Assessing impacts on biodiversity in the building sector

A study on wood and concrete as building materials

Master's thesis in Industrial Ecology

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Cover:
Wood and concrete placed side by side. Photo by Brianna Tucker on Unsplash.

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SUMMARY

Biodiversity is the vast variety of all life on this planet and their interactions together in ecosystems. As the building sector is one of the top three sectors that threatens global biodiversity, the Swedish building company, Sveafastigheter, wants to address the impacts the building sector has on biodiversity by comparing two building materials to each other in a project called Wood vs. concrete. The purpose of this study is to support the Wood vs. concrete project by finding methods to assess biodiversity in the building sector, with the aim to develop tools for biodiversity assessment. The method used has been a literature search, with an integrated case study where Sveafastigheter was interviewed about the Wood vs. concrete project, as well as the indicators identified in this thesis project.

Over a hundred different indicators to assess biodiversity were found which were categorised into three different categories depending on how they were measured. The three different categories were (1) measured with the help of experts, (2) measured with the help of maps or datasets, and (3) measured in investments or reports. A majority of the indicators could be found in category two which included indicators such as the Biodiversity Integrity Index (BII), threatened forest species and Ecosystem Integrity Index (EII). The results of the case study showed that the found indicators were too complex to aggregate into one and that choosing just one that can accurately represent the variety and intricate nature of biodiversity was too complicated.

No current policies, regulations or frameworks that target biodiversity specify what needs to be measured or how to measure biodiversity and the findings of this thesis project showed that there is a need for fast-paced development within this area. Taking this into consideration, five different internal Key Performance Indicators, KPIs, based on the indicator and methods findings, as well as future policy scenarios, were suggested to Sveafastigheter. These internal KPIs would enhance transparency and demonstrate that Sveafastigheter actively engages in measuring something related to biodiversity. Measuring something means that there is at least a sense of direction of where biodiversity assessment and policies should be, and are, headed. The proposed internal KPIs establish a foundation which provides other companies within the building sector knowledge on where to start on their journey in assessing biodiversity impacts when choosing materials.

Keywords: biodiversity, biodiversity assessment, building sector, concrete, extraction sites, indicators, wood

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Louise Albinsson & Mikhaela Larsson
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Acronyms

BII	Biodiversity Intactness Index	26, 27, 29, 30, 40, 49
BREEAM	Building Research Establishment Environmental Assessment Method	36, H6
CBD	Convention on Biological Diversity	1, 3, 5, 6, 9
CCF	Continuous Cover Forestry	17, 18
DNSH	Do No Significant Harm	23–26
EIA	Environmental Impact Assessment	25
EII	Ecosystem Integrity Index	29, 30, 40, 49
ENCORE	Exploring Natural Capital Opportunities, Risks and Exposure	27
FSC	Forest Stewardship Council	14, 36, 38
FSII	Forest Structural Integrity Index	27, 30
GBF	The Global Biodiversity Framework	44, 52
GBIF	Global Biodiversity Information Facility	26
GFW	Global Forest Watch	26
GRI	Global Reporting Initative	35
HSI	Habitat Suitability Index	28, H3
IBAT	Integrated Biodiversity Assessment Tool	26, 35
IBRA	Interim Biogeographic Regionalisation for Australia	42
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services	5
IPCC	Intergovernmental Panel on Climate Change	25
IUCN	International Union for Conservation for Nature	20, 26, 35
KBA	Key Biodiversity Areas	26
KPI	Key Performance Indicator	22, 35, 47, 50
LCA	Life Cycle Assessment	9, 10, 51, 53
MSA	Mean Species Abundance	30, 40, 49
NFP	National Forest Programme	18
PEFC	Programme for the Endorsement of Forest Certification	14, 38
SBTN	Science Based Targets Network	26, 44, 45
SCI	Forest Structural Condition Index	30
SDG	Sustainable Development Goal	4, 5, 37, H6
SFM	Sustainable Forest Management	18
SoEF	State of European Forest	18, 22
UNBL	UN Biodiversity Lab	27
UNEP	United Nations Environmental Programme	1
USGBC	U.S. Green Building Council	37
WDPA	World Database on Protected Areas	26

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1 Introduction

Biodiversity is the vast variety of genes, populations, species and ecosystems, including the interactions between life at all levels on land, in water, in the sea and in the air. Ecosystems can be terrestrial, freshwater or marine, including forests, grasslands and the ocean, and provide us with services vital for life on Earth, such as food and resources, as well as regulate climate, natural hazards, air-and freshwater quality, and soil-and ocean acidification (Almond et al., 2022).

The topic of biodiversity loss raised voices in the 1980's, and the United Nations Environmental Programme (UNEP) created a working group dedicated to biodiversity. In 1992, the Convention on Biological Diversity (CBD) was opened for signature during the Earth Summit in Rio. The convention was inspired by the growing concern of biodiversity loss, and the convention became a legal instrument for the conservation and sustainable use of biological diversity (CBD, 2023). It is estimated that 90% of the global biodiversity loss is due to natural resource extraction and processing (UNEP, 2020). Material extraction and land use changes entails habitat loss for many species, and simultaneously the preservation, conservation, and restoration of habitats are conflicting with the demand for materials in today's society.

In Sweden, the building sector accounts for 20% of the total CO_2 emissions and a third of the country's energy consumption (Sveafastigheter, 2022). A majority of the CO_2 emissions originates from the value chain where the acquisition and use of material and energy use can be identified as the major contributors to this (Skanska, 2022). Sheriff (2022) states that this is often the case of sustainability in the sector, that is, finding itself focusing on carbon and energy, leaving biodiversity overlooked. This despite the fact that the building sector is one of the top three sectors that threatens global biodiversity (Ning Li, 2021).

At present, there is no straightforward approach for the actors in the building sector to assess their impact on biodiversity in the areas where building materials are extracted, as well as throughout the life cycle of a building (Kellner, 2020). The Swedish building company Sveafastigheter has launched a project called Wood vs. concrete, in which they analyse the environmental impact of two similar buildings, one built in wood and the other in concrete. In this project they aim to provide a blueprint for material selection in the building sector, with biodiversity as one of the factors considered. This master's thesis project will contribute to Sveafastigheter's ongoing project by providing an overview of ways to assess impact on biodiversity.

1.1 Aim and research questions

With the starting point in Sveafastigheter's Wood vs. concrete project, the purpose of this thesis was to find methods to assess biodiversity for use in the building sector. The goal was to identify and test the methods for determining whether wood or concrete is the better building material, taking biodiversity into consideration.

Based on the purpose and aim the following research questions was answered during the course of the thesis project.

1. How are limestone and wood extracted and how do the sites and processes impact biodiversity?
2. Are there currently any methods to assess impacts on biodiversity that could be relevant for the building sector?
3. What phases of the materials' life cycles should be considered when evaluating biodiversity impact?
4. What policies and regulations that target biodiversity are used today, and what assessment methods could be usable in the future?

The methods found by answering the second research question provided insights into which stages of the building materials' life cycles that are represented. The third research question was hence partially based on the findings from the second.

1.2 Delimitations

This study concerns the impact on biodiversity when building two semi-identical houses, one with its framework built in wood and the other in concrete. The houses considered for this study are nearly identical with some material quantity adjustments necessary for construction reasons. These adjustments will not be considered, meaning, the differences in material use for isolation and other components in the buildings that entails the material choice of wood or concrete will not be considered. The state of biodiversity will first and foremost be studied in Europe with focus on countries where most raw materials are extracted.

The technical aspects of the building practices, and the differences in the construction phase that may occur for each house will not be considered. This means that the material choice with respect to biodiversity will not be affected by how the entrepreneurs and constructors handle the material at the construction site, but rather the operational aspects of extraction and production of the building materials.

2 Background

Human activities are the main driver of changes to the Earth system in the Anthropocene. Rockström et al. (2009) suggested a way to quantify the boundaries for which human activities could operate safely on Earth. Safely in this context means without destabilising biophysical systems or entering irreversible states of environmental change, especially where functions are crucial for human well-being. The approach was to define planetary boundaries, i.e., limits set to ensure that mankind operates within the Earth's capacity.

Rockström et al. (2009) estimated that three of the boundaries were transgressed, among them is the rate of biodiversity loss. The current rate, and the projected future rate of species loss is what some call the sixth major extinction, the first to be caused or driven by human activities. The importance of biodiversity, besides the end value of life itself, is the services that a healthy ecosystem provides.

The construction industry relies heavily on the natural environment for the supply of raw materials, and the environmental impacts occur at the extraction sites as well as construction sites and by operational services. The construction industry stands for 40% of the world consumption of sand, stone and gravel, and 25% of wood (Ametepey & Ansah, 2015). The building and construction sector by itself contributes to 40% of the total CO_2 emissions and represents a key area where sustainability improvements have to be made (Stora Enso, 2022).

2.1 Drivers of biodiversity decline

Billions of years of evolution have led to the forms of life we see on Earth today, and the biological diversity is the result of adaptation and development through natural processes in nature. Biological diversity, or biodiversity, can be understood as the variety of plants, fungi, animals, and microorganisms found on Earth, as well as genetic variations within different species. Looking more broadly, biodiversity is also defined as the difference between ecosystems on a larger scale, e.g., in forests, deserts, and wetlands (CBD, 2009).

It is the ecosystem services that are the preconditions for life as we know it, with the goods and services nature provides that are essential for breathing, eating, and thriving. In 1992, the Convention on Biological Diversity (CBD) was an agreement adopted at the Earth Summit in Rio. The convention established three goals: conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of the benefits from the use of genetic resources (CBD, 2009).

Twenty years after the Earth Summit in Rio 1992, another set of goals was developed: the Sustainable Development Goals (SDGs) addressing 17 different sustainability issues, among them SDG 15 - Life on land. The goal is to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (UNEP, 2017).

UNEP (2021) states that none of the agreed upon global goals to halt land degradation has been achieved and almost 66% of land is impacted by humans. The consequences are shown in the form of loss of biodiversity and eroding of ecosystem services essential for human well-being, as well as the threat of extinction of one million species of plants and animals. To maintain ecosystems and prevent the irreversible loss of organisms, biodiversity conservation and restoration must be integral when exploiting the ecosystems, as well as protecting areas of importance to biodiversity (UNEP, 2021). This can be done by addressing the five drivers of biodiversity loss which are: changing land and sea use, direct overexploitation of natural resources, pollution, climate change and invasive alien species.

1. **Changing land and sea use**
   Changes of land and sea due to agriculture and urban use is still expanding, putting pressure on natural habitats for all sorts of species. The global food system is the main reason for land use changes. Forests are being cut down to become farmlands, and the ocean is affected by fishery.

   Raw materials such as minerals also entails land use changes, both on land on the ocean floor, together with the direct establishment of built societies and infrastructure (UNEP, 2022).

2. **Direct overexploitation of natural resources**
   The ecosystems providing humanity with food, material and even clean air are threatened to decline due to overexploitation. The limited natural resources are in danger of being used up, such as minerals. Renewable resources are on the other hand threatened by management operations. An ecosystem can be degraded and take a long time to recover, if ever recovered, due to overexploitation (Lampert, 2019).

3. **Pollution**
   Both chemical pollution and waste has negative effects on biodiversity. For example, pesticides can have short term toxic effects on living organisms where the chemicals can directly poison species. Long-term effects from pesticides can be that the toxins accumulate in flora and fauna in the beginning of the food chain, which can be deadly for top predators. Some pesticides used for agricultural uses are harmful for the surrounding environment (Brühl & Zaller, 2019).

4. **Climate change**
   Climate change with increasing mean temperatures globally is estimated to threaten one in six species. Especially marine life and corals, polar ecosystems and mountains are sensitive to the increasing temperatures. Forests, wetlands, and peatlands are important carbon sinks, which is why conserving those nature types are of particular importance regarding biodiversity and the effect that climate change has on it (UNEP, 2022).

5. **Invasive alien species**
   Species that are introduced into an ecosystem they do not originally come from, are called alien. If they disrupt the ecosystem they are introduced to, they are called invasive. Invasive alien species can be both animals, plants, fungi, and microorganisms. They can cause decline or even extinction of natural species in an area. Since the 17th century, invasive alien species have contributed to up to 40% of animal extinction (UNEP, 2022).

2.2 Global and European initiatives for biodiversity

Apart from the former mentioned SDGs created by the UN, there are many other global initiatives created to acknowledge the importance of working against biodiversity decline. In this section four other such initiatives will be introduced, namely IPBES, CBD, The European Union Biodiversity Strategy for 2030 and Natura 2000.

2.2.1 IPBES

IPBES, The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, is an independent intergovernmental body that currently has almost 140 member States whose aim is to improve the interface between science and policy concerning biodiversity and its ecosystem services. The work of IPBES can be grouped into four different categories: *Assessments, Policy Support, Building Capacity and Knowledge* and *Communications and Outreach*. The assessments are made on either specific themes or methodological issues and spatially both globally and regionally (IPBES, 2017a).

2.2.2 CBD

The Convention of Biological Diversity (CBD) was created in Rio in 1992 at the United Nations Conference on Environment, also called Earth Summit. The convention has three main goals:

- The conservation of biodiversity,
- Sustainable use of the components of biodiversity, and
- Sharing the benefits arising from the commercial and other utilisation of genetic resources in a fair and equitable way

Since the creation of the convention, over 187 countries have ratified the agreement, and international law is based on it. The convention is used as guidance and reminds decision-makers that resources are finite, and encourages sustainable use (CBD, 2009).

2.2.3 The European Union Biodiversity Strategy for 2030

In response to the loss of biodiversity, the European Union Biodiversity Strategy for 2030 was put in place in 2020. The strategy sets out a comprehensive long-term plan to protect and strengthen biodiversity globally. The strategy addresses the five main drivers of biodiversity decline and puts an enhanced governance framework in place that encourages and supports the whole of society to take action by building partnerships on local, national and European level (European Commission, 2020).

The strategy is built up by four pillars. The first is protecting nature in the EU, the second is to restore nature, the third to enable transformative change. The fourth pillar is that the EU is to put actions in place to support biodiversity globally and ensuring a high level of EU ambition. By 2030, 30% of the land and sea-area in the EU is to be legally protected and member states are to designate sites to be protected as well as restoring significant areas. According to the strategy, the transformative change will come from the governance framework that will steer implementation of biodiversity commitments on national and European levels (European Commission, 2020).

The EU Biodiversity Strategy Actions tracker shows the progress of the over 100 actions that are to be implemented by 2030. As of writing of this thesis project in May 2023, 47 actions are completed, 47 are in progress and ten are delayed (European Commission, n.d.-a).

2.2.4 Natura 2000

The EU has developed The Habitats Directive, from which Natura 2000 is created. The Habitats Directive is a policy tool to reach the goals set out by CBD. Natura 2000 is a network of areas within the EU of certain protection values, where rare species reside. Different kinds of ecosystems are covered within the network, e.g., freshwater, land, and marine ecosystems (Naturvårdsverket, n.d.).

A protected area can lose its Natura 2000 protection if the area has lost the protection value due to natural happenings and is not possible to restore through maintenance. An open GIS system has been developed so that Natura 2000 areas can be found quite precisely, with borders and characteristics of nature ("Vanliga frågor om Natura 2000", n.d.). The economic activities in a Natura 2000 area may continue as long as they are proven to have no negative effects on the habitats and species in the area. These activities have to be evaluated separately from case to case.

2.3 Indicators

Initiatives, goals, policies and regulations for biodiversity have to be understandable, but assessing biodiversity is complex. Apart from describing the needed actions to enhance the health of ecosystems, it must be possible to communicate their state and compare which actions have improved biodiversity, and which have not.

One way to describe the state of ecosystems or species is with the help of indicators. With indicators one can facilitate monitoring of status and trends, making the information communicative and manageable ("Biodiversity A Global Outlook", 2010). IPBES (2017b) writes that quantitative indicators can have the potential to standardise what guidelines derived from information and knowledge may fail to do - provide a common comparison tool. What needs to be emphasised though is that indicators do not reflect reality completely, but are merely a representation of what can be measured in a complex system. CBD (2007) has developed guidelines to make indicators for biodiversity useful. These guidelines are set up to make the indicators useful and relevant, and to help ensure that they gain legitimacy publicly. When selecting indicators, they should be:

- Policy relevant and meaningful
- Biodiversity relevant
- Scientifically sound
- Broadly accepted
- Based on affordable monitoring
- Based on affordable modelling
- Sensitive

3 Method

Starting off with a request from Sveafastigheter to assess biodiversity impact for material choice, the method has been a literature search, with an integrated case study. The major part of the method has been to map the biodiversity issue, explore extraction practices for raw material, search for tools and methods for assessing biodiversity, and then applying them to a real scenario in a case study. The steps were:

- Literature search: describe biodiversity and its relevance for sustainable development, drivers of biodiversity decline
- Explore practices in forestry and the concrete sector for raw material extraction
- Identify tools and methods: continued literature search by exploring established tools and methods
- Case study: apply the findings to the case in collaboration with Sveafastigheter

3.1 Literature search

To initiate the project on biodiversity impact from building materials, the first task was to describe what biodiversity is, and how it is affected by human activities. Drivers of biodiversity decline were investigated to be able to identify how the building sector and its material demand can affect ecosystems.

The literature search can be described as a narrative literature review and was done by using relevant terms deduced from the problem formulation (Demiris et al., 2019). Key terms in the research were *biodiversity* in combination with the words *assessment*, *measurement*, *decline*, *impact*, and *materials*. The choice of sources for background information was primarily from official organisations to create a legitimate knowledge base. Google Scholar was used for the search. The choices of relevant literature were based on whether the reports and articles provided means of measuring biodiversity, or indicators helpful for biodiversity assessment. Policies, regulations, political and voluntary initiatives were found in the literature search, which then formed the basis in the background for current guidelines and standards.

Information about extraction methods and practices in the geographical area of interest was investigated for by another literature search. Forestry and concrete manufacturing was explored as extraction methods, where the limestone extraction phase was of interest within concrete manufacturing. Articles from NGOs and industry associations have been chosen to get a nuanced picture of the industry and the political issues that are influencing ongoing practices and development.

3.2 Identify tools and methods

A second literature search was conducted to find existing frameworks and initiatives that aimed at measuring, comparing, and describing biodiversity decline. The focus was on the quantification and comparison of biodiversity impacts from the construction and building sectors, specifically in relation to concrete and wood. However, those materials are not isolated to the building sector only, due to which, the research spanned more sectors. Focus was on frameworks relevant in Europe, but also globally. When a tool was identified, the focus was on finding indicators for biodiversity within that tool. By finding indicators that could be useful for assessing biodiversity impact from materials such as wood and concrete, research question number two was targeted.

The indicators within the found tools were chosen according to their relevance for the building sector, or more precisely, for the materials used in the buildings of interest for the case study. Their relevance was decided according to how intuitive, understandable, and measurable the indicators appeared. The CBD guidelines for useful biodiversity indicators in section *2.3. Indicators* provided criteria for choosing indicators. *Scientifically sound*, *biodiversity and policy relevant* were the most important criteria. This means that the sources or developing organs of the indicators, were often scientists, researchers or NGOs.

The third research question, on which phases of the materials life cycle that is relevant for material's biodiversity impact, was answered through reviewing the chosen indicators, together with the case study that was conducted in collaboration with Sveafastigheter. In for example a Life Cycle Assessments (LCA), a system boundary is defined, and the assessments are done with respect to the whole life cycle. Similar choices have to be made for the buildings regarding biodiversity, but all life cycle phases might not be the obvious option for biodiversity assessment, especially not for extraction sites and practices.

Choosing which tools and indicators that could be of good fit for comparison of the two materials was a critical part for this project. The choice of tools and indicators to use in comparison of materials is based on the applicability and usability for Sveafastigheter. Characteristics for the indicators could be, e.g., easily interpreted, data availability, intuitive and understandable, and applicability for different scenarios. The indicators were presented briefly to Sveafastigheter, who could give feedback and thoughts on how they wish to work with biodiversity.

3.2.1 Indicator categorisation

The indicators where categorised according to how they are measured. The categories can be described as different stages in a flowchart, where the first category of indicators was directly measurable attributes in an area or of a material. The second category is generalised data, or data collection, that have been developed from information of category one indicators. The third category includes management strategies, investment statements and certifications, i.e., communication tools for investors and other stakeholders. The third category can entail that the steps in category one and two have already been done.

3.3 Case study

A case study was designed to test the found indicators. This was done to see if the indicators and tools could be applied to the real case, with the goal of making a real contribution to Sveafastigheter and their main issue - to find out which material of wood and concrete that is more sustainable for biodiversity.

The established, already ongoing, project initiated by Sveafastigheter was used as a starting point. The questions Sveafastigheter asks regarding material choices and biodiversity, guided this project when choosing tools for material comparison. Thanks to the case being a real project, material sourcing, quantities and geographical aspects of policies and regulations could be strongly connected to reality. The case was described with basic information about the buildings provided by Sveafastigheter.

3.3.1 Suppliers for the buildings

For the case description for the buildings, a study of the possible suppliers was done. Sveafastigheter suggested suppliers for wood and concrete. It is not yet fully decided which suppliers that will deliver the material, but the suggestions from Sveafastigheter make representative examples that can be used for assessment purposes.

The suppliers' sustainability reports were reviewed, and how, or if, the companies work with biodiversity was derived from information found on their websites and reports. The relevant information on the suppliers was then presented in the case description of this report.

3.3.2 Interview with Sveafastigheter

An interview was conducted with Sveafastigheter when all the identified indicators and methods had been categorised. The interview was held in Swedish through a video call with both interviewers present, interviewing the communications manager and sustainability coordinator, the project manager, the executive CEO, and the team that has conducted the LCA of the buildings studied in the case study.

An outline of the interview questions was prepared, but the interview was kept semi-structured to allow for follow up questions and discussion. The primary objective of this interview was to identify how the interviewees view biodiversity and discuss the relevance and usefulness of the methods that measure biodiversity that had been identified in this thesis project. The questions that were prepared in the outline were:

- How would you define the concept of biodiversity?
- Tell me about how you incorporate biodiversity into your current sustainability work.
- What has been the driving force behind bringing forward these questions about biodiversity?
- Are there any policies that target biodiversity that you address? Which ones are compulsory to follow or report?

In addition to the questions, a short presentation was prepared by the interviewers where the three indicator categories were presented, as well as some examples of indicators. The interview was not recorded, instead key points were noted during the interview.

3.3.3 Apply findings on the case

The findings in the suppliers' sustainability reports that were presented in the case description of this report are mostly analysed and discussed in the discussion section. Some indicators and policies were related to the transparency and sustainability work presented in the reports from Sveafastigheter's possible suppliers, and the case study results section were mostly based on the interview with Sveafastigheter and the indicator collection.

After the interview with Sveafastigheter, and when most of the data collection had been done, the findings were used to evaluate how the tools and indicators could be used in the building sector. The interview answers provided insights in how the company wants to work with biodiversity, and what sustainability issues they wish were possible to assess. The interview answers that were noted were summarised and presented as answers, but without citing each and every respondent. When the indicators were presented to the interviewees, the key takeaways from the discussion that followed the presentation were used as criteria, or guidelines, when selecting some indicators to develop further. These takeaways are presented in the results section.

An explorative development of indicators that could be used by a construction company was done on the basis of the indicator findings and their relevance to current policies and regulations. The five suggested indicators, called internal Key Performance Indicators (internal KPIs), were presented with *purpose*, *definition*, *method*, and *notes*. In purpose, a brief motivation of why the indicator could be relevant was presented. The definition elaborates what is being measured, e.g., unit or comparable description. There are suggestions of methods to assess data, and lastly follows notes with comments on biodiversity positive actions, suggested regulations related to the indicator, further elaboration of appropriate indices, and possible executioners, i.e., what professionals that could be needed for the assessment. These indicators, or internal KPIs, were presented as an inspirational result, on how indicators, tools and policies can be integrated and developed for future research.

4 Case description

In this section the case study is presented, starting with a brief introduction of the buildings that will be studied, as well as the company Sveafastigheter, who are the project owners and initiators of the Wood vs. concrete project. Thereafter the material suppliers of wood and concrete are introduced, with a focus on their sustainability work and the traceability of the raw material.

4.1 The buildings

The buildings that were the focus of the case study are two apartment blocks at 1000 m^2 each. Each apartment will be four stories high and will have the same footprint at the construction site as the width and length are the same for both houses. In total eleven apartment blocks will be built in Vallentuna, Sweden, of which two will be studied for the Wood vs. concrete project.

4.2 The company

Sveafastigheter is a Swedish property development company that develops, builds and manages properties. The company's sustainability strategy was established in 2019 and is the foundation of Sveafastigheter's sustainability work. The sustainability strategy was established using materiality analysis where eight different focus areas were identified: *Working conditions and work environment, Discrimination, Safe environment, Housing for all, Greenhouse gas emissions, Sustainable materials, Energy efficiency* and *Bribes and corruption.* Since the materiality analysis 2019 the focus area *Sustainable suppliers* has been added as well as a climate action plan in 2022. Within Environment the focus areas *Construction waste, Biodiversity* and *Climate certification* have been included (Sveafastigheter, 2022).

During the interview with Sveafastigheter, it was stated that each property built should include at least one action that promotes biodiversity, these actions include, but are not limited to, the inclusion of insect hotels and the planting of fruit trees or berry bushes on the property.

4.3 Material suppliers

Sveafastigheter has suggested three different suppliers for wood, Martinsons, Setra and Stora Enso, and one for concrete, Thomas Betong. In this section a brief introduction will be given to each company, as well as if they do any sustainability work, in particular for biodiversity.

4.3.1 Martinsons & Holmen

Martinsons is a Swedish wood, or sawmill, company that constructs, develops and delivers wooden parts for buildings. They are a part of the Holmen corporation, which is one of Sweden's biggest forest owners with 1.3 million hectares of forest. Since Martinsons became a part of Holmen, they refer to the sustainability report released by Holmen.

On Holmen's official website they write about the importance of preserving forest species, hence they have since many years worked actively with nature conservation and to contribute positively to biodiversity. One of their commitments is to set aside 20% of their forests for conservation. Looking at the fraction of productive forest, 5% is set aside for conservation, with the goal of setting aside another 5%. Holmen make sure to leave deadwood to benefit fauna that are categorised as heritage trees in managed forests, which can help the ecosystem in terms of species conservation (Holmen, n.d.-b).

Apart from managing forests and setting aside forests of high conservation value, Holmen has also helped to restore or create wetlands. Many bird species thrive in wetlands, and the work has been done in collaboration with Svensk Våtmarksfond (Swedish Wetlands Foundation, own translation), (Holmen, n.d.-a).

Holmen state in their sustainability report that their forests are certified with Programme for the Endorsement of Forest Certification (PEFC) and Forest Stewardship Council (FSC), which are two separate global organs working for sustainable forestry, and that all timber is traceable (Holmen, 2021). PEFC are the largest certification organ for sustainable forest management. They take the UNs and Forest Europe's definitions of sustainable forest management into consideration, but they also state that local and national stakeholders are considered as well. It is stated in the Swedish PEFC forestry standard that sustainable forestry should be economically valuable, preserve biodiversity as well as social and cultural values (PEFC, n.d.). Similar to PEFC, FSC have global standards, but with regional and local adjustments. Some topics included in their standard are work environment, indigenous rights, environmental values, and conservation values (FSC, 2020).

4.3.2 Setra

Setra is one of the largest wood industries in Sweden with the core of their business being to refine wood and own no forests themselves. Instead, they have a sustainability policy that dictates that all the wood used in their operations should be traceable back to the logging site and originate from FSC or PEFC certified suppliers (Setra, 2022).

In 2022, all the wood that Setra purchased was exclusively from Sweden and most of it came from the company's owners, Sveaskog, and Mellanskog. In 2022 Setra purchased a total of 3.5 million cubic metres of wood, where pine trees made up 51% of the delivered raw material and fir trees 49%. According to Setra, most of the wood is felled within 13 miles from their own sawmills (Setra, 2022).

To preserve biodiversity, Sveaskog has set aside 10%, or 300 000 hectares of their productive forest areas for conservation purposes, with the goal of setting aside 20% more. Mellanskog has also voluntarily set aside 55 000 hectares of forest for conservation purposes (Setra, 2022).

4.3.3 Stora Enso

Stora Enso is a Finnish-Swedish forest industry group with forests as a real asset that represents almost half of the company's balance sheet. Stora Enso is one of the world's largest forest owners and sources wood through their own forests as well as private forests and are 30% self-sufficient through own assets and long-term agreements with private owners. The total land cover of their total forest assets, both owned and leased, covers a total area of 2.01 million hectares worldwide. Approximately 80% of Stora Enso's wood in 2022 originated from European forests (Stora Enso, 2022). Stora Enso's wood procurement in Europe by region can be seen in table 1 below.

Table 1:
Stora Enso's wood procurement in Europe by region in %. The supply of wood from own and managed forests are included in the total wood procurement. All numbers are approximates (Stora Enso, 2022).

Location	**Total wood procurement**	**Supply from own and managed forests**
Finland	38%	7%
Sweden and Norway	25%	13%
Central Europe	16%	0%
Baltic countries	6%	0%

Stora Enso (2022) states in their annual report for 2022 that biodiversity management has been an integral part of their forest management since the 1990's and have further ambitions, having established a Biodiversity Leadership Programme (BLP). Through this programme, full attention is given to biodiversity management as well as keeping their businesses in line with policy developments regarding biodiversity. When establishing new plantations, only land with low biodiversity areas is used (Stora Enso, 2022). Furthermore, six biodiversity impact indicators, presented in section *6.7. Stora Enso Sustainability Report*, are used to measure biodiversity progress in their own forests in Sweden, Finland and the Baltics (Stora Enso, n.d.).

4.3.4 Thomas Betong

Thomas Betong is a Swedish concrete factory part of the Thomas Concrete Group started in 1955, and is active in Sweden, Poland, Germany, Norway, and USA. In the upstream value chain, the supplier of cement is a company within the Thomas Concrete Group, Thomas Cement, whose mission statement is to secure and develop the long term supply of raw material to the whole group ("Welcome to Thomas Cement", n.d.). Further up the value chain, the suppliers of cement to Thomas Cement are unknown which means that there is no traceability back to where the limestone is extracted. In Team Thomas' Sustainability Report for 2021 however, it is stated that all ready-mixed concrete is produced locally, with local raw materials to shorten the transport routes (Thomas Concrete Group, 2021).

It is also stated that sustainability is a part of Thomas Concrete Group's core business and mission, with several group-wide committees that coordinate and work together, one being the Sustainability Group that focuses on environmental sustainability. The group sets specific sustainability targets that make it easy and clear to set goals and track progress. The four focus areas within environmental sustainability are (1) Concrete with low CO_2 emissions, (2) Concrete constructions with low CO_2 emissions, (3) The lifespan and use phase of concrete and (4) Circular construction. Primary focus is on CO_2 emissions throughout the report, and how to reduce or replace the use of cement, which stands for the majority of the CO_2 emissions in concrete production. Biodiversity is not mentioned in the sustainability report (Thomas Concrete Group, 2021).

5 Extraction sites' impact on biodiversity

The first research question is: How are limestone and wood extracted and how do the sites and processes impact biodiversity? Here follows explanations of how the raw materials are extracted, and common practices for forestry and concrete manufacturing. The industries' impacts on biodiversity are presented as well, with some initiatives to enhance biodiversity in each sector.

5.1 Forestry and biodiversity

There are different types of forestry, depending on, e.g., economic growth, revenue, tradition and politics. The most used forestry method in Sweden is clear-cutting. Another method is continuous cover forestry (Albrektson et al., 2012). According to Hertog et al. (2022), the interest in continuous cover forestry (CCF) is growing in Europe, for example in Switzerland, Southern Germany, Slovenia and Eastern France. In Sweden and Finland, using CCF instead of clear-cutting forestry is met with more scepticism (Hertog et al., 2022).

5.1.1 Clear-cutting forestry

Clear-cutting forestry, or rotation forestry, can be compared to a plantation where the age of the tree cover is homogeneous. When the trees are harvested, they are about the same age and ready for felling, which makes the area of forest almost completely cleared of trees. A few trees are left to protect the new plants from frost, protect the soil from getting saturated by water, and to provide the soil with seeds. The time scale of rotation forestry are decades, with usually longer time spans the further north the forest is located (Albrektson et al., 2012).

The effect that clear-cutting forestry has on biodiversity is that the conditions for life for several species disappear when all trees are cut down, given the homogeneous character it gets when the whole forest is removed. Many concerns regarding the state of the Swedish forest are raised, meaning that it resembles a plantation more than a forest (Naturskyddsföreningen, 2022). The topic is up for debate though, and lack of research on alternative forestry methods is emphasised by academics to map the actual impact on biodiversity that different methods have (SLU, 2023). Associations representing the forest industry, such as the Swedish Forest Industries Federation, stress the climate positive impact the Swedish forest can have, as a response to the criticism clear-cutting forestry faces (Skogsindustrierna, 2020).

5.1.2 Continuous cover forestry

With continuous cover forestry (CCF), the forest is never clear-cut, and trees from all different size and age classes grow in the area. This means that when the trees are harvested, the vegetation still has similar appearance as before, due to the heterogeneous structure of the forest (Albrektson et al., 2012). It is estimated that 22-30% of the European forests are managed with CCF. As for Sweden, it is hard to find data on the share of forest that is managed with CCF, but Hertog et al. (2022) have estimated it to be roughly 5%, or even less.

The yield from clear-cutting forestry and CCF has been empirically studied for comparison and concluded to be approximately 20% lower for CCF. It is hard to tell though the exact difference in yield, and what it depends on (Albrektson et al., 2012). Since the productivity of a forest depends on many different factors, and the life cycles are decades long, assumptions have to be made and that leaves the topic open for discussion.

5.1.3 Forest Europe

Forest Europe is the brand name of the longer version: Ministerial Conference on the Protection of Forests in Europe. Since 1990 they have worked to develop strategies for sustainable forest management in Europe. They develop criteria and indicators that voluntarily can be implemented by the member states (SFRAU, n.d.). The developed framework is called Sustainable Forest Management (SFM), and it is described as guidelines for maintaining a sustainable forestry.

In the State of European Forests (SoEF) report from 2020, Forest Europe collected data from member states. The report shows that most European countries have a National Forest Program (NFP) that uses the guidelines from Forest Europe as input to NFP activities, which gives an indication of the legitimacy of Forest Europe and how it relates to decision-making regarding forest policies. The NFPs are usually used to develop strategic documents that provide guidance on forest policies within a country. 27 out of 31 reporting countries use an NFP. The government, parliament or ministers responsible for forestry within many of the European countries are the formal decision-making organ of the NFP (Köhl et al., 2020).

Forest Europe has aggregated data for how large fractions of forests in each member state that are protected for biodiversity. The standard is called MCPFE class 1, 2 and 3. Class 1 is biodiversity conservation, class 2 is protection of landscapes and specific natural elements, and class 3 is protective functions, which refers to the protective service a forest provides for the surroundings (Alarcón, 2022).

Table 2:
Northern Europe countries' fraction of total forest area and fraction of protected forest area according to MCPFE classification (Köhl et al., 2020)

Country	Forest cover [%]	Class 1 & 2 [%]	Class 3 [%]
Sweden	68.7	7.7	16.4
Germany	32.7	81.1	n/a
Latvia	54.9	16.4	6.4
Lithuania	35.1	16.1	9.9
Estonia	53.8	22.9	5.6
Finland	73.7	18.3	1.1
Norway	33.4	8.8	37.8
Denmark	12.5	20.8	0.0

5.2 The concrete industry and biodiversity

Concrete is the second most used resource in the world after water and is produced by mixing cement with water and an aggregate - a mix of sand and stone. The production of concrete stands for 4-8% of the world's total CO_2-emissions, from which a major part of the carbon footprint comes from the cement production (Watts, 2019).

Cement is made of about 70% of limestone, which is sourced in limestone quarries. In Europe there are about four hundred limestone quarries, many of which affect so-called karst ecosystems which often have unique fauna and underground streams, caves and large springs. These key limestone habitats are unique and formed over millions of years by natural processes which means they are difficult, and sometimes impossible, to restore once damaged. In these areas particular species may exist in a specific part of the extraction site, meaning that operations can lead to global extinction of that species (IUCN, 2014).

Climate change by itself has a major impact on the overall biodiversity but is considered an indirect impact since it does not affect the biodiversity at the specific limestone quarries directly (IUCN, 2014). The conversion and destruction of habitats when clearing for the development of the quarry, but also the surrounding infrastructure such as the construction of roads are direct impacts of quarry operations. Human access to previously unmanaged areas also means that wildlife gets disturbed by noise from blasting and traffic and the extraction activities can also result in polluting the surroundings by emitting a lot of dust to air, disturbing the karst ecosystems where a lot of freshwaters can be found and pollution of soil through the settling of the dust (IUCN, 2014).

5.2.1 A risk-based approach to biodiversity in extraction operations

The IUCN, International Union for Conservation of Nature, suggests a risk-based approach to integrate biodiversity from cradle to grave in extraction operations. The planning stage consists of trying to minimise and avoid impacts by addressing risks of high value biodiversity zones as early as possible, meaning that investments should not be made if risks outweigh the opportunities. At the operational stage all impacts should be minimised as much as possible and biodiversity enhancement should be done. When closing an extraction operation, the used site should be rehabilitated for its final use (IUCN, 2014).

5.2.2 Success stories of quarry restoration

Of the four hundred limestone quarries in Europe, 23% is to be converted to Grassland, 33% to native forest, 36% is for other and 8% to lakes for nature conservation. During the process of rehabilitation, the idea is that the new habitats will create a new space for animals and plants (CEMBUREAU, 2022b).

Creating new habitats during the rehabilitation processes of quarries ensures that animal and plant life can flourish and prosper at the site, contributing to Sustainable Development Goal 15. According to CEMBUREAU (2022b) the ambition of the cement industry is to deliver net gain for nature conservation through projects related to habitat management and restoration and presents successful projects related to the conversion categories: native forest, grassland and lakes. CEMBUREAU (2022b) does however not elaborate on how many of their sites are currently under rehabilitation and lists only a few examples.

CEMEX UK successfully restored the area surrounding its Rugeley site, an active limestone quarry, to Lowland Deciduous woodland. The site was restored in two phases, in the first phase two thirds of the overgrown woodland and scrub was cleared and the bracken on the heathland was controlled. In the second phase the former quarry, called Bevin's Birches, was restored. Rare bird species now inhabit the restored area and there are 41 species of mining bees and wasps present (CEMEX, n.d.). CEMBUREAU (2022a) also presents two cases where the cement industry works with scientific bodies in the pursue of rehabilitation, one in Greece where Titan Cement collaborates with two local universities to record the existing ecosystem around a limestone forest. In this forest over 300 000 plants that were grown at nurseries, have been used for its rehabilitation.

There are currently no quarries that have been successfully rehabilitated as grassland, but in Germany, Cemex is planting grassland in and around the cement plants to increase biodiversity. CEMBUREAU (2022a) lists three examples of when quarries have been rehabilitated as lakes for nature conservation. One is on the Balearic Islands where Cemex rehabilitated land as lake both for the sake of biodiversity conservation, but also as a water supply. In Belgium, parts of a LafargeHolcim quarry is inhabited by a variety of plants, some of which are rare for the region, and a man-made lake environment has been created for recreational and conservatory purposes in the Vicat-Konya Quarry in Turkey.

CEMBUREAU (2022a) specifies that 15% of land that is to be converted is left at active quarries as temporary habitats, that is, leaving extracted land untouched and with no rehabilitative actions for at least a year which enables specific animals and plants to develop. This was done at a Cemex quarry in the UK where grassland naturally regenerated, as well as at a HeidelbergCement site in Germany where the quarry floor naturally developed into wetland and grassland habitats.

6 Assessment methods to measure biodiversity

The second research question is: Are there currently any methods to assess impacts on biodiversity that could be relevant for the building sector? Tools and methods with their corresponding indicators that could be of relevance for Sveafastigheter, and the building sector, are presented in this section. Many indicators are displayed in the appendices to make the section more comprehensible.

6.1 Forest Europe indicators

Forest Europe is a voluntary pan-European forest policy process with the aim of developing common strategies in forestry for member states and organs. The State of Europe's Forests 2020 (SoEF 2020) presents data from member states of the current state of forests in Europe. The authors have presented most of the data by dividing the report into different sustainability issues with corresponding indicators (Köhl et al., 2020).

The indicators are developed as tools to report progress towards the Sustainable Forest Management framework. The indicators are divided into different sustainability categories, where the most accurate category for this project is "Criterion 4: Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems", and are presented in Appendix A.

Examples of indicators are Diversity of tree species, Genetic resources, Forest fragmentation, and Common forest bird species. The indicators are all quite area specific, where an assessment must be done for each forest of interest. As for forest fragmentation, maps and GIS data can be of use for data collection.

6.2 CEMBUREAU Biodiversity Roadmap

CEMBUREAU, a representative organisation of the cement industry in Europe, has developed a Biodiversity Roadmap aimed to improve and continue the biodiversity work at limestone quarries. In this roadmap, a number of biodiversity indicators can be found in the form of Key Performance Indicators (KPIs) where each indicator falls into one of the four focus areas: (1) Ecosystem rehabilitation and Ecosystem services, (2) EU Pollinators Initiative, (3) Invasive Species and (4) Protected Species. These four focus areas address three targets in the EU Biodiversity Strategy Actions Tracker, more specifically targets four, five and twelve (CEMBUREAU, 2022b). The indicators identified in the CEMBUREAU Biodiversity Roadmap are found in Appendix B.

6.3 EU taxonomy

To help guide companies with financing of sustainable activities, a classification system has been created by the EU. This system is called EU taxonomy, a regulation created to set a common definition of which activities that can be called "sustainable". One of the reasons for having this system is to avoid greenwashing by helping investors to more easily navigate towards climate- and nature-friendly investments.

The EU taxonomy consists of six major categories: climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems. While contributing to one or more of these objectives, the economic activity must also Do No Significant Harm (DNSH) to any other of the remaining five objectives (TEG, 2020).

The regulation came into force during the summer of 2020. It is described as a "living document", where sustainable activities will be added continuously. For example, the first sectors that were prioritised for climate change mitigation were those responsible for 93.5% of greenhouse gas emissions in the EU (TEG, 2020).

The most relevant objective for this project is number six: The protection and restoration of biodiversity and ecosystems. The relevant economic activities are forestry, cement and the building sector.

6.3.1 EU taxonomy findings

The first two objectives of the EU taxonomy are the only ones that have substantial contribution criteria. This means that the economic activities, or businesses, can make a positive environmental contribution instantly or for the future, to society. No criteria for substantial contribution to any economic activity has been published for the other four objectives. For the remaining sustainability objectives, only Do No Significant Harm (DNSH) criteria have been published (“EU taxonomy for sustainable activities”, n.d.).

6.3.2 Generic criteria for biodiversity in the EU taxonomy

In EU regulation 2020/852 on the establishment of a framework to facilitate sustainable investment, there are some generic mentions of how biodiversity and ecosystems benefit from the regulation. It says that an economic activity can contribute substantially to the environmental objective of the protection and restoration of biodiversity and ecosystems in several ways. Examples given are protection, conservation, and restoration. Sustainable forest management is defined in the document as well. The term should be used as "management that does not allow degrading of biodiversity, or management that enhances it". Sustainable forest management also covers productivity, regeneration capacity and the potential to fulfil ecological, economic, and social functions now and in the future (European Union, 2020).

Listed in article 15 in Regulation 2020/852 are the descriptions for when an activity is contributing substantially to the protection and restoration of biodiversity and ecosystems. The technical screening criteria for substantial contribution has not yet been published regarding biodiversity and ecosystems, but article 15 gives an indication of what the EU wants to display in the future.

The first point in Article 15 states that an economic activity is contributing if it protects and restores biodiversity and ecosystems through several actions, such as

- nature conservation
- sustainable land use
- sustainable agricultural practices
- sustainable forest management
- enabling activities to the above mentioned actions

Article 15 then describes how the EU will continue to develop the technical screening criteria and implement the regulation by the year 2023. The full article text can be found in Appendix C.

6.3.3 Construction of new buildings in the EU taxonomy

The sector for construction of new buildings falls under "Construction and real estate". This category suits the project of Sveafastigheter, as a developer and manager of housing (Sveafastigheter, n.d.).

The description of this sector clarifies that housing for both residential and non-residential means are covered. For biodiversity, the DNSH criteria presented for this sector is firstly a reference to an appendix, namely "Regulation (EU) 2020/852 Appendix D: Generic criteria for DNSH to protection and restoration of biodiversity and ecosystems". The appendix (European Commission, 2021) says:

> An Environmental Impact Assessment (EIA) or screening has been completed in accordance with Directive 2011/92/EU.
>
> Where an EIA has been carried out, the required mitigation and compensation measures for protecting the environment are implemented.
>
> For sites/operations located in or near biodiversity-sensitive areas (including the Natura 2000 network of protected areas, UNESCO World Heritage sites and Key Biodiversity Areas, as well as other protected areas), an appropriate assessment, where applicable, has been conducted and based on its conclusions the necessary mitigation measures are implemented.

Secondly, the regulation brings up land use, where the criteria is that the buildings can not be established on land that has a high value of soil fertility or greenfield land with high biodiversity value that serves as habitat for red listed species. Furthermore, one can not build on land defined as forest used in the national greenhouse gas inventory, which is land used as carbon sinks (EEA, n.d.-b). If that is non-existent in a given country, the rule applies for UNs Food and Agriculture Organisation's definition of a forest (more than 0.5 hectares of land, covered with at least 10% of trees, minimum five metres high (FRA, 2020)).

6.3.4 Forestry in the EU taxonomy

The forestry sector has been divided into four subcategories. Afforestation, conservation forestry, forest management, and rehabilitation and restoration of forests, including reforestation and natural forest generation after an extreme event.

Afforestation is the plantation, seeding and regeneration on land that was under another kind of use, or no use before this activity. Conservation forestry is conserving what is, and not making any land category changes. "The forest management sector" means the economic activity related to a system that influences the ecological, economic, or social function of a forest. The last category, rehabilitation and restoration, can have a wide range of meanings. If rehabilitation and restoration is not defined by law, the activity can be related to findings in peer-review literature. An extreme event is defined by law, or otherwise it is defined by UNs Intergovernmental Panel on Climate Change, IPCC's explanation of an extreme weather event.

All forestry categories, or sectors, have the same DNSH criteria for biodiversity. For the activities to be aligned with the DNSH criteria, the conversion on land can not be done on land with high conservation value. The activity should also ensure good conservation status of habitats and species and exclude the use or release of invasive species. Non-native species can be allowed if they seem to have a positive impact on the ecosystem. Soil quality and maintenance or enhancing of mature stage stands and dead wood are two other objectives important for the DNSH criteria.

6.3.5 Manufacturing of cement in the EU taxonomy

The sub-category "manufacturing of cement" includes cement clinker, cement, or other alternative binder. The DNSH criteria for this category only mention Appendix D in Regulation 2020/852, presented in section *6.3.3. Construction of new buildings in the EU taxonomy.*

6.4 Tools presented by The Science Based Targets Network

The Science Based Targets Network, SBTN, is a global cooperation of organisations and non-profits that helps companies set scientifically based climate goals (IVL, 2022). SBTN (2020) presents several existing tools to identify indicators and assessing corporate impacts which, are chosen with the following criteria in mind (1) available and free to the public, (2) updated regularly, (3) can be used globally and (4) tools that also can be used on regional scales where applicable. From the toolbox a number of tools were selected as of significance for this thesis project which are presented in this section, these tools are *Global Forest Watch, Integrated Biodiversity Assessment Tool, Global Biodiversity Information Facility, ENCORE* and *UN Biodiversity LAB*. The full list of indicators for each tool can be seen in Appendix D.

1. **Global Forest Watch**
   Global Forest Watch (GFW) is an online tool that monitors forests and how they change in real time. An interactive online map can be used to visualise the The Biodiversity Intactness Index (BII), key biodiversity areas and biodiversity hotspots.

2. **Integrated Biodiversity Assessment Tool**
   The Integrated Biodiversity Assessment Tool (IBAT) is, according to them, the "The world's most authoritative biodiversity data for your world-shaping decisions". IBAT hosts three key global biodiversity datasets: (1) The IUCN Red List of Threatened Species that provides information on threats and habitats of over 150 388 species and actions that can be done to prevent extinction, (2) The World Database on Protected Areas (WDPA) that uses the IUCN definition of a protected area (3) World Database of Key Biodiversity Areas (KBA) that shows sites that contribute to the global persistence of biodiversity in all three ecosystems.

3. **Global Biodiversity Information Facility**
   GBIF, the Global Biodiversity Information Facility, is a data infrastructure and international network aimed at providing open access, best possible biodiversity data about where, when and what species have been recorded in different parts of the world using tables and interactive maps.

4. **ENCORE**
   Exploring Natural Capital Opportunities Risks and Exposure (ENCORE) is a tool that helps users understand how businesses depend, but also impact, nature. Hotspots of natural capital depletion and biodiversity depletion can be visualised using an interactive map tool.

5. **UN Biodiversity Lab**
   The UN Biodiversity Lab (UNBL) is an open-source environment platform that visualises over 400 data layers on climate change, sustainable development and nature. There are 66 layers in the layer category *Biodiversity*, including layers showing the BII and FSII, Forest Connectivity, Forest Fragmentation, Global Forest Change, World Terrestrial Ecosystems and Species Richness as well as Threatened Species Richness.

6.5 Biodiversity indices

Biodiversity indices aim to describe the general properties of communities that can be used to compare different regions, trophic levels, and taxa. Because of their comparable nature they are essential for environmental monitoring and conservation according to Morris et al. (2014), although there is no general agreement which indicator that is more appropriate or informative than the other.

The simplest measure of biodiversity, as well as the most applied according to Morris et al. (2014) is the *species richness* (S). The species richness quantifies the number of different species in an area (Sohier, 2022).

Three assumptions must be made when measuring diversity using indices, namely that: (1) All species are equal, (2) All individuals are equal (3) Species abundance has been recorded using appropriate and comparable units. No distinction is made between rare and abundant species, nor the species' place in the food chain. The second assumption makes no distinction between the sizes of the individuals, meaning that the largest individual can be compared equally to the smallest (Magurran, 2004).

6.5.1 Shannon Diversity Index

The Shannon Diversity Index, sometimes called the Shannon-Wiener index, is often denoted as H and can be calculated as (Supriatna, 2018):

$$H = -\sum p_i \cdot ln(p_i) \tag{1}$$

A higher value H means a higher diversity of species and vice versa, a value of zero means that the ecosystem only has one species. p_i is the proportion of the dataset that the species, i, makes up (Zach, 2021a).

6.5.2 Simpson's Diversity Index

Simpson's Diversity Index is an indicator that can be used to measure biodiversity in a given habitat. The indicator takes both the number of species present into account, known as richness, as well as the relative abundance of each species, called evenness ("Simpson's Diversity Index", n.d.). In "Simpson's Diversity Index" (n.d.) it is also stated that as richness and evenness increase, so does biodiversity. Simpson's Diversity Index can be calculated using equation (2).

$$D = 1 - \left(\frac{\sum n_i(n_i - 1)}{N(N-1)}\right) \tag{2}$$

To calculate Simpson's Diversity Index the area under investigation is sampled using random quadrants. The number of different species in the quadrants are noted, as well as the number of organisms of each species. In equation (2) N is the total number of organisms in the given habitat or quadrant and n is the number of individuals of species, i. The value of D ranges between 0 and 1, with a higher value of D indicating lower diversity. Using Simpson's Diversity Index, *Simpson's Index of Diversity*, see equation (3), and *Simpson's Reciprocal Index*, see equation (4), can be calculated (Zach, 2021b).

$$\text{Simpson's Index of Diversity} = 1 - D \tag{3}$$

The higher the value of Simpson's Index of Diversity, the higher the diversity of species.

$$\text{Simpson's Reciprocal Index} = \frac{1}{D} \tag{4}$$

The lowest value of Simpson's Reciprocal Index is 1 and the highest value is equal to the number of species, and the higher the value, the greater the diversity.

6.5.3 Habitat Suitability Index (HSI)

The Habitat Suitability Index (HSI) measures the capacity of a given habitat to support a specific species or group of species, and often combines many different variables such as soil type, land cover and predator abundance. The University of Southampton (n.d.) describes three instances of how HSI can be used in environmental management: (1) the index can be used to complete incomplete data of species distribution by estimating the species distribution of an unsurveyed portion of an area based on the available habitat, (2) it can predict changes in species distribution by forecasting the likely effect of a particular action on a particular species and (3) help identify areas where rare or particularly important species can be found based on map layers of for example soil type and local climate.

There are two methods to produce Habitat Suitability Indices, a *Data-driven method* and *Expert methods*. The data-driven method involves statistical analysis of data on where the species is currently distributed. An approach suggested by The University of Southampton (n.d.) is the *environmental envelope* that includes finding the maximum and minimum values for many different variables, such as temperature, for the habitats that the species can be found and thereby produce an "envelope" of the values that describes the habitat that the species occupy (The University of Southampton, n.d.).

The expert method of creating a HSI is instead conducted by creating a panel of experts, e.g., ecologists, and letting them describe the habitat preferences of a species. An expert method is the *Analytical Hierarchy Process* in which the experts rank two habitat attributes to one another and creates a formula to derive HSI by considering the rankings of all the attribute pairs (The University of Southampton, n.d.).

6.5.4 The Ecosystem Integrity Index (EII)

The Ecosystem Integrity Index (EII) uses best available data to create an index at scales of $1km^2$ globally for organisations to use to measure biodiversity. Ecosystem integrity is defined as "to which the composition, structure, and function of an ecosystem fall within their natural range of variation" (Hill et al., 2022). The structure is the habitat density, built-up areas, roads, and mining etc., composition is the patterns of species communities, and function represents the ecosystem services provided. A lower EII score means a higher grade of ecosystem degradation and a score of over 0.7 is considered natural land (Hill et al., 2022).

6.5.5 The Biodiversity Intactness Index (BII)

The Biodiversity Intactness Index (BII) is a way to measure biodiversity change by comparing the abundance of a diverse and large set of organisms due to human pressures, compared to their reference population in a specific geographical area. The reference population is the state of the population before alteration by human pressures, but can also be a specific baseline year within records where accurate data of the pre-modern population is unavailable (Scholes & Biggs, 2005).

BII gives an indication of the biodiversity intactness and can be calculated according to equation (5) below. The BII should be calculated 'top-down', meaning that the impacts from a set of land use activities, from protection to urbanisation, should be calculated on population sizes of ecologically similar species (Scholes & Biggs, 2005).

$$BII = (\sum_i \sum_j \sum_k R_{ij} A_{jk} I_{ijk}) / (\sum_i \sum_j \sum_k R_{ij} A_{jk}) \tag{5}$$

The population impact is given by I_{ijk} where i is the population of the species, k is the land use activity and j the ecosystem. The population impact, I_{ijk}, is often based on expert judgement who estimate species loss caused by land use activities. Scholes and Biggs (2005) used more than three specialists in each broad taxonomic group (amphibians, birds, mammals, plants and reptiles) to estimate the population reduction and in total 4,650 estimates of I_{ijk} were made.

According to Scholes and Biggs (2005), the major shortcoming of the BII is that calculating a single index of biodiversity is not sufficient for all purposes. It does not, for example, highlight threatened species individually, where it needs to be used together with other indicators. The BII is also insensitive to slow and diffuse impacts on biodiversity, such as the long-term impacts of climate change and pollution. However, the main feature of the BII is that it can be used to compare within and across scales and show species richness at all scales.

6.5.6 Mean Species Abundance (MSA)

The Mean Species Abundance (MSA) is a local biodiversity intactness indicator that can be used for terrestrial biodiversity which measures the average response of the total set of species belonging to a specific ecosystem under a given driver of biodiversity loss relative to the expected response in a pristine state (Alkemade et al., 2009).

MSA is, similarly to the Ecosystem Integrity Index (EII), mapped on scales of 1km^2 and also ranges from 0 to 1 where 0 means that all original species are locally extinct and 1 that the total set of species is intact (IPBES, n.d.). The MSA indicator is also similar to the Biodiversity Intactness Index (BII) with the main difference being that every hectare is given equal weight in the MSA whilst the species rich areas are given more weight in BII (Alkemade et al., 2009).

6.5.7 The Forest Structural Condition Index (SCI) and The Forest Structural Integrity Index (FSII)

To derive the Forest Structural Condition Index (SCI), Hansen et al. (2019) combined the canopy stature, cover and disturbance history or forest loss, across a given area. In the case of Hansen, the humid tropics was used to produce a SCI classification scheme with values ranging from 1 (low SCI) to 18 (high SCI). According to their findings the tallest and most dense forests are found in areas with little or no natural or human disturbance, as well as with favourable climate and soils.

By overlaying the human footprint on the SCI, Hansen et al. (2019) could derive the Forest Structural Integrity Index (FSII) using equation (6) seen below.

$$FSII = SCI \cdot \frac{1}{\text{Human Pressure Weight}} \tag{6}$$

The Human Pressure Weight was derived by weighting the human footprint and the SCI. The FSII ranges from 0.1 to 18 with a higher value meaning a higher FSII and thereby a forest with high integrity affected by no or little human pressure (Hansen et al., 2019).

6.6 Northern European Indicators for forestry

The Swedish University of Agricultural Science released a report in 2020 in Swedish, where the title can be translated to "Measuring biodiversity" (Mäta biologisk mångfald, (Pilstjärna & Hannerz, 2020)). The report covers different methods and systems for measuring biodiversity in forests in five Northern European countries. The indicators that could be useful for the building sector are presented in this section.

6.6.1 Swedish indicators

The environmental goal setting in Sweden makes the basis for governmental agencies and politicians when the state and development in nature is assessed. Indicators are created and used to enable follow-up on the environmental impacts and actions taken to prevent harm. Measurements that target biodiversity can be both direct and indirect. The indirect indicators are usually human actions taken to prevent negative impacts, or factors in nature that entails an effect on biodiversity. The direct indicators are measurements of the actual state of species (Pilstjärna & Hannerz, 2020).

A report for the development of indicators for living forests was released in 2019 with suggestions of development and improvements (Andersson et al., 2019). A description for the indicators states that they should be communicative, available for updates, and be based on standardised methods.

A way to categorise indicators is to use the DPSIR framework (EEA, n.d.-a). It has been adopted by the European Environmental Agency, and the abbreviation stands for the categories in which environmental and society interact. The categories are driving forces, pressures, states, impacts, and responses. Driving forces are trends in society that affect activities. Pressures are human and natural processes that lead to changes for the environment. States refer to the state of the environment. Impacts mean how the environmental changes lead to changes in nature or well-being. Responses are how society reacts in terms of policies, laws, and regulation as a response to environmental changes (Pilstjärna & Hannerz, 2020).

The indicators found in the report by Anderson et al. (2019) are found in Appendix E, and below are descriptions of the categories and brief information of some of the indicators in each category.

The category for Forest land properties includes management behaviour, e.g., how forest machines such as harvesters damage the ground. Transportation over water courses is also an indicator, where the damages to the water course can affect the ecosystem negatively.

Green infrastructure is a category that has indirect impact indicators. Many of the indicators are measurable, and can be quantified for comparison if the forest owners or managers have the right idea of the structure of the forests.

The indicators for endangered species and restored habitats include direct indicators, e.g., Swedish bird taxation. The first indicator, number of red-listed species with declining populations, targets species that are dependent on forests, which have shown a decline due to land use or other anthropogenic activities.

There is a suggestion of a new indicator which should be Biodiversity in production forests. The suggestion is based on an identified knowledge gap. The amount of deadwood, area of protected land and forestry sustainability management are assessed, but not the impacts those measures have on biodiversity.

6.6.2 Finnish indicators

Since 2006 the Finnish Environmental Cluster Research Programme, financed by the Ministry of Environment, has developed indicators for biodiversity. Governmental authorities, researchers and NGOs have together developed the indicators. Twenty indicators regarding forestry have been developed for forestry intensity, total harvested area, and forestry road preparations, among others (Pilstjärna & Hannerz, 2020). Some are repeated from the Swedish indicators, but are included to show their representation. The indicators are presented in table E4. Units or explanations are included as well.

Different species categories as included in the Finnish indicators. Trees, wildlife, and management practices are represented. Many of the indicators are reoccurring from the Swedish indicators. Some examples are regeneration, deadwood, forest fragmentation and red-listed species.

6.6.3 Norwegian indicators

Naturindeks (Nature index, own translation) is a measurement used in Norway that was ordered by the government in Norway in 2005. It is a statistical index of the state of the nature of interest. Index 1 means that the nature or area is undisturbed. Since no areas are undisturbed per definition, the value 1 can only be calculated and assumed, but never appear in real life. A complete deserted ecosystem would have the value 0. The index is built and calculated depending on indicators, for forest the number of indicators are 87. In total there are 301 indicators, divided into different ecosystem types. The indicators are mostly different species and their index, and listing them here would rather take up space than create ideas for useful indicators (Pilstjärna & Hannerz, 2020).

Worth mentioning though is that the index for forests is lower in Norway than for other ecosystems. A classification of disturbance factors has been made, and the 87 indicators have been put under one or several disturbance factors. 67 of the 87 indicators are affected by the disturbance factor "land use", of which most land use is due to forestry.

6.6.4 Estonian indicators

The national strategy for sustainable development and its policies for forestry are to be found in the so-called "Sustainable Estonia 21" document for strategies. There are several other official strategies as well, but the used indicators and the state of the forest is presented outside of official reports. The indicators come from the Estonian Environment Agency, found in table E5. The Estonian indicators are mostly based on official statistics, and the system is expressed as "in need of development", given their general character. Most indicators are about endangered species, and how their preservation state is developing (Pilstjärna & Hannerz, 2020).

6.6.5 German indicators

Five themes consisting of a total of nineteen indicators have been developed in Germany and are presented by the Federal Agency for Nature Conservation. Nine of the indicators are strongly connected to forests, and the majority of the indicators are measured with percentage-based indices. The indicators are presented in table E6, and most of them are reoccurring from earlier presented indicators. One new indicator that has not been presented before is "alien species associated with forested wetlands" (Pilstjärna & Hannerz, 2020).

6.7 Stora Enso Sustainability Report

In their Annual Report for 2022 Stora Enso measures their progress towards biodiversity using six impact indicators that measure harvesting operations in Sweden, Finland, and the Baltics. The six indicators are *High Stumps, Ground Deadwood, Soil and Water, Prioritised habitats, Tree retention* and *Buffer zones* (Stora Enso, 2022).

The performance of each indicator is assessed at randomly selected harvesting sites each summer by having 12 external consultants audit 12 different areas at 120 randomly selected sites and assessing how many of the surveyed suites follow the biodiversity guidelines. The measurements for each indicator are presented in table 3. However, the guidelines set for the biodiversity indicators by Stora Enso vary depending on the region where they have forestry operations (Stora Enso, 2022). The different guidelines for each indicator measurement and region are further elaborated in Appendix F.

Table 3:
The six biodiversity indicators used by Stora Enso and how they measure each indicator (Stora Enso, 2022).

Indicator	**Measurement**
High stumps	Number of high stumps created per hectare harvested.
Ground deadwood	Amount of undamaged natural deadwood
Soil and water	How well protected soil and water are when crossing watercourses.
Prioritised habitats	Preservation of identified prioritised habitats on all operational sites.
Tree retention	Number of trees preserved per hectare at harvesting
Buffer zones	Number of correctly handled buffer zones according to forestry best practice.

6.8 Sustainable Development Goal 15

In Sustainable Development Goal 15 there are three targets of interest, as well as the indicators to measure the progress of the targets, which are presented below (UNSD, 2022).

Target 15.1: sustainable use
Ensure the sustainable use, conservation and restoration of terrestrial and freshwater ecosystems and their services. Two indicators are used to measure this, one being the forest area as a proportion of total land area and the other one the proportion of important sites for biodiversity that are considered protected areas.

Target 15.2: sustainable management
This target concerns a more sustainable management of all forest types by halting deforestation and restoring degraded forests, as well as increasing reforestation. The indicator measures the progress towards sustainable forest management.

Target 15.3: degraded land
The indicator measures the proportion of land that is degraded over the total land area to achieve the target of restoring degraded land and soil by 2030. Degraded land is land that, due to human activities, has lost some of its productive capacity. For degraded forests this includes the lowered capacity to store carbon.

6.9 GRI 304: Biodiversity

GRI 304 is the topic-specific Global Reporting Initiative (GRI) standard addressing the topic of biodiversity. GRI 304 has for this project been used to identify possible indicators for biodiversity and below are Key Performance Indicators (KPIs) included in the GRI, that fully, or partially, could prove useful when choosing a biodiversity assessment method (GRI, 2022).

KPI 304-1-b: operational sites that may impact biodiversity
Organisations are to report the name, size and coordinates of operational sites that have or could have significant impact on biodiversity. These operational sites include those where operations have ceased, and sites where operations have been announced.

KPI 304-1-d: operational sites near areas of high biodiversity value
If the operational sites are near, or include, an area of high biodiversity value the name and distance to these areas are to be reported, including whether these areas are *legally protected, internationally recognised* or *other areas of importance for biodiversity.*

Organisations are to use the Integrated Biodiversity Assessment Tool (IBAT) to assess if areas fall into any of the above categories, see section *6.4. Tools presented by The Science Based Targets Network.*

KPI 304-2-c-ii: size and type of ecosystem converted
Organisations are to report the size and type of the natural ecosystem converted using the IUCN Global Ecosystem Typology. The Global Ecosystem Typology contains four core realms: *terrestrial, marine, freshwater, subterranean* and six transitional realms: *marine-terrestrial, subterranean-freshwater, freshwater-marine, marine-freshwater-terrestrial, subterranean-marine, terrestrial-freshwater.*

KPI 304-3-a: Ecosystem types, size and condition
For each operational site organisations are to report the type, the size in hectares and the condition of the ecosystems that are affected by operations. Suggested indicators to measure the ecosystem condition are the Ecosystem Integrity Index, Mean Species Abundance, Biodiversity Intactness Index and Potentially Disappeared Fraction.

6.10 Indicators in building certifications

Regarding certifications in the building sector, the connection between biodiversity and material choice is vague and mostly lined with requirements on the selected material, such as FSC-certification or the rate of recycled material used. Consequently, not many indicators are found that could be used to measure biodiversity directly.

What the findings showed was that when selecting and managing the construction site there were some biodiversity indicators that could be used as, or developed further, to apply to any kind of project or extraction site and not only construction sites. These biodiversity indicators are present in three different building certifications, BREEAM, LEED and Nordic Swan Ecolabel Buildings.

6.10.1 BREEAM

Building Research Establishment Environmental Assessment Method, BREEAM, is an international certification standard developed by the Building Research Establishment. It is customised to fit Swedish laws and regulations since 2013 in the form of BREEAM-SE. BREEAM is used to certify newly produced buildings' environmental performance within ten different assessment categories. For each category certain credits are awarded and the credits from each category are then aggregated to a total credit and a certain certification grade (SGBC, 2023b).

The assessment category *Land use and Ecology sections*, with the aim of minimising the long-term impact of the surrounding area's biodiversity, is of particular interest. Within this assessment category are four issues that are to be considered with each awarding a certain amount of credit. These four issues are *Site selection, Ecological value of site and protection of ecological features, Enhancing site ecology* and *Long-term impact on biodiversity.*

SGBC (2023a) mentions several criteria in these issues that need to be fulfilled to gain credit. The criteria encompass parts of the life cycle of the building, the first being site selection in which it is encouraged to use land that has been previously occupied, and the more of the construction footprint that covers occupied land, the more points. Occupied land is defined as land where there previously have been, e.g., buildings, mineral extraction and parks.

When deciding a site, it should also be a site of low ecological value, as assessed by an ecologist or according to a checklist by BREEAM-SE which includes mature trees (>400 mm trunk diameter) and,- semi-mature trees (200-400 mm trunk diameter) but also thinner trees with structures that counts as valuable. Here high ecological value land counts as for example as woodlands and wetlands within 100 m of the site, croplands with high fertility and belowground biodiversity and land with high biodiversity that inhabits some of the endangered species according to the European Red List (SGBC, 2023a).

Enhancing ecological value of the sites, as well as minimising long term impact on biodiversity is done by implementing solutions from ecology reports and management plans. The ecology reports should include recommendations for enhancing the ecological value by for example implementing new species, not using pesticides, or building bird or insect boxes at the site. The management plans on the other hand are very site specific and vary between each site (SGBC, 2023a).

6.10.2 LEED

The LEED Green Building Rating System is a certification system developed by the U.S. Green Building Council (USGBC) is earned by, as USGBC (n.d.) describes it, "adhering to prerequisites and credits that address carbon, energy, water, waste, transportation, materials, health and indoor environmental quality".

There are several different LEED rating systems depending on the type of project and the projects are awarded points or credits that lead to certain levels of LEED certification: certified, silver, gold or platinum. Of the total LEED credits, 35% relate to climate change, 20% direct impact on human health, 15% impact on water sources, 10% affect biodiversity, 10% green economy and 5% impact community and natural resources (USGBC, n.d.).

In this context, the LEED credits that relate to the impact on biodiversity and natural resources are of interest and can be connected to SDG 15. The credit category of interest is *sustainable sites*. In this category the following credits are of interest (USGBC, 2023):

1. **Site Assessment**
   Project sites are to be assessed and include the following information: topography, hydrology, climate, vegetation, soils, human use and human health effects. Information that should be included for vegetation is primary types of vegetation, tree mapping, a list of endangered species as well as a list of invasive plant species on the site.

2. **Protect or Restore Habitat**
   To promote biodiversity on the given project site existing natural areas should be conserved and damaged areas restored.

   (a) Disturbed soil should be restored, and the imported soil should not be from other greenfield sites nor sphagnum peat moss.

   (b) A minimum of six species of vegetation native to the region should be planted, including a minimum of two of the three categories, tree, shrub, and ground cover.

6.10.3 Nordic Swan Ecolabel Buildings

Nordic Swan Ecolabel Buildings is a Nordic environmental label that can be used to label new buildings under the product group "New Buildings 089" which covers office- and apartment buildings as well as residential buildings ("New buildings 089", n.d.). In a criteria document for New Buildings there are several focus areas that each have their own requirements, or criteria, that need to be fulfilled to obtain the Nordic Swan Ecolabel for buildings. Some of these are *Biodiversity, Energy and Climate, Resource Efficiency, Indoor Environment, Innovation and Green Initiatives*. Some of the areas and criteria that ouch upon the subject of biodiversity and that are considered relevant to some extent are (Nordic Ecolabelling, 2023):

1. **Biodiversity**
   (a) Tree species with restricted use
   All wood-based products are restricted to use trees that are not listed on CITES, IUCN red list, Rainforest Foundation Norway's tree list or Siberian larch. The use of virgin trees species listed on CITES is strictly not permitted whilst tree species listed in the other three lists may be used if the tree species is not (1) from a IUCN red listed area (2) from an Intact Forest Landscape. The tree species may however be used if the tree species is from a FSC or PEFC certified plantation established before 1994.

   (b) Assessment of the biodiversity in the project area
   An ecology report on the biodiversity at the project area must be done by an expert and should include the existing plant cover, fauna and habitats, a terrain description, types of nature or species that are protected, threatened or prioritised, as well as any invasive species.

   (c) Measures to preserve and improve biodiversity
   Based on the ecology report a description of measures to protect and preserve existing biodiversity which should include (1) protection of elements with natural value, (2) invasive plant species are to be removed or controlled and (3) tree species that can be deemed as national by having adapted to that particular environment must be preferred to plant on the project site.

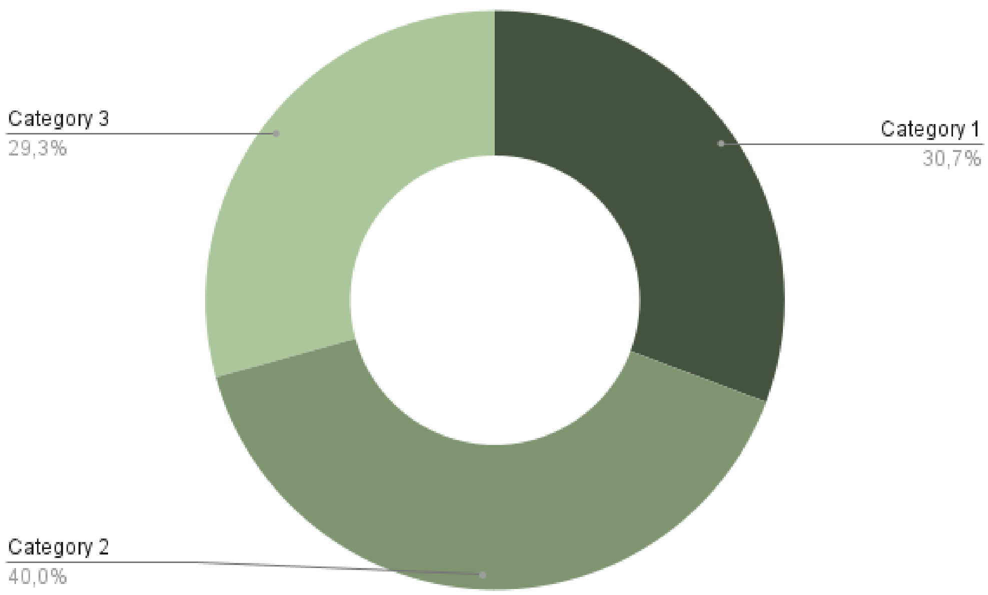
2. **Innovation and Green Initiatives**
   Points are awarded if a minimum of 25% of the certified wood used comes from forests that are managed according to the close-to-nature forestry principle, e.g., continuous cover forestry.

6.11 Summary of measurement methods

The indicators and methods to measure biodiversity presented in section *6. Assessment methods to measure biodiversity* are divided into three different categories depending on how the indicators are measured. The three different categories are (1) measured with the help of experts, (2) measured with the help of maps or datasets, and (3) measured in investments or reports.

As seen in Figure 1 a majority of the indicators and methods fall into category two. A full list of all indicators and their corresponding category can be found in Appendix G.

Figure 1:
The distribution of the indicators and methods among the three different categories.



6.11.1 Indicators measured with the help of experts

Methods and indicators that fall into this category require one or more experts, ideally an ecologist or biologist, who assesses site-specific biodiversity by counting or measuring species and biomass or assessing impacts on species, landscapes, and ecosystems. Some of the indicators included in this category are Diversity of Tree Species, and Genetic Resources that can both be found in the Forest Europe report. Others are High stumps, Ground Deadwood, Degraded land, and Forest vegetation. Indicators measured using a combination of counting species to use in equations are quite few in this category, with the Shannon Diversity Index and Simpson's Diversity Index being the only ones.

6.11.2 Indicators measured with the help of maps or data

A number of indicators found can be measured with the help of datasets or maps that visualise spatial data. All indicators found in the Science-Based Targets for Nature report (presented in section *6.4. Tools presented by The Science Based Targets Network*) are exclusively part of this category, as well as some in section *6.5. Biodiversity Indices* since there is an overlap between biodiversity indices and the spatial data that can be shown using the tools in SBTN, such as the Biodiversity Integrity Index (BII), Ecosystem Integrity Index (EII) and Mean Species Abundance (MSA).

Furthermore, spatial data and datasets can also be used to find areas that are inhabited by for example threatened forest species, common forest bird species and forest landscape structures of which the first two indicators can be found in the Forest Europe report, and the latter in the report by Pilstjärna and Hannerz (2020) on how to measure biodiversity.

6.11.3 Indicators measured in investments or reports

Indicators in this category are more difficult to define as investments and reporting can be vastly different from industry to industry, or even company to company in the same industry. What these indicators have in common are that they are often more of the managerial type, with indicators such as the number of biodiversity management plans that a company has in mind for a site at different or all life cycle stages, the percentage of the area that has been restored and the type of forest harvested. Other indicators include reporting on the type of species found on the site, in particular red-listed species, which can be used as a database for future research, as well as reporting on the type of areas that surround the site and stretches of road established for operations.

A majority of the indicators found in the CEMBUREAU Biodiversity Roadmap fall under this category, found in section *6.2. CEMBUREAU Biodiversity Roadmap*. Indicators include reporting on areas that are restored, the proportion of quarries that have a management plan and number of projects that support protected species, but there are also more unconventional indicators such as measuring how many meetings that are conducted each year with the EU Pollinators Initiative and the reach of communication material regarding biodiversity.

7 Life cycle stages of relevance for the materials

The third research question is: What phases of the materials' life cycles should be considered when evaluating biodiversity impact? Here follows a reasoning about what stages in the life cycle that could be possible to assess with the found indicators. Both the life cycles of the buildings and the extraction sites are explored in relation to the findings in the second research question.

7.1 Life cycle of the buildings

Sveafastigheter follows the same definition of a building life cycle as Boverket, which divides a building's life cycle into three stages:

- A1-5: Construction
- B1-7: Usage
- C1-4 End of life

The first part, A, is divided into two parts according to the European standard SS-EN16978:2011, "A1-3 Production stage" which encompasses raw material extraction, transport and manufacturing, and "A4-A5 Construction process stage" that includes transport and the building process (Boverket, 2019).

Since the two buildings in the case study are nearly identical except for the material choice of the framework, the use phase will be identical and of no relevance for this thesis project. It is harder to assess whether C1-4 should be included when considering its relevance for comparison of materials since on one hand, there are no obvious numbers of how much of a building that can be recycled today but on the other hand, the recyclability of a material should in theory mean that less raw material is extracted - reducing land use which is one of the drivers of biodiversity loss.

Since no definite numbers can be found regarding the recyclability of wood and concrete, and because Sveafastigheter has stated that what will happen with the buildings in the future are more of theoretical scenarios today, this life cycle stage is excluded when comparing wood versus concrete.

Using Boverket's life cycle of a building it is clear that when choosing which material that is more beneficial for biodiversity, the only life cycle stage of relevance in this project is what Boverket defines as "A1-5 Construction stage". More specifically, it is "A1 Raw material supply" that is of interest for this thesis project (Boverket, 2019). By observing A1 by its own, the life cycle stages of the materials can instead be studied, and their relevance can be connected to the indicators and methods found in this thesis project.

7.2 Extraction sites' life cycle

What is most feasible, and comparable, for the two materials can be argued to be the life cycles of the extraction sites. The establishing of an extraction site, the use and the "end-of-life", which in this case will be the restoration of the sites, are all embodied in the indicators and methods found.

Indicators developed to handle different spatial scales have been presented by Interim Biogeographic Regionalisation for Australia (IBRA). Some key ideas are that they include the percentage of threatened ecosystems, bioregions of high fauna value, relative importance of bioregions to threatened bird taxa, and total number of threatened species (Nolan et al., 2011). Different kinds of land transformations have different impacts on biodiversity. The transformation stages are described by Nolan et al. (2011) as transformation, occupation and relaxation. Measuring biodiversity impacts regarding land use requires a reference state of the ecosystem.

Regarding forestry and other renewable resources, the transformation impact is hard to define, since the resources are not finite (Nolan et al., 2011). Comparing transformation impact from forestry to a finite resource, limestone for example, will be hard.

7.3 Life cycle stage of indicators

The nature of the indicators are geared toward the extraction sites and nature itself. They measure, for example, the biodiversity intactness before establishing a site, but also during its use, and what the biodiversity intactness will be after operations have ceased. The same mindset can be used whether the indicator is geared towards counting species or long-term management plans that span over the entire life cycle.

The biodiversity indicators presented by Forest Europe, Appendix A, are all targeting the forestry and the state in the forest, hence it can be derived that the extraction phase is targeted, in relation to what life cycle stage of the buildings that is considered. Looking instead at the extraction site, here the forest, there are several life cycle stages mentioned. Diversity of tree species, naturalness, genetic resources, and forest fragmentation are all indicators that can be measured in an area independent of which life cycle stage that is assessed. Regeneration and protected forests are two indicators that are more specific. Regeneration is targeting more of the end-of-life stage, and protective forest can be both applied in the establishment phase, and end-of-life, if one views harvesting or actively managing a forest as its use phase.

For a limestone quarry, the CEMBUREAU Biodiversity Roadmap has some indicators for different life cycle stages as well (Appendix B). The first category of indicators, Ecosystem Rehabilitation and Ecosystem services, is targeting the end-of-life stage. The second category, EU Pollinators Initiative, can cover all stages in the life cycle. The same goes for Invasive Species, which is the third category. The last category is Protected Species, which might target the initial stage of establishment of a quarry, where assessments of the sites are done to identify threatened species and make plans on how to protect, conserve and enhance them. It can also be argued that the management plans span over the whole life cycle of the quarry.

8 Current policies and regulations that could be usable

The fourth research question is: What policies and regulations that target biodiversity are used today, and what assessment methods could be usable in the future? Here, the tools, methods and indicators are related to existing policies and regulations to map out the significance for the building sector.

Despite the building sector being one of the top three sectors that threatens global biodiversity still not enough is done for biodiversity according to Ning Li (2021). Practical approaches can and have been implemented to increase biodiversity in the building sector, such as planting regimes and beehive installations at construction sites and whilst the reduction of CO_2 emissions and pollution are important for biodiversity protection direct actions that protect biodiversity are few (Sheriff (2022); Ning Li (2021)). Ning Li (2021) further elaborates that this is because the indirect benefits of biodiversity are not captured by the financial system in the sector and thus do not influence the decisions of management.

Sheriff (2022) does however highlight that the building sector has an opportunity to take the lead and become protectors of biodiversity. As biodiversity is becoming more of an issue for other major economic sectors, the building sector should expect corporate policies on biodiversity affecting how buildings are to be commissioned and built. In an environment where business and biodiversity are moving fast and catching up to climate change on the agenda it is, according to Jewell (2022), clear that companies need direction in what way the journey of biodiversity should go with initiatives such as the Science Based Targets Network (SBTN).

Jewell (2022) means that developing methodologies and metrics must be derived by science, and that financial systems must fall in line with the current environmental agenda. By doing this financial support can be redirected towards nature-positive outcomes where biodiversity can be included. What is then needed is ways to quantify biodiversity impacts with the same convenience as other environmental impacts.

8.1 The Global Biodiversity Framework (GBF) and its significance for companies

The Kunming-Montréal Global Biodiversity Framework was signed at the UN Biodiversity Conference (COP15) in December 2022 with 196 countries committed to halt and reverse biodiversity loss by 2030 (European Commission, n.d.-b) and will be, according to Zhu and Douglas (2022) the biodiversity equivalent to what the 2015 Paris Agreement was to climate change. The framework has set 23 targets for conserving and promoting sustainable use of nature and the financial sector and its businesses are according to Quinney and Lu (2023) key to implementing the Global Biodiversity Framework (GBF).

Quinney and Lu (2023) states that businesses that lead on implementing the framework will protect their long-term interests and can enter new markets as new business models and products are introduced, as well as public image improves. They suggest that businesses should monitor, assess, and transparently disclose the impacts on biodiversity of their operations, services, and products. To be able to do this, businesses need robust biodiversity performance indicators.

Zhu and Douglas (2022) further elaborate that by addressing the biodiversity loss on a global level, the GBF will mitigate nature-related risks to companies and their supply chains and create opportunities for those with business models that are nature-positive. Zhu and Douglas mean that the behaviour of companies that already mitigate their operations' nature-related risks, as well as invest in business opportunities that contribute to targets in the framework, need to be mainstream. It is this way that the Global Biodiversity Framework can provide a concrete direction for policies and goals regarding biodiversity.

The target in the framework that will most likely change business strategies and operations is target 15 that aim to reduce negative impacts on biodiversity by assessing, monitoring and disclosing the impacts on biodiversity and thus be able to reduce the related risks and negative impacts (Zhu & Douglas, 2022). Targets 2-8 will "accelerate policies and stakeholder expectations for companies to address drivers of biodiversity loss", examples including habitat destruction, overexploitation, and invasive alien species. Targets 18 to 19.1 aims to increase funding that protect biodiversity and cancel subsidies that are instead harming biodiversity. Zhu and Douglas (2022) conclude that "Ultimately, all companies will be impacted by and required to act on climate change and biodiversity loss."

8.2 The Science Based Targets Network

Zhu and Douglas (2022), as well as Jewell (2022) suggest that companies use different frameworks to help guide them on how to assess, manage and report their impact on nature, one of them being the Science Based Targets Network (SBTN). The SBTN consists of 45 partner organizations with the goal to guide companies to make nature-positive decisions by using science-based targets (SBTs), which are scientifically developed climate objectives that are measurable, actionable, and time-bound. By using the guidance put forward by the SBTN, companies will be able to align their goals and efforts to sustainability efforts such as the Convention on Biological Diversity, the Paris Agreement and the UN Sustainable Development Goals (SBTN, 2020).

There are five steps in the process of setting SBTs for nature: (1) Assess, (2) Interpret and prioritise, (3) Measure, set and disclose, (4) Act and (5) Track. The first step is assessing the company's "environmental footprint" to identify potential improvements and targets to set. This step includes measuring the company's dependence and impacts on nature and thus tools and data to assess these must be used. Some of the tools presented in the Science Based Targets Network's "Guidance for Business" report are used in this thesis project to find indicators to measure biodiversity, see section *6.4. Tools presented by The Science Based Targets Network* (SBTN, 2020).

Next is interpreting the previous assessment and prioritising where targets need to be set and how much effort that is needed for each. The baseline is then measured in the next step, and a target description and timeline for the target are made. Using the Action Framework put forward by SBTN it is then time to act and implement the target by using best practices action plans. The last step is monitoring and reporting the progress towards the targets and adapting the strategy if needed (SBTN, 2020).

8.3 EU taxonomy reporting

Companies that fall under the Corporate Sustainability Reporting Directive (CSRD) are required to report according to the EU taxonomy. They are obliged to include to what extent their activities are covered by it, and companies not covered by the CSRD can choose to report anyway.

The affected companies are EU companies, and non-European companies listed on the EU market, beginning during the years 2023-2027 (the time span is due to the developing nature of the taxonomy). The companies should have two of the following criteria: >250 employees, total balance sheet of >20 million euros, or a turnover of >40 million euros. Additionally, all companies listed on the EU regulated market, except micro companies, should report (Holzheuser & Jordan, 2023). The EU taxonomy will be of high relevance for the construction sector since it includes companies on different levels. If a company is not directly affected, it will most certainly be possible to find a company with taxonomy-eligible activities in the supply chain.

9 Case study results

The case study results are presented here to exemplify and integrate findings from the earlier research questions. In this section the answers from the interview with Sveafastigheter are presented. From the interview some key points were derived, such as the need for a one-dimensional, "one-fits-all" biodiversity indicator that Sveafastigheter can use to compare suppliers. What follows after the interview results are then the result of the case study; a suggestion of five biodiversity indicators, called internal Key Performance Indicators (KPIs) that can be used to measure the performance of Sveafastigheter's material suppliers.

9.1 Interview answers

During the interview with Sveafastigheter five questions were asked, with a discussion at the end after the three indicator categories were presented. Below a compressed version of the interview is presented, with the key answers for each question.

1. **How would you define the concept of biodiversity?**
    - Different species and plants and the variety of those. All-in-all, a favourable living environment for all plants and insects.
2. **Tell me about how you incorporate biodiversity into your current sustainability work.**
    - Each property should have at least one measure that supports biodiversity, this can be e.g., the implementation of insect hotels, berry bushes or fruit trees.
    - There are requirements from the municipality on what you need to achieve regarding biodiversity on each property that we comply with.
    - We have established an initial dialogue with IVL regarding biodiversity and choosing and assessing construction sites.
3. **What has been the driving force of bringing forward questions about biodiversity?**
    - There are two reasons, one is that our sustainability should be credible and that the work done is transparent and visualised to avoid greenwashing. The second is to make educated, long-term decisions when choosing materials. The current narrative in the building sector is that building in wood is the best when considering sustainability, no questions asked. This narrative has been challenged however with the topic of biodiversity.
        (a) **When did the topic of biodiversity become more important?**

    - Perhaps the last two years, especially with the release of the documentary series "Slaget om skogen", that is when people in the business started to really question the narrative of forest being the best building material.
  - There are also directives from the EU that dictates how Swedish forests should be used.
  - Assessing biodiversity is the biggest problem at the moment, and that is where we are now.

4. **Are there any policies that target biodiversity that you address? Which ones are compulsory to follow or report?**
   - There are none right now. Sometimes the municipalities have competitions regarding land allocation agreements with certain requirements attached.

5. **To what extent are you willing to work with biodiversity?**
   - Right now, we would like to be able to measure biodiversity similarly to how we measure carbon emissions each year.
   - Committing to certifications that show that the material that we use are sustainably produced considering biodiversity.
   - Look further into what can be done at the construction site and property that benefits biodiversity.
   - Truth be told, we do not really know and need help.

   The interviewees were presented with the three indicator categories, as well as some examples. This is what was gathered from the discussion following the presentation of the indicators:

   - LCA is very conventional so from that point of view these methods are difficult to implement. This means that we would need different indicators for each piece of material.
   - We would like some kind of aggregated indicator for biodiversity.
   - When considering which supplier to choose, we would like to know where they acquire their wood from, is it from areas with low or high biodiversity. Will these indicators capture that?

9.2 Internal Key Performance Indicators suggested for Sveafastigheter

This case study highlights biodiversity indicators that measure the performance of Sveafastigheter's material suppliers, both wood and concrete. Sveafastigheter can emphasise that these indicators are the internal biodiversity requirements when it comes to material supplier choice, and will be called internal Key Performance Indicators (KPIs).

The internal KPIs developed for Sveafastigheter are, as much as possible, in accordance with the preferences explicitly stated in the interview, that is, using them should make comparing suppliers possible, as well as aggregate some of the identified indicators and methods to create "all-in-one" indicators.

The internal KPIs do to some extent conform to current certifications, policies, and regulations, and ideally to future regulations given the information gathered from regulations that span forward in time such as the Global Biodiversity Framework and EU Taxonomy. This way the internal KPIs are also "Policy relevant and meaningful" which is one of the guidelines developed by CBD (2007) when selecting biodiversity indicators. For each internal KPI suggested below the possible compliance with legislation is discussed in more detail for each KPI in the corresponding KPI table found Appendix H.

- Impact on biodiversity
- Change of habitat area
- Area restored
- Buffer zones
- Number of biodiversity management plans

In these tables it is also discussed how the KPIs are measured, the internal KPI "Impact on biodiversity" is for example measured by calculating the mean value of the Biodiversity Intactness Index (BII), the Ecosystem Integrity Index (EII) and the Mean Species Abundance (MSA). This is done by adding the score of each indicator and dividing the sum by three.

The internal KPIs are thus chosen because they fulfil the requirements set below:

1. In accordance with the preferences explicitly stated in the interview with Sveafastigheter
2. Conform to current certifications and regulations, and in an ideal scenario, also conform to future ones.
3. Use one or more of the indicators or methods that have been found in this master's thesis project as reference.

10 Discussion

The discussion section presents the key findings that have emerged from this master's thesis project, highlighting their significance and relevance for Sveafastigheter and the building sector. Furthermore, this discussion section provides an opportunity to consider the limitations and constraints of the used method and the presented results, and identifies what kind of future research based on this work that could be explored.

10.1 Wood versus concrete

When comparing wood and concrete and their impact on biodiversity, it is difficult to state whether one is better than the other due to the substantial difference in how each material is extracted, as well as where they are extracted. Although presented with different ways of forestry, they are not comparable to how limestone is extracted, leaving little to no room for arguments for one material over the other in that aspect. What can be compared however is how the two industries compare to one another in terms of how they work and report on biodiversity.

What can be observed when comparing the suppliers for Sveafastigheter is that there is a distinct lack of focus on biodiversity on the concrete side. In the sustainability report last published by Thomas Concrete Group (2021) the word "biodiversity", in Swedish translated to "biologisk mångfald" or "biodiversitet", was found zero times. Thomas Betong's sustainability report instead focuses on CO_2 emissions, with two of their four focus areas in environmental sustainability dedicated to reducing CO_2 emissions. This in contrast to Sveafastigheter's wood suppliers that all include biodiversity work in their sustainability reports.

In the interview with Sveafastigheter, it was stated that the topic of biodiversity has become more important over the last few years. They mean that wood has, without question, always been considered the most sustainable building material and that this view has been challenged due to concerns of biodiversity, which might be an explanation as to why the topic is so prevalent in the forestry industry. For the concrete industry on the other hand, the issue of CO_2 emissions is where public attention is directed as the production stands for 4-8% of the global CO_2 emissions (Watts, 2019), and arguably why focus in sustainability reporting is largely coupled to this.

The European cement association, CEMBUREAU, has published a Biodiversity Roadmap (CEMBUREAU, 2022b) where internal KPIs can be found, as well as plans on how to handle the issue of biodiversity. The main issue of the roadmap is the lack of transparency, whilst the KPIs set could be useful for the building sector and restoration projects are presented, nothing is said about where member sites are located, nor the restoration projects. And whilst restoration is important, the number of sites that have an active restoration project in progress, or how many sites that have been successfully restored in relation to the total number of member sites, is not reported.

The lack of transparency when reporting on sustainability work involving biodiversity should be a concern for the building sector and contractors that want to make sure that they choose suppliers that provide the most sustainable material considering biodiversity. With the increasing concern for biodiversity in society, the demand for transparency increases as well, and actors in the building sector should choose suppliers with that in mind. As there are, as of now, no clear regulations on how biodiversity progress should actually be measured and reported, transparency throughout the value chain should be considered the minimum requirement.

10.2 The relevance and usefulness of the found methods and indicators

When presented with the three different categories of indicators, Sveafastigheter made clear that ideally, the indicator should be an aggregated indicator for biodiversity. Furthermore, it was stated that LCA as a method is very square and that the indicators that were presented would prove a challenge to actually implement, since the indicators would be different for each piece of material - circling back to the need for an aggregated biodiversity indicator. The ambition is simply that biodiversity should be as easily measurably as CO_2 emissions that are measured and accounted for each year in the sustainability report.

The indicators identified can not be aggregated into one however due to the many different aspects of biodiversity that they measure. As the policies and regulations for biodiversity studied are still very much in an early phase for the building sector, and the indicators many and different, it is also difficult to select just one that can accurately represent the variety and complex nature of biodiversity.

With the problematics of aggregated and comparable indicators for different materials in mind, one might need to take a step back and see what the start of future assessments could be: knowledge creation and data collection. Firstly, there were gaps in how much space biodiversity take in sustainability reports, which reflects how much attention it gets within different sectors, or different companies in the same sector.

Many of the identified indicators and methods can help bridge the knowledge gap within companies. CEMBUREAU's Biodiversity Roadmap, Appendix B, is an example of how knowledge can be created by doing the assessment. It guides a company towards biodiversity measures by describing activities that includes data collection, reporting, and engaging activities to develop more knowledge on the topic.

The Science Based Target Network criteria for indicators and assessment methods are of interest for building up a knowledge base. The criteria are available and free to the public, and can be used globally and regionally where applicable, makes the SBTN democratic and usable worldwide. This statement indicates that it could be a useful first step of assessing a company's biodiversity impact, and to create a strategy and setting goals towards a sustainable path. To become certified by the SBTN, there are different fees for different certifications (SBTN, n.d.). Using the tools they have developed is still free though, which can lower the bar for small companies to start their biodiversity work.

10.3 Outcome of the case study

The case study shifts its focus from Sveafastigheter having to measure the direct impacts on biodiversity of their suppliers to making more conscious supplier choices by having the suppliers meet certain biodiversity requirements that are based on the indicators found in this master's thesis project. These biodiversity requirements are reflected in the five internal KPIs suggested for Sveafastigheter. As stated earlier these KPIs were suggested because they fulfilled the three requirements presented in section *9.2. Internal Key Performance Indicators suggested for Sveafastigheter*.

Sveafastigheter did mention in their interview that to be able to measure biodiversity, they need to know what should be measured. As there are currently no regulations that specify what should be measured, or how to measure biodiversity, there is a need for fast development within the area of policies and regulations that target biodiversity. This is true not only for the building sector, but for all companies across several sectors. What can be noticed today is that regulations and policies are developing, such as the EU taxonomy that has included biodiversity and the GBF that specifically targets companies and the issue of biodiversity.

The compliance of the five suggested internal KPIs with possible future regulations and policies is an important aspect to consider for Sveafastigheter. Since it is impossible to know what needs to be measured for full compliance Sveafastigheter can use the suggested KPIs to provide transparency to at least measure *something* in regard to biodiversity. Measuring something may sound nonsensical, but as Zhu and Douglas (2022) have previously emphasised, measuring something means that there is at least a sense of direction of where biodiversity assessment and policies are going.

As Sveafastigheter wants to provide the building sector with the Wood vs. Concrete project to guide not only themselves, but other building companies as well when choosing materials, initialising and using the suggested internal KPIs means that other companies can recognise where to start in their biodiversity assessments regarding material choice.

10.4 Method reflection

The process of choosing indicators that could be useful for the building sector was quite an arbitrary process, where the authors' knowledge and background played a large part in the selections. Consequently, replicating the exact tool selection process for a another project, with other authors, might not be possible. Many of the indicators were either similar or identical, but there were also large variations in the findings. Both the means of measuring, collecting, and calculating the indicators varies, but also the usefulness and presentation of indicators are different. The literature search for stopped when time became limited, but also as new findings became more rare.

The literature has consisted mostly of sources from NGOs and governmental organs, and from private companies as well. The so-called grey literature has been dominant when searching for useful indicators. Exploring more academic texts from researchers and institutions would have been a good contribution to get a wider discussion on how to measure biodiversity.

10.5 Suggestions for future research

The indicators and methods identified are limited to a very specific segment of a building's life cycle. The delimitations and the thesis's starting point in Sveafastigheter's Wood vs. concrete project formed the life stages of relevance and hence a lot is left to explore in the other stages of a building's life cycle. The lifetime of the buildings will affect the impact on biodiversity, as well as the recyclability of materials. There is also potential to do more future research within the studied life cycle.

Whilst a quantity of indicators and methods have been found in this thesis project, they all measure the direct impact on biodiversity. Methods and indicators that measure the indirect impact on biodiversity on a project site should be further explored. This may include exploring how activities other than extraction affects the site of operations, such as the need for equipment or transportation modes that use fossil fuels when extracting one material or the other. The CO_2 emissions from these and their impact on biodiversity both locally and globally are not covered in the methods and indicators in this thesis project but should be to get an even more accurate impact assessment on biodiversity. For this a Life Cycle Assessment, LCA, would serve as a valuable complement when evaluating indirect impacts, thus providing a comprehensive perspective on each building material's biodiversity impact.

11 Conclusion

This master's thesis project examined what current indicators and methods that can be used to assess biodiversity in the building sector. A total of 139 different methods and indicators were found that could be divided into three different categories, based on how the indicators were measured. The three different categories were (1) indicators measured with the help of experts, (2) indicators measured with the help of maps or datasets, and (3) indicators measured in investments or reports. Most of the indicators are inherently non-aggregable, which results in the indicators being highly localised in spatial terms. Consequently, there is a need for examining specific locations or sites of extraction to obtain more accurate biodiversity assessments.

Of the five categorised drivers of biodiversity decline, *changing land use*, *direct overexploitation of resources*, and *invasive alien species* have almost exclusively been targeted here. These drivers can be measured locally, and biodiversity assessments on specific areas are possible with many of the category one indicators: indicators measured with the help of experts. These indicators could be a complement to methods with aggregated data and generalised information, to be geographically accurate.

The problem with most indicators is that they are difficult to use as comparable entities for different materials. Comparing different forestry methods and sustainable management commitments could be feasible, but to do such assessments, the need for data and traceability comes first. A knowledge gap has been discovered, especially in the concrete sector. Whereas forestry brings up the topic of biodiversity and how the sector needs to work with it, the concrete company that has been briefly assessed in this case study barely mentions biodiversity. What has also been discovered is that it is quite hard to find from where the concrete companies source their limestone and other raw materials, making the traceability and transparency questionable.

Data collection and knowledge gathering of biodiversity and companies' impacts will be the first assessment step towards working to enhance biodiversity. Science based policies and regulations are important in this aspect, since they can lead sustainability work in the same direction, with more stakeholders involved in the development of biodiversity assessments. Economic incentives, such as the EU taxonomy, will help push the development forwards, make polluters pay and being unsustainable costly.

The case study showcased that although the development of incentives and policies that target biodiversity is on-going, it is crucial for companies to take the lead in biodiversity assessment. By adopting the suggested internal Key Performance Indicators, Sveafastigheter has the opportunity to become one of these leading companies and demonstrate the benefits of assessing biodiversity and promoting transparency in their sustainability reporting. This proactive approach will prove an advantage when more policies and regulations related to biodiversity emerge.

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Appendices

Appendix A - FOREST EUROPE indicators

Indicator 4.1 Diversity of tree species
Several factors affect the composition of species in the forest. Among them are climate, soil quality, forestry, and grazing. It is said that forests with several tree species are richer in biodiversity and more resilient than forests with fewer species. Invasive species can pose a threat to the diverse forests, but at the same time, some natural forests consist of one or two dominant species.

Indicator 4.2 Regeneration
There are two main categories of regenerating a forest, natural and artificial. The artificial way is by planting or artificial seeding. The natural category is self-explained. Which category that is represented depends on the type of forest, management system in action and scale. It is not clear if one category is preferred over the other. Artificial regeneration can help introduce species that are more adapted to the climate to an area, create a more diverse forest, and help restore a disturbed forest if attacked by unwanted insects.

Indicator 4.3 Naturalness
The classification system of naturalness is divided into three different types: semi-natural forest, forest plantations, and undisturbed forest. The latter category has high conservation value and can be used as reference for management strategies for other forests in the same area. Semi-natural forests can, e.g., be a planted forest that has been left unattended for a while, allowing for a natural development over a longer time.

Indicator 4.4 Introduced tree species
Deadwood provides habitats for many species, both animals and plants. Deadwood also stores carbon and provides the soil with nutrients and protects the ground from erosion. The quality and quantity of deadwood in European forests are quite low due to the long tradition of forest management. However, too much deadwood may be in favour of forest fires or insect infestation.

Indicator 4.6 Genetic resources
This indicator handles the conservation and sustainable use of Forest Genetic Resources. The genetic diversity is important for the robustness of forests, e.g., to resist diseases or changing climate. There are native species and non-native species categorized for this indicator.

Indicator 4.7 Forest fragmentation
The fragmentation is supposed to give an idea of how much of the European forests are continuous. Ecosystems may be affected negatively if forests are fragmented, but that is not always the case. The information of how biodiversity gets impacted is limited.

Indicator 4.8 Threatened forest species
Forest species are the species that are dependent on the forest for their survival. The factors affecting the decline or loss of species are complex, and reasons as to why a species is declining is hard to determine. Some directly related, measurable factors are the quality and quantity of deadwood, tree microhabitats and other tree-based features. The datasets of threatened species vary between countries in abundance, method for data collection and accuracy.

Indicator 4.9 Protected forests
There are two classifications of protection schemes according to MCPE Assessment Guidelines for Protected and Protective Forest and Other Wooded Land in Europe (2003). Those are protection for biodiversity, and protection of landscapes and specific natural elements. The former one is divided into sub-classes that support the conservation of biodiversity. Natura 2000 is an instrument implemented by the EU for conservation.

Indicator 4.10 Common forest bird species
Why this indicator is used is because of the public interest in birds, and the support of the public reporting of birds sighted is helpful in the assessment of common bird species. The populations of different forest bird species are not only affected by forest management, but are also affected by other types of environments in their habitat, climate changes and conditions during migration.

Appendix B - CEMBUREAU Biodiversity Roadmap

1. Ecosystem Rehabilitation and Ecosystem services

1. All members should each year report their data to calculate KPIs and publish the hectares rehabilitated per year.
   (a) KPI 1: Area restored
   (b) KPI 2: Type of area restored
   (c) KPI 3: The percentage of the quarried area allocated to temporary habitats
2. Improvement of the quality of quarry rehabilitation by increasing knowledge, promoting the creation of temporary habits and increasing the number of studies on ecosystem services provided by quarry rehabilitation.
   (a) KPI 1: The proportion of quarries in relation to total quarries that has incorporated an impact assessment methodology into their quarry rehabilitation plans
   (b) KPI 2: Number of studies on ecosystem services provided by quarry rehabilitation

2. EU Pollinators Initiative

1. The members of CEMBUREAU are encouraged to record and compile a database of wild pollinators inhabiting quarries across Europe and communicate to the EU Pollinators Initiative.
   (a) KPI 1: The existence of a database of pollinators and the number of entries during a year
   (b) KPI 2: Number of meetings with the EU Pollinators Initiative.
2. Members are to share and hold public engagement on their knowledge of pollinator rehabilitation activities, as well as should undertake activities that target pollinators specifically.
   (a) KPI 1: The reach of their pollinator-related communication material given in number of people
   (b) KPI 2: Number of activities that are related to conserving pollinators.

3. Invasive Species

1. Members are to develop and keep an updated database of invasive alien plant species, as well as share the knowledge they gather.
   (a) KPI 1: Measure communication activity on invasive alien species management by number of people reached

2. Members should with the help of the information gathered in the previous point develop a plan to manage invasive alien plants.
   (a) KPI 1: Number of companies with management plans regarding invasive plant species implemented

4. Protected Species

1. The KPIs below are developed to support the industry in identifying the most commonly encountered species and how to protect them. They also promote the implementation of Biodiversity Management Plans (BMPs).
   (a) KPI 1: Keep a record of protected species found at member sites
   (b) KPI 2: Number of sites that operate with a BMP near, or within, areas with high biodiversity value
2. Encouragement to engage with relevant partners and stakeholders that could help develop case studies and projects to improve the knowledge and status of protected species.
   (a) KPI 1: Number of projects to support the enhancement of protected species
   (b) KPI 2: Number of case studies that enhances the conservation of protected species by partnerships between members and stakeholders

Appendix C - Article 15 Regulation 2020/852

Article 15 in Regulation 2020/852

1. An economic activity shall qualify as contributing substantially to the protection and restoration of biodiversity and ecosystems where that activity contributes substantially to protecting, conserving or restoring biodiversity or to achieving the good condition of ecosystems, or to protecting ecosystems that are already in good condition, through:

   (a) nature and biodiversity conservation, including achieving favourable conservation status of natural and semi-natural habitats and species, or preventing their deterioration where they already have favourable conservation status, and protecting and restoring terrestrial, marine and other aquatic ecosystems in order to improve their condition and enhance their capacity to provide ecosystem services;

   (b) sustainable land use and management, including adequate protection of soil biodiversity, land degradation neutrality and the remediation of contaminated sites;

   (c) sustainable agricultural practices, including those that contribute to enhancing biodiversity or to halting or preventing the degradation of soils and other ecosystems, deforestation and habitat loss;

   (d) sustainable forest management, including practices and uses of forests and forest land that contribute to enhancing biodiversity or to halting or preventing degradation of ecosystems, deforestation and habitat loss; or

   (e) enabling any of the activities listed in points (a) to (d) of this paragraph in accordance with Article 16.

2. The Commission shall adopt a delegated act in accordance with Article 23 to:

   (a) supplement paragraph 1 of this Article by establishing technical screening criteria for determining the conditions under which a specific economic activity qualifies as contributing substantially to the protection and restoration of biodiversity and ecosystems; and

   (b) supplement Article 17 by establishing, for each relevant environmental objective, technical screening criteria for determining whether an economic activity in respect of which technical screening criteria have been established pursuant to point (a) of this paragraph causes significant harm to one or more of those objectives.

3. Prior to adopting the delegated act referred to in paragraph 2 of this Article, the Commission shall consult the Platform referred to in Article 20 regarding the technical screening criteria referred to in paragraph 2 of this Article.

4. The Commission shall establish the technical screening criteria referred to in paragraph 2 of this Article in one delegated act, taking into account the requirements of Article 19.

5. The Commission shall adopt the delegated act referred to in paragraph 2 by 31 December 2021, with a view to ensuring its application from 1 January 2023

Appendix D - Indicators found in the tools presented by SBTN

Global Forest Watch

Table D1:
Indicators found in the Global Forest Watch tool in the category forest change that can be used to measure biodiversity.

Indicator	**Measurement/explanation**
Tree cover gain	Areas that have gained tree cover due not only to restoration, afforestation or reforestation.
Tree cover loss	Areas with gross tree cover loss due to not only deforestation but also other factors such as mechanical harvesting or storm damage.
Net change in tree cover	Shows areas' net tree cover change.

Table D2:
Indicators found in the Global Forest Watch tool in the category land use that can be used to measure biodiversity.

Indicator	**Measurement/explanation**
Protected areas	Areas that are legally protected, e.g., national parks, state-and wildlife reserves using IUCN management categories I-VI, World Heritage Sites and UNESCO-MAP Biosphere reserves.

Table D3:
Indicators found in the Global Forest Watch tool in the category land cover that can be used to measure biodiversity.

Indicator	**Measurement/explanation**
Tree cover	Areas of tree cover, both natural and plantations.
Tree cover height	Shows the height of forest canopy, minimum of 3 m.
Forest Landscape Integrity Index (FLII)	The condition of the forest determined by anthropogenic modification.
Intact Forest Landscapes (IFL)	Areas with unfragmented forest that are large enough to maintain all native biodiversity as well as show no signs of human activity as of 2020.
Land cover	The distribution of land cover in different classes, e.g., urban areas, forests, and grasslands

Table D4:
Indicators found in the Global Forest Watch tool in the category climate that can be used to measure biodiversity.

Indicator	**Measurement/explanation**
Tree biomass density	Aboveground live woody biomass in megagrams AGB per hectare or per pixel.
Soil carbon density	Organic carbon density at 0 to 30 cm depth (topsoil depth).

Table D5:
Indicators found in the Global Forest Watch tool in the category biodiversity that can be used to measure biodiversity.

Indicator	Measurement/explanation
Biodiversity Intactness Index (BII)	The impact on the biodiversity intactness due to forest change.
Biodiversity significance	Shows the importance of each forest location for biodiversity for forest-dependent amphibians, mammals, birds, and conifers.
Alliance for zero extinction zones	587 different sites for conservation worldwide that contain species with extremely small populations and global ranges. Any change to the site and the species' habitat may lead to extinction.
Key biodiversity areas	Sites that significantly contribute to the global persistence of biodiversity if they meet any of the criteria in five different categories, threatened biodiversity, geographically restricted biodiversity, ecological integrity, biological processes and irreplaceability.
Biodiversity hotspots	Regions where biodiversity conservation is most urgent due to human threat.

ENCORE

Table D6:
Indicators found in the Encore tool that can be used to measure biodiversity.

Indicator	Measurement/function
Biodiversity depletion	Relative rate of natural capital depletion of biodiversity.
Soil and sediments depletion	Measured through soil erosion and change in soil carbon stocks.
Water depletion	Measured through, e.g., water stress and high coastal eutrophication potential.

UN Biodiversity Lab

1. Biodiversity Intactness Index (BII)
2. Forest Biodiversity Intactness Index (Forest BII)
3. Forest Landscape Integrity Index
4. Global Forest Change
5. Intact Forest Landscapes
6. IUCN Species Richness and IUCN Threatened species Richness
7. Mammalian Genetic Diversity
8. NatureMap - Human Impact on Forests
9. NatureMap - Human Pressures

Appendix E - Northern European Indicators for forestry

Swedish indicators

Table E1:
Indicators in Sweden for Forest land properties and processes

Indicator	**DPSIR**
ground damage from machines	R
transportation over water courses	R
consideration for water courses when preparing land	R
eutrophication from forestry	P
carbon storage	S
fall-out of sulphur	P
fall-out of nitrogen	P

Table E2:
Indicators in Sweden for Green infrastructure

Indicator	**DPSIR**
forest excepted from timber production	R
old forest	S
age distribution of the forest	S
old trees	S
regeneration felling and its impact on sensitive habitats and protection zones	R
logged key habitats	P
registered key biotopes	R
forest landscape structures	S
deadwood	S
wildlife damage	S

Table E3:
Indicators in Sweden for Endangered species and restored habitats

Indicator	**DPSIR**
no. red-listed species with declining populations	S
breeding birds	S
completed and ongoing action plans for threatened species living in forests	R

Finnish indicators

Table E4:
Indicators for biodiversity in Finnish forestry

Indicator	**Unit/explanation**	**DPSIR**
wood removals	Timber removal in cubic meters in relation to growth, divided into sawlogs, pulpwood, and energy wood	D
fellings	Harvested area divided into clearcutting and seed tree stands	D
soil scarification	Area of prepared land distributed among clear-cut plowing, mound cultivation, spot scarification, and harrowing. Measuring silvicultural intensity	D
articifial regeneration	The area of planting and sowing, as well as the use of domestic plant material	D
forest roads	Length of forest roads to measure forest fragmentation	D
dead wood	Volume of dead wood divided into standing and downed dead wood. In the Swedish National Forest Inventory 2009-2013, the volume in managed forests was 3.6 m^3/ha and in protected forests was 14.0 m^3/ha	S
forest fragmentation	Indicator under development	S
forest age structure	Fraction of forest over 100 years and 140 years, and under 40 years	S
tree species composition	Distribution of tree species on pine, spruce and deciduous as well as the proportion of aspen forest	S
forest birds	Index for forest birds based on winter bird counts and index for forest birds from summer inventories, divided into forest generalists and coniferous forest specialists	S
wildlife richness	State of big mammals and forest grouse though hunting statistics	S
forest vegetation	Coverage of lingonberries, blueberries, lichens, and mosses in both mature and harvested forests	S

Table E4:
Indicators for biodiversity in Finnish forestry

Indicator	Unit/explanation	DPSIR
red-listed species	Number of threatened species (Vulnerable, Endangered, Critically Endangered) and the proportion found in forest environments, as well as trends for threatened forest-dwelling species	I
directive forest species	Status and population trends for 33 forest species on the list for the EU's Habitat Directive	S
red-listed forest habitat types	Threat categories for the 70% of forest habitat types considered threatened. Together, they make up nearly half of Finland's forest land area	S
directive forest habitat types	Status of the six habitat types in the EU's Habitat Directive that are directly classified as forest	S
nature management in managed forests	Retention trees left after harvesting (living and dead) and conservation of valuable habitats in private forestry	R
prescribed burning	Annual area of prescribed burning and natural fires	R
protected areas	Proportion of forest land that is protected, formally or otherwise. Data beyond the strictly protected area is preliminary	R
restoration and management	Area with active measures such as burning, creating dead wood, and gap felling, as well as nature management in protected forests	R

Estonian indicators

Table E5:
Estonian indicators for nature preservation

Indicator	indicator type	DPSIR
The number of habitat types under the Habitats Directive that have shown improved conservation status	endangered species	S
Percentage of species with a favourable conservation status under the Birds Directive	endangered species	S
Number of species with developed conservation recommendations	endangered species	R
Area of strictly protected forest in hectares	protected areas	R
Proportion of habitat types at European level with inadequate conservation status that have improved	prioritised areas	S
The number of species under special monitoring	endangered species	R
Number of indicator species indicating positive correlations in the landscape	landscape quality	S

German indicators

Table E6:
German indicators for biodiversity in forests

Indicator	unit/measurement	DPSIR
Biodiversity and landscape quality	Weighted percent index (0-100), where 100% is the population size that was estimated to be achievable given the implementation of nature conservation legislation in 2015	S
Endangered species	Percentage index (0-100), weighting depending on threat category - greater impact for species with a higher threat category. 0 means there are no threatened species, and 100 means all species are extinct	I
Conservation status of species and habitats related to the Species and Habitats Directive	Percentage index, weighted measure of conservation status within biogeographic region	S
alien species associated with forested wetlands	Number of alien species, rate of spread	P
Protected area. Refers to all protected land area, not just protected forest area	Percentage of total land area	R
Landscape fragmentation	Percentage of land area unaffected or only slightly affected by road construction	P
Sustainable forestry	Proportion of certified forest land	R
Length of vegetation season	Start of spring and winter periods	S
Public awareness of biodiversity	Proportion of the German-speaking population with basic knowledge about biodiversity	S

Appendix F - Stora Enso Sustainability Report

Guidelines for indicator measurement in Sweden

1. High stumps - create at least **3 high stumps/ha** at harvesting
2. Ground deadwood - no harm should be done to deadwood logs which have been **dead for more than a year** with a diameter of **at least 15 cm**
3. Soil and water - how many watercourses that have been crossed without damage.
4. Prioritised habitats - preservation of **all** identified prioritised habitats
5. Tree retention - at least **10 trees/ha** left at harvesting
6. Buffer zones - the width of the buffer zone depend on the site

Guidelines for indicator measurement in Finland

1. High stumps - create at least **1-4 high stumps/ha** at harvesting
2. Ground deadwood - no harm should be done to deadwood logs
3. Soil and water - how protected the soil is when operating at sites including waters
4. Prioritised habitats - preservation of **all** identified prioritised habitats as per the definition given in Article 10 of the Finnish Forest Act.
5. Tree retention - at least **10 trees/ha** left at harvesting
6. Buffer zones - the width of the buffer zone should be at least **10 m**

Guidelines for indicator measurement in the Baltic States

1. High stumps - this is not measured in the Baltics. Natural high stumps are instead left with the target of leaving at least **5 dead trees/ha**
2. Ground deadwood - at least **5 standing and 5 lying deadwood stems per hectare** should be left.
3. Soil and water - how protected the soil is when operating at sites including waters
4. Prioritised habitats - not measured in the Baltics.
5. Tree retention - at least **7-10 trees/ha** left at harvesting
6. Buffer zones - the width of the buffer zones are in line with national legislation in each Baltic state.

Appendix G - List of indicators and methods

Table G1:
The indicators and methods found in this master's thesis project categorised.

	Indicators measured with the help of experts	Indicators measured with the help of maps or data sets	Indicators measured in investments or reports
FOREST EUROPE indicators			
Indicator 4.1 Diversity of tree species	x		
Indicator 4.2 Regeneration	x		x
Indicator 4.3 Naturalness			x
Indicator 4.4 Introduced tree species	x		
Indicator 4.6 Genetic resources	x		
Indicator 4.7 Forest fragmentation		x	
Indicator 4.8 Threatened forest species		x	
Indicator 4.9 Protected forests			x
Indicator 4.10 Common forest bird species		x	
CEMBUREAU Biodiversity Roadmap			
1. Ecosystem Rehabilitation and Ecosystem services			
Area restored			x
Type of area restored			x
The percentage of the quarried area allocated to temporary habits			x
The proportion of quarries in relation to total quarries that has incorporated an impact assessment methodology into their quarry rehabilitation plans.			x
Number of studies on ecosystem services provided by quarry rehabilitation			x
2. EU Pollinators Initiative			
The existence of a database of pollinators and the number of entries during a year	x		
Number of meetings with the EU Pollinators Initiative.			x
The reach of their pollinator-related communication material given in number of people			x
Number of activities that are related to conserving pollinators.			x

3. Invasive Species			
Measure communication activity on invasive alien species management by number of people reached			x
Number of companies with management plans regarding invasive plant species implemented			x
4. Protected Species			
Keep a record of protected species found at member sites	x		
Number of sites that operate with a BMP near, or within, areas with high biodiversity value			x
Number of projects to support the enhancement of protected species			x
Number of case studies that enhances the conservation of protected species by partnerships between members and stakeholders			x
EU Taxonomy			x
Science Based Targets Network			
Global Forest Watch			
Tree cover gain		x	
Tree cover loss		x	
Net change in tree cover		x	
Protected areas		x	
Tree cover		x	
Tree cover height		x	
Forest Landscape Integrity Index (FLII)		x	
Intact Forest Landscapes (IFL)		x	
Land cover		x	
Tree biomass density		x	
Soil carbon density		x	
Biodiversity Intactness Index (BII)		x	
Biodiversity Significance		x	
Alliance for zero extinction zones		x	
Key biodiversity areas		x	
Biodiversity hotspots		x	
ENCORE			
Biodiversity depletion		x	
Soil and sediments depletion		x	

Water depletion			x	
UN Biodiversity LAB				
Biodiversity Intactness Index (BII)			x	
Forest Biodiversity Intactness Index (Forest BII)			x	
Forest Landscape Integrity Index			x	
Global Forest Change			x	
Intact Forest Landscapes			x	
IUCN Species Richness and IUCN Threatened species Richness			x	
Mammalian Genetic Diversity			x	
NatureMap - Human Impact on Forests			x	
NatureMap - Human Pressures			x	
Biodiversity indices				
Species richness	x			
Shannon Diversity Index	x			
Simpson's Diversity Index	x			
Habitat Suitability Index (HSI)	x			
The Ecosystem Integrity Index (EII)			x	
The Biodiversity Intactness Index			x	
Mean Species Abundance (MSA)			x	
The Forest Structural Condition Index (SCI) and The Forest Structural Integrity Index (FSII)		x		
Northern European Indicators for forestry (SLU report)				
Indicators in Sweden for Forest land properties and processes				
ground damage from machines	x			
transportation over water courses				x
consideration for water courses when preparing land				x
eutrophication from forestry	x			
carbon storage			x	
fall-out of sulphur			x	
fall-out of nitrogen			x	
Indicators in Sweden for Green infrastructure				
forest excepted from timber production	x			
old forest	x			
age distribution of the forest	x			
old trees	x			
regeneration felling and its impact on sensitive habitats and protection zones	x			
logged key habitats				x

registered key biotopes		x	
forest landscape structures		x	
deadwood	x		
wildlife damage	x		
Indicators in Sweden for Endangered species and restored habitats			
no. red-listed species with declining populations	x		
breeding birds	x		
Completed and ongoing action plans for threatened species living in forests			x
Indicators for biodiversity in Finnish forestry			
wood removals	x		
fellings	x		
soil scarification	x		
artificial regeneration	x		
forest roads		x	
dead wood	x		
forest fragmentation		x	
forest age structure	x		
tree species composition	x		
forest birds		x	
wildlife richness		x	
forest vegetation	x		
red-listed species	x		
directive forest species			x
red-listed forest habitat types	x		
directive forest habitat types	x		
nature management in managed forests			x
prescribed burning			x
protected areas			x
restoration and management			x
Estonian indicators for nature preservation			
The number of habitat types under the Habitats Directive that have shown improved conservation status		x	
Percentage of species with a favourable conservation status under the Birds Directive		x	
Number of species with developed conservation recommendations	x		
Area of strictly protected forest in hectares		x	
Proportion of habitat types at European level with inadequate conservation status that have improved	x		

The number of species under special monitoring			x
Number of indicator species indicating positive correlations in the landscape	x		
German indicators for biodiversity in forests			
Biodiversity and landscape quality	x		
Endangered species		x	
Conservation status of species and habitats related to the Species and Habitats Directive		x	
alien species associated with forested wetlands	x		
Protected area. Refers to all protected land area, not just protected forest area		x	
Landscape fragmentation		x	
Sustainable forestry			x
Length of vegetation season		x	
Public awareness of biodiversity			x
Stora Enso			
High stumps	x		
Ground deadwood	x		
Soil and water	x		
Prioritised habitats			x
Tree retention	x		
Buffer zones		x	
SDG 15			
Target 15.1: sustainable use			x
Target 15:2 sustainable management			x
Target 15:3 degraded land	x		
GRI 304: Biodiversity			
KPI 304-1-b: operational sites that may impact biodiversity			x
KPI 304-1-d: operational sites near areas of high biodiversity value		x	
KPI 304-2-c-ii: size and type of ecosystem converted		x	
KPI 304-3-a: Ecosystem types, size and condition		x	
BREAAM			
site selection - previously occupied			x
site selection - site of low ecological value	x		

ecology reports and management plans enhancing ecological value			x
LEED			
Site assessment			x
Protect or Restore habitat			
Disturbed soil should be restored and the imported soil should not be from other greenfield sites nor sphagnum peat moss.			x
A minimum of six species of vegetation native to the region should be planted, including a minimum of two of the three categories, tree, shrub and ground cover.			x
Nordic Swan Ecolabel Buildings			
Biodiversity			
Tree species with restricted use			x
Assessment of the biodiversity in the project area			x
Measures to preserve and improve the biodiversity			x
Innovation and Green Initiatives			x
SUMMARY	34	53	46

Appendix H - Suggested internal KPIs for Sveafastigheter

Table H1:
The internal KPI "Impact on biodiversity" that measures the change of biodiversity before and after extractive operations have started

	Impact on biodiversity
Purpose	To measure how extractive operations have affected the biodiversity in the area.
Definition	The change in biodiversity in the area before and after extractive operations started.
Method	Using spatial data or datasets, determine the mean value of the following: • Biodiversity Integrity Index • Ecosystem Integrity Index • Mean Species Abundance This is done by adding the scores together and dividing by three. If the mean values are identical, or similar for two suppliers, determine whether the site is established on used land or land of low ecological value.
Notes	**Baseline biodiversity.** If possible, use the baseline biodiversity of the area as the reference point for comparison. If unavailable, the oldest available data should be used.
	Used land is preferred to establish new operations on. If the criteria "used land" is true, the baseline biodiversity should not be used as the basis of comparison, but rather the biodiversity on the previously used land.
	Land of low ecological value is also preferred to establish new operations on, as opposed to areas of high ecological value such as woodlands and wetlands.
	An ecologist or biologist can give a more accurate assessment of the area's biodiversity than spatial data.

	Possible compliance with legislation. A trend can be observed in building certifications, regulations and reporting standards, highlighting the importance of choosing where to establish new sites with biodiversity in mind. BREEAM mentions the importance of choosing construction sites with low ecological value, and other building certifications in this report emphasises the need to understand the current biodiversity at the area. KPI 304-1-b also highlights the importance of transparency when choosing sites. This is also in compliance with SDG15 that aims to protect ecosystems, as well as the EU taxonomy.

Table H2:
The internal KPI "Change of habitat" that measures the proportion of the total area that has been left untouched for the purpose of preservation.

	Change of habitat area
Purpose	To measure how much of the total area that is left for preserving habitats.
Definition	The proportion of the total area that has been left untouched for the purpose of preserving natural habitats, expressed in percentage.
Method	Utilise documentation such as Sustainability reports and management plans to see whether areas are set aside for preservative purposes.
Notes	**The Habitat Suitability Index (HSI)** can be used to measure the capacity of the preserved area to support a group of species. An expert could monitor the HSI of the area during operations to see if the habitat maintains the same capacity at the start and end of operations.
	Prioritised habitats should be preserved as well. In Sweden Stora Enso preserves all that are chosen by an ecologist, whilst in for example Finland prioritised habitats are given a definition in Article 10 of the Finnish Forest Act.
	Possible compliance with legislation. Preserving part of the operational area could be considered an economic activity contributing to protecting and restoring biodiversity through nature conservation according to Article 15 in Regulation 2020/852. It can also be seen as a way to comply with SDG15 and the EU Biodiversity Strategy for 2030.

Table H3:
The internal KPI "Area restored" that measures The proportion of the area restored compared to the total operational area.

	Area restored
Purpose	To promote biodiversity on the site of operations by restoring areas previously damaged by extractive operations.
Definitions	The proportion of the area restored compared to the total operational area.
Method	When calculating the area restored, make sure that the following are true: • A minimum of six species of vegetation native to the region are planted • Invasive plants species have been removed or controlled • Disturbed soil should have been restored In addition to this also include transparency regarding: • The area restored • Type of area restored • If the habitat is temporary or not • Tree cover gain
Notes	**Non-native tree species**. If operations have yet to have ceased non-native tree species that have adapted to the new environment can be planted.
	Regenerating forests naturally or artificially. Since it is not clear whether natural or artificial regeneration of forests is preferable either regeneration category is fine.
	Possible compliance with legislation. Could fulfil target 15.2: sustainable management in SDG15 by restoration of degraded forests and increased reforestation. In LEED it is mentioned that damaged areas are to be restored, and even though this applies for construction sites, it is not impossible that it reflects future legislation regarding extraction sites.

Table H4:
The internal KPI "Buffer zones" that measures the number of correctly handled buffer zones in relation to the area that needs protecting.

	Buffer zones
Purpose	Showcases how operations respect surrounding nature.
Definition	The number of correctly handled buffer zones in relation to the area that needs protecting.
Method	Whilst reporting on the number of buffer zones it is also important with transparency by providing information on: • The size of the buffer zones • Name and distance to the protected area • Whether these areas are legally protected, internationally recognised or other areas of importance for biodiversity.
Notes	**Protected areas** include national parks, state-and wildlife and reserves using IUCN management categories I-VI. They can also be key biodiversity areas found in Natura 2000.
	The size of buffer zones varies from country to country. In Sweden the width depends on the site, whilst in some countries the buffer zone sizes should be in line with national legislation.
	Correctly handled buffer zones are those that follow legislation or are approved by an expert, preferably an ecologist or biologist.
	Possible compliance with legislation. GRI 304-1-d states that all operational sites that are near, or include, areas of high biodiversity value should state the distance to these areas. However, the importance of buffer zones can be highlighted in the fact that some countries already have legislation on buffer zone sizes and that protection of 30% of the total land area is one of the four pillars in the Biodiversity Strategy for 2030.

Table H5:
The internal KPI "Number of biodiversity management plans" that measures the proportion of extraction sites with a BMP or ecology report, in relation to the total number of sites that the company operates.

	Number of biodiversity management plans
Purpose	Obtain an overview of the management actions to deliver nature-positive outcomes on all operative sites.
Definition	The proportion of extraction sites with a biodiversity management plan (BMP), or ecology report, compared to the total number of sites that the company operates.
Method	BMPs can target different aspects of biodiversity, such as invasive species or certain areas. Below are some examples of what can be compared between material suppliers: • The number of sites with plans for enhancing ecological value at the site during operations • The number of sites with management plans regarding invasive species • The number of sites that operate with a biodiversity management plan near, or within, areas with high biodiversity value
Notes	**External ecologists or biologists** should preferably be the ones doing the assessments of the sites, and thus also the BMP or ecology report. This indicates that impartial assessments have been made and that the actions will have positive outcomes for nature.
	Possible compliance with legislation. Both BREEAM and the Nordic Swan Ecolabel emphasize the need for ecology reports that assess project sites so that appropriate measures can be taken regarding biodiversity. A site with a BMP also contributes to protecting and restoring biodiversity in line with SDG15.

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