Overview of quantitative biodiversity indicators

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Summary

Loss of biodiversity is one of today's most important environmental issues, both nationally and globally. Companies contribute to loss of biodiversity through their direct activities and through their supply chain (e.g. import of resources).
Therefore, the Ministry of Infrastructure and Environment (I&M) wishes to encourage companies to become more transparent with regard to their impact on biodiversity in the Netherlands and abroad. They want to focus primarily on business sectors with the largest impact on biodiversity. Moreover, the Ministry seeks broad support for a method of reporting that can be readily applied by companies.

Goal

On 2 May 2013 the Ministry of I&M commissioned CE Delft to explore the methodologies available for quantifying the impact of business activities on biodiversity. The most suitable method selected was used to gain insight into the impact of Dutch business sectors on biodiversity. This study had three research questions:

1. How can the impact on biodiversity of businesses and business sectors be quantified?
2. How large is this impact of the Dutch business sectors on biodiversity how do the sectors compare to each other?
3. What are the trends in these sectors? Do they have biodiversity policy? Is there national or international policy in place which may change sectoral impacts?

Scope

To answer the questions above, several sub-studies were done:

1. The selection of a suitable method and indicator. The setup and results of this selection are reported on separately (CE Delft, 2014).
2. A sector analysis: the chosen method/indicator was applied to the Dutch economy, which was divided into 25 sectors.
3. A company analysis: we assessed whether companies currently report on the impacts which are most relevant to biodiversity in their sector.
4. Four case studies: the chosen method was applied to the activities of four companies and the Dutch government.

All analyses, results and conclusions, were discussed with a steering committee and a committee with representatives from nine companies from several relevant sectors.

Selection of method and indicator

There are a lot of different methods and indicators available related to biodiversity. An indicator is a measure for the loss (or gain) of biodiversity; a common unit in which all kinds of different activities (e.g. emission of CO_2) can be expressed (comparable to CO_2-eq being the indicator/unit used for the impact category climate change). A method describes the quantitative translation of activities into such a common unit.

An important goal of this study is the selection of a suitable indicator and method, which can help companies quantify their impact on biodiversity. With such information they can report on their impact and know which activities to target to reduce their impact. The method and indicator we select will be used to conduct the sector analysis, the company analyses and the case

studies. The challenge is to translate companies' activities into a common measure, so that comparison is possible.

Therefore, the following criteria are important:

- the method is quantitative: it translates activities and pressure factors related to these activities (e.g. emission of CO_2 or SO_2) into a common unit reflecting the impact on biodiversity;
- the input of pressure factors is the basis for the method: this makes it suitable to be used by companies, as companies have extensive information on their emissions, etc.;
- the method makes monitoring possible: changes in activities should be clearly reflected in the final score, so that companies know the effect of their policy.

ReCiPe and water scarcity

We looked at around 60 methods and indicators. Based on the criteria listed above, the ReCiPe LCA-methodology (Goedkoop et al., 2012) was selected to run the subsequent analyses with. With ReCiPe, pressure factors (e.g. emission of CO_2) can be translated into an impact on biodiversity. ReCiPe links pressure factors to the impact categories climate change, land use, acidification, eutrophication, toxicity and water depletion. Some impact categories important to biodiversity, are currently not included. For this reason we chose to integrate the water scarcity method into ReCiPe. The water scarcity method developed by Pfister (Pfister et al., 2009) was selected; this method translates water use into the same common unit as ReCiPe does.

Research on indicators for biodiversity is ongoing. Currently ReCiPe (as would any LCA-methodology) does not clearly distinguish between local impacts and global impacts.

ReCiPe does not cover all known pressure factors. To check the robustness of the results we made a comparison of results between our sector analysis and an assessment of the Dutch impact on biodiversity with the method GLOBIO, by PBL. GLOBIO is commonly used to quantify impact on biodiversity in different regions on a global scale. It is therefore less suitable to be used by companies. Out comparison shows that the main conclusion is the same regardless of the method used: land use and climate change are the most import drivers of biodiversity loss.

Cees van Houwelingen, Operations Regulatory Services Leader, Dow Benelux
"We find the results from the biodiversity analysis recognizable. Our most important pressure factor is the emission of CO_2 and we are already focussed on reducing our emissions of greenhouse gases. At first we were surprised that a substantial part of our impact is accounted for by the resources we buy. That our suppliers face biodiversity challenges is now more clear to us. The current setup entails a cradle-to-gate analysis. We think this is a pity, because our innovative products reduce impacts downstream. It would be nice to see such a reduction be reflected in the results".

Even though not all pressure factors and impact categories are included in ReCiPe (complemented by the water scarcity method), ReCiPe suits the criteria listed above. The method is quantitative, uses pressure factors as input and satisfies the wish of companies to gain insight into the contribution of their activities to loss of biodiversity and the effect of options for improvement. An easy and practical tool would help companies (without access to LCA software) use the method to quantify their impact.

Linkage to EU activities

The ReCiPe method is in accordance with the EU's LCA-activities (Product Environmental Footprint - PEF and Organisational Environmental Footprint - OEF). Currently, biodiversity is not included in these programmes yet.

Recommendations for further research and continuation

The results we presented regarding the sector analysis, the company analyses and the case studies, give insight into the impact on biodiversity of activities of companies in the Netherlands. We think the topic would benefit by further research and elaboration. There are several themes which we distinguish regarding continuation:

Methodology - researchers

To make the method more robust, we recommend to:

- integrate more specific land use factors (e.g. from GLOBIO) in the ReCiPe LCA-methodology (in collaboration with PBL and RIVM);
- explore the options to distinguish between local and global impacts;
- include other relevant pressure factors in ReCiPe (e.g. light or noise).

Link to existing initiatives

- Integrate ReCiPe and water scarcity methods in the PEF/OEF method.

1 Introduction

1.1 Background

Loss of biodiversity is one of today's most important environmental issues, both nationally and globally. In 2013, the sustainable use of natural resources was mentioned by the Dutch Government as a topic of high priority in the Letter to Parliament 'Green growth: for a strong and sustainable economy'. For that reason the Ministry of Infrastructure and Environment (I&M) wishes to encourage companies to become transparent with regard to their impact on biodiversity in the Netherlands and globally. They want to focus primarily on business sectors with the largest impact on biodiversity. Moreover, the Ministry seeks broad support for a method of reporting that can be readily applied by companies.

1.2 Goal

On 2 May 2013 the Ministry of I&M commissioned CE Delft to explore the options for developing a biodiversity benchmark for business sectors and companies.

The main findings are reported separately (CE Delft, 2014). In this report the assumptions and decisions regarding the selection of a suitable methodology and indicator are elaborated on.

1.3 Content

This report covers the first phase of the project:
- Making a clear overview of quantitative biodiversity indicators that are available to benchmark biodiversity dependencies and impacts, evaluating both the scientific acceptance of the indicators and the practical applicability of the indicators to businesses.
- Selection of the most suitable methodology and indicator, with which the subsequent analyses will be executed. These analyses, scope, results and conclusions, are elaborated on in Benchmark Biodiversity, Main report (in Dutch, CE Delft, 2014).

After a short introduction into benchmarking and indicators (Chapter 2), Chapter 3 briefly explains the relationship between business and biodiversity. Thereafter Chapter 4 informs about desired policy and methodological specifications. In Chapter 5 a detailed description of the selected methodologies that in principle are suited for measuring biodiversity impacts is presented, as well as the choice with which we will proceed: the LCA ReCiPe methodology, supplemented with the water scarcity method. Because of data availability and differences in scope between the analyses, we propose a Tier methodology (in Chapter 6), which we hope will clarify these differences and the decisions we made in applying the methodology in the analyses.

2 Benchmarking and indicators

2.1 What is benchmarking?

A benchmark is a measurement of the quality of a company's policies, products, programmes, strategies, etc., and the comparison of these measurements with standard measurements, or measurements of its peers[1]. The objective of benchmarking are:

1. To determine what and where improvements are called for.
2. To analyse how other companies achieve their high performance levels.
3. To use this information to improve the company's performance.

2.2 Benchmarking biodiversity: previous projects

In the past 10 years two biodiversity benchmarking projects have been executed. In 2004, F&C Asset Management examined the relationship between biodiversity and business, the specific sectors and risks involved, and whether these risks were material (F&C, 2004). Based on a questionnaire distributed among 35 professionals, nine sectors were identified as high risk, indicating that most companies in these sectors are exposed to biodiversity risks and that the risks faced by individual companies in these sectors are likely to be significant (Table 1).

Table 1 Level of biodiversity risk per sector

Red zone High-risk sectors: Most companies exposed to risks Risks likely to be significant	Amber zone Medium-risk sectors: Some companies exposed to risks Risks may be significant	Green zone Lower-risk sectors: Risk variable and significance unknown
Construction & Building Materials Electricity Food & Drug Retailers Food Producers & Processors Forestry & Paper Leisure & Hotels Mining Oil & Gas Utilities	Beverages Chemicals Financial Services General Retailers Household Goods & Textiles Personal Care & Household Products Pharmaceuticals & Biotech Support Services Tobacco Transport	Aerospace & Defence Automobiles & Parts Diversified Industrials Electronic & Electrical Equipment Engineering & Machinery Health Information Technology Hardware Media & Entertainment Software & Computer Services Steel & Other Metals Telecom Services

Source: F&C, 2004.

In 2004 and in 2005, Insight Investment, in collaboration with Flora & Fauna International, executed a benchmarking project that focused on companies in the oil & gas sector, the utilities sector and the mining sector with the aim to inform investment decision-making (Insight Investment, 2004; Foxall et al., 2005). This benchmark focused on the extent that the business management systems, of the companies examined, actively managed biodiversity risks.

[1] www.businessdictionary.com.

In 2009 the Natural Value Initiative developed a toolkit for institutional investors to better understand the impacts and dependency of their investments on biodiversity and ecosystem services, the Ecosystem Services Benchmark (ESB) (Grigg et al., 2009).
With the tool, investors can identify companies that are proactively managing biodiversity risks and those that are less (or not). To companies, the tool provides a framework for considering biodiversity.

2.3 What is an indicator?

Most definitions focus on the principle that the indicator is a means to understand and manage complex information. A rigorous definition is given by the International Institute for Sustainable Development (IISD):
"An indicator quantifies and simplifies phenomena and helps us understand complex realities. Indicators are aggregates of raw and processed data but they can be further aggregated to form complex indices."

The Energy and Biodiversity Initiative (EBI, 2003) uses the following definition:
"Indicators are a way of presenting and managing complex information in a simple and clear manner that can form the basis for future action and can be readily communicated to internal or external stakeholders as needed."

In this context it is helpful to distinguish between 'monitoring' and 'measurement':
- **monitoring**: being the analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (after Elzinga et al., 2001); and
- **measurement**: being the collection of data.

When 'monitoring' one needs one or more indicators, whereas the 'measurement' provides input for indicators.

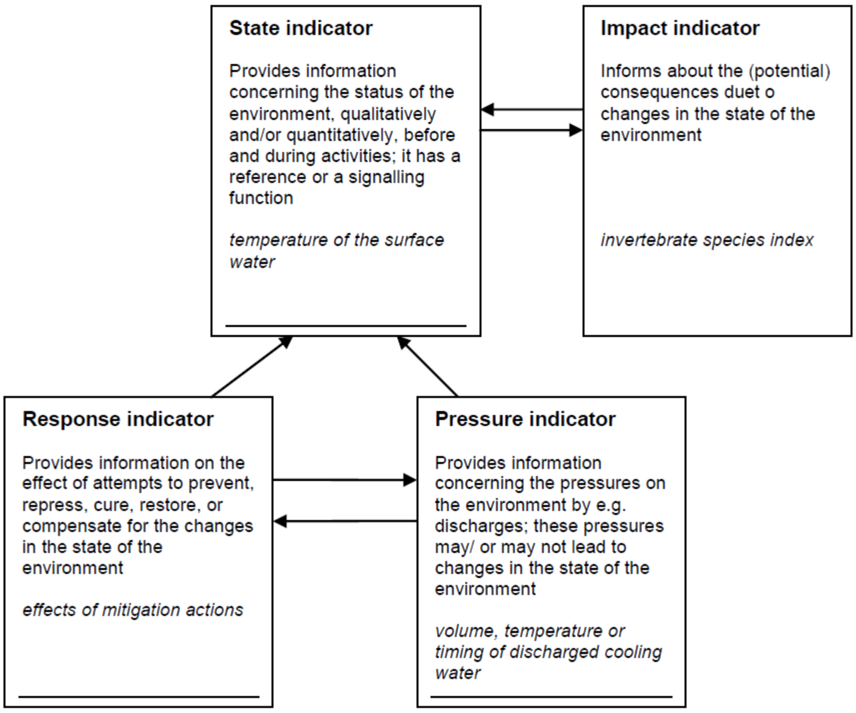
2.4 The DPSIR indicator framework

The Organisation for Economic Cooperation and Development (OECD, 1993) presented a systematic approach to the identification of *environmental* indicators based on causality, in order to arrive at uniformity in monitoring and steering environmental policy in various countries. The model is based on the link between discharges (in the broad sense) and the state of the environment:
*"Continuous examination of the **state** of the environment is necessary to determine the effectiveness of **response** in reducing **pressure** and therefore improving **state**"*.

To the three types of indicators, **pressure** indicators, **state** indicators and **response** indicators, Weterings and Smeets (1994) added a fourth category, the **impact** indicator. The impact indicator provides information concerning the (potential) consequences of a change in 'state' of the environment. For the description of the PS(I)R framework, see Figure 1. To this, a fifth indicator was added: drivers (see Figure 2). Drivers represent social and economic development which are related to pressure on the environment. From a policy perspective it is very useful to include these in the framework.

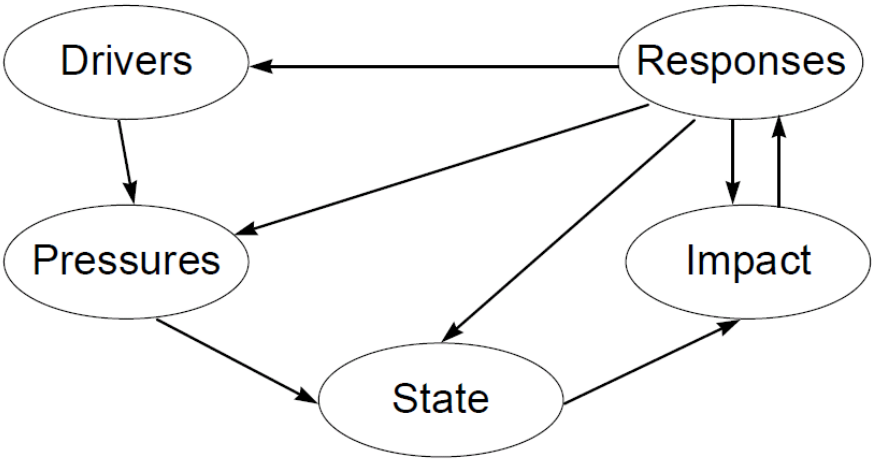
The DPS(I)R framework is a useful approach for identifying and developing indicators for biodiversity conservation, as demonstrated by e.g. the work of Conservational International (Conservation International, 2005).

Figure 1 PS(I)R framework



Source: Gilden, 2006.

Figure 2 DPSIR framework



Source: EEA, 1999.

3 Business and biodiversity

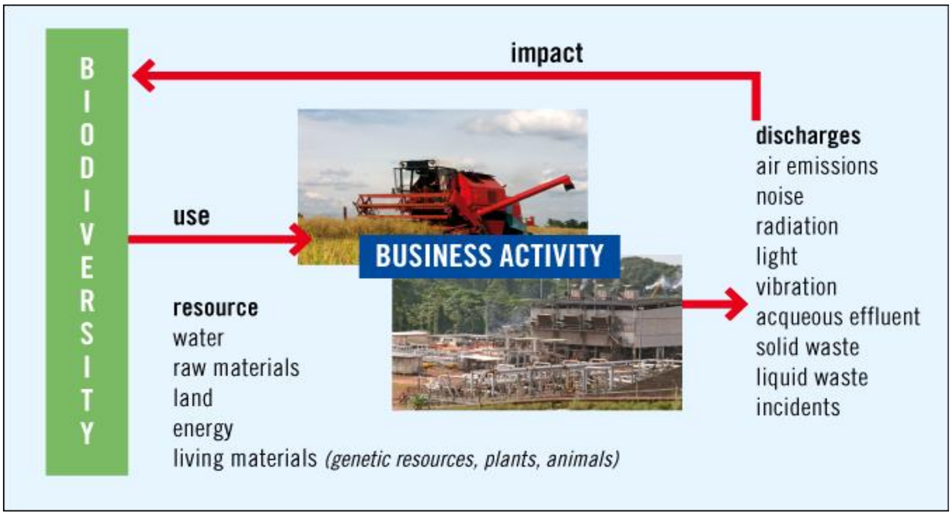
Biodiversity[2] has become an increasingly important environmental impact to consider in environmental assessments. Businesses in particular have begun to realise the importance of accounting for biodiversity impacts in their practices, considering that supply chains are often global and materials and resources are extracted from highly threatened ecosystems.

Despite dozens of biodiversity tools that have been developed over the last few years (for an overview see IUCN, 2012), a practical tool that enables companies identifying their main dependencies and impacts on biodiversity is lacking. Thus it is difficult for businesses to decide how they should account for biodiversity and ecosystem services in their business practices.

3.1 Pressures on Biodiversity

Biodiversity and ecosystem provide services which companies use to their benefit depending on scale, location and value chain they are part of.
As a consequence business activities also impact on biodiversity and related ecosystem services, see Figure 3.

Figure 3 Relationship between biodiversity and company activities

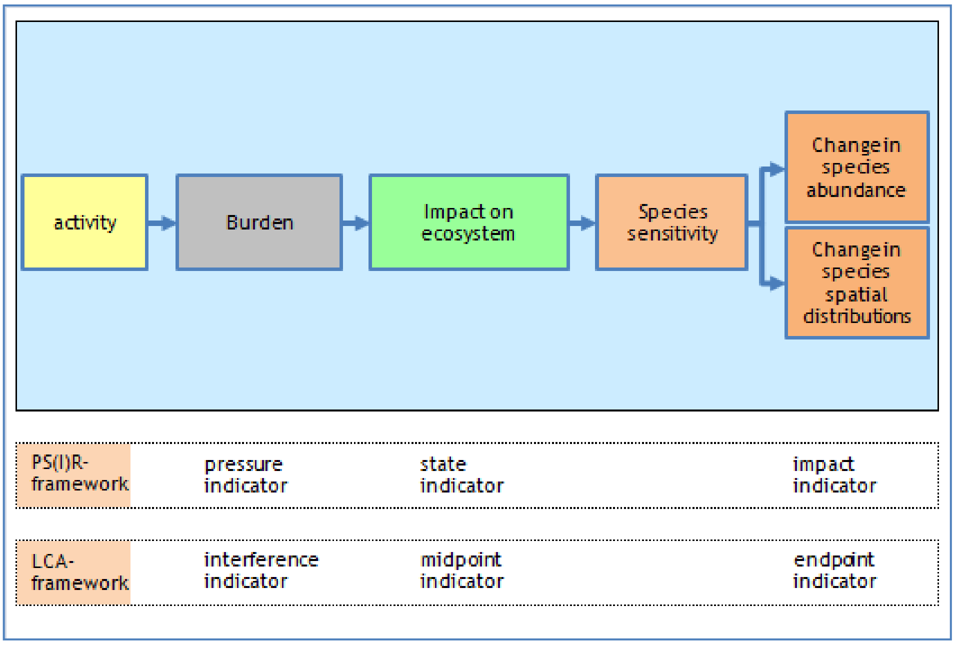


These dependencies and impacts are collectively addressed as 'pressure factors' or 'burdens'.

A schematic – but simplified – illustration of the relation between burdens (pressures) and the resulting biodiversity change is given in Figure 4.

2 See Annex A for a description of biodiversity.

Figure 4 Schematic illustration of the relationship between activity, burden, impact and biodiversity change



The basic mechanism is that with executing a business activity some burden is exerted on the environment (e.g. an emission to air). The burden results in primary and secondary changes in the ecosystem or species, e.g. temperature increase. Ecosystems and species react to this change (e.g. by reduced reproduction). The response may be dependent on the sensitivity of the species and on the existing situation in the ecosystem and the degree to which it has already been exposed.

4 Quantifying biodiversity impacts

The aim of this project is finding and applying a methodology that can be used by a company for benchmarking the impacts of its activities, either internally or in comparison with activities of other companies. This requires quantifying the impact of operations and associated activities.

Quantifying biodiversity impacts requires a methodology that can translate pressures (burdens) into a quantitative value for the resulting change in biodiversity, see Figure 4 in the preceding chapter.

4.1 Desired policy and application scope

The ambition is to have a methodology that will take into account both the full production chain associated with the company activities and all related changes in biodiversity in that chain, including:

- direct impacts: directly attributable to an activity (i.e. habitat loss from an extractive operation and its infrastructure);
- indirect impacts: resulting from other impacts that are directly attributable to project actions (loss of large animal species as a result of habitat fragmentation from mining roads);
- secondary impacts: resulting from actions that are not an intrinsic part of the activity in question (increase logging and forest loss as a result of improved access via new roads);
- cumulative impacts: arising in combination with activities from other (loss of species requiring large territories via combined habitat loss and fragmentation).

We also assume that the methodology is able to give a result that can be used in a policy context and other forms of decision-making. From that perspective the methodology should ideally give a result that allows for:

- a comparison between two different locations (in different regions);
- a comparison between a biotic and a fossil product for the same service;
- comparing different products for different regions to give focus to a general biodiversity policy of a country;
- comparing effects of different management types in production, e.g. with respect to land use: more intensive production (less biodiversity) and less intensive and less yielding production (more area needed) including potential indirect land use change.

The desired qualities mentioned above have been used for selecting and evaluating the methodologies in this project.

4.2 The ideal methodology

Given the desired policy and application scope, the sought methodology should ideally have following specifications:

- can convert any business activity related biodiversity influencing pressure into a quantitative value for the resulting change in biodiversity;
- can aggregate all contributions of different burdens (pressures) into one quantitative overall value for biodiversity impact;
- can be used in any region and for any ecosystem in the world;

- can be used for quantifying impacts on the different geographical levels (spot, local, regional, (supra)national);
- can take into account site specific characteristics (e.g. soil characteristics) and reference levels of stress in the shape of e.g. background, concentrations of environmentally harmful substances, reference land use and water extraction;
- is able to include time for e.g. restoration of affected ecosystems as a parameter.

Besides the impact on overall biodiversity, it should ideally also be able to quantify the influence at a species level (plant, animal), in particular Red List species.
The sought methodology could include a weighting factor, expressing the uniqueness and vulnerability of such ecosystems (e.g. intertidal areas such as the Wadden Sea or mangrove forests) or of ecosystems endangered due to previous degradation (e.g. the Atlantic Forest in Southern Brazil).

4.3 The realistic picture

However, the possibility that such a methodology can be found or developed is small, given the number of problems, limitations and issues that can be identified beforehand. These include (not exhaustive):
- The data requirement would be enormous, given all the different parameters, ecosystems, impacts, current exposure, etc. to consider.
- It is not (yet) possible to quantify biodiversity impact for every (type of) burden; for example, can the impact of the use of glass on office buildings be translated into a number of dead birds per year for a specific location and is this with or without learning effect?
- It is not always possible to aggregate the impacts related to different activities.
- Entrepreneurs may not always have sufficient insight and information with respect to the level of burden and biodiversity impact higher up or lower down in the production chain they are a part of.
- For some types of burdens – e.g. construction of infrastructure or land use change – it may be difficult to indicate the responsible parties, as more than one party or company may be involved.

The above mentioned specifications and obstacles are used for selecting and evaluating methodologies for further application and consideration in this project.

4.4 Applied criteria

In view of the desired application scope and ideal methodology we have adopted a selection process based on the precondition that the selected methodology should be able to:
- convert business activities related pressures (burdens) into quantitative indicators for biodiversity impact;
- express biodiversity impacts in absolute units (e.g. decrease in number of species) or express impacts relative to a common absolute reference situation (pristine natural ecosystem); the latter allows aggregating or comparing impacts from different burdens (= pressures) and activities.

These selection criteria imply that only methodologies that focus on '*burden – impact'* relationship (see Chapter 4) are deemed relevant.

5 Characteristics of selected methodologies

Annex B describes the methodology selection process and Annex C presents a gross list of different methodologies and indicators falling into different categories.

Using the selection criteria described in Chapter 5 we identified the following relevant methodologies:
- ReCiPe LCA methodology (Goedkoop et al., 2012);
- GLOBIO methodology (Alkemade et al., 2009; GLOBIO, 2013);
- TNO methodology (Lindeijer et al., 2002);
- Water footprint methodology, water extraction and impact on biodiversity (Pfister et al., 2009).

In this chapter the selected methodologies are evaluated against the desired characteristics.

5.1 Completeness and possibilities for aggregation

This section gives an overview of what pressures are included in the different selected methodologies (see Table 2). The manner of presentation indicates:
- Completeness with respect to:
  - Emissions: the number of different substances considered under the different categories. For example, does 'emission of acidifying substances' concern all substances that can cause acidification or just one or a subset of substances.
  - Land use: the differentiations in land use management.
    This for example includes intensity of crop cultivation in terms of fertilizer inputs and pesticides, soil treatment intensity (no till, conventional tillage) for agriculture or percentages of felling residues removal from the forest for forestry.
- Whether burden (pressure) – biodiversity impact relations are considered.

A sign in **red and bold** indicates the methodology contains a *burden – biodiversity impact* relationship relevant to our project in which every substance or other type of burden is considered.

As the focus of the project is on development (and application) of a methodology related to activities of and to pressures caused by individual enterprises, the way in which a '*burden – impact*' relation is included in a methodology is discussed when:
- this concerns all relevant emissions or other kinds of burdens per type of environmental impact or driver;
- the methodology considers an emission – biodiversity impact relation.

Table 2 **Overview of the completeness of the methodologies**

Burden[1])	**GLOBIO**	**ReCiPe**	**TNO**	**Water foot print**	**(other methodology)**
Completeness:					
Land use or change in land use	X	X	X		
Land management aspects	(X)[2]	(X)	(X)		
Water extraction	X			X	
Raw materials					
Living material					
Greenhouse gas emissions	(X)	X			
Emissions of acidifying substances	(X)	X			
Emissions of eutrophying substances	(X)	X			
Emissions of toxic substances					
- to air	(X)	X			
- to fresh water		X			
- to sea		X			
- to soil		X			
Noise emissions	X[3]				
Light emissions	X[3]				
Effluent					
Waste (solid)					
Aggregation of impacts to one value?	Yes	Yes	Yes	Yes	

1) Listed according to Figure 3.

2) Elucidation (between brackets): only one or limited number of substances or other types of burdens taken into account.

3) Included in infrastructure.

GLOBIO methodology

The GLOBIO approach (see GLOBIO, 2013) for climate change, land use change, acidification, eutrophication and toxicity seems less suitable for this project as the methodology considers the relation between 'impact on ecosystem' and subsequent changes in biodiversity, but not the whole relation from burden to biodiversity change. Used in combination with the IMAGE model, the whole DPSIR chain is modelled. The model is, however, currently not set up to easily calculate a score reflecting the total impact on biodiversity of a company's activities.

The GLOBIO methodology on the other hand contains an extensive set of biodiversity values for different land uses with a global coverage and several types of land use management and includes an approach for taking the impact of ecosystem fragmentation on biodiversity into account.

In the GLOBIO methodology effects of infrastructure on the biodiversity of the surrounding ecosystem are included as a separate mechanism. The mechanism includes both direct impacts related to disturbances (predominantly noise) and indirectly impacts related to increased hunting activities and tourism, and small-scale land use change along roads. As the indirect impacts seem to result in low biodiversity changes only, the impacts related to infrastructure may perhaps also be considered an approach for a *burden - impact* relation for noise.

ReCiPe methodology

In the ReCiPe methodology (Goedkoop et al., 2012) emissions are translated into biodiversity impacts by means of a) dispersion models for the emitted substances and b) dose/effect relations for exposed species, expressing biodiversity decline with increasing exposure levels.

Biodiversity impact (impact on local species abundance) due to land occupation and land use change are included and is expressed as the relative change in biodiversity compared to the biodiversity of the pristine natural biome representative for the region, where the land use (change) occurs. The method of quantification is similar to that applied in GLOBIO (in GLOBIO the indicators mean species abundance and regional species richness are linked). Additional compared to the GLOBIO methodology are:

- that for land use change the time required for the area to return to its previous level of biodiversity (as during the former type of land use) is taken into account as a weighing factor for expressing the severity of the biodiversity decline;
- that the interaction between occupied land and surrounding area is included in the estimation of biodiversity impact.

TNO methodology

The TNO methodology (Lindeijer et al., 2002) focuses specifically on land use and land management and is comparable in approach with the ReCiPe methodology. As mentioned in Annex B the most interesting aspect of this methodology is the fact that it combines local changes in biodiversity with global relative ecosystem scores.

Water footprint methodology

The water footprint methodology describes water extraction and water use per unit of product, e.g. the volume of water per cup of tea.
In the latest version of the water footprint methodology that consumption is combined with the ratio between water consumption and water influx, the water stress factor. The water stress factor is determined for a specific geographical area, which can be a continent, country or region (Pfister, 2009).

Overall conclusions

No methodology offers a complete set of approaches for calculating biodiversity impacts related to different potential pressures.
However, combined the methodologies can cover most types of pressures.

For some burdens no approach for calculating biodiversity impacts seems to exist or at least is not included in the selected methodologies.
For these burdens perhaps a limiting precondition can be considered.
For example, for the discharge of effluents the limiting precondition could be that the effluent should have characteristics in terms of salinity and pH similar to those of the receiving surface water.

With respect to the burdens that are considered and the resulting impact on biodiversity, all selected methodologies can aggregate the impact related to different burdens into one overall impact value.

5.2 Geographical coverage and applicability for different ecosystems

An overview of the geographical scope of the considered methodologies is shown in Table 3.

Table 3 Overview of the geographical scope of considered methodologies

Burden (= pressure) or environmental impact (= driver or midpoint indicator)	GLOBIO	ReCiPe	TNO	Water footprint
Land use type or change in land use	**Global, region specific**	EU	Forest on Swiss plateau	
Landscape management aspects	**Global, average**	EU		
Water extraction				**Global, region specific**
Raw materials				
Living material				
Greenhouse gas emissions	**Global, region specific**	Global, average		
Emissions of acidifying substances	*Not considered*	EU forest		
Emissions of eutrophying substances	**Global, region specific**	EU freshwater		
Emissions of toxic substances		Northern hemisphere, all climates		
- to air	*Not considered*			
- to fresh water				
- to sea				
- to soil				
Noise emissions	**Global, region specific**			
Light emissions				
Effluents				
Waste				

GLOBIO and water footprint methodology have a global coverage. For GLOBIO the burden to impact chain is modelled using a set of complementary models.

In contrast, the '*burden - impact*' relations applied in ReCiPe have mostly been developed for the situation in the EU or other specific regions.
For example, impacts on biodiversity for emissions of acidifying substances are based on the following approaches:
– dispersion of acidifying emissions into the environment were calculated with a model with a name that says it all: EUTREND;
– the subsequent changes in soil base saturation were calculated with another model (SMART 2), which focuses on European soils;

– thirdly, for the sensitivity of species to exposure of changed soil base saturation, the sensitivity of species in European forests was taken into account.

The TNO methodology considers an even narrower geographic unit as a reference for quantifying impacts of land use: the forests in the Swiss Plateau. The focus of the ReCiPe methodology on the European situation obviously raises the question if the methodology will give representative results for other regions and continents.

5.3 Other desired methodological characteristics

As stated in Chapter 4 other desired methodological characteristics include:
– the methodology can be used for quantifying impacts on the different geographical levels (spot, local, regional, (supra)national);
– the methodology can take into account site specific characteristics[3] and reference levels of stress in the shape of e.g. background concentrations of environmentally harmful substances, reference land use and water extraction.

In theory, the methodologies we selected allow for an assessment at different geographical levels and can take into account reference burdens and a reference situation. For that matter, there is no difference between the methodologies and no limitation in their applicability.

However, there may be practical limitations. An example: the approach of the ReCiPe methodology for the impact of emissions of acidifying substances can be copied and applied for other continents than Europe and can also be applied on a more detailed level of for example a region or a local area. However, the models and data required for this approach may not always be available for:
– every continent/region/local area/spot location;
– every type of ecosystem and land use.

With respect to the impact on specific species (plant, animal) or ecosystems, in theory all methodologies also allow for determining these impacts, but data and models are probably not always available.

Land use

With respect to land use the methodology would ideally allow for taking into account the main policy-related issues, comparisons and policy choices (see Table 4):
– comparison between different intensities of land use and variation, e.g.:
  - the intensity of arable land use by means of e.g. tillage and the use of fertilisers and pesticides;
  - the effects of forestry management types and the extent to which felling residues (stumps, tops, branches) are collected and removed on forest biodiversity.
– extent of land area used and spatial structure of land use;

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3 These characteristics include e.g.:
– the characteristics of receiving soil;
– background concentrations, background emissions;
– present populations;
– local landscape design.

– the presence of ecological corridors, buffer zones and landscape components (e.g. hedgerows).

As already discussed in a previous study (CE Delft, 2011) the different selected methodologies partly possess these characteristics.

Table 4 Overview of match of the considered methodologies with desired specification (X = Yes)

	GLOBIO	ReCiPe	TNO
Methodological differences			
– Considers impact of land use on surrounding area?		X	
– Accounts for long term decrease of biodiversity for land use change?		X	
– Takes into account restoration time?		X	
– Weighing factors for representing uniqueness and remaining area?			X
– Considers fragmentation, impacts of roads?	X		
Data set issues, applied dataset allows for considering:			
– Differences in land use intensity	X	X	X
– Differences in landscape design			Partly
– Differences in affected biomes	X		Partly

Conclusions

The ReCiPe LCA methodology seems most fit at present to use for the analyses we aim to do in the second part of this study. It can be complemented by the water footprint methodology regarding water scarcity (Pfister, 2009).
With ReCiPe, pressures factors or burdens, such as emission of CO_2, are translated into an impact on biodiversity, using the indicator 'species.year'. For (fresh) water use, Pfister elaborates on impact in species.year per cube of water used in a specific region, and this method can therefore easily be incorporated in analyses with the ReCiPe methodology.

6 Tier methodology

Several analyses will be done in this project; sector analyses, company analyses based on public data and cases based on company data (see CE Delft, 2014). The availability of data differs between these analyses, as well as the (perceived) responsibility of the entity (sector or company) and its options for change. Furthermore, the system boundaries differ. A sector analysis inherently does not include a chain approach; sectors supply each other, e.g. the energy sector supplies electricity to the other sectors. On the other hand, in a company analysis a chain approach is possible and desirable; companies wish to know the impact of their products, including the impact of all preceding life cycle phases. This gives them insight into their options to improve their performance.

In order to help us choose the best approach for each of the analyses, we propose a tier method. There are three reasons we propose such an approach:
1. Data availability: as explained above, data availability differs for different analyses.
2. Responsibility: 'own' activities of a country/company should be shown separately from upstream activities; the options for change differ.
3. Methodology: because we know some pressure factors are not included in the current methodology we want to make clear that, in the future, additions are possible.

In each subsequent tier, additional life cycle phases are added; Tiers 1a, 1b, and 2a do not incorporate a chain approach, from Tier 2b the tiers do include that. Table 5 summarizes the types of analyses, the data sources used for each analysis and the corresponding tier.

Table 5 Proposed tier approach

Analysis	Source/data	Tier
Sector analysis	CBS, emission registration An additional analysis is required to calculate the impacts of import, we used 'Nederland Importland'(CE Delft, 2010)	1a, 1b
Company analysis	Publicly available company information, published by the company e.g. annual reports	2a, 2b
Company analysis; case with company	Company information; based on an extensive questionnaire, which includes upstream data	3
Company; location or product(s)	Not included in this project; inclusion of additional pressure factors.	4

As shown in Table 5, Tiers 1 and 2 have two levels; a and b. Figure 5 shows when to chose the a or b level; if import (or indirect pressure factors) are unknowns, the analysis can be done on level a. Preferably, those pressure factors are taken into account, in which case level b is suitable.

Dividing types of analyses into different tiers helped us in our approach. We feel that in theory, a Tier 2b analysis could be equal to a Tier 3 analysis. We found, however, that information concerning pressure factors given by companies in their annual (sustainability) reports, differed significantly

between sectors and within sectors. The first step towards more transparency would be to start with reporting on the most relevant pressure factors.
To keep the company analyses interesting, we therefore focused on the most important pressure factors in each sector.

Figure 5 Schematic Tier approach decision tree

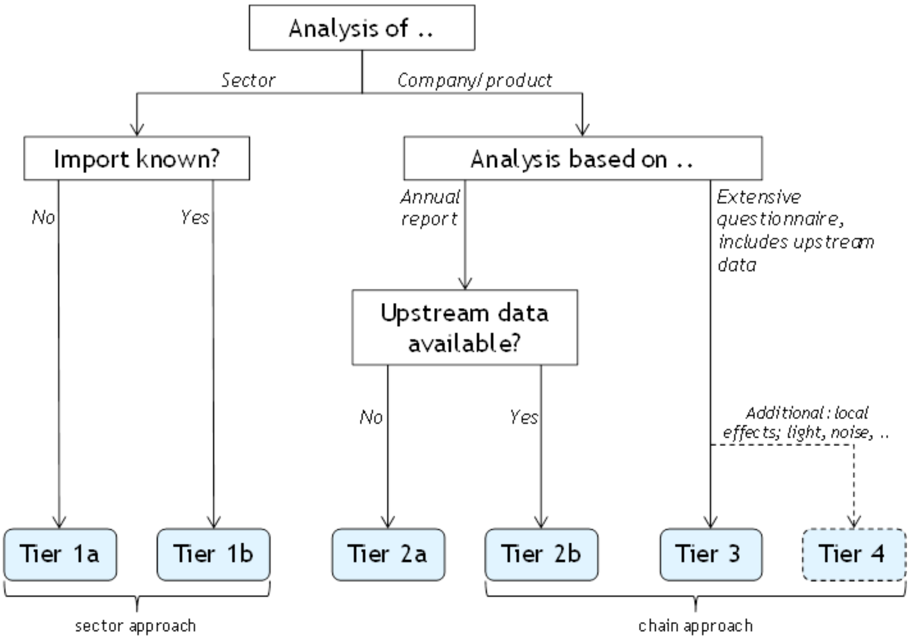

Figure 5 schematically shows how to decide what kind of analysis is fitting. The pressure factors and data corresponding to the tiers are listed in Table 6.

Table 6 Tier approach - included pressures factors, data source and environmental themes

Tier	Entity	Pressure factors (additional pressure factors are listed in the subsequent Tiers)	Data	Themes
1a	Sector Excluding import (upstream)	In the Netherlands: Emissions to air Emissions to water Emissions to soil Water use Land use	CBS, Emission registration	Climate Change Land use Acidification Eutrophication Toxicity Desiccation
1b	Sector including import (upstream)	Tier 1a factors + pressures related to production of (raw) materials abroad	Via CBS (for now: 'Nederland Importland', CE Delft, 2010)	Comparable to Tier 1a themes
2a	Company excluding upstream data	Transport Wastes (for landfill and incineration)	Public company data (e.g. annual reports)	Most relevant themes for the company's sector; covering >90% of sectoral impact
2b	Company Including upstream data	Electricity (Raw) material	Public company data (e.g. annual reports)	Most relevant themes for the company's sector; covering >90% of sectoral impact
3	Company Including upstream data	All activities listed above	Company data	Tier 1 themes
4	Company Location or product(s)	E.g. light, noise,…		E.g. light, noise,…

6.1 Pressures

Tier 1 – sector analyses

The basis for the sector analyse are the data as reported by CBS and emission registration. This also determines the sector classification (see Annex A in CE Delft, 2014). Import is not included in the CBS data on sectors, and should be analysed separately.

Emissions to air:

- greenhouse gas emissions (CO_2, CH4, N_2O, PFCs, SF_6);
- acidifying emissions (SO_2, NO_x, NH_3);
- other (NMVOC, PM_{10}, CO);
- eutrophying emissions (NH_3, NO_x);
- toxic emissions (ammonia, anthracene, arsenic, benzene, cadmium, carbon dioxide, carbon monoxide, chromium, copper, cyanide, dinitrogen monoxide, fluoranthene, lead, mercury, methane, naphthalene, nickel, nitrogen oxides, nmvoc (non-methane volatile organic compounds, unspecified origin), particulates (< 10 um), pfc-9-1-18, sulfur dioxide, sulfur hexafluoride, toluene, zinc.

Emissions to water:

- eutrophying emissions (P, cyanide);
- toxic emissions (anthracene, benzene, copper, cyanide, fluoranthene, mercury, naphthalene, phosphorus, toluene, xylene).

Emissions to soil:

- eutrophying emissions (P);
- toxic (N,P).

Land use

- Occupation (type, e.g.: traffic area, dump site, industrial area, mineral extraction site, construction site, urban, arable, permanent crop, pasture and meadow, forest).

Water use

- Water use (fresh water: sum of tap water, surface water and groundwater).

Tier 2: company analyses based on public information

In Tier 2 the chain approach is introduced; products and services provided to a company (e.g. materials, energy) are included. Impacts of direct pressure factors (Tier 2a) can be presented separately from impacts from such indirect pressures (included in Tier 2b).

This means all pressure factors listed under Tier 1 are included in Tier 2, but the scope is widened to include indirect pressures;

- **wastes** (for landfill and incineration);
- **transport** (if related pressures are not included in emissions to air);
- **energy use** (if related pressures are not included in emissions to air).

In Tier 2b: all pressures related to the raw materials used in the company's production processes.

While the scope is widened to include more activities, our analyses on Tier 2 focus on the most important pressure factors related to the company's sector. As shown in Table 7, for the 6 key sectors in the Dutch economy, which cover around 75% of the total impact on biodiversity (CE Delft, 2014), one to three pressure factors cover over 90% of the impact for all six sectors.
These pressure factors were the basis for our company analyses.
When companies in another sector would be assessed, we advise to look at the sector first, to establish which pressure factors are most relevant to companies in that sector.

Table 7 Most relevant pressure factors for the 6 key sectors (CE Delft, 2014)

Sector	Most relevant pressure factors	% of total impact
Food and stimulant industry	Land use	75%
	Emission of GHGs (CO_2 eq.)	20%
Agriculture	Land use	45%
	Phosphor (to soil)	34%
	Emission of GHGs (CO_2 eq.)	19%
Chemical industry	Emission of GHGs (CO_2 eq.)	90%
Wood industry	Land use	98%
Energy industry	Emission of GHGs (CO_2 eq.)	93%
Metal industry	Emission of GHGs (CO_2 eq.)	90%

Tier 3: company analyses - cases based on company information

Tier 3 includes all aforementioned themes and pressure factors. Impacts related to upstream pressures can be presented separately to distinguish between pressures related to a company's 'own' activities, and those of its suppliers.

Tier 4: location-specific company analyses

Tier 4 focuses on a specific location, and includes location-specific pressure factors, e.g. light and noise. Furthermore, land use transformation could be included in a Tier 4 analysis. To include this impact category quite specific information regarding location is required, as well as detailed information about previous land use and when transformation occurred. An analysis on Tier 4 is not included in the present analyses, but was added in the tier approach to show that we see potential to include additional pressure factors which are not included in the methodology at present.

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Annex A Biodiversity definition

Biodiversity is the variation of life on our planet. Broadly accepted is the definition of biodiversity as put forward by the Convention on Biological Diversity (see http://www.biodiv.org) which focuses not just on species[4], but also takes into account their interrelationships: 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' (Article 2 of the Convention).

More scientific, narrow definitions of biodiversity often focus on species diversity and population size, as for example quantified by Shannon and Simpson indices. These diversity indices are based on the species richness (the number of species present) and species abundance (the number of individuals per species.

Biodiversity at a certain location ('on the spot') is influenced by a variety of micro, meso and macro aspects, ranging from the type of biome on a micro scale to the flow of oceanic currents on a continental scale (see Figure 6).

The involvement of different aspects on both micro, meso and macro levels in the 'on the spot' biodiversity is logical if one considers the fact that:
- large mammals, such as wolves, occupy territories of tens or hundreds of square kilometres;
- migrating birds use breeding grounds and overwintering grounds situated many thousands of kilometres apart;
- seeds of mussels travel tens or hundreds of kilometres before they settle and grow into mussels.

Biodiversity and ecosystem services

Biodiversity is part of a larger system, called or ecosystem. The ecosystem consists of biodiversity 'in conjunction with the non-living components of the environment (things like air, water and mineral soil), interacting as a system' (Tansley, 1935). Hence, an ecosystem is an integral unit in our environment of biodiversity, geography, hydrology, soil and other aspects, such as a forest, mountain or swamp.

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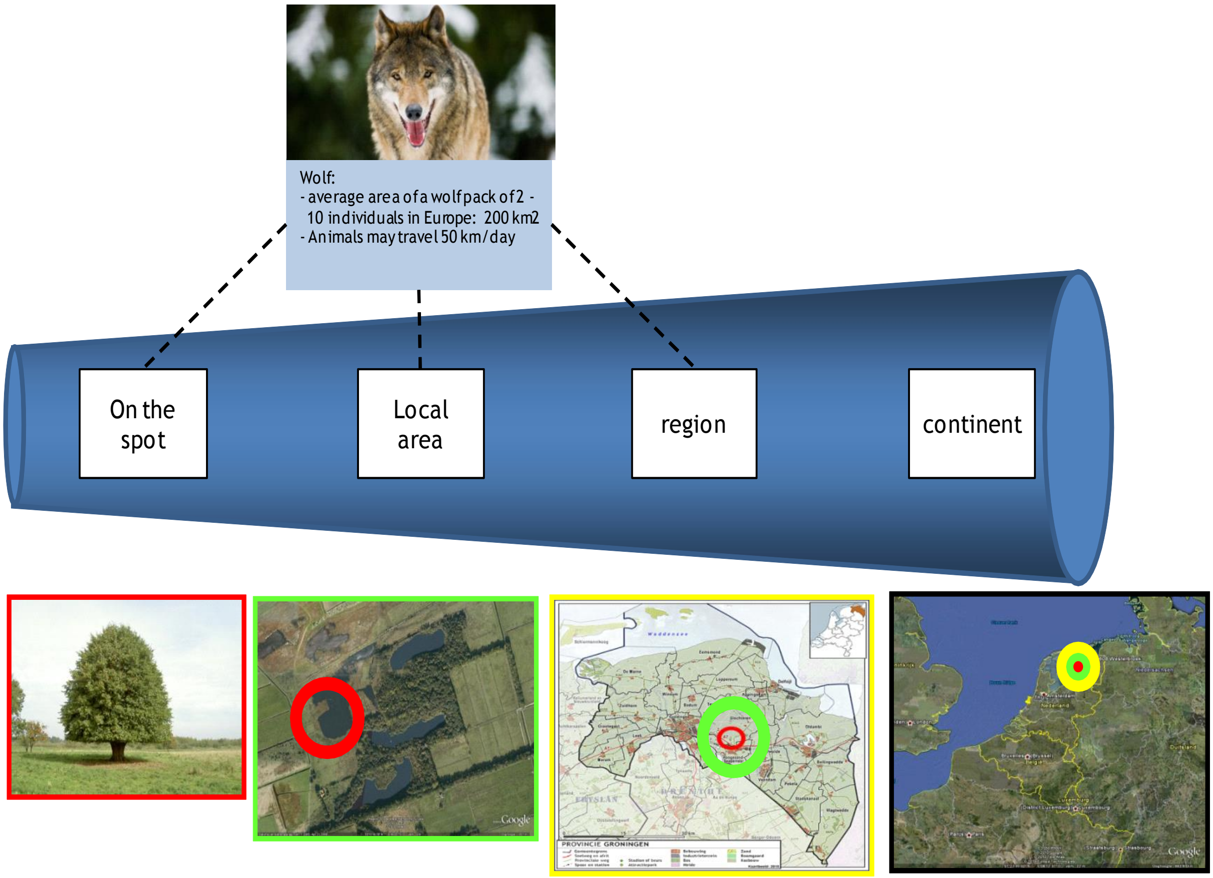
4 The 1992 United Nations Earth Summit in Rio de Janeiro defined 'biological diversity' as 'the variability among living organisms from all sources, including, ''inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems'. This definition is used in the United Nations Convention on Biological Diversity.

Figure 6 Factors influencing biodiversity on a specific location



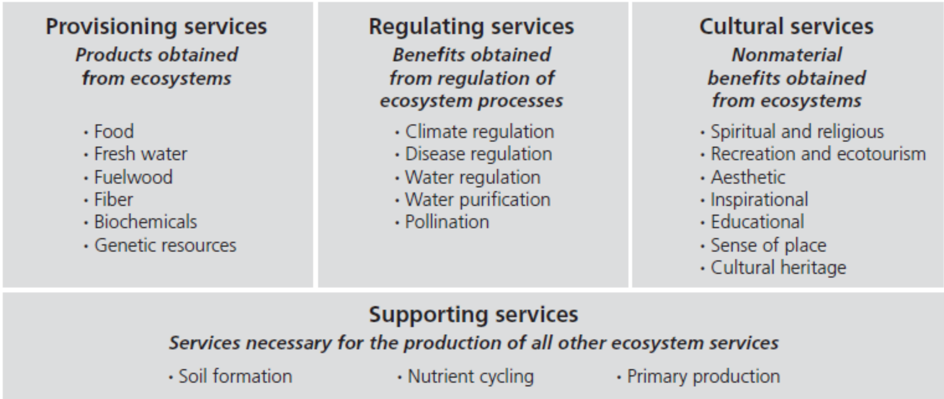
Biodiversity influencing aspects			
- Type and intensity of land use - Presence of landscape components (hedgerow, bushes, pools, ...) - soil fertility - Nitrogen deposition and other forms of soil pollution	- Infrastructure - Encroachment - Fragmentation and size of patches of biotopes	- Regional land planning - Level of natural area's being linked, natural corridors natural corridors	- Climate change - Invasive species
	-------- Level of protection of high biodiverse area's -------		
		sea and oceanic currents	
----------- geographical and temporal availability of water -------------			

Westerbroek natural area near Hoogerzand Sappermeer in the province of Groningen in the Netherlands

Humanity receives countless benefits from ecosystems in the form of so-called ecosystem services - goods and services such as food, wood, clean water, energy, protection from floods and soil erosion (UNEP, 2010) – see Figure 7.

Natural, undisturbed ecosystems are also the source of many life-saving drugs as well as providing sinks for our wastes, including carbon. Human development has also been shaped by the environment, and this inter linkage has strong social, cultural and aesthetic importance. The well-being of every human population in the world is fundamentally and directly dependent on ecosystem services.

Figure 7 Ecosystem services as identified in the Millennium Ecosystem Assessment



Source: Ranganathan, 2008.

Ecosystem services and biodiversity are interlinked by the necessity of retaining adequate biodiversity in an ecosystem for retaining ecosystem productivity and stability (Haines-Young, 2009; Ten Brink et al., 2008).

Annex B Methodology selection

Applied criteria for first selection

In view of the desired application scope and ideal methodology (Section 4.2) we have adopted a selection process based on the precondition that the selected methodology should be able to:

- convert business activities related pressures (burdens) into quantitative indicators for biodiversity impact;
- express biodiversity impacts in absolute units (e.g. decrease in number of species) or express impacts relative to a common absolute reference situation (pristine natural ecosystem); the latter allows aggregating or comparing impacts from different burdens (= pressures) and activities.

These selection criteria imply that only methodologies that focus on '*burden – impact'* relationship (see Chapter 4) are deemed relevant.

Table 8 Overview of considered and selected (bold) biodiversity related methodologies

	Midpoint aspects		Endpoint aspects		
	m^2 area	population	PDF/m^2	MSA	Estimated impact
Selected methodologies					
GLOBIO (by PBL)				X	
ReCiPe			X		
TNO			X		
Water footprint meth, for water extraction					
Not selected					
Midpoint monitoring methodologies – (Land occupation, land use transition) – CML2 methodology, PAS 2050, etc.	X				
Monitoring methodologies for biodiversity – Living Planet Index (WWF), IUCN Red Lists of species		X			
VROM biodiversity assessment framework					
Carbon foot printing methodologies – Ecological footprint, IPCC, etc.					
– IBIS methodology (CREM)					X
– BioScore tool					X

This list of relevant methodologies is perhaps not yet complete and efforts are made to find additional methodologies.

The TNO methodology is included because it contains some methodological choices that may be interesting for the purpose of benchmarking and could be adopted in this project. It combines local changes in biodiversity with global relative ecosystem scores. In this manner, the global perspective and the local details are both assessed.

Arguments for not considering some methodologies

Midpoint methodologies
Midpoint methodologies such as applied by CML or PAS 2050 consider and quantify land use related to a specific activity such as mining or agriculture. They do, however, not include a relationship between land use and biodiversity and thus do not allow quantifying impacts of these land using activities on biodiversity.

Monitoring methodologies
Monitoring methodologies monitor trends in regional or global biodiversity. The Living Planet Index, for example, is generated by averaging three separate indices for the forest, freshwater, and marine biomes. Each index describes the average trends in populations of vertebrate species from around the world since 1970. Each index is set at 100 in 1970 and given an equal weighting.

Monitoring methodologies however do not include mechanisms that directly relate the observed trends with aspects such as types of land use, intensity of land use and extent of different areas of land use. This makes them unfit for linking a land-requiring activity with the impact of that activity on biodiversity.

Carbon foot printing methodologies
In carbon foot printing methodologies, it is not biodiversity, but emissions of greenhouse gases that are considered. The considered emissions result from e.g. use of fossil fuels and also from land use related changes in natural carbon stocks in the biosphere. However, since greenhouse gas emissions have no direct relationship with biodiversity these methodologies do not allow for linking biodiversity and land use.

Some other, specific methodologies
WWF's Ecological Footprint Methodology combines aspects of monitoring methodologies and carbon footprinting methodologies. The Ecological Footprint uses yields of primary products (from cropland, forest, grazing land and fisheries) to calculate the area necessary to support a given activity. Greenhouse gas emissions and waste are included and are translated into land area by calculating the amount of biologically productive land and sea area required to absorb these emissions and wastes. Greenhouse gas emissions are, for example, translated into land area by considering the area of growing forest required to absorb and sequester the emitted greenhouse gases or an equivalent amount of CO_2.

The IBIS methodology can be used for estimating the scale of negative and positive impacts of an activity on biodiversity, but does not allow for estimating absolute impacts of burdens on biodiversity.

In the BioScore tool a large number of environmental variables and the impact of their change on biodiversity are considered. The tool allows for estimating the impact of changes on the level of individual EU Member States.
However, the starting point of the impact assessment of the BioScore methodology is the change in the environmental variables. This means the methodology does not allow for converting business activities related burdens into biodiversity changes.
Another reason for not considering the Bioscore tool was that it considers a number of different categories of organisms and for each category considers dozens of specific species. For example, for amphibians, 20 different

individual species are distinguished. The methodology would require a weighing of changes in population or species richness of the different categories relative to each other to allow expressing changes in biodiversity in one single value that can be included in an LCA.

Annex C Gross list of methodologies

Indicator	P/S/I/R ?	Midpoint	Monitoring	Carbon footprint methodologies	Benchmark indicator - no dose response	Qualitative	Quantitative methodologies (dose-response)
Beoordelingskader Biodiversiteit	SIR		x			x	
Biobanking Credit Calculator	R	x				x	
Biodiversity Accountability Framework (BAF)	S	x	x				
Biodiversity Action Reporting System (BARS)	R		x			x	
Biodiversity Audit	R		x			x	
Biodiversity Certification	R		x			x	
Biodiversity Check	PSIR		x			x	
Biodiversity in Impact Assessments	SI					x	
Biodiversity Management System (1) IUCN	-		x			x	
Biodiversity Management System (2)	-		x			x	
Biodiversity Performance Standard	R		x			x	
Biodiversity Planning Toolkit	R		x			x	
Biodiversity Quick Scan	S		x			x	
Biodiversity Reporting	SIR		x			x	
Biodiversity Risk Assessment Tool	R		x			x	
Biodiversity Scan	SIR		x			x	
Bioscore	PSI						x
BROA (Biodiversity Risk and Opportunity Assessment)	R		x			x	
Business & Biodiversity Checklist	?		x			x	
Business and Biodiversity Offsets Programme (BBOP)	R		x			x	
Corporate Biodiversity Management Framework	R		x			x	
Corporate Ecosystem Services Review (ESR)	R		x			x	
Corporate Ecosystem Valuation (CEV)	R		x			x	
Co$ting Nature	SIR		x			x	
Ecoindicator 99 Method	PSI						x
Ecologically based life cycle assessment (ELCA)	SR						
Ecological Asset Inventory and Management (EcoAIM)	R		x			x	
Ecological Footprint	PSI			x			
Ecometrix	SR						
Ecosystem banking	?				x		
Ecosystem Services Benchmark	SI		x			x	
Ecosystem Services Review for Environmental Impact Assessments	-		x			x	
EcoValue	S						
ESValue	R		X			x	

Indicator	P/S/I/R ?	Midpoint	Monitoring	Carbon footprint methodologies	Benchmark indicator - no dose response	Qualitative	Quantitative methodologies (dose-response)
European Biodiversity Standard	S		X			x	
Evaluations des Interrelations Biodiversité et Entreprises pour la vie	S		X			x	
Extractives Industry Biodiversity Benchmark	R		X			x	
Gaia biodiversity checklist	R		x				
Global Water Tool (GWT)		x					
GLOBIO (MSA Method)	PSI						x
High Conservation Value Areas (HCVA)	S		x			x	
Initial Biodiversity Assessment and Planning (IBAP)	IR		x			x	
Integral Biodiversity Impact assessment System (IBIS)	SI		x			x	
Integrated Biodiversity Assessment Tool (IBAT)	IR		x			x	
Integrated Valuation of Ecosystem Services and Tradeoffs (InVest)	S		x			x	
ISO14001	R		x			x	
Land Use Change in ecoinvent	PSI						x
LIFE Methodology	R		x			x	
Living Planet Index	SI		x				
Local Biodiversity Action Plan	R		x			x	
Marine Trophic Index	SI		x			x	
Multi-scale Integrated Models of Ecosystem Services (MIMES)	SI		x				
Natural Assets Information System (NAIS)	SI		x				
ReCiPe Method	PSI						x
Risk and Opportunity Tool	IR		x			x	
Standard on Biodiversity Offsets	R		x			x	
Streamlining European Biodiversity Indicators	-		x			x	
TNO Method	PSI						x
TruCost	I		x				
Vista	R		x			X	
Water Quality Index for Biodiversity	SI	X					
Wild Commodities Index	SI	X					
Wildlife Trust Biodiversity Benchmark	R		x			x	

Annex D Overview of tools and indicators

This overview of tools and indicators, summarized by CE Delft in this annex, was taken from IUCN's study of biodiversity indicators (IUCN, 2012).

Artificial Intelligence for Ecosystem Services (ARIES)
ARIES is a web-based technology, developed by University of Vermont, Basque Centre for Climate Change, Conservation International, Earth Economics, Instituto de Ecologica Mexico, to assist rapid ecosystem service assessment and valuation. ARIES can accommodate a range of different use scenarios, including spatial assessments and economic valuations of ecosystem services, optimization of ecosystem payment schemes and spatial policy planning.

Beoordelingskader Biodiversiteit
The Beoordelingskader Biodiversiteit is an 11-step programme, developed by VROM and CREM, to analyse impacts of activities on biodiversity. It analyses effects of activities on soil, water, air and biodiversity values and designs alternatives and mitigation measures.

BAF (Biodiversity Accountability Framework)
BAF, developed by Oree Institute, expands environmental management accounting with biodiversity and ecosystem services indicators. It quantifies the various ecosystem inputs-outputs associated with assets, liabilities, expenses or revenues.

Biodiversity Action Reporting System (BARS)
BARS is a web-based information system that provides a standardised way to record Biodiversity Action Plan progress towards targets and actions.

Biodiversity Audit
The Biodiversity Audit is a checklist-based monitoring tool, developed by Biodiversity in Good Company, in the form of a gap analysis: determines the legal framework and compliance and examines the success of performance objectives related to biodiversity.

Biodiversity Certification
Biodiversity Certification is accomplished via a set of 36 standards through established, explicit sets of requirements (including biodiversity requirements) for a process or practices, that are influencing the environmental impact of business practices.

Biodiversity Check
The Biodiversity Check is a joint initiative from Global Nature Fund and Dokeo. It assesses potential negative impacts on biodiversity of individual business units, manufacturing facilities, products or processes, identifies potential risks and opportunities and provides arguments for decision making regarding biodiversity.

Biobanking Credit Calculator
The Biobanking Credit Calculator calculates the number and type of credits created at a biobank site or required to be purchased and retired to offset the negative impacts of a development site. It was developed by New South Wales and the Office of Environment and Heritage.

Biodiversity in Impact Assessments

Biodiversity in Impact Assessments, developed International Association for Impact Assessments, is a biodiversity-inclusive environmental impact assessments for projects, and strategic environmental assessment (SEA) for policies, plans and programs.

Biodiversity Management System - IUCN, Holcim

The Biodiversity Management system developed by IUCN, Holcim, inserts biodiversity at three levels of the company business: (1) policy, (2) strategic planning and environmental management and (3) operational levels.

Biodiversity Management System - Earthmind

The Biodiversity Management system developed by Earthmind, establishes a common set of transparent, accountable and practical steps for biodiversity responsibility in line with ISO 14001.

Biodiversity Performance Standard

Developed by Green Destinations in South Africa, Biodiversity Performance Standard aims to establish a voluntary, market-based and industry-specific instrument for biodiversity conservation, and create new market opportunities in the local building industry n South Africa.

Biodiversity Planning Toolkit

Developed by Alge, the biodiversity planning toolkit is an online planning resource that applies for planning permission in developments where biodiversity may be encountered. It incorporates biodiversity into spatial planning.

Biodiversity Quick Scan

The Biodiversity (developed by VBDO) quick scan consists of 5 steps and checklists to identify impacts of operations on biodiversity.

Biodiversity Reporting

GRI is a network organisation that develops a standard for reporting on the sustainability of companies. The standard, known as the GRI Reporting Framework, gives specific guidelines on the reporting of various sustainability effects. A few years ago, biodiversity was added the to the framework (GRI, 2007). The performance indicators that are specific to biodiversity are shown in Figure 8.

Figure 8 **'Core' and 'Additional' performance indicators for biodiversity**

CORE	**EN11**	Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.
CORE	**EN12**	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.
ADD	**EN13**	Habitats protected or restored.
ADD	**EN14**	Strategies, current actions, and future plans for managing impacts on biodiversity.
ADD	**EN15**	Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk.

* Core = relevant for most organisations; Additional = interesting for most stakeholders.
Source: GRI, 2007.

The guidelines for reporting biodiversity are mostly qualitative, thus other indices would be needed in order to obtain quantitative scores.

Biodiversity Risk Assessment Tool

The Biodiversity Risk Assessment Tool is a joint project of British America Tobacco, Fauna & Flora International, Earthwatch Institute and the Tropical Biology Association. It identifies potential deficiencies, alerts senior managers to areas of concern and identifies opportunities for corrective action in a 3 phase approach: desk study, field study, action planning.

BROA (Biodiversity Risk and Opportunity Assessment)

Developed by the Earthwatch Institute, Fauna & Flora International, Tropical Biology Association and British American Tobacco, BROA provides a method to identify the impacts and dependencies of business operations on biodiversity in agricultural landscapes, to assess and prioritise the risks and opportunities arising from those impacts and dependencies, and to produce action and monitoring plans to address the identified risks and opportunities.

Biodiversity Scan

The Biodiversity Scan, developed by MVO Nederland, is an analysis of company's sustainability and practical advice for biodiversity conservation and enhancement.

Business & Biodiversity Checklist

This has been developed by Hitachi, but there is no information available yet on this tool.

Business and Biodiversity Offsets Programme (BBOP)

The BBOP is a collaboration of companies, government agencies and social organizations with the goal to develop a 'best practice' for a decreasing biodiversity. BBOP has recently published a standard and overview document: To No Net Loss and Beyond: An Overview of the Business and Biodiversity Offsets Programme (BBOP) (BBOP, 2013). This publication aims to help stakeholders with achieving a net zero loss in biodiversity through the mitigation hierarchy. The mitigation hierarchy prioritises measures in order to ensure that projects with negative effects on biodiversity cannot simply proceed due to a pledge to compensate with offsets elsewhere. The steps in the hierarchy are as follows:

- avoidance;
- minimise;
- restoration;
- compensation;

Corporate Ecosystem Services Review (ESR)

Developed by World Resources Institute, World Business Council for Sustainable Development and Meridian Institute, the ESR is a methodology for corporate managers to proactively develop strategies for managing business risks and opportunities arising from their company's dependence and impact on ecosystems.

Corporate Ecosystem Valuation (CEV)

CEV is developed by World Business Council for Sustainable Development, IUCN, World Resources Institute, ERM and PwC. The CEV guide assists companies in scoping, planning, valuation, application and embedding corporate ecosystem valuation.

Co$ting Nature

Co$ting Nature is a web based tool developed by Mark Mulligan (an independent consultant) that calculates the spatial distribution of ecosystem services for water, carbon, hazard mitigation and tourism and combines these with maps of conservation priority, threatened biodiversity and endemism.

Eco-indicator 99

See Annex H for more details.

Ecological Asset Inventory and Management (EcoAIM)

EciAIM develops specific estimates of ecosystem services and offers the means for evaluating tradeoffs of ecosystem services resulting from different land or resource management decisions.

Ecologically based life cycle assessment (ELCA)

ELCA is an online tool developed by Ohio University, which provides a qualitative accounting system and quantifies the role of natural resources. It complements other LCA tools by taking into account a broad range of ecosystem services.

Ecological Footprint

The Ecological Footprint is a measure of human demand on productive land for all consumption and to absorb CO_2. It is managed through the Global Footprint Network and is regularly updated.

EcoMetrix

Developed by Parametrix, EcoMetrix measures existing conditions of ecosystem services and functions, analyzes change from baseline to future scenarios and relates the results to landscape-level analyses to meet policy objectives

Ecosystem Services Benchmark

The Ecosystem Services Benchmark is developed by Natural Value Initiative. It is used for benchmarking sectors and companies and their activity on managing biodiversity and ecosystems risks and identification of common areas of weakness across sectors that might benefit from cross-sector collaboration.

Ecosystem Services Review for Environmental Impact Assessments

This review developed by the World Resources Institute contains steps to address ecosystem services in impact assessments. Steps include an impact scoping tool, dependence scoping tool, baseline tool, impact analysis tool, dependence analysis tool.

EcoValue

Developed by the University of Vermont, EcoValue is a web-based, interactive decision support system for assessing and reporting the economic value of ecosystem services.

ESValue

ESValue, developed by Cardno Entrix, is a strategic decision support tool that integrates scientific and economic information to show the impact and value of alternative environmental management strategies on ecosystem services.

European Biodiversity Standard

European Centre for Nature Conservation developed this tool to assess company's impact on the natural environment by using a ten-point system to certify a company's ecological performance.

Evaluations des Interrelations Biodiversité et Entreprises pour la vie

Developed by the French Ministry of Ecology, Sustainable Development and Energy, this is tool designed to help analyse relationships between businesses and the environment.

Extractives Industry Biodiversity Benchmark

The Extractives Industry Biodiversity Benchmark indicates best practices and standards for the extractive industry.

Gaia biodiversity checklist

The Gaia biodiversity checklist is developed by CML and measures actions of agribusiness to conserve or restore biodiversity.

GLOBIO

This tool was developed by PBL and UNEP and addresses the impacts of environmental drivers on MSA and their relative importance, expected trends under various future scenarios, and the effects of policy response options (MSA Method).

The MSA Method is a part of the GLOBIO modelling framework that was developed in 2003 in order to evaluate the global targets of biodiversity. GLOBIO is use in order to quantify the impacts of five biodiversity drivers (GLOBIO, 2013).

The MSA method is calculated by adding the relationship between pressures on biodiversity and species richness for the various biodiversity drivers.
The impact on biodiversity (for location i) is calculated by multiplying the drivers as follows:

$MSA_i = MSA_{LU(i)}\ MSA_{N(i)}\ MSA_{I(i)}\ MSA_{F(i)}\ MSA_{CC(i)}$

MSA_{LU} = land use
MSA_N = nitrogen deposition
MSA_I = development infrastructure
MSA_F = fragmentation by infrastructure
MSA_{CC} = climate change

PBL is one of the GLOBIO consortium partners. The MSA method is applied by PBL and seems to be relatively easy to use. Although the method is applicable in LCA in theory, this is less easy than applying ReCiPe, for example.

In comparison to other method, the MSA method has a global reach – biodiversity effects can be quantified for all important biomes in the world. See Annex D for more details.

High Conservation Value Areas (HCVA)

HCVA is an integrated evaluation approach to identify six different categories of high conservation and social use value areas.

Initial Biodiversity Assessment and Planning (IBAP)

Conservation International has released IBAP and biodiversity screening study to identify potential risks, socio-economic threats and opportunities.
This results in a biodiversity action plan with conservation recommendations and monitoring protocols

IBIS (Integral Biodiversity Impact assessment System)

Developed by CREM, IUCN N, IBIS determines the biodiversity impacts of products and compares the impacts of different products by scoring positive and negative impacts.

Integrated Biodiversity Assessment Tool (IBAT)

IBAT (developed by BirdLife International, Conservation International, IUCN and UNEP World Conservation Monitoring Centre) is a central database for biodiversity information including Key Biodiversity Areas and Legally Protected Areas. Through an interactive mapping tool, decision-makers are able to identify biodiversity risks and opportunities within a project boundary.

Integrated Valuation of Ecosystem Services and Tradeoffs (InVest)

InVest is used for estimating the amount and value of environmental services that are provided on the current landscape or under future scenarios, producing maps as outputs.

ISO14001

ISO14001 is a certification system that analyses the environmental risks of a business. A management plan is developed to manage and reduce these risks.

Land Use Approach in Ecoinvent

See Annex J.

LIFE Methodology
LIFE is a certification and auditing procedure developed by Instituto Life that covers compliance with legislation, evaluation of environmental and business management and commitments for improvements and biodiversity conservation action.

Living Planet Index
The Living Planet Index is calculated with time series data from more than 9,000 populations with 2,600 types of mammals, birds, reptiles, amphibians and fish worldwide. It is already in use, following update in 2014.

Local Biodiversity Action Plan
The Local Biodiversity Action Plan is developed by Business and Biodiversity Research Centre is actually several tools towards an action plan for a specific local area in order to conserve and enhance protected species and habitats. The action plan identifies what to measure and manage with respect to biodiversity impact.

Marine Trophic Index
The Marine Tropic Index maps the complex interactions between fisheries and aquatic ecosystems. It uses FAO catch data, which is then allocated to ecosystem components.

Multi-scale Integrated Models of Ecosystem Services (MIMES)
MIMES quantifies the effects of land and sea use change on ecosystem services. It uses input data from GIS sources and time series to simulate ecosystem components under different scenarios.

Natural Assets Information System (NAIS)
Developed by Spatial Informatics Group, NAIS estimates ecosystem services values using value transfer methods and geospatial science.

ReCiPe method
The ReCiPe method was a collaboration between RIVM, CML, PRé Consultants and Radboud university Nijmegen. The method, which was published in 2009, combines the CML and Eco-indicator 99 methods, including a numbering of improvements such a biodiversity indicator.

The ReCiPe methodology uses species richness in vascular plans as an indicator and is base don the area-species Arrhenius relationship:

$$S = a * A^b$$

S = species richness for considered area A
a = species richness factor, species richness for area of considered biome (infinite size)
A = area (m^2)
b = species accumulation factor (measure of the speed which the number of species increases with area size)

This method is widely used by LCA practioners in Europe, particularly in the Netherlands. ReCiPe is also widely accepted by governments, NGOs and businesses, especially in the Netherlands.

Since ReCiPe includes many other environmental indicators (18 in total), it is also practically applicable for LCA studies.

ReCiPe was developed in a European context, thus the land use reference situation is boreal and temperate deciduous forest or woodland.

Although ReCiPe is a suitable method for quantifying biodiversity, the method could be improved for policy applications by adding use function from other methods, such as a scarcity factor for biomes in order to include ____ in the factor. See Annex I for more details.

Risk and Opportunity Tool

Developed by a IUCN and SustainAbility, the risk and opportunity tool is used to map the degree of impact, degree of opportunity and degree of influence, based on the Millennium Ecosystem Assessment.

Standard on Biodiversity Offsets

Developed by the Business and Biodiversity Offset Programme, this is a standard on biodiversity offsetting that helps to determine whether an offset has been designed and subsequently implemented in accordance with the ten BBOP Principles, criteria and indicators.

Streamlining European Biodiversity Indicators (SEBI)

The SEBI initiative was launched in 2005 and aimed to develop a European set of biodiversity indicators. This set of biodiversity indicators was based on pre-existing indicators and some new indicators.

TNO method

The 'TNO method' was developed due to the theme 'degradation of ecosystems and landscapes' was not operational in CML 1992 guidelines. The focus of the method was a flexible method that is usable all around the world.

The stakeholder acceptance and reach of the method is unclear, however the methodology includes a few unique points that are not considered in other methods. The inclusion of a uniqueness factor biomes is particularly interesting.

The method can be easily applied in LCA studies and is furthermore focused on worldwide use. However, non-European ecosystems are not included in the method.

As in the Eco-indicator 99 and ReCiPe methods, land occupation and land transformation are differentiated. Both are expressed in terms of percentage species loss.

Land occupation is determined by the following equation:

$$ED_{occ} = A * t * EQ_i * ES_i * EV_i * PDF_{nature - occ.}$$

With ecosystem level factors:

- EQ_i (Ecosystem "Quality" of biome i) = S_i / S_{min} ($SR \geq 1$).
- ES_i (Ecosystem Scarcity of biome i) = $A_{pot,max}$ / $A_{pot,i}$ ($ES \geq 1$).
- EV_i (Ecosystem Vulnerability of biome i) = $(A_{exi}/A_{pot,i})^{b-1}$ ($EV \geq 1$).

Where

- S_{min} = the species richness in the least species rich biome in the world.
- $A_{pot,i}$ = the global potential (natural) area of biome i.
- $A_{pot,max}$ = the globally largest value for A_{pot} (to render scores ≥ 1).
- A_{exi} = the existing global ecosystem/biome area left.

Land transformation is determined for the following equation:

$$ED_{trans} = A * EQ_i * ES_i * EV_i * PDF_{1\rightarrow 2}$$

See Annex K for more details.

TruCost
Environmental profiling model that examines the interactions and cash flows between sectors to map each sector's supply chain.

Vista
Developed by Nature Serve, Vista is a decision support system to help users integrate conservation with land use and resource planning through conservation assessment and mitigation planning.

Water Quality Index for Biodiversity (WQIB)
The Water Quality Index for Biodiversity was developed by the United Nation's Environment Programs Global Environment Monitoring System and is based on the most comprehensive global water quality dataset in the world. Various water data is used to determine how water quality is affecting biodiversity. The WQIB approach incorporates spatial patterns of observed species response to fragmentation operating at multiple spatial scales.

Wild Commodities Index
Developed for the Biodiversity Indicators Partnership, the Wild Commodities Index tracks changes in the sustainability of the use of a selection of wild animals and plants. The index consists of three components:

1. Indicator tracking population sizes of species since 1970 (based on Living Planet Index).
2. Indicator tracking changes harvest of species over time.
3. Indicator tracking changes in price of wild commodities vs. other commodities.

Wildlife Trust Biodiversity Benchmark
Biodiversity Benchmark is a standard for assessing and certifying an organisation's systems for achieving continual biodiversity protection and enhancement on its landholdings and their implementation.

Waterfootprint methodology
Water use has long been seen as a relevant issues in environmental assessment, especially in life cycle assessment. Until recently, water use and the associated 'waterfootprint' was expressed solely in terms of the volume usage (litres or m^3).

Recently, a significant amount of research has been done on the topic of finding a more representative manner of calculating and expressing waterfootprints. Kounina et al. (2013) conducted a macro analysis of all important recent studies on the topic of waterfootprinting. This study will eventually form the basis for ISO 14046 – the water footprinting standard – that is currently in development. The nineteen examined approaches all have a somewhat different emphasis than others, however some methods are indeed more advanced than others. The most elementary approach remain at the water use inventory level, while others go a step further and define midpoint factors and others still define endpoint factors in terms of human health, ecosystem quality and resources. Some approaches also links water use to biodiversity loss. Some of the most accepted approaches are listed below:

- **Pfister et al. (2009) - Assessing the environmental impacts of freshwater consumption in LCA**
  This approach defines water stress indices, such that water withdrawal is related to hydrological availability for a particular region. The regions are examined on several levels: per country, per watershed and per grid cell (in a map). The water stress indices can then be used to characterise factors (midpoint) for freshwater use and water quality degradation.
  The impact of water use is then fully converted to three endpoint categories: human health, ecosystem quality and resources. In a more recent study, Pfister et al. (2012) also examined monthly water stress indices (instead of just annual). This provides better insights for fluctuating use, such as for agriculture.
- **Hoekstra et al (2011) - The water footprint assessment manual: Setting the global standard**
  The concept waterfootprint, was introduced by Hoekstra in 2002 (Hoekstra et al., 2003). Following a few years of further development, Hoekstra et al. (2011) published the waterfootprint handbook. Such as in Pfister et al.'s (2009) approach, water scarcity indices have been determined via the relationship of water withdrawal and hydrological availability of a particular region. Furthermore, blue, green and grey water are differentiated from one another. As opposed to Pfister et al. (2009) de indices are determined per watershed and month. In addition, the impacts of water use are not expressed at an endpoint level.
  Aside from the approaches that are covered in the Kounina et al. (2013) review, researchers at KU Leuven have developed an approach for waterfootprinting whereby water use is related to a natural system, such as is done in the quantification of biodiversity loss.
- **KU Leuven (Heuvelmans et al., 2005; Muys et al., 2006, etc.)**
  The research at KU Leuven is focused on the quantification of the land use impacts that are related to the hydrological response of the land. The time series of water fluxes have been generated using the SWAT hydrological model. According to Kounina et al.'s (2013) analysis, this research has quantified the impact of water use (via land use), however up to now (at least up until the publication of Kounina et al., 2013) there was still no concrete characterisation factors determined to quantify the relationship between green water use and the resources endpoint.

Annex E Initiatives/organisations

Natural Value Initiative (NVI)

The Natural Value Initiative is a collaboration of several stakeholders that are focused on the link between companies and ecosystems and how biodiversity and system services can be managed. NVI has carried out a few projects and publications, recently having published 'Is natural capital a material issues? An evaluation of the relevance of biodiversity and ecosystem services to accountancy professionals and the private sector. NVI's focus has mostly been the valuation of the ecosystem services for companies.

Company projects via the Platform for Biodiversity, Ecosystems and Economy

The Platform for Biodiversity, Ecosystems and Economy is a VNO-NCW (Confederation of Netherlands Industry and Employers) and IUCN (International Union for Conservation of Nature) Netherlands initiative for preservation and restoration of biodiversity and ecosystems as these are of vital importance for both the liveability of the environmental and the economy. Since its establishment, several other Dutch companies have joined the initiative.

Recently, a group of Dutch companies (Essent, Eneco, FMO, Interface and Desso) have begun a pilot to establish carbon credits to counteract deforestation and the degradation of biodiversity in the tropics. This initiative is associated with the U.N. REDD+ programme, which is focused on the prevention of deforestation in developing countries. The companies have signed a declaration of intent, and as such they are bound to the co-financing of the pilot (Platform BEE, 2013).

TEEB process methods

TEEB (The Economics of Ecosystems and Biodiversity) is an international initiative to bring attention to the economic benefits of biodiversity. The aim of TEEB is to emphasise the increasing cost of biodiversity loss and ecosystem degradation and to make practical solutions possible through a group of experts in the field of science, economy and policy. In 2010, TEEB wrote a chapter for a UNEP publication (UNEP, 2010) that gave an overview of biodiversity indicators. Various measures and indicators were mentioned in this chapter, including several that are mentioned in this overview. The focus of the chapter, however, was to the extent that the indicators characterise the economic value of the species and ecosystems.

Annex F Biodiversity and area size – some theoretical background information

Relationships between biodiversity and land use have been developed in the field of ecology. In ecology, the biodiversity – expressed as species richness, the number of species per unit of area – has been described as a function of the size of that area of a habitat, or of part of a habitat in so-called species-area curves.

The challenge of this project is identifying and evaluating methodologies utilising these relationships in a shape that allows for meeting the requirements defined in the previous paragraph.

For a better understanding of the theory behind these methodologies and the evaluation of these methodologies, a brief introduction into the theory of species-area relationships – as far as relevant for this study – is given in this paragraph.

The theory of species - area relationships

Larger areas tend to contain larger numbers of species, and empirically, the relative numbers seem to follow systematic mathematical relationships[5]. The species-area relationship is usually constructed for a single type of organism, such as all vascular plants or all species of a specific trophic level within a particular site. It is rarely, if ever, constructed for all types of organisms if simply because of the prodigious data requirements.

Arrhenius in 1921 was the first to develop a mathematical relationship between area and species richness [6]. All methodologies for linking land use and biodiversity are based on his the area-species relationship, expressed as:

$$S = a * A^b$$

In which:

S = Species richness for the considered area A

a = Species richness factor, species richness for an area of the considered biome of infinite size

A = Area (m^2)

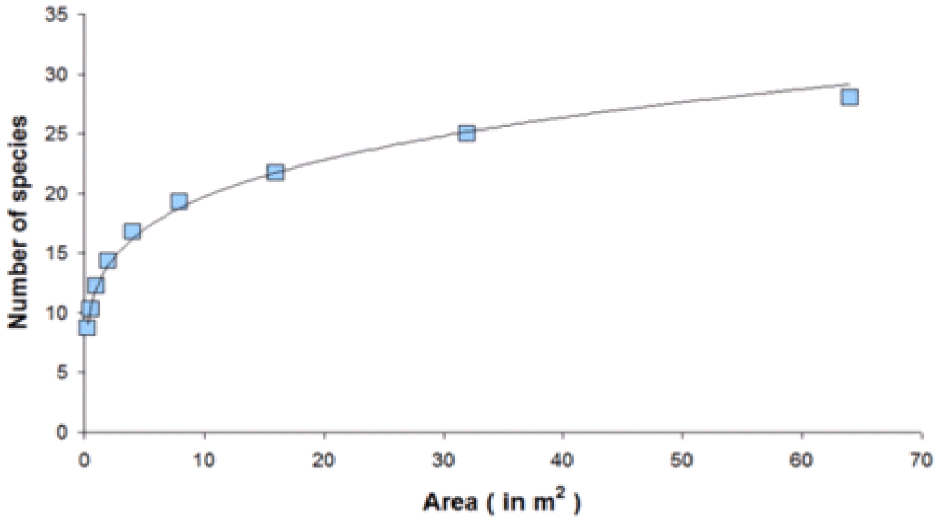
b = Species accumulation factor – a measure for the tempo with which the number of species increases with area size

The relationship indicates that biodiversity ***S*** in a specific biotope increases with increase in area ***A***. The parameter ***b*** indicates how quickly biodiversity increases with area size.

5 Preston, F.W. 1962. The canonical distribution of commonness and rarity: Part I. Ecology 43:185-215 and 431-432, as cited at http://en.wikipedia.org/wiki/Species-area_curve.

6 See http://www.ime.unicamp.br/sinape/sites/default/files/Resumo_gSARModel.pdf for more information.

Figure 9 Illustration of a species-area relationship



Alternative formulations of his relationship have been proposed by e.g. Gleason (1922) and Plotkin et al. (2000). Alternative relationships have been postulated, but as far as can be deducted these variations or alternatives are not applied.

The PDF parameter

In addition to Arrhenius' relationship, impacts on biodiversity are often expressed in Potential Disappeared Fraction of species (PDF). The PDF parameter is a measure for the relative **change** in biodiversity, relative to the biodiversity of a reference situation. This reference may be:

- for land occupation: the natural, pristine biome that would be present without any human interference;
- for transformation or land use change: the land use in the situation after land use change.

Both situations are mathematically expressed below. The parameters *S* and *a* in these relationships are the same as in Arrhenius' species-area relationship. The difference between *S* and *a* is that the *S* refers to the species richness of a standardised unit or area, e.g. 10,000 ha.

For occupation:

$$PDF_{nature \to occ.} = \frac{S_{nature} - S_{occupation}}{S_{nature}}$$ or $$PDF_{nature \to occ.} = \frac{a_{nature} - a_{occupation}}{a_{nature}}$$

For transformation:

$$PDF_{1 \to 2.} = \frac{S_1 - S_2}{S_2}$$ or $$PDF_{1 \to 2} = \frac{a_1 - a_2}{a_2}$$

Another option of expressing changes in biodiversity is expressing the relative **level** of the species richness for a considered situation, relative to the species richness in a reference situation: the Mean Species Abundance.

For this methodology of reporting the reference as a rule is the natural, pristine biome that would be present without any human interference.

The mathematical formulation is:

$$MSA = \frac{S_{occ}}{S_{nature}}$$ or $$MSA = \frac{a_{occ}}{a_{nature}}$$

Annex G MSA methodology

Text is abstract from PBL website (GLOBIO, 2014, see http://www.globio.info/what-is-globio/science-behind-globio).

G.1 General principles of the MSA methodology

The lack of a quantitative overview of global species trends makes it difficult to project development trends into the future. To bypass species biodiversity data problems, an indicator – the Mean Species Abundance indicator (MSA indicator) - was developed at the European and global levels, using a number of proximate drivers (or pressures) as a crude measure for ecosystem quality. These relationships between pressures and species abundance (dose-response relationships) are based on extensive literature reviews. The MSA can be calculated with the GLOBIO model.

The driving forces (pressures) incorporated in the model are:
- land use - e.g. forest and built up area - and land use intensity (MSA_{LU});
- nitrogen deposition (MSA_N);
- infrastructure development (MSA_I);
- fragmentation (derived from infrastructure) (MSA_F);
- climate change (MSA_{CC}).

Assuming no interaction among the drivers, for a specific location ***i*** the overall MSA is calculated by multiplying the MSA's related to the different drivers:

$$MSA_i = MSA_{LU(i)} \cdot MSA_{N(i)} MSA_{I(i)} \cdot MSA_{F(i)} \cdot MSA_{CC(i)}$$

The different land use types mentioned in the considered studies were categorized into six globally consistent groups:
- primary vegetation;
- lightly used primary vegetation;
- secondary vegetation;
- pasture;
- plantation forestry;
- agricultural land, including cropland and agro-forestry systems.

Different agricultural land use intensity classes are distinguished. A gradual increase in external inputs in agricultural systems forms the basis for different intensity classes:
- agro-forestry;
- low-input (or traditional) farming;
- intensive (or conventional) farming;
- irrigated farming.

Each intensity class carries a specific biodiversity value.

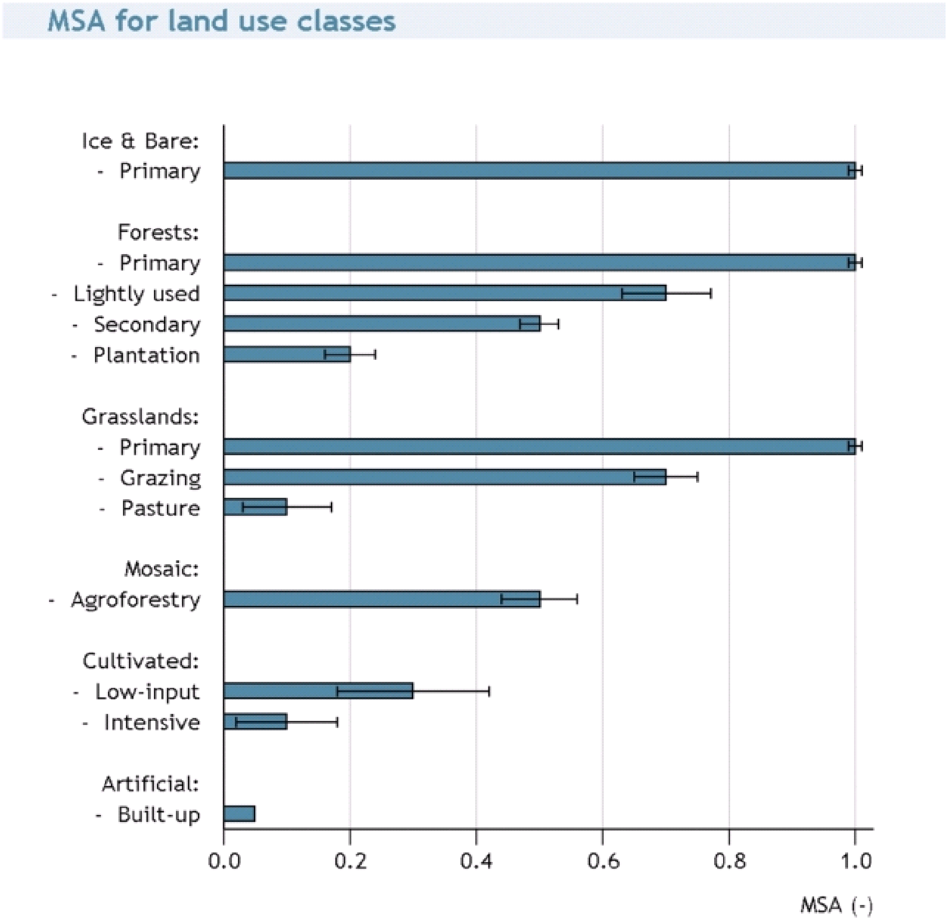
Most of the considered studies describe plant or animal species in the tropical forest biome, however; the sparse studies from other biomes confirm the general picture.

The values of the different MSAs for the different considered drivers are presented below.

G.2 Land use and land use intensity

MSA values are based on datasets comparing measured species abundance between at least one land use type and primary vegetation. A linear mixed effect model was fitted to the data.

Figure 10 MSA for land use classes (http://www.globio.info/what-is-globio/science-behind-globio/land-use)

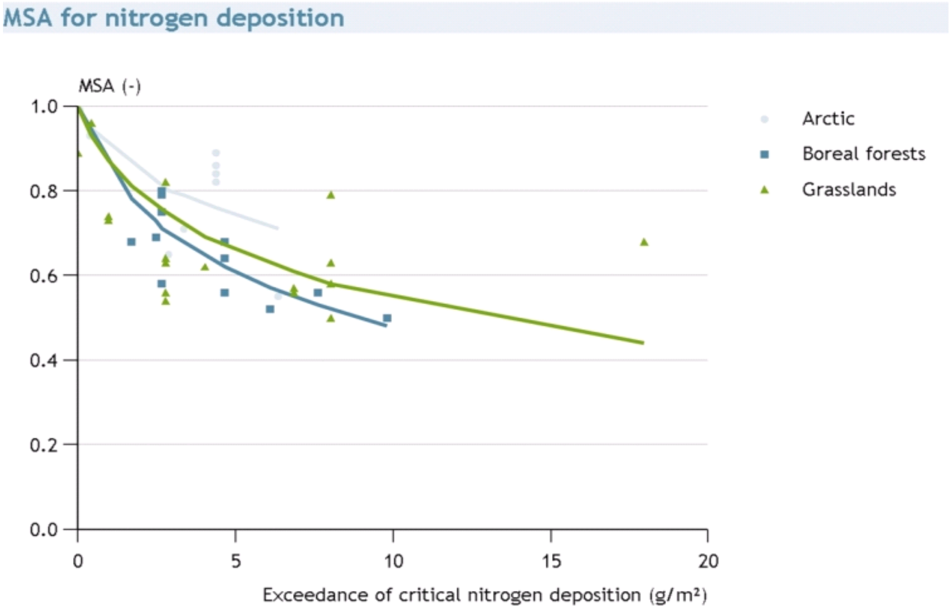


MSA values for land use.

G.3 Nitrogen desposition

In the MSA methodology for separate biomes, (log) linear regression models describe the relationship between N exceedance and MSA.
For croplands, atmospheric N deposition is considered not to affect MSA, because the atmospheric N deposition is relatively small compared to the addition of N by fertilizers. The latter is already accounted for in the estimation of agricultural impacts (land use).

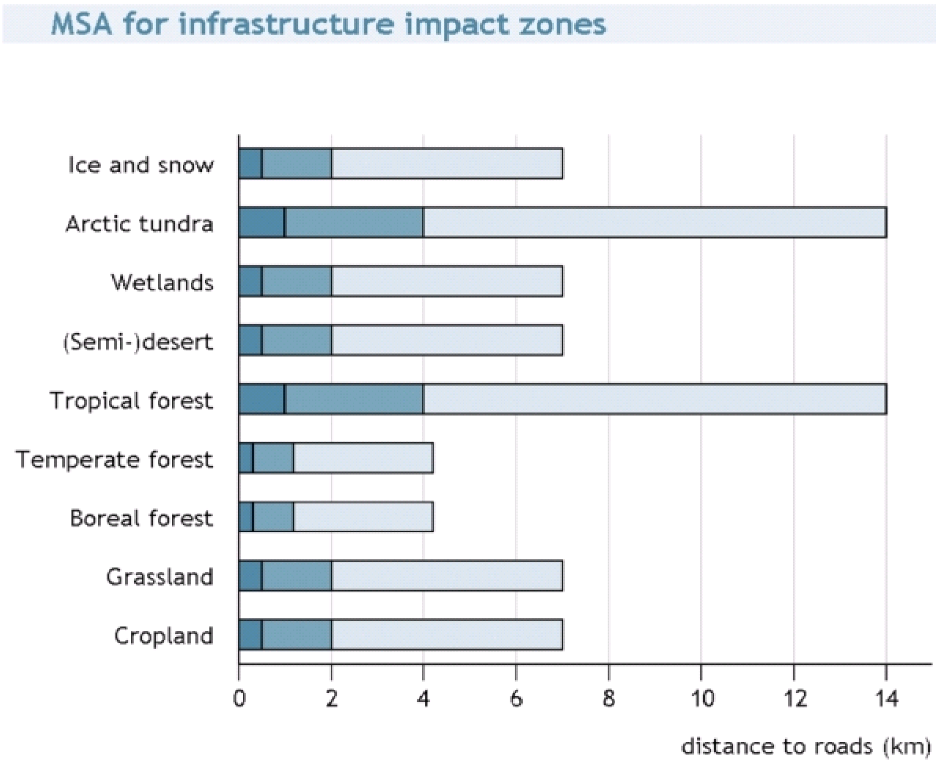
Figure 11 MSA for nitrogen deposition



G.4 Infrastructure

For impact of infrastructure on biodiversity, impact zones (high, medium, low) around roads have been defined, based on the distance to the road. The depth of the impact zones differs among ecosystems.

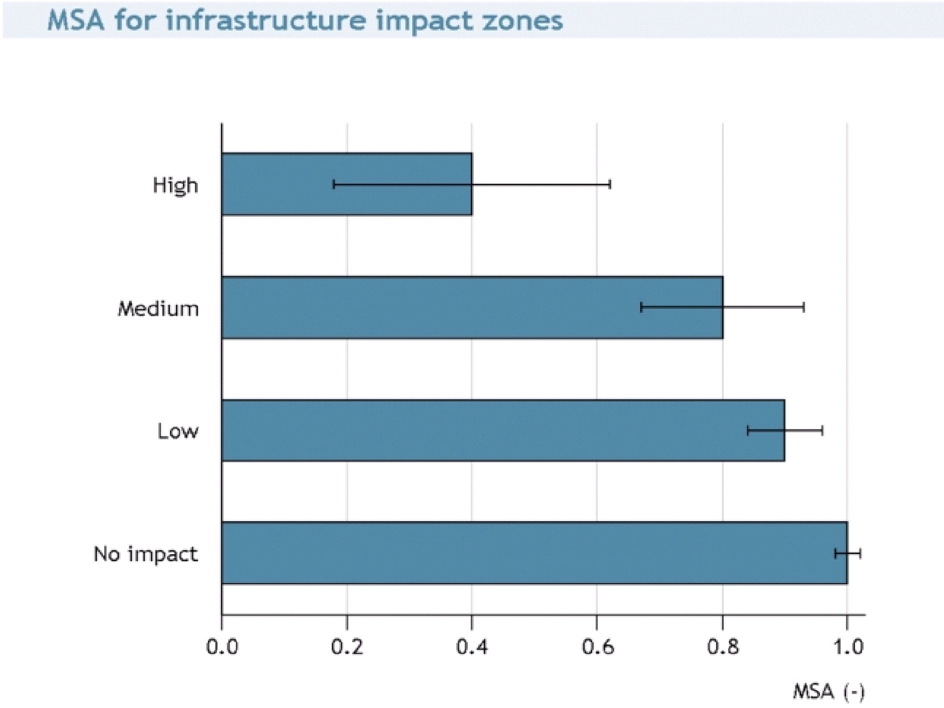
Figure 12 MSA for infrastructure impact zones



High = dark color, medium = intermediate intensity, low = light color.

The MSA values associated with the different impact zones are given below. The impacts include direct effects of disturbance on wildlife, and indirect effects such as increased hunting activities and tourism, and small-scale land use change along roads.
Infrastructure is set to affect only natural and semi-natural areas.
In protected areas, infrastructure is set to have no impact. For each impact zone, MSA was estimated using generalized mixed models.

Figure 13 **MSA for infrastructure impact zones (http://www.globio.info/what-is-globio/science-behind-globio/infrastructure)**

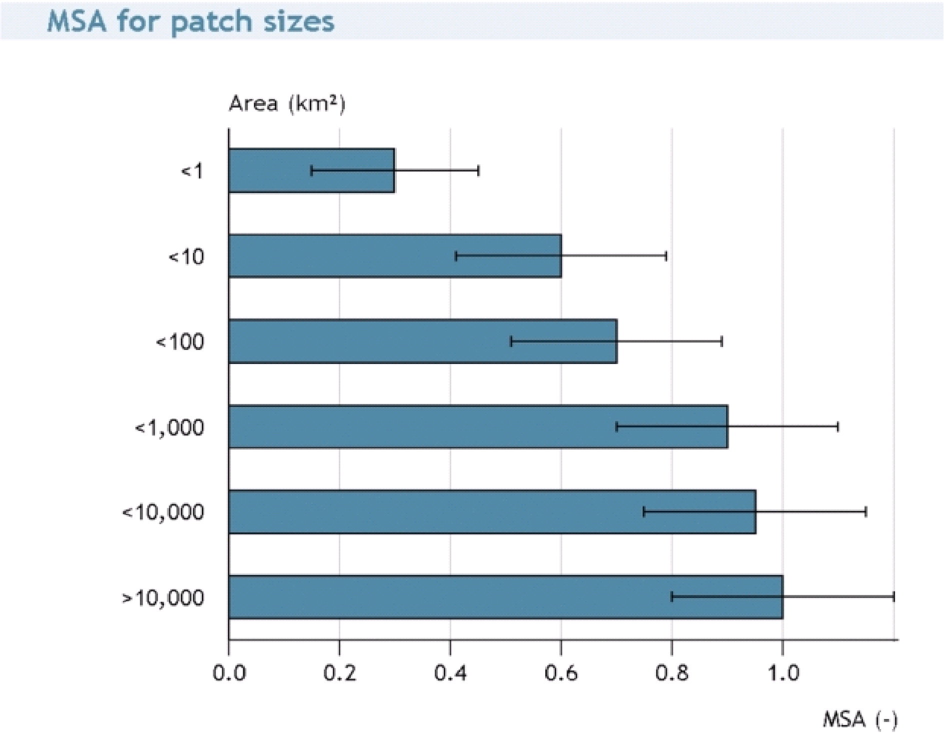


G.5 Fragmentation

GLOBIO includes the effects on fragmentation in terms of the effects of patch size on MSA. Distance between patches is not included.

The relationship between MSA and patch size is based on data on the minimum area required to support a viable population of a certain animal species (MVP). The proportion of species for which a certain area is sufficient for their MVP is calculated and considered a proxy for MSA.
The data show that patches of over 10,000 km^2 of suitable habitat provide sufficient space for viable populations of any species.

Figure 14 MSA for patch sizes (http://www.globio.info/what-is-globio/science-behind-globio/fragmentation)



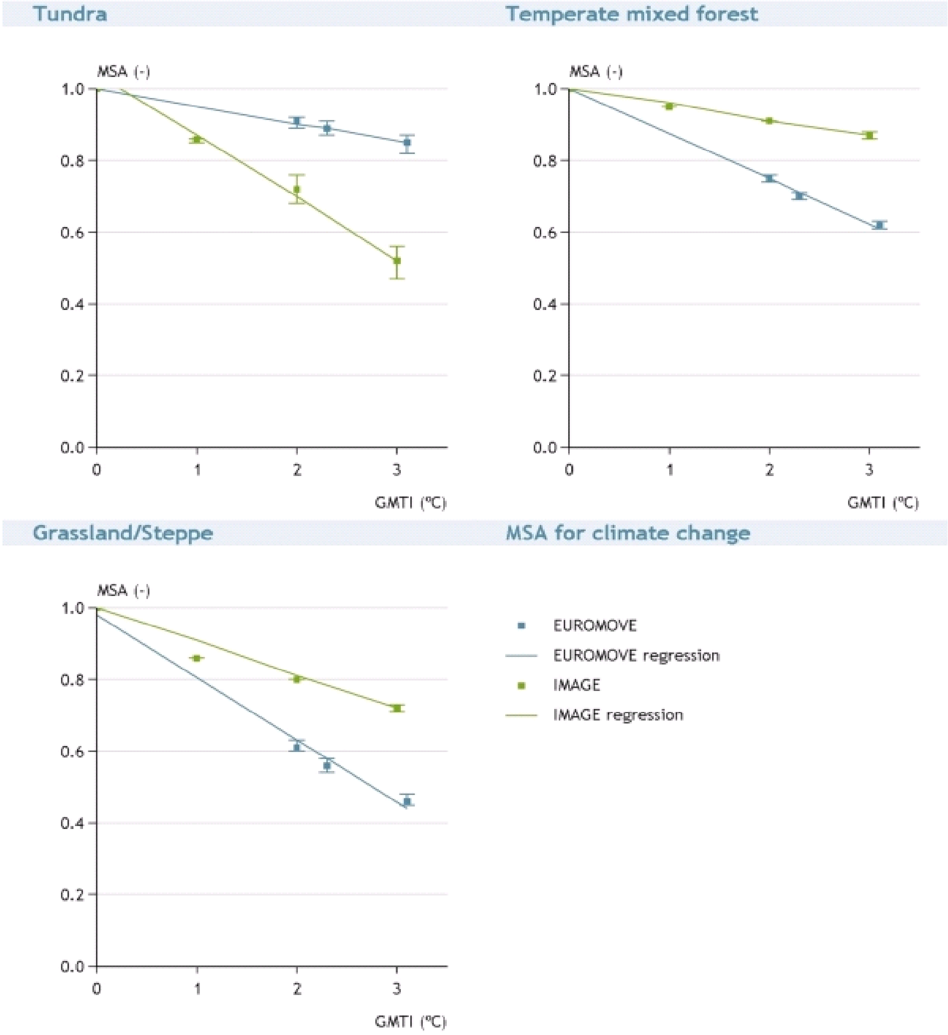
G.6 Climate change

For the impact of climate change, biome-specific regression equations relating changes in global mean temperature increase (GMTI) to MSA have been developed. As with infrastructure, climate change is set to only affect natural and semi-natural areas.

Three examples of regression lines relating estimated MSA values with global mean temperature increase (degrees Celsius) are given below for tundra, temperate mixed forests and grasslands. The error bars reflect only the standard error derived from the regression analysis.

The treatment of climate change is different from that of the other drivers, as the available empirical evidence is limited to areas that are already experiencing significant impacts (such as the Arctic and montane forests).
The cause-effect relationships for climate change are based on model studies. The models EUROMOVE and IMAGE were used to predict the proportion of remaining plant species and the proportion of stable area of biomes respectively, as a function of global mean temperature increase (GMTI).
Stable groups of plant species occurring within a biome (EUROMOVE), or stable areas for each biome (IMAGE), are considered proxies for MSA.
For each biome a linear regression equation was estimated to relate cause and effect, i.e. GMTI and the MSA proxy. For each biome, the regression-equation was selected that predicts the smallest effects, either from EUROMOVE or from IMAGE, yielding conservative estimates.

Figure 15 Impact of climate change and associated temperature increases on biodiversity, as expressed with MSA (http://www.globio.info/what-is-globio/science-behind-globio/climate-change)



Annex H Eco-indicator 99 methodology

H.1 General outline of methodology

The Eco-indicator 99 methodology concerns an endpoint impact methodology focussed on impacts on biodiversity. The methodology is based on the area-species relation of Arrhenius[7], expressed as:

$$S = a * A^b$$

In which:
S = Species richness for the considered area A
a = Species richness factor, species richness for an area of the considered biome of infinite size
A = Area (m^2)
b = Species accumulation factor – a measure for the tempo with which the number of species increases with area size

In the Eco-indicator 99 methodology, the species richness of vascular plants is taken as indicator value for total biodiversity.

In the Eco-indicator 99 methodology, impacts of land occupation and land use change on 'Ecosystem Quality (EQ)' on both local and regional scale are taken into account, according to:

$$EQ_{total} = EQ_{local,occupation} + EQ_{local,conversion} + EQ_{regional,occupation} + EQ_{regional,conversion}$$

$$= 1.2 * A * (t_{restoration} * \Delta PDF_{1 \to 2} + t_{occupation} * \Delta PDF_{natural \to 2})$$

$$= 1.2 * A * (t_{restoration} * \frac{a_1 - a_2}{a_2} + t_{occupation} * \frac{a_{natural} - a_2}{a_{natural}})$$

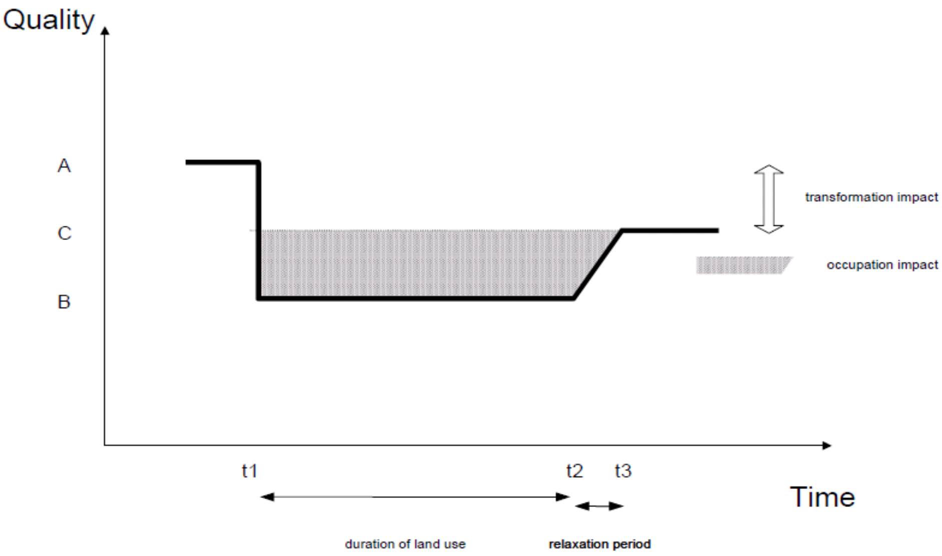
In this relationship:
- ***A*** represents the considered area;
- $t_{restoration}$ represents the period of time required for a converted area to return from land use 2 back to situation 1;
- $t_{occupation}$ represents the period of time during which the area will be in situation 2;
- a_2 refers to the species richness of the considered actual land use;
- a_1 and $a_{natural}$ refer to respectively the species richness of a previous land use and the species richness of the original natural system;
- PDF is the potentially disappeared fraction, a measure for the relative decline (or increase) in species richness.

The factor 1.2 indicates that regional effects result in a 20% increase in the local impacts of land occupation and conversion.

The local effect on biodiversity is naturally the result of the change in land use and associated change in land cover (see Figure 16).

[7] See http://en.wikipedia.org/wiki/Species-area_curve.

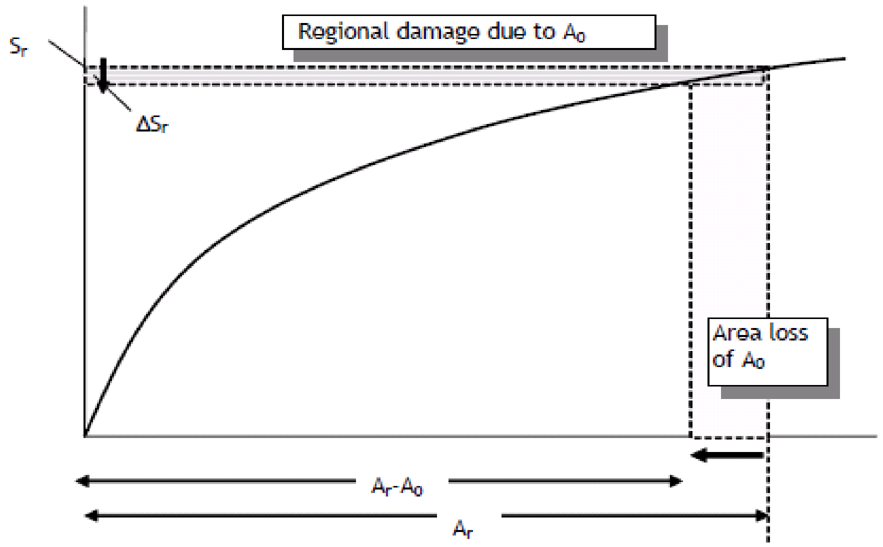
Figure 16 Visualisation of local impact of land occupation and transformation on biodiversity



Source: TNO, 2002, 'Quality'= biodiversity.

The regional effect refers to the change in area size of the original biome and the – according to Arrhenius relation – associated decrease in biodiversity (see Figure 17).

Figure 17 Visualisation of regional effect



Source: ReCiPe, 2009.

A_o (= occupied area) represents the transformed and/or occupied area, evaluated in the LCA.

Ar represents the total original area of the biome from which part is occupied for a different use.

For $t_{restoration}$ two default values are to be applied:

- $t_{restoration}$ = 5 years for conversion between two unnatural types of land use (agricultural, built-up);
- $t_{restoration}$ = 30 years for conversion back to natural state of land used for unnatural uses.

As illustrated by the given relation, the methodology is based on ecosystem specific species richness (the number of species present in a specific ecosystem). The methodology also refers to the relative change in biodiversity, not to the absolute level of biodiversity.

Though the methodology is based on a mathematical relation with a power in it, by considering relative changes in biodiversity the resulting land use – the impact relationship is a simple first-order relationship in which the size of occupied or transformed area has been removed as factor of influence.

The methodology has been elaborated for Central European ecosystems, more specifically ecosystems in Switzerland and Germany. The assumed reference natural state has been defined as natural area in the Swiss lowlands.

H.2 Example

Two examples have been adapted from the Eco-indicator 99 manual. Used values can be found in Paragraph H.4.

Example 1
An organic meadow is converted into continuous urban area.
The associated damage to the ecosystem is calculated as:

$$1.2 * A * t_{restoration} * PDF_{meadow \rightarrow continuous\,urban} = 1.2 * 5 * (0.96 - 0.70) = 1.56 / m^2$$

Example 2
The continuous urban area is or will subsequently be occupied for an assumed period of 50 years.
The associated ecosystem damage is calculated as:

$$1.2 * A * t_{restoration} * PDF_{natural \rightarrow continuous\,urban} = 1.2 * 50 * 0.96 = 57.6 / m^2$$

H.3 Purpose, strengths and weaknesses

Purpose

The Eco-indicator 99 methodology is an update of the Eco-indicator 95 methodology. The latter was developed as a tool for designers to be used within Integrated Product Policy (IPP) and the associated management system, the Product-Orientated Environmental system (POEM system). The aim of IPP and the associated POEM were/are the reduction of the total environmental impact of a product during its entire life cycle.
In view of this context, the Eco-indicator methodologies were/are aimed at supplying of ready for use information about the environmental impact related to raw materials, processing and waste removal processes. .
The methodologies should cover as many relevant types of environmental impact as possible and should allow for the weighing of contributions to the different considered environmental issues, giving 1 aggregated value for the total environmental impact over the entire life cycle.

Strength

Strength of the approach of land use (change) and associated impacts on biodiversity in the Eco-indicator 99 methodology is its simplicity.

Limitations

The mean limitations to the Eco-indicator 99 methodology are:

- Has been elaborated only for a specific European region.
- Based on a limited set of observations of species richness in different types of land use, especially for continuous urban land.
- Data for agricultural land use is based on observations of species in the field only and doesn't take into account species richness in landscape components such as hedges and waterways.
- Uncertainties in available data have been corrected by application of 'somewhat arbitrary' correction factors, lying between 1 and 4.
- The examples above seem to indicate that land use change is less important than land occupation.
- The considered periods of time are highly arbitrary and theoretical or are very difficult to predict.
- The methodology assumes a uniform response of all vascular plants present to the pressure introduced y land transformation and/or occupation.
  In practice plants and other species can respond in very different ways and can be very sensitive or insensitive to such pressures.

H.4 Default values

Values for $\boldsymbol{PDF}_{natural \rightarrow use}$ as mentioned in the Eco-indicator 99 methodology report are given in Table 9. The correction factors included in the table have been introduced for compensating for limited data availability and associated uncertainty in the value of PDF.

Table 9 Values for PDF for transition from natural area's to indicated land uses

	CORINE classification	n	a	a_{low}	a_{high}	correction	$PDF_{natural \rightarrow use}$	σ^2_g
Continuous urban	1.1.1	9	11.0	0.7	164.0	1.0	**0.96**	2.4
Discontinuous urban	1.1.2	59	54.6	36.6	90.0	1.0	**0.80**	1.2
Industrial area	1.2.1	29	81.5	27.1	244.7	1.0	**0.70**	7.3
Rail area	1.2.2.2	41	81.5	73.7	90.0	1.0	**0.70**	1.05
Green urban	1.4.1	75	81.5	73.7	90.0	1.0	**0.70**	1.05
Conventional arable	2.2.1.1	16	12.2	11.0	13.5	2.0	**0.91**	1.2
Integrated arable	2.2.1.2	18	12.2	11.0	13.5	2.0	**0.91**	1.2
Organic arable	2.2.1.3	12	24.5	24.5	27.1	2.0	**0.82**	1.5
Intensive meadow	2.3.1.1	20	14.9	13.5	14.9	2.0	**0.89**	1.2
Less intensive meadow	2.3.1.2	17	40.4	36.6	40.4	2.0	**0.70**	2.1
Organic meadow	2.3.1.3	20	40.4	40.4	44.7	2.0	**0.70**	2.5
Broad-leafed forest	3.1.1	126	244.7	244.7	244.7	1.0	**0.10**	1.0
Swiss Lowlands (nature)		46	270.4	200.3	330.3	1.0	**0.00**	

Associated values for relative changes in species richness for local and local plus regional occupations are given in Table 10.

Table 10 PDF values for land use transitions

	PDF Occupation		Local and regional PDF of conversion from column to row												
	Only local	regional plus local	Continuous urban	Conventional arable	Integrated arable	Intensive meadow	Organic arable	Less intensive	Organic meadow	Discontinuous urban	Industrial area	Rail area	Green urban	Broad-leafed forest	Swiss Lowlands
Continuous urban	*0.96*	1.15		0	0	0.01	0.05	0.11	0.11	0.16	0.26	0.26	0.26	1.04	1.15
Conventional arable	*0.95*	1.15	0		0	0.01	0.05	0.10	0.10	0.16	0.26	0.26	0.26	1.03	1.15
Integrated arable	*0.95*	1.15	0	0		0.01	0.05	0.10	0.10	0.16	0.26	0.26	0.26	1.03	1.15
Intensive meadow	*0.94*	1.13	-0.01	-0.01	-0.01		0.04	0.09	0.09	0.15	0.25	0.25	0.25	1.02	1.13
Organic arable	*0.91*	1.09	-0.05	-0.05	-0.05	-0.04		0.06	0.06	0.11	0.21	0.21	0.21	0.98	1.09
Less intensive meadow	*0.85*	1.02	-0.11	-0.10	-0.10	-0.09	-0.06		0	0.05	0.15	0.15	0.15	0.91	1.02
Organic meadow	*0.85*	1.02	-0.11	-0.10	-0.10	-0.09	-0.06	0		0.05	0.15	0.15	0.15	0.91	1.02
Discontinuous urban	*0.80*	0.96	-0.16	-0.16	-0.16	-0.15	-0.11	-0.05	-0.05		0.10	0.10	0.10	0.84	0.96
Industrial area	*0.70*	0.84	-0.26	-0.26	-0.26	-0.25	-0.21	-0.15	-0.15	-0.10		0	0	0.72	0.84
Rail area	*0.70*	0.84	-0.26	-0.26	-0.26	-0.25	-0.21	-0.15	-0.15	-0.10	0		0	0.72	0.84
Green urban	*0.70*	0.84	-0.26	-0.26	-0.26	-0.25	-0.21	-0.15	-0.15	-0.10	0	0		0.72	0.84
Broad-leafed forest	*0.10*	0.11	-1.04	-1.03	-1.03	-1.02	-0.98	-0.91	-0.91	-0.84	-0.72	-0.72	-0.72		0.11
Swiss Lowlands	*0.00*	0.00	-1.15	-1.15	-1.15	-1.13	-1.09	-1.02	-1.02	-0.96	-0.84	-0.84	-0.84	-0.11	

Annex I ReCiPe methodology

I.1 Overview of the methodology

The ReCiPe methodology for characterising land use and associated impacts on biodiversity could be described as an adjusted version of the methodology for land use and biodiversity included in the Eco-indicator 99 methodology.

As in the latter methodology, the ReCiPe methodology is developed for a European context, uses the species richness in vascular plants as indicator value and is based on Arrhenius'[8] area-species relationship:

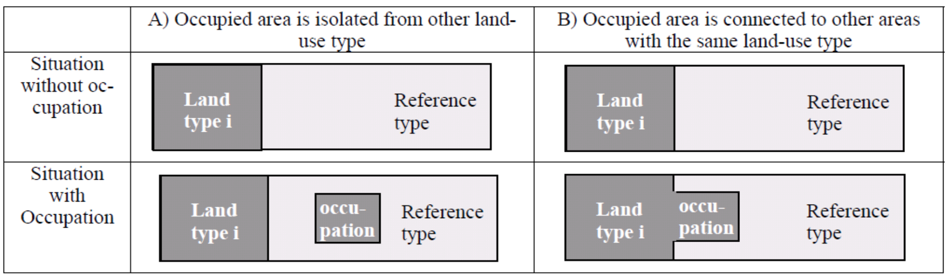
$$S \;=\; a * A^{b}$$

In which:
S = Species richness for the considered area A
a = Species richness factor, species richness for an area of the considered biome of infinite size
A = Area (m^2)
b = Species accumulation factor – a measure for the tempo with which the number of species increases with area size

The reference situation for land use considered in the methodology is boreal and temperate deciduous forest or woodland - the biome that would cover 80-90% of Europe's surface without human impact. A characterization factor for occupation (and also of transformation of and transformation to) of tropical rain forest is also included.

In contrast to the Eco-indicator 99 methodology, the methodology in ReCiPe considers two different situations regarding a considered and used plot of land:
- situation A: attached to land used for a similar use;
- or situation B: an isolated plot, surrounded by land applied for some other use.

Figure 18 Different approaches considered in ReCiPe for regional impacts of land use



Source: Goedkoop, 2012.

8 See http://en.wikipedia.org/wiki/Species-area_curve.

For these situations following generalized relations have been derived for the environmental damage (ED) due to occupation and transformation.

$$ED_{occ.,sit.A} = (b_{ref} + \frac{a_{ref} - a_{occ} * A_{occ}^{z_{occ} - z_{ref}}}{a_{ref}}) * A_{occ} * t_{occ}$$

$$ED_{occ.,sit.B} = (b_{ref} - b_{occ} + \frac{a_{ref} - a_{occ} * A_{occ}^{z_{occ} - z_{ref}}}{a_{ref}}) * A_{occ} * t_{occ}$$

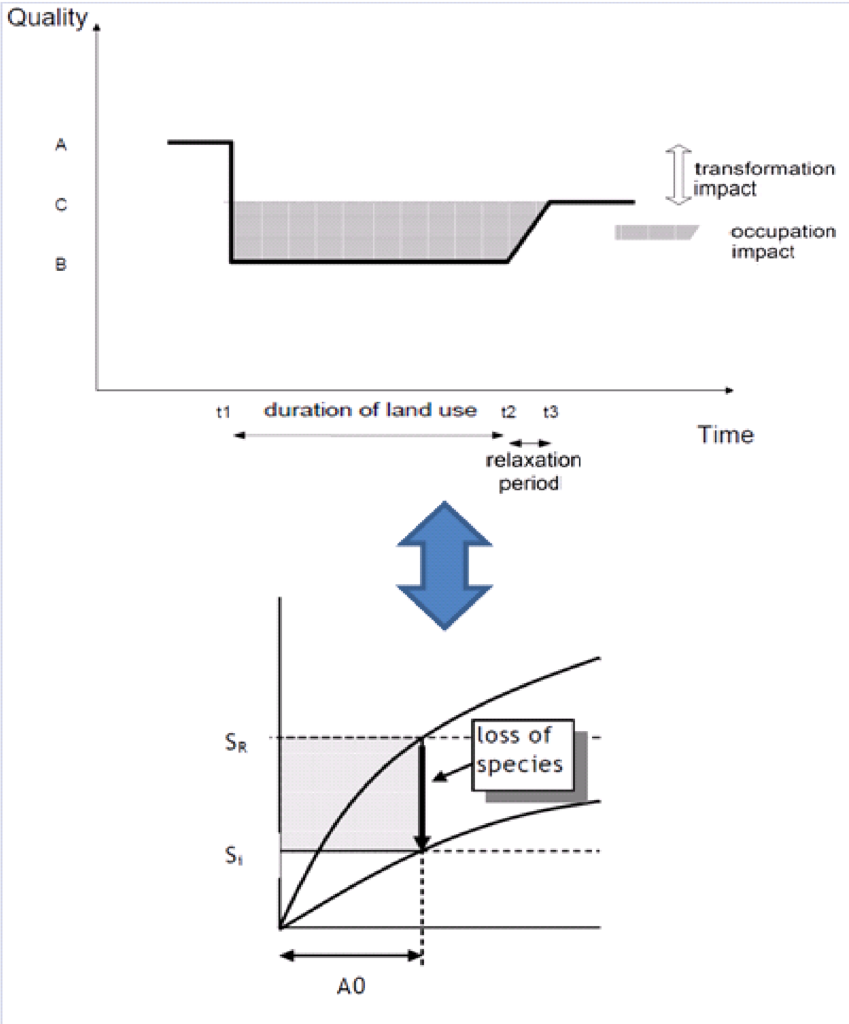
$$ED_{trans.,sit.A} = (b_{ref} + \frac{a_{ref} - a_{occ} * A_{occ}^{z_{occ} - z_{ref}}}{a_{ref}}) * A_{occ} * t_{restoration}$$

$$ED_{trans,sit.B} = (b_{ref} - b_{occ} + \frac{a_{ref} - a_{occ} * A_{occ}^{z_{occ} - z_{ref}}}{a_{ref}}) * A_{occ} * t_{restoration}$$

In these relations ED is equal with EQ in the Eco-indicator 99 methodology.

The essence of these relationships is more or less illustrated by both figures in previous Appendix (Figure 16, Figure 17).The approach of these effects in the ReCiPe methodology is a more mathematical one as perhaps illustrated by the illustration in Figure 19.

Figure 19 Difference in mathematical approach between Eco-indicator 99 methodology and ReCiPe methodology for local impact



Source: Combination by authors of Figure 16 and Figure 17.

The relationship for damage caused by transition and occupation is the same apart for the considered time required for restoration. This factor is free for the LCA practitioner to select for occupation, but is a predefined value for transition.

In the ReCiPe methodology three different perspectives are distinguished, representing different views on the damages caused by environmental impacts:

- Egalitarian Perspective E is the most precautionary perspective, taking into account the longest time-frame, impact types that are not yet fully established but for which some indication is available, etc.
- Individualist Perspective I, which is based on the short-term interest, impact types that are undisputed, technological optimism as regards human adaptation.
- Hierarchist Perspective H, which is based on the most common policy principles with regards to time-frame and other issues.

These different views are reflected in the restoration times assumed for land use transition and in the assumed geographic embedding of the occupied or transformed area (A - isolated or B – connected).

Table 11 **Selected restoration time and geographic embedment in different perceptions**

	Range	Egalitarian	Individualist	Hierarchism
Assumed geographic embedment		A - isolated	B - connected	A – isolated
Restoration time		Maximum restoration time	Mean restoration time with maximum of 100 years	Mean restoration time
Vegetation of arable land, pioneer vegetation	< 5	5	2.2	2.2
Species poor meadows and tall-herb communities, mature pioneer vegetation	5-25	25	11	11
Species poor immature hedgerows and shrubs, oligotroph vegetation of areas silting up, relatively species rich marshland with sedges, meadows, dry meadows and heath land	25-50	50	35	35
Forests quite rich in species, shrubs and hedgerows	50-200	200	100	100
Low and medium (immature) peat bogs, old dry meadows and heath land	200–1,000	1,000	100	500
High (mature) peat bogs, old grow forests	1,000-10,000	10,000	100	3,300

I.2 Strengths and Weaknesses

Purpose
The ReCiPe methodology was developed with the aim of harmonizing LCA methodologies at the level of detail and modeling principles, while allowing a certain degree in freedom in terms of the main principles; their orientation towards midpoint or endpoint indicators.

Strengths
Strength of the methodology is the possibility for including different risk and damage perceptions.

Limitations
Apart from the limitations mentioned for Eco-indicator 99 methodology, it is a very mathematical approach.

I.3 Default Values

Default characterization factors are included in Table 12 to Table 16.
All default values refer to a reference area of 10,000 ha. The variables Z and c in these tables refer to the variables b and a in the relations in previous paragraphs.

The damage caused by occupation of a certain area of land can be found by multiplying the proper CF value with:
- for occupation: the area and time of occupation;
- for transformation: the area.

For transformation, only transformation of natural into non-natural area has been considered as – according to the developers of the ReCiPe methodology - for LCA it is especially relevant to be able to express environmental damages due to the transformation of natural areas into an artificial area ($S=c*A^Z$).
For the agricultural land use types the authors only calculated the impact for the intensive land use, not for the monocultures or the extensive land use types.

Table 12 **Characterisation factors for land occupation, for the egalitarian and hierarchistic perspectives**

Land use type	Z	c	Local effect $PDF.m^2.yr$	Regional effect $PDF.m^2.yr$	Total effect $PDF.m^2.yr$	CF_{occ} * 10^{-9}
Monoculture Crops/Weeds[1]	0.210[3]	2.0[1]	0.95	0.44	1.39	19.2
Intensive Crops/Weeds[1]	0.210[3]	4.6[1]	0.89	0.44	1.33	18.4
Extensive Crops/Weeds[1]	0.210[3]	6.2[1]	0.85	0.44	1.29	17.8
Monoculture Fertile Grassland[1]	0.349	3.7[1]	0.69	0.44	1.13	15.6
Intensive Fertile Grassland[1]	0.349	6.2[1]	0.48	0.44	0.92	12.7
Extensive Fertile Grassland[1]	0.349	7.9[1]	0.25	0.44	0.69	9.5
Monoculture Infertile Grassland[1]	0.349	7.1[1]	0.41	0.44	0.85	11.7
Extensive Infertile Grassland[1]	0.349	10.5[1]	0.00	0.44	0.44	6.1
Monoculture Tall Grassland/Herb[1]	0.349	0.9[1]	0.92	0.44	1.36	18.8
Intensive Tall Grassland/Herb[1]	0.349	4.7[1]	0.61	0.44	1.05	14.5
Extensive Tall Grassland/Herb[1]	0.349	7.2[1]	0.31	0.44	0.75	10.4
Monoculture Broadleaf, mixed forest and woodland[1]	0.439	3.1[1]	0.19	0.44	0.63	8.7
Extensive Broadleaf, mixed and yew LOW woodland[1,*]	0.439	5.2[1]	0.00	0.00	0.00	-
Broad-leafed plantation[2]	0.439	3.3[2]	0.37	0.44	0.81	11.2
Coniferous plantations[2]	0.439	2.8[2]	0.47	0.44	0.91	12.6
Mixed plantations[2]	0.439	1.8[2]	0.76	0.44	1.10	15.2
Continuous urban[2]	0.214	1.4[2]	0.96	0.44	1.4	19.3
Vineyards[2]	0.210[3]	2.8[2]	0.42	0.44	0.86	11.9

** Reference land use type; [1] data of CS2000; [2] data of Köllner; [3] z values taken from Köllner*

Source: Goedkoop, 2012.

Table 13 Characterisation factors for land occupation, for the individualistic perspective

Land use type	z	c	Local effect PDF.m².yr	Regional effect PDF.m².yr	Total effect PDF.m².yr	CF_{occ} * 10^{-9}
Monoculture Crops/Weeds[1]	0.210[3]	2.0[1]	0.95	0.23	1.18	16.3
Intensive Crops/Weeds[1]	0.210[3]	4.6[1]	0.89	0.23	1.12	15.5
Extensive Crops/Weeds[1]	0.210[3]	6.2[1]	0.85	0.23	1.08	14.9
Monoculture Fertile Grassland[1]	0.349	3.7[1]	0.70	0.09	0.79	10.9
Intensive Fertile Grassland[1]	0.349	6.2[1]	0.50	0.09	0.59	8.1
Extensive Fertile Grassland[1]	0.349	7.9[1]	0.27	0.09	0.36	5.0
Monoculture Infertile Grassland[1]	0.349	7.1[1]	0.43	0.09	0.52	7.2
Extensive Infertile Grassland[1]	0.349	10.5[1]	0.03	0.09	0.12	1.7
Monoculture Tall Grassland/Herb[1]	0.349	0.9[1]	0.93	0.09	1.02	14.1
Intensive Tall Grassland/Herb[1]	0.349	4.7[1]	0.62	0.09	0.71	9.8
Extensive Tall Grassland/Herb[1]	0.349	7.2[1]	0.33	0.09	0.42	5.8
Monoculture Broadleaf, mixed and yew LOW woodland[1]	0.439	3.1[1]	0.40	0.00	0.19	2.6
Extensive Broadleaf, mixed and yew LOW woodland[1,*]	0.439	5.2[1]	0.00	0.00	0.00	-
Broad-leafed plantation[2]	0.439	3.3[2]	0.37	0.00	0.37	5.1
Coniferous plantations[2]	0.439	2.8[2]	0.47	0.00	0.47	6.5
Mixed plantations[2]	0.439	1.8[2]	0.66	0.00	0.66	9.1
Continuous urban[2]	0.214	1.4[2]	0.97	0.22	1.19	16.4
vineyards[2]	0.210[3]	2.8[2]	0.42	0.23	0.65	9.0

Reference land use type; [1] data of CS2000; [2] data of Köllner; [3] z values taken from Köllner

Source: Goedkoop, 2012.

Table 14 Characterisation factors for land transformation, for the hierarchistic perspective

	Restoration time	Crops and weeds	Grassland	Broad-leaved plantation	Coniferous plantation	continous urban
PDF		1.3	0.8	0.9	1.1	1.4
Species poor immature hedgerows and shrubs + [a]	35	46	28	32	39	49
Forests, shrubs and hedgerows	100	130	80	90	110	140
Low and medium[b] peat bogs, old dry meadows and heath land	450	585	360	405	495	630
High (mature) peat bogs, old grow forests	3300	4290	2640	2970	3630	4620

[a] oligotroph vegetation of areas silting up, relatively species rich marshland with sedges, meadows, dry meadows and heath land.
[b] immature

Source: Goedkoop, 2012.

Table 15 Characterisation factors for land transformation, for the egalitarian perspective

	Restoration time	Crops and weeds	Grassland	Broad-leaved plantation	Coniferous plantation	Continous urban
PDF		1.3	0.8	0.9	1.1	1.4
Species poor immature hedgerows and shrubs + [a]	50	65	40	45	55	70
Forests quite rich in species, shrubs and hedgerows	200	260	160	180	220	280
Low and medium[b] peat bogs, old dry meadows and heath land	1000	1300	800	900	1100	1400
High (mature) peat bogs, old grow forests	10000	13000	8000	9000	11000	14000

[a] oligotroph vegetation of areas silting up, relatively species rich marshland with sedges, meadows, dry meadows and heath land.
[b] immature

Source: Goedkoop, 2012.

Table 16 Characterisation factors for land transformation, for the individualistic perspective

	Restoration time	Crops and weeds	Grassland	Broad-leaved plantation	Coniferous plantation	Continous urban
PDF		1.12	0.65	0.37	0.47	1.2
Species poor immature hedge-rows and shrubs, + [a]	35	39	23	13	16	42
Forests quite rich in species, shrubs and hedgerows	100	112	65	37	47	120
Low and medium[b] peat bogs, old dry meadows and heath land	100	112	65	37	47	120
High (mature) peat bogs, old grow forests	100	112	65	37	47	120

[a] *oligotroph vegetation of areas silting up, relatively species rich marshland with sedges, meadows, dry meadows and heath land.*
[b] *immature*

Source: Goedkoop, 2012.

Annex J Land use change in Ecoinvent

A more simplified version of the ReCiPe methodology, discussed in previous Appendix, has been integrated in the Ecoinvent LCA tool.
The difference between both methodologies concerns the methodology for land transformation. For land occupation, the Ecoinvent methodology is identical with the ReCiPe methodology.

For land transformation only transformation of natural areas is considered. For natural areas, only two reference types are distinguished: tropical rainforest and other natural areas.
For land with unknown initial use a 40:60 ratio of natural to non-natural area is assumed.

Difference in species richness (expressed in PDF) between natural areas and non-natural areas is assumed to be uniform for any kind of natural area and any kind of non-natural area. However, the restoration time is assumed to be 3,300–10,000 years for tropical rainforests and only 100–200 years for other natural areas. As a consequence, characterisation factors for tropical rainforest are very much higher than those for other natural areas (see Table 17).

Table 17 **Restoration time, PDF and characterisation factors for land transformation in the Ecoinvent methodology**

	Hierachist	Individualist	Egalitarian
Restoration time (years)			
- Tropical rainforest	3,300	3,300	10,000
- Other natural areas	100	100	200
Difference in species richness (PDF)			
- Tropical rainforest	1.05	0.8	1.05
- Other natural areas	1.05	0.8	1.05
Characterisation factor (PDF·m^2·year)			
- Tropical rainforest	4,390	3,630	13,000
- Other natural areas	130	110	260

This approach is inconsistent with the approach in ReCiPe, in which tropical rainforests are treated similarly to other types of fully developed and biodivers biomes, such as temperate rainforests and other types of primeval forests, such as Cerrado.
It is also inconsistent with the approach applied in determining environmental damage related to occupation, in which the reference is European forest or woodland.

Annex K TNO methodology

K.1 Methodology outline

The methodology elaborated by TNO for Rijkswaterstaat was based on previous work, LCACAP, by Weidema and Lindeijer for the EU Commission.
The methodology takes into account occupation related and transformation related impacts.

For occupation the impact is determined using:

EO (Ecosystem Occupation) = $A * t * SR_i * ES_i * EV_i * SD$

With:
- Local Species Density factor (SD) = $(1 - S_{act} / S_{ref})$ (SD ≤ 1)
- And ecosystem level factors:
  - SR_i (relative Species Richness of biome i) = S_i/S_{min} (SR ≥ 1)
  - ES_i (Ecosystem Scarcity of biome i) = $A_{pot,max}/A_{pot,i}$ (ES ≥ 1)
  - EV_i (Ecosystem Vulnerability of biome i) = $(A_{exi}/A_{pot,i})^{b-1}$ (EV ≥ 1)

Where:
- S_{act}= the actual species density, standardised to a certain area
- S_{ref} = the species density in the reference state, standardised to a certain area
- S_i = the species density in biome i
- S_{min} = the species richness in the least species rich biome
- $A_{pot,Ii}$ = the potential (natural) area of biome i
- $A_{pot,max}$ = the largest value for Apot (to render scores ≥ 1)
- A_{exi} = the existing ecosystem/biome area left

The relation implies combining a local, relative biodiversity score with global relative ecosystem scores (based on Weidema, 2001). In this manner, the global perspective and the local details are both assessed.

Species density scores have been standardised to the same standard area as Köllner has applied: 0.01 ha.

For land transformation, the same approach as for land occupation is chosen: using three ecosystem level factors and one species level factor:

ET (Ecosystem transformation): $A * SR_i * ES_i * EV_i * (S_{ini}-S_{fin}) / S_{ini}$

With:
- S_{ini} = the initial species density before transformation, standardized to 0.01 ha
- S_{fin} = the final species density after transformation, standardized to 0.01 ha

Methodological choices have been summarized in Table 18.

Table 18 Overview of methodological choices made in TNO methodology

Subject	Choices made
Biodiversity levels included	Ecosystem and species level
Species included	Only vascular plant species included; equal weighting of all species
Relation of actual state to reference state for occupation	1 – {actual state/reference state}, or {reference state – actual state}/reference state
Species diversity reference state	Maximum or average score for regional biome
Species diversity standardisation	To 0.01 ha via Arrhenius formula using a = 4.1 and b = 0.2
Reference state data	Taken from [Barthlott, 1997]
Relation between initial and final state for transformation	1 – {final state/initial state}, or {initial state – final state}/initial state
Biome definition for ecosystem level	Taken from [Leemans et al., 1998]
Ecosystem quality aspects	Scarcity, vulnerability and value/quality
Ecosystem scarcity factor	Largest potential biome area/potential area of biome i
Ecosystem vulnerability factor	{Existing area of biome i/potential area of biome i}$^{b-1}$
Ecosystem value/quality	Species richness$_i$ / minimum biome species richness

K.2 Limitations mentioned for the proposed methodology

Purpose of the methodology

In order to integrate land use in LCA, the Road and Hydraulic Engineering Institute (DWW) has initiated the development of a new method.
The original reason to start the development of the land use methodology was that the theme 'degradation of ecosystems and landscapes' as mentioned in the CML guideline (1992) was not operational and that this theme is relevant for LCA's within the working field of several environmental policies, e.g. sustainable building and the Structure Plan on Surface Raw Materials.
The focus was to develop a general method which can be used for all types of processes all over the world, just like other characterisation methods in the CML guideline.

Regional and local diversity in biodiversity

Land use impacts are very dependent on the place and time of the intervention. Not only are temporal aspects generally expelled from LCA studies, but for land use in general, the nature value will vary very much from one location to another as well as over time. All biodiversity and life support indicators for land use will suffer from this natural variation to a certain degree. When an indicator is applied in a very generic manner, this variation may be ignored or neglected, but the potential impacts will inevitably contain this variation.
It must be noted that natural variation in space and time is not restricted to land use impacts. In fact all LCA characterisation models are gross oversimplifications of the real impacts, which occur from a given intervention in the environment at a certain point in time and space.

Completeness of impacts considered

The cause-effect network between a type of land use and its potential impacts is complex. Many different impacts may result from a single land use, and many relationships may exist between those impacts. Therefore, there is an inherent limitation in the extent to which these impacts can be expressed in LCA. Either many indicators are applied to express initial stressor responses to land use, or a few indicators are chosen to indicate the impacts on high-level impacts on areas of protection such as biodiversity. In the first case the interpretation of different scores is hard, because the ultimate impacts can not be perceived.

In the second case the interpretation may be easier, but maybe less valid due to various side-effects on excluded aspects of the area of protection.
The balance between completeness of impact types and relevance to areas of protection determines the perceived adequacy of the impact indicators chosen.

Uncertain

Especially for re-naturation processes (often performed in mining practice nowadays) the uncertainty on the final state after re-naturation is large. Although this uncertainty can be estimated (as done in this project), it remains to be considered when performing such LCA studies.

Table 19 Biome specifications considered in the TNO methodology

Biome	Potential biome area [km^2]	Actual area [km^2]	Ecosys Scarcity	Ecosys Vulner. $_{b=0.2}$	Species Density [10'000 km^{-2}]	Ecosys Quality	$S_{ref.\ av.}$ [0.01ha]	$S_{ref.\ max}$ [0.01ha]
Ice	6.66E+06	6.68E+06	**3.80**	**1.00**	1	**0**	**0**	**0**
Tundra	9.03E+06	9.54E+06	**2.80**	**0.96**	100 - 200	**1**	**4**	**5**
Wooded tundra	3.08E+06	3.77E+06	**8.22**	**0.85**	200 - 500	**2 - 2.5**	**9**	**13**
Tundra total	1.21E+07	1.33E+06	**4.19**	**0.93**	100 - 500	**1 - 2.5**	**5**	**7**
Boreal forest	2.53E+07	2.07E+07	**1.00**	**1.17**	200 - 1000	**2 - 5**	**15**	**25**
Cool conifer forest	4.72E+06	2.44E+06	**5.36**	**1.70**	500 - 1000	**5**	**19**	**25**
Temp. deciduous forest	6.20E+06	1.01E+06	**4.08**	**4.26**	1000 - 1500	**7.5 – 10**	**31**	**38**
Temp. mixed forest	7.69E+06	1.71E+06	**3.29**	**3.32**	500 - 1500	**5 – 7.5**	**25**	**38**
Warm mixed forest	4.76E+06	8.96E+05	**5.32**	**3.81**	1500 - 3000	**15**	**57**	**75**
Mixed forest total	1.24E+07	2.61E+06	**4.07**	**3.49**	500 - 3000	**5 – 15**	**36**	**51**
Grassland/Steppe	1.72E+07	9.02E+06	**1.47**	**1.67**	200 - 1500	**2 – 7.5**	**21**	**38**
Savanna	1.15E+07	5.39E+06	**2.19**	**1.84**	200 - 3000	**2 – 15**	**40**	**75**
Grassland total	2.87E+07	1.44E+07	**1.77**	**1.74**	200 - 3000	**2 – 15**	**28**	**52**
Hot desert	1.42E+07	1.16E+07	**1.78**	**1.18**	100 - 200	**1**	**4**	**5**
Scrubland	8.12E+06	2.24E+06	**3.12**	**2.80**	500 - 4000	**5 – 20**	**57**	**100**
Tropical woodland	6.79E+06	4.25E+06	**3.73**	**1.45**	1000 - 3000	**10 – 15**	**50**	**75**
Tropical forest	5.74E+06	3.78E+06	**4.41**	**1.40**	1500 - 9000	**15 – 45**	**132**	**226**
Agricultural land		3.15E+07						
Extensive grassland		1.23E+07						
Regrowth forest		3.31E+06						
Major cities		8.32E+05						
Total area	131E+06	131E+06						

Annex L Previous analysis of indicators

L.1 Biodiversity indicators platform

The CBD (Convention on Biological Diversity) supports the BIP (Biodiversity Indicators Partnership), an international partnership between forty organisations that develop biodiversity indicators. The BIP has a published a strategic plan for 2002-2010, in which 17 broad 'headline' indicators are presented (UNEP-WCMC, 2013):

Figure 20 BIP indicators from the CBD strategic plan

Focal Area	Headline Indicator	Indicator
1. Status and trends of the components of biodiversity	1.1 Trends in extent of selected biomes, ecosystems, and habitats	1.1.1 Extent of forests and forest types
		1.1.2 Extent of assorted habitats
	1.2 Trends in abundance and distribution of selected species	1.2.1 Living Planet Index
		1.2.2 Global Wild Bird Index
		1.2.3 Waterbird Indicator
	1.3 Coverage of protected areas	1.3.1 Coverage of Protected Areas
		1.3.2 Overlays with biodiversity
		1.3.3 Management effectiveness
	1.4 Change in status of threatened species	1.4.1 Red List Index and Sampled Red List Index
	1.5 Trends in Genetic Diversity	1.5.1 *Ex situ* crop collections
		1.5.2 Genetic diversity of terrestrial domesticated animals
2. Sustainable use	2.1 Areas under sustainable management	2.1.1 Area of forest under sustainable management: certification
		2.1.2 Area of forest under sustainable management: degradation and deforestation
		2.1.3 Area of agricultural ecosystems under sustainable management
	2.2 Proportion of products derived from sustainable sources	2.2.1 Proportion of fish stocks in safe biological limits
		2.2.2 Status of species in trade
		2.2.3 Wild Commodities Index
	2.3 Ecological Footprint and related concepts	2.3.1 Ecological Footprint and related concepts
3. Threats to biodiversity	3.1 Nitrogen Deposition	3.1.1 Nitrogen Deposition
	3.2 Invasive Alien Species	3.2.1 Trends in Invasive Alien Species
4. Ecosystem integrity and ecosystem goods and services	4.1 Marine Trophic Index	4.1.1 Marine Trophic Index
	4.2 Water Quality	4.2.1 Water Quality Index for Biodiversity
	4.3 Connectivity/fragmentation of ecosystems	4.3.1 Forest Fragmentation
		4.3.2 River fragmentation and flow regulation
	4.4 Health and well being of communities	4.4.1 Health and well being of communities directly dependant on ecosystem goods and services
	4.5 Biodiversity for food and medicine	4.5.1 Nutritional status of biodiversity
		4.5.2 Biodiversity for food and medicine
5. Status of traditional knowledge, innovations and practices	5.1 Status and trends of linguistic diversity and numbers of speakers of indigenous languages	5.1.1 Status and trends of linguistic diversity and numbers of speakers of indigenous languages
6. Status of access and benefits sharing	*To be determined*	
7. Status of resource transfers	7.1 Official development assistance provided in support of the Convention	7.1 Official development assistance provided in support of the Convention

Source: UNEP-WCMC, 2013

L.2 Eco4Biz

WBCSD published Eco4Biz in April 2013 (WBCSD, 2013). Eco4Biz gives a structured overview of existing public tools and approaches. The goal is help companies in making more informed choices about which tools during the assessment and management of ecosystem impacts. The publication provides a decision tree, which contains the following tools that have a specific focus on biodiversity:

Check/score:
- Biodiversity, Accountability Framework;
- Corporate Biodiversity Management Framework;
- Biodiversity in GWT (Global Water Tool);
- LIFE Methodology;
- BROA (Biodiversity Risk and Opportunity Assessment);
- Business & Biodiversity Checklist;

– IBIS (Integral Biodiversity Impact assessment System).

Map:

– NBM (Normative Biodiversity Metric);
– Biodiversity in GWT (Global Water Tool).

Figure 21 BIP indicators from the CBD strategic plan

Focal Area	Headline Indicator	Indicator
1. Status and trends of the components of biodiversity	1.1 Trends in extent of selected biomes, ecosystems, and habitats	1.1.1 Extent of forests and forest types
		1.1.2 Extent of assorted habitats
	1.2 Trends in abundance and distribution of selected species	1.2.1 Living Planet Index
		1.2.2 Global Wild Bird Index
		1.2.3 Waterbird Indicator
	1.3 Coverage of protected areas	1.3.1 Coverage of Protected Areas
		1.3.2 Overlays with biodiversity
		1.3.3 Management effectiveness
	1.4 Change in status of threatened species	1.4.1 Red List Index and Sampled Red List Index
	1.5 Trends in Genetic Diversity	1.5.1 *Ex situ* crop collections
		1.5.2 Genetic diversity of terrestrial domesticated animals
2. Sustainable use	2.1 Areas under sustainable management	2.1.1 Area of forest under sustainable management: certification
		2.1.2 Area of forest under sustainable management: degradation and deforestation
		2.1.3 Area of agricultural ecosystems under sustainable management
	2.2 Proportion of products derived from sustainable sources	2.2.1 Proportion of fish stocks in safe biological limits
		2.2.2 Status of species in trade
		2.2.3 Wild Commodities Index
	2.3 Ecological Footprint and related concepts	2.3.1 Ecological Footprint and related concepts
3. Threats to biodiversity	3.1 Nitrogen Deposition	3.1.1 Nitrogen Deposition
	3.2 Invasive Alien Species	3.2.1 Trends in Invasive Alien Species
4. Ecosystem integrity and ecosystem goods and services	4.1 Marine Trophic Index	4.1.1 Marine Trophic Index
	4.2 Water Quality	4.2.1 Water Quality Index for Biodiversity
	4.3 Connectivity/fragmentation of ecosystems	4.3.1 Forest Fragmentation
		4.3.2 River fragmentation and flow regulation
	4.4 Health and well being of communities	4.4.1 Health and well being of communities directly dependant on ecosystem goods and services
	4.5 Biodiversity for food and medicine	4.5.1 Nutritional status of biodiversity
		4.5.2 Biodiversity for food and medicine
5. Status of traditional knowledge, innovations and practices	5.1 Status and trends of linguistic diversity and numbers of speakers of indigenous languages	5.1.1 Status and trends of linguistic diversity and numbers of speakers of indigenous languages
6. Status of access and benefits sharing	*To be determined*	
7. Status of resource transfers	7.1 Official development assistance provided in support of the Convention	7.1 Official development assistance provided in support of the Convention

Source: UNEP-WCMC, 2013.

L.3 Considered Biodiversity Indicators

The aim of this overview is to consider all biodiversity initiatives that both broadly cover biodiversity and that are currently usable for businesses.
This will include all of the indicators included in the CE Delft (2011) study, the indicators in the IUCN & Platform BEEE (2012) study and some of the indicators considered by BIP.

Annex M Shannon and Simpson indices

Biodiversity is in practice defined in various ways.

The more narrow definition of biodiversity is to focus on or species diversity and population size, as often quantified by Shannon and Simpson indices.

$$\text{Shannon Index (H)} = -\sum_{i=1}^{s} p_i \ln p_i$$

$$\text{Simpson Index (D)} = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

These diversity indices are based on the species richness (the number of species present) and species abundance (the number of individuals per species). However, there are two types of indices, dominance indices and information statistic indices.

The Shannon index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled. In the Shannon index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N).
The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity. Can you point out any problems in these assumptions?

A broader definition is to focus not just on species[9], but also take into account their interrelationships and define biodiversity as the "totality of genes, species, and ecosystems of a region", thus presenting a unified view of the traditional three levels at which biological variety has been identified:
- species diversity;
- ecosystem diversity;
- genetic diversity.

This broader version follows the standard Convention on Biological Diversity definition (see http://www.biodiv.org).

The indicator we are to develop in this project should include both species richness, species diversity, and ecosystem diversity.

[9] The 1992 United Nations Earth Summit in Rio de Janeiro defined 'biological diversity' as 'the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems'. This definition is used in the United Nations Convention on Biological Diversity.