BIODIVERSITY FOOTPRINT OF FOOD PRODUCTS AND PERCEPTIONS OF BIODIVERSITY FOOTPRINT INFORMATION: CASE S GROUP

Department of Biological and Environmental Science
Jyväskylä University School of Business and Economics
School of Resource Wisdom

Master's Thesis

2024

Author: Laura Hynönen
Subject: Corporate Environmental Management & Environmental Science
Supervisors: Sami El Geneidy, Janne Kotiaho, Marileena Mäkelä, Maiju Peura
Examiners: Elisa Vallius, Janne Kotiaho

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

ABSTRACT

Author Laura Hynönen	
Title Biodiversity footprint of food products and perceptions of biodiversity footprint information: Case S Group	
Subject Corporate Environmental Management and Environmental Science	Type of work Master's thesis
Date 19.5.2024	Number of pages 70 + Appendices 2p.
Abstract Agriculture is one of the major causes of biodiversity loss, contributing to land use, climate change, and pollution. At the same time, food system is highly dependent on biodiversity and ecosystems. There is a need for systemic shift towards more sustainable food industry and dietary patterns to mitigate global biodiversity loss. Retail companies can play an important role in the efforts to develop food supply chains and consumption patterns more sustainable. The shift from status quo requires information about the adverse biodiversity impact of human activities and consumption as well as leadership towards environmental sustainability. In this study, production country specific terrestrial biodiversity footprints for ten protein-rich food products were assessed per three functional units: retail weight, protein content, and energy content. In addition, the purpose of this study was to gain business perception of utilizing such biodiversity footprint information. The results showed that different sources of proteins and production countries have substantially different biodiversity footprints. Plant originated proteins had significantly lower biodiversity footprint than animal originated proteins. From the business perspective, biodiversity footprint information was considered useful. The results revealed benefits, challenges, and needs related to applying biodiversity footprint in business context.	
Key words biodiversity, biodiversity footprint, biodiversity loss, biodiversity management, food system, environmental management	
Place of storage Jyväskylä University Library	

TIIVISTELMÄ

Tekijä Laura Hynönen	
Työn nimi Ruokatuotteiden luontojalanjälki ja näkemyksiä luontojalanjälkitiedosta: Case S-Ryhmä	
Oppiaine Ympäristötiede ja Yritysten ympäristöjohtaminen	Työn laji Pro gradu -tutkielma
Päivämäärä 19.5.2024	Sivumäärä 70 + liitteet 2s.
Tiivistelmä Ruokajärjestelmä on vahvasti riippuvainen monimuotoisesta luonnosta ja toimivista ekosysteemipalveluista, joita globaali luontokato uhkaa. Luontokadon pysäyttämiseksi tarvitaan systeemisiä muutoksia ruokajärjestelmään, jolla on itsellään merkittävä rooli luonnon monimuotoisuuden heikkenemisessä. Päivittäistavarakaupan yrityksillä on mahdollisuus vaikuttaa tähän kehitykseen niin tuottajien kuin kuluttajien suuntaan. Nykytilan parantamiseksi tarvitaan tietoa ihmisen toiminnan ja kulutuksen aiheuttamista luontohaitoista. Tässä tutkimuksessa selvitettiin tuote- ja tuotantomaakohtaiset luontojalanjäljet kymmenelle eri proteiinilähteelle kulutuksen määrää, sekä proteiini- ja energiasisältöä kohden. Lisäksi selvitettiin päivittäistavarakaupan yrityksen näkökulmia luontojalanjälkitiedon hyödyntämisestä. Tulokset osoittivat, että eri proteiininlähteillä ja tuotantomailla oli merkittäviä eroja niiden aiheuttaman luontohaitan määrässä. Kasviperäisten proteiinien kulutuksella oli merkittävästi pienempi luontojalanjälki kuin eläinperäisillä. Yritystoiminnan näkökulmasta luontojalanjälkitieto nähtiin hyödyllisenä. Tulokset osoittivat, että luontojalanjälkitiedon hyödyntämisessä nähtiin sekä hyötyjä että haasteita. Lisäksi tunnistettiin yritysten tarpeita luontojalanjälkitietoon liittyen.	
Asiasanat biodiversiteetti, biodiversiteettijohtaminen, luontohaitta, luontojalanjälki, luontokato, ruokajärjestelmä, ympäristöjohtaminen	
Säilytyspaikka Jyväskylän yliopiston kirjasto	

CONTENTS

1 INTRODUCTION

1.1 Background

Biodiversity is crucially important for all life on Earth. It is essential for the function of ecosystem services, such as pollination, clean water and air, raw materials, and fertile soil (The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES, 2019). Human activities, such as food production, are dependent on the functioning of these ecosystem services. During the post-industrial era, the ever-growing intensity and magnitude of human activities has caused nature destruction which has led to a global loss of biodiversity (IPBES, 2019). Biodiversity loss happens on a local and ecosystem scale, due changes caused by human activities. The magnitude of biodiversity loss varies by location as the amount of biodiversity varies between ecosystems. Biodiversity has continued to decline rapidly around the world despite decades of national and international policy efforts (IPBES, 2019) and biodiversity loss is currently one of the most major environmental, economic, and societal challenge together with climate change (World Economic Forum, WEF, 2020b). Mitigating biodiversity loss requires leadership and actions from various actors of the society, including businesses (Sihvonen et al, 2022). Biodiversity should become mainstream in business decision making (IPBES, 2019).

Agriculture is one the human activities that has major contribution to biodiversity loss through land use, climate change, and pollution (Kurth et al., 2021), fundamentally driven by food consumption patterns and unsustainable production practices. Of agricultural products, the production of many protein sources has high environmental impacts (Poore & Nemecek, 2018). However, biodiversity impacts of protein sources have not been widely studied before. Assessing the biodiversity impacts of a product’s production in different countries enables comparison between different production countries of the same product.

Different actors of food system can be informed by such biodiversity footprint information. Grocery businesses are the purchasers of food products and providers of food product options to consumers, thus having leverage towards both actors (Poore & Nemecek, 2018). The concept of biodiversity footprint and its calculation are rather new for businesses. A challenge that companies currently face is measuring biodiversity impacts and finding suitable indicators to follow and disclose their impacts on biodiversity (Kämäräinen, 2021; Salmi, 2023; Schaltegger et al., 2023). Biodiversity footprint is a novel, still developing, tool designed to measure biodiversity impacts of organisations and products. Some organisations have already applied this methodology, for example the University of Oxford (Bull et al., 2022), the University of Jyväskylä (El Geneidy et al., 2021), ASN Bank (Kan et al., 2022), S Group (Peura et al., 2023), and the City of Tampere (Pokkinen et al., 2024). However, business insights related to the implementation of biodiversity footprint information in practice are not yet studied extensively.

1.2 Aim of the thesis

Purpose of this thesis is to assess biodiversity impacts of food protein sources and gain business insights of applying such information. This study aims to increase current understanding of the biodiversity impacts of food production in different countries, and to gather business perceptions regarding the use of biodiversity footprint information. The research questions this study aims to answer are:

RQ1: What are the biodiversity footprints of different protein-rich food products in different production countries?
RQ2: How can companies utilize biodiversity footprint information?
RQ3: What are the needs companies have towards biodiversity footprint information?

To answering these questions, the study consists of two empirical parts. Firstly, to answer RQ1, the biodiversity impacts of the supply chain of different food protein sources are measured using biodiversity footprint methodology. Focus is on the supply chain stages from the production (farm) to retail, which is the point of choice for consumers. The data for the calculations was collected from scientific databases. Secondly, to answer RQ2 and RQ3, grocery and retail business experts were interviewed focusing on their views of how biodiversity footprint information can be applied in business context. The data was collected following semi-structured interview methodology.

The thesis is an interdisciplinary study, written jointly for two master's programmes in University of Jyväskylä: Environmental sciences in the Department of Biological and Environmental Sciences and Corporate

Environmental Management in the Jyväskylä School of Business and Economics. Thus, the thesis examines the topic from the perspective of both disciplines.

1.3 Structure of the thesis

After the introduction, this Master's Thesis continues with a theoretical framework of two main chapters. First chapter introduces biodiversity and how food system is associated with biodiversity loss to create understanding about the role of food system and biodiversity loss. Second theoretical chapter focuses on creating understanding about the relationship of biodiversity and businesses, with an emphasis on food industry and grocery business. In addition, corporate biodiversity management and biodiversity impact assessment are introduced. After theoretical framework, Chapter 4 continues to describe the empirical research design and reasoning the chosen methods and data. Chapter 5 presents the results and findings of the study. Chapter 6 discusses the findings and how they relate to existing literature. Chapter 7 concludes the thesis and the limitations of the study. Suggestions for further research avenues are also discussed. After final chapter, references and appendices are included.

2 BIODIVERSITY AND FOOD SYSTEM

Food system is strongly dependent on biodiversity, ecosystems, and natural resources. This chapter focuses on explaining the main concepts of biodiversity, biodiversity loss and the relationship of food system to these.

2.1 Biodiversity and ecosystem services

In this chapter, the definition of biodiversity and its role in ecosystem services is explained. One of the most common definitions of biodiversity, or biological diversity, describes it as the variety among three levels: among species, between species, and of ecosystems (IPBES, 2019). It includes the variation in all kinds of living organisms from animals and plants to micro-organisms, such as bacteria. Another widely established, slightly broader definition to explain biodiversity is the one adopted in the Convention on Biological Diversity (CBD) in 1992: "Biological diversity means 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." (CBD, 2011, p.4). Biodiversity can be evaluated by ecological characteristics including amounts, abundance, composition, interactions, and spatial distribution (Diaz et al., 2006), for example the number of species or composition of individuals in a population.

Ecosystems are dynamic natural units, either terrestrial, marine, or freshwater, that consist of the community of biological organisms and their interaction with abiotic (non-living) environment with physical and chemical qualities (Campbell et al., 2018). The three levels of biodiversity form complex dynamics and interactions, which establish the basis for functioning of all ecosystems (MA, 2005). Ecosystem services are the tangible and intangible benefits and contributions that are produced by ecosystems for human well-being (Millennium Ecosystem Assessment, MA, 2005). Usually, ecosystem services are divided into four categories: provisioning services (e.g. food, water, pharmaceuticals), regulatory services (e.g. pollination, climate regulation), support services (e.g. photosynthesis, nutrient cycling), and cultural services (e.g. recreation) as described by Millennium Ecosystem Assessment (2005). Support services, for example photosynthesis, soil formation, and water and nutrient cycles, are the basis for functioning of all the ecosystem services and are thus considered as the most important ones (Kurth et al., 2021).

Mace et al. (2012), explained the complex relation of biodiversity and ecosystem services by introducing three roles, where biodiversity can be seen "as regulator of fundamental ecosystem processes, a final ecosystem service itself, or a good". All these roles should be considered in ecosystem management (Mace et al., 2012). Biological diversity is connected to several essential ecosystem properties, such as stability, productivity, and resilience (Balvanera et al. 2006; Cardinale et al., 2012; Mace et al., 2012; Oehri et al., 2017), enabling proper function and maintenance of ecosystem services. It is possible however, that some small-scale studies might underestimate the importance of biodiversity in ecosystem functions (Cardinale et al., 2012).

It is well established that human wellbeing is strongly dependent on natural resources and ecosystem services, where biodiversity plays an important role (IPBES, 2019). Biodiversity and ecosystem services are not only important in ecological sense but also vital in the modern economy and societies providing direct and indirect benefits (Kurth et al., 2021). Recent estimates (World Economic Forum, WEF, 2023) claim that over half of the world economy, around 43 trillion (10^{12}) dollars, is dependent on biodiversity and ecosystem services enabled by it. In addition, there are various attempts by researchers to estimate the economic value of biodiversity and ecosystem services (Costanza et al., 1997; Hanley & Perrings, 2019; Pearce & Moran, 1994). One of the recent estimates by Kurth et al. (2021) resulted that the economic value of ecosystems services is over 150 trillion dollars, which corresponds around twice global gross domestic product (GDP). It is, however, worth noting that economic valuation does not give credit to the entire value of biodiversity and ecosystems, as nature also has an intrinsic value without anthropocentric justification (Naess, 1984), which is generally not measurable.

2.2 Biodiversity loss

This chapter explains the meaning of biodiversity loss. Biodiversity loss means the decline in any component of biological diversity, from individuals to ecosystems, and it is often associated with long-term or permanent changes in the ecological state of ecosystems (CBD, 2000). Anthropogenic activities have caused extensive changes on nature, which have led to global decline in the state of ecosystems and biodiversity (IPBES, 2019). Despite international agreements and commitments to conserve biodiversity, for example the United Nations Sustainable Development Goals and the CBD Aichi Targets, the decline in biodiversity has continued (IPBES, 2019). In contrast, biodiversity loss is happening faster than ever in human history, and an estimated 25 per cent of animal and plant species are in danger to face extinction, already during next decades (IPBES, 2019). In addition to single-species extinction, the loss of one species can lead to cascading co-extinctions of other species (Brook et al., 2008). It has been stated that we are in the middle of sixth mass extinction, caused entirely by human activities (Barnosky et al., 2011; Cowie et al., 2022). It should also be noted that human induced global biodiversity loss should not be mistaken with natural temporary variation in biodiversity caused by natural cycles, such as seasonal changes, or temporary natural ecological disturbances, like wildfires or floods (MA, 2005).

Typically, biodiversity impacts distribute unevenly among regions, countries, and social groups (IPBES, 2019). The consequences of the decline of biodiversity and ecosystems are unpredictable (Diaz et al., 2006), but it is well established that further degradation poses a global risk on the ability of ecosystems to maintain their functions properly, threatening also human activities and well-being (Hooper et al., 2012; IBPES, 2019; MA, 2005). The World Economic Forum (WEF, 2020b) has identified biodiversity loss and ecosystem collapse as one of the five most important global risks to societies during next decade, together with risks related to failure in climate change mitigation and adaptation. It has been estimated that over half of the world's GDP, 44 trillion dollars, is threatened by the causes of biodiversity loss (WEF, 2023).

In addition to preserving species, measures are needed to preserve and restore species composition, relative abundance, and functional organization in ecosystems (Diaz et al., 2006). Recently, the global community has shown commitment to halt biodiversity loss and restore ecosystems. In December 2022, the UN Biodiversity Conference COP15 agreed on Kunming-Montreal Global Biodiversity Framework, where 196 countries committed to urgent actions, including conservation of at least 30% of the world's land, freshwater and seas by 2030, as well as restoration of 30% of degraded areas, also by 2030 (CBD, 2022).

2.3 The drivers of biodiversity loss

In this chapter, the drivers of biodiversity loss are introduced. Main direct and indirect drivers of global biodiversity decline have been introduced by IPBES (2019, p. 29). Drivers can also be referred to as pressures (IPBES, 2019). Direct drivers originate from human institutions and governance systems, and they have direct physical impact on ecosystems (IPBES, 2019).

There are five main direct drivers: land and sea use and change, direct exploitation, climate change, pollution, and invasive alien species. Globally, land use change has relatively the largest impact of direct drivers on terrestrial and freshwater ecosystems, whereas marine ecosystems are impacted relatively the most by direct exploitation of fish and seafood. Around 75% of land, and 66% of ocean areas have been significantly changed by humans, of which large part is driven by food production, but also forestry and urbanization (IPBES, 2019).

Land use and land use change driver is the major contributor to biodiversity loss (Jaureguiberry et al., 2022). Harnessing ecosystems to meet human needs causes degradation and complete loss and fragmentation of ecosystems and habitats (Banks-Leite et al., 2020). Habitat loss and degradation reduce suitable areas for different species to live, and fragmentation reduces the connectedness of suitable habitats.

Climate change is continuously increasing direct driver of biodiversity loss globally, as well as accelerating the impact of other drivers (IBPES, 2019; Román-Palacios & Wiens, 2020; Urban, 2015). The causes of climate change, such as drought, flooding, storms, ocean warming are also contributing to biodiversity loss (IPBES, 2019). It has been well established that climate change and biodiversity loss are intricately interconnected, and they should be mitigated simultaneously, considering possible synergies and trade-offs discussed by Pörtner et al. (2021). Synergies mean, for example, that by protecting biodiversity, there are contributions to also mitigating or adapting to climate change. Trade-offs happen when an action to mitigate either climate change or biodiversity loss result in negative consequences for the other.

Agriculture is a great example of the interconnectedness of climate change and biodiversity. Agriculture is sensitive to climate conditions and extreme weather events caused by climate change (IPBES, 2019). At the same time, diverse ecosystems are more resilient to the adverse impacts of climate change, such as extreme weather fluctuations and storms (Pörtner et al., 2021).

The direct drivers of biodiversity loss are fuelled by a collection of indirect societal drivers, such as economic (trade), demographic (human population dynamics), and institutional causes, which are underpinned by societal values and behaviour (IPBES, 2019). Wilting et al. (2017) estimated that over 50% of the biodiversity loss associated in developed economies happens in other locations than in the developed countries themselves, meaning that the biodiversity impacts are significantly outsourced. Of different consumption categories, food consumption seems to have the highest biodiversity impacts (Kurth et al., 2021; Peura et al., 2023; Wilting, et al., 2017). The world population is expected to grow from 7.6 billion to almost 10 billion by 2050, which in turn is expected to increase the demand for food and other goods, increasing the pressure on biodiversity (The Economics of Ecosystems and Biodiversity, TEEB, 2012; United Nations, 2022).

The loss of biodiversity is fundamentally driven by human activities, institutions, consumption patterns, values, and behaviour – the way we consume, appreciate, and value nature and its resources IPBES, 2019). Over the last century, humans have gained profits by exploiting ecosystems and biodiversity, but these benefits have been built upon loss and degradation of nature and increase in poverty and social inequality for others (Fanning et al., 2022; Hickel et al., 2022; MA, 2005). As the changes to ecosystems distribute differently, it further deepens this social inequality related to availability and use of ecosystem services (Hales et al., 2005). It has been proposed that economic growth should be decoupled from destroying ecosystems and material consumption (World Business Council for Sustainable Development, WBCSD, 2010). Measures on reducing the pressure of indirect drivers are essential, as fundamentally, they are the originators of direct drivers of biodiversity loss. Food system is one of these major drivers and the primary cause of global biodiversity loss, which is discussed more in the following chapters.

2.4 Food system as a driver of biodiversity loss

2.4.1 Food system

This chapter explains the definition of food system and food supply chain. Food system is defined as the broad entity of actors and their interlinked activities in the production, processing, distribution, consumption, and disposal of food products, originating from agriculture, fisheries, or forestry (FAO, 2018). It also covers the economic, societal, and natural operating environments (FAO, 2018), as well as the impacts on nutrition, human health, and the environment (Benton et al., 2021). The global food system consists of many interacting local subsystems, which have different qualities depending on the specific location's mix of food produced locally, nationally, regionally, and globally (Benton et al., 2021). Factors influencing the dynamics between these, such as conflicts, climate change, and biodiversity loss, are linked to the stability and functionality of food systems and food supply chains. Main actors in the food system and food value chain are primary producers, food and drink manufacturers, food retail and services, and consumers (European Environment Agency, 2017). Governments and policy makers are also included as they set the policy context.

Agriculture is economically important sector. In the EU, its contribution to the GDP was 1.3% in 2023 (Eurostat, 2024). The share of agriculture of global GDP is 4%, but in some developing countries, it can account for more than 25% of GDP (FAO, 2022). Of all food production, international food trade accounts for 25% (Springmann et al., 2023). Animal feed has an important role in the global food trade, with production of over one billion tonnes, and turnover of 400 billion dollars (International Feed Industry Federation, 2023). Population and demographic changes, income development, and food prices directly influence the demand of food (OECD/FAO, 2021). Poultry, pork, and cattle consist of 90% of the world's meat production (FAO, 2022). The demand of animal feed is influenced by the demand for animal products and how much feed is needed to produce a given output, i.e. efficiency (OECD/FAO, 2021). Feed demand is expected to grow at 1.2% annually by 2030 because livestock production is expected to expand especially in low and middle-income countries.

Food system covers the entire supply chain of a food product. Generally, the supply chain of a food product starts from the farm where the primary production happens, and continues to post-farm stages: processing, retail, cooking, and disposal (Benton et al., 2021). In addition, one should also consider the needed inputs when exploring the supply chain. In primary production, important inputs are for example fodder to feed domestic animals, fertilizers, energy, seeds, and pesticides. The inputs required in the following supply chain stages are for example energy, packaging materials, and water. Many of the inputs, e.g. fodder and fertilizers, are not always sourced locally, and farms are dependent on off-farm foreign production and food trade flows (Ahvo, 2023; The Finnish Food and Drink Industries' Federation, 2023).

Most animal feed is originated from plants. For example, soy is a common plant ingredient used in animal fodder in Europe, where livestock production is dependent on soy imports (Kuepper & Stravens, 2022). Soy is imported to Europe mainly from Argentina, Brazil, and United States (Finnwatch, 2021). More than 96% of the soy imported from South America ends up as animal feed or cooking oil (Ritchie et al., 2022). Around 75% of the soy imported to Europe is used as fodder in the production of pork, poultry, and eggs (Finnwatch, 2021). In Finland, soy is used in the production of poultry and fish meat but has nearly ended in beef and dairy production (Finnwatch, 2021).

Food systems and their operational environments modify food supply chains. Competition of food products in global markets has resulted in supply chains where the food consumed in certain country is produced in another country or a combination of local and overseas production (Benton et al., 2021). Current economic system and global market dynamics have shaped food system to emphasize efficient production and lower prices, on the cost of environment (Benton et al., 2021).

2.4.2 Agricultural drivers of biodiversity loss

This chapter discusses how food production is driving biodiversity loss. Current food system is fundamentally resource intensive, and the principal driver of biodiversity loss (Benton et al., 2021). At the same time, it is essentially dependent on biodiversity and ecosystem services, as natural resources are the most important factors of production for farms (FAO, 2008). At the same time, climate change threatens the productivity of agriculture and hence global food security (Kang et al., 2009). In addition to environmental aspects, food systems contribute to various other unsustainable and ethical issues such as malnutrition, inequality, concentration of power, and animal rights. In the following chapters, I will discuss more about the relationship of food system and biodiversity loss.

Of all major value chains in global economy, food value chains account for over 50% of the total pressure on biodiversity (Kurth et al., 2021). Every activity within the food supply chain has environmental impacts (Benton et al., 2021), contributing to the drivers of biodiversity loss (Figure 1). These impacts are originated by millions of food producers, primary production being the dominating source of the wide range of environmental impacts: land use and land use change, greenhouse gas emissions, acidification, and eutrophication (Benton et al., 2021; Poore & Nemecek, 2018). In addition to driving land use and climate change, food production causes biodiversity loss through fertilizer and pesticide pollution, water use, and overexploitation of species, for example certain fish stocks (Benton et al., 2021). Also, the extensive use of antibiotics in food production has harmful impacts on the microbial communities in ecosystems (IPBES, 2019). In addition, the production of farm inputs causes environmental impacts. Impacts can be grouped to impacts at different scales: farm, landscape, regional, and global scale (Benton et al., 2021).

Globally, agricultural activities require major amount of land use for cultivation and grazing, causing changes in land cover and natural habitats, such as deforestation (Benton et al., 2021; MA, 2005). Between 2001 and 2015, almost 30% of global deforestation was related to the production of agricultural commodities such as beef, palm oil, soy, and wood fibre (Curtis et al., 2018). Land use change required for agriculture is driven by a vicious cycle, as the current unsustainable agricultural practices result in relatively fast degradation of soil productivity and ecosystems in general, which accelerates the need to converse more natural habitats for food production (Benton et al., 2021).

It is estimated that agriculture has already occupied 45% of the habitable land on Earth (Poore & Nemecek, 2018; Ritchie & Roser, 2024), of which one third is cropland and two-thirds grazing land (Ritchie & Roser, 2024). Considering that a large share of cropland is to produce feed for animals, livestock accounts for 80% of the total agricultural land use (Ritchie & Roser, 2024), whereas croplands for human direct consumption accounts only for 16% of the total agricultural land, and non-food crops for the rest 4% (Ritchie & Roser, 2024). In the local level, agricultural ecosystems have substantially moved away from traditional practices, such as grazing of meadows, and adopted monoculture approach (Benton et al., 2021). Monocultures do not provide suitable habitats for different species thus they have scarce biodiversity compared to heterogenic farmlands (Benton et al., 2003). This increases vulnerability to invasion of pests as well as plant and fungal diseases. For example, in Finland, all the traditional agricultural biotopes have become critically endangered or endangered as most of them have been cleared for grain and grass fields during the last 50 years (Kontula & Raunio, 2018).

In addition to land use, agricultural greenhouse gas emissions impact on biodiversity loss through climate change (Benton et al., 2021). Food production causes 25% of the total global greenhouse gas emissions, of which highest share (31%) is caused by livestock and fisheries (Poore & Nemecek, 2018). Crop production accounts for 27% and land use, mainly land use change, accounts for 24%. Rest of the supply chain (processing, transport, packaging, retail) totals 18% (Poore & Nemecek, 2018). Most greenhouse gas emissions originate from land use changes and energy consumption of production (Poore & Nemecek, 2018).

It may be concluded that animal originated food production is a principal contributor to the total land use and greenhouse gas emissions caused by agriculture. However, as a global nutritional source, animal originated proteins (meat, dairy, farmed fish) only provide 17% of the world's calories, and 38% of protein (Ritchier & Roser, 2024), meaning that despite the major amount of land use and greenhouse gas emissions, animal originated proteins hold quite moderate share of the global nutritional supply. There are high losses of energy related to livestock production, as energy transfer between trophic levels – here, from plants or fodder to animals – is inefficient (Bonhommeau et al., 2013). Several studies have shown that plant originated proteins have lower environmental and biodiversity impacts per production and nutritional unit than animal products (Nijdam et al., 2012; Poore & Nemecek, 2018; Crenna et al., 2019; Peura et al., 2023). The production of animal originated protein has almost doubled globally over the past decade and is still estimated to rise by 2030 (OECD/FAO, 2021). Considering the adverse biodiversity impacts of animal production, this is a challenge for the reduction of biodiversity impacts of food production.

3 BIODIVERSITY MANAGEMENT IN FOOD SYSTEM

This chapter focuses on explaining sustainable food system and the role of different actors, including grocery retailers, in the sustainable development of food systems, focusing on the environmental dimension and mitigation of biodiversity loss. I will also discuss corporate biodiversity management with an emphasis on food industry perspective, finally presenting some current approaches for corporate biodiversity management, including biodiversity footprint assessment.

3.1 Sustainable food system

This chapter explains sustainable food system and the role of different food chain actors in biodiversity mitigation measures. Brundtland report (United Nations, 1987, p.41) established the grounds for sustainable development as "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". Deriving from the Brundtland definition, sustainable food system generates food security and nutrition by taking care of environmental, social, and economic aspects, and does not compromise the food security and nutrition for future generations. When being sustainable, food system impacts positively or neutrally on environment, has benefits for society, and is economically profitable, while providing healthy diets and nutrition (Committee on World Food Security, 2021; FAO, 2018). Current food system is not fulfilling the delivery of nutrition through these three dimensions of sustainable development. Transition of food system requires changes in which the food system supports environmental and human health instead of deteriorating them, which calls for overall reshaping with holistic co-operative measures at local, national, regional, and global levels to achieve sustainability (Benton, 2021; Committee on World Food Security, 2021). This thesis focuses on environmental dimension with focus on biodiversity but recognizes that there are various interlinked social and economic sustainability issues as well to be solved simultaneously.

Benton et al. (2021) concluded three simultaneously interdependent levers for redesigning current food system to support biodiversity: protecting land areas for biodiversity, adopting environmentally friendly food production practices, and aligning food consumption patterns with sustainability and health. In addition, policy improvements and incentives for sustainable practices are required to support this transition. Food systems are dynamic, where even small changes in the forces acting on it can lead to effects creating responsive feedback loops and unexpected responses within the system (Benton et al., 2021). These dynamics should be considered carefully when analysing and creating policies related to food system (Benton et al., 2021).

Uptaking biodiversity-based land management and mainstreaming agro-ecological and regenerative practices – already applied in organic farming – have potential to upgrade the sustainability of food production and enhance biodiversity (Benton et al., 2021; Nemecek et al., 2011), Bommarco et al., 2013; Kremen & Merenlender, 2018). These practises include for example internal product input optimization (e.g. manure) and replacing external inputs with ecosystem services (e.g. natural biocontrol). Ancient agricultural practices have relied on the knowledge of the ecology of diverse crops, soil, and water resources, and re-adopting these approaches instead of modern ones could support biodiversity providing sufficient yields at the same time (Kremen & Merenlender, 2018). Meta-analysis by Bengtsson et al. (2005), revealed that organic farming practices support more species than conventional farming.

There are, however, possible trade-offs related to considering environmental aspects and receiving yields (Benton et al., 2021). For example, yields in organic agriculture are usually lower than in conventional agriculture, so reaching the same yield level as with intensive cultivation would require more land use (Benton et al., 2021). Thus, the environmental benefits of organic farming products are realized per unit of area, but not per product unit (Tuomisto et al., 2012). Despite possible yield-biodiversity trade-offs, organic farming has socio-economic and health benefits as well (Seufert & Ramankutty, 2017). To achieve desired results for biodiversity, landscape- and farm-specific strategies should be applied when considering the on-farm practices, as the surrounding landscape qualities also have their impact on biodiversity in agricultural areas (Bengtsson et al., 2005).

There are differences between producers of the same food product, which indicates potential to mitigate impacts already in the farm by changing farming practices (Poore & Nemecek, 2018), highlighting the important role of farmer's choices to promote biodiversity. However, farmers alone have limited possibilities to adopt sustainable practices as the food system and its cost pressures drive farmers increasingly towards intensification and continuous growth, which are among the root causes of biodiversity loss and other sustainability issues associated with agriculture (Kuhmonen, 2023; Stringer et al., 2020). Farmers need resources and viable business opportunities to harness their potential to drive on-farm sustainable practices (Kuhmonen, 2023).

In addition to implementing agro-ecological food production approach, fundamental changes are required to the global food demand – to the way we consume food. There are at least two essential aspects to consider: the type of consumed food, and the amount of food consumption.

The changes to the type of consumed food relate to including less resource-intensive options to diets. Vegetarian diet has a significant potential to reduce environmental impacts of food consumption (Poore & Nemecek, 2018; Springmann et al., 2018), even by half (Read et al., 2022). This basically means that increasing the use of plant originated proteins would reduce the land needed for pasture and animal feed production, thereby freeing up the land area for cultivation of alternative protein sources, land protection and restoration, as well as reduce the overall environmental burden of farming (Benton et al., 2021; Hayek et al., 2021).

Another dietary aspect to consider is related to food demand. In addition to consuming environmentally low-footprint food products, the diet should be consisted of right amount of food to prevent wasting or overconsuming food products (Benton et al., 2021). Even reasonable changes in diets could contribute rather well, assuming there will be supportive changes to agricultural policies and productivity of agriculture as well (Lehtonen & Rämö, 2023).

There is an interdependence between supply and demand side actions to move towards sustainable food system (Benton et al., 2021). In addition to focusing on the biodiversity-enhancing actions in farming or consumer's choices, grocery businesses are essentially important actors, as they are a central part of the food value chain as purchasers of food products and providers of food options to consumers (Poore & Nemecek, 2018).

3.2 Biodiversity and grocery business

This chapter discusses the relation of biodiversity and business, with an emphasis on food industry and grocery businesses. In principle, all businesses are either directly or indirectly dependent on biodiversity and ecosystem services, thus are exposed to risks of biodiversity loss (Sihvonen et al, 2022). In addition, businesses have great potential of contributing to biodiversity loss mitigation and conserving biodiversity, given their spatial and temporal operating scale, resources, and political leverage (Houdet et al., 2012). As central actors in the food chain, grocery businesses can initiate measures for biodiversity considering their own operations, but also encourage other actors of the food chain to mitigate biodiversity loss (Poore & Nemecek, 2018).

Recent changes in the operating environment have influenced to the uptake of biodiversity topics in companies (Sihvonen et al., 2022). Increasing regulatory changes, for example through EU Biodiversity Strategy 2030 and Farm to Fork Strategy, have also influenced companies to consider biodiversity aspects better to meet the regulatory requirements and avoid additional costs (Kurth, 2021). Biodiversity aspects have also risen as a criterion for companies to receive funding (Sihvonen et al., 2022). At the same time, consumers are increasingly aware of environmental issues and consider biodiversity in their purchasing decisions (Sihvonen et al., 2022; TEEB, 2012). In food products this is especially emphasized by millennials and generation z consumers (McKinsey & Company, 2024). In general, mitigating biodiversity loss is relevant from the perspective of social acceptability and license to operate for businesses (Kurth et al., 2021; Sihvonen et al., 2022).

Currently, many of the biodiversity impacts of companies are outsourced to society as companies are not required to pay for their adverse impacts on biodiversity (Sihvonen et al., 2022). Biodiversity impacts of a company originate directly from its own operations, and indirectly through supply chains or use of its products (Marques et al., 2017; Sihvonen et al., 2022). For example, it is common that Finnish food industry uses raw materials imported from overseas, outsourcing biodiversity impacts to locations with high biodiversity values (The Finnish Food and Drink Industries' Federation, 2023; Sandström et al., 2017). High proportion, even 40%, of the land use required for agricultural consumption in Finland is outside Finnish borders (Furman et al., 2018). In addition to mitigating its adverse impacts, food sector has great potential to create positive impact on biodiversity (The Finnish Food and Drink Industries' Federation, 2023).

Considering biodiversity dependencies is a matter of managing business risks. Impacts of biodiversity loss can cause disruptions in the availability of raw materials, raising costs and increasing competition of natural resources as the access to degrading ecosystem services narrows (Kurth et al., 2021; Sihvonen et al., 2022; TEEB, 2012). This concerns closely food system actors like grocery retail businesses with high dependence on primary production and raw materials. Assessment of biodiversity dependencies in the food supply chain can reveal raw materials and production locations with high business and biodiversity risks (The Finnish Food and Drink Industries' Federation, 2023).

In addition to risk management, biodiversity efforts and nature positive solutions can create viable business opportunities and competitive advantage (Jones, 2014; Klein et al., 2023; Sihvonen et al., 2022). For example, The World Economic Forum has estimated that the annual business value of nature-positive business models and resource efficiency could reach 10 trillion dollars globally and generate almost 400 million jobs by 2030 (WEF, 2020a). These opportunities are especially evident in food sector (Sihvonen et al., 2022; WEF, 2020a).

3.3 Biodiversity management in business

This chapter introduces the concept and implementation of corporate biodiversity management and discusses potential measures for companies operating in the food value chain. Biodiversity considerations in companies and food businesses are also briefly discussed.

Inclusion of biodiversity in the sustainability scope of companies has increased in recent years as the understanding of the risks related to biodiversity loss has grown. The management of biodiversity in businesses, corporate biodiversity management, refers to consideration of biodiversity systematically in business decisions and operation. To align biodiversity with its core business, it is reasonable to adopt biodiversity in business strategy and vision, based on materiality assessment (Kurth et al., 2021; Salmi et al., 2023; Sihvonen et al., 2022). Basically, materiality assessment is a method for companies to recognize which environmental, social, and economic topics and impacts are relevant in their operation and which topics are important for their stakeholders (Garst et al., 2022).

In the centre of applying biodiversity management is to understand biodiversity dependencies, opportunities, and impacts (Kurth et al., 2021; Sihvonen et al., 2022). Setting science-based targets, assessing impacts and risks can work as a start for corporate biodiversity management (Kurth et al, 2021; Salmi, 2023). Businesses that create value with sustainability tend to develop and establish targets and supportive key performance indicators (Rosenfield, 2021).

Material impacts of the entire value chain should be mitigated in collaboration with other associated actors (Lammerant et al., 2022b). Obviously, value chain impacts are not completely within the sphere of company’s influence. Thus, companies rely on the engagement and collaboration of stakeholders in biodiversity management of multi-tier supply chains (Salmi et al., 2023).

Mitigation hierarchy is a decision-making approach and guiding principle for biodiversity impact management and mitigation. It can be applied as a guideline in both strategic and everyday decisions regarding biodiversity (Lammerant et al., 2022b; Sihvonen et al., 2023). Mitigation hierarchy sets guiding principles to manage biodiversity impacts in a priority order as follows: avoid, minimize, restore, compensate. Primarily, biodiversity impacts should be avoided, for example by relocating the activity to a less ecologically harmful location (Phalan et al., 2018). If this is not possible, the new and ongoing impacts should be made as low as possible, after which the remaining necessary impacts should be offset to reach no net loss or net positive impact (Lammerant et al., 2022b; Moilanen & Kotiaho, 2021).

Companies can adopt environmental goals that target to no net loss (NLL) and net positive impact (NPI), or nature positive goals (Lammerant et al., 2022b), which mean that the impacts of certain activity or project on biodiversity are balanced (NLL) or exceeded (NPI), so that no overall loss of biodiversity is caused (Rainey et al., 2015). Nature positive means that the company reinforces biodiversity and is transparent with reporting its baseline, targets, actions, and results (Lammerant et al., 2022; Sihvonen et al., 2022). Following principles of mitigation hierarchy is key in achieving successful NLL or NPI targets (Lammerant et al., 2022; Moilanen & Kotiaho, 2021).

Kurth et al. (2021) presented seven biodiversity objectives for businesses operating in the food value chain. Five of them are related straight to the activities on farms, including zero net land conversion, pollution-free & soil-friendly operation, crop diversity increase, and sustainable fisheries and freshwater use. Processing, distribution, and consumption should aim for low-emissions and zero release of packaging and other waste (Kurth et al., 2021). In addition, businesses operating in the food industry can influence promotion and mainstreaming of food chain solutions that improve biodiversity (The Finnish Food and Drink Industries' Federation, 2023). Grocery retails interact with both demand and supply of food through food producers and consumers, having leverage to reduce environmental impacts of food production as well as consumption (Poore & Nemecek, 2018). This can be done for example by setting demands towards producers through sustainability standards, and by communicating and providing options for consumers to make environmentally friendlier dietary decisions (Poore & Nemecek, 2018). Setting targets, engaging producers, and influencing consumer choices requires knowledge of biodiversity impacts. To avoid greenwashing, biodiversity disclosures should be backed with quantitative biodiversity impact information (Lammerant et al., 2022b).

Considering the current biodiversity crisis and related risks related, it should be of interest for businesses to initiate managing biodiversity. Recently, contributed by the rapid changes in the operational environment, biodiversity accounting has emerged as part of companies' sustainability agenda, alongside climate change mitigation efforts (Roberts et al., 2020). There is yet no extensive number of previous studies about biodiversity management in companies, as biodiversity research and literature are quite focused on natural sciences perspectives (Schaltegger, 2022). Recently, studies about biodiversity management in companies have started to emerge. WWF (World Wildlife Fund) Finland together with Bain & Company studied the current state of Finnish companies' biodiversity management by surveying 48 Finnish large companies from different sectors (Klein et al., 2023). They found that businesses are aware of biodiversity and the risk of biodiversity loss to their business. However, when asked about their impacts on biodiversity, the impacts to local and global biodiversity were underestimated or not recognized. These findings were similar to studies made in Sweden and Denmark (Klein et al., 2023). It was also found that businesses might not recognize the advantages of biodiversity mitigation and nature-positive approach. Companies had set biodiversity targets, but they were many times intangible (Klein et al., 2023). In the past years, food chain businesses have expressed they are actively working with biodiversity protection and restoration. 19 global companies, including Unilever, Nestle, Kellogg Co. and Danone S.A., have partnered with WBCSD in a business coalition on biodiversity, focusing on regenerative agriculture and product diversification (Siegner, 2019; WBCSD, 2024). Of these companies, for example Nestle states an increase of regenerative practices in their supply chain (Nestle, 2024).

3.4 Biodiversity impact assessment

This chapter introduces biodiversity impact assessment and biodiversity footprint as a method for assessing biodiversity impacts. To be able to perform effective and informed measures for biodiversity, companies need tools to assess their biodiversity impacts (Jones, 2014). Assessment of biodiversity impacts requires basic understanding of causalities between business operations and biodiversity (Sihvonen et al., 2022). There are already variety of different frameworks, tools, and indicators for businesses to assess biodiversity risks, opportunities and impacts depending on the purpose (Lammerant et al., 2022a; Sihvonen et al., 2022). Some methodologies are already published but harmonized applicable methods of assessing biodiversity impacts of global supply chains have so far remained unavailable for companies (Sihvonen et al., 2022).

The methods to assess biodiversity impacts can be roughly divided to organisational, project, product, or value chain levels (Sihvonen et al., 2022). Before selecting any measurement approach or tool, it is useful to define the purpose, scope, and level of the assessment. For example, are the impacts assessed at organizational or product level, and how precisely one aims to measure the impacts (Lammerant et al., 2022a).

European Business and Biodiversity Platform has created the Biodiversity Measurement Navigation Wheel to guide companies to decide suitable biodiversity impact assessment approach for a given business context and biodiversity drivers (Lammerant et al., 2022a). Recently published biodiversity frameworks, for example by the Taskforce on Nature-related Financial Disclosures, TNFD and Science Based Targets Network, SBTN, also guide on selecting suitable tools for biodiversity impact assessment and disclosures (SBTN, 2023; TNFD, 2024). The SBTN framework requires companies to assess their impacts within their own direct operations, and across the value chain including upstream and downstream segments (SBTN, 2023).

Companies supply chains are often global, long, and spatially disconnected which makes it challenging to link biodiversity impacts of production and consumption (Marques et al., 2017). Such methods covering up- and downstream impacts already exist for the assessment of greenhouse gas emissions, for example Greenhouse Gas Protocol standard (WBCSD & World Resources Institute, WRI, 2004). European Business and Biodiversity Platform has proposed (2022) that it is not necessarily purposeful to develop only one indicator to cover biodiversity, instead there could be several indicators for different purposes. However, this variety of indicators can cause uncertainties of which indicator(s) to use (The Finnish Food and Drink Industries' Federation, 2023). Moreover, different methods assess different biodiversity pressures, varying from land use, climate change, pollution, invasive alien species, marine plastic pollution, and overexploitation (Institute for European Environmental Policy, IEEP, 2021). Currently, there is no method that could exclusively capture the variety of different biodiversity aspects, from the pressures on biodiversity, ecosystems, to the different levels of biodiversity, at the same time (Damiani et al., 2023).

Biodiversity footprint methods aim to measure the impact of certain anthropogenic drivers (e.g., product or activity) to biodiversity loss (IEEP, 2021; Marques et al., 2017). To calculate biodiversity impacts of production and consumption patterns, understanding of the environmental impacts of production is required first (IEEP, 2021). Hereby, combination of different approaches is needed to first capture the amount of mid-point environmental impacts, or drivers of biodiversity loss (e.g. land use, pollution, greenhouse gas emissions), and combine these with end-point biodiversity impacts (IEEP, 2021). For this purpose, the combination of life cycle assessment (LCA) and environmentally extended multi-regional input-output analysis (EEMRIO) can be applied to measure biodiversity footprints (Crenna et al., 2020; IEEP, 2021). In addition, there are also other methods that utilize EEMRIO analysis, but are not directly utilizing LCA (Crenna et al., 2020; Damiani et al., 2023).

Commonly, biodiversity impact assessment methods for assessing the value chain are often based on life cycle assessment (LCA) framework (Crenna et al., 2020; Damiani et al., 2023). Life cycle assessment (LCA) is a product or process specific approach, which considers all the phases of the life cycle of a commodity, from raw material extraction to production, use, and disposal (Marques et al., 2017). After collecting all the resource inputs and emissions from different phases, the amount of environmental impact is measured. LCA is increasingly utilized to assess the environmental impacts associated with food products (Meier et al., 2015). LCA can be based on hybrid analysis, which combines traditional product process analysis (bottom-up) and environmentally extended input-output analysis (top-down) (Crawford et al., 2018).

Environmentally extended multi-regional input-output analysis (EEMRIO) is based on input-output models describing global economic flows across different sectors, with an environmental extension (IEEP, 2021; Marques et al., 2017). Environmental extension enables measuring environmental pressures driven from a certain economical flow, i.e. activity or production sector (Marques et al., 2017). Hereby, EEMRIO analysis can be used to assess biodiversity impacts of consumption patterns and procurements (Marques et al., 2017). Methods require utilizing extensive global databases, such as EXIOBASE, to identify resource use (inputs) and impacts (outputs) of certain activities (Marques et al., 2017). Finally, by combining the information of the LCA and EEMRIO with environmental databases such as LC-IMPACT (Verones et al., 2020), the environmental impacts can be converted to biodiversity loss (El Geneidy et al., 2023).

As a result of combining these approaches, biodiversity footprint of certain consumption activity can be informed with a suitable metric. In LCA-based methods, potentially disappeared fraction of species (PDF) is one of the most used metric (Damiani et al., 2023). As an indicator, PDF describes the amount of risk for species extinction globally due to certain activity. Other applied biodiversity footprint metrics are, for example, LBII, local biodiversity intactness index, and MSA, mean species abundance (IEEP, 2021; Schipper et al., 2020).

4 DATA AND METHODOLOGY

In order to answer the research questions, the empirical part of the study consists of two methodologically separate sections which are described more in depth below in this chapter. The quantitative results of the first empirical part were utilized in the second part which applied qualitative methodology. In the first empirical part, the biodiversity footprint methodology was used to assess biodiversity footprints of different protein sources in respective production countries. In the second empirical part, employees of the case company were interviewed with focus on their perspectives of utilization of such biodiversity footprint information. This chapter explains the two empirical sections of the study after the case company description.

4.1 Case company description

The research was carried out with case study approach of a Finnish organisation S Group. S Group consists of 19 regional cooperatives and SOK Corporation with their subsidiaries, being one of the biggest Finnish grocery chains and market retail companies with its network covering Finland widely with over 1,800 local outlets. In 2022, the amount of S Group's retail sales totalled 13.5 billion EUR and the organisation employed 40,000 people (S Group, 2022). S Group had the biggest market share of Finnish grocery trade in 2022 (Finnish Grocery Trade Association, 2023).

S Group has a wide selection of operations, providing services for example in supermarket consumer trade, department and speciality store trade, traffic services and fuels, travel and hospitality, and banking (S Group, 2022). S Corporation provides expert and support services for S Group cooperatives, for example in sustainability, supply chain management, procurement, and marketing services, and is responsible for the strategic steering and development of the whole S Group and its business chains (S Group, 2022). S Group has a sustainability program, aiming to reach 65% share of plant-based products of total sold products. They are also targeting to sell 80% domestically produced goods. In collaboration with the University of Jyväskylä, S Group has started to measure its impacts on nature and biodiversity (Peura et al., 2023).

4.2 Biodiversity footprint

The purpose of the biodiversity footprint assessment was to calculate biodiversity footprints for food protein sources produced in different countries. Three biodiversity footprint values were calculated for each protein source for functional units: per weight (kilogram), per nutritional content (100 grams of protein), and per energy content (1,000 kilocalories).

Assessed protein sources in this study were beef, lamb, pork, poultry, fish (farmed), crustaceans (farmed), tofu (soybeans), peas, pulses (beans, lentils), and cheese. Production countries of each protein source were selected based on the most common countries of origin in S Group's selection. If the sourcing data was not available, the secondary criteria for selection of production country was based on the biggest production countries of a given protein source globally or in Europe. For example, the origin of human consumed soy, for example in tofu, is often from Europe (Koistinen, 2020).

Finland was used as a production country by default with every protein to be able to compare possible domestic and foreign production scenarios. Because of the outsourcing of biodiversity impacts and different distribution of biodiversity in different countries, it was essential to assess different production countries of protein sources. No hypotheses were formed, but it was expected that differences are found among the protein sources, based on their different environmental impacts.

The applied biodiversity footprint methodology is developed by the researchers in the Biodiversity Footprint Team of the School of Resource Wisdom in the University of Jyväskylä (El Geneidy et al., 2021; El Geneidy et al., 2023; Peura et al., 2023; Pokkinen et al., 2023). Basically, what is needed to calculate the biodiversity footprint of a product is the type and amount of the drivers of biodiversity loss caused by the product supply chain, geographical location of the drivers, and the pressure of the drivers on biodiversity, to be combined with the amount of consumption of the product, such as procurements in euros or amount of a product (El Geneidy et al., 2021; El Geneidy et al., 2023; Peura et al., 2023). The methodology enables assessing a combined biodiversity footprint for terrestrial, marine, and freshwater ecosystems. This study focuses on determining the terrestrial biodiversity footprints, so matters related to freshwater and marine ecosystem methodologies are excluded in this report. As with carbon footprint, biodiversity footprint can be calculated with spend based approach (i.e. EMRIO), LCA-based approach, or with the combination of these two (Crawford et al., 2018). LCA-based approach can provide more realistic information about the actual impacts than spend based approach. In this study, information was combined from LCAs and environmentally extended input-output analysis which applied EXIOBASE database (Figure 1).

	1. Collect product specific driver data: type, amount		2. Determine the location of the drivers		3. Determine biodiversity impact factors, LC-IMPACT		4. Combine biodiversity footprints of all drivers as total biodiversity footprint, PDF/unit
Animal originated protein sources:	Land use of animal feed production, m^2/unit	→	EXIOBASE-model, m^2/unit	x	Country specific factors PDF/m^2	=	Land use biodiversity footprint, PDF/unit
	Land use of pasture, m^2/unit	→	Production country, m^2/unit				
Plant originated protein sources:	Land use of plant cultivation, m^2/unit	→	Production country, m^2/unit				+
Both protein source types:	GHG emissions, CO_2e/unit	→	Global, CO_2e/unit	x	Global factor PDF/CO_2e	=	Climate change biodiversity footprint, PDF/unit

Figure 1. Phases of the calculation process of terrestrial biodiversity footprint for animal and plant originated protein sources per given unit. First phase includes collecting driver specific data, followed by determining the location of the drivers. Third phase applies LC-Impact database to combine biodiversity impact factors with the data obtained from previous steps. Final step is to combine footprints of all drivers to capture total biodiversity footprint per unit. According to the methodology described in El Geneidy et al., 2023; Peura et al., 2023 and Pokkinen et al., 2024).

The calculation started with collecting driver-specific data from different stages of the supply chain of the protein sources in question. The LCA-information in this study was collected from the database of Our World in Data (2023), which is based on Poore & Nemecek (2018) broad meta-analysis of food systems and environmental impacts of food production. The study of Poore and Nemecek (2018) covered around 38,700 commercially viable farms in 119 countries and 40 products representing around 90% of global protein and calorie consumption. The amount of drivers was available for three different units: per kilogram of product, per 100 grams of protein, and per 1,000 kilocalories.

Considered drivers were greenhouse gas emissions (GHG) and land use, which have been previously shown as the main drivers of the total terrestrial biodiversity footprint of agricultural products (Peura et al., 2023). Hence, the collected information of each protein source was land use (in m^2) and emissions (in kg CO_2e) per unit. The global mean values of these drivers for each protein source were used.

Land use data was available regarding the primary production stage. GHG emissions data covered land use change, crop production, pasture, processing, packaging, and retail. Some supply chain stages were excluded, e.g. consumption and disposal, as no useful LCA information was available. However, the included stages represent the supply chain rather well. Hereafter, supply chain refers to the supply chain stages from the primary production and resource extraction to retail stage.

For animal originated protein sources, land use footprint was calculated separately for the land use required to produce the animal feed and for the pastureland needed for grazing. For poultry, fish, and crustaceans, land use driver comprised of animal feed, as there was no information available on the pastureland use or it was not relevant for these protein sources. Beef, lamb, pork, and cheese land use driver comprised of both animal feed production and pastureland use. Land use of pasture was assumed to locate in the production country. Land use distribution associated with the production of animal feed was modelled with EXIOBASE database, which provided the distribution of land use associated with feed consumption in each production country to other countries based on environmentally extended multi-regional input-output analysis approach. The land use of plant originated protein sources was assumed to locate entirely in the production country.

After this, the data was transformed into compatible form with driver-specific characterization factors derived from LC-IMPACT database (Verones et al., 2020). LC-IMPACT provides endpoint characterization factors, i.e. biodiversity impact factors, for each driver, and they are spatially differentiated when appropriate. The metric is PDF, and the values are based on global distribution maps of present number of species in taxonomic groups of vascular plants, birds, mammals, amphibians, and reptiles (Verones et al., 2020). For climate change, the characterization factors are global as the impact distributes globally in the atmosphere. For land use, LC-IMPACT provides country specific characterization factors. Combining the midpoint and endpoint factors resulted with driver specific biodiversity footprint values. Finally, to end up with the total biodiversity footprint, the biodiversity footprints of climate change and land use were combined.

The results of the assessment are reported in Chapter 5 as PDF -values per studied functional unit: kg retail weight, 100 g protein content, or 1,000 kcal energy content. The PDF -value describes the fraction of species globally that are in risk of extinction caused by the consumption of each protein, where higher value means higher footprint, i.e. risk. In addition, the shares of land use and climate change drivers to each footprint are reported. Results are also included in the appendix 1. The individual PDF -values are small, so for clarity they are presented as converted to pPDF -values. Prefix 'p' refers to the SI-system multiplier unit of subdivision, pico, which denotes a factor of one trillionth, 10^{-12}, or 0.000 000 000 001.

4.3 Business perceptions of biodiversity footprint information

The second part of the study follows qualitative research approach with the purpose of collecting subjective information about the case company to gain as versatile understanding as possible about the research topic. Qualitative research aims to interpret and understand different phenomena, relations, and meanings associated with them by the participants, while quantitative research is more interested in testing hypothesis and create generalizable conclusions with statistical analysis (Eriksson & Kovalainen, 2008).

Qualitative research approach was chosen to this part of the study, as the biodiversity footprint concept is rather new, and the objective was to study insights that the case company experts have about biodiversity footprint. In general, case studies are interested in the point of view of the individual, here the case company (Eriksson & Kovalainen, 2008). These insights could be useful for the future development of biodiversity footprint. For this purpose, it was not reasonable to use quantitative approach.

This part of the study aimed to understand the benefits and challenges that business experts associate to biodiversity footprint. The focus is on the food retail business and the purpose is not to test hypotheses but to gain understanding about the topic from business perspective. In general, qualitative study's nature is to gather information with no strict presumptions (Eriksson & Kovalainen, 2008), which aligns with having no hypotheses.

4.3.1 Data collection

Qualitative data can be collected in different ways, such as questionnaires, interviews, observation, or document analysis (Eriksson & Kovalainen, 2008). To answer research questions 2 and 3, interviews were used to collect the information. Qualitative interviews can be strictly structured, semi-structured, or unstructured (Eriksson & Kovalainen, 2008). This study used semi-structured interview, which includes guided outline of topics and questions, and includes both "what" and "how" questions (Eriksson & Kovalainen, 2008).

This method was chosen to gain versatile understanding of the topic, but not give too much freedom to the respondents, aiming to gain insights from premeditated questions. However, the method gives a possibility for conversation between the researcher and interviewee (Eriksson & Kovalainen, 2008), and asking specific questions if necessary was important as the topic and concepts of the study are rather new. Opportunity to ask further questions supports the collection of new information and prevents from making assumptions or conclusions too easily. As the interview included biodiversity footprint examples assessed in the first empirical phase of the study, it was however beneficial to plan the interview structure beforehand.

The data was collected from six individual interviews of experts representing sustainability, business management, and finance business functions (Table 1) in the case company. The focus in this study was mainly on the retail, restaurant, and hospitality operations as those procure and utilize different agricultural products, including protein-rich food products. The participants got a brief material about the topic and main concepts of the interview beforehand, to get familiar with the concept of biodiversity footprint. This was done because the concepts are rather new and complex, to clarify what they mean in this study.

Table 1. Information about data collection with interviews, showing the duration of each interview and business function of the interviewees.

No.	Interviewee	Duration (min)
1	Sustainability	41
2	Sustainability	43
3	Business development	46
4	Sustainability	35
5	Finance	59
6	Sustainability	57

The semi-structured interview focused on the benefits, challenges, and needs related to biodiversity footprint information in business context. It included 5 sections and 13 questions, which are presented in the appendix 2. Interview questions should be related to, but not equal to the research questions (Eriksson & Kovalainen, 2008), which was considered when developing the questions. The interviews were held in Finnish, the questions are translated in English in the attachment. Interview progressed in the following order: first it focused on background questions, after which there was a short theoretical introduction about biodiversity footprint given by the interviewer. After that, the discussion proceeded to the questions towards interviewee regarding biodiversity footprint information. Selected biodiversity footprints were used as illustrative examples to discuss about biodiversity footprint information. All the respondents were asked the same premeditated questions.

4.3.2 Data analysis

In this part of the study, the data from the interviews was transcribed into text for further analysis. Transcribing was done by the researcher by listening the recordings and writing them down at the same time. At this point, the personal information of the interviewees was separated from the transcription.

Thematic analysis is commonly used in qualitative research (Braun & Clarke, 2006), and was chosen as a data analysis method in this study. The purpose of thematic analysis is to analyse and report patterns within data (Braun & Clarke, 2006). Basic idea in thematic analysis is that codes are drawn from the original data, after which the codes are grouped to form themes. Theme is a relevant indicator of something important related to the research question and represent common pattern within the data set (Braun & Clarke, 2006).

In this thesis thematic analysis was performed by the guidelines provided by Braun & Clarke (2006). After the transcription of the text, the transcribed interviews were read through carefully. At the same time, initial codes were drawn from the text. Most of the codes repeated in different interviews. After coding, the codes were translated into excel file, where the grouping of codes to higher level themes was performed. The codes that were not relevant to answer the research questions were not considered in the results of the thematic analysis. Eight themes in total were identified, which were categorized as advantages, challenges, and needs. Final task was to select suitable extracts from the themes that relate to the research question. It is to be noted that thematic analysis is always somewhat influenced by the decisions and interpretations of the researcher (Braun & Clarke, 2006). The results of thematic analysis are explained in Chapter 5.

5 RESULTS

5.1 Biodiversity footprint

5.1.1 Biodiversity footprint per retail weight

Biodiversity footprint per retail weight describes the footprint that is caused by the supply chain of one kilogram of a given protein source. The biodiversity footprints (pPDF/kg) are reported in Figure 2 for each protein source and respective production countries.

As expected, the results showed significant differences in biodiversity footprints among the products as well as between respective production countries. Most of the animal originated proteins had higher biodiversity footprint than plant originated proteins. The mean biodiversity footprint of animal originated proteins (0.29 pPDF/kg) was 16-times higher than of plant originated proteins (0.018 pPDF/kg).

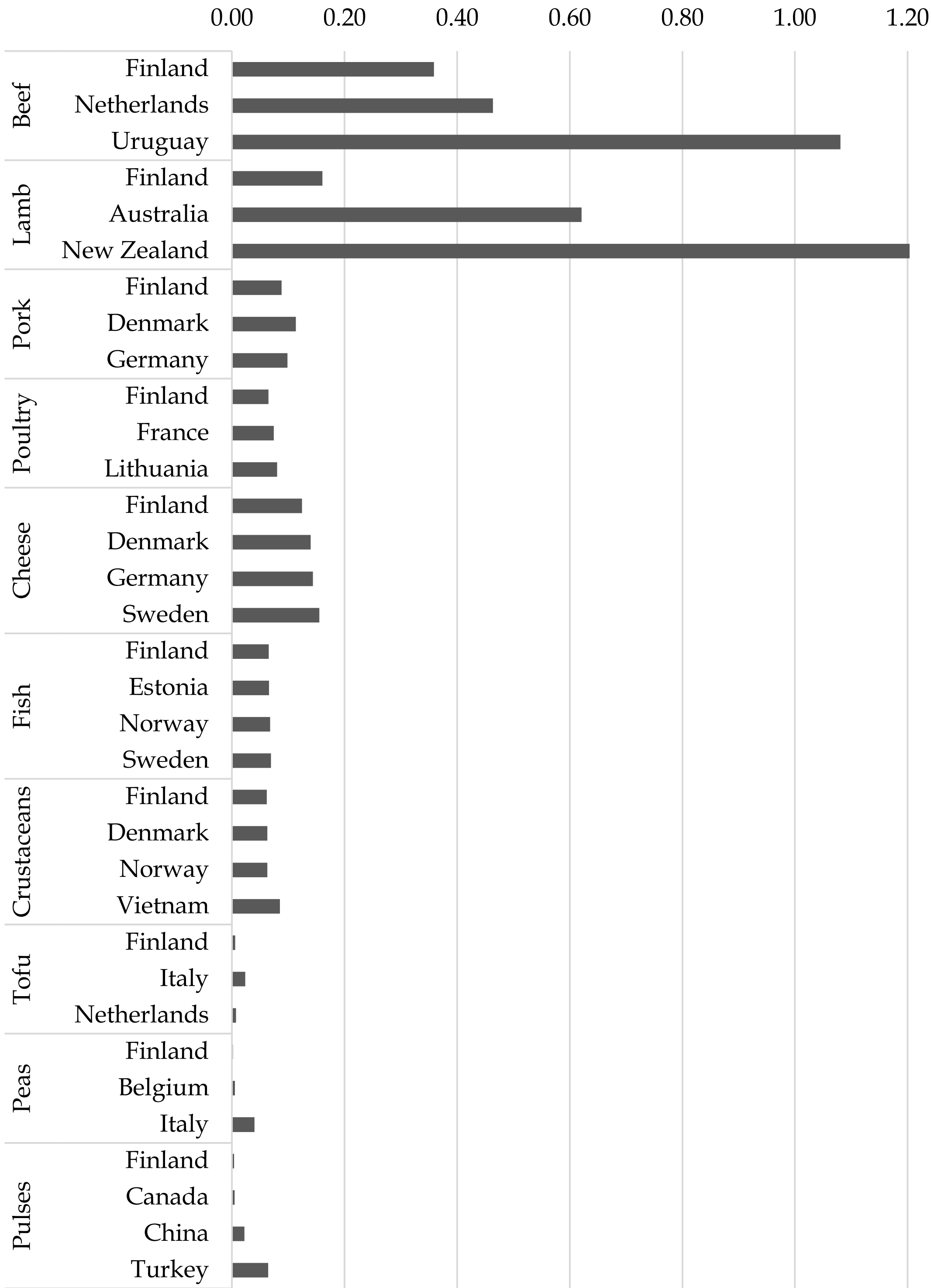

Figure 2. Terrestrial biodiversity footprint of protein sources per kilogram of retail weight (pPDF/kg) for different production countries. The X-axis range is cut at 1.2. to make smaller results distinguish better. The value of lamb produced in New Zealand is 2.6 pPDF/kg).

Of all the protein sources, lamb and beef had the highest biodiversity footprints in every production country. The highest footprint was for lamb produced in New Zealand, followed by beef produced in Uruguay, 2.6 pPDF/kg, and 1.1 pPDF/kg, respectively (Figure 2). Interestingly, cheese had the third highest footprint exceeding pork and poultry. Of animal originated proteins, crustaceans produced in Finland, Denmark, and Norway had the lowest footprint, 0.062 pPDF/kg, followed closely by poultry and fish.

Peas produced in Finland have the lowest biodiversity footprint, 0.0020 pPDF/kg, followed by pulses produced in Finland, 0.0037 pPDF/kg. Interestingly, the production of pulses in Turkey had almost the same biodiversity footprint than the production of poultry and fish.

5.1.2 Biodiversity footprint per protein content

Biodiversity footprint per nutritional content measures the biodiversity footprint of gaining certain nutritional quantity from a food product, here 100 grams of protein. The biodiversity footprints (pPDF/100 g protein) are reported in Figure 3 for each protein source and respective production countries.

As well as with the results per retail weight, there were significant differences between the products and respective production countries as well. All the animal originated proteins had higher biodiversity footprint than plant originated proteins, except for pulses produced in Turkey which have higher footprint than fish or crustaceans. However, the mean biodiversity footprint of animal originated proteins (0.15 pPDF/100 g protein) was almost 17-times higher than of plant originated (0.0089 pPDF/100 g protein).

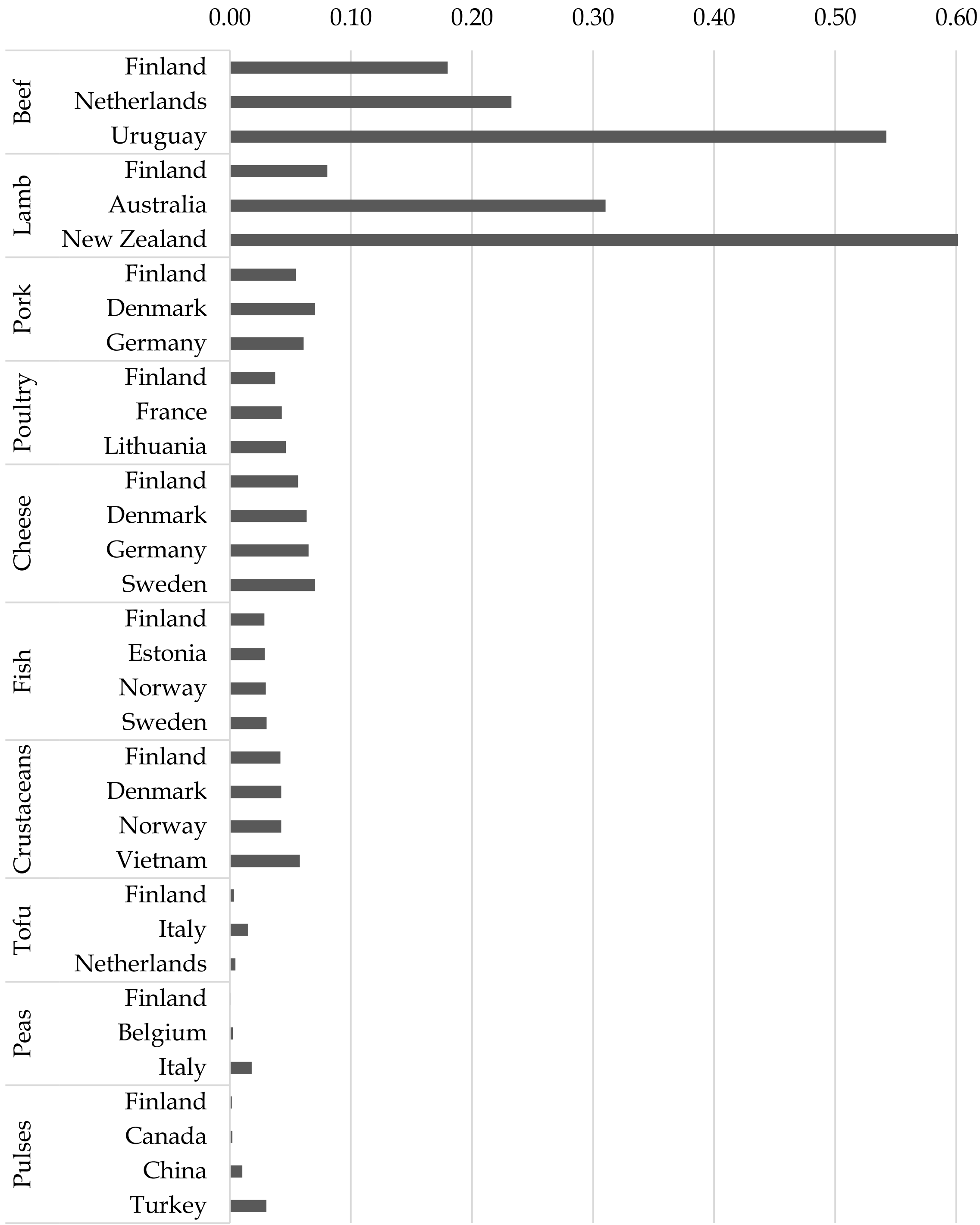

Figure 3. Terrestrial biodiversity footprints of protein sources per nutritional content (pPDF/100 g protein) for different production countries. The X-axis range is cut at 0.6 for the smaller results to distinguish better. The value of lamb produced in New Zealand is 1.3 pPDF/100 g protein.

Of all the protein sources, lamb and beef had the highest footprints in every production country. Lamb produced in New Zealand and beef produced in Uruguay had the highest footprints, 1.3 pPDF/100 g protein, and 0.54 pPDF/100 g protein, respectively (Figure 3). In this comparison, cheese and pork had quite even results. Of animal originated proteins, fish had the lowest footprint, 0.030 pPDF/100 g protein, followed by poultry and crustaceans.

Peas produced in Finland had the lowest footprint, 0.00089 pPDF/100 g protein, followed by pulses produced in Finland, 0.0017 pPDF/100 g protein. Of plant originated proteins, the footprint of Turkish pulses was the highest, 0.030 pPDF/100 g protein, which was the same as fish.

5.1.3 Biodiversity footprint per energy content

Biodiversity footprint per nutritional content indicates the biodiversity footprint of gaining certain nutritional quantity from a food product, here 1,000 kilocalories of energy. The biodiversity footprints (pPDF/1,000 kcal) are reported in Figure 4 for each protein source and respective production countries.

The results per energy content followed the same pattern as the ones per weight and protein content, however with some differences. Here, the difference between animal and plant originated proteins was shown clearly, since all the animal originated proteins had higher biodiversity footprint than plant originated proteins. In addition, the mean biodiversity footprint of animal originated proteins (0.11 pPDF/1,000 kcal) was over 19-times higher than of plant originated proteins (0.0055 pPDF/1,000 kcal).

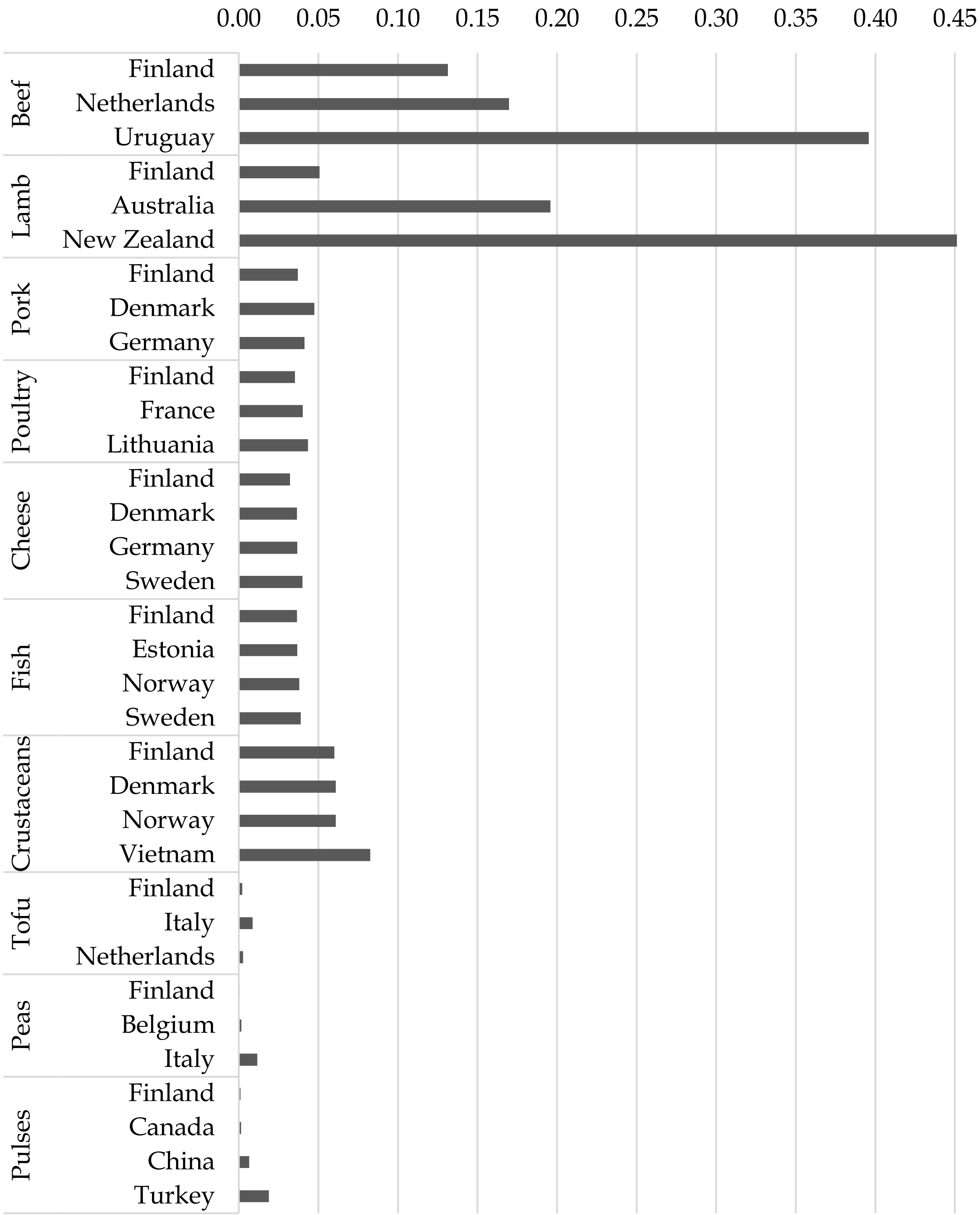

Figure 4. Terrestrial biodiversity footprints of protein sources per nutritional content (pPDF/1,000 kcal) for different production countries. The X-axis range is cut at 0.45 to make smaller results distinguish better. The value of lamb produced in New Zealand is 0.83 pPDF/ 1,000 kcal.

Of all the protein sources, lamb produced in New Zealand and beef produced in Uruguay had the highest biodiversity footprints, 0.83 pPDF and 0.40 pPDF per 1,000 kilocalories, respectively (Figure 4). Crustaceans had the third highest footprint. Of all the protein sources, peas produced in Finland had the lowest footprint, 0.00057 pPDF, followed by pulses produced in Finland, 0.0011 pPDF.

Of animal originated proteins, pork, poultry, cheese, and fish had quite even results, placing between 0.030 and 0.050 pPDF/1,000 kcal. Of plant originated proteins, Turkish pulses (0.019 pPDF) and Italian peas (0.012 pPDF), had the highest biodiversity footprints.

5.1.4 Drivers of biodiversity footprint

To understand the contribution of the drivers of biodiversity loss to the total biodiversity footprint, the shares of land use and climate change were studied. This chapter presents the shares of the drivers of biodiversity loss to the total biodiversity footprint for each protein source and respective production countries in each functional unit: retail weight, amount of protein, and amount of energy. Figures 5, 6, and 7 visualize the shares of land use and climate change drivers of the total terrestrial footprint of different protein sources in respective production countries for each functional unit.

In general, it was shown that the shares of drivers to the total biodiversity footprint behaved similarly in every functional unit of protein sources. Among animal products, land use driver contributed almost always at least 50% to the total biodiversity footprint despite production country or functional unit. An exception to this were crustaceans, where climate change was the principal contributor to the total biodiversity footprint. Among animal originated proteins, the contribution of land use was the highest in New Zealand, whereas plant originated proteins had the same situation for production of tofu in Italy and production of pulses in Turkey.

When comparing animal and plant originated proteins, the latter group showed more variation in the influence of drivers of the total footprint between different production countries and protein types. For example, contribution of the drivers to the footprint of tofu produced in Italy and Netherlands was nearly opposite (Figure 5). Land use had higher influence on the total footprint of plant originated proteins produced in Italy, China, and Turkey.

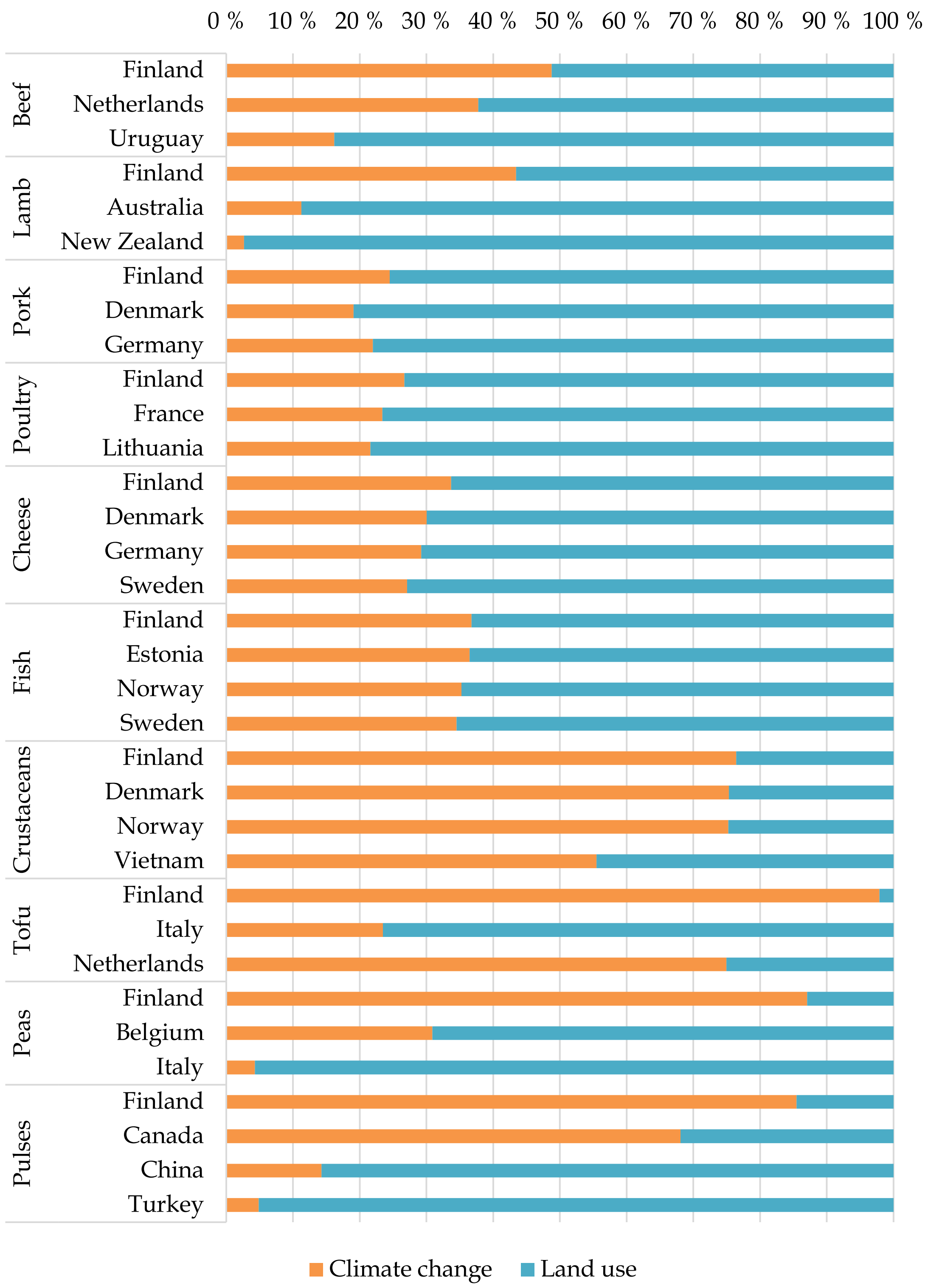

Figure 5. Share of the terrestrial biodiversity footprint (pPDF/kg) driven by climate change or land use for different protein sources in respective production countries.

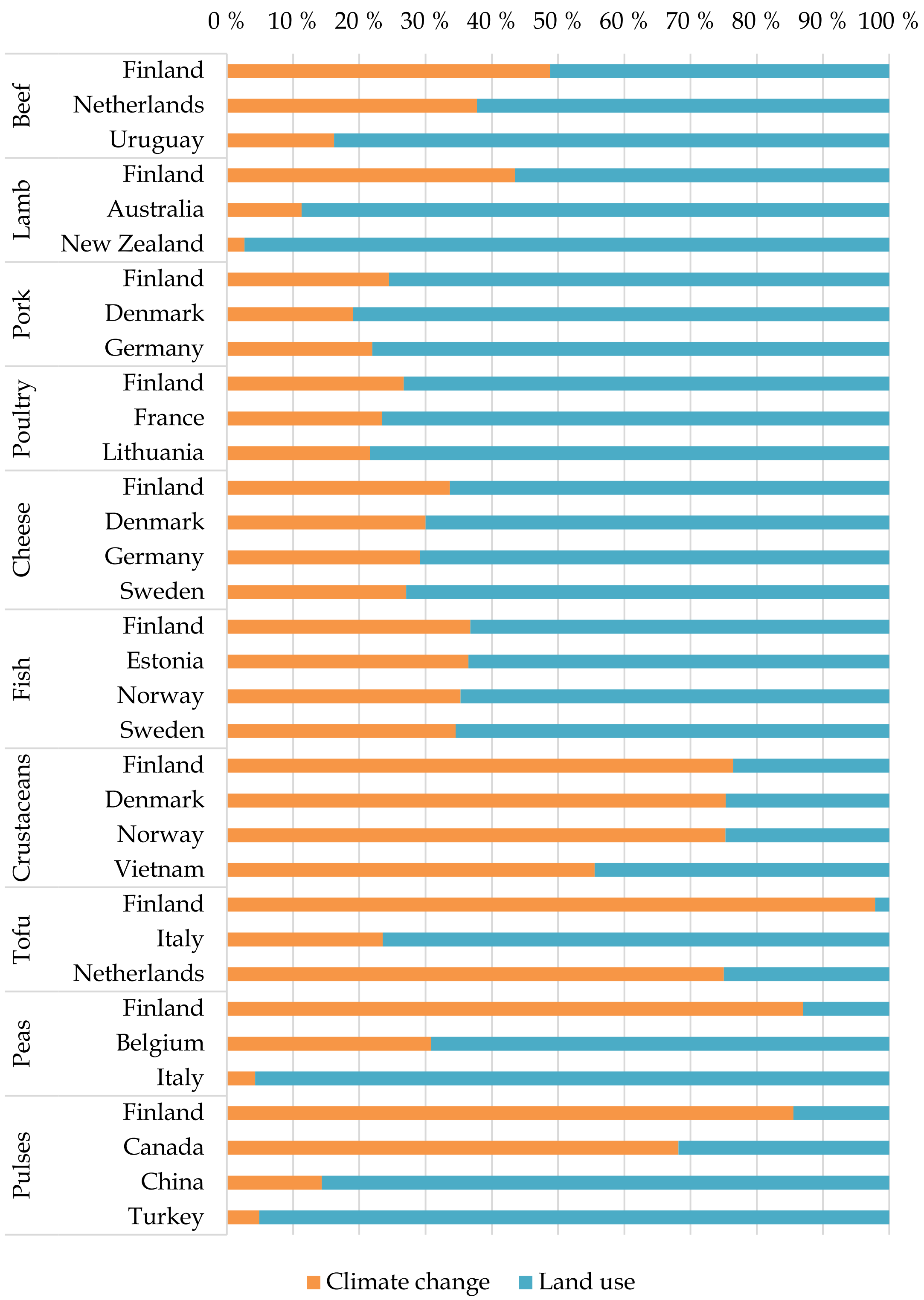

Figure 6. Share of the terrestrial biodiversity footprint (pPDF/100 g protein) driven by climate change or land use for different protein sources in respective production countries.

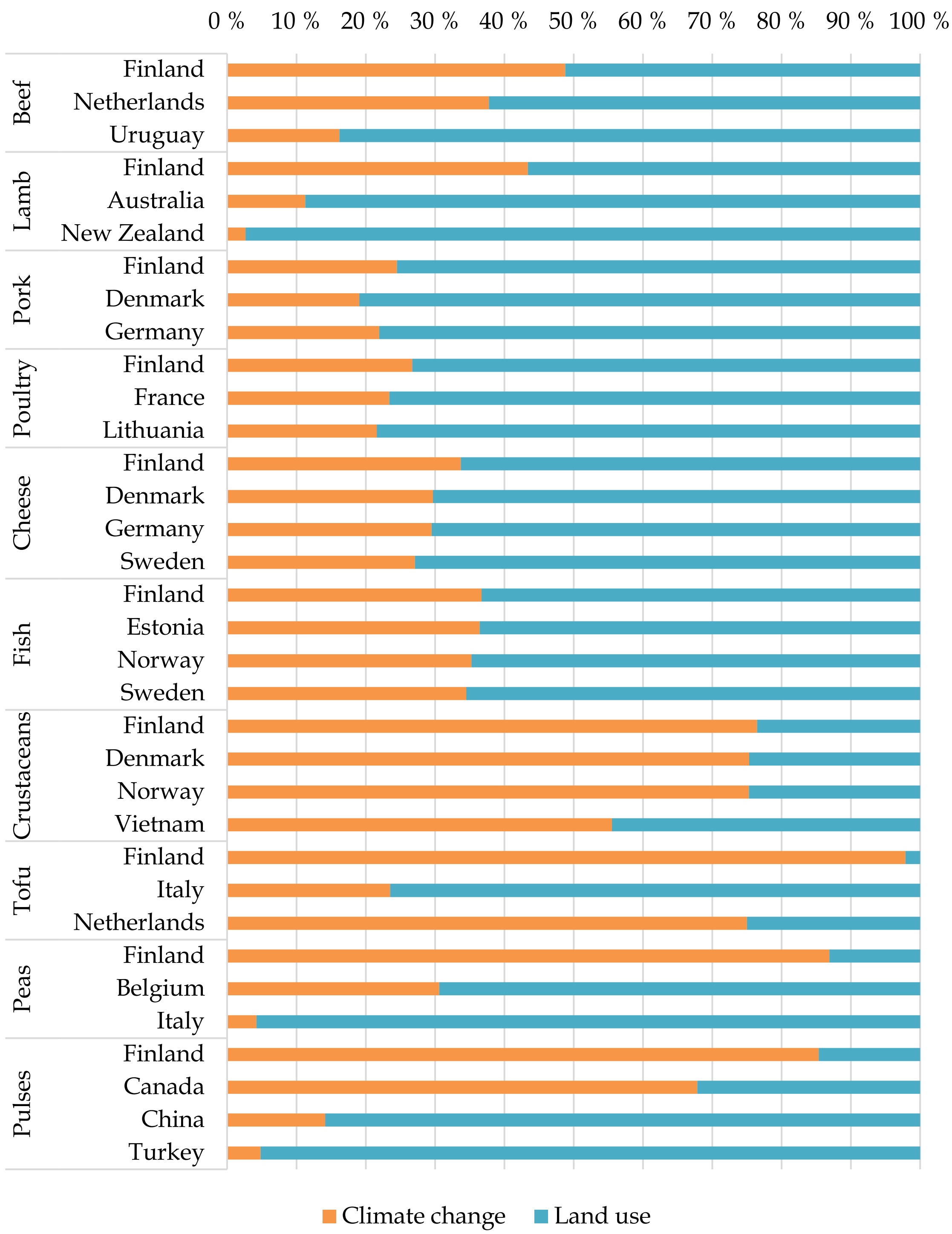

Figure 7. Share of the terrestrial biodiversity footprint (pPDF/1,000 kcal) driven by climate change or land use for different protein sources in respective production countries.

5.2 Business perceptions of biodiversity footprint information

5.2.1 Themes from thematic analysis

This chapter presents the main findings of the thematic analysis of the transcribed interview data. Table 2 presents the found themes and their respective categories to illustrate the main findings.

Table 2. The themes and categories from thematic analysis.

Category	Themes
Advantages	• Management • Serving customers • Business benefits
Challenges	• Qualities of the information • Relation to other environmental data • Resources
Needs	• Qualities of the information • Sources of the information

Advantages, challenges, and needs related to biodiversity footprint information were identified as the main findings in relation to the research questions. As a background information the experts were asked to describe what kind of environmental or climate information is currently used in the company. Greenhouse gas emissions data was the most common tool in use regarding environmental information. Biodiversity footprint information was not in common use at the time of the interviews as management tool in the company. Next, the findings are discussed more in detail in their own chapters.

5.2.2 Advantages of applying biodiversity footprint information

This chapter presents the advantages that the interviewees of the case company associate with biodiversity footprint information and the use of it. Main advantages of biodiversity footprint information and its application were related to managing biodiversity impacts, serving consumers, and gaining business benefits.

In general, biodiversity loss was recognized by all the respondents as the next major topic that will raise on companies' environmental agenda alongside climate change. All the interviewees saw potential in applying biodiversity footprint information either in their own work or in some other way in the organisation.

Management

Management advantages related to biodiversity footprint information were the most mentioned topics by the interviewees. The identified advantages could be divided into areas of understanding impacts of different activities, managing own activities, supply chain management, target setting and follow-up. Biodiversity footprint information was also seen as a tool to reason the measures that are done or needs to be done.

Firstly, biodiversity footprint information was frequently seen as a tool to understand the impacts of own operation and procurements, which was found as a prerequisite of managing the impacts on biodiversity. Understanding biodiversity impacts helps to plan where the mitigation efforts should be focused on. Biodiversity footprint information was mentioned to enable the comparison between products and production locations and give understanding about where the production of different food products is reasonable from the environmental perspective. This was described for example like this:

"Especially when talking about a wholesale or retail business where the value chain is long, where most of the impacts are happening in the beginning of the value chain, this information would be important for our industry" – Interviewee 5

Biodiversity footprint information was also seen as a key to increase the understanding of business management and other stakeholders of the broad concept of nature and biodiversity loss. In addition, quantified data can be used to set goals and increase commitment to reduce biodiversity impacts. Using biodiversity footprint information was seen as a tool for the company to take care of its responsibility towards society. These aspects were discussed for example like this:

"If I think about management, they will understand when we have these metrics. They see that okay, our biodiversity footprint is now five and it should be three, two, or one. Next, they ask how you reach three, two, one, or zero. When we have something that can be measured, we can actually follow that and improve" – Interviewee 1

In supply chain management, biodiversity footprint information can guide the company to make purchasing decisions that have lower impact on biodiversity, for example by avoiding production locations that have higher biodiversity impacts. The information can also be used to guide suppliers and other partners to take measures to reduce biodiversity impacts.

Serving customers

Another often mentioned benefit was the usefulness of biodiversity footprint information in serving customers. Providing biodiversity footprint information to customers was seen as one element to inform customers, as they could compare the biodiversity impacts of different products. The aspects of serving customers were discussed for example like this:

"It would be our job to give consumers the tools they need to easily make decisions of what kind of products – healthy, sustainable or some other – they buy." – Interviewee 5

Providing information was considered as a tool to drive changes in consumers behaviour towards choosing low-impact products if they prefer to do so. Biodiversity footprint information was also seen to be helpful when the company makes decisions on behalf of the customers, meaning that the company itself has leverage to the options among which customers can choose in the first place.

Business advantages

The third frequently mentioned advantage related to the use of biodiversity footprint information was associated with other long-term business benefits, such as ensuring operational conditions for the future, gaining competitive advantage, and brand and reputational benefits.

Considering biodiversity impacts was identified important by few interviewees to manage risks related to the availability of raw materials and products. In the long-term, these considerations were considered to ensure the operational conditions for the business in general. Preparing for biodiversity related risks beforehand was also seen to ensure competitional abilities in a situation where availability of some raw materials is threatened. Business benefits were discussed like this, for example:

"Applying biodiversity footprint information will be beneficial in the long run to ensure that we continue to have food or other products to sell." – Interviewee 2

In addition, it was recognized by some of the interviewees that with applying and reporting biodiversity footprint information as a forerunner, organisation can prove it operates sustainably, which in turn can bring competitional advantage for example in comparison to other companies, or in receiving better funding from financial institutions. Implementing biodiversity footprint information could also support preparing for possible future regulations related to biodiversity impacts of companies.

Brand and reputational benefits were recognized by some of the participants as beneficial causes of applying biodiversity footprint information, showing a forerunner behaviour in sustainability topics. It was mentioned that forerunner status can be appealing to consumers but also to the employees of the company, enhancing employer brand image.

5.2.3 Challenges of applying biodiversity footprint information

This chapter presents the challenges that the interviewees of the case company associate with biodiversity footprint information and the use of it. Main challenges of biodiversity footprint information and its application were matters relating to the information itself, relation of biodiversity footprint information to other environmental information, and resources needed to implement biodiversity footprint information.

Qualities of the information

Matters related to the biodiversity footprint data itself were mentioned by all the respondents as a challenge in applying the information. These matters included data management and quality, reliability, comparability, and clarity. Another main point of the respondents' answers was also that as the concept of biodiversity footprint is new, it needs to gain more familiarity so that different stakeholders understand what it means.

Increasing the familiarity of biodiversity footprint information might require some reasoning of why this kind of new metric should be used. Operational environment and stakeholders were mostly seen as challenges for broad mainstreaming of biodiversity footprint information. Related to operational environment, current carbon footprint focused regulation was seen as a general challenge for adopting biodiversity footprint information broadly, as companies' measures are focused on climate mitigation. Stakeholder-related challenges were related to the interests, and attitudes towards biodiversity footprint information. For example, it was recognized that there might be varying interest among customers towards the information.

In addition, as biodiversity footprint captures many environmental impacts, the respondents saw a challenge that if the meaning and information captured by the biodiversity footprint is not understood, the information is neglected in decision making both within the organization and by customers. It is important that the management of the company is familiar with the concept of biodiversity footprint to promote applying the information in the organisation. Some respondents saw similar challenges as with carbon footprint, referring to the comparability of the information as one challenge. This meant that it can be a challenge if it is not clear how much is a high biodiversity footprint and how much is low. Comparability and meaning of the information was described for example this way:

"Is it a risk, can we continue at the same pace as before, or what does it mean" – Interviewee 4

Another challenge recognized by many of the respondents was related to the management and quality of the biodiversity information. Related topics were collection, accuracy, and updating the information and the background variables of the calculation, as well as the amount of the data especially in case if there would be biodiversity footprints for all products. It was seen as a challenge if these matters would weaken the reliability and comparability of the information. Responsibilities related to data management and quality were also seen as a challenge, if it is not clear which party is responsible for data management and quality, is it the company itself, suppliers, or some other actor.

On a broader scale, assumptions related to the calculation of biodiversity footprint were seen as one challenge if it leads to a situation where the food system gradually begins to take advantage of possible calculation biases. For example, one potential challenge is that changing food production to locations where theoretical biodiversity impact is smaller, could turn out eventually having higher impacts for example due the expansion of land use in new locations.

Relation to other environmental information

Based on the background information described by the respondents, the case company already utilizes some environmental indicators or tools in their environmental management, for example carbon footprint and energy consumption metrics as well as environmental certifications. They also provide carbon footprint for their customers of their purchases via mobile app. There were two kinds of perspectives frequently mentioned among the respondents about the challenge related to the relation of biodiversity footprint with other environmental information.

First one was the relation of biodiversity footprint to carbon footprint information. It was seen as a possible challenge to determine, are biodiversity and carbon footprint information used together, separately, or is the other excluding the other, and when to apply which approach. The decisions between trade-offs of reducing carbon footprint and biodiversity impacts were also recognized as a potential challenge. This topic was described for example like this:

"I recognize that such contradictions might come up, so then you have to evaluate which one is more valuable to you, or from the point of view of your own activity the more valuable thing to promote"
- Interviewee 6

Another perspective mentioned by few participants was the relation of biodiversity footprint information with other environmental information, or eco-labels that are in use currently. It was seen as challenging if the company itself or its stakeholders do not understand how biodiversity information relates to other environmental information. As an example, it was mentioned that consumers might get confused about how they should interpret environmental labels together with biodiversity footprint information.

Resources

A challenge mentioned by almost every interviewee was related to resources required for the implementation of biodiversity footprint information. Resources are comprised here of competence and knowledge related to biodiversity footprint, financial resources needed for implementing and possibly validating the data, and time required for training stakeholders about the concept of biodiversity footprint and information. The size of the company was also seen as a minor challenge in a sense that in a global comparison, relatively small company do not have enough leverage alone to demand changes from larger multinational companies to disclose biodiversity impacts of their products, for example.

Regarding knowledge and competence, the challenges were mostly related to the understanding of the variety of where the biodiversity impacts originate in the first place within the supply chain and that it is not clear what information is needed to assess biodiversity footprint. It was also mentioned that is might be a challenge to recognize what kind of competence a company needs in the first place to interpret the results of biodiversity footprint information correctly to be used in the company in the right way. This was discussed like this:

> *"A good question to ask at the corporate level is what kind of expertise does this kind of indicators mean? What skills need to be increased in the organisation for us to be able to interpret these correctly."- Interviewee 6*

Another challenge was related to the possible financial resources needed to obtain and implement biodiversity footprint information. Obtaining information can cause external costs if the information is not produced within the company. If the information is implemented into company's internal IT-systems, this requires investments as well.

Concentration of knowledge only for certain experts in the company was also seen as a possible challenge in implementing biodiversity footprint information. Increasing the understanding of biodiversity footprint requires training of internal and external stakeholders, which takes time and effort.

5.2.4 Needs related to biodiversity footprint information

To gain understanding about the practical needs for the qualities of biodiversity footprint information, the views of interviewees regarding the topic were collected. Main needs regarding biodiversity footprint information were related to the qualities of the information and the sources for obtaining the information. All participants mentioned that the needs for the accuracy and format of biodiversity footprint information varies depending on the purpose.

Qualities of the information

Mostly mentioned needs for the qualities of the information were related to accuracy, interpretive information, and consistency. All the participants brought up that information about the total footprint was regarded as sufficient level of accuracy when working with most stakeholders. Interviewees were unanimous that detailed information on the components of the total footprint, such as driver-specific data, was regarded relevant especially for sustainability and environmental experts to serve for example in planning mitigation efforts. Product and production country specific information was considered necessary for most of the interviewees, and the need for spatially more accurate information than country level was also mentioned by few participants. In addition, few participants discussed the need for recognizing biodiversity footprints for different production types, to recognize if environmental efforts have an impact on the footprint.

Interpretive information that explains the quantitative biodiversity footprint information and performed calculation was also brought up by most of the interviewees. Common needs related to interpretive information were related to explaining the background variables and assumptions and interpretation of the results. It was considered important to understand why there are differences between countries or products and what would these differences mean if measures are taken based on them. These aspects were described for example as follows:

"If we want to aim towards reducing impact, we also need to know what could be done within the product or production to reduce it and are there factors that influence more than other factors" – Interviewee 2

In addition, it was mentioned by one participant that there could be an estimation about the representativeness of the information, for example how well the results capture the desired drivers, as well as recommendations of complementary tools or indicators in addition to the biodiversity footprint values.

Consistency was also frequently mentioned as a need for biodiversity footprint information. Few respondents brought up, that the information should be in a consistent form which enables its implementation to company's own systems for the purpose of sustainability reporting. In relation to this, almost all interviewees mentioned a need for a standardized methodology or framework for companies to assess and disclose biodiversity footprint in the future.

Sources of the information

There were two ideas brought up by the participants related to the sources of biodiversity footprint information. Mostly, it was highlighted that biodiversity footprint information could be implemented straight into the product information to consider biodiversity aspects already in the procurement. On the other hand, it was suggested that product and production country specific footprint information could be available in a form of a public database service, as the implementation of information to company's own IT-systems might take time and other resources as well, which might delay the uptake of implementing the information in decision-making. This perspective was described for example like this:

"I would not prefer integration into the company's IT systems at the very beginning because it takes a long time and here, we would like to move quickly forward with utilizing the data" – Interviewee 3

Data sources were also discussed from the perspective of consumers by a few interviewees. They brought up that consumers might be interested in knowing the total biodiversity footprint of their purchases as well as the biodiversity footprint of individual products. It was mentioned that in the future, this kind of information could possibly be visible in the company's app for their customers. In addition, it was mentioned that if the biodiversity footprint information is used alongside other product information, it should be stated very clearly so that consumers understand what biodiversity footprint means.

6 DISCUSSION

In this chapter I will discuss the main findings of the results of both empirical parts of the study. First, the results of biodiversity footprint assessment of protein sources are discussed. After that, the chapter continues discussing the main findings of the case company interviews.

6.1 Biodiversity footprints of protein rich food products

This study assessed terrestrial biodiversity footprints for ten commonly used protein-rich food products for different production countries applying the biodiversity footprint methodology by El Geneidy et al. (2023). The purpose was to calculate product and production country specific biodiversity footprint values of the supply chain of each protein per consumption weight (kg) and per nutritional content (protein and energy). Hereby, three production country specific biodiversity footprint values were calculated for each source of protein: per kilogram, per 100 g of protein content, and per 1,000 kcal energy content. It is well known that the environmental and biodiversity impacts of food products vary between animal and plant originated products (Cheng et al., 2024; Crenna et al., 2019; Poore & Nemecek, 2018). However, the product and production country specific biodiversity footprints of protein sources have not been widely studied.

As expected, the results showed that different sources of proteins had substantially different biodiversity footprints per quantity and nutritional units. In principle, animal originated protein sources had significantly higher biodiversity footprints than plant originated protein sources. Beef and lamb had the highest biodiversity footprints, whereas pork, poultry, cheese, fish, and crustaceans had medium footprints. In addition, it was shown that the biodiversity footprint of only producing the animal feed was higher than the total footprint of plant originated protein sources. Peura et al. (2023) and Pokkinen et al. (2024) have previously studied biodiversity footprints of food products, which showed similarly that animal originated products have relatively high biodiversity footprints among food products. Biodiversity impacts of food products have been assessed with different assessment method by Crenna et al. (2019). The results of this study are similar with the results of Crenna et al. (2019), where biodiversity impact of animal products was substantially higher than plant products such as tofu and beans.

Although plant originated protein sources represented most of the lowest biodiversity footprints, the production country could influence that biodiversity footprint reached the level of some animal originated products. This could be explained by the high level of biodiversity in the production country of plant originated protein in question, for example Italy and Turkey (Verones, 2021).

The results showed differences in the biodiversity footprint values of same protein sources and the order of magnitude between protein sources in different functional units. For example, from the perspective of retail weight, crustaceans and fish were the best options among animal products, while from the perspective of protein content, the low-footprint option is fish. In addition, cheese had relatively high biodiversity footprint per retail weight, exceeding for example pork and poultry. Different results have been reported for cheese indicating it has lower impacts than pork and poultry, however similarity is the clear difference to plant products (Crenna et al., 2019). Therefore, substituting meat products with dairy products might cause higher biodiversity footprint, or provide rather low benefits compared to plant originated protein substitutes. However, when the biodiversity footprints were expressed per 100 grams of protein or 1,000 kilocalories, the differences between animal products flattened. For example, when examining the footprint values per nutritional content, cheese did not stand out as clearly than in the comparison of footprints per kilogram weight. These results were explained by the different nutritional density of the protein sources. For example, fish and cheese are the most protein dense animal products (Poore & Nemecek, 2018).

The aspect of domestic production was also studied. Results showed that almost every protein source had the lowest biodiversity footprint when produced in Finland, although there were quite even results among production countries of some protein sources, such as fish and crustaceans. However, it should be noted that any plant originated protein source had significantly lower footprint than any animal originated protein source that was produced in Finland. This implies that changing the production country only results in minor benefits in reducing biodiversity footprint compared to changing the protein source itself. In addition, the degree of domestic origin of the consumption of animal originated proteins in Finland is already high, 83% in 2021 (Lihatiedotusyhdistys ry, n.d.). Experiments of Natural Resources Institute in Finland have indicated that there is potential for increasing the production of protein plant species in southern parts of Finland, for example broad bean and even soybeans (Rantalainen, 2020). However, to increase the attractiveness of protein plant cultivation, farmers need training and support for ensuring yield and productivity, as well as suitable risk management tools in case production is disturbed (Kekkonen et al., 2018).

Biodiversity footprint of production in Finland is lower mainly because in a global comparison, Finland does not have as much biodiversity than the other studied production countries, for example Uruguay, New Zealand, or Italy (Verones, 2021). However, the local biodiversity of Finland or any other country should not be undervalued despite the global comparison, as each country or area has importance in the context of their local ecosystems and species (Peura et al., 2023).

The influence of the drivers of biodiversity loss to the total biodiversity footprint of each product was also studied. Recognizing the influence of drivers creates understanding about the principal driver influencing on the total biodiversity footprint. The results showed that to almost every animal originated protein source, land use was the predominant contributor (over 50%) to the total footprint. Similarly, the study by Crenna et al. (2019), showed land use as the predominant contributor to the total product level biodiversity impact in most of the assessed animal originated food products. Interestingly, climate change was the predominant driver to the footprint of crustaceans. This might be explained by the relationship between the amount of drivers for the supply chain of crustaceans. There are relatively high greenhouse gas emissions (27 kg CO_2e/kg), and at the same time, relatively low requirement of feed land use (3.0 m^2/kg), according to Poore & Nemecek (2018).

In addition, examining production countries revealed great differences in the influence of land use to a given footprint – especially among land use intensive protein sources, such as beef and lamb. These results could be explained by the variables underlying the footprint. Simply, land use footprint is influenced by two variables: the amount of land use and the amount of biodiversity in the location of the land use. For example, of the assessed production countries of beef and lamb, Uruguay and New Zealand have relatively high biodiversity impact factors (Verones, 2021), which means that land use in these countries results in higher biodiversity footprint than in some other production countries with lower biodiversity impact factors. Moreover, the same explanation applies to the variation of the predominant driver among plant originated protein sources.

To conclude, biodiversity footprint per quantity (kg) can be utilized for example to estimate biodiversity impacts of certain amount of food consumption, or food waste. Biodiversity footprint per nutritional content can be used for example to estimate biodiversity impacts of different diets and comparing diets composed of different protein sources. Country specific biodiversity footprints can be utilized to recognize low-impact production countries and production locations where stronger emphasis on agricultural practices securing biodiversity are required. For example, Uruguay and New Zealand are globally among locations of low biodiversity intactness, which indicates that the resiliency and functioning of the ecosystems is already disturbed (WWF, 2022), emphasizing the consideration of biodiversity mitigation in these countries.

Moreover, it is concluded that changing production country without changing the protein source itself does not bring best possible results in lowering biodiversity footprints. Large-scale relocation of production is not the solution but may, despite good intentions, potentially lead to trade-offs or rebound effects (Nijdam et al., 2012). For example, shifting high-impact production to another location might result in similar or greater biodiversity footprint if the pressure of the drivers of biodiversity loss grows significantly in the target areas. Shifting production of highest footprint products to locations with lower biodiversity footprint is a weak shortcut, especially in the current situation where systemic changes to the whole food system are required from the production practices and economic incentives to consumption patterns (Benton et al., 2021).

The findings of this study can serve as directional information for measures that aim to reduce biodiversity footprint of the consumption of protein sources to be used by different actors in food chain, including consumers and groceries. In addition to human population growth, food demand is estimated to be shaped during the next decade by socio-cultural changes, such as urbanisation, and increasing awareness of health and sustainability issues (OECD & FAO, 2021). In the long run, recognizing food products of low biodiversity footprint can inform environmentally sustainable choices. In addition to environmental aspects, there are however social and economic considerations as well to ensure fair sustainability transition of food systems (European Union, 2020).

6.2 Business perceptions of biodiversity footprint information

This chapter discusses the main findings of the interviews, in relation to the research questions of this thesis. The purpose of this second empirical part of thesis was to gain understanding about the business perceptions of applying biodiversity footprint information in the organisation. The findings identified benefits and challenges related to the use of biodiversity footprint information in business context. The interviews also highlighted business needs for biodiversity footprint information and its sources.

Findings of the study indicated that biodiversity footprint information is seen as a useful tool for business. Main advantages of applying biodiversity footprint information were related to strategic and operative management of biodiversity, serving consumers, and gaining business benefits. These findings are similar to the results of previous studies about the role of environmental performance indicators in sustainability strategy implementation and environmental management. For example, review study by Hristov and Chirico (2019) indicated the relevant role of environmental performance indicators in integrating sustainability into business strategy. Previous studies about the business impacts or advantages of specifically implementing biodiversity impact assessment and indicators were not found. However, a study by Kämäräinen (2021) highlighted that companies biodiversity management is challenged by difficulties in finding suitable indicators to measure biodiversity, indicating need for biodiversity assessment tools, such as biodiversity footprint. The findings also indicated that applying biodiversity footprint information could bring business benefits, such as better funding and competitive advantage. The business benefits and value creation advantages of managing environmental performance have been discussed in various studies. For example, Nandy and Lodh (2012) established that companies with higher environmental score are admitted favourable loans than companies with lower environmental performance.

In addition, some challenges were recognized related to the use of biodiversity footprint information in business context. Main challenges of biodiversity footprint information and its application were the matters relating to the information itself, relation of biodiversity footprint information with other environmental information, and resources needed to implement biodiversity footprint information. The concept of biodiversity impacts and footprint are relatively new in business context, and even though the study highlighted the usefulness of biodiversity footprint information, it was also found that resources are needed for adopting biodiversity information into decision-making. Similar barriers for corporate biodiversity management were listed by Schaltegger et al. (2023), including high complexity and abstract nature of the biodiversity concept. This was also highlighted in the findings of Kämäräinen (2021), where it was shown that the understanding of the concept of biodiversity and how to use biodiversity-related information in business context is considered difficult. The challenges related to the novelty of biodiversity footprint might be resolved naturally as people get more familiar with the concept.

In addition to advantages and challenges, this study recognized needs that companies might have related to biodiversity footprint information. The recognized needs were related to the qualities of the information and the sources of the information. The needs associated with the qualities of information were related to its accuracy, comparability, and explanatory information. In addition, business experts might have different needs for the depth of the information depending on the purpose of use.

To conclude, the information regarding benefits of biodiversity footprint information enables identifying where the information can be utilized, whereas recognizing challenges brings visible matters that might hinder the implementation of biodiversity footprint information. Identifying information-related needs can be of use with the further development and mainstreaming of the use of biodiversity footprint. Insights related to the adequate sources of biodiversity footprint information can support companies to identify how the data management and acquisition should be organized in the future to serve efficient biodiversity management.

6.3 Limitations of the study and ideas for future research

Limitations of the study and future research avenues are discussed in this chapter. Biodiversity footprint assessment was based on the availability of LCA information about the environmental impacts of the assessed products. There was variation in the scope of applied LCA information: climate change data covered supply chain stages of production to retail, whereas land use data covered only the production stage. Land use data of further supply chain stages was not available. However, the production stage represents land use well, considering the high land use associated with cultivation and livestock (Nijdam et al., 2012; Poore & Nemecek, 2018). The results of this study are based on average values, and it is recognized that the results might vary among production systems and farms (Poore & Nemecek, 2018).

In addition, it is to be noted that at the time of the biodiversity footprint assessment of this study, the methodology did not enable combining terrestrial, freshwater, and marine biodiversity footprints. As the methodology has developed, it is currently possible to combine the footprints of different ecosystems (El Geneidy et al., 2023). Thus, the terrestrial biodiversity footprint values calculated in this study could be complemented with freshwater and marine ecosystem footprints to gain understanding of the total pressure to terrestrial, marine, and freshwater ecosystems altogether. That would enable analysis of how assessing all ecosystems compares to the results of this study and to the mutual order of magnitude between protein sources. For example, aquaculture is associated with aquatic environmental impacts, such as eutrophication in marine and freshwater ecosystems (Martinez-Porchas & Martinez-Cordova, 2012), therefore considering marine and freshwater footprints might provide more complete view of the biodiversity impacts of fish and crustaceans.

Production country-specific biodiversity footprints might be too high-level to assess and compare different production areas, so the results of this study are not accurate in that sense. In the future, it is possible to assess production areas more precisely within production countries (Peura et al., 2023). Further research is also needed for example regarding the environmental impacts of alternative farming practices, such as organic or regenerative farming (Meier et al., 2015), to demonstrate the biodiversity impacts of these agricultural approaches in comparison to conventional practices.

Regarding the second empirical part which studied the perceptions of business experts of applying biodiversity footprint information, limitations are related to the amount of data. The data was collected from six experts of one company, so more data would be needed to draw broader conclusions about business perceptions of biodiversity footprint information. In addition, majority of the interviewees in this study were working in sustainability business function. Studying views of experts broadly from various business areas, such as marketing and procurement, might reveal different findings. The findings of this study might also be influenced by the predetermined structure and questions of the interview, as these might impact on the topics raised by the respondents (Eriksson & Kovalainen, 2008).

However, the results of this study might indicate ideas for further studies about biodiversity footprint information in business context. From the perspective of applying and mainstreaming the use of biodiversity information among food chain actors, studying the insights of other key food chain actors, for example farmers and consumers, could be useful. Moreover, studying the insights of the experts from companies of different industries and sizes could reveal complementary views and widen the understanding about the application of biodiversity footprint information in business context.

7 CONCLUSIONS

In this interdisciplinary master's thesis, the focus was on combination of two empirical settings: assessing biodiversity footprints of food products and studying the application of such information in business context. First, production country specific biodiversity footprints for different protein-rich food products were assessed. The second part explored insights that business experts of the case company have regarding implementation of biodiversity footprint information, from the perspective of a Finnish retail business.

As one of the first studies about this specific topic of product and country specific biodiversity footprints of protein-rich food products, this thesis shed new light on the different biodiversity impacts of protein-rich food products produced in different countries. As expected, it was found that biodiversity footprint of protein sources had significant differences among protein sources as well as production countries. Thus, changing protein sources to low-footprint options could be an effective measure to reduce the biodiversity footprint of diets.

It was also found that biodiversity footprint information can be applied in the management of biodiversity impacts in grocery business. However, the novelty and complexity of the concept of biodiversity footprint were found to challenge the implementation of biodiversity footprint information, highlighting the need for biodiversity competence in companies.

Findings of this thesis contribute to the understanding of the biodiversity footprint of food production and provides tools for the use of businesses and the society to halt biodiversity loss.

ACKNOWLEDGEMENTS

I want to thank my supervisors Sami El Geneidy, Janne Kotiaho, Marileena Mäkelä, and Maiju Peura for your expertise and support during the thesis project. I also want to thank S Group for the collaboration during the project.

Jyväskylä May 19, 2024
Laura Hynönen

REFERENCES

Ahvo, A., Heino, M., Sandström, V., Chrisendo, D., Jalava, M., & Kummu, M. (2023). Agricultural input shocks affect crop yields more in the high-yielding areas of the world. *Nature Food, 4*, 1037–1046. https://doi.org/10.1038/s43016-023-00873-z

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.-S., Nakashizuka, T., Raffaelli, D., & Schmid, B. (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters, 9,* 1146–1156. https://doi.org/10.1111/j.1461-0248.2006.00963.x

Banks-Leite, C., Ewers, R. M., Folkard-Tapp, H., & Fraser, A. (2020). Countering the effects of habitat loss, fragmentation, and degradation through habitat restoration. *One Earth, 3,* 672-676. https://doi-org.ezproxy.jyu.fi/10.1016/j.oneear.2020.11.016

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., Marshall, C., McGuire, J. L., Lindsey, E. L., Maguire, K. C., Mersey, B., & Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature, 471,* 51–57. https://doi.org/10.1038/nature09678

Bengtsson, J., Ahnström, J., & Weibull, A.-C. (2005). The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of Applied Ecology*, *42*, 261–269. https://doi.org/10.1111/j.1365-2664.2005.01005.x

Benton, T. G., Bieg, C., Harwatt, H., Pudasaini, R., & Wellesley, L. (2021). Food system impacts on biodiversity loss. Three levers for food system transformation in support of nature. Chatham House. https://www.chathamhouse.org/sites/default/files/2021-02/2021-02-03-food-system-biodiversity-loss-benton-et-al_0.pdf

Benton, T. G., Vickery, J. A., & Wilson, J. D. (2003). Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution, 18*(4), 182–188. https://doi.org/10.1016/S0169-5347(03)00011-9

Bommarco, R., Kleijn, D., & Potts, S. G. (2013). Ecological intensification: harnessing ecosystem services for food security. *Trends in Ecology & Evolution, 28*(4), 230–238. https://doi.org/10.1016/j.tree.2012.10.012

Bonhommeau, S., Dubroca, L., Le Pape, O., Barde, J., Kaplan, D. M., Chassot, E., & Nieblas, A. E. (2013). Eating up the world's food web and the human trophic level. *Proceedings of the National Academy of Sciences of the United States of America, 110*(51), 20617–20620. https://doi.org/10.1073/pnas.1305827110

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Brook B. W., Sodhi N. S., & Bradshaw C. J. A. (2008). Synergies among extinction drivers under global change. *Trends in Ecology & Evolution, 23*(8), 453–460. https://doi.org/10.1016/j.tree.2008.03.011

Bull, J. W., Taylor, I., Biggs, E., Grub, H. M. J., Yearley, T., Waters, H., & Milner-Gulland, E. J. (2022). Analysis: the biodiversity footprint of the University of Oxford. *Nature*, *604*, 420–424. https://doi.org/10.1038/d41586-022-01034-1

Campbell, N. A., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Reece, J. B. (2018). *Biology. A Global Approach.* (11th ed.). Pearson Education Limited.

Cardinale, B., Duffy, J., Gonzalez, A. et al. (2012). Biodiversity loss and its impact on humanity. *Nature, 486*, 59–67. https://doi.org/10.1038/nature11148

Cheng, E. M. Y., Cheng, C. M. L., Choo, J., Yan, Y. Carra, L. R. (2024). Biodiversity footprints of 151 popular dishes from around the world. *PLOS ONE 19*(2). https://doi.org/10.1371/journal.pone.0296492

Committee on World Food Security. (2021). *Voluntary Guidelines on Food Systems and Nutrition.* https://www.fao.org/fileadmin/templates/cfs/Docs2021/Documents/CFS_VGs_Food_Systems_and_Nutrition_Strategy_EN.pdf

Convention on Biological Diversity, CBD. (2000). *Sustaining life on Earth.* https://www.cbd.int/doc/publications/cbd-sustain-en.pdf

Convention on Biological Diversity, CBD. (2011). *Convention on Biological Diversity: Text and Annexes*. https://www.cbd.int/doc/legal/cbd-en.pdf

Convention on Biological Diversity, CBD. (2022, December 22). COP15: final text of Kunming-Montreal Global Biodiversity Framework. https://www.cbd.int/article/cop15-final-text-kunming-montreal-gbf-221222

Costanza, R., d'Arge, R., de Groot, R. et al. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387,* 253–260. https://doi.org/10.1038/387253a0

Cowie, R. H., Bouchet, P., & Fontaine, B. (2022). The Sixth Mass Extinction: fact, fiction or speculation? *Biological Reviews, 97*, 640–663. https://doi.org/10.1111/brv.12816

Crawford, R. H., Bontinck, P. A., Stephan, A., Wiedmann, T., & Yu, M. (2018). Hybrid life cycle inventory methods – A review. *Journal of Cleaner Production*, *172*, 1273–1288. https://doi-org.ezproxy.jyu.fi/10.1016/j.jclepro.2017.10.176

Crenna, E., Marques, A., La Notte, A., & Sala, S. (2020). Biodiversity Assessment of Value Chains: State of the Art and Emerging Challenges. *Environmental Science and Technology, 54*(16), 9715–9728. https://doi.org/10.1021/acs.est.9b05153

Crenna, E., Sinkko, T., & Sala, S. (2019). Biodiversity impacts due to food consumption in Europe. *Journal of Cleaner Production*, *227*, 378–391. https://doi.org/10.1016/J.JCLEPRO.2019.04.054

Curtis, P. G., Slay, C. M. Harris, N. L., Tyukavina, A., & Hansen M. C. (2018). Classifying drivers of global forest loss. *Science, 361*(6407), 1108–1111. https://doi-org.ezproxy.jyu.fi/10.1126/science.aau3445

Damiani M., Sinkko, T., Caldeira, C., Tosches, D., Robuchon, M., & Sala, S. (2023). Critical review of methods and models for biodiversity impact assessment and their applicability in the LCA context. *Environmental Impact Assessment Review, 101*. https://doi.org/10.1016/j.eiar.2023.107134
Díaz, S., Fargione, J., Chapin, F. S., 3rd, & Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS biology, 4*(8), e277. https://doi.org/10.1371/journal.pbio.0040277
El Geneidy, S., Alvarez Franco, D., Baumeister, S., Halme, P., Helimo, U., Kortetmäki, T., Latva-Hakuni, E., Mäkelä, M., Raippalinna, L.-M., Vainio, V., & Kotiaho, J. S. (2021). *Sustainability for JYU: Jyväskylän yliopiston ilmasto- ja luontohaitat*. Jyväskylän yliopisto, JYU.Wisdom - School of Resource Wisdom. Wisdom Letters, 2/2021. http://urn.fi/URN:NBN:fi:jyu-202104232476
El Geneidy, S., Baumeister, S., Peura, M., & Kotiaho, J. S. (2023). Value-transforming financial, carbon and biodiversity footprint accounting. https://doi.org/10.48550/arXiv.2309.14186
Eriksson, P., & Kovalainen, A. (2008). *Qualitative Methods in Business Research.* SAGE Publications Ltd. https://doi.org/10.4135/9780857028044
European Environment Agency. (2017, October 18). *Actors in the food chain.* https://www.eea.europa.eu/media/infographics/actors-in-the-food-chain-2/view
Eurostat. (2024, May). Performance of the agricultural sector. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Performance_of_the_agricultural_sector#Value_of_agricultural_output
Fanning, A. L., O'Neill, D. W., Hickel, J., & Roux, N. (2022). The social shortfall and ecological overshoot of nations. *Nature Sustainability, 5*, 26–36. https://doi.org/10.1038/s41893-021-00799-z
Finnish Grocery Trade Association. (2023). *Finnish Grocery Trade*. https://www.pty.fi/wp-content/uploads/2023/06/Paivittaistavarakauppa-ry-2023_EN.pdf
Food and Agriculture Organization of the United Nations, FAO. (2008). *Economics for market-oriented farming*. http://www.fao.org/3/a-i0411e.pdf
Food and Agriculture Organization of the United Nations, FAO. (2018). *Sustainable Food Systems – Concept and Framework*. https://www.fao.org/3/ca2079en/CA2079EN.pdf
Food and Agriculture Organization of the United Nations, FAO. (2022). *World Food and Agriculture – Statistical Yearbook 2022*. Rome. https://doi.org/10.4060/cc2211en
Furman, E., Häyhä, T., & Hirvilammi, T. (2018). *Maapallolle mahtuva tulevaisuus, Näkökulmia Ympäristöpolitiikkaan*. Syke Policy Brief. Finnish Environment Institute. https://helda.helsinki.fi/bitstreams/68fa5c62-3ba3-42f5-980e-c4e0f7d8accb/download
Garst, J., Maas, K., & Suijs, J. (2022). Materiality Assessment Is an Art, Not a Science: Selecting ESG Topics for Sustainability Reports. *California*

Management Review, *65*(1), 64-90. https://doi-org.ezproxy.jyu.fi/10.1177/00081256221120692
Hales, S., McMichael, A. J., & Butler, C. (2005). *Ecosystems and human well-being - health synthesis: A report of the millennium ecosystem assessment.* World Health Organization.
Hanley, N., & Perrings, C. (2019). The Economic Value of Biodiversity. *Annual Review of Resource Economics, 11*. https://doi.org/10.1146/annurev-resource-100518-093946
Hayek, M.N., Harwatt, H., Ripple, W.J., & Mueller, N. D. (2021). The carbon opportunity cost of animal-sourced food production on land. *Nature Sustainability*, *4,* 21–24. https://doi.org/10.1038/s41893-020-00603-4
Hickel, J., Dorninger, C., Wieland, H., & Suwandi, I. (2022). Imperialist appropriation in the world economy: Drain from the global South through unequal exchange, 1990–2015. *Global Environmental Change*, *73*. https://doi.org/10.1016/j.gloenvcha.2022.102467
Hristov I, Chirico A. (2019). The Role of Sustainability Key Performance Indicators (KPIs) in Implementing Sustainable Strategies. *Sustainability*, *11*(20). https://doi.org/10.3390/su11205742
Hooper, D., Adair, E., Cardinale, B., Byrnes, J. E. K., Hungate, B., Matulich, K. L., Gonzalez, A., Duffy, J. E., Gamfeldt, L., & O'Connor, M. I. (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature, 486,* 105–108. https://doi.org/10.1038/nature11118
Houdet, J., Tommetter, M., & Weber, J. (2012). Understanding changes in business strategies regarding biodiversity and ecosystem services. *Ecological Economics*, *73,* 37–46. https://doi.org/10.1016/j.ecolecon.2011.10.013
International Feed Industry Federation. (2023). *Global Feed Statistics.* https://ifif.org/global-feed/statistics/
Institute for European Environmental Policy, IIEP. (2021). *Biodiversity footprints in policy and decision-making: Briefing on the state of play, needs and opportunities and future directions.* Policy report. https://ieep.eu/uploads/articles/attachments/027980bb-f4b6-4c81-a157-504f51d6b373/Biodiversity%20Footprint_Report_IEEP.pdf?v=63801513552
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services.* https://doi.org/10.5281/zenodo.3553579
Jaureguiberry, P., Titeux, N., Wiemers, M., Bowler, D. E., Coscieme, L., Golden, A. S., Guerra, C. A., Jacob, U., Takahashi, Y., Settele, J., Díaz, S., Molnár, Z., & Purvis, A. (2022). The direct drivers of recent global anthropogenic biodiversity loss. *Science Advances, 8*(45). https://doi.org/10.1126/sciadv.abm9982
Jones, M. (Ed.). (2014). *Accounting for Biodiversity*. Routledge.
Kan, D., Patel, R., Pillay, S., Dumont, M., & Broer, W. (2022). *ASN Bank Biodiversity Footprint.* PRé Sustainability B.V. https://www.asnbank.nl/web/file?uuid=14df8298-6eed-454b-b37f-

b7741538e492&owner=6916ad14-918d-4ea8-80ac-f71f0ff1928e&contentid=2453

Kang, Y., Khan, S., Ma, X. (2009). Climate change impacts on crop yield, crop water productivity and food security – A review. *Progress in Natural Science, 19*(12), 1665-1674. https://doi.org/10.1016/j.pnsc.2009.08.001

Kekkonen H., Niemi J., Heinola K., Liu X., Sipilä A., Tuomisto J., Suvanto H., Lähdesmäki M., Enbuska M., Niska nen M., Laitila N. & Vihonen E. (2018). *Valkuaiskasveista Voimaa. Tuota Valkuaista- hankkeen loppujulkaisu*. Luonnonvara- ja biotalouden tutkimus 66/2018. Luonnonvarakeskus. Helsinki. https://jukuri.luke.fi/bitstream/handle/10024/543463/luke-luobio_66_2018.pdf?sequence=1

Klein, A., Tarvainen, A., Nordman, B., Korpela, E-V., Niemi, E., Elofsson, E., Nordbø, E., Namuth, G., Darfelt, J., Lindberg Andersen, J., Kelloniemi, J., Luukkonen, J., Jyrkänkallio-Mikkola, J., Lundgren, J., Fritze, J., Nikula, J., Schrewelius, K., Malmelin, K., …Hvidt, T. (2023). *Finnish businesses & the biodiversity crisis.* WWF & Bain & Company. https://wwf.fi/app/uploads/3/n/t/brj1gr8rj0yjt1az27juij/finnish-businesses-and-the-biodiversity-crisis.pdf

Kremen, C., & Merenlender, A. M. (2018). Landscapes that work for biodiversity and people. *Science 362*(6412). https://doi.org/10.1126/science.aau6020

Koistinen, M. (2020). Soija Syynissä: Ruuaksi, rehuksi vai boikottiin? WWF. https://wwf.fi/uutiset/2020/01/soija-syynissa-ruuaksi-rehuksi-vai-boikottiin/

Kontula, T. & Raunio, A. (eds.). (2018). *Threatened habitat types in Finland 2018. Red List of habitats. Part I: Results and basis for assessment*. (The Finnish Environment 5/2018). Finnish Environment Institute and Ministry of the Environment. http://urn.fi/URN:ISBN:978-952-11-4816-3

Kuepper, B. & Stravens, M. (2022). *Mapping the European Soy Supply Chain – Embedded Soy in Animal Products Consumed in the EU27+UK.* Profundo. https://www.wwf.at/wp-content/uploads/2022/03/WWF-Report-European-Soy-Supply.pdf

Kuhmonen, I. (2023). *Imprisoned by the regime? : farmer agency and farm resilience in the making of a sustainable food system*. [Doctoral dissertation, University of Jyväskylä]. JYU Dissertations. http://urn.fi/URN:ISBN:978-951-39-9854-7

Kurth, T., Wübbles, G., Portafaix, A., zum Felde, M. & Zielcke, S. (2021). *The Biodiversity Crisis Is a Business Crisis*. BCG. https://ec.europa.eu/newsroom/env/redirection/document/76660

Kämäräinen, K. (2021). *Biodiversity management in companies*. [Master's thesis, University of Helsinki]. University of Helsinki Open Repository. http://hdl.handle.net/10138/327429

Lammerant J., Driesen, K., Verhelst, J., De Ryck, J., & Verstraeten, Y. (2022a). *Assessment of Biodiversity Measurement Approaches for Businesses and Financial Institutions. Update Report 4.* EU Business @ Biodiversity Platform. https://circabc.europa.eu/ui/group/da655eff-acfa-4b21-a366-

2795d0e7de39/library/36eb9fd8-751a-4cfb-a043-037ea6b59cb1/details?download=true
Lammerant, J., Verhelst, J., Verstraeten, Y. (2022b). *Nature Positive in a Business Context: Current Working Definition*. Thematic report. EU Business @ Biodiversity Platform. https://ec.europa.eu/environment/biodiversity/business/assets/pdf/2022/EU_B@B_platform_Thematic_Report_Nature_Positive_final_link.pdf
Lihatiedotusyhdistys ry. (n.d.). Lihantuotanto Suomessa. Retrieved April 12, 2024, from https://www.lihatiedotus.fi/tilastotietoa/lihantuotanto-suomessa-2.html
Mace, G. M., Norris, K., & Fitter, A. H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology & Evolution, 27*(1), 19–26. https://doi.org/10.1016/j.tree.2011.08.006
Marques, A., Verones, F., Kok M. TJ., Huijbregts M. AJ., & Pereira, H. M. (2017). How to quantify biodiversity footprints of consumption? A review of multi-regional input–output analysis and life cycle assessment. *Current Opinion in Environmental Sustainability, 29,* 75–81. https://doi.org/10.1016/j.cosust.2018.01.005
Martinez-Porchas, M., & Martinez-Cordova, L. R. (2012). World Aquaculture: Environmental Impacts and Troubleshooting Alternatives. *The Scientific World Journal*. https://doi.org/10.1100%2F2012%2F389623
McKinsey & Company. (2024). *State of Grocery Europe 2024: Signs of Hope*. https://www.mckinsey.com/industries/retail/our-insights/state-of-grocery-europe-2024-signs-of-hope
Meier, M. S., Stoessel, F., Jungbluth, N., Juraske, R., Schader, C., & Stolze, M. (2015). Environmental impacts of organic and conventional agricultural products – Are the differences captured by life cycle assessment? *Journal of Environmental Management, 149,* 193–208. https://doi.org/10.1016/j.jenvman.2014.10.006
Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Biodiversity Synthesis*. World Resources Institute. https://www.millenniumassessment.org/documents/document.354.aspx.pdf
Moilanen, A., & Kotiaho, J. S. (2021). Three ways to deliver a net positive impact with biodiversity offsets. *Conservation Biology, 35*(1), 197–205. https://doi.org/10.1111/cobi.13533
Naess, A. (1984). A defence of the deep ecology movement. *Environmental Ethics, 6,* 265–270. https://doi-org.ezproxy.jyu.fi/10.5840/enviroethics19846330
Nandy, M., & Lodh, S. (2012). Do banks value the eco-friendliness of firms in their corporate lending decision? Some empirical evidence. *International Review of Financial Analysis, 25,* 83-93. https://doi.org/10.1016/j.irfa.2012.06.008
Nemecek, T., Huguenin-Elie, O., Dubois, D., Gaillard, G., Britta Schaller, B., & Chervet, A. (2011). Life cycle assessment of Swiss farming systems: II.

Extensive and intensive production. *Agricultural Systems, 104* (3), 233–245. https://doi.org/10.1016/j.agsy.2010.07.007
Nestle. (2024). *Sustainability at Nestle*. https://www.nestle.com/sustainability
Nijdam, D., Rood, T., Westhoek, H. (2012). The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. *Food Policy, 37*(6), 760–770. https://doi-org.ezproxy.jyu.fi/10.1016/j.foodpol.2012.08.002
OECD/FAO. (2021). *OECD-FAO Agricultural Outlook 2021-2030*. OECD Publishing, Paris. https://doi.org/10.1787/19428846-en
Oehri, J., Schmid, B., Schaepman-Strub, G., & Niklaus, P.A. (2017). Biodiversity promotes primary productivity and growing season lengthening at the landscape scale. *Proceedings of the National Academy of Sciences of the United States of America, 114*(38), 10160–10165. https://doi.org/10.1073/pnas.1703928114
Pearce, D., & Moran, D. (1994). *The Economic Value of Biodiversity*. The World Conservation Union. Earthscan Publications Ltd, London. https://www.cbd.int/financial/values/g-economicvalue-iucn.pdf
Peura, M., El Geneidy, S., Pokkinen, K., Vainio, V., & Kotiaho, J. S. (2023). *Väliraportti: S-ryhmän luontojalanjälki*. University of Jyväskylä. https://doi.org/10.17011/jyureports/2023/20
Phalan, B., Hayes, G., Brooks, S., Marsh, D., Howard, P., Costelloe, B., Vira, B., Kowalska, A., & Whitaker, S. (2018). Avoiding impacts on biodiversity through strengthening the first stage of the mitigation hierarchy. *Oryx, 52*(2), 316–324. https://doi.org/10.1017/S0030605316001034
Pokkinen, K., Kotiaho, J. S., Nieminen, E., Ollikainen, L., Peura, M., Pykäläinen, E., Savolainen, V., Tuunanen, S., Vainio, V., & El Geneidy, S. (2024). *Tampereen kaupun hiili- ja luontojalanjälki.* JYU reports. University of Jyväskylä. https://jyx.jyu.fi/bitstream/handle/123456789/92853/978-951-39-9898-1_JYU_Reports_34_jyx.pdf?sequence=1&isAllowed=y
Poore and Nemecek. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987–992. https://doi-org.ezproxy.jyu.fi/10.1126/science.aaq0216
Pörtner, H.O., Scholes, R.J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W.L., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C., Hickler, T., Hoegh-Guldberg, O., …Ngo, H.T. (2021). *Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change*. IPBES secretariat, Bonn, Germany. https://zenodo.org/doi/10.5281/zenodo.4659158
Rainey, H. J., Pollard, E. H. B., Dutson, G., Ekstrom, J. M. M., Livingstone, S. R., Temple, H. J., & Pilgrim, J. D. (2015). A review of corporate goals of no net loss and net positive impact on biodiversity. *Oryx, 49*(2), 232-238. https://doi.org/10.1017/S0030605313001476
Rantalainen, E. (2020). *Kotimainen soija voi pian olla arkipäivää, vaikka viljelyn piti olla Suomessa mahdotonta – voidaanko tuontisoijalle heittää hyvästit?* Yle. https://yle.fi/a/3-11510270

Read, Q. D., Hondula, K. L., & Muth, M. K. (2022). Biodiversity effects of food system sustainability actions from farm to fork. *Proceedings of the National Academy of Sciences, 119*(15). https://doi.org/10.1073%2Fpnas.2113884119

Ritchie, H., Rosado, P, & Roser, M. (2022) - "*Environmental Impacts of Food Production*". OurWorldInData.org. https://ourworldindata.org/environmental-impacts-of-food

Ritchie, H., & Roser, M. (2024, February 16). *Half of the world's habitable land is used for agriculture*. OurWorldInData.org. https://ourworldindata.org/global-land-for-agriculture

Roberts, L., Hassan, A., Elamer, A., & Nandy, M. (2020). Biodiversity and extinction accounting for sustainable development: A systematic literature review and future research directions. *Business Strategy and the Environment, 30*(1), 705–720. www.doi.org/10.1002/bse.2649

Román-Palacios, C., & Wiens, J. J. (2020). Recent responses to climate change reveal the drivers of species extinction and survival. *Proceedings of the National Academy of Sciences*, *117*(8), 4211–4217. https://doi.org/10.1073/pnas.1913007117

Rosenfield, J. (eds.). (2021). How companies capture the value of sustainability: Survey findings. McKinsey & Company. https://www.mckinsey.com/capabilities/sustainability/our-insights/how-companies-capture-the-value-of-sustainability-survey-findings#/

Salmi, A., Quarshie, A. M., Scott-Kennel, J., & Kähkönen, A.-K. (2023). Biodiversity management: A supply chain practice view. *Journal of Purchasing and Supply Management, 29*(4). https://doi.org/10.1016/j.pursup.2023.100865

Schaltegger, S., Gibassier, D., & Maas, K. (2023). Managing and accounting for corporate biodiversity contributions. Mapping the field. *Business Strategy and the Environment, 32*(5), 2544–2553. https://doi-org.ezproxy.jyu.fi/10.1002/bse.3166

Sandström, V., Kauppi, P. E., Scherer, L., & Kastner, T. (2017). Linking country level food supply to global land and water use and biodiversity impacts: The case of Finland. *Science of the Total Environment*, *575*, 33–40. https://doi.org/10.1016/j.scitotenv.2016.10.002

Schipper, A. M., Hilbers, J. P., Meijer, J. R., Antão, L. H., Benítez-López, A., de Jonge, M. M. J., Leemans, L. H., Scheper, E., Alkemade, R., Doelman, J. C., Mylius, S., Stehfest, E., van Vuuren, D. P., van Zeist, W.-J., & Huijbregts, M. A. J. (2020). Projecting terrestrial biodiversity intactness with GLOBIO 4. *Global Change Biology*, *26*(2), 760–771. https://doi.org/10.1111/gcb.14848

Science Based Targets Network, SBTN. (2023). *Technical Guidance: Step 1: Assess.* https://sciencebasedtargetsnetwork.org/wpcontent/uploads/2023/05/Technical Guidance-2023-Step1-Assess-v1.pdf

S Group. (2022). *S Group and Sustainability 2022 report*. https://assets.ctfassets.net/8122zj5k3sy9/2DPwP469NRA5xJGy0LqQWj/2d90af4dc3a80b0dd1961f3937a53009/S_Group_and_Sustainability_2022.pdf

Sihvonen, H., Clément, N., Pessala, P., Koski, I., Linnamaa, P., Mäntylä, I., Saario, M., & Hjelt, M. (2022). *Mitä luonto merkitsee liiketoiminnalle? Riippuvuudet, vaikutukset ja mahdollisuudet*. Sitran Selvityksiä 202. https://media.sitra.fi/app/uploads/2022/04/sitra-mita-luonto-merkitsee-liiketoiminnalle-1.pdf

Seufert, V., & Ramankutty, N. (2017). Many shades of gray—The context-dependent performance of organic agriculture. *Science Advances*, *3*(3). https://doi.org/10.1126/sciadv.1602638

Siegner, C. (2019). *Food Companies lead the charge to increase biodiversity*. https://www.fooddive.com/news/food-companies-lead-the-charge-to-increase-biodiversity/563531/

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., de Vries, W., Vermeulen, S. J., Herrero, M., Carlson, K. M., Jonell, M., Troell, M., DeClerck, F., Gordon, L. J., Zurayk, R., Scarborough, P., Rayner, M., Loken, B., Fanzo, J., Godfray, H., … Willett, W. (2018). Options for keeping the food system within environmental limits. *Nature*, *562*(7728), 519–525. https://doi.org/10.1038/s41586-018-0594-0

Springmann, M., Kennard, H., Dalin, C., & Freund, F. (2023). International food trade contributes to dietary risks and mortality at global, regional and national levels. *Nature Food* *4*, 886–893. https://doi.org/10.1038/s43016-023-00852-4

Stringer, L. C., Fraser, E. D. G., Harris, D., Lyon, C., Pereira, L., Ward, C. F. M., & Simelton, E. (2020). Adaptation and development pathways for different types of farmers. *Environmental Science & Policy, 104*, 174–189. https://doi.org/10.1016/j.envsci.2019.10.007

Task Force on Nature-Related Disclosures, TNFD. (2024). *Tools catalogue*. https://tnfd.global/guidance/tools-catalogue/

The Economics of Ecosystems and Biodiversity, TEEB. (2012). *Business and Enterprise. The Economics of Ecosystems and Biodiversity in Business and Enterprise*. Edited by Joshua Bishop. Earthscan: London and New York. http://www.teebweb.org/media/2012/01/TEEB-For-Business.pdf

The Finnish Food and Drink Industries' Federation. (2023). *Selvitys luonnon monimuotoisuuden merkityksestä elintarviketeollisuudelle*. https://www.etl.fi/wp-content/uploads/2023/08/biodiversiteettiselvitys_2023.pdf

The United Nations. (1987). *Our Common Future - Brundtland Report*. Oxford University Press. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

The United Nations. (2022, July). *World Population Prospects 2022: Summary of Results*. https://www.un.org/development/desa/pd/

The World Economic Forum, WEF. (2020a). *New Nature Economy Report II: The Future of Nature and Business*. http://www3.weforum.org/docs/WEF_The_Future_Of_Nature_And_Business_2020.pdf

The World Economic Forum, WEF. (2020b). *The Global Risk report 2020*. https://report-files.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf

The World Economic Forum, WEF. (2023, February). *50% of the global economy is under threat from biodiversity loss*. https://www.weforum.org/agenda/2023/02/biodiversity-nature-loss-cop15/

Tuomisto, H. L., Hodge, I. D., Riordan, P., & Macdonald, D. W. (2012). Does organic farming reduce environmental impacts? – A meta-analysis of European research. *Journal of Environmental Management, 112*, 309–320. https://doi.org/10.1016/j.jenvman.2012.08.018

Urban, M. C. (2015). Accelerating extinction risk from climate change. *Science, 348*(6234), 571–573. https://doi.org/10.1126/science.aaa4984

Verones, F., Hellweg, S., Antón, A., et al. (2020). LC-IMPACT: A regionalized life cycle damage assessment method. *Journal of Industrial Ecology, 24*, 1201–1219. https://doi.org/10.1111/jiec.13018

Verones, F. (2021). *LC-IMPACT1.3 (1.3)* [Data set]. Zenodo. https://doi.org/10.5281/zenodo.6200606

World Business Council for Sustainable Development, WBCSD. (2010). *Vision 2050: The New Agenda for Business*. World Business Council for Sustainable Development. https://www.wbcsd.org/Overview/About-us/Vision_2050/Resources/Vision-2050-The-new-agenda-for-business

World Business Council for Sustainable Development, WBCSD & World Resources Institute, WRI. (2004). *A Corporate Accounting and Reporting Standard.* (Rev. ed.). World Resources Institute and World Business Council for Sustainable Development. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

World Economic Forum, WEF. (2023). *The Global Risks* Report 2023. 18th Edition. https://www.weforum.org/reports/

Wilting, H. C., Schipper A. M., Bakkenes, M., Meijer, J. R., Huijbregts, M. A. J. (2017). Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis. *Environmental Science and Technology, 51*(6), 3298–3306. https://doi.org/10.1021/acs.est.6b05296

World Wildlife Fund, WWF. (2022). *Living Planet Report 2022 – Building a nature-positive society*. Almond, R.E.A., Grooten, M., Juffe Bignoli, D., & Petersen, T. (Eds). WWF, Gland, Switzerland. https://wwflpr.awsassets.panda.org/downloads/lpr_2022_full_report_1.pdf

APPENDICES

APPENDIX 1: Biodiversity footprint results

Protein Source	Production country	pPDF/ kg retail weight	pPDF/ 100g protein	pPDF/ 1,000 kcal
Beef	Finland	0.36	0.18	0.13
Beef	Netherlands	0.46	0.23	0.17
Beef	Uruguay	1.08	0.54	0.40
Lamb	Finland	0.16	0.08	0.05
Lamb	Australia	0.62	0.31	0.20
Lamb	New Zealand	2.62	1.31	0.83
Pork	Finland	0.09	0.05	0.04
Pork	Denmark	0.11	0.07	0.05
Pork	Germany	0.10	0.06	0.04
Poultry	Finland	0.07	0.04	0.04
Poultry	France	0.07	0.04	0.04
Poultry	Lithuania	0.08	0.05	0.04
Cheese	Finland	0.12	0.06	0.03
Cheese	Denmark	0.14	0.06	0.04
Cheese	Germany	0.14	0.07	0.04
Cheese	Sweden	0.16	0.07	0.04
Fish (farmed)	Finland	0.07	0.03	0.04
Fish (farmed)	Estonia	0.07	0.03	0.04
Fish (farmed)	Norway	0.07	0.03	0.04
Fish (farmed)	Sweden	0.07	0.03	0.04
Crustaceans (farmed)	Finland	0.06	0.04	0.06
Crustaceans (farmed)	Denmark	0.06	0.04	0.06
Crustaceans (farmed)	Norway	0.06	0.04	0.06
Crustaceans (farmed)	Vietnam	0.09	0.06	0.08
Tofu	Finland	0.006	0.004	0.002
Tofu	Italy	0.024	0.015	0.009
Tofu	Netherlands	0.007	0.005	0.003
Peas	Finland	0.002	0.001	0.001
Peas	Belgium	0.006	0.003	0.002
Peas	Italy	0.040	0.018	0.012
Pulses	Finland	0.004	0.002	0.001
Pulses	Canada	0.005	0.002	0.001
Pulses	China	0.022	0.010	0.006
Pulses	Turkey	0.065	0.030	0.019

APPENDIX 2: List of interview questions

Interview questions: The use of biodiversity footprint information
(Translated from Finnish)

1. **General information**
    a. What is your role in the company?
    b. How environmental sustainability is related to your work?
    c. What environmental information is currently used in your work?
        i. How is that information used?
2. **The utilization of biodiversity footprint information**
    a. What kind of information about the biodiversity impacts of your company is currently available?
        i. How is that information used?
    b. What kind of information you would need about biodiversity footprint?
    c. To what purposes do you need biodiversity footprint information?
    d. What challenges there are in obtaining biodiversity footprint information?
    e. To what extent and accuracy is the information needed?
3. **Challenges and advantages of biodiversity footprint information**
    a. What kind of benefits there are in the use of biodiversity footprint information from your perspective? Why?
    b. What kind of challenges there are in the use of biodiversity footprint information from your perspective? Why?
4. **Qualities of the biodiversity footprint information**
    a. How the biodiversity footprint information should be presented to be efficiently utilized in your work?
    b. Where biodiversity footprint information should be available from your perspective?
5. **Ending**
    a. Would you like to add something?
    Thank you!