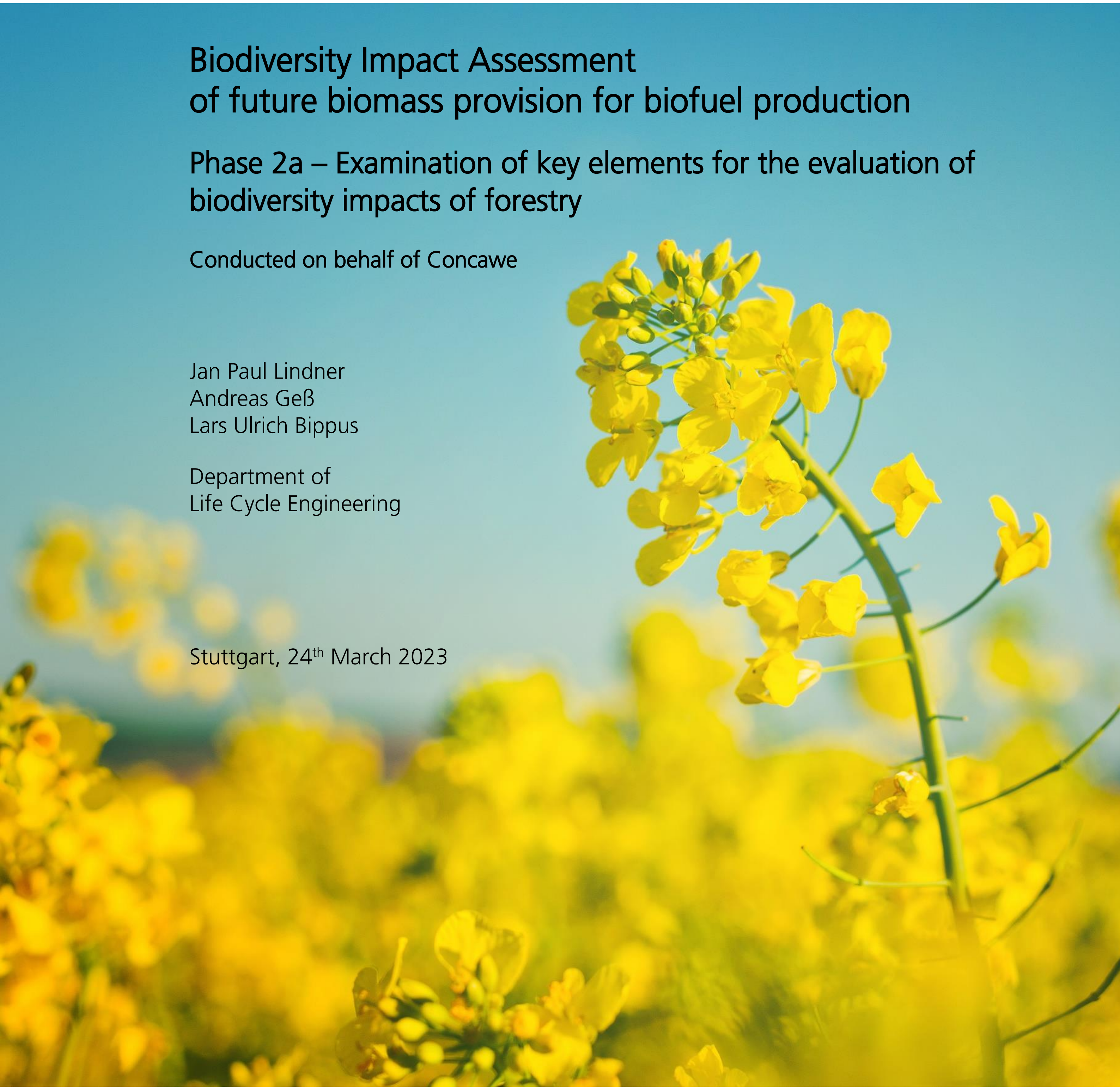
Fraunhofer IBP

Fraunhofer-Institute for Building Physics IBP
Head of Institute
Prof. Dr. Philip Leistner



Biodiversity Impact Assessment of future biomass provision for biofuel production

Phase 2a – Examination of key elements for the evaluation of biodiversity impacts of forestry

Conducted on behalf of Concawe

Jan Paul Lindner
Andreas Geß
Lars Ulrich Bippus

Department of
Life Cycle Engineering

Stuttgart, 24th March 2023

Fraunhofer-Institute for Building Physics IBP
Nobelstraße 12 | 70569 Stuttgart
Telephone +49 711 970-00
Telefax +49 711 970-3395
www.ibp.fraunhofer.de

Contracted by Concawe

Under the Supervision: Themistoklis Neokosmidis (Concawe Science Associate)

Contact:
FuelsManufacturing@Concawe.eu

Concawe
Environmental Science for European Refining

Contents

Executive Summary

Biodiversity preservation has become a significant topic in Europe due to the increasing demand for more sustainable goods. Concawe, as part of its research activity in biomass availability and mobilization for biofuels production, has commissioned this study to obtain a better understanding of how biomass removal from forests affects biodiversity. To attain this, a good understanding of how biodiversity can be measured is needed. For this purpose, a literature review of the available biodiversity assessment methods is conducted in this study. More specifically, the methods and tools used in the EU project ALIGN [1], which applies a broad spectrum of biodiversity assessment methods and tools, were investigated. Additionally, forestry labels and political development strategies for forests have been examined with a focus on their criteria and parameters of measurement.

Generally, it can be stated that most of the reported methods in the literature are not based on standalone background data and should be identified as tools with most of them to making use of or relying on three established assessment methods: the **PDF (**Potentially Disappeared Fraction of species) method, the **GLOBIO** (Global biodiversity model for policy support) framework and the **ReCiPe** method. While PDF and GLOBIO specifically assess biodiversity, ReCiPe assesses the damage to ecosystems, which is then used as an indicator for damage to biodiversity. The methods are then compared to the **B.I.A.** (Biodiversity Impact Assessment) method developed at Fraunhofer IBP. PDF and GLOBIO use standardized characterization factors (derived from average values varying per region and management form) deduced from other assessment or monitoring frameworks and are therefore easy to apply. On the other hand, B.I.A. calculates characterization factors for each case study or assessed production process individually. This means that it is possible to integrate more detailed field data, but it is therefore more complex to apply. Consequently, in the case of detailed data availability, B.I.A. can show more detailed results that are more individual to a case study or production process than PDF and GLOBIO.

Another focus of the study is the assessment of the most relevant criteria for assessing the impact on forest biodiversity. For this purpose, eco labels and political strategies were examined and compared to the inputs of the above mentioned biodiversity assessment methods. The most mentioned criteria are **area and region, species abundance, deadwood, soil effects, planting or management practice, fertilization and pesticides application.** Weighting or favoring certain criteria is hardly possible as the combination and interaction of all criteria leads to a robust result of the biodiversity assessment. Since some of these criteria often complement each other – e.g. management practice, fertilization and pesticides application, the inclusion or the way of inclusion varies in the different methods. Especially through the usage of global or regional standard values or characterization factors, which often differ strongly from the actual state on-site, sometimes different results may be obtained.

Summarizing the literature review findings of this study, it can be concluded that several biodiversity methods and tools have been developed and reported, with many of them to be possibly used to assess the impact of forest biomass removal on forest biodiversity. Quantifying biodiversity in forests can be complex, however, the influencing factors have been widely discussed and listed in the different European eco-labels and guidelines. Finally, taking a decision on which method is more suitable for such a biodiversity analysis as well as the level of detail and accuracy that can be attained is relevant to the type and extent of available data.

1 Introduction and Outline

As biodiversity assessment in Life Cycle Assessment is not yet standardized, many different methods are applied, resulting in various conclusions or having different direction of assessment focus. This report gives an overview of applied methods and tools to assess biodiversity and their different outlines, input data and outcomes. For example, some methods account the presence of certain species, while others account the absence of species. Further, some methods include ecosystem system services, whereas others focus on certain indicator species. Some are locally limited and highly specified, others use a top-down approach to give a broader insight on biodiversity interrelations. Therefore, the findings are difficult to interpret or to communicate to non-biodiversity experts and choosing the correct method for an application requires expert knowledge.

In this context, the European Commission (EC) intends to structure biodiversity assessment and to identify strengths and weaknesses of the numerous biodiversity assessment methods. For this purpose, the ALIGN project - Aligning accounting approaches for nature - was put into action [1].

The objective of this study is to assess the impacts of biomass provision for biofuels production in Europe on the different habitats' biodiversity. A first phase of this project, completed and published in 2022, put the focus was on assessing the biodiversity in unused, abandoned and degraded lands in Germany and Bulgaria (as representative countries) as a result of energy crops cultivation (Miscanthus was chosen as a representative example). For the analysis, the findings of a preceding study on biomass availability by Concawe and the ICL Consultants [2] were used and two methods were applied – the PDF method, which is mentioned by the EC within the LCA context, and the B.I.A. method, which was developed by Fraunhofer GaBi. The focus of this new study is set on forestry. It is designed to give an overview of various biodiversity methods and their use cases with a focus on forest management. An assessment of biodiversity in forests based on industry data shall be conducted afterwards. As the ALIGN project applies a broad range of tools and methods, the here included methods are examined regarding their field of application, their required input parameters and their type of results. Furthermore, frameworks from eco labels, conservation strategies and development plans given out by the EU, national governments or regional entities are analyzed to give an overview of biodiversity assessment schemes.

2 Methods from the ALIGN project

The Align project is an approach to standardize biodiversity metrics. It is funded by the European Commission and aims to develop "recommendations for principles and criteria for biodiversity measurement and valuation" [1]. It was chosen for this biodiversity assessment methods overview due to its large scale, its objective to produce scientifically robust results and the number of biodiversity methodologies investigated with respective case studies. In addition, stakeholders of businesses and financial institutions are involved in the project who have an interest in integrating sustainability metrics into their corporate goals and therefore face similar challenges in quantifying biodiversity impacts of their products.

Although the Align project does not focus specifically on forestry, biofuel production, or LCA, it can be assumed that widely used or accepted methods for assessing the biodiversity impact of forestry have been included in the Align study for the reasons stated above. As all the methods and tools in the Align study deal with biodiversity in general, they include various vegetation or cultivation forms including forestry. Thus, the results of the Align project can provide a first overview and reflect some currently discussed, applied and therefore potentially relevant methods and tools to assess biodiversity impacts in forest areas. The question of how these can also be used in Life Cycle Assessment is addressed in this literature study. In this chapter, a general overview of the currently applied biodiversity assessment methods, and their characterization factors – meaning the values that quantify the assessed impact category like biodiversity -, is presented (see list below). This broad selection of methods assessed in the above mentioned Align project will then be compared to the PDF and B.I.A methods, that were applied in Phase 1 of this project.

Biodiversity Assessment Methods included in the Align project:

- Product Biodiversity Footprint(PBF):
  determines a score for each of the 5 Millennium Ecosystem Assessment (MEA) drivers (habitat change, pollution, climate change, invasive species, overexploitation). [3]

- Biodiversity Footprint Methodology (BFM):
  measures Mean Species Abundance (MSA) meaning the mean abundance of endemic species relative to their abundance in undisturbed ecosystems. [4]

- Corporate Biodiversity Footprint (CBF):
  measures Mean Species Abundance. [5]

- LIFE Key:
  provides the LIFE Methodology Metrics: Biodiversity Pressure Index, Biodiversity Minimum Performance and Biodiversity Positive Performance [6–8]

- Species Threat Abatement and Recovery (STAR):
  calculates the STAR Score based on the extinction risk per species and the STAR threat abatement score based on the effort required for all species to become Least Concern. [9, 10]

- Integrated Biodiversity Assessment Tool (IBAT):
  combines the number of protected areas with STAR. [10, 11]

- Biodiversity Indicators for Site-based Impacts (BISI):
  provides a score based on the SPR (state-pressure-and response) drivers concerning remaining, endangered and managed habitats, area and populations. [12]

- Global Biodiversity Score (GBS):
  measures Mean Species Abundance. [13]

- Biodiversity Net Gain Calculator (BNGC):
  gives a biodiversity value between 0 and 1 based on a field survey by an experienced ecologist i.e. a score of 1 represents a high quality habitat with a very rich biodiversity comparable to totally undisturbed nature. [14]

- Biodiversity Impact Metric (BIM):
  compares the biodiversity loss to the original habitat. [15]

- Biodiversity Indicator and Reporting System and Long Term Biodiversity Index (BIRS + LBI):
  provides a Biodiversity index based on extent of the habitat and plant heritage species. [16]

- ReCiPe (LCA Framework):
  calculates a Life Cycle Assessment (LCA), and hence is not a typical biodiversity impact assessment. The impacts on biodiversity are deducted from the impact category "damage to ecosystems". [17, 18]

- The Agro-biodiversity Index (ABD):
  evaluates the agricultural species diversity and includes values for genetic, species and landscape levels, i.e. the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture. [19]

- Biodiversity Footprint for Financial Institutions (BFFI):
  calculates the potentially disappeared fractions (PDF) based on LCA Inventories. [20, 21]

- Bioscope:
  uses the potentially disappeared fractions (PDF) as a unit with individualized background calculations and characterization factors . [17, 22]

- Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)
  gives a coarse overview on impacts generated through a certain production process and includes biodiversity impact through species extinction risk and ecological integrity risk. [23]

- Global Impact Database (GID):
  provides values for biodiversity loss and its monetary value (the method uses two frameworks (exact characterization factors are not provided): 1. The Framework for Impact Statements (FIS) (2019) released by the Impact Institute, 2. The Integrated Profit and Loss Assessment Methodology (IAM) core which builds from FIS. It offers guidance and practical advice on how to put the principles of FIS into practice and focuses on some of the key topics in FIS). [24]

The ALIGN project highlights the strengths and weaknesses of the methods covered. The methods proposed by the ALIGN project partners are aimed at production and financial undertakings. Table 1 shows the required input data and if the methods are connected to LCA, meaning if the impacts are product-based, or if they make use of pre-existing biodiversity impact assessment methods. Furthermore, the most common criteria are listed and their inclusion in the respective methods and tools are examined. Those are:

- Species: addressing the variety or abundance of located species;
- Product/ Process data: inclusion of the way of production or production yields, also addressing (forest) management forms, e.g. use of pesticides, extensive management, machine use;
- Area: most assessments are related to the size of a certain area;
- Coordinates: inclusion of regional effects (e.g. vegetation form, climate zone, …, etc.) and
- Land Use type: possibility of differentiation between various form of land use, e.g. biomass production, conservational area or recreational purpose.

Furthermore, it is assessed if the tool or method makes use of other standalone biodiversity assessment methods or indices, like GLOBIO, PDF, B.I.A. and RECIPE as well as of the IUNC Red List and the WWF Wildfinder.

Table 1: Required input data for the various biodiversity assessment methods and compatibility with LCA and other biodiversity indices (x = Data required; (x) = Inclusion possible. Mean values used, if no data is available; [empty] = Not required/possible

	Required Input Data					Connectivity	
	Species	Product/ Process data	Area	Coordi-nates	Land Use type	Use of other Biodiv. indices	LCA Compati-bility
PBF				x	x		x
BFM			x		x	x	x
CBF		x				x	x
LIFE Key		x	x	x		x	
STAR			x	x	x	x	
BISI			x	x	x	x	
GBS		x	x	x		x	
BNGC	(x)		x	x		(x)	
BIM		(x)	x	x	x		
BIRS + LBI	x	x	x	x	x	x	
Re CiPe		x		(x)			x
ABD	(x)	x				x	
BFFI		x	x			x	x
Bio-scope		x		x	x	x	
IBAT			x	x	x	x	
EN-CORE						x	
GID					x	x	
BFA			x		x	x	x
B.I.A.	x	x	x	x	x	(x)	x
PDF	x	x	x	(x)	x	x	x

Almost all methods make use of other biodiversity assessment methods, databases – e.g. the characterization factors from PDF or GLOBIO - and indices – e.g. PDF or MSA as a unit for biodiversity impact. Most methods, namely BFM, CBF, LIFE Key, GBS and BNGC, use the GLOBIO framework [25, 26]. This framework assesses the changes in terrestrial biodiversity intactness of future socio-economic developments by calculating Mean Species Abundance (MSA). Others from the listed methods measure the possible disappeared fractions (PDF), a methodology developed by Chaudhary and Brooks in 2018 [27].

BIM uses its own calculation scheme for biodiversity loss. However, it is based on the work of the Projecting Responses of Ecological Diversity In Changing Terrestrial Systems (PREDICTS) database. [15] The ReCiPe method was developed for LCA characterizing and weighting. The assessment of biodiversity is deduced from the herein calculated "areas of protection" which consist of the end-point impact categories damage to human health, damage to ecosystems and damage to resources.

ReCiPe uses species richness with the PDF unit as a proxy for ecosystem quality. The areas of protection are represented by an endpoint indicator in LCA terms. The calculation is done via damage pathways from midpoint indicators (with known weak points) and results in more indirect than direct impacts from land occupation. It is compatible with other PDF methods[18]. It must further be mentioned that the Biodiversity Net Gain Calculator is "aligned with how mean species abundance (MSA) is scored in GLOBIO" [14]. It therefore includes a unique scoring system that has the same range as the MSA, but is designed to address land use.

Another method stands out: ABD focusses on cultivated species and promotes diversity of agrarian plant species. It has therefore its own evaluation scheme.

Other methods and indices are applied in the following approaches:

GBS uses separate methods for physical risk (CRIS Methodology: Climate Risk Impact Screening) and transition risk (CIA Methodology: Carbon Impact Analytics) [13].

ENCORE uses a broad variety of impact assessment methods or indices, e.g. the IUCN Red List, creating overview maps highlighting hotspot areas for various impacts [23].

GID uses calculation baselines that are not publicly available [24].

Consequently, it can be stated that the methods used in the ALIGN project are rather tools than standalone biodiversity impact calculation methods. Most of them are based on the characterization factors and calculation schemes of GLOBIO framework and the PDF or ReCiPe method and they bring in additional factors, values to fit their individual field of application and make those methods easy to use.

In contrast to the ALIGN tools, B.I.A. and PDF are standalone assessment methods for assessing the effects of a production process. B.I.A. provides a calculation scheme that is individually applicable for a specific site or a unique production process. On the other hand, the PDF method uses standardized characterization factors for certain management forms and areas. This means, that in the case of forests, intensive management in a particular forest area is assigned a certain characterization factor – meaning a factor that puts the prevailing management form in relation to the impact unit - , which leads to a PDF result. This characterization factor would be different for a different management form or area,. These factors are the background calculations that were defined by the PDF method developers. As these factors use the average values of the parameters concerning a respective management form or area, individual cases can differ. In contrast to the PDF method, the characterization factors for a specific case can be individually calculated with the B.I.A. method, if sufficient data is available. This makes the PDF easier to apply but coarser, while B.I.A. requires more input data but is more precise.

3 Forest labels and strategies

Many companies producing forest based products use labels for certification of their forest management form or the origin of their product. These labels specify evaluation schemes for the forest area. Similarly to that, conservation programs from governmental bodies specify indicators for the ecological state of an area. In contrast to biodiversity impact assessment methods, labels and political strategies are not product or yield based and rely on limit values. Political strategies provide legislations, but they do not recommend methods or labels. However, they often relate to the same qualities and analyzing these qualities is useful to identify the key biodiversity influencing factors that should be measured in the different biodiversity methods. In this chapter, the most relevant labels and strategies are analyzed according to their used parameters.

As Biodiversity Indexes and strategies are similar and often are only available in the respective national language, the focus of this study was on the German framework and policies. As an example to show the similarity in all regions and nations throughout Europe, a French biodiversity index is provided as well.

3.1 PEFC Label

promotes sustainable forest management, certifies regions instead of supply chains or companies by conducted random checks. The regions self-commit to certification (on-site audits possible).

The criteria are not weighted and all criteria of the checklist have to be fulfilled. They are clustered in improvement of forest resources, conservation of forest ecosystems, protection of production functions, improvement of biological diversity, improvement of protective functions of forests and socioeconomic functions [28].

The PEFC provides country specific limits. For example the PEFC Austria lists factors that limit tree felling for biomass use due to soil composition, historic forest exploitation, low precipitation climate, relief and soil compaction [29]. Another example are the rules given by the PEFC Finland. They regulate how much may be felled and how it is reforested afterwards, how endangered species are to be protected and promotes native tree species, water conservation and the exclusive use of "approved" pesticides [30].

3.2 FSC Label

provides rules for forest agronomy similar to PEFC. They subdivide into social functions, ecological functions and forest use/forestry. The framework of FSC certification consists of 10 principles and 70 criteria, which apply to all forests on earth. Indicators and verifiers are developed through national processes to verify the FSC principles and criteria in a given country. It is not about the initial situation of the forest, but about management that should bring improvement of the ecological state and environmental quality.

Indicators are checked for certification, minor violations do not prohibit certification, major violations must be corrected. Major violations are violations over a long period of time or large area or nothing is done about it. Minor violations are short term or unabated [31].

3.3 Ökoland / Naturland Label

certifies forests for ecological forest use. This means native stocking, possibly first afforestation, no tillage, regulated forest use (e.g. clear-cutting), regulated hunting, defined skid road system, prohibition of non-forest substances (chemical fertilization), promotion of natural dynamics and the designation of reference areas for the determination of the natural state [32].

3.4 EU Biodiversity Strategy

demands protected areas to promote biodiversity (NATURA 2000) and the status of protected species not to deteriorate. Further, the use of pesticides is to be controlled and planting of at least 3 billion new trees in the EU by 2030 is defined as a target. However indicators are yet to be developed in the coming years while the EU forest strategy, which was already discussed in the EU Council, is about to be issued [33].

3.5 State of Europe's Forests 2020

The overall aim of this report is to provide policy and decision-makers and stakeholders with updated information on the status and trends in forests and sustainable forest management in Europe.

As it presents the most recent harmonized and objective data related to the sustainability of forest management in Europe, it can also provide a solid basis for future political commitments on forests and forest-related issues. It was prepared with technical support of the FAO (United Nations Food and Agriculture Organization) and the UNECE (United Nations Economic Commission for Europe).

The report describes different criteria consisting of several indicators for forests in Europe to estimate e.g. biodiversity or naturalness. However, no values are presented, as each country requires its own thresholds.

1. Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles
    - Forest area
    - Growing stock
    - Age structure and/or diameter distribution
    - Forest carbon
2. Maintenance of Forest Ecosystem Health and Vitality.
    - Deposition and concentration of air pollutants
    - Soil condition
    - Defoliation
    - Forest damage
    - Forest land degradation
3. Maintenance and Encouragement of Productive Functions of Forests (Wood and Non-Wood)
    - Increment and fellings
    - Roundwood
    - Non-wood goods
    - Services
4. Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems
    - Diversity of tree species
    - Regeneration
    - Naturalness
    - Introduced tree species
    - Deadwood
    - Genetic resources
    - Forest fragmentation

- Threatened forest species
- Protected forests
- Common forest bird species

5. Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (Notably Soil and Water)
    - Protective forests – soil, water and other ecosystem functions – infrastructure and managed natural resources
6. Maintenance of other Socioeconomic Functions and Conditions
    - Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles
    - Maintenance and Encouragement of Productive Functions of Forests (Wood and Non-Wood)
    - Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems
    - Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (Notably Soil and Water)
    - Protective forests – soil, water and other ecosystem functions – infrastructure and managed natural resources
    - Maintenance of other Socioeconomic Functions and Conditions
    - Maintenance of Forest Ecosystem Health and Vitality [34].

3.6 German Biotope value points

Is a value point system to help conserve biotopes that comprises of several parameters and results from the sum of different "ecopoints": areas and changes to areas are assessed and compensation measures for interventions are determined. The assessed area is divided into sub-areas, each of which has a biotope type that can be assessed with uniform value points. In each federal state value points differ, even within the state regional differences can be seen. The basic evaluation aims at:

- the closeness to nature,
- the importance for endangered and rare species (Each species has a function within an ecosystem and therefore the loss of species could impact the functions of the ecosystem), and
- the importance as an indicator for local and natural characteristics or the restorability [35, 36].

The German Federal Agency for Nature Conservation and Federal Ministry for the Environment introduced a list of biotope types according to the model of the Red List of endangered biotope types with the following criteria:

- Area size,
- Abiotic and biotic equipment, and
- Location to other biotopes.

If a project or undertaking has a particularly severe impact on the protected goods – i.e. animals, plants, soil, water, climate / air and landscape, - further examination of the individual protected goods takes place. The severity and avoidance of the impairment is determined and compensation measures are introduced accordingly [37].

3.7 German Forest Strategy 2050

sets milestones and intermediate targets for the year 2050 by creating and fulfilling action plans for biodiversity improvement and natural regeneration. The forest use shall be aimed at carbon storage and the sustainable use of raw materials and social services of forests like recreation, sports and health. It aims to increase biodiversity and closeness to nature through a diverse tree species composition, deadwood supply and the protection of red list species. The German Federal Environment Agency mentions the certificates of PEFC and FSC as a reliable indicator for sustainable forestry [38].

3.8 Bundeswaldinventur 2012 (German Federal Forest Inventory 2012)

takes place every ten years, the next one was in 2022 and describes the forests by classical inventory results. The ecological stability is assessed by naturalness of tree species composition, dead wood quantity, forest edges or formation of ground vegetation. Further, a habitat monitoring is conducted according to the German Habitats Directive and the capacity for carbon storage is estimated. Values are measured and variables are compared, but not quantified.

The applied criteria are:

Farm type, ownership type, forest structure, tree species, tree diameter, tree height on selected sample trees, dead wood, land use before or after forest [39].

3.9 German Federal Environment Agency Definition

has the goal of near-natural, integrative and sustainable forest management. This includes aspects such as closeness to nature and natural diversity in tree species selection, mixture of different tree species and age classes in individual stands, natural regeneration, timely forest maintenance, careful forest management, integrated forest protection and integrated nature conservation objectives (e.g. habitat diversity, species diversity and genetic diversity, deadwood richness, rare forest communities, forest edges, etc.) [40].

3.10 Assessment of the biodiversity of border-crossing forest ecosystems

was a research project funded by the European Regional Development Fund (ERDF) that provides a set of 12 indicators that determine biodiversity. The basis is a point system, with each indicator giving different points depending on its fulfillment. Adding up the indicator scores gives an overall score for evaluation.

1. forest structure
2. types of conservation interest
3. number of species in shrub layer
4. standing dead matter
5. lying dead matter

6. occurrence of big structures
7. microhabitats
8. reproduction and breeding areas for rare species
9. presence of lights
10. habitats in connection with morphology and waters
11. area within protected
12. interfering factors for the biodiversity

[41]

3.11 French Index Of Biodiversity Potential (IBP)

is similar to the Assessment of the biodiversity of border-crossing forest ecosystems. It provides the indicators tree abundance, structure, deadwood, large trees and macro-habitats [41].

4 Synopsis of the suitability of biodiversity assessment methods, the labels and political strategies

This section compares the parameters and criteria that are commonly used for evaluation in the biodiversity assessment methods, strategies and labels investigated. It can be seen that the evaluation of biodiversity in forest areas often relies on the same or similar criteria for impacts on biodiversity. Especially, the evaluation by naturalness (meaning the human interference measured e.g. through use of fertilizers, pesticides, soil tillage), deadwood, and endangered species are essential and can be found in most methods. But also carbon storage and natural regeneration are regularly mentioned in the political strategies and are therefore identified as important parameters for biodiversity assessment methods, however, they are never directly measured (rather through indigenous species or the remaining deadwood etc.). Table 2 provides an overview of the parameters and influencing factors that are most commonly used in the respective methods, guidelines and labels for assessing biodiversity. First, it can be stated that most of the methods (e.g. B.I.A, GLOBIO and PDF) reported can be applicable to forest biodiversity, which is not the case for a few methods (ReCiPe) that have more general or different target areas and can be applied to forests to some extent. Section 2 showed that the relevant biodiversity tools considered in the Align project by the EU Commission are based on three different methods; PDF. GLOBIO and ReCiPe. For this reason, only these three plus the standalone method of B.I.A. are listed in Table 2 and compared to the labels and policies.

While in the B.I.A. method, parameters linked to the influencing factors from the column headings can be individually adjusted to the use case, in the other here reported methods such as PDF, ReCiPe and GLOBIO, they are incorporated indirectly via other parameters that do not represent specifically the influencing factor in question. Therefore, these methods require the outline of the management practice, the used area and the location, but no values for the influencing factors in question. The guidelines and labels considered often use parameters that directly reflect many of these criteria, but differ in the number and selection of input factors on biodiversity impact. In Table 2, this is marked with '(x)', while the possibility to adjust the factors individually is marked with 'x'

In general, guidelines, frameworks and regulations are often clustered in regions or countries. As a result, indicators are site-specific and highly individual. The assessment is usually conducted via tools that rely on complex frameworks, which makes them easy to use but hard to individualize for a certain region, process or site.

Table 2: Criteria for forestry assessment in the various assessment methods, labels and strategies (x = Assessed directly - individually adjustable ; (x) = assessed indirectly via other more general parameters - included in background data , not individually adjustable ; [empty] = Not included

Criteria	Forest specific valuation	Species diversity	Deadwood	Planting	Fertilization	Pesticides	Soil tillage
Biodiversity Methods							
B.I.A	x	x	x	x	x	x	x
PDF	x	(x)	(x)	(x)	(x)	(x)	(x)
ReCiPe		(x)	(x)	(x)	(x)	(x)	(x)
GLOBIO (Mean Species Abundance)	x	(x)	(x)	(x)	(x)	(x)	(x)
Ecolabels on forests							
PEFC Label	x	x	x	x	x	x	x
FSC Label	x	x	x	x	x	x	x
Ökoland / Naturland Label	x	x		x	x	x	x
Political Strategies							
EU Biodiversity Strategy		x			x	x	x
State of Europe's Forests 2020	x	x	x	x			x
German Biotope value points	x	x	x	x			
German Forest Strategy 2050	x	x	x	x			x
Bundeswaldinventur 2012 (German Federal Forest Inventory 2012)	x	x	x	x			
German Federal Environment Agency Definition	x	x	x	x	x	x	x
Assessment of the biodiversity of border-crossing forest ecosystems	x	x	x	x			
French Index Of Biodiversity Potential (IBP)	x	x	x	x			

Table 2 gives an overview of the various parameters applied or recommended in the biodiversity assessment methods, forestry labels or political development strategies. B.I.A., PDF and GLOBIO address the here mentioned impact criteria. However, in the PDF method and the GLOBIO frameworks, the criteria are addressed via average values for certain regions and management practices called characterization factors derived from other assessment or monitoring frameworks like the IUCN Red List or the WWF Wildfinder. The ReCiPe method generally addresses "damage to ecosystems", not explicitly forests, although it can be applied for forestry activities as well.

All labels are explicitly designed for forestry evaluation. All criteria are addressed or mentioned, except for deadwood in the Naturland label.

The EU Biodiversity Strategy doesn't focus on forestry as it targets biodiversity in general. It is however intended to develop an EU Forestry Strategy that is already commissioned [42]. In the political strategies, the criteria of soil tillage and especially fertilization and pesticide use are often not mentioned. In these reports, the focus is set on species diversity and forests as carbon sinks.

5 Conclusions

There are a number of factors affecting biodiversity that are applied in most of the available biodiversity assessment methods and tools. However, these methods/tools differ in the selection of criteria used, and the way parameters are incorporated (directly or via background data). From the literature review conducted in this study, it can be concluded that most of the reported methods are not based on standalone background data and should be identified as tools. These tools use the framework and/or indicators primarily of three biodiversity methods: PDF, ReCiPe and GLOBIO. With each of these three methods or the B.I.A. biodiversity assessment method which has been developed by Fraunhofer, many parameters listed in European and national guidelines and labels can be addressed if sufficient and reliable data on the criteria from Table 1 and Table 2 is available.

The evaluations of the biodiversity in the forest areas are often conducted using similar biodiversity influencing factors (defined as criteria). Especially, the biodiversity evaluation by naturalness (anthropogenic influence), deadwood (removal or remainder of dead material) or endangered species (abundance of individuals of endangered species) is decisive, but also carbon storage (ability to store carbon in the soil or biomass) and natural regeneration (rate of flora and fauna regenerating from anthropogenic influences) are regularly mentioned in the political strategies. In general, guidelines, frameworks and regulations are often clustered in regions or countries. As a result, indicators are site-specific and highly individual, but also their application requires expert knowledge. The assessment often is conducted via tools that rely on complex frameworks, which make them easy to use but hard to individualize for a certain region, process or site.

Which method should be recommended for a forest biodiversity assessment depends not only on the objective and scope of the study but also on the available data. If the data availability is low, PDF and GLOBIO have an advantage as they use average values derived from other assessment or monitoring frameworks which makes them easier to apply. The B.I.A. method can also make use of average data – as it was done in Phase 1 with the assessment of Miscanthus in Germany and Bulgaria – but this requires more effort. If more detailed measured or literature data is available, the B.I.A. method has the possibility to be individualised to the area and production process in question and therefore deliver more precise results.

6 References

[1] European Commission, *ALIGN: Business@Biodiversity.* [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/align/index_en.htm (accessed: Nov. 17 2022).

[2] C. Panoutsou and K. Maniatis, "Sustainable Biomass Availability in the EU to 2050," 2021. [Online]. Available: https://www.concawe.eu/publication/sustainable-biomass-availability-in-the-eu-to-2050/

[3] iCare & Consult and Sayari, *Product Biodiversity Footprint.* [Online]. Available: http://www.productbiodiversityfootprint.com/ (accessed: Oct. 18 2022).

[4] European Commission, "Biodiversity Measurement Approaches – Summary descriptions Biodiversity Footprint Methodology," Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/BFM%20and%20BFC%20summary%20description.pdf

[5] B. Marechal, "Corporate Biodiversity Footprint- Methodological guide," 2022.

[6] LIFE Institute, "Life Technical Guide - 01: Version 3.2," Accessed: Oct. 11 2022. [Online]. Available: https://institutolife.org/wp-content/uploads/2018/11/LIFE-BR-TG01-Technical_Guide_01-3.2-English.pdf

[7] LIFE Institute, "LIFE Certification Permises: Version 1.0," Jun. 2021. Accessed: Oct. 11 2022. [Online]. Available: https://institutolife.org/wp-content/uploads/2018/11/LIFE-IN-CP-Premises-1.0-English.pdf

[8] LIFE Institute, "LIFE Certification Standarts: Primary, Secondary and Tertiary Sectors," Version 3.2. Accessed: Oct. 11 2022. [Online]. Available: https://institutolife.org/wp-content/uploads/2018/11/LIFE-BR-CS-Standards_LIFE-3.2-English.pdf

[9] European Commission, "Biodiversity Measurement Approaches – Summary descriptions Species Threat Abatement and Restoration metric (STAR)," Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/STAR%20summary%20description.pdf

[10] L. Mair *et al.,* "A metric for spatially explicit contributions to science-based species targets (STAR)," *Nat Ecol Evol*, vol. 5, no. 6, pp. 836–844, 2021, doi: 10.1038/s41559-021-01432-0.

[11] IBAT Alliance, *Integrated Biodiversity Assessment Tool (IBAT).* [Online]. Available: https://www.ibat-alliance.org/ (accessed: Oct. 18 2022).

[12] European Commission, "Biodiversity Measurement Approaches – Summary descriptions Biodiversity Indicators for Site-based Impacts," Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/BISI%20summary%20description.pdf

[13] European Commission, "Biodiversity Measurement Approaches – Summary descriptions Global Biodiversity Score," Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/GBS%20summary%20description.pdf

[14] European Commission, "Biodiversity Measurement Approaches – Summary descriptions Biodiversity Net Gain Calculator," Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/BNGC%20summary%20description.pdf

[15] European Commission, "Biodiversity Measurement Approaches –Summary descriptions Biodiversity Impact Metric," 2021. Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/BIM%20summary%20description.pdf

[16] European Commission, "Biodiversity Measurement Approaches – Summary descriptions LafargeHolcim," Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/LafargeHolcim%20Spain%20summary%20description.pdf

[17] European Commission, “Biodiversity Measurement Approaches – Summary descriptions ReCiPe & BioScope,” Accessed: Oct. 11 2022. [Online]. Available: https://ec.europa.eu/environment/biodiversity/business/assets/pdf/tool-descriptions/RECiPe%20and%20BioScope%20summary%20description.pdf
[18] M. A. J. Huijbregts *et al.,* “ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level,” *Int J Life Cycle Assess*, vol. 22, no. 2, pp. 138–147, 2017, doi: 10.1007/s11367-016-1246-y.
[19] Bioversity International, “The Agrobiodiversity Index: Methodology Report v.1.0.,” *Bioversity International*, 2018.
[20] J. Lammerant, “Assessment of Biodiversity Measurement Approaches for Businesses and Financial Institutions: Update Report 1 on behalf of the EU Business @ Biodiversity Platform,” Nov. 2018.
[21] J. Lammerant, A. Grigg, J. De Ryck, and Y. Verstraeten, “Assessment of Biodiversity Measurement Approaches for Businesses and Financial Institutions: Thematic Report on Biodiversity Dataon behalf of the EU Business @ Biodiversity Platform,” Accessed: Oct. 11 2022.
[22] PRé Sustainability, Arcadis and CODE, “BioScope Methodolgy Report,” 2022.
[23] UN Environment Programme (UNEP), *Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE).* [Online]. Available: https://encore.naturalcapital.finance/en (accessed: Oct. 18 2022).
[24] Impact Institute, *Global Impact Database.* [Online]. Available: https://www.impactinstitute.com/products/global-impact-database/ (accessed: Oct. 18 2022).
[25] R. Alkemade, M. van Oorschot, L. Miles, C. Nellemann, M. Bakkenes, and B. ten Brink, “GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss,” *Ecosystems*, vol. 12, no. 3, pp. 374–390, 2009, doi: 10.1007/s10021-009-9229-5.
[26] A. M. Schipper *et al.,* “Projecting terrestrial biodiversity intactness with GLOBIO 4,” *Global change biology*, vol. 26, no. 2, pp. 760–771, 2020, doi: 10.1111/gcb.14848.
[27] A. Chaudhary and T. M. Brooks, “Land Use Intensity-Specific Global Characterization Factors to Assess Product Biodiversity Footprints,” *Environ. Sci. Technol.*, vol. 52, no. 9, pp. 5094–5104, 2018, doi: 10.1021/acs.est.7b05570.
[28] PEFC, “PEFC Standards für nachhaltige Waldbewirtschaftung,” 2020.
[29] PEFC, “PEFC-Standard für die nachhaltige Waldbewirtschaftung in Österreich,” 2017.
[30] PEFC, “Criteria for Forest Certification Finland,” 2014.
[31] FSC, “Deutscher FSC®-Standard 3-0,” 2018.
[32] Naturland e.V., “Richtlinien zur ökologischen Waldnutzung,” 2014.
[33] European Commission, “EU Biodiversity Strategy for 2030: Bringing nature back into our lives,” 2020. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52020DC0380
[34] Ministerial Conference on the Protection of Forests in Europe - FOREST EUROPE, “State of Europe’s Forests 2020,” 2020.
[35] Bayrisches Staatsministerium für Umwelt, “Biotopwertliste,”
[36] Institut Für Botanik Und Landschaftskunde, “Bewertung der Biotoptypen Baden-Württembergs zur Bestimmung des Kompensationsbedarfs in der Eingriffsregelung,” 2005.
[37] Bundesamt für Naturschutz, “Handreichung zur Bundeskompensationsverordnung,” 2021.
[38] Bundesministerium für Ernährung und Landwirtschaft, “Waldstrategie 2050,” 2021.
[39] Dr. Thomas Riedel, Petra Hennig, Franz Kroiher, Dr. Heino Polley, Friedrich Schmitz, Frank Schwitzgebel, “Die dritte Bundeswaldinventur BWI 2012,” 2017. [Online]. Available: https://www.bundeswaldinventur.de/fileadmin/SITE_MASTER/content/Downloads/BWI_Methodenband_web.pdf
[40] Umweltbundesamt, *Nachhaltige Waldwirtschaft.* [Online]. Available: https://www.umweltbundesamt.de/daten/land-forstwirtschaft/nachhaltige-waldwirtschaft#die-vielfaltigen-funktionen-des-waldes (accessed: Oct. 19 2022).

[41] Claudio Betetto, Paola Bolzon, Arianna Bonavida, Ilaria Doimo, Paola Gatto, Emanuele Lingua, Giacomo Pagot, Luca Bronzini, Maurizio Odasso, Mauro Tomasi, A. S. Michele Cassol, and Daniele Belli, “Bewertung der Biodiversität von grenzüberschreitenden Waldökosystemen,” 2020.
[42] General Secretariat of the Council, “Council Conclusions on the New EU Forest Strategy for 2030,” 2021.