with the sub-categories Diversity Indices, Functional Diversity, Genetic Diversity and Phylogenetic Diversity. There has also been an attempt to define Essential Biodiversity Variables (EBVs), "a minimum set of essential measurements to capture major dimensions of biodiversity change, complementary to one another" (Pereira et al., 2013), acting as an intermediate layer between primary observations and more aggregated indicators. The six suggested EBVs are genetic composition, species populations, species traits, community composition, ecosystem structure, and ecosystem function.

Biodiversity can also be measured at different scales, usually divided into alpha, beta and gamma diversity (Andermann, Antonelli, Barrett, & Silvestro, 2022). Alpha diversity covers diversity on a local scale, in a particular defined area such as a pond or a field. Beta diversity is measured at one level higher, and describes the amount of differentiation between local sites. The exact definition of beta diversity has varied over time. On one layer higher than beta is the gamma diversity, representing the overall species diversity for many communities in a larger area.

Biodiversity is essential for the goods and services provided by ecosystems, referred to as ecosystem services (ESs), that are fundamental for human survival and well-being (Secretariat of the Convention on Biological Diversity, 2003). Ecosystem services are commonly divided into four categories; supporting, regulating, provisioning and cultural services. Some examples are primary production, pollination, food, and sense of place. The concept of ecosystem services has lately been complemented by the broader Nature's Contribution to People (NCP) (IPBES, 2018). The NCPs highlight the central role of culture in all the links between people and nature, and also recognises the knowledge of e.g. local communities and indigenous people more than the earlier concept of ecosystem services.

While people in many places now consume much more food, energy and materials than ever before, this comes with a cost; nature will not be able to provide these contributions in the future, and it also undermines many other contributions (IPBES, 2019). Biodiversity is declining faster than at any time in human history. Already in 2019, IPBES estimated that around 1 million species were facing extinction, and that compared to the average for the last 10 million years the global extinction rate has increased tens to hundreds of times. In Europe, this prediction has been updated to include around 2 million threatened species in 2023 (Hochkirch et al., 2023).

2.1.1 Drivers of Biodiversity Loss

The loss of biodiversity is mainly caused by the five direct drivers, sometimes also referred to as pressures, identified by The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). In order of decreasing impact, these are: changes in land and sea use; direct exploitation; climate change; pollution; and invasion of alien species (IPBES, 2019). The direct drivers are in turn the results of the indirect drivers, which can be categorised into demographic and sociocultural, economic and technological, institution and governance, and conflicts and epidemics (IPBES, n.d.), see Figure 2.1 below.

The five direct drivers affect biodiversity in different ways. There are three main types of land use change; alteration of land cover, modifications in the management of ecosystems or agroecosystems, and changes in the structure of the landscape (IPBES, n.d.). Deforestation is an example of alteration of land cover, management modification can be e.g. agricultural intensification or forest harvesting, and changes in the structure of the landscape includes for instance fragmentation of habitats. Exploitation and use of natural resources has always happened during the course of human history, however the rate has recently accelerated. Some of the most prone species are marine fish, invertebrates, and trees - the first mentioned particularly due to overfishing in the oceans. IPBES further describes how climate change affects all ecosystems by altering their functioning, and causing species, and

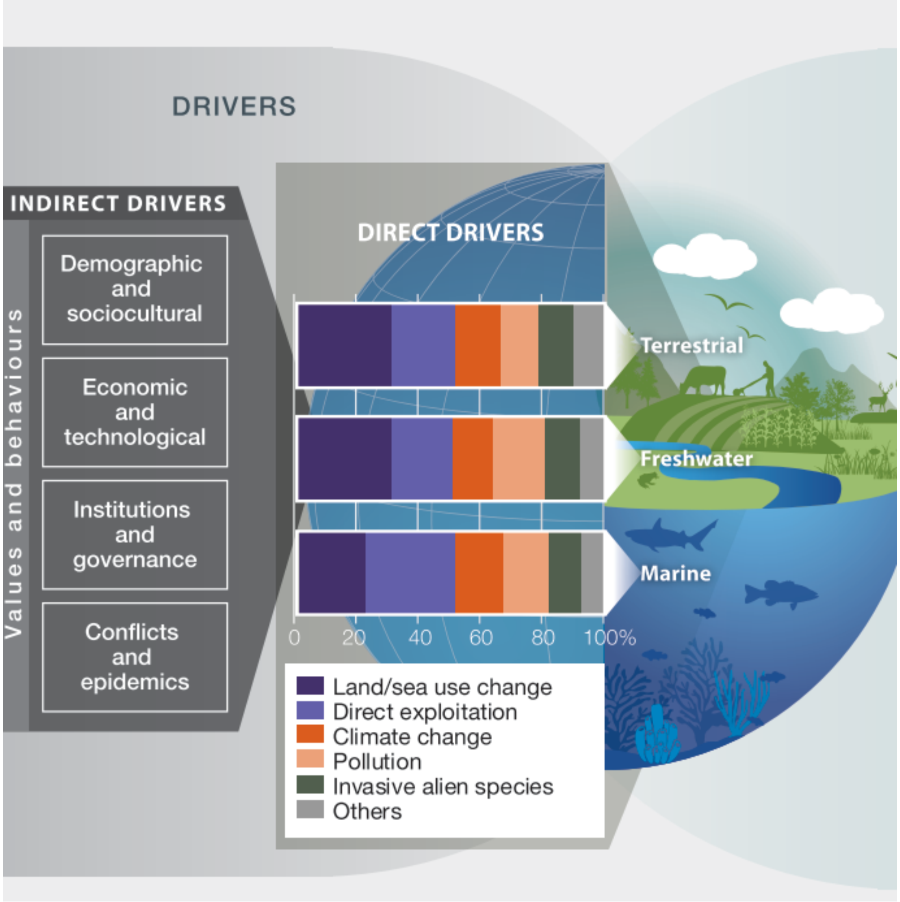


Figure 2.1: Indirect and direct drivers of biodiversity loss. Adapted from IPBES (2019)

sometimes even whole ecosystems, to migrate. In the oceans, increasing levels of atmospheric CO_2 not only causes higher temperatures but also acidification, which is anticipated to be especially detrimental to coral reefs and seabed living organisms. Pollution affects all biomes but has particularly destructive impacts on freshwater and marine habitats. Nitrogen deposition from the atmosphere, mainly from agricultural activities and combustion processes (European Environment Agency, 2023), can in terrestrial biomes hinder decomposition and slow microbial growth (IPBES, n.d.). In freshwater and marine habitats, high nitrogen and phosphorus concentrations cause eutrophication and hypoxic zones. Invasive species can be plants, animals, pathogens, or other organisms. They compete with, predate on or transmit pathogens to native species, and can cause adverse disturbances in ecosystems (CBD, 2021).

2.2 Food and biodiversity

The relation between food production and biodiversity is closely connected to the development of agriculture and human societies, as well as the population growth (Raven & Wagner, 2021). Since agriculture was introduced about 11 000 years ago, the human population has grown from about 1 million people (Raven & Wagner, 2021) to over 8 billion in 2023 (Ritchie et al., 2023). The introduction of agriculture enabled people to establish permanent residencies in forms of villages and towns, which contributed to an increase in human population but also a larger impact on nature (Raven & Wagner, 2021). Along with industrialization and development of larger cities, the small-scale or single-family agriculture decreased and more intensive and large-scale practices emerged. Raven and Wagner (2021) further explain that since around the middle of the 20th century, farming has been performed on greatly expanded scales and been developed into large commercial operations, often at the expense of natural landscapes like grasslands and forests. This is known as agricultural expansion, defined as "the conversion of natural vegetation to land-use for agriculture" (Jellason et al., 2021). It is the main form of land-use change, which in turn is the largest driver of biodiversity loss globally (IPBES, 2019).

Along with agricultural expansion, new agricultural practices focused on highly productive monocultures and increased pesticide and fertiliser use emerged during the 20th century to feed the rapidly growing population (Raven & Wagner, 2021). Practices like these contribute to agricultural intensification, which can be defined as increased output, i.e. yield, per unit of area and/or time or per unit of inputs (Emmerson et al., n.d.). Agricultural intensification can also contribute to biodiversity loss, for example through increased use of fertilisers, pesticides and herbicides, crop specialisation, and simplification of the farmed landscapes.

The historical developments of the agricultural sector and our society has led us to the current food system, which both affects and depends on biodiversity. Between the 1600s and 2021, the agricultural land area has increased 5.5 times and is still increasing globally, which has reduced the variety of landscapes and habitats (Benton et al., 2021). Thereby, the breeding, feeding and/or nesting of birds, mammals, insects and microbial organisms are threatened or destroyed, and native plant species are crowded out. The food system also contributes to biodiversity loss via climate change; in 2020, the agrifood system accounted for 31 percent of total anthropogenic greenhouse gas emissions (FAO, 2022). The global warming brings about changes in conditions for species to live, e.g. alterations in habitats and life cycles, and can also affect biodiversity negatively through for example higher frequency of extreme weather events or increased evapotranspiration (Shah Habibullah, Haji Din, Tan, & Zahid, 2022). Regarding dependence, more than 75 percent of global food crop types, such as fruit and vegetables, depend on animal pollination (IPBES, 2019). The loss of biodiversity in terms of local varieties and breeds of domesticated plants and animals, including genetic diversity, is a serious risk to global food security since it weakens the resilience of agricultural systems to pests, pathogens and climate change.

In order to reverse the negative impacts of the food system on biodiversity, Benton et al. identifies three principal levers: shifts in patterns of demand for food; the degree to which we protect and restore natural ecosystems; and actions to increase biodiversity on agricultural land (Benton et al., 2021). By reducing the overall demand for food, the demand for land to produce it will be lowered. This can mainly be achieved by adopting diets which to a larger extent exclude animal products, reducing food waste and avoiding over-consumption of calories. The second lever emphasises the value of conserving and restoring whole natural ecosystems, which often results in greatest gains for biodiversity and benefits for natural carbon sequestration. As Benton et al. (2021) points out in the third lever, the agricultural land where farming does occur should however be managed in a more biodiversity-supporting way. Even the most wildlife-friendly agricultural practices will entail some modification of the natural habitat, but the effects it has on biodiversity depend greatly on farming methods. Positive contributions can for example be achieved by retaining pockets of habitat for wildlife within the agricultural landscape. The decision between setting aside land for biodiversity purposes or incorporating biodiversity friendly measures within managed land is known as the land sparing vs. land sharing dichotomy (Dudley & Alexander, 2017). The topic has been widely discussed by researchers that advocate for the different strategies, while others, like Dudley et al. (2017) suggests a combination between protection, restoration, and sustainable management. This is also what Benton et al. (2021) proposes in the three levers, while emphasising that new dietary patterns is an enabler of the two other levers - without this change, even more land will be required to feed a growing global population.

2.3 The DPSIR framework

The DPSIR framework was developed by the European Environment Agency (EEA), with the purpose of classifying environmental indicators to be used within reporting and policy-making (Smeets & Weterings, 1999). It describes the relationships between the origins and consequences of environmental problems (EEA, 2007), and illustrates a cyclic cause-effect chain which connects high-level drivers at a societal level to changes in the environment, and further to societal response (Ran et al., 2024). See Figure 2.2 below.

The EEA defines the five indicator categories as (EEA, 2007): **Drivers** are social, demographic and economic developments in society, which lead to changes in lifestyles, consumption levels and production patterns, for instance population growth or increased demand for animal products. **Pressures** include both the release of substances (emissions) and the use of resources, including land. For example, greenhouse gas emissions or forest harvesting. **State** refers to both the abiotic and biotic condition of nature. Abiotic factors are the condition of soil, air and water, whereas the biotic condition is essentially biodiversity, which, as previously explained, covers three levels; ecosystem, species and genetic. This can for instance be represented by the pH in a lake or species abundance. **Impacts** are the effects on human and ecosystem health, resource availability and biodiversity which happen due to changes in the abiotic and biotic conditions. Some examples are species or habitat loss. **Responses** are measures taken by society, which can address all the other indicator categories, including for instance common biodiversity goals or

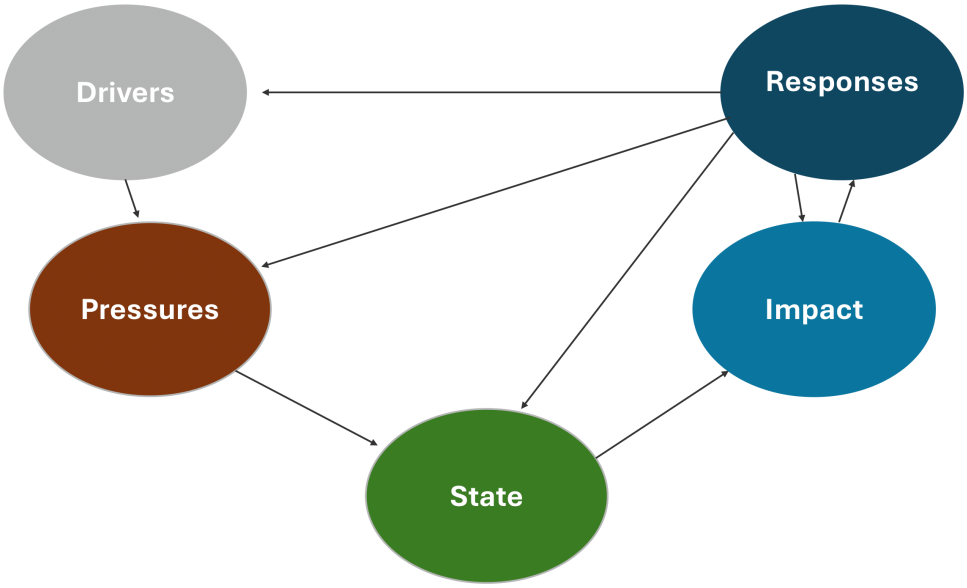


Figure 2.2: The DPSIR framework. Adapted from EEA (1999).

regulations on emissions.

2.4 Biodiversity Frameworks, Regulations and Directives

During the recent years many new international frameworks and regulations connected to biodiversity have been approved. An important milestone is the Kunming-Montreal Global Biodiversity Framework, adopted at the UN Biodiversity Conference in 2022. It contains 4 goals for 2050 and 23 targets for 2030, and delineates a pathway for attaining the vision of a world living in harmony with nature by 2050 as well as achieving the UN Sustainable Development Goals (Convention on Biological Diversity Secretariat, n.d.). Among the global targets for 2030 are restoration of 30% of degraded ecosystems, management and conservation of 30% of areas (e.g. terrestrial, coastal and marine), reduction of nutrients lost to the environment and risk from pesticides by at least 50%, sustainable management of areas under agriculture (among others) and increase of biodiversity-friendly practices (European Commission, n.d.). All parties have committed to implement the framework and thereby must prepare updated National Biodiversity Strategies and Action Plans as well as financial strategies before the next UN Biodiversity Conference in October 2024.

The European Union has also recently adopted several strategies and regulations with major impact on future biodiversity work. In the EU Green Deal, the European growth strategy that aims to decouple economic growth from resource use and achieve net zero emissions of greenhouse gases by 2050, one of the designated policy initiatives concerns preserving and restoring ecosystems and biodiversity (European

Commission, 2019). As an important part of this, the EU 2030 Biodiversity Strategy has been launched (European Commission, 2022). The strategy is a long-term plan to protect and reverse the degradation of nature and ecosystems, which contains over 100 specific actions and commitments, of which 50 are already completed, 46 in progress and 8 are delayed.

The adopted strategies and regulations will also have direct effects on companies in the European Union, for example through the extensive regulative requirement EU Corporate Sustainability Reporting Directive (CSRD). One of the standards within the directive, ESRS E4, specifically concerns biodiversity and ecosystems. It contains eight disclosure requirements, including for example a transition plan, material impacts, risks and opportunities, and targets, all related to biodiversity and ecosystems (EFRAG, n.d.). Depending on the companies' size and whether they are already subject to previous reporting directives, companies will be required to start reporting from the financial year 2024, up to 2026 when also small and medium-sized enterprises are included (European Parliament, 2022).

A directive complementary to CSRD, the Corporate Sustainability Due Diligence Directive (CSDDD), was adopted by the European Parliament in April 2024 (Spinaci, 2024). The purpose of the directive is to promote "sustainable and responsible corporate behaviour throughout global value chains", meaning that companies are obligated to mitigate the adverse effects their activities have on both human rights and the environment, for instance biodiversity loss and pollution. While CSRD is a tool for transparency regarding companies' areas of sustainability, CSDDD will govern how companies act (PwC, n.d.). In total, around 5,400 companies in the EU will be covered, of which ca. 500 are Swedish. The directive will be introduced in three steps according to the size and turnover of the company, starting with the largest companies which will be required to start complying in 2027. By 2029, all companies covered by the directive will be obliged to comply, which means all companies with more than 1,000 employees and a net turnover of 450 million euro. Notably, the companies covered by the directive will place demands on their partners and suppliers, implying that many more companies will be indirectly affected by the directive. Though not compelled to do so by law, they must be able to show compliance in order to be competitive on the market.

The current and upcoming regulations globally and within the EU entails an increased need for biodiversity management strategies at company level, from impact assessment and monitoring to target-setting, implementation of measures, reporting and follow-up. However, the company awareness on nature impact and dependency is currently lacking, and only 5% of almost 400 of the world's most influential companies within sectors with especially high nature impact have evaluated their biodiversity impact in a science-based manner (World Benchmarking Alliance, 2022). This can be compared to e.g. climate actions, where 50% of the assessed companies are implementing measures for emission reductions.

2.5 Science Based Targets for Nature

The Science Based Targets Network (SBTN) is a part of the Global Commons Alliance, a coalition of organisations in business, advocacy and campaigning, science and philanthropy working to protect the global commons (McGlyn et al., 2020). SBTN consists of more than 80 NGOs, business associations and consultancies, some of them being World Economic Forum, World Wildlife Foundation (WWF) and Rockefeller Philanthropy Advisors (SBTN, n.d.-b). Their mission is to create a methodology for companies and cities to set science based-targets for nature which will ensure that they, and thereby society as a whole, stay within the Earth's environmental boundaries. This work builds on what was started by the Science Based Targets initiative (SBTi), who developed science-based targets for climate, and although SBTi and SBTN are two separate organisations, some of the core founding partners are the same. The SBTs for Nature methodology follows a step-by-step process with detailed guidance, including tools, data, and models. With connections to a long list of other sustainability frameworks, standards, and regulations (e.g. ESRS, GRI and TNFD), the aim is to provide a more streamlined process for companies to pursue multiple sustainability goals simultaneously.

Science Based Targets (SBTs) are defined as "measurable, actionable, and time-bound objectives, based on the best available science, that allow actors to align with Earth's limits and societal sustainability goals" (SBTN, n.d.-b). The SBTs for Nature framework is based on the five largest direct drivers of biodiversity loss identified by IPBES but with slight modifications, referred to as pressure categories. SBTs for Nature has the pressure categories Ecosystem use and change, Resource exploitation, Climate change, Pollution and Invasives and others (SBTN, 2023i). Each pressure category is divided into several more distinct pressure categories, which are further translated into pressure indicators. For instance, Ecosystem use and change is divided into terrestrial, freshwater and marine ecosystem use and change, and terrestrial ecosystem use and change is further represented by the two pressure indicators land use change and land use. See Fig 2.3 for an overview of the SBTN indicator framework, which will be further explained in the Methodology chapter.

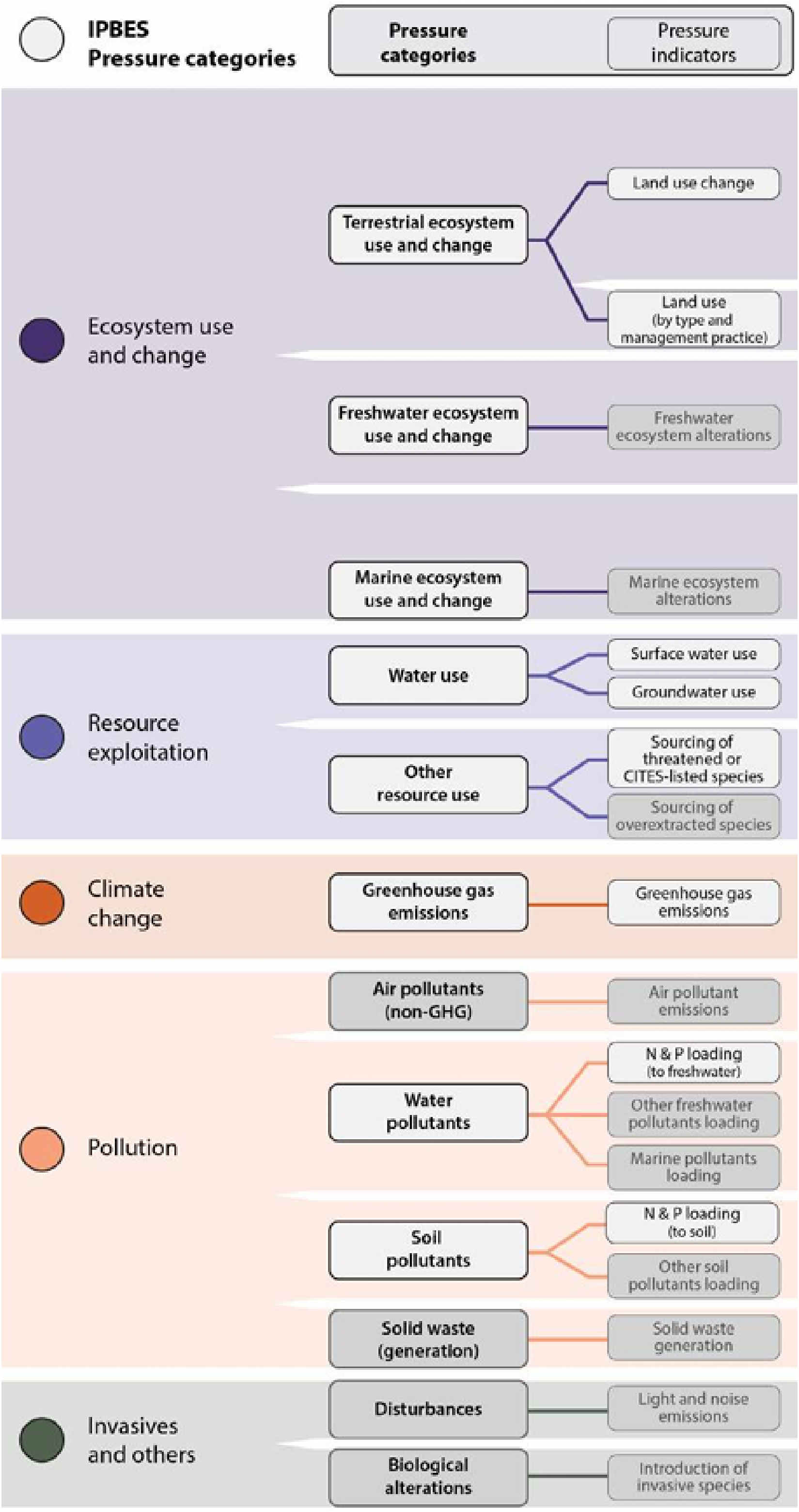


Figure 2.3: The SBTN Indicator Framework. Adapted from SBTN (2023i)

The SBTs for Nature methodology is a five-step process, consisting of the steps 1. Assess, 2. Interpret & Prioritize, 3. Measure, Set & Disclose, 4. Act, and 5. Track, see Figure 2.4 below (SBTN, n.d.-a). Currently, technical guidance is available for

Step 1 and 2, as well as Step 3 for the realm of freshwater. A draft technical guidance for Step 3 Land has also been issued. All steps with published guidance are marked with dark green in Figure 2.4, and those in light green are preliminary included in the other published guidance. Currently, the target validation process for freshwater and land is being piloted by 17 companies across different sectors. Additional methods concerning targets, as well as guidance on Step 4 and Step 5, are expected to be published in 2025 and marked with grey in the overview of the process in Figure 2.4. Although guidance for all steps is not yet available, companies are encouraged to start with the first steps already, to be prepared for setting targets during 2024 or 2025.

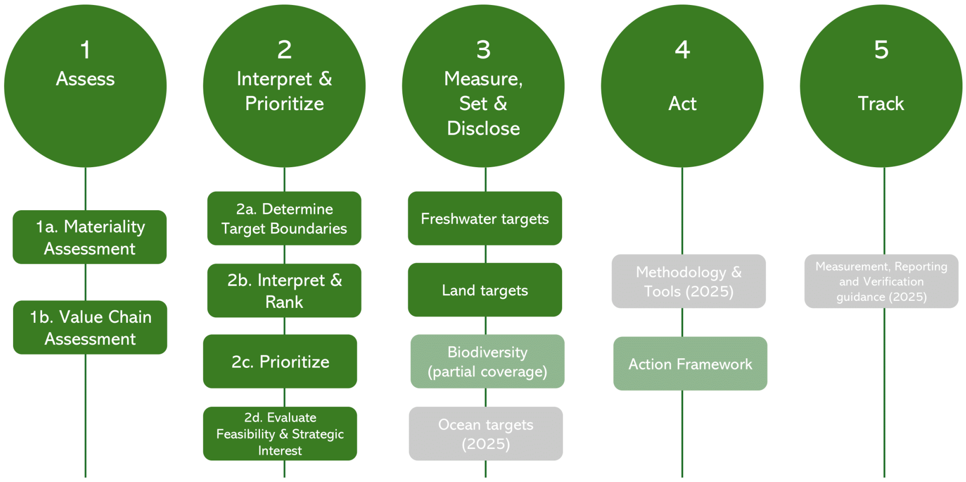


Figure 2.4: Overview of the five-step process of setting SBTs for Nature

Since the method is still under development and not yet widely used, its usefulness and effects are unknown. SBTN's ambition is that companies and cities will reduce their impact on nature and society through the use of SBTs for Nature (SBTN, n.d.-b), in the same manner as SBTi have mobilised the private sector to combat climate change, with over 4000 companies committed to SBTs for Climate by the end of 2023 (Science Based Targets Initiative, n.d.). According to the creators, SBTs for Nature have been designed to recognise interconnections with other environmental problems to increase synergies and interoperate with existing frameworks and regulations to enable target achievement in multiple sustainability areas at once.

2.6 Ewerman & Greenfood Group

The company acting as a case study in this project is Ewerman, a subsidiary within Greenfood Group, see Figure 2.5 below. Greenfood is a Swedish company offering customers in retail, restaurants and catering fresh and healthy food, both in raw and processed form (Greenfood, 2024). The company has three business areas, Picadeli, Food solutions and Fresh Produce. The Picadeli concept is a self-service takeaway salad bar and food-to-go products sold in grocery and convenience stores as well as food service operators. Food Solutions makes ready-made and packaged food for grocery and convenience retailers, restaurant chains and HoReCa (Hotels, Restaurants and Catering) wholesalers. Fresh Produce purchases local and imported fruit and vegetables, selling them to grocery retailers and HoReCa wholesalers. Greenfood Group operates in eight European countries, but are relatively largest in Sweden and Finland. Some of their customers are Sweden's largest convenience goods traders and multi-national fast food restaurants.

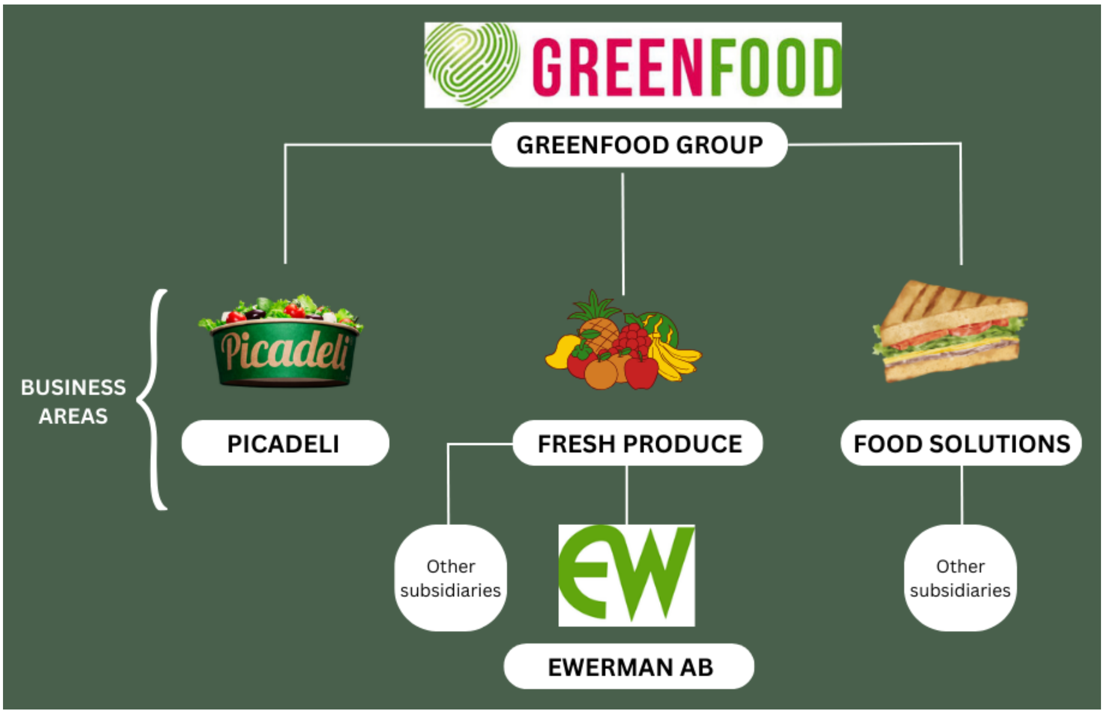


Figure 2.5: The structure of Greenfood Group. Other subsidiaries within the group are not included for clarity.

Regarding sustainability, Greenfood aspires to "be an engine of change driven by a determination to exceed expectations" (Greenfood, 2024). For a food company like Greenfood, there is both a large impact and dependence on nature. The five UN Sustainable Development Goals (SDGs) where they presume to be able to have the biggest impact are Zero Hunger, Decent work and Economic growth, Responsible consumption and production, Climate action and Life on land. Greenfood's environmental sustainability work is divided into four focus areas: climate, packaging, water consumption and biodiversity. Biodiversity was added as a focus area during the last year, by beginning to formulate a biodiversity strategy and targets.

This project will be part of this initial undertaking, and is focused on one of Greenfood's subsidiaries Ewerman, part of the Fresh Produce operational area. Ewerman is a wholesaler of local and globally imported fruits and vegetables, delivering to both retail and food service companies across Sweden (Ewerman AB, n.d.). Their upstream value chain consists of cultivation of fruits and vegetables, including the inputs required such as fertilisers and fuel. This is followed by several intermediate steps of e.g. transporting, sorting and packaging, where different actors and suppliers are involved, see Figure 2.6 below. Ewerman's own operations consist of storage and office, located in Helsingborg, Sweden. They pay for a large share of both inbound and outbound transports to their warehouse, but do not conduct packaging of products themselves. The company was founded in 1964 and had an annual turnover of SEK 1.75 billion in 2022 (Ewerman AB, 2023).

Figure 2.6: Simplified illustration of Ewerman's value chain, with their own operations in blue, upstream in green and downstream in turquoise.

3

Methodology

This chapter describes the methodology applied in the project, starting with a through description of the application of SBTs for Nature, followed by the methodology for the literature study. Lastly the approach for comparison between the literature study and the SBTs for Nature coverage and the analysis of challenges and opportunities of using the first two steps of the method is presented, corresponding to the second and third research question.

3.1 Application of Science Based Targets for Nature

In this project, Step 1, Step 2a and 2b of SBTs for Nature was performed for the subsidiary Ewerman within Greenfood's business area Fresh Produce. The SBTs for Nature methodology currently covers the company's own activities, called Direct Operations, and the activities in the upstream value chain. Downstream operations are not included, but work is ongoing to include this part of the value chain in future SBTs for Nature methods (SBTN, 2023i). For each step, there is a Technical Guidance which was read and interpreted in order to understand how the methodology could be applied to Ewerman's value chain. SBTN provides a Toolbox (SBTN, 2023d) with recommended tools and datasets to be used in the different substeps. A majority of the tools are externally developed, but SBTN has created some tools specifically for the SBTs for Nature methodology, for example the High Impact Commodity List (HICL) (SBTN, 2023a), the Materiality Screening Tool (MST) (SBTN, 2023c) and the SBTN Unified State of Nature datasets for Water Availability and Water Pollution (SBTN, 2023e). Available documentation for the subsequent Step 3 for Land (SBTN, 2023h) and Freshwater (SBTN, 2023g) was also read, to deepen the understanding for what is required in the later steps. The following section will explain how each step was performed in this project, including the additional tools and datasets that were used.

3.1.1 Step 1. Assess

The purpose of the first step is to provide companies with information on which pressure categories they will likely need to include in their target setting, and which parts of their business that are most urgent to begin with (SBTN, 2023i). The two substeps are 1a. Materiality Screening and 1b. Value Chain Assessment. In Step 1a, SBTN's own Materiality Screening Tool (MST) was used as an initial screening to understand which pressures are relevant for the sector(s) the company operates in. The meaning of materiality in this context is "a way of distinguishing importance or significance" (SBTN, 2023b). In step 1b, the pressures which the company generates on nature were estimated, and information on the State of Nature in the different geographic areas where the company, or its upstream value chain actors, operates was collected.

3.1.1.1 Step 1a. Materiality Screening

In this step, companies can choose between the Prescriptive Approach, using SBTN's own Materiality Screening Tool (MST) and High Impact Commodity List (HICL), and the Flexible Approach, using either other tools from the Toolbox, or alternative tools that meet SBTN's criteria. For this project, the Prescriptive Approach was chosen, to enable an evaluation of the MST and HICL.

The MST consists of an Excel Spreadsheet where the company's activities according to the International Standard Industrial Classification of All Economic Activities (ISIC) (United Nations, 2008) group level are entered. The tool then connects these to a number of production processes, which in turn generates a list of pressure categories (i.e. terrestrial use or water pollution) which are material for the company. The pressure categories which are evaluated in the MST are the pressure categories in the second column of Figure 2.3. In this project, only the required pressure categories were included, corresponding to the white boxes in the figure. In an upcoming version of the MST, entering the company's own activities, i.e. its direct operations, will automatically render a list of upstream activities and thereby a complete screening of both direct operations and the upstream value chain. However, in the current version the activities in the upstream value chain must be entered manually. The relevant activities according to the ISIC group level were identified in communication with a company representative. Within each ISIC group, only the production processes considered relevant for the company were included in the screening. The data underlying the results of the materiality screening tool is derived from ENCORE, an online tool for nature-related risk assessment developed by, amongst others, the UN Environment Programme World Conservation Monitoring Centre (UN Environment Programme, 2024).

The HICL is a non-exhaustive list of major commodities which have a direct impact on at least one of the pressures driving biodiversity loss. For each commodity, the material pressures both according to the literature review performed by SBTN and the ENCORE database are listed. For this project, the commodities in Ewerman's purchasing bill which were listed as HICs were identified, their volumes recorded, and their material pressure categories noted.

3.1.1.2 Step 1b. Value Chain Assessment

The purpose of Step 1b is two-fold; estimate the pressures which the company generates on nature both in its direct operations and upstream value chain, and estimate the State of Nature in the geographical areas where these pressures take place (SBTN, 2023i). Within the SBTs for Nature methodology, State of Nature indicators describe "the general condition of nature in physical, chemical, or biological terms" (SBTN, 2023b). The term can be situated in the DPSIR framework, corresponding to the indicator category State. For this project, the basis for the assessment was Ewerman's purchasing volumes from 2023. Using Excel, the commodities were sorted according to purchased weight. Products were included until 67 % of the total purchased weight was covered by the assessment, which is the coverage required by SBTN. The assessment was performed at a national level since this is the information available in the purchasing data. A similar assessment was done for the direct operations but will not be treated in this report since the focus is on the upstream value chain, and the magnitude of pressures in direct operations was considered negligible compared to the pressures in the upstream value chain.

The pressure categories covered in the value chain assessment were Land use, Water use, GHG emissions, Water pollution and Soil pollution. Land use change was only partly included due to difficulties in finding data to estimate the land use change caused by Ewerman's upstream value chain operations. These six pressure categories are the ones required by the SBTN methodology, and are represented by the white boxes in the third column in Figure 2.3. Other resource use currently includes sourcing of threatened or CITES-listed species (Convention of International Trade in Endangered Species), which was controlled for in communication with a Greenfood employee. According to the SBTs for Nature methodology, the pressure data collected for commodities should be associated with the most impactful activity in the supply chain, which is assumed to be the extraction stage unless other evidence is provided by the company (SBTN, 2023i). The contribution of the company to a specific pressure category is denoted pressure (P). To estimate P for Ewerman, data was mainly collected from sources recommended in the SBTN Toolbox. For land use, data from FAO Stat on yield for specific crops in specific countries was used (FAO Stat, 2023a). For water use, data from The Water footprint Assessment Tool on the blue water footprint of specific crops in specific countries was used (Water Footprint Network, n.d.-a). Blue water footprint is defined as "water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time" (Water Footprint Network, n.d.-b). This information was used in combination with data from FAO Stat on the total production quantities of specific crops in specific countries (FAO Stat, 2023a). For GHG emissions, data from Ewerman's SBTi assessment was used, which is based on the RISE food climate database (RISE, n.d.). For Water pollution, data from FAO stat on use of nitrogen and phosphorus fertiliser for each country (FAO Stat, 2023b) was used in combination with calculations on total land use, and run-off factors from (Mekonnen & Hoekstra, 2011) and (Tarkalson & Mikkelsen, 2004). For Soil pollution, the same data as for Water pollution from FAO stat, on use of nitrogen and phosphorus fertiliser for each country, was used.

For each pressure category, the purchased volumes were combined with the collected secondary data to calculate an estimation of the pressure from Ewerman's upstream agricultural activity. SBTN recommends which metric to be used for each pressure estimation. Example calculations for each pressure estimation can be found in Appendix A. The pressures were summed up according to country, which is the spatial scale at which the assessment has been performed in this project. See Table 3.1 below for an overview of covered pressures, the recommended metrics from SBTN as well as the sources and data types used.

Table 3.1: Required pressures categories and recommended metrics according to SBTs for Nature methodology, along with data sources and data types & units used in the case study. The pressure within Land use change was not estimated.

Pressure category	**Recommended metric**	**Data Source**	**Data type and unit**
Land use	Area (km^2 or ha) of land use, including known land management practices (e.g., crop rotation, tillage practices, or fire regimes)	FAO Stat	Yield per country and crop (kg/ha)
Land use change	Area (km^2 or ha) converted since 2020 (or earlier), by pre- and post-conversion ecosystem type and use	-	-
Water use	m^3 or km^2 per source (surface water, groundwater etc)	Water footprint Assessment Tool; FAO Stat	Blue WF per country and crop (m^3/year); Production quantity per country and crop (kg/year)
GHG emissions	ton CO_2, per activity estimates separately for industrial activities and land-based emissions; tCO_2/t (product, e.g., cement or steel) or gCO_2/spatial unit	SBTi assessment based on RISE climate database	GHG emissions per product and country (kg CO_2-eq)
Water pollution	kg N, P eq; total or concentration (%) in discharged water (and volume of these discharges)	FAO Stat, Mekonnen and Hoekstra (2011)	Average fertilizer use per country (kg/ha); Runoff-factor (%)
Soil pollution	Applied nitrogen (N) and phosphorus (P) (kg/ha)	FAO Stat	Average fertilizer use per country (kg/ha)

To estimate the State of Nature, two types of indicators were used: pressure-sensitive State of Nature indicators (SoN_P) and biodiversity State of Nature indicators (SoN_B). For SoN_P, SBTN recommends the metrics to be used for each pressure. For SoN_B, SBTN recommends the use of several complementary indicators to capture the different dimensions of biodiversity, for example at both the species and ecosystem level. For this project, all State of Nature Indicators, both SoN_P and SoN_B, were collected from the WWF Biodiversity Risk Filter (WWF-BRF) (WWF, 2023a) and the WWF Water Risk Filter (WWF-WRF) (WWF Water Risk Filter, 2021), which are two of the datasets that are suggested in SBTN's Toolbox. WWF provides a crosswalk between SBTN's recommended state of nature metrics and the indicators supplied in the WWF-BRF and WWF-WRF (WWF, 2023b). Table 3.2 below shows the metrics recommended for each SoN_P, and the corresponding WWF-BRF Indicator which was used. The indicators have a value between 1 and 5, with 5 indicating the highest risk. For SoN_P, this means that the indicated state of nature, such as the ecosystem's condition, is worse.

Table 3.2: The SoN_P metrics recommended by SBTN and the corresponding WWF-BRF Indicators used

Pressure category	**Recommended metric**	**WWF-BRF Indicator**
Land use	Natural ecosystem structure, function, and composition	2.4 Ecosystem Condition
Land use change	Area (km^2 or ha) of remaining intact ecosystem and land use by ecosystem and land use type	5.1 Land, Freshwater and Sea Use Change 5.2 Tree Cover Loss
Water use	Surface water flows and groundwater flows	1.1 Water scarcity
GHG emissions	Assessed within the SBTi framework but can be captured through state indicators such as temperature, precipitation, and extreme events	3.2 Fire hazard; 3.5 Extreme heat; 3.6 Tropical cyclones
Water pollution	Instream N and P concentrations	2.2 Water condition
Soil pollution	Soil nitrogen (N) and phosphorus (P) concentrations	5.4 Pollution

The SBTN Unified Datasets on Water Availability and Water Pollution (Camargo et al., 2023) are required to use according to the SBTN methodology. However, due to differences in spatial resolution and limited time available for the task of aggregation, indicators from the WWB-BRF on country level were used instead.

For the $\mathrm{SoN_B}$s, indicators from the Biodiversity Risk Filter as well as the Water Risk Filter were used. Table 3.3 below shows SBTN's dimensions of biodiversity and the corresponding BRF/WRF indicators that were used. All BRF and WRF indicators are shortly described in Appendix B. For a more complete description, it is referred to the respective methodologies WWF Biodiversity Risk Filter tool Methodology Documentation (WWF Biodiversity Risk Filter, 2023) and WWF Water Risk Filter Methodology Documentation (WWF Water Risk Filter, 2021). As previously mentioned, the BRF and WRF have a value between 1 and 5, with 5 indicating the highest risk. For the $\mathrm{SoN_B}$s, a higher value indicates more valuable biodiversity. for instance in terms of a higher range rarity or more key biodiversity areas.

Table 3.3: The $\mathrm{SoN_B}$ dimensions recommended by SBTN and the corresponding WWF-BRF or WWF-WRF Indicators used

SBTN's Dimension of Biodiversity	**Corresponding WWF-BRF or WWF-WRF Indicators**
Species Endemism	BRF 6.5 Range Rarity WRF 10.1 Freshwater Endemism*
Ecosystem integrity/condition and Ecosystem Connectivity	BRF 6.4 Ecosystem Condition 10.2 WRF Freshwater Biodiversity Richness*
Delineated Areas of Importance for Biodiversity	BRF 6.1 Protected/Conserved Areas BRF 6.2 Key Biodiversity Areas BRF 6.3 Other Important Delineated Areas

*WRF 10.1 and 10.2 are combined into a single indicator at the country level,

which was utilised in this project.

3.1.2 Step 2. Interpret & Prioritize

The purpose of the second step is to use the data collected in Step 1 to decide where to act first, to reduce negative impacts and increase potential positive impacts most effectively (SBTN, 2023f). The first two substeps, Step 2a. Determine Target Boundaries and Step 2b. Interpret and Rank, are required, whereas Step 2c. Prioritize is required for a certain category of company activities and Step 2d. Evaluate Feasibility & Strategic Interest is only recommended. In this project, Step 2a and Step 2b was performed.

3.1.2.1 Step 2a. Determining Target Boundaries

Target boundaries are defined as "the spatial extent of companies' pressure footprints managed through (science-based) targets" (SBTN, 2023f). Target boundaries should be determined separately for direct operations and the upstream value chain, and for each material pressure category. For the upstream value chain, there are two types of target boundaries, A and B, which locations are sorted into depending on the quality (precision and accuracy) of the available data. According to the guidance, target boundary A should include locations for which the company's data is at least at national level, and where the company is able to gather more precise and accurate data within 1-2 years. This information can either be gathered through organisations providing supply chain data/certification, or directly through the company's suppliers. Target boundary B should include locations for which the company's data is at a coarser scale than national level, and the company cannot easily obtain more detailed information. For commodities or locations included in target boundary B, the company must increase their transparency and traceability efforts.

Ewerman only has one site in its direct operations, a combined office and warehouse in Helsingborg, Sweden. This is the target boundary for direct operations. For the upstream value chain, all origin countries, and the products which Ewerman source from there were placed in target boundary A, since the data is at a national level. This means that the target boundary for the upstream value chain is the same for all pressure categories.

3.1.2.2 Step 2b. Interpret and Rank

In this substep, companies follow a process to provide a ranking of its locations, according to both impact and environmental importance. The process is required for locations within direct operations and upstream target boundary A. An overview of the process is shown in Figure 3.1 below. First, normalised Pressure (P) and Pressure-sensitive State of Nature indicators ($\mathrm{SoN_P}$), collected during Step 2b, are multiplied to give a Pressure State index ($\mathrm{I_P}$). The $\mathrm{I_P}$ can theoretically take on a value between 0 and 5, however an $\mathrm{I_P}$ of 5 is never obtained due to no country having a maximised normalised pressure (1) and simultaneously a maximised $\mathrm{SoN_P}$ (5). For both P and $\mathrm{SoN_P}$, higher values mean more damage potential or greater damage already felt by the ecosystem, so that a higher $\mathrm{I_P}$ indicates more urgent need for action. The locations are then ranked according to their $\mathrm{I_P}$ values. During Step 1b, Biodiversity State of Nature indicators ($\mathrm{SoN_B}$) were also collected. For each location, the highest $\mathrm{SoN_B}$ is selected, and then locations are ranked according to their $\mathrm{SoN_B}$ values. A final ranking is obtained by combining $\mathrm{I_P}$ and $\mathrm{SoN_B}$, listing the top-ranked location from each first, and then moving down both lists alternately, starting with $\mathrm{I_P}$. For the pressure categories Water pollution and Soil pollution, where one $\mathrm{I_P}$ for nitrogen and one $\mathrm{I_P}$ for phosphorus was calculated, the final ranking was obtained by combining both $\mathrm{I_P}$s with the $\mathrm{SoN_B}$.

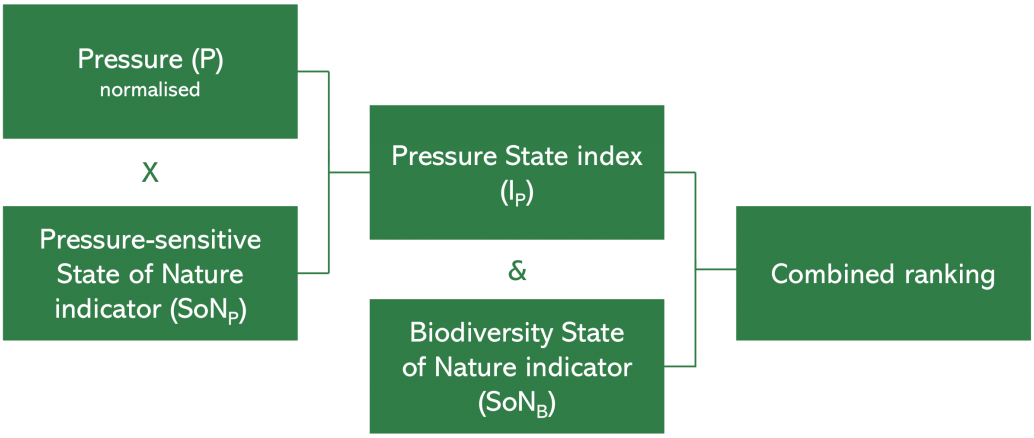


Figure 3.1: Overview of Step 2b Interpret & Rank. Based on WWF (2023b) and created by the authors.

3.2 Comparison between biodiversity impact of agriculture and the SBTs for Nature

In the following section the methodology for answering the second research question is presented. Initially, a literature study on the main biodiversity impacts from agriculture was conducted, followed by a comparison of the obtained results from the study and the coverage of biodiversity impacts in Step 1 and 2 of the SBTs for Nature methodology.

3.2.1 Literature study

The literature study had two main purposes. The first was to provide relevant information of the context and concepts related to the project for the background chapter. The second was to provide a deeper understanding of how agriculture affects biodiversity and serve as a basis for answering the second research question on whether the impacts captured by the first two steps of the SBTN framework are in accordance with published research on the topic. Therefore, it includes general information on topics like biodiversity, biodiversity frameworks, regulations and directives, and a short introduction to the SBTs for Nature methodology, Ewerman and Greenfood Group for the background. The literature study for the results section was delimited to include the main areas of impact from agriculture on biodiversity, and therefore these were initially identified from the literature. Following this, a more detailed review of them was conducted, focusing on the impact mechanisms of the practices on biodiversity or how they contribute to the drivers of biodiversity loss, and the resulting effect on nature and biodiversity.

Literature and research articles were mainly collected from the databases Google Scholar and ScienceDirect, complemented with grey literature. The literature study for the background chapter was performed in an iterative manner with the rest of the project, with new topics for the background chapter added as they became relevant in the project. For the literature study in the results, search words and terms were identified based on the research question to find the main impacts and contributors to the drivers of biodiversity loss from agriculture. Thereafter, more detailed search words were selected based on the identified dominating areas of impacts that mainly affects biodiversity and their effects. The search words were combined into search blocks using Boolean operators like 'and' and 'or' to find relevant literature. All search words used in the literature study are presented in Appendix D. From the literature found the snowballing method was additionally applied to broaden the search, where relevant cited articles were considered and included.

3.2.2 Comparison with coverage of SBTs for Nature

The identified areas of impacts from the literature study, and the insights on how these relate to impacts on biodiversity and how they can be measured, were compared to the pressure categories and metrics used within SBTs for Nature. The technical guides on Step 1 and 2 of the SBTs for Nature methodology were used as the main basis for the coverage of the method, together with additional knowledge about the method gained from the case study. The comparison was performed in terms of which areas of impacts are covered by the pressure categories and how these are measured. Additional insights from the literature study that did not correspond to a particular area of impact was also utilised in the comparison to evaluate how the method in general reflect important aspects such as level of aggregation and indicators needed to measure biodiversity impacts.

Based on the comparison and identified disparities between the literature and the SBTs for Nature method, some possible alternatives or complements on the scope of impact areas and indicators to measure them in the methodology were formulated, supported by the literature. The literature study and comparison with SBTs for Nature were to a certain degree performed in an iterative manner, and additional concepts or aspects was included as further insights from the literature or regarding the method were gained.

3.3 Identification of challenges and opportunities connected to the first two steps of the SBTs for Nature

In order to answer the third research question, several different perspectives on using the first two steps of the SBTs for Nature method to assess the impact on biodiversity were collected and used as a basis for the analysis. Experiences from the case study, both regarding challenges and difficulties in the application of the method and potential challenges and opportunities when utilising the results, were identified, and analysed. Insights from RQ2 regarding missing aspects in the methodology compared to literature on biodiversity impacts from agriculture were also incorporated to analyse the challenges this entails for the utilisation of the results of the first two steps. Additional perspectives were collected from reviewed literature, mainly regarding the use of indicators to measure impacts on biodiversity. The results of the case study and the possibilities for the company to use them were also discussed with representatives from Greenfood responsible for sustainability within different areas of the company. The input from the mentioned sources were reviewed and common themes were identified to find main challenges and opportunities, which were elaborated upon from the different perspectives.

4

Results & Analysis

This chapter presents the obtained results, structured according to the three research questions. First, the results from the application of the substeps of the SBTs for Nature are presented. This is followed by a comparison and analysis between published research on the biodiversity impact of agriculture and the coverage of the SBTN framework. Lastly, the identified challenges and opportunities of using the first two steps of the SBTs for Nature methodology for companies like Greenfood are presented.

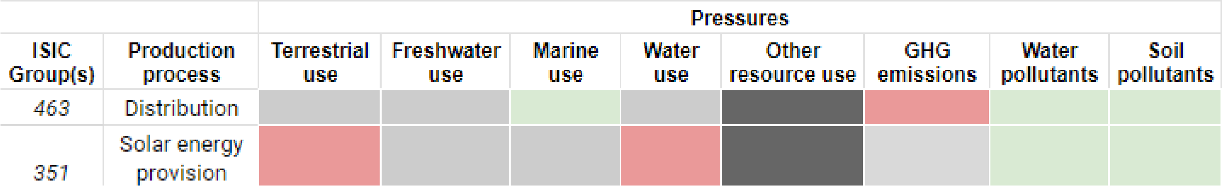
4.1 Research question 1 - Application of Science Based Targets for Nature

In this section, the results from the case study of the application of SBTs for Nature on Greenfood's subsidiary Ewerman are presented. The presentation of the results follows the structure of Step 1-2b of the method.

4.1.1 Step 1a. Materiality Screening

The results of the materiality screening for direct operations and upstream value chain can be seen in Figure 4.1 and Figure 4.2 below. Red colour means that the pressure category is material, green that it is not material, light grey that no data is available, and dark grey that the pressure category was not assessed for the production process.

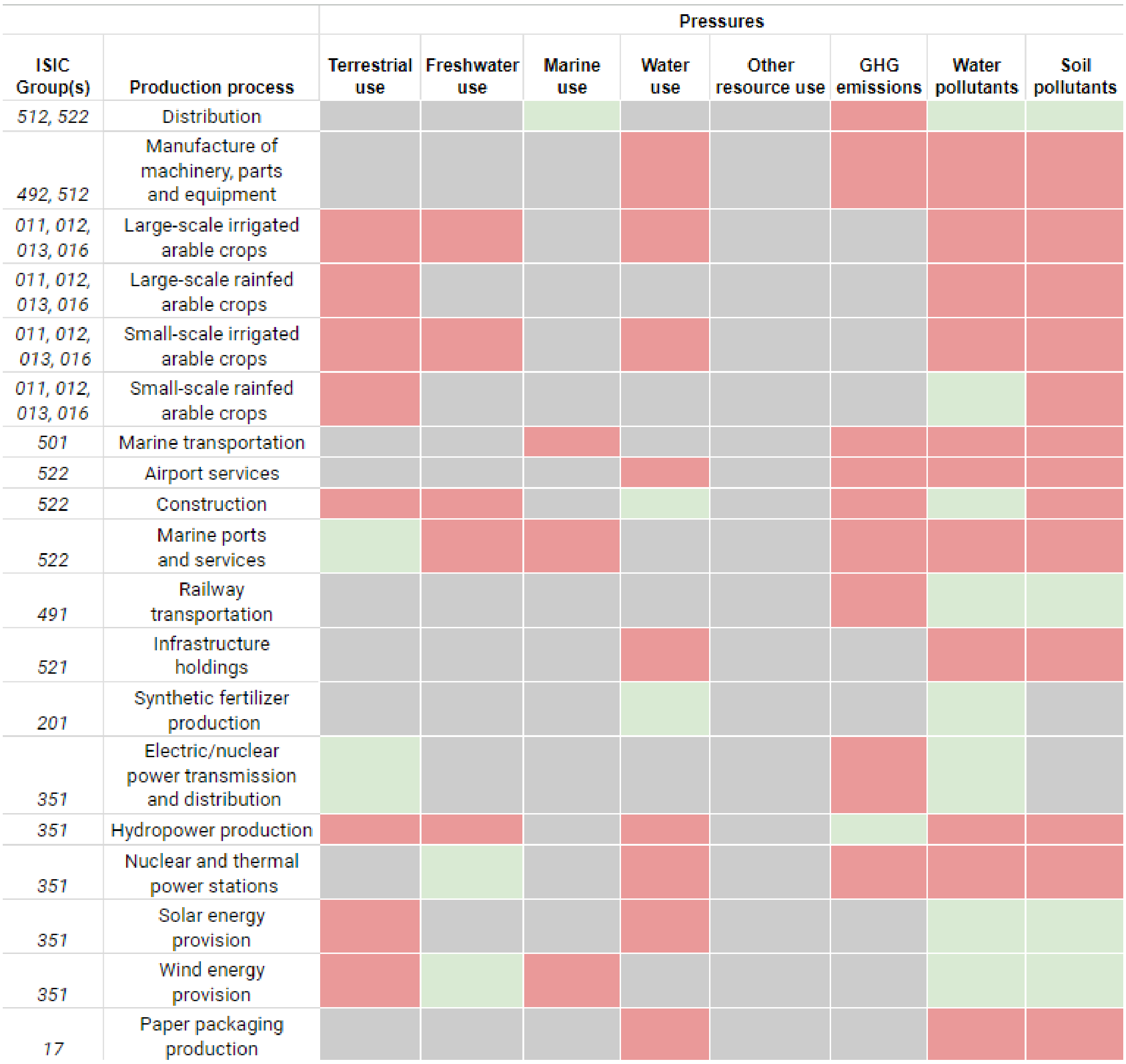
For direct operations, two production processes were included: distribution and solar energy provision, since Ewerman's combined office and warehouse building has solar panels on the roof. For distribution, GHG emissions was the only material pressure category, and for solar energy provision Terrestrial use and Water use were material. For many pressure categories, there is no data available.



		Pressures							
ISIC Group(s)	**Production process**	**Terrestrial use**	**Freshwater use**	**Marine use**	**Water use**	**Other resource use**	**GHG emissions**	**Water pollutants**	**Soil pollutants**
463	Distribution	⬜	⬜	🟩	⬜	⬛	🟥	🟩	🟩
351	Solar energy provision	🟥	⬜	⬜	🟥	⬛	⬜	🟩	🟩

Figure 4.1: Result of the materiality screening for direct operations. Colour coding: Red = material, Green = not material, Light grey = No data available, Dark grey = Not accessed for the production process.

For the upstream value chain, a range of production processes which can be seen in Figure 4.2 below were included, in order to give as full a picture of the value chain as possible. As the figure also illustrates, the most frequent material pressure categories are Soil pollution, Water pollution, GHG emissions and Water use. For many production processes, there is no data available, and for the pressure Other resource use category, there is never any data available.



		Pressures							
ISIC Group(s)	Production process	Terrestrial use	Freshwater use	Marine use	Water use	Other resource use	GHG emissions	Water pollutants	Soil pollutants
512, 522	Distribution	⬜	⬜	🟩	⬜	⬜	🟥	🟩	🟩
492, 512	Manufacture of machinery, parts and equipment	⬜	⬜	⬜	🟥	⬜	🟥	🟥	🟥
011, 012, 013, 016	Large-scale irrigated arable crops	🟥	🟥	⬜	🟥	⬜	⬜	🟥	🟥
011, 012, 013, 016	Large-scale rainfed arable crops	🟥	⬜	⬜	⬜	⬜	⬜	🟥	🟥
011, 012, 013, 016	Small-scale irrigated arable crops	🟥	🟥	⬜	🟥	⬜	⬜	🟥	🟥
011, 012, 013, 016	Small-scale rainfed arable crops	🟥	⬜	⬜	⬜	⬜	⬜	🟩	🟥
501	Marine transportation	⬜	⬜	🟥	⬜	⬜	🟥	🟥	🟥
522	Airport services	⬜	⬜	⬜	🟥	⬜	🟥	🟥	🟥
522	Construction	🟥	🟥	⬜	🟩	⬜	🟥	🟩	🟥
522	Marine ports and services	🟩	🟥	🟥	⬜	⬜	🟥	🟥	🟥
491	Railway transportation	⬜	⬜	⬜	⬜	⬜	🟥	🟩	🟩
521	Infrastructure holdings	⬜	⬜	⬜	🟥	⬜	⬜	🟥	🟥
201	Synthetic fertilizer production	⬜	⬜	⬜	🟩	⬜	⬜	🟩	⬜
351	Electric/nuclear power transmission and distribution	🟩	⬜	⬜	⬜	⬜	🟥	🟩	⬜
351	Hydropower production	🟥	🟥	⬜	🟥	⬜	🟩	🟥	🟥
351	Nuclear and thermal power stations	⬜	🟩	⬜	🟥	⬜	🟥	🟥	🟥
351	Solar energy provision	🟥	⬜	⬜	🟥	⬜	⬜	🟩	🟩
351	Wind energy provision	🟥	🟩	🟥	⬜	⬜	⬜	🟩	🟩
17	Paper packaging production	⬜	⬜	⬜	🟥	⬜	⬜	🟥	🟥

Figure 4.2: Result of the materiality screening for the upstream value chain of Ewerman. Colour coding: Red = material, Green = not material, Light grey = No data available.

Products purchased by Ewerman which are classified as High Impact Commodities (HICs) by SBTN were avocado, banana, cassava, maize/corn, and tree nuts (almonds, walnuts). Phosphorus fertiliser and nitrogen fertiliser were also included in the screening since they are an important input to the agriculture. SBTN provides a qualitative list of material pressures for each commodity, of which the commodities included in the assessment can be seen in 4.1 below.

Table 4.1: The High Impact Commodities of Ewermans' purchases and their material pressures, from SBTN's HICL.

High Impact Commodity	Material Pressure, from SBTN Literature Review	Additional material pressures, from ENCORE
Avocado	Land use and land use change; other resource use; water use; soil pollution	Freshwater ecosystem use; climate change; freshwater pollution
Banana	Land use and land use change; water use; soil pollution; freshwater pollution	Freshwater ecosystem use; climate change
Cassava	Land use and land use change; soil pollution	Water use; climate change; freshwater pollution
Maize/corn	Land use and land change; climate change	Water use; soil pollution; freshwater pollution
Tree nuts	Land use and land use change; water use; soil pollution; freshwater pollution	Freshwater ecosystem use; climate change
Phosphorus fertilizer	Land use and land use change; climate change; soil pollution; freshwater pollution; non-GHG air pollution	Water use
Nitrogen fertilizer	Climate change; soil pollution; freshwater pollution; marine pollution	Water use

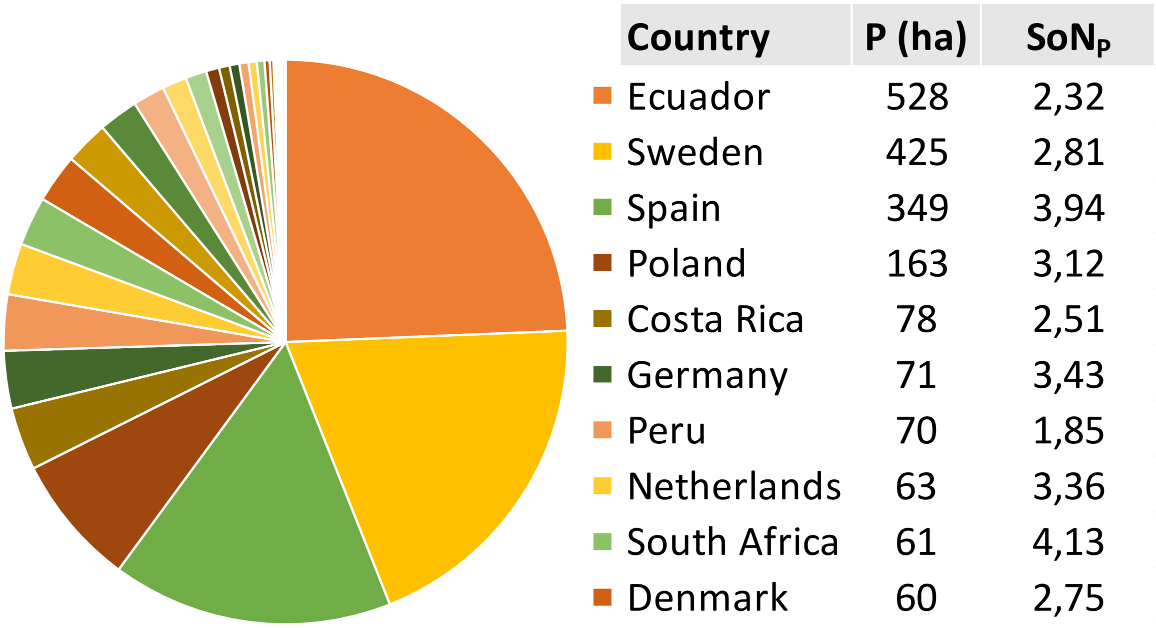
4.1.2 Step 1b. Value Chain Assessment

For the value chain assessment, estimations of Ewerman's contribution towards the material pressure categories were calculated, and indicators on the State of Nature in the locations for upstream activities were collected. Figures 4.3-4.7 below present the results for each pressure category. The pressures in all countries are visualised, and the ten countries with the highest estimated pressure along with their associated

SoN$_\text{P}$ are also listed. Regarding the pressure category Other resource use, Ewerman does not source any threatened or CITES-listed species.

Land use

The results of the pressure estimation of Land use are presented in Figure 4.3 below. The country in which the upstream agriculture occupies the largest area is Ecuador, with an estimated agricultural area of 528 ha, followed by Sweden and Spain. Together, these three countries comprise more than half of the total Land use pressure from the assessed products. The SoN$_\text{P}$ Ecosystem condition vary among the ten highest-pressure countries, with South Africa highest at 4.13 and Peru lowest at 1.85.



Country	P (ha)	SoN$_\text{P}$
🟧 Ecuador	528	2,32
🟨 Sweden	425	2,81
🟩 Spain	349	3,94
🟫 Poland	163	3,12
🟫 Costa Rica	78	2,51
🟩 Germany	71	3,43
🟧 Peru	70	1,85
🟨 Netherlands	63	3,36
🟩 South Africa	61	4,13
🟧 Denmark	60	2,75

Figure 4.3: The ten countries with the highest estimated pressure within the pressure category Land use, along with the associated SoN$_\text{P}$ Ecosystem condition.

Land use change

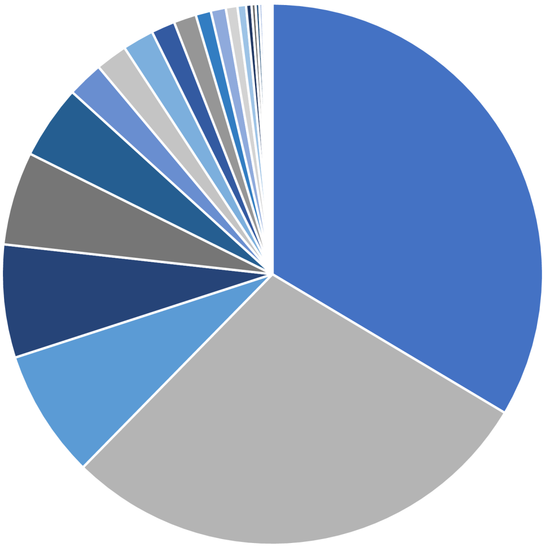
As explained in the Methodology chapter, the Land use change pressures from Ewerman were not estimated in this project. However, two Pressure-sensitive state of nature indicators were collected, which can serve as some guidance regarding in which countries the risk of land use change related impacts on biodiversity are more likely. In Table 4.2 below, the ten countries with the highest $\mathrm{SoN_P}$ within the pressure category Land use change are presented, along with which $\mathrm{SoN_P}$ this highest score corresponds to. Portugal has the highest $\mathrm{SoN_P}$, 4.45, corresponding to Tree Cover Loss. Zimbabwe has the highest Land, Freshwater and Sea Use Change score, 3.57.

Table 4.2: The 10 countries with the highest $\mathrm{SoN_P}$ within the pressure category Land use change

	Country	**$\mathrm{SoN_P}$**
1	Portugal	4.45 - Tree Cover Loss
2	Sweden	4.06 - Tree Cover Loss
3	Zimbabwe	3.57 - Land, Freshwater and Sea Use Change
4	Dominican Republic	3.52 - Tree Cover Loss
5	Belgium	3.47 - Land, Freshwater and Sea Use Change
6	India	3.42 - Land, Freshwater and Sea Use Change
7	Serbia	3.2 - Land, Freshwater and Sea Use Change
8	Germany	3.18 - Tree Cover Loss
9	Netherlands	3.16 - Land, Freshwater and Sea Use Change
10	Brazil	3.15 - Tree Cover Loss

Water use

The results of the pressure estimations of Water use are presented in Figure 4.4 below. The two countries with the highest estimated pressure are Ecuador and Spain, with a blue water use of 977 x 10^3 m^3 and 837 x 10^3 m^3 respectively. Together, they comprise more than half of the total estimated pressure for all assessed products. Among the ten countries with the highest estimated pressure, the SoN$_P$ Water Scarcity is highest for Egypt at 4.3, and lowest for Sweden at 1.5.

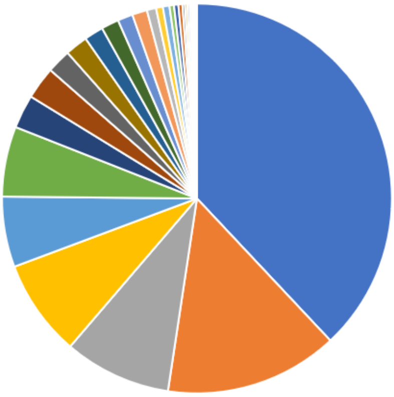


	Country	Water use (10^3 m^3)	SoN$_P$
■	Ecuador	977	2,2
■	Spain	837	3,75
■	Costa Rica	223	2,13
■	Morocco	196	3,86
■	Egypt	162	4,3
■	South Africa	128	3,41
■	Zimbabwe	62	2,81
■	Italy	55	2,95
■	Sweden	54	1,5
■	Germany	41	2,31

Figure 4.4: The ten countries with the highest estimated pressure within the pressure category water use, along with the associated SoN$_P$ Water Scarcity.

GHG emissions

The results from the pressure estimations of GHG emissions are illustrated in Figure 4.5 below. The country in which Ewerman's upstream operations emit most greenhouse gases is Ecuador, with a total of 10,346 t CO_2-eq, representing about one third of the total estimated pressure for all products. This is followed by Spain and Costa Rica. Regarding the SoN$_P$s, South Africa has the highest fire hazard (4.78) and extreme heat score (2.28), and Costa Rica has the highest Tropical cyclones score (2.44).

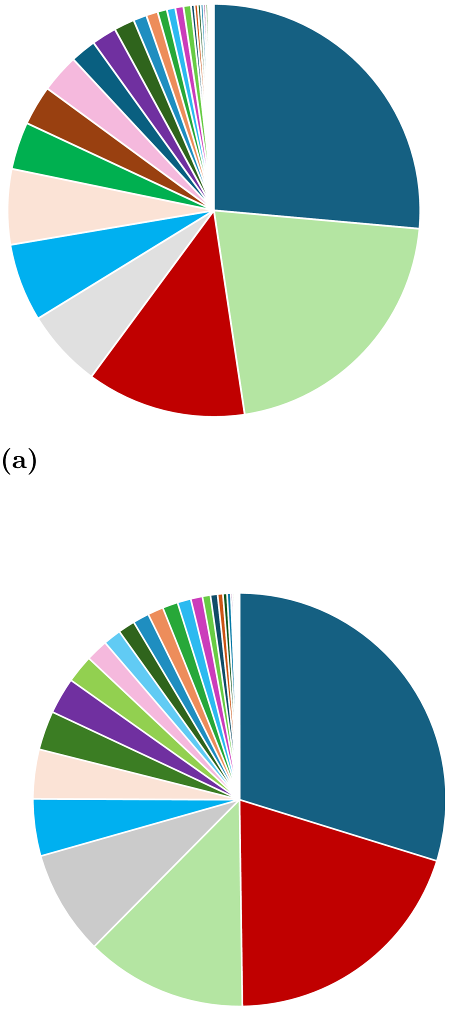


Country	P (t CO2-eq)	SoN$_P$ 3.2 Fire hazard	SoN$_P$ 3.5 Extreme heat	SoN$_P$ 3.6 Tropical cyclones
■ Ecuador	10346	2,23	1,98	1,9
■ Spain	3915	3,95	2,03	1
■ Costa Rica	2420	3,11	2,08	2,44
■ Poland	2188	3,5	1,95	1
■ Netherlands	1592	2,99	1,48	1
■ Sweden	1583	1,36	1	1
■ Germany	759	2,93	1,89	1
■ Italy	733	3,48	1,92	1
■ South Africa	543	4,78	2,28	1,85
■ Peru	511	2,9	1,95	1,13

Figure 4.5: The ten countries with the highest estimated pressure within the pressure category GHG emissions, along with the associated SoN$_P$s 3.2 Fire hazard, 3.5 Extreme heat and 3.6 Tropical cyclones.

Water pollution

Within the pressure category Water pollution, there are estimations for both nitrogen and phosphorus runoff and the results are presented in Figure 4.6 below. Ecuador has the highest runoff in terms of both nitrogen and phosphorus, and together with Sweden and Spain comprises more than half of the total estimated pressure for all products. The countries with the highest estimated pressures are similar for both nitrogen and phosphorous, with Poland, Costa Rica and Egypt following the top three countries. Among the highest pressure countries, the SoN_P Water condition is highest for the Netherlands with a score of 5, and lowest for Sweden with 1.7.



Country	P (kg N runoff)	SoN_P
■ Ecuador	4489	2,95
■ Sweden	3602	1,7
■ Spain	2125	4,51
■ Poland	1039	4,72
■ Costa Rica	1037	2,91
■ Egypt	1002	4,61
■ Netherlands	631	5
■ Germany	528	4,97
■ Denmark	512	4,17
■ Peru	343	2,51

(a)

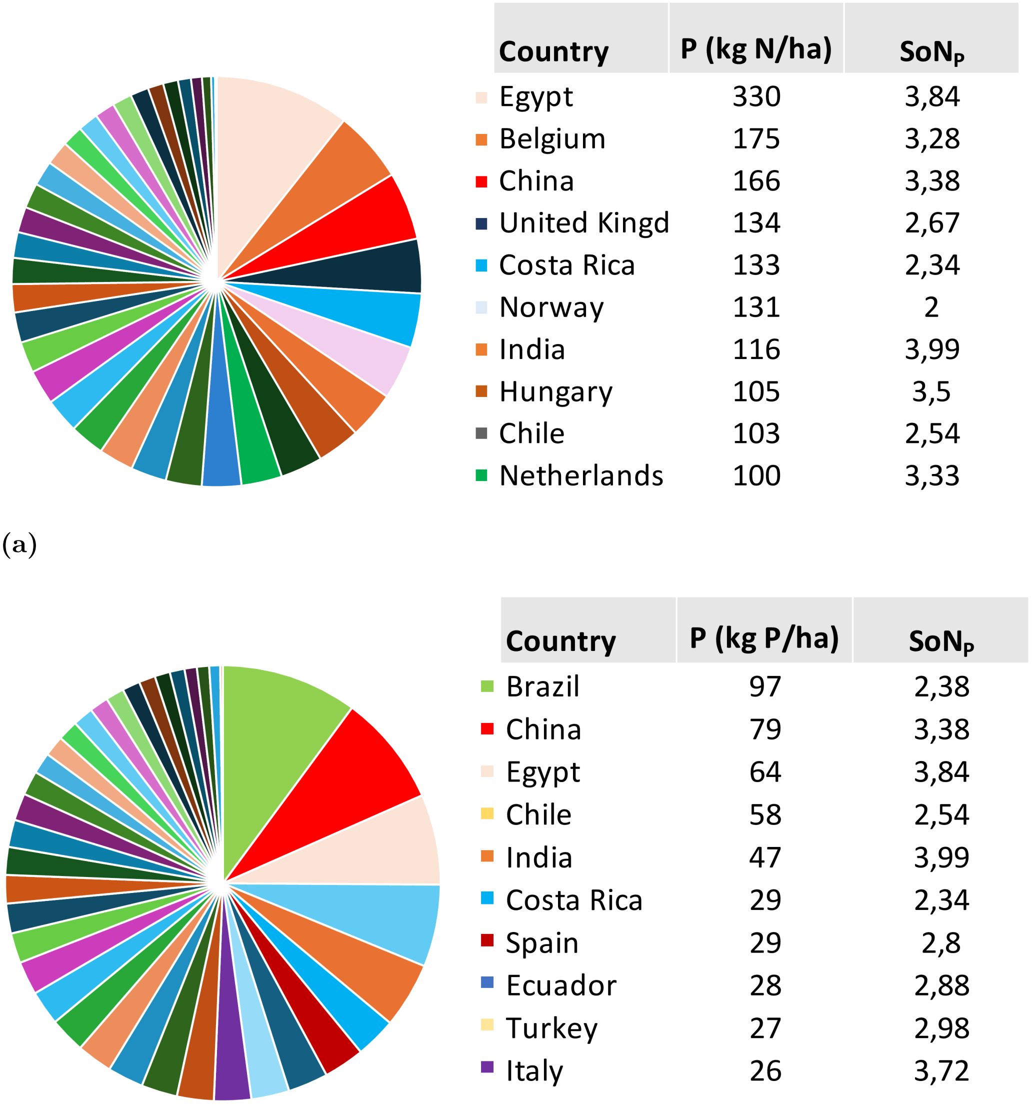
Country	P (kg P runoff)	SoN_P
■ Ecuador	548	2,95
■ Spain	368	4,51
■ Sweden	233	1,7
■ Poland	151	4,72
■ Costa Rica	82	2,91
■ Egypt	71	4,61
■ South Africa	56	3,94
■ Italy	52	4,59
■ Brazil	40	2,13
■ Denmark	32	4,17

(b)

Figure 4.6: The ten countries with the highest estimated pressure within the pressure category Water pollution, for a) nitrogen (N) and b) phosphorus (P), along with the associated SoN_P Water condition.

Soil pollution

The results of the pressure estimations in the pressure category Soil pollution are visualised in Figure 4.7 below. The countries with the highest estimated pressure differ somewhat between nitrogen and phosphorous fertiliser. Egypt has the highest pressure for nitrogen, with an application rate of 330 kg nitrogen fertiliser/ha, whereas Brazil has the highest pressure for phosphorus, with an application rate of 97 kg/ha. The SoN$_{\text{P}}$ Pollution among the countries with the highest estimated pressures varies between 3.99 for India and 2 for Norway.



(a)

Country	P (kg N/ha)	SoN$_{\text{P}}$
■ Egypt	330	3,84
■ Belgium	175	3,28
■ China	166	3,38
■ United Kingd	134	2,67
■ Costa Rica	133	2,34
■ Norway	131	2
■ India	116	3,99
■ Hungary	105	3,5
■ Chile	103	2,54
■ Netherlands	100	3,33

(b)

Country	P (kg P/ha)	SoN$_{\text{P}}$
■ Brazil	97	2,38
■ China	79	3,38
■ Egypt	64	3,84
■ Chile	58	2,54
■ India	47	3,99
■ Costa Rica	29	2,34
■ Spain	29	2,8
■ Ecuador	28	2,88
■ Turkey	27	2,98
■ Italy	26	3,72

Figure 4.7: The ten countries with the highest estimated pressure within the pressure category Soil pollution, for a) nitrogen (N) and b) phosphorus (P), along with the associated SoN$_{\text{P}}$ Pollution.

4.1.3 Step 2a. Determining Target Boundaries

Here, the results from Step 2a are presented, where the target boundaries for Ewermans' activities in their upstream operations within target boundary A are illustrated in Figure 4.8 below. As explained in the Methodology chapter, all 39 sourcing countries are placed in target boundary A, which is the same for all pressure categories.

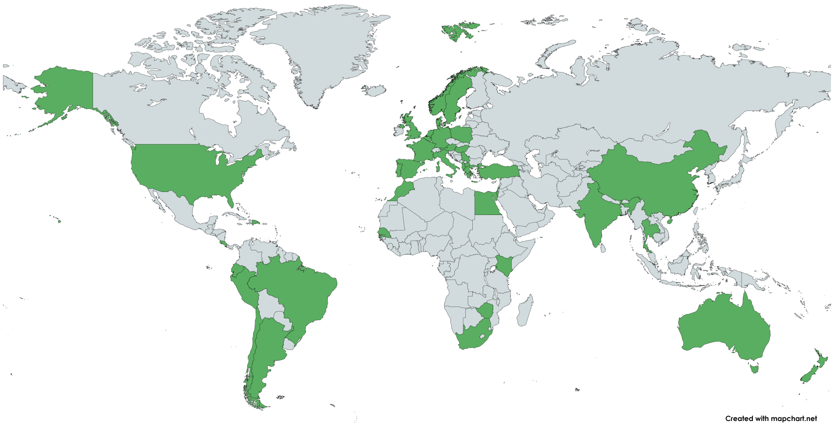


Figure 4.8: Target Boundary A marked in green for the upstream value chain of Ewerman. Created with mapchart.net.

4.1.4 Step 2b. Interpret and Rank

In the following section, the results for the Step 2b Interpret and Rank are presented. Within each pressure category, the top 10-ranked countries in the combined ranking are presented, along with their highest $\mathrm{SoN_B}$ and calculated $\mathrm{I_P}$ that the ranking is based on. Detailed explanation of the calculation procedure are provided in the methodology chapter 3.1.2.2. Results for land use change are not presented, since an estimation towards this pressure category was not performed, and hence an $\mathrm{I_P}$ and subsequent combined ranking could not be calculated.

Land use

The top 10 ranked countries within the pressure category Land use are shown in Table 4.3 below. Spain is at the top of the ranking, due to its high $\mathrm{I_P}$ at 2.6, followed by Costa Rica and the Dominican Republic which both has a $\mathrm{SoN_B}$, Range rarity, of 5. Ecuador is fourth in the ranking with both a relatively high $\mathrm{I_P}$ of 2.5 and $\mathrm{SoN_B}$ Range rarity of 4.99.

Table 4.3: Top 10 ranked countries within the pressure category Land use, along with their highest $\mathrm{SoN_B}$ and calculated $\mathrm{I_P}$.

Ranking	**Country**	$\mathbf{SoN_B}$	$\mathbf{I_P}$
1	Spain	Key Biodiversity Areas: 3.76	2.6
2	Costa Rica	Range rarity: 5	0.37
3	Dominican Republic	Range rarity: 5	0.014
4	Ecuador	Range rarity: 4.99	2.3
5	Sweden	Ecosystem condition: 3.19	2.3
6	Poland	Protected/conserved areas: 4.19	0.96
7	USA	Range rarity: 4.59	0.16
8	South Africa	Range rarity: 2.9	0.48
9	Peru	Range rarity: 4.42	0.24
10	Germany	Key Biodiversity Areas: 3.47	0.46

Water use

The top 10 ranked countries within the pressure category Water use are shown in Table 4.4 below. Once again, Spain is at the top of the ranking with an I_P of 3.2, followed by Costa Rica and the Dominican Republic due to their SoN_B Range Rarity of 5. Next in the ranking is Ecuador with an I_P of 2.2.

Table 4.4: Top 10 ranked countries within the pressure category Water use, along with their highest SoN_B and calculated I_P.

Ranking	Country	SoN_B	I_P
1	Spain	Key Biodiversity Areas: 3.76	3.2
2	Costa Rica	Range rarity: 5	0.5
3	Dominican Republic	Range rarity: 5	2.7e-5
4	Ecuador	Range rarity: 4.99	2.2
5	Morocco	Biodiversity importance*: 2.99	0.8
6	Egypt	Ecosystem condition: 3.56	0.7
7	Brazil	Biodiversity importance*: 4.66	6.9e-4
8	USA	Range rarity: 4.59	0.06
9	South Africa	Range rarity:2.9	0.4
10	Thailand	Biodiversity importance*: 4.54	0

*For freshwater

GHG emissions

For the pressure category GHG emissions, the top 10 ranked countries are shown in Table 4.5 below. Ecuador is ranked first with an I_P of 2.2, followed by Costa Rica and the Dominican Republic, and then Spain with an I_P of 1.5.

Table 4.5: Top 10 ranked countries within the pressure category GHG emissions, along with their highest SoN_B and calculated I_P.

Ranking	Country	SoN_B	I_P
1	Ecuador	Range rarity: 4.99	2.2
2	Costa Rica	Range rarity: 5.0	0.7
3	Dominican Republic	Range rarity: 5.0	0.02
4	Spain	Key Biodiversity Areas: 3.76	1.5
5	Poland	Protected/conserved areas: 4.19	0.7
6	USA	Range rarity: 4.59	0.1
7	Netherlands	Protected/conserved areas: 4.2	0.5
8	Peru	Range rarity: 4.42	0.1
9	South Africa	Range rarity: 2.9	0.3
10	Italy	Protected/conserved areas: 3.61	0.2

Water pollution

For the pressure category Water pollution, countries are included in the ranking according to both nitrogen and phosphorous water pollution, and the result is shown in Table 4.6 below. Ecuador and Spain are at the top of the ranking, Ecuador having the highest I_P for nitrogen with 2.9, and Spain for phosphorus with 3.0. Costa Rica and the Dominican Republic are ranked third due to their SoN_B of 5, and thereafter comes Sweden and Poland with an I_P (nitrogen) and I_P (phosphorus) of 1.4 and 1.3, respectively.

Table 4.6: Top 10 ranked countries within the pressure category Water pollution, along with their highest SoN_B and calculated I_Ps. N = nitrogen and P = phosphorus.

Ranking	**Country**	**SoN_B**	**I_P (N)**	**I_P (P)**
1	Ecuador	Range rarity: 4.99	2.9	2.9
2	Spain	Key Biodiversity Areas: 3.76	2.1	3.0
3	Costa Rica	Range rarity: 5.0	0.7	0.4
4	Dominican Republic	Range rarity: 5.0	0.02	0.007
5	Sweden	Ecosystem condition: 3.19	1.4	0.7
6	Poland	Protected/conserved areas: 4.5	1.1	1.3
7	Brazil	Biodiversity importance*: 4.66	0.05	0.2
8	Egypt	Ecosystem condition: 3.56	1.0	0.6
9	USA	Range rarity: 4.59	0	0
10	Netherlands	Biodiversity importance*: 4.5	0.7	0.2

*For freshwater

Soil pollution

For the pressure category Soil pollution, countries are included in the ranking according to both nitrogen and phosphorous soil pollution, and the result can be seen in Table 4.7 below. Egypt and China are ranked highest, Egypt's I_P for nitrogen being 3.8 and China's I_P for phosphorus being 2.8. After Costa Rica and the Dominican Republic follows Belgium, with an I_P for nitrogen of 1.7 and Brazil with an I_P for phosphorus of 2.4.

Table 4.7: Top 10 ranked countries within the pressure category Soil pollution, along with their highest SoN_B and calculated I_Ps. N = nitrogen and P = phosphorus.

Ranking	**Country**	**SoN_B**	**I_P (N)**	**I_P (P)**
1	Egypt	Ecosystem condition: 3.56	3.8	2.5
2	China	Ecosystem condition: 2.69	1.7	2.8
3	Costa Rica	Range rarity: 5	0.9	0.7
4	Dominican Republic	Range rarity: 5	0.6	0.3
5	Belgium	Protected/conserved areas: 3.29	1.7	0.4
6	Brazil	Other important delineated areas: 3.66	0.6	2.4
7	Ecuador	Range rarity: 4.99	0.7	0.8
8	India	Range rarity: 2.65	1.4	1.9
9	USA	Range rarity: 4.59	0.2	0.2
10	Israel	Range rarity: 4.07	1.1	0.5

Ranking summary

In Figure 4.9 below, a summary of the top ranked countries within all pressure categories is shown. The top 7 countries within each pressure category have been included. Three countries are ranked among the top 7 within all five pressure categories: Ecuador, Dominican Republic and Costa Rica. Spain is ranked high within all pressure categories except for Soil pollution. Following this, Brazil and Poland are among the top 7 countries for three pressures each.

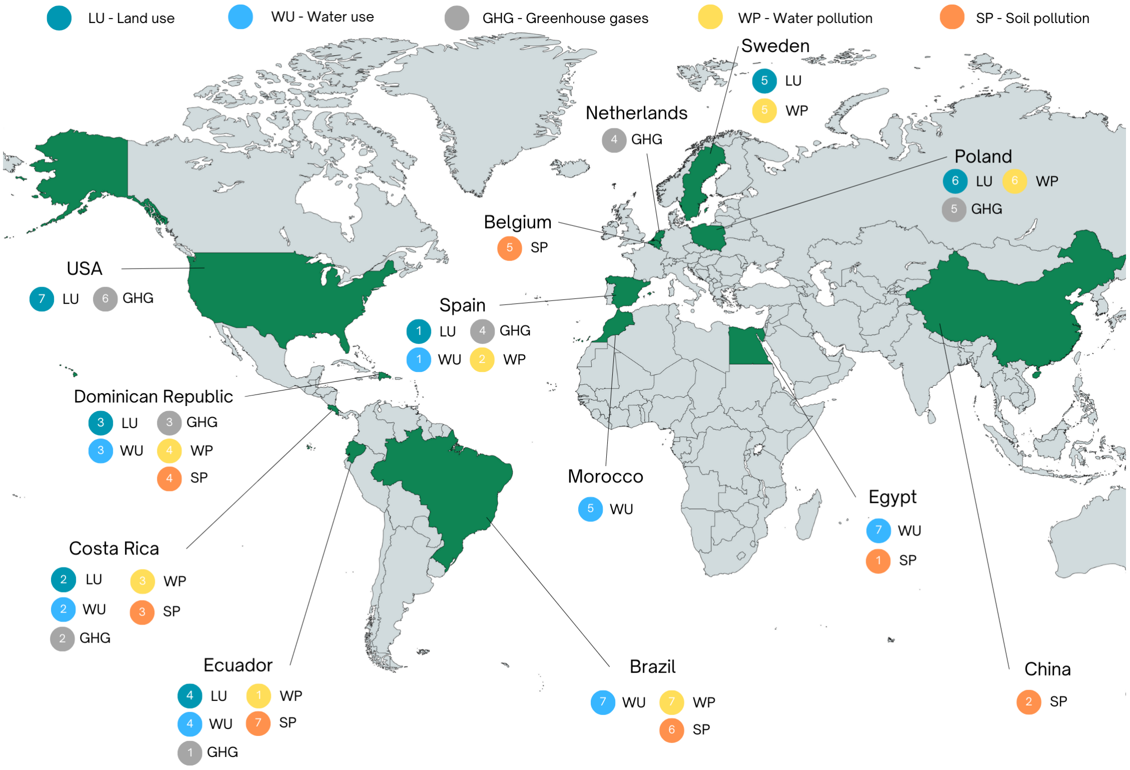


Figure 4.9: A summary of the highest ranked countries within each pressure category. Dark blue = Land use (LU), Light blue = Water use (WU), Grey = GHG emissions (GHG), Yellow = Water pollution (WP), Orange = Soil pollution (SP). Created with mapchart.net and Canva.

4.2 Research question 2 - Comparison between biodiversity impact of agriculture and the SBTs for Nature

To answer the second research question, results from the literature study on the impacts from agriculture on biodiversity are first presented. This is followed by an analysis regarding how these impacts are covered in the assessment in the first two steps of the SBTs for Nature.

4.2.1 Literature study

The current food production system is the principal cause of biodiversity loss globally (Benton et al., 2021), due to the agricultural expansion and intensification which has happened since the 1950s (Raven & Wagner, 2021). However, it should be emphasised that neither agriculture in itself, any particular agricultural practice or the need to feed a growing population is solely responsible for the resulting biodiversity loss (Benton et al., 2021). Rather, it is the combination of a wide range of factors connected to the current demand-driving food system that is responsible, ranging from what kind of foods are produced and in which manner, to down-prioritization of sustainable resource use in favour of productivity growth. This in turn leads to deterioration of biodiversity through both land conversion and unsustainable agricultural practices, globally as well as on farm level. The subsequent chapter is structured according to the main areas of impact from agriculture on biodiversity identified from the literature, including a description of how they influence biodiversity and their resulting effect on nature. The identified areas of impact are agricultural expansion, landscape homogenisation, climate change, fertilisers, pesticides, and water use. It is however important to notice that the areas of impact are acting on different scales of time and space, and therefore are not entirely comparable, for example in terms of effect.

4.2.1.1 Agricultural expansion

The first area of impact identified from the literature is Agricultural expansion, defined as "the conversion of natural vegetation to land-use for agriculture" (Jellason et al., 2021). Agricultural expansion is as previously mentioned the most prevalent form of land-use change, which is the largest driver of biodiversity loss (IPBES, 2019). Specifically, 80 % of all land-use change globally is attributed to agriculture (Benton et al., 2021), and the food production system also accounts for 80% of deforestation, making it the largest contributor to terrestrial biodiversity loss (United Nations Convention to Combat Desertification, 2022). Today, about 38% of the Earth's total surface is dedicated to agriculture (Barros-Rodríguez, Rangseekaew, Lasudee, Pathom-aree, & Manzanera, 2011), corresponding to around 49% of the habitable land (Benton et al., 2021).

However, the agricultural expansion is not uniform across the globe. In subtropical and tropical regions the scale of agricultural areas has rapidly increased in recent decades (Raven & Wagner, 2021). Natural vegetation such as tropical forests have to a large extent been converted in favour for crop production, especially in Central Africa and America, Southeast Asia and parts of South America. More than 25% of tropical forests have been cleared since 1992 according to Raven & Wagner, mainly for the production of soy, palm-oil and cattle, causing the greatest loss of pristine ecosystems during the last decades (Benton et al., 2021). Grasslands and prairies spread over the world have also been subjected to extensive conversion to croplands, making grassland habitats one of the most vulnerable biomes on the planet (Raven & Wagner, 2021). One example is the tallgrass prairie in Central North America, where less than 10% remains of the previous 60 million hectares and where conversion has mainly been driven by agriculture.

Through land-use change and conversion of natural ecosystems, the availability and quality of natural habitats and sources of food and shelter for many species are reduced (Benton et al., 2021). For some species, particularly larger animals, this may cause habitat fragmentation that affects the ability to range freely and ultimately may reduce the number of species. For others, the habitat may be vital during certain times or points in their life cycle, or it might be the only habitat they are adapted to live in. The risk for extinction is especially prominent for species with small geographical ranges, of which the vast majority have lost over 70% of their natural habitat as a result of human actions (Pimm & Vijay, 2020). However, in a literature review on the topic of land-use change and biodiversity impacts conducted by Davison et al. (2021), it is emphasized that the effect on biodiversity depends on a number of factors including biome, type of disturbance, taxonomic group and the biodiversity metric used (Davison, Rahbek, & Morueta-Holme, 2021).

Other conclusions from the review by Davison et al. is that land-use change, of which agricultural expansion is the most prominent cause, can affect biodiversity both directly through modification of the environment or habitat destruction, but also that it can have small and cumulative impacts that may be hard to observe. Among the most common findings in the articles reviewed by Davison et al. was that land-use change considerably decreases local species richness, alters species composition, and diminishes abundance. However, the review also explains that depending on what metrics that are considered, the perceived effects of land-use change may differ. It is common to examine species richness or abundance, but information on more rarely investigated terms like species behaviour or demographics may illustrate other, more subtle land-use change effects. For example, abundance may still be high in an agricultural area but information on demographics and behaviour might show that the area is unsuitable for shelter or reproduction, or that immigration from other areas conceals an increased death rate.

Overall, agricultural expansion and other human actions have increased the global rate of species extinction 10 to up to 100 times compared to the average rate during the previous 10 million years (Benton et al., 2021). Compared to the earliest estimations of ecosystem states, the quality and quantity of natural ecosystems have declined by 50%, and if no reformation of the current system is achieved, the biodiversity loss is projected to continue to escalate.

4.2.1.2 Landscape homogenisation

In addition to agricultural expansion, modification of the management of ecosystems or agroecosystems, for example trough agricultural intensification, is another form of land-use change (IPBES, n.d.). Commonly, this includes practices like specialization on single crop production and increased field sizes, causing landscape homogenisation and simplification (Emmerson et al., n.d.). Landscape homogenisation can substantially affect biodiversity through for example loss of natural and semi-natural habitats and landscape features.

Agricultural intensification can take place at different spatial scales, landscape or local, but can on both scales affect the homogeneity of the landscape depending on the practices used (Tscharntke, Klein, Kruess, Steffan-Dewenter, & Thies, 2005). On farm level, intensification practices that reduce heterogeneity are for example increased field sizes and decreased crop diversity. Included in this are monocultures, a system where only one genotype is produced on a field or area (Bourke et al., 2021). As production increasingly has been limited to a smaller number of crops, diversity both between and within species have been reduced. This kind of diversity, that primarily has a productive function and is chosen by the farmer is called planned biodiversity (Duru et al., 2015).

On landscape scale, homogenisation is driven by intensification practices like limitation of the land cover types, specialisation on fewer arable crops and minimisation of non-crop area, for example by reduction of edge habitats like hedges and field boundaries (Tscharntke et al., 2005). Landscape diversity, i.e. composition of crops, grasslands and semi-natural areas across space and time, is a prerequisite for associated biodiversity, which includes all organisms inhabiting or colonising cultivated areas, their natural enemies and pollinators (Duru et al., 2015). When natural and semi-natural features are eliminated and non-cropped areas reduced, important habitats that provide food and shelter for wild species are lost (Benton et al., 2021).

In addition to loss of habitat and shelter, the reduction of semi-natural elements and natural 'corridors' also reduces connectivity between habitats and impedes movement of species across landscapes, which adds further pressure on biodiversity (Benton et al., 2021). A homogenised landscape is also more sensitive to impacts from agricultural intensification than a landscape with higher diversity. The landscape structure on large- and local scale, including abundance of species habitats, is a large determinant of composition and richness of species (Emmerson et al., n.d.). This is illustrated in a study conducted by Winqvist, where the richness of plants and birds were reduced by 33% and 45,5% respectively when agricultural land was expanded from 20% to 100% of the surveyed area (Winqvist et al., 2011).

It is however important to notice that the effect on biodiversity can differ largely between farming or management methods (Benton et al., 2021). Even though Benton et. al points out that the wildlife is commonly limited in some way in farmed environments, since it has to compete with crops or farmed animals for space and resources, there is also evidence that agricultural management can enhance biodiversity and support ecosystem functions (Tscharntke et al., 2005). Agricultural landscapes are home to a lot of the world's biodiversity, and traditional agriculture in for example Europe, before the intensification in the middle of the 20th century, greatly supported diversity of species and habitats. According to Tscharntke et al, agriculture may not only entail increased competition but can also contribute with higher productivity of resources that can support population of species, even endangered or uncommon ones. However, the potential for integrated biodiversity conservation, through low agricultural intensity and creation of habitats, is highly site-specific and most efficient in simple landscapes, whereas complex landscapes more often benefit from preservation of pristine habitats.

The effects on biodiversity of landscape homogenisation and elimination of semi-natural features, like unused pockets of land, field margins and riparian zones, which is land areas adjacent to bodies of water like rivers, streams and ponds, are extensive (Benton et al., 2021). For example, field margins have been found to contain individual organisms and species richness up to three times higher than the centre of the field, and they often support native plant species. Riparian zones have also been shown to be vital for many terrestrial wildlife species, like insects, which feeds predators that in turn contributes to pest control in the cultivated area. In addition to effects on species level, functional diversity at landscape level is also impacted, where the maintenance of functionally diverse communities depend on diversity of the land cover types at landscape level (Gámez-Virués et al., 2015). Landscape simplification dominates the composition of the community, which means that a complex and low-intensity managed landscape can promote a more diverse functional community and compensate for high in-field management intensity. It also makes the landscape more resilient and improves its ability to handle disturbances, according to Gámez-Virués et al.

4.2.1.3 Climate change

Climate change is as previously mentioned one of the main drivers of biodiversity loss (IPBES, 2019), and the agrifood system is a big contributor to global warming, accounting for 31% of all greenhouse gas emissions in 2022 (FAO, 2022). Anthropogenic emissions of greenhouse gases have caused a series of major changes in temperature, precipitation and evaporation, along with more frequent and extreme weather events such as droughts and floods (Shah Habibullah et al., 2022). Biodiversity can be affected directly by the increase in temperature, for example through changes in habitat and habitat range, but other consequences of climate change also have an impact. Biodiversity has been found to be negatively affected by increased evaporation and extreme weather events and can also be affected by climate change induced ocean acidification or proliferation of invasive species. According to Shah et al. this can result in changed life cycles and influence both species abundance and distribution, migration patterns and ecosystem function and composition.

Climate change is not only driving biodiversity loss, the two phenomena are also strongly interconnected in other ways (Shin et al., 2022). Degradation of the biodiversity could affect the carbon storing capacity at ecosystem level, which would further reinforce the changes in climate (Secretariat of the Convention on Biological Diversity, 2003). This interconnection illustrates how negative reinforcement can occur between climate change and biodiversity, but they can also influence each other positively. According to the Convention on Biological Diversity, ecosystems with higher functional diversity have been found to better adapt to climate change, while also playing an important role in climate change mitigation through the uptake of carbon dioxide from the atmosphere.

Looking forward, the impacts on biodiversity from climate change are predicted to continue to increase, particularly regarding ecosystem functioning, but with geographical and contextual variances (IPBES, 2019). Species ranges are predicted to be severely affected already at an increase of 1.5°C or 2°C, which would greatly increase the risk of global extinction. Hence, it is crucial to limit global warming in order to reduce the impacts on nature and biodiversity, and agriculture has an important role to play when decreasing the greenhouse gas emissions.

4.2.1.4 Fertilisers

Fertilisers, in the form of nitrogen, phosphorus and potassium, are applied to increase crop yields, and have enabled a large rise in the worldwide ability to produce food (Penuelas, Coello, & Sardans, 2023). However, as high nutrient levels may negatively affect biodiversity, it is crucial that nutrient levels are maintained at a level which is high enough to ensure adequate crop yield, while not being so high that biodiversity in terrestrial and aquatic ecosystems is adversely affected (EEA, 2023b). The use of fertilisers has increased both in total numbers and intensity. In 2021, a total of 195 Mt inorganic fertilisers was used for agriculture worldwide (FAO, 2023a), and between 1961 and 2018 the application rate per hectare increased more than fivefold (Benton et al., 2021). However, fertiliser use is not evenly distributed over the world. In Africa, the agricultural use of about 25 kilograms per hectare is one-fifth of the use rate in Europe (FAO, 2023a).

According to a report from the European Environment Agency (EEA), the level of nitrogen and phosphorus nutrients in soil can have both a positive and negative impact on biodiversity, on agricultural and non-agricultural land (EEA, 2023b). Nitrogen inputs especially affect soil biodiversity, by reducing the abundance, activity, and composition of soil fungi, saprotrophic (feeding on dead material) decomposers, mycorrhizal fungi and nitrogen fixing bacteria. This creates effects throughout the soil food web and can ultimately also affect the food web above ground. Another report, by Emerson et al., presents inconsistent results on the effect of fertiliser use on field-level biodiversity, varying between taxa and geographic location (Emmerson et al., n.d.). Some studies show no significant effects on either vascular plants, carabid beetles or birds, while there are also cases of a positive effect on bird functional groups, as well as negative effects on plant species richness. In non-agricultural ecosystems, nitrogen is in general the limiting nutrient, and its increased availability may first enhance growth and productivity, but can later lead to eutrophication and acidification (EEA, 2023b). The increased growth can also lead to reduced plant diversity, as competitive grasses crowd out more nutrient-limited species (Benton et al., 2021).

A major pathway through which fertilisers affect biodiversity is by entering freshwater and marine habitats (IPBES, n.d.). Applying more fertilisers than the plants can absorb, or doing it in an inappropriate way, can cause run-off from the field to nearby water streams (Bronzízio, Settele, Díaz, & Ngo, 2019). The nutrients then flow into coastal waters, where they contribute to excessive plant growth, which in the worst case can lead to hypoxic zones. The number and range of hypoxic zones have increased during the recent decades and are more common in the Northern Hemisphere where the use of fertilisers is more widespread. The abundance of nutrients can also stimulate the growth of harmful algal blooms, which can release toxins and poison aquatic species. Transportation of nutrients downstream is further amplified by alterations of rivers and streams, as well as removal of wetlands for agricultural purposes, which eliminates the natural ability of ecosystems to manage excess nutrients (Benton et al., 2021). The initial water eutrophication status and other local factors also influence the extent of impacts from nitrogen and phosphorus fertilizer application (Ran et al., 2024).

Further, the use of fertilisers has an indirect effect on biodiversity via climate change (IPBES, n.d.). Nitrous oxide is emitted from fields where fertilisers are applied, and the production of fertilisers also requires substantial fossil fuel inputs. According to a recent study, the production and use of nitrogen fertilisers contribute to 5 % of global greenhouse gas emissions, of which two-thirds of these emissions take place after field application (Gao & Cabrera Serrenho, 2023).

4.2.1.5 Pesticides

Pesticides are substances used to kill organisms that harm crops, and are normally categorised by the type of organism they are aimed to control, for instance herbicides, insecticides, fungicides and bactericides (Encyclopaedia Britannica, 2024). The use of pesticides per hectare has almost doubled since 1990 (Benton et al., 2021), and amounted to 3.54 Mt of active ingredients in 2021 (FAO, 2023b). Of these, herbicides are most used, followed by fungicides, bactericides, and insecticides. Pesticides have been shown to have impacts on a wide range of taxa, including insects, birds, bats, earthworms, aquatic plants, fish and amphibians (EEA, 2023a). Many of these impacts are related to banned substances such as neonicotinoid insecticides, but there is also documentation of adverse impacts from approved substances e.g. glyphosate. In addition, the use of several pesticides can cause synergistic effects, which can be hard to predict.

Pesticides along with fertilisers are the second largest driver of insect species loss (Benton et al., 2021). Studies in Europe have shown that fertilisers and pesticides negatively affected 80 % of 576 butterfly species (EEA, 2023a). Through the declination of insect abundance, diversity and biomass, pesticides have indirect effects on birds which feed on these species and is therefore one of the main factors for the reduced numbers of birds and farmland birds both in Europe and other parts of the world. Regarding the flora, the study by Emmerson et al. (2016) reports that with increased frequency of herbicide and insecticide application, and amounts of active ingredients of fungicides, the wild plant species richness declined.

Applied pesticides can drift far from the application point (Dudley & Alexander, 2017), hence there may be impacts also in areas where usage has been halted locally (Emmerson et al., n.d.). For example, regions with high pesticide loads have lower bumblebee and butterfly species richness (Brittain, Vighi, Bommarco, Settele, & Potts, 2010). Pesticide residues have also been found inside nature conservation areas (EEA, 2023a). In addition, pesticide leakage into adjacent water streams can negatively affect aquatic communities both locally and downstream, affecting their physiology and thereby reduce their resilience to infections and fertility (Benton et al., 2021).

4.2.1.6 Water use

Between 1961 and 2006, the global irrigated area doubled, which has also entailed an increase in the withdrawals for agriculture (FAO, 2011). The region in which the highest share of cultivated area is equipped for irrigation is Asia, particularly the southern and eastern parts. The irrigation water is extracted from rivers, lakes, and aquifers. Globally, water resources are irregularly allocated, some countries holding an abundance of water whereas others experience severe scarcity. This means that in some regions, especially the Middle East, Northern Africa and Central Asia, water is withdrawn to such an extent that the ecosystem functioning is affected. About 40 % of irrigation today happens at the expense of environmental flows, i.e. the groundwater flows required to maintain a functioning ecosystem (Jägermeyr, Pastor, Biemens, & Gerten, 2017). Both the amount and quality of water is important for biodiversity, and extended or recurring periods of low or zero levels of groundwater can cause significantly altered biodiversity (Benton et al., 2021). Moreover, water transfer schemes completely change the local aquatic habitat and threaten its biodiversity. As an example, less than one fifth of the world's pre-industrial freshwater wetlands remain.

4.2.2 Comparison with coverage of SBTs for Nature

To be useful as an initial assessment tool for Greenfood and similar companies, the first steps of SBTs for Nature must capture the most important impact areas of agriculture on biodiversity and measure them in relevant ways. In the following section, the results of the literature study are compared with the pressure categories and metrics within SBTs for Nature, to answer the second research question. The analysis is complemented with possible alternatives regarding choice of impact areas accounted for and indicators to measure them, supported by findings from literature.

One recurring shortcoming of the SBTs for Nature method which do not align with insights from the literature is the level of aggregation for the assessment, where the method accepts national level aggregation which is also the level at which this project is conducted. SBTN do encourage the use of as fine-level data as possible, however it may be impossible or very time-consuming to find for companies. Within a country, there can be significant variations, both in terms of pressure, e.g. different farmers using different amounts of fertilisers, and in terms of the state of nature, e.g. that not all areas of a country are key biodiversity areas even though some are, or that not all aquatic ecosystems within a country are polluted. This limits the possibilities of drawing accurate conclusions based on country-level data, which will be elaborated upon further in the next chapter. Another general limitation of the method that is not consistent with important findings from the literature is that it solely uses pressure indicators, which only measure the pressures on ecosystems which may lead to damage and not the actual biodiversity impacts. The real impacts on biodiversity on local level therefore risk going unnoticed in this kind of assessment. This reasoning is supported by a recent article on indicator choice in environmental assessments of diets by Ran et al., pointing out that coarse indicators do not reflect local consequences, and that impact indicators in many situations are preferable, but that they often require site-specific information that is difficult to obtain (Ran et al., 2024). More details and specific examples on how this affect the assessment will be provided in connection to the different areas of impacts.

Agricultural expansion is covered in the SBTs for Nature methodology through the inclusion of the pressure category Land-use change (SBTN, 2023i). Land-use change is required to be included both in Step 1a Materiality Screening and Step 1b Value Chain Assessment, and is measured in area (in km^2 or ha) converted since a defined base year by pre- and post-conversion ecosystem type and use. The pressure category is intended to estimate how much land that has been converted due to the company's operations (both direct and upstream), and also to reflect what kinds of ecosystems that has been affected and what use they have now. This means that all kinds of land-use change can be included, and that ecosystem conversion due to agricultural expansion is encompassed in this category. However, the pre- and post conversion ecosystem type and use is not reflected in the estimation of the magnitude of the pressure in the first two steps of the method, where only the area of conversion is considered (in km^2 or ha), and is therefore not quantitatively accounted for. The effects on biodiversity that depend on the type of ecosystem that is converted and the management practices of the newly established agricultural area in this case therefore risk being missed out. It is however possible that information on pre- and post conversion ecosystem type will be taken into consideration in later, still unpublished, stages of the SBTs for Nature methodology if collected during the initial steps.

Landscape homogenisation is as previously explained a generic term for many different practices and occurrences that contribute to simplification and homogenisation of the landscape. Hence, it can be measured in many ways and its effects on biodiversity can be observed through a wide range of indicators. In the SBTs for Nature methodology, Land use is one of the required pressure categories both in Step 1a Materiality Screening and Step 1b Value Chain Assessment, measured in km^2 or ha. Here, known land management practices are also encouraged to be stated along with the sourcing locations, e.g. crop rotation, tillage practices and fire regimes. Inclusion of land management practices could give an indication on the potential of biodiversity supporting management, but just as for Land-use change, the additional information is not visible in the estimation of the pressure. As mentioned, it is possible that additional information like land management practices will be considered in later stages of the method, and therefore will be at least qualitatively accounted for. As explained in the literature study, land management practices have great influence on biodiversity in agricultural areas, and it is therefore important that efforts for biodiversity-supporting agriculture or landscape diversification are taken into account. Especially in these kinds of assessments where only pressure and not actual impact are measured.

As illustrated in the literature study, agricultural management can support and enhance biodiversity, commonly by using less intensive methods (Tscharntke et al., 2005). But if this kind of agricultural management is performed on a larger area it will still generate a greater pressure when estimated with this method than a highly intensive monoculture that occupies a smaller space. This problem is highlighted in the article by Ran et al., explaining that intensive systems generally are favoured when indicators such as land use is considered, and that aspects like positive ecological feedback are then usually missed out (Ran et al., 2024). They also conclude that indicators that measure the area of land used can be used to reflect the resource-use perspective of land use, but that indicators such as number of affected species should be used if biodiversity impacts related to land use should be covered.

Climate change is one of the main drivers of biodiversity loss and is included in SBTs for Nature through SBTi. The consequences for nature of climate change are also included through the SoNPs. However, in contrast to the other pressure categories, the origin of the pressure, i.e. where the emission occurs, does not affect the severity since the effects are global. In other words, one ton of CO_2 emitted in Ecuador will contribute to the same global warming as one ton of CO_2 emitted in Sweden. It might therefore not be necessary to reduce emissions in the country which is at the top of the ranking, but rather focus on a strategy where origin countries yielding as low emissions as possible per kilogram of product are chosen. Once again, this strategic work is already part of SBTi, and will not be discussed in detail here.

Fertilisers are included in SBTs for Nature via the two pressure categories Water pollution and Soil pollution. In Water pollution, the recommended metric is kilograms of nitrogen and phosphorous equivalents, either total or concentration in discharged water. In Soil pollution, the recommended metric is applied itrogen and phosphorous in kg/ha. Thereby, potassium (K) fertilisers are not considered. A high application rate of Nitrogen and Phosphorous fertilisers could mean higher biodiversity impact indirectly via climate change; however these impacts are already covered for in the pressure category climate change.

The literature study shows that the largest impact on biodiversity from fertiliser use happens when fertilisers enter aquatic ecosystems, and one way to capture this is to measure water pollution in terms of nitrogen and phosphorus loadings. However, measuring soil pollution in terms of applied nitrogen and phosphorous is not as representative of the biodiversity impact, given that the on-field effect on biodiversity from fertilisers are mixed and that they depend on local conditions and initial concentrations. Ran et al. therefore suggests that measuring nitrogen and phosphorous footprints, which is total reactive nitrogen or phosphorous emissions per unit of consumption, better capture the environmental pressure since it considers emissions from both new and old inputs (Ran et al., 2024). To compare potential impacts, for example between food groups like beef and vegetables, these kinds of indicators might be sufficient even though they do not reflect actual impacts on nature. Ideally, impact indicators that illustrate the effects of nitrogen and phosphorous flows, like eutrophication or acidification, should be used according to Ran et al. However, this requires data on site-specific conditions to accurately capture the impacts.

Pesticides are currently not covered by the SBTs for Nature required pressure categories and recommended metrics. Considering the clear evidence of pesticides' impacts on both terrestrial and aquatic biodiversity summarised in the literature study, it is a clear deficiency of the method that it is not included. In accordance with this, Ran et. al concludes that even in basic environmental assessments of diets, which reflects the lowest level of ambition, ecotoxicity or pesticide use should be included and measured (Ran et al., 2024). They recommend using impact indicators that takes toxicity into account primarily, since environmental impact is strongly influenced by the substance used and local circumstances. If specific data is not available, pressure indicators such as pesticide use in kg should be used to still take notice of the potential biodiversity harm of high pesticide use. This would enable a more fair comparison to alternative farming methods that utilises less or no pesticides, like organic farming. FAO provides data on the total use of different pesticides at country level, which can be used as a source for this information.

Water use is covered by SBTN as its own pressure category, with the recommended metric m^3 per source, such as surface water, groundwater etc. However, the literature study revealed that water abundance and scarcity is highly local (FAO, 2011). Therefore, it would be relevant to assess the water stress, which reflects the water use in relation to available amount. Ran et al. has similar reasoning and recommends usage of indicators on water stress to illustrate environmental impacts (Ran et al., 2024). SBTN aims to account for this problem by incorporating pressure sensitive State of Nature-indicators (SoN$_\text{P}$), like water scarcity, that is combined with the pressure in form of water use in m^3. However, the importance of the spatial scale of the assessment is here once again highlighted since regional areas of high and low water stress might not be reflected in country-level data and therefore make the results too unspecific to reflect the actual impacts.

4.3 Research question 3 - Challenges and opportunities

In the following section the results and analysis connected to the third research question are presented. Some of the main challenges and opportunities for fruit and vegetable wholesalers with global value chains when assessing their impact on biodiversity with the first two steps of the SBTs for Nature methodology are identified and expounded, based on the findings from the case study on Ewerman, the literature study and input from Greenfood employees responsible for sustainability. Since Step 1 and 2 mainly covers screening and assessment of impacts as well as ranking and prioritizing of locations for initial action, the challenges and opportunities will mainly be connected to these initial parts of the process. They will concern both the application of the method and the prospects of using the obtained results as a basis for further work.

4.3.1 Challenges

Overall, the main challenges with the application and use of the results of Step 1 and 2 for wholesale companies of fruits and vegetables can be summarised as relating to accuracy and complexity, and the trade-offs between them.

Regarding accuracy, the state of and impact on biodiversity is very local and site-specific, as ascertained in the literature study, and depends greatly on aspects like natural landscape complexity, management practices (Tscharntke et al., 2005) and habitat availability (Benton et al., 2021). Biodiversity is largely variable all the way down to alpha (local) scale, e.g. a field or a pond (Andermann et al., 2022), which makes it difficult to generalise and accurately study biodiversity effects on large scales like countries.

In the SBTs for Nature method the pressure estimations for upstream operations, which constitutes the segment of largest impact for vegetable wholesale companies, are only required to be compiled at country level (SBTN, 2023i). Further, biodiversity State of Nature (SoN_B) and the pressure sensitive State of Nature indicators (SoN_P) should be expressed on a scale that harmonises with the scale of the pressure estimation data, meaning that national level is accepted. In the case study on Ewerman, WWF-BRF Country profiles were therefore used both for SoN_B and SoN_P indicators. WWF, that has developed the BRF, however states that a national aggregation level entails some loss of spatial granularity, and that local variations in biodiversity should be considered when assessing company biodiversity-related risks since biodiversity is site dependent (WWF Biodiversity Risk Filter, 2023). SBTN also states in their technical guidance that "Pressure flows of the same magnitude occurring in different geographic locations will have different significance, depending on factors such as the sensitivity of the local ecosystem to additional changes, presence of threatened species, or reliance of local communities on an impacted resource" (SBTN, 2023i). If a country for example has areas with high intrinsic biodiversity values, reflected in the SoN_B values, it will always receive a high ranking in the SBTs for Nature ranking system, regardless of whether the pressure from the company has any connection to the valuable ecosystems or areas or not. Consequently, assessing pressures driving biodiversity loss and biodiversity impacts at country level is not representative of local effects, which reduces the accuracy of the results and might lead to misinterpretations and wrong prioritised actions further ahead.

Related to specificity, there is also a considerable difference between assessing pressure flows and actual biodiversity impact, which is demonstrated in the comparison between the literature study and SBTs for Nature coverage. As explained in the literature study, impacts from one single pressure, like land-use change, can be measured in many different ways and through different metrics, that reflects different aspects of reality (Davison et al., 2021). If only the driving pressure is considered, like it is in the SBTs for Nature methodology, there is a risk of missing the actual magnitude and character of impacts. And if pressure indicators are used, it is important to emphasise that they only measure the size of the pressure and do not reflect actual impact to avoid any misinterpretation (Ran et al., 2024). If companies want to improve their accuracy and assess their real impact on biodiversity, another set of indicators is needed. However, impact indicators require more specific data that can be extremely demanding for a global company to collect, which relates to the next challenge for companies using this method, complexity.

Complexity is in many ways a challenge in the use of this method and is strongly related to the accuracy of the results. As deducted from the analysis above, improved accuracy of the results requires more specificity, both on local conditions and locations of pressure flows and impacts. This would increase the requirements on the granularity of the data used for the assessment significantly, and thereby the demands on the company conducting the assessment. For wholesale companies with global value chains this would require traceability of products down to farm or regional level. In the case of Greenfood, and their subsidiary Ewerman, full traceability down to farm or field level is not routinely collected, and although it is possible to obtain it would be very time consuming since it requires inquiry of all individual suppliers (A. Klenell, Head Of Sustainability at Greenfood Fresh Produce, personal communication, 19 April 2024). Generally, origin of food products can be difficult to obtain (Ran et al., 2024), especially if they contain several ingredients. For animal products, traceability is even more challenging since both the origin of the animal product itself and the feed must be collected. Both the acquisition of data and the resulting handling of it in the subsequent steps of the method would be much more complicated and time consuming, since site-specific data would result in more sourcing sites (several per country) and thereby many more combinations between sites, pressures, and commodities.

Further, site-specific sourcing locations would require estimations of $\mathrm{SoN_B}$ and $\mathrm{SoN_P}$ on a harmonising level. Here the trade-off between accuracy and complexity is especially clear, since more site-specific estimations on biodiversity would increase the accuracy of the results, but would also entail an increased complexity that would be challenging for companies within this industry to handle. It would require time and resources which companies might not want or be able to spend, just for the screening and assessment of impacts. As emphasised in the article by Ran et al. (2024), assessment methods that require data that is not generally available risk being considered too impractical (Ran et al., 2024). At the same time, it is crucial that the initial steps of screening and assessment accurately captures the material pressures and impacts to steer future work in the right direction and avoid inadequate prioritisation.

An overall challenge regarding the application of the method is that it is not adapted to the agricultural sector, but rather developed to be universal and possible to use for many companies spanning a broad spectrum of sectors. This means that the instructions and guidance is very general and that no details on how e.g. the pressure estimation calculations should be conducted is provided. There is also a wide range of tools and databases suggested in the method for companies to choose from when finding their secondary data, intended to provide companies from different sectors with relevant data. As a consequence of this, there is some room for freedom and interpretation on how to implement the method from companies using it. This may lead to different approaches for pressure estimation or State of Nature-assessments, which might in turn affect the results and counteract the benefits of using a standardised method. Additionally, as illustrated in the previous section, the generality of the method also entails some shortcomings when it is applied to a specific sector, in this case the agricultural sector, since it disregards some important areas of impacts like pesticide use.

Looking forward, there are a number of challenges for Ewerman and similar companies to utilise the results from the first two steps of the SBTN framework. The main outcome of the initial two steps is a prioritisation on where to direct initial efforts based on the magnitude of the pressure and state of nature in the company's sourcing locations. Since all parts of Step 3. Measure, Set and Disclose are not published yet, including technical guidance on Biodiversity target setting, it is not currently known how this prioritisation and initial assessment will be used in further work. According to Greenfood representatives, many companies that are initiating their biodiversity work have focused on identification of their largest impacts, but the challenge for this and similar methods is to guide companies in what to do with this information (K. Sunér, Group sustainability manager – Healthy food lead at Greenfood Group, personal communication, 19 April 2024). For a company like Greenfood that buys a high number of products from many different suppliers, it is important that a large share of the purchases can be automated. For a method on biodiversity assessment to be successful, it is therefore important that the findings can eventually actually be used to guide strategic purchasing and be incorporated into existing purchasing systems. To summarise, the challenges of using the SBTs for Nature for companies like Ewerman are mainly related to the trade-off between accuracy and complexity. Studying biodiversity at a national level is not representative of local effects, and focusing on pressure indicators rather than impact indicators means that there is a risk of missing the actual magnitude and character of the impacts. Addressing these shortcomings is a challenge for companies, with more specificity requiring both more and more detailed data, which might be difficult to obtain. It is however important to view these circumstances as challenges requiring time and resources, and not as impossible barriers to overcome. Further, the methodology is not adapted to the agricultural sector, and companies must still find a way to transform the results of the assessment into actual action.

4.3.2 Opportunities

For a wholesaler of fruits and vegetables with global value chains like Ewerman, there are also several opportunities connected to the prospects of using the results from Step 1 and 2 of the SBTs for Nature methodology, which are described below.

First of all, applying the first two steps of SBTs for Nature supports companies in prioritising where to begin their work on biodiversity. Since many companies are currently initiating their biodiversity work this is very useful, and even more so if the understanding of their value chain's pressures and consequential impact on biodiversity is low. The output of Step 2b is a ranking of locations according to several aspects: the magnitude of the pressure on biodiversity, and the condition of nature in terms of both the specific pressure category and biodiversity. Additionally, Step 2c and 2d provides further guidance for prioritisation, applying cut-offs and a co-benefit approach, as well as considering social and financial aspects.

As described in previous sections, the information provided in the ranking is not as detailed as would be optimal, since it for example consists of only pressure indicators and not impact indicators and is aggregated at a national level. At the same time, there is a trade-off between accuracy and complexity, and collecting more detailed information for their entire value chain might make the method too complicated for companies to use. A compromise between accuracy and complexity is therefore most likely needed for assessment methods to actually be utilised by companies. The ranking obtained from the SBTs for Nature methodology is one way of making such a compromise and might therefore provide a valuable basis on where the potential impacts are greatest and constitute guidance regarding which locations in the company's value chain to direct their efforts to primarily. In accordance with this, Ran et al. (2024) states that for decision support and direction of future change, pressure indicators can be helpful and important (Ran et al., 2024). The top-ranked locations can thereafter be examined more closely, and more specific information can be acquired when it only applies to a limited part of their value chain, to obtain a higher accuracy of the assessment and adequately support subsequent action plans and target setting.

Another option would have been to simply start with the countries from where most products are purchased, but this approach gives no information on which pressures that has highest impacts in the different locations. By assessing the value chain according to SBTs for Nature, another "filter" is added to the assessment, something which was expressed as valuable by Greenfood's employees. Additionally, using an established and standardised method to identify potential locations of high impact in the value chain can be a good way for companies to justify their prioritisation, both externally and internally. Many food wholesale companies that have started to work with these questions have been trying to identify ways to support their prioritisation (K. Sunér, Group sustainability manager – Healthy food lead at Greenfood Group, personal communication, 19 April 2024). A publicly available method like SBTs for Nature can therefore furhter ahead be a transparent way to show what the company's prioritisation is based on, which might be valuable if the method has high credibility.

Secondly, there is an opportunity for companies to utilise the outcome of the steps for their sustainability reporting. The materiality screening tool and the value chain assessment can support companies in fulfilling several of the disclosure requirements within ESRS E4, for instance material impacts, risks, and opportunities, their anticipated financial effect, and processes to identify and assess material biodiversity and ecosystem-related impacts, risks and opportunities. While not applied in this project, Step 3 of the SBTs for Nature methodology will support companies in setting targets related to biodiversity and ecosystems, another disclosure requirement within ESRS E4. In other words, the first two steps are preparatory for fulfilling a majority of the ESRS E4 disclosure requirements.

Connected to regulatory requirements, their introduction can potentially also improve the possibilities for companies to perform assessments such as the SBTs for Nature. For example, since CSDDD forces large companies to increase their traceability, data at a more detailed geographical level can become available to actors throughout the value chain. Greenfood will be required to follow the directive in 2029 but will be affected earlier since many of their customers are large corporations which need to comply already in 2027. In addition, as explained in the background, being able to provide thorough traceability will provide a competitive advantage, something which was also mentioned by a Greenfood employee (A. Svensson, Group Sustainability Manager - Environment at Greenfood Group, personal communication, 8 May 2024).

In summary, while there are several challenges of using the SBTN framework, there are also many opportunities, especially looking forward. When faced with the complex task of addressing their impacts on biodiversity throughout the value chain, the first two steps can provide guidance on where to focus. The process and results can also be used for sustainability reporting, such as fulfilling the disclosure requirements within CSRD's ESRS E4. Finally, the CSDDD can improve traceability throughout the value chain, as well as give a strategic incentive for directing resources towards the biodiversity work.

5

Discussion

In this chapter, the results and methodology of the study are discussed. The chapter begins with a discussion of the results from the application of the first two steps of SBTs for Nature, divided into the different substeps within the methodology. This is followed by some remarks on the technical aspects of the SBTs for Nature methodology, along with suggested modifications. Lastly, the methodological choices specific to the project are discussed.

5.1 Results from SBTs for Nature Steps 1-2b

In the following subsections, the results from the different substeps of the SBTs for Nature are discussed.

5.1.1 Materiality screening

Since the materiality screening tool (MST) governs which pressure categories are included in the subsequent steps, it is important that all relevant pressure categories are included, while simultaneously not denoting everything as equally important. In other words, that it has the capacity to identify the most significant pressure categories where impacts on biodiversity occur. Many of the production processes used in the materiality screening tool lack data for several pressure categories, which is a clear weakness. SBTN encourages companies to treat pressure categories with no data as material, but it is not a requirement. Since this is the case for many pressure categories, it would entail a considerable workload for companies, especially if the pressure in the end turns out to be insignificant. Moreover, it is surprising that some production processes lack data for pressure categories where impacts are well-known, for example greenhouse gas emissions for synthetic fertiliser production. For the upstream value chain, all ISIC groups should be included in the MST, but in the subsequent assessment steps only the extraction stage is considered. The connection between the MST and subsequent steps is therefore not entirely clear.

Regarding the High Impact Commodities, seven commodities were identified for Ewerman, five of which appear on their purchasing bill. Since the literature study of this project focuses on the general biodiversity impact of agriculture and not the impact from production of specific crops, it is not possible to judge the accuracy of the list, in terms of which commodities are included or not, or their material pressures. After consulting the High Impact Commodity List, no additional pressure categories were added to the assessment.

5.1.2 Value chain assessment

The purpose of the value chain assessment is to estimate the magnitude and location of the pressures exerted by the company's upstream value chain, as well as provide information on different aspects of the State of Nature in those locations. Ecuador is consistently the country with the highest estimated pressure, except for the pressure category Soil pollution. Other countries where the estimated pressures are frequently high are Sweden, Spain, Poland, and Costa Rica. Within the pressure category Water use, Morocco and Egypt also appears, whereas Sweden is not among the ten countries with the highest pressure in this category. This reflects that the amount of irrigation needed, and hence the blue water use, varies between countries and crops.

For the pressure category Soil pollution, Ewerman's purchasing volumes do not affect the pressure estimation, since the metric recommended by SBTN is kg fertiliser/ha and data was not found for specific crops. Thereby, the countries with the highest pressure estimations are different from the other pressure categories, with e.g. Egypt, Belgium, China and Brazil, and the distribution of the pressure is also more equally divided between the countries compared to other pressure categories. The choice of this metric (kg fertiliser/ha) can on the one hand be considered logical since the application intensity per area is considered rather than the total amount on an area of varying size. On the other hand, the intention of the methodology is to estimate the pressure specifically due to the company's operations, and a general application rate, which in addition is at country level for all crops, does not reflect that intention very well.

5.1.3 Target boundaries

All origin countries for the selected products were placed in target boundary A within all pressure categories. SBTN requires companies to gather data at a finer scale than national level within 1-2 years for locations in target boundary A, which might not be feasible from an economic and time perspective for Ewerman to do for 39 countries. However, obtaining more detailed information for the top ranked countries is more within reach, and hence all countries were placed in target boundary A to enable a complete ranking.

5.1.4 Ranking of locations

In the ranking of locations, three factors have been combined; an estimation of the magnitude of Ewerman's contribution to the pressure category (P), an indicator on an aspect of nature which is sensitive to the pressure ($\mathrm{SoN_P}$), and the biodiversity importance of the location ($\mathrm{SoN_B}$). By combining P and $\mathrm{SoN_P}$ to produce $\mathrm{I_P}$, the harm which has already been done within the pressure category is represented, and thereby gives information on how urgent it is for Ewerman to reduce their contribution to the pressure category. For example, within land use, Spain is listed highest in the combined ranking, despite being the country in which Ewerman's pressure contribution is the third largest. This is due to Spain's high $\mathrm{SoN_P}$, indicating that the ecosystem is in worse condition compared to e.g. in Sweden. Many of the countries ranked highest are the same as the ones listed high during Step 1b Value chain assessment, however some are new due to their high $\mathrm{SoN_B}$, for instance Dominican Republic, USA and Thailand. Considering Figure 4.9, where a summary of the highest ranked countries are presented, there are some recurring countries to which Greenfood can direct further efforts on traceability and more detailed information. Ecuador is ranked high within all pressure categories, as is Costa Rica and the Dominican Republic. Spain is highly relevant for all pressure categories except soil pollution, especially since it is ranked highest within both land use and water use. As described in the results of the second and third research questions, there is a considerable uncertainty with results at a country level, where local effects risk going unnoticed. Therefore, the results should be interpreted as an indication of where the risk for potential impacts are highest, and not as an assurance that impacts do not occur in other locations.

5.2 Remarks on the SBTs for Nature methodology and suggested modifications

Based on the experiences from the application of the SBTN framework, some remarks on the methodology and potential modifications are discussed below.

First of all, one interesting element of the methodology is the combined ranking conducted in Step 2b. The ranking combines locations with highest $\mathrm{I_P}$ index and $\mathrm{SoN_B}$-values into a single ranking by listing the top ranked locations from each list first, and then moving down both lists alternately. Since the $\mathrm{SoN_B}$-values included are often the same for the different pressure categories, it is to a large extent the same countries that receive high $\mathrm{SoN_B}$-ranking in all categories. Consequently, it is the same countries that receive high positions in the combined ranking as well, regardless of their contribution to that pressure category. Some examples from the case study are Costa Rica and Dominican Republic, that because of their high score in the $\mathrm{SoN_B}$ Range Rarity are high priority in all pressure categories, despite that they often have low $\mathrm{I_P}$ index values, which reflects a lower pressure.

The aim with this kind of ranking is to prioritize both the locations where companies have the possibility to decrease their pressure the most and where nature is most crucial to protect. This is of course important, since not only magnitude of pressure decides where the most serious biodiversity impacts occur. However, when the ranking is performed in this way, the two aspects are entirely equalised in importance no matter how big the pressure is and how sensitive the ecosystem is to that pressure. The ranking could thereby show that actions should be prioritised towards certain locations even though the company is only sourcing a very limited volume from that place, and possibly do not contribute to the pressure driving biodiversity loss significantly. A possible option to counteract this problem is to add up the $\mathrm{I_P}$ and $\mathrm{SoN_B}$ for each location, to obtain a combined score which can be used for subsequent ranking. The two aspects can potentially also be given different weights to reflect their importance, to enable a more balanced ranking.

The SBTN framework have also made the methodological choice to only require value chain assessment of the activity which is expected to have the highest impact in the upstream value chain. This activity is according to the method assumed to be the sourcing (such as extraction or growing), unless the company has data proving that another activity has higher impact. This means that the entire life cycle perspective is not applied in this method and that the pressure contribution from later stages, like packaging or transport, is not accounted for. Although the sourcing is probably rightfully assumed to be the highest impact activity in the upstream value chain for most agricultural products, this way of accounting dismisses impacts in later stages of the value chain that may also be of importance. Later stages of the value chain were however not covered in the literature study on biodiversity impacts, which means that no basis to justify or object the exclusion of other activities in the value chain is available.

As stated in the comparison between the literature and the SBTs for Nature coverage, one implication of using pressure categories, like Land use, instead of impact categories is that it can favour more intense farming methods. Positive effects of biodiversity supporting agricultural areas and integrated biodiversity conservation on managed land will not be reflected in the pressure estimation, while intensively managed farmland that doesn't support biodiversity at all might appear as a better option. Hence, one could say that the method reflects the benefits of land sparing more than those from land sharing, even though the literature points out that the potential for integrated or segregated conservation depends strongly on the initial complexity of the ecosystem.

The method is built upon the principle of assessing pressures from as many commodities as possible from the company's procurement data. This results in a comprehensive assessment which provides a good overview of the pressure contributions from a large share of the products, which can be useful to identify prioritised locations and pressures. On the other hand, the comprehensiveness of the assessment together with the mentioned trade-off between accuracy and complexity might result in that the process either becomes too complex and time consuming or lacks accuracy and necessary level of detail. If the outcome is simply a prioritisation of locations with very general results that needs to be verified and nuanced with assessments of higher detail in order to be useful, other methods for identification of prioritised areas that are less time-consuming might be preferable. An alternative and less comprehensive approach of identifying areas of initial actions could for example be a detailed assessment of high impact commodities. Companies could also choose to look at the countries with highest purchasing volumes (where pressure contribution can be assumed to be largest) and the sourcing locations with highest $\mathrm{SoN_P}$ and $\mathrm{SoN_B}$ without estimating the pressure from all or many of their commodities. In that way they can still identify prioritised countries based on both where they have a large share of their business and where nature is at certain risk or of particular importance, but without spending too much time on the initial assessment phase. Instead, companies could utilise the time to get site-specific information from more locations in a few selected countries directly, to perform a more detailed and accurate assessment in prioritised areas.

The purpose of the SBTN framework is to enable companies to set Science Based Targets for Nature, in the same way as many companies have done for climate within SBTi. However, it can be questioned whether such targets will be possible to define for nature. Since greenhouse gases can be measured and their contributions towards global warming are well known, quantitative limits can be determined at a global level, and then allocated between companies (although the allocation process used within SBTi has been criticised). For nature, and particularly biodiversity, as highlighted in the literature study, both pressures and impacts are very site-specific, and cannot be aggregated in the same way as greenhouse gases. Thereby, it will be a complex task to determine targets both for SBTN and companies. SBTN must be able to define the acceptable threshold at a local level, for a multitude of pressure categories, with even more categories being included in future versions of the framework. Companies must, as illustrated in this project, gather detailed information from locations throughout their value chain, and then set targets, act, and monitor the progress for all these locations. It will also be harder for a third party to audit the process, from the defined thresholds, via companies' actions to the final effects they have on nature. Something which should be regarded as essential in order to place the label "science-based" on the targets adopted by companies.

5.3 The project's methodology

Methodological choices made during the application of the SBTs for Nature which are specific to this project and not inherent to the SBTs for Nature methodology are discussed below, as well as the methodology for addressing the second and third research question.

5.3.1 RQ1: Application of Science Based Targets for Nature

When applying the first two steps of the SBTs for Nature framework, the only primary data was Ewerman's purchasing volumes, which means that the estimations are very rough. More accurate information, either in the form of primary data on factors such as sourcing area, yields or water use from suppliers, or more detailed secondary data, e.g. on probable sourcing areas or regional water use, would enhance the estimations as well as provide a better starting point for Step 3 in the framework. Estimations based on secondary data of the pressures in the upstream value chain is accepted by the SBTN, but if primary data is available it should be used.

Due to limitations in the access to tools and data, pressures for the category Land use change could not be estimated. Since land use change is one of the main drivers of biodiversity loss, this represents a substantial shortcoming of the project. The collected SoN_P indicators can provide some guidance on in which countries land use change is more prevalent, but the information is not connected to the magnitude of Ewerman's upstream pressure contribution. LCA datasets can potentially assess the Land use change for specific commodities, and provide more accurate data on e.g. water use. In addition, complementary information to the pressure estimations like farming practices and pre- and post- conversion ecosystem type and use was not collected in this project due to time and data limitations. But as explained in the comparison between the literature study and the SBTs for Nature coverage, it is not stated in the technical guidance how this information is quantitatively accounted for. Therefore, it is uncertain how it would have affected the results in this project.

The indicators used as SoN_Ps and SoN_Bs have a large influence on the final results. For this project, indicators from WWF-BRF and -WRF were used according to the crosswalk provided by WWF. The BRF and WRF are suggested in SBTN's toolbox, but other sources can also be used for the State of Nature indicators. There are some drawbacks of using the BRF and WRF indicators. For the pressure category land use, the BRF indicator Ecosystem condition is used, which includes both terrestrial, freshwater, and marine ecosystems. Thereby, it is not specific for terrestrial land use, which is the most relevant category for agricultural land use. Further, for the pressure category soil pollution, the BRF indicator Pollution is used. As the name suggests, this indicator covers several types of pollution, including marine and air pollution which is not relevant for this pressure category. Moreover, some of the input data comes from FAO Stat's data on fertiliser and pesticide use, which is the same data as in this project was used for estimating the pressure itself. It also means that the BRF indicator does not reflect measured aspects of the state of nature itself, such as soil concentrations, but is based on coarse data and assumptions. Finally, it is not clear how frequently the data used in the BRF and WRF is updated, since it depends on the data sets used as input for the indicators. Some data sets are also relatively old, for example the Ecosystem Condition indicator is partly based on a dataset from 2016. This means that more recent changes in nature can be overlooked, and further accentuates the importance of interpreting the results as a guidance for further assessment, and not as a true representation of reality.

5.3.2 RQ2 and RQ3: Literature study, comparison and challenges & opportunities

The literature study was limited in time and scope and could have been both broader and deeper. Instead of only focusing on the impact of agriculture on biodiversity, it could have been extended to consider the activities along the whole value chain. For instance, this could be done by reviewing LCAs on agricultural commodities or studies on the biodiversity impact from certain other activities such as transport or packaging. This would also enable an analysis of whether SBTN's approach of only considering the most impactful stage, namely the sourcing stage, of the value chain is reasonable or not as discussed previously. Regarding the impact of agriculture on biodiversity, more areas of impact could have been included, and more details on how conditions and practices vary between different regions of the world covered.

To answer the third research question, a few meetings were held with Greenfood employees with responsibility for sustainability within different areas of the company. The meetings were open-ended and did not solely focus on the opportunities and challenges with applying the SBTs for Nature. Structured interviews with a predefined script, or even a workshop, would potentially have generated even more useful input from the perspective of a company with a global value chain.

6

Conclusions

The aim of this thesis was to apply the first two steps of the SBTs for Nature framework on Ewerman's value chain as a case study, identify the challenges and opportunities for similar companies doing so, and evaluate whether the framework covers the main ways through which agriculture affects biodiversity.

The assessment resulted in ranking of origin countries according to five pressure categories, based on pressure estimations, the condition of nature, and/or high biodiversity value. Some countries are frequently ranked high, such as Ecuador, Spain, Costa Rica, and the Dominican Republic. The study had limited access to tools and data, such as LCA, and importantly, the pressure category land use change could not be assessed.

The framework covers some of the main agricultural impacts on biodiversity, such as agricultural expansion, greenhouse gas emissions, fertilisers, and water use, but in general more information and data at a local level is needed to achieve a more accurate assessment. Notably, pesticide use is not included in the framework despite its large negative impact on biodiversity. For some pressure categories, such as soil pollution, the choice of the metrics N and P fertiliser applied is inadequate for representing biodiversity impacts. One reason for these deficiencies might be that the framework is not specifically adapted to the agricultural sector. Moreover, the framework's indicators measure potential pressures rather than actual impacts on biodiversity, and accepts information at a national level, which is too coarse to capture the site-specific effects on biodiversity. This connects to the main challenge of applying the framework, the trade-off between complexity and accuracy. While regional or even farm-level data on pressures, or preferably actual impacts, would yield more accurate results, the process of obtaining such data is resource consuming for companies. Sometimes it may even be impossible, which reduces the feasibility of the framework.

One major opportunity of the first two steps of the SBTs for Nature is the guidance it can provide on the direction of further strategical work on biodiversity, in terms of where and on what to focus. However, the question remains on what actions companies can take in these locations. Further, it can serve as a basis for sustainability reporting and for complying with legislative requirements such as CSRD and CSDDD.

The SBTs for Nature framework is still under development, with further pressure categories to be included as well as publication of specific guidance for setting biodiversity targets. Hence, the framework should be continuously evaluated, especially as more companies within different sectors apply the methodology. This will help ensure that important pressures on biodiversity are not overlooked, and most importantly that the framework, if possible, achieves what it has set out to do; enable companies, and thereby society, to stay within Earth's environmental boundaries.

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A

Pressure estimation calculations

A.1 Land use

To estimate the land use pressure, data from FAO stat on the yields of a crop in a specific country (in kg/ha) was used. These numbers were then combined with Ewerman's purchase volumes of products from each country (kg), to give a number on the hectares used in a specific country for a specific product. The areas were aggregated countrywise to enable the spatial assessment. Due to time and data limitations, data on land management practices, as recommended by SBTN, was not included.

A.2 Water use

To estimate the water use pressure, data from Waterfootprint Assessment Tool on the blue water footprint for specific crops in specific countries was used (m3/year), and combined with total production quantities from FAO Stat (kg/year) to give a water footprint per kg of crop (m3/kg). The water footprint per product was then combined with Ewerman's purchasing quantities (kg) to give the total water use (m3).

A.3 Soil pollution

To estimate the soil pollution pressure, two different approaches were used, one of them using a different metrics than the one prescribed by SBTN. When following the SBTN procedure, data on both nitrogen and phosphorus fertilizer use intensity for each country was retrieved from FAO stat (kg/ha). However, using this procedure, the pressure estimation does not reflect the specific impact from Greenfood at each location but rather just the generall fertilizer use intensity in that country. Therefore, an alternative approach where the fertilizer use intensity was combined with the land use pressure, to give total fertilizer use (kg) within each country was also applied.

A.4 Water pollution

To estimate the water pollution pressure, data from FAO Stat on fertilizer use intensity per country (kg/ha) was combined with land use pressure estimations (ha) and a runoff-factor (%) to give an estimation of the amount of fertilizer discharged to nearby waters (kg). This was done for nitrogen and phosphorus fertilizer separately.

A.5 GHG emissions

To estimate the GHG emission pressure, previous calculations within Greenfood on the GHG emissions for each product and origin country was used. The calculations are based on RISE food climate database.

B

BRF and WRF Indicators

Pressure-Sensitive State of Nature Indicators

1.1 Water Scarcity: based on 7 datasets covering different aspects of scarcity; aridity index, water depletion, baseline water stress, blue water scarcity, available water remaining, drought frequency probability, and projected change in drought occurrence (WWF Water Risk Filter, 2021).

2.2 Water Condition: includes freshwater condition through a water quality index based on three parameters; biological oxygen demand, electrical conductivity and nitrogen level (WWF Water Risk Filter, 2021), and marine water quality based on the three datasets Ocean Health Index nutrient pollution data (Halpern, et al., 2012), ocean acidification data sets (Halpern, et al., 2012), and the WRI's Eutrophication and Hypoxia data set (Diaz, Selman, & Chique, 2011) (WWF Biodiversity Risk Filter, 2023)

2.4 Ecosystem Condition: includes terrestrial ecosystem intactness and connectivity based on the datasets Biodiversity Intactness Index from the Natural History Museum (2016) and Functional Connectivity of the World's Protected Areas from Brennan et al. (2022), freshwater connectivity based on mapping the world's free-flowing rivers by Grill et al. (2019) and marine connectivity based on the ocean health index by Harpern et al. (2012) (WWF Biodiversity Risk Filter, 2023). A more connected or intact ecosystem gives a lower risk score.

3.2 Wildfire Hazard: based on the Global Facility for Disaster Reduction and Recovery's (GFDRR) global wildfire hazard levels (2017) (WWF Biodiversity Risk Filter, 2023).

3.5 Extreme heat: based on GFDRR's indicator, which is in turn based on the heat-stress indicator wet bulb globe temperature (WWF Biodiversity Risk Filter, 2023). A higher daily maximum wet bulb globe temperature gives a higher risk score.

3.6 Tropical cyclones: based on GFDRR's tropical cyclonic strong wind and storm surge model (WWF Biodiversity Risk Filter, 2023). A higher predicted maximum wind speed during a 50-year return period gives a higher risk score.

5.1 Land, Freshwater and Sea use change: includes terrestrial cropland expansion based on Potapov's Global maps of cropland extent gain (2021), fragmentation of rivers based on mapping the world's free-flowing rivers by Grill et al. (2019) and direct marine human impact and fishing based on Harpern et al. shipping and direct human impact score (2019). More cropland expansion, more river fragmentation or a higher impact score gives a higher risk score for the indicator (WWF Biodiversity Risk Filter, 2023).

5.2 Tree Cover Loss: based on Hansen et al. Landsat data at a 30-metre spatial resolution to characterise tree cover extent, loss and gain (2021) (WWF Biodiversity Risk Filter, 2023). Only tree cover loss since 2020 was accounted for, and a higher average tree loss in % gives a higher risk score.

5.4 Pollution: includes terrestrial nutrient pollution based on FAO's total nitrogen used and total area of cropland, terrestrial pesticide pollution based on FAO's total pesticide use and total area of cropland, freshwater nutrient pollution based on McDowell et al. Global mapping of freshwater nutrient enrichment and periphyton growth potential (2020), marine nutrient pollution based on Halpern et al. impact score for nutrient pollution (2019), marine pesticide pollution based on Halpern et al. impact score for organic chemical pollution (2019) and air pollution based on Hammer's concentration of annual global surface concentrations of all composition ground-level of PM2.5 or smaller (2022) (WWF Biodiversity Risk Filter, 2023).

Biodiversity State of Nature Indicators

From the Biodiversity Risk Filter:

6.1 Protected/Conserved Areas: based on the assessment unit's overlap with protected areas according to UNEP-WCMC's World Database of Protected Areas (UNEP-WCMC and IUCN, 2021) (WWF Biodiversity Risk Filter, 2023). A higher percentage overlap gives a higher risk score.

6.2 Key Biodiversity Areas: based on the assessment unit's overlap with Key Biodiversity Areas according to BirdLife International's database (WWF Biodiversity Risk Filter, 2023). A higher percentage overlap with the key biodiversity areas or its 15km buffer area gives a higher risk score.

6.3 Other Important Delineated Areas: based on the assessment unit's overlap with Intact forest landscapes, WWF's Global 200, Ecologically or biologically significant marine areas or Vulnerable marine ecosystems (WWF Biodiversity Risk Filter, 2023). A higher risk score is given depending on which of these areas the assessment unit has an overlap with.

6.4 Ecosystem Condition: The inverse of indicator 2.4, i.e. a more intact and connected ecosystem gives a higher risk score (WWF Biodiversity Risk Filter, 2023).

6.5 Range Rarity: a measure of species endemism, i.e. whether a species is only found in a single and/or restricted geographical range (WWF Biodiversity Risk Filter, 2023). Based on the IUCN Red List of Threatened Species data and summed across all species, with a higher range rarity score giving a higher risk score for the indicator.

From the Water Risk Filter:
10 Biodiversity Importance: combines data on freshwater endemism (number of endemic species) and freshwater biodiversity richness (count of fish species), both based on the Freshwater Ecoregions of the World data developed by WWF and TNC (WWF Water Risk Filter, 2021).

C

Biodiversity State of Nature Indicators

Table C.1: The Biodiversity State of Nature Indicators for all assessed countries

Country	**BRF 6.1**	**BRF 6.2**	**BRF 6.3**	**BRF 6.4**	**BRF 6.5**	**WRF 10**
Albania	3.79	3.7	3	2.92	2.84	3.93
Argentina	1.96	2.5	2.02	3.1	2.69	3.75
Australia	2.64	1.92	2.8	3.21	2.11	2.73
Austria	3.45	2.34	2.65	2.82	1.64	3.8
Belgium	3.29	2.45	1	2.25	1.21	4.5
Brazil	2.59	2.24	3.66	3.58	2.86	4.66
Chile	2.95	2.58	3.81	3.84	3.19	2.74
China	1.27	2.39	2.35	2.69	1.9	2.87
Costa Rica	3.97	4.44	3.51	3.49	5	2.55
Denmark	3.96	3	1	3.25	2	4.05
Dom. Republic	4.03	3.84	3.63	2.74	5	3.5
Ecuador	2.79	4.02	4.02	3.68	4.99	4.7
Egypt	1.96	1.4	1.03	3.56	1.47	1.84
France	2.96	1.97	1.51	2.6	1.59	4.08
Germany	3.47	2.75	1.11	2.57	1.09	4.45
Greece	3.9	3.14	3	2.73	2.3	3.47
Hungary	3.16	2.99	1.34	2.57	1.05	3.5
India	1.19	2.42	2	2.32	2.65	3.27
Israel	2.92	3.92	2.24	2.48	4.07	2.13
Italy	3.61	2.11	2.96	2.55	2.4	3.54
Kenya	2.68	2.89	3.02	3.64	3.66	3.74
Morocco	2.33	2.72	2.8	2.51	2.21	2.99
N. Macedonia	3.04	3.62	3	2.36	2	3.55
Netherlands	4.2	3.29	1	2.64	1.77	4.5
New Zealand	3.98	2.8	3.77	2.96	3.65	4
Norway	3.95	3.02	2.35	3.37	1.32	1.81

Table C.1: The Biodiversity State of Nature Indicators for all assessed countries (continued)

Country	**BRF 6.1**	**BRF 6.2**	**BRF 6.3**	**BRF 6.4**	**BRF 6.5**	**WRF 10**
Peru	2.72	3.25	4.28	4.15	4.42	4.15
Poland	4.19	2.32	1.2	2.88	1.13	4.5
Portugal	3.16	3	2.97	2.2	2	3.5
Senegal	3.17	2.69	1.05	3.26	2.13	3.5
Serbia	2.6	2.38	2.14	2.23	1.25	3.5
South Africa	2.52	2.7	2.41	1.87	2.9	2.35
Spain	3.47	3.76	2.84	2.06	2.34	3.44
Sweden	3.16	1.8	2.33	3.19	1.03	2.22
Thailand	3.47	3.19	3.51	2.81	3.82	4.54
Turkey	1.21	2.98	2.98	2.49	2.11	3.21
United Kingdom	3.76	2.55	1	2.68	1.8	3.94
USA	1.59	2.19	1	3.25	4.59	2.73
Zimbabwe	2.7	2.26	1.39	2.39	2.32	2.25

D

Search words

Table D.1: Search words utilised for the literature study

Agricultural development	Agricultural expansion	Agricultural intensification
Agriculture	Assessment	Biodiversity
Biodiversity framework	Biodiversity loss	Biodiversity regulation
Climate Change	CSDDD	CSRD
DPSIR framework	Driver	Ecosystem
Effect	ESRS	EU Biodiversity Strategy
EU Green Deal	Eutrophication	Farming
Fertiliser	Food	Food production
Impact	Indicator	Irrigation
Landscape homogenisation	Land-use	Land-use change
Measure	Monoculture	Pesticide
Pollution	Pressure	Soil
Water scarcity	Water use	

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