Biodiversity-positive investments in the Biodiversity Footprint Financial Institutions (BFFI)

Description of methodology for three case studies

Background information to the cases in the report 'Biodiversity-positive investments in the Biodiversity Footprint Financial Institutions', CREM, PRé Sustainability, 4 July 2019

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1. Introduction

In this project, the methods to calculate the positive impact on biodiversity for three different types of investment opportunities are described. The investment opportunities are (re-)forestry, shade grown coffee, and offshore wind energy. The procedure to include these investment opportunities in a BFFI (Biodiversity Footprint Financial Institutions) based biodiversity footprint are described in chapter 2, 3 and 4. First, the possible positive impacts are described and we determine which of these benefits can be quantified in a biodiversity footprint. In this step we address the issue of the reference situation. We also describe what kind of data is needed to calculate the impact. Second, the (adaptations to) the impact assessment method are described, and the steps from primary data to (positive) biodiversity impact are explained.

2. Forestry

Most terrestrial species can be found in forests as they offer a diverse set of habitats for trees, animals and micro-organisms. Unfortunately, only 68% of the global forest area is left compared with the estimated pre-industrial level[1]. Numbers on more recent periods do not offer any reassurance as researchers have identified a "7% reduction of intact forests (>500 sq. km with no human pressure) from 2000-2013 in developed and developing countries[2]." 290 million hectare (this accounts for approximately 6%) of native forest cover was lost between 1990 and 2015 due to clearing and wood harvesting[3].

The authors of the IPBES report have identified the following top five drivers for change in nature to have the biggest detrimental effect. The first is land and sea use change, followed by direct exploitation. Third and fourth are climate change and pollution, respectively. The top five is completed with invasive alien species[4]. In the BFFI method, the land occupation, climate change, and pollution are included in the calculation of the footprint. The introduction of invasive alien species is covered in the BFFI by means of a qualitative analysis, covering the limitations of the BFFI calculations to ensure a correct interpretation of the results.

2.1. Reference situation

For forestry, we currently calculate the impacts from land occupation, but they are always detrimental due to the choice of reference situation in the impact assessment method (ReCiPe 2016[5]). There are several options to choose a reference situation. One could argue to use the pristine situation (before any human activity). Another option is the current mix of natural land within a biome or ecoregion, or a

[1] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 'Nature's Dangerous Decline "Unprecedented"; Species Extinction Rates "Accelerating"'.
[2] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
[3] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
[4] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
[5] Huijbregts et al., 'ReCiPe2016'.

mix of all land uses[6]. In Recipe 2016 the 'Potential Natural Vegetation' (PNV) approach was used, which means that the reference situation or state is defined as the state of vegetation that would develop if the human activities would be stopped immediately[7]. This concept is described for ecoregions by De Baan et al.[8], and for biomes by Elshout et al.[9]

In this approach, all economic activities involving the use of land are decreasing the level of biodiversity in the footprint because the PNV level biodiversity is assumed to be higher in the models used. In some cases however, a comparison to the PNV does not fit the system boundaries of the impact calculation. For instance when an investment is made in a forestry project which converts degraded land into a forestry site, or when an existing plantation area is upgraded by means of better management practices. In these cases, it can be argued that the impact should be assessed using the 'old' situation of the degraded area rather than the pristine situation.

2.2. Drivers

In the footprint calculation for ASN Bank, we found that for most investments, the most important drivers for the loss of biodiversity were land occupation, climate change and sometimes water use. These findings correspond with the findings in the IPBES report where land use, land exploitation and climate change are the top three drivers. Therefore, we choose to focus on land use and climate change for the assessment of positive impacts from forestry projects. The detrimental impacts of any reforestation actions or interventions, such as fuel use and emissions caused by cutting machines and tree harvesting, are included in the 'Exiobase' input-output data. For the positive impacts, we need to determine the level of biodiversity loss per hectare before the investment, and after the investment. Furthermore, we need to determine the carbon sequestration from the trees.

2.3. Land use and biodiversity in EXIOBASE and ReCiPe 2016

In the biodiversity footprint, two types of input data can be used. We can use primary data on land use, resource use and emissions collected at a company or at a forestry project. We can also use life cycle inventory databases like ecoinvent or Agrifootprint for generic data on a specific process, for instance banana production. As investment portfolios often consist of hundreds of thousands of companies, each with hundreds of different products, the default option is to use so-called environmentally extended input output databases with sector and country specific data on land use, resource use and emissions. The input output database used in the BFFI methodology is EXIOBASE (further referred to as Exiobase)[10].

2.3.1. Exiobase

In the Exiobase input output tables[11], the following types of land use are distinguished based on the FAOSTAT database.

[6] Koellner et al., 'UNEP-SETAC Guideline on Global Land Use Impact Assessment on Biodiversity and Ecosystem Services in LCA'.
[7] Huijbregts et al., 'ReCiPe2016'.
[8] de Baan, Alkemade, and Koellner, 'Land Use Impacts on Biodiversity in LCA'.
[9] Elshout et al., 'A Spatially Explicit Data-Driven Approach to Assess the Effect of Agricultural Land Occupation on Species Groups'.
[10] Stadler et al., 'EXIOBASE 3'.
[11] Stadler et al.

1. Cropland
2. Permanent pastures
3. Forest area
4. Settlement areas
5. Other land
6. Wilderness, unproductive areas and marginally used land

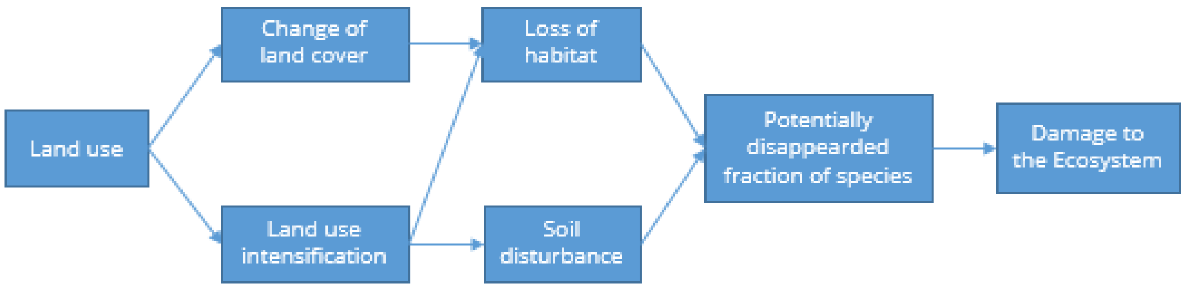
However, the impact of land use is not only determined by the level of detail in the inventory data provided by Exiobase, but also by the granularity of the impact assessment model. Inventory data based on primary data can be very specific. For instance 23.456 Ha of land in country x, region y, used for activity a, with management type b. The specifics of that inventory data can only be translated into an impact on biodiversity if the impact assessment model provides equally specific characterization factors that translate such specific information on land use into impacts on biodiversity. In other words, very specific inventory data will not always result in a more accurate footprint. This also depends on the impact assessment model used.

The data on environmental impacts in Exiobase is quite aggregated because of the scope of the database: worldwide coverage with harmonized sectors across different countries and regions. There is (only) data available for the types of land use mentioned and the country or region in which this land use takes place.

2.3.2. ReCiPe 2016

In ReCiPe 2016 impact pathway from land use to the loss of species is explained and quantified. The land use consists of land transformation[12], land occupation[13] and land relaxation[14]. The impact pathway is modelled as visualized in Figure 1.

Figure 1: Cause-and-effect chain of land use, leading to relative species loss in terrestrial ecosystems. Note that indirect pathways (e.g. the relative species loss due to land-use-induced climate change) are excluded (copied from ReCiPe 2016 documentation[15]).



Based on this impact pathway, the following characterization factors are identified (see Table 1).

Table 1: Midpoint CFs for the impact of land transformation/occupation and land relaxation on total species richness. Data is taken from De Baan et al. (2013) on relative species loss related to different types of land use. The recovery time used in the calculation is the global average recovery time, as

[12] de Baan, Alkemade, and Koellner, 'Land Use Impacts on Biodiversity in LCA'.
[13] Elshout et al., 'A Spatially Explicit Data-Driven Approach to Assess the Effect of Agricultural Land Occupation on Species Groups'.
[14] Scholz, 'Assessment of Land Use Impacts on the Natural Environment. Part 1'.
[15] Huijbregts et al., 'ReCiPe2016'.

derived from Curran et al. (2014). This table and the heading is adapted from ReCiPe2016 documentation[16]

Land use type	Land Occupation (annual crop eq)	Recovery time (annual crop eq x yr)
Used forest	0.30	5.1
Pasture and meadow	0.55	9.3
Annual crops	1.00	17.0
Permanent crops	0.70	11.9
Mosaic agriculture	0.33	5.6
Artificial areas[1]	0.73	12.4

[1] Urban areas, industrial areas, road and rail networks, dump sites.

In ReCiPe 2016, the biodiversity impact is based on species richness. The unit for biodiversity impact assessment is PDF.m2.yr, with PDF as the 'Potentially Disappeared Fraction of species. Loss of species is calculated in a certain area (hence m2) during a certain time (hence the addition of years). In the BFFI, this is translated to Ha by looking at investments in one particular year and a 100% loss of biodiversity (PDF = 100% = 1).

The characterization factors in ReCiPe 2016 are not yet regionalized, even though the natural potential vegetation (NPV) can be substantially different per region and biome. Instead, a global characterization factor is used because the coverage of the regionalization was considered insufficient to implement this the in the methodology[17]. However, in the literature that is used to define the global characterization factor, four different biomes are distinguished: (sub-) tropical broad leaf forest; temperate broadleaf forest; temperate coniferous forest; (sub) tropical grassland & savanna[18].

Here we can see that even though the inventory data in Exiobase is regionalized to a country level (and 5 rest of the world regions), the land use part of the ReCiPe 2016 impact assessment model does not provide regionalized characterization factors and is therefore unable to match this level of granularity.

2.4. Forest management and species richness

Chaudhary et al.[19] criticized Baan et al.[20], for not including different characterization factors for different management types. Therefore, a distinction was introduced between intensive and extensive forestry. In a paper published in Nature, Chaudhary et al. [21] go one step further by zooming in on management practices. In this paper, the variation of species richness resulting from the ten most common forest management types is evaluated by reviewing 287 peer-reviewed studies on 1008 cases. This allows the authors to differentiate the effect of forest management system for different taxa, on different continents. The authors rank the following management types from best to worse:

1. Retention harvesting
2. Selection systems

[16] Huijbregts et al.
[17] Huijbregts et al.
[18] de Baan, Alkemade, and Koellner, 'Land Use Impacts on Biodiversity in LCA'.
[19] Chaudhary et al., 'Quantifying Land Use Impacts on Biodiversity'.
[20] Koellner et al., 'UNEP-SETAC Guideline on Global Land Use Impact Assessment on Biodiversity and Ecosystem Services in LCA'.
[21] Chaudhary et al., 'Impact of Forest Management on Species Richness'.

3. Reduced impact logging
4. Conventional selective logging
5. Clear-cutting
6. Agroforestry
7. Timber plantations
8. Fuelwood plantations
9. Slash and burn
10. Plantation non-timber

The supplementary information of the article provides a table with a biodiversity response ratio per management type. These ratios can be used as a correction factor for the ReCiPe2016 biodiversity score of a forest, based on the forest management type. The response ratios are shown in the following table.

Table 2: Overall response ratio (R) and management type, taxa and continent specific R (calculated by back-transforming the effect size lnR). Adapted from Chaudhary et al. (2016)[22]

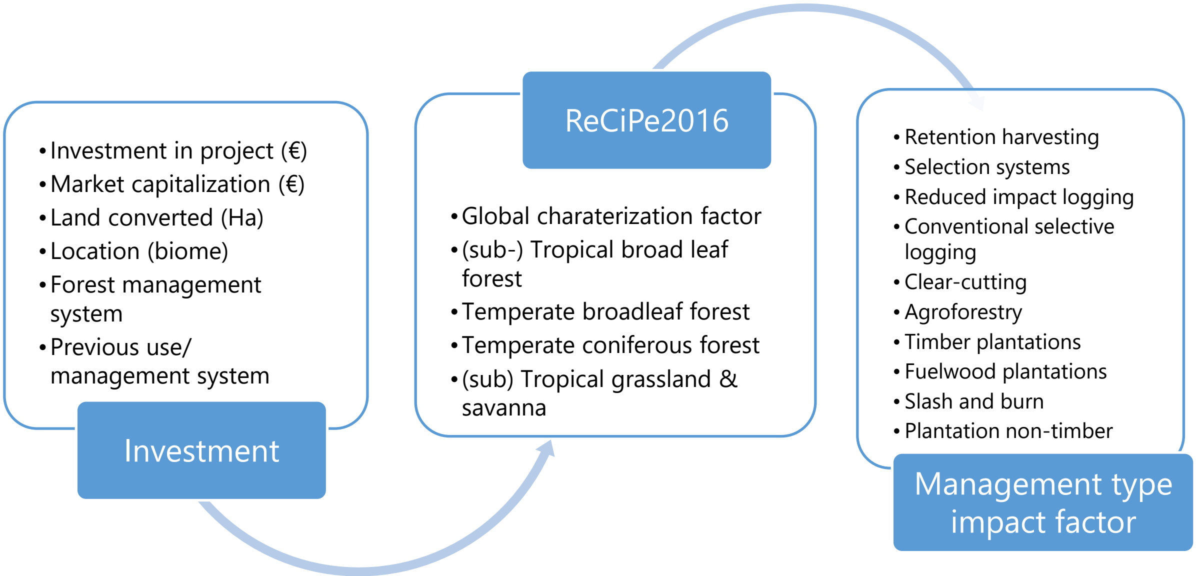
Management type	#Comparisons	Mean response ratio (*R*)	PDF
Agroforestry	238	0,678	0,322
Clear-cut	106	0,782	0,218
Plantation timber	88	0,603	0,397
Plantation fuel	71	0,566	0,434
Plantation non-timber	75	0,452	0,548
Reduced impact logging	22	1,009	-0,009
Retention harvesting	85	1,012	-0,012
Selection system	79	1,011	-0,011
Selective logging	165	0,866	0,134
Slash-and-burn	79	0,467	0,533

2.5. Site specific forestry projects

The calculation of the impact of land use on biodiversity of a site specific forestry project is shown in the following chart.

Figure 2: Schematic overview of the calculation steps and data sources of the land use impact on biodiversity from different forestry management systems.

[22] Chaudhary et al.



For the impact assessment of specific investment projects, first the share of the impacts of the project that can be attributed to the investor needs to be determined. This can be done in several ways. One way is to look at the level of influence in a decision making context. In this case, a majority shareholder of 51% would he held responsible for 100% of the environmental impact of the project, because the majority shareholder is assumed to be able to determine the environmental impact of the company. However, the Biodiversity Footprint for Financial Institutions takes a different approach. In the BFFI, the attribution of environmental burdens and benefits of investments in equity is allocated to all investors proportionally based on the value of their investment compared to the total value of the project, company or fund.

Once the share of burdens and benefits to be attributed to the investor is determined, the environmental impact of the project is calculated. The negative impacts are based on the environmentally extended input-output database 'Exiobase'. The sector 'Forestry, logging and related service activities' is included for all countries and rest-of-the-world regions[23]. In the scope of this project, also positive impacts are included. The most important causes of loss in biodiversity are land transformation and occupation, and climate change[24]. Therefore, land use and carbon sequestration are included in the analysis.

2.6. Data needs for land use impacts

For the calculation on land use impacts on biodiversity, the following information should be collected for the forestry project(s).

1. Market capitalization of the project
2. Size of the area in Ha
3. Location (and biome)
4. Forests management system (after the investment)

[23] Stadler et al., 'EXIOBASE 3'.
[24] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 'Nature's Dangerous Decline "Unprecedented"; Species Extinction Rates "Accelerating"'.

5. Previous use of the site (or previous management system)

2.7. Carbon uptake and emissions from Forestry

Changing the forest management system in existing forests or converting (degraded) land to forest land, results in greenhouse gas emissions (GHG) and GHG-emission removals. The international consensus on how to estimate the amount of GHG emissions and uptake from forests is described by the IPCC in the Guidelines for National Greenhouse Gas Inventories[25]. Six categories of GHG sources and sinks are described: above ground biomass growth, below ground biomass growth, wood removal and disturbance, dead organic matter, soil carbon and non-CO_2 emissions from biomass burning. The magnitude of these impacts is different depending on the forest type, age of the trees, domain, and climate zone.

The IPCC documentation [26] provides tables with continental 'default values'. These values can be used for a so called 'tier 1' basic estimation with a relatively large uncertainty. The methodology allows for more precision by using (tier 2) country-specific estimates of activity data (biomass growth, disturbance, soil carbon etc.) and emission/removal factors and species-specific wood density values and species-specific forest inventory data. Tier 3 is even more precise, using spatial and temporal specific forestry site data. For the BFFI it is sufficient to use tier 1 primary data. The following chart shows the steps of the methodology to include positive impact form carbon sequestration.

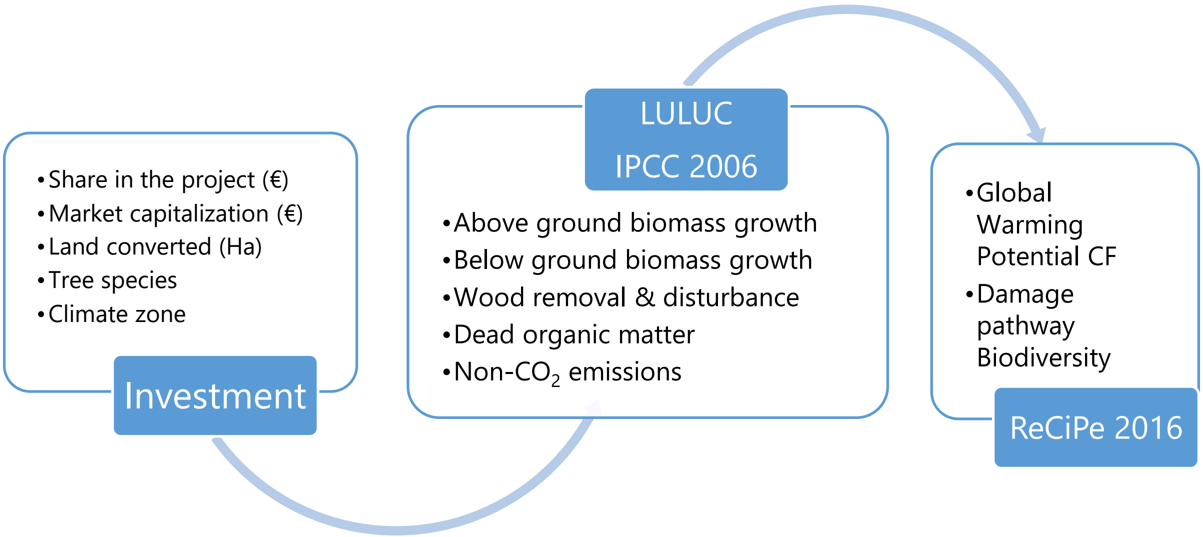
2.8. Data needs for carbon sequestration

For the calculation on carbon sequestration impacts on biodiversity, the following information should be collected for the forestry project(s).

1. Market capitalization of the project
2. Size of the area in Ha
3. Location (and biome)
4. Tree species

Figure 3: Schematic overview of the calculation steps and data sources of the carbon sequestration and the impact on biodiversity from forestry

[25] Eggleston et al., *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.
[26] Eggleston et al.


Share in the project (€)
Market capitalization (€)
Land converted (Ha)
Tree species
Climate zone
Investment
LULUC
IPCC 2006
Above ground biomass growth
Below ground biomass growth
Wood removal & disturbance
Dead organic matter
Non-CO_2 emissions
Global Warming Potential CF
Damage pathway Biodiversity
ReCiPe 2016

3. Shade grown coffee

In scientific literature, shade grown coffee is often presented as supporting and protecting local and regional biodiversity[27]-[28]-[29]. Investment in shade grown coffee are therefore considered to have a positive environmental impact. The eco.business Fund for instance lists the following positive impacts from their investment in shade-grown coffee plantations[30].

- Carbon sequestration
- Soil preservation
- Protection of the region's biodiversity (such as migratory and resident birds, small mammals, and reptiles, among other species).
- The preservation of groundwater resources

This section aims to examine how we can quantify the positive impacts related to shade grown coffee practices.

3.1. Different types of coffee production

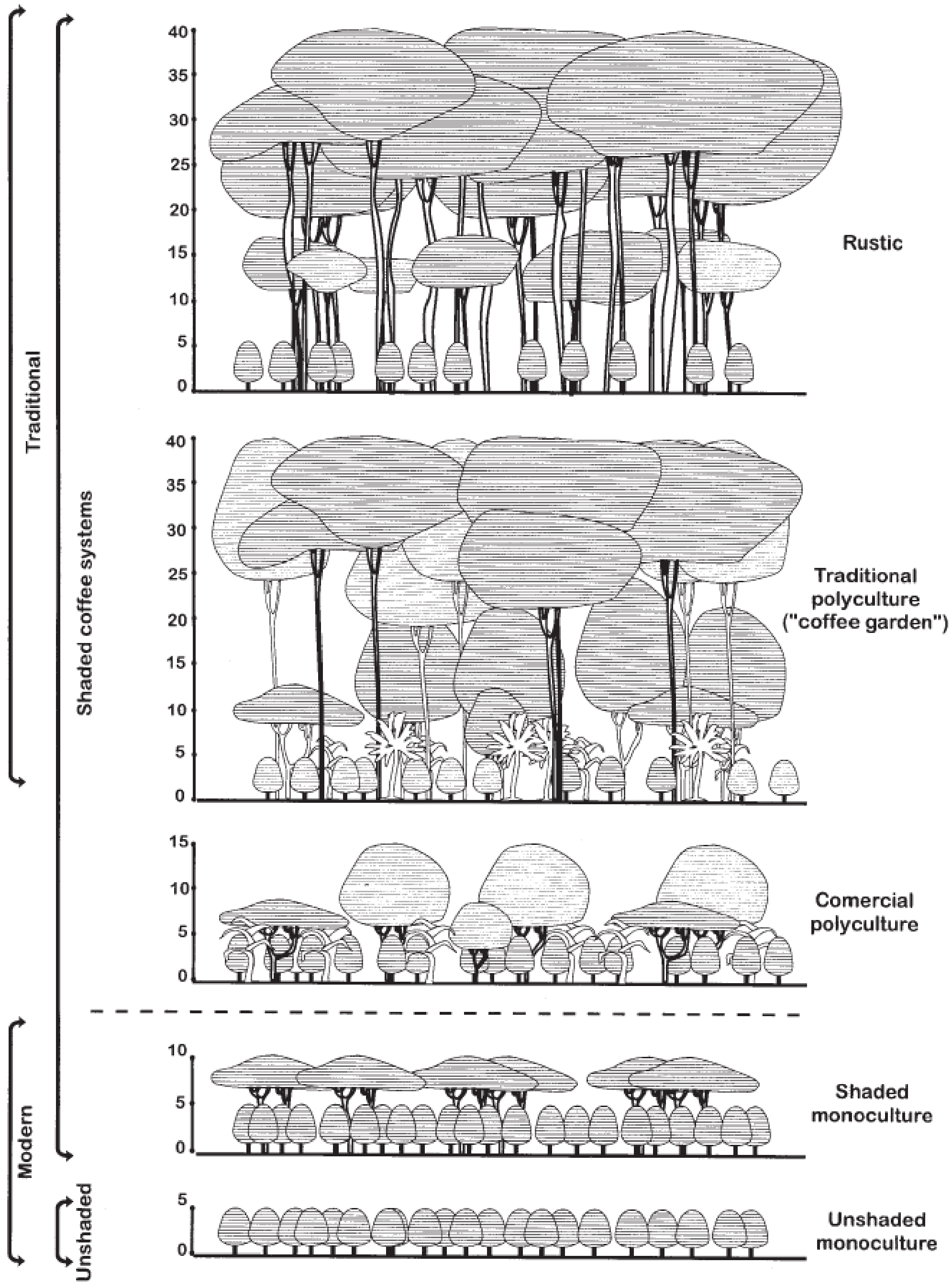
Globally, approximately 41% of coffee area is managed with no shade, 35% with sparse shade, and only 24% with traditional diverse shade[31]. Shade grown coffee can be managed in different ways. Figure 4[32] shows five different types of shade grown coffee plantations. Two traditional shaded agroforests with native trees (Rustic and coffee garden), a commercial polyculture shaded plantation, and two 'modern' systems (shaded and unshaded monocultures)[33]. The article focusses on Mexican shade grown coffee, but differences in the types of shade grown coffee, or agroforestry with other crops is also described by Chaudhary et al.[34] in their article on the biodiversity impact of different forest management types.

Especially in 'Rustic' and 'Coffee garden' agroforestry, the original understory of the forest is replaced, but at least a part of the structural diversity of the original forest remains intact. Therefore, these types of (coffee) crop production systems maintain biodiversity better than conventional pastures, row crops of monocultures[35]. Sometimes multiple crops are grown, like cocoa, jungle rubber, banana or other plants. When multiple crops are harvested, an allocation step is needed to determine the biodiversity impact per crop.

In a Nature publication by Chaudhary et al. all types of agroforestry are grouped together due to limited data availability. They conclude that the overall response rate to an agroforestry management type is 0.678. Meaning that about 68% of all species is maintained[36].

[27] Chaudhary et al., 'Impact of Forest Management on Species Richness'.
[28] Jha et al., 'Shade Coffee'.
[29] Moguel and Toledo, 'Biodiversity Conservation in Traditional Coffee Systems of Mexico'.
[30] eco.business Fund, 'Casal - A Look into Shade Grown Coffee in El Salvador'.
[31] Jha et al., 'Shade Coffee'.
[32] Moguel and Toledo, 'Biodiversity Conservation in Traditional Coffee Systems of Mexico'.
[33] Moguel and Toledo.
[34] Chaudhary et al., 'Impact of Forest Management on Species Richness'.
[35] Chaudhary et al.
[36] Chaudhary et al.

Figure 4: Schematic overview of five coffee-growing systems (image from Moguel & Toledo[37])



Estimates from Bhagwat et al., conclude a similar effect. They have estimated that mean values for species richness in agroforestry systems exceed 60% of the forest values[38]. It should be noted that there is a large variety between taxa, regions and type of agroforestry, but the authors do consider agroforestry to be a better alternative than monoculture. These conclusions are based on a literature review of 69 agroforestry sites for coffee, cocoa, and a few other plants in America, Asia and Africa. As an additional benefit, agroforestry systems serve as a corridor by connecting different ecosystems. Also,

[37] Moguel and Toledo, 'Biodiversity Conservation in Traditional Coffee Systems of Mexico'.
[38] Bhagwat et al., 'Agroforestry'.

pressure on protected areas is decreased by growing additional timber for instance. Finally, the heterogeneity at the habitat and landscape scale is maintained[39].

3.2. Benefits from shade grown coffee

The following benefits of shade grown coffee are listed by the eco.business Fund:

- Carbon sequestration
- Soil preservation
- Protection of the region's biodiversity (such as migratory and resident birds, small mammals, and reptiles, among other species).
- The preservation of groundwater resources

The key question that needs to be answered is which coffee growing systems are used. Literature shows that the species richness compared to natural vegetation is approximately 65%[40]-[41]. This is still a loss over the natural moist broad leaved forest background. This number does not distinguish between different types of agroforestry. In the worst case, with coffee grown without shade in a monoculture, the species richness will be very low. In this case the level of biodiversity will be approximately 45% compared to natural vegetation, similar to a non-timber plantation (based on Chaudhary et al). This category represents unshaded monocultures like palm oil plantations (see

Table *2*). The best case will be the Rustic coffee-growing system. Here we can expect a negligible impact (approximately 95% of species will remain) on biodiversity as the original vegetation remains largely intact. This value is similar to retention harvesting, selection, and reduced impact logging (see

Table *2*). The species richness can be translated to PDF as PDF is equal to 1 - species richness.

Table 3: Biodiversity impact of different coffee-growing schemes

Management type	Species richness compared to natural vegetation	PDF	Source
Rustic	95 %	0.05	Approximation based on Chaudhary et al. (2016)[42]
Traditional polyculture (coffee garden)	80 %	0.2	Approximation
Commercial policulture	65 %	0.35	Chaudhary et al. (2016)[43] Moguel & Toledo (1999)[44]
Shaded monoculture	55 %	0.45	Approximation
Unshaded monoculture	45 %	0.55	Chaudhary et al. (2016)[45]

[39] Bhagwat et al.
[40] Chaudhary et al., 'Impact of Forest Management on Species Richness'.
[41] Moguel and Toledo, 'Biodiversity Conservation in Traditional Coffee Systems of Mexico'.
[42] Chaudhary et al., 'Impact of Forest Management on Species Richness'.
[43] Chaudhary et al.
[44] Moguel and Toledo, 'Biodiversity Conservation in Traditional Coffee Systems of Mexico'.
[45] Chaudhary et al., 'Impact of Forest Management on Species Richness'.

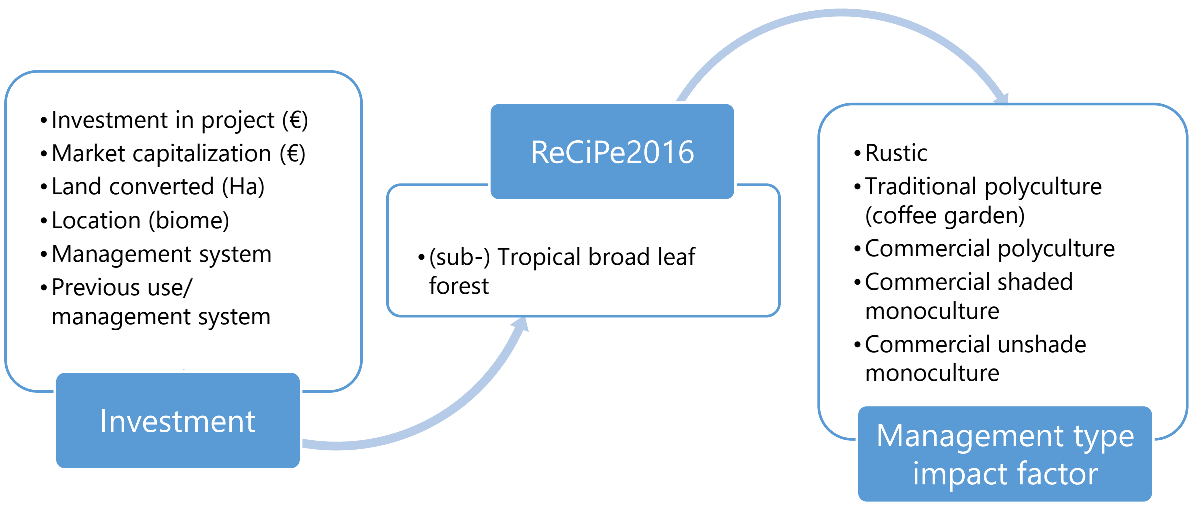
If the eco.business Fund invests in restoring a monoculture to one of the four shade-grown systems we can expect a positive impact from the change in land use impact on biodiversity.

To calculate the carbon sequestration from shade grown coffee, the IPCC 2006 guidelines[46] can be used as described in the chapter on forestry (paragraph 2.7)

3.3. Site specific shade grown coffee impacts

The following scheme shows the impact from land use on biodiversity of a site specific shade grown coffee project. Note that we only use the (sub) tropical broad leaf forest biome from ReCiPe, because coffee production occurs in tropical countries[47].

Figure 5: Schematic overview of the calculation steps and data sources of the land use impact on biodiversity from different shade grown coffee management types.



3.4. Data needs for land use impacts

For the calculation on land use impacts on biodiversity, the following information should be collected for the shade grown coffee project(s).

1. Market capitalization of the project
2. Size of the area in Ha
3. Location (and biome)
4. Forests management system (after the investment)
5. Previous use of the site (or previous management system)
6. Amount of other crops grown (if any)

[46] Eggleston et al., *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.
[47] Krishnan, *Sustainable Coffee Production*.

4. Offshore Wind Energy

Currently there are four operational wind parks with a combined power of 957 MW in the Dutch part of the North Sea. Before 2023, an additional 4.5 GW shall be added and according to the New Offshore Wind Energy Roadmap, an additional 7 GW should be added between 2024 and 2030. The growth of the offshore wind sector is not only taking place in the Netherlands. The UK has the largest installed capacity, followed by Germany and China. These countries are also planning to increase their share of wind power. The ambition to add these amounts of GW's offers investment opportunities for the financial sector. Additional wind power is needed to lower the carbon footprint of electricity production. The overall effect of offshore wind energy on biodiversity however, is not necessarily positive.

4.1. Impacts from offshore wind energy

In the documentation of the BFFI study for ASN Bank a qualitative assessment of the negative and positive impacts on biodiversity not covered by the BFFI calculations is made and presented in the following table.

Table 4: Main impacts on biodiversity related to offshore wind parks

Negative impacts	**Positive impacts**
Collisions with birds and bats *Construction phase:* • Increased vessel traffic associated with surveying and installation activities creates the risk of collision with marine mammals, sea turtles, and fish (Bailey et al. 2014). *Operational phase:* • One of the major concerns for this phase are seabird mortality caused by collision with the moving turbine blades (Bailey et al. 2014, Birdlife International, 2003, Seys et al., 2001). Both for birds migrating through the area as well as for those that breed or forage in the vicinity. • Bats (migratory and non-migratory) regularly forage around the offshore wind turbines because of the accumulation of flying insects, increasing the risks to be killed (Ahlén, et al., 2007).	No fishing zones (positive for marine biodiversity) *Operational phase:* • Local species benefit from fisheries exclusion, both targeted species and non-targeted bycatch species (Bergström et al. 2014). • The exclusion also prevents bottom trawling (the dragging of nets on the sea floor) so benthic organisms benefit as well (Bergström et al. 2014). • Surrounding areas may also see an increase in species abundance (Bergström et al. 2014). • There may be opportunities to combine offshore wind farms with open ocean aquaculture (Bailey et al. 2014).
Displacement and deviation of migratory routes of birds and bats (barrier effects) *Operational phase:* • Birds may fly around, rather than between, clusters of wind turbines , thereby increasing the energetic costs of flight or disrupting ecological links between feeding, roosting, breeding and moulting areas, and extending migration routes (Birdlife International, 2013) • One of the major concerns for this phase is seabird displacement from key habitats as a result of avoidance responses (Bailey et al. 2014, Birdlife International, 2003, Seys et al., 2001). These issues can affect birds migrating through the area as well as those that breed or forage in the vicinity.	Artificial coral reefs/ marine reserves (positive for marine biodiversity) *Operational phase:* • Windmills can produce habitat gain by acting as artificial reefs, thereby enhancing local species abundances and biodiversity (Bergström et al. 2014). • Fish are seasonally attracted to wind farms and seals potentially use them as foraging sites (Reubens et al. 2014), (Russell et al. 2014).
Increased noise levels *Construction phase:*	

• Sounds emitted during pile driving cause potential hearing damage, mask of calls, or displacement of animals (Bailey et al. 2014). • Sounds emitted during pile driving cause potential mortality and tissue damage in fish (Bergström et al. 2014). • Increased vessel traffic associated with surveying and installation activities creates the risk of noise disturbance to marine mammals, sea turtles, and fish (Bailey et al. 2014). *Operational phase:* • Acoustic disturbances from electricity generation and boat traffic for service and maintenance. The acoustic disturbances caused by the operation of the windmills are within the hearing range of fish and mammals, but underwater sound levels are unlikely to reach dangerous levels or mask acoustic communication of marine mammals (Bergström et al. 2014), (Bailey et al. 2014).	
Electromagnetic fields *Operational phase:* • Transmission cables transporting the generated electricity produce electromagnetic fields, which can affect cartilaginous fish, like sharks, which use electromagnetic signals in detecting prey (Bergström et al. 2014). • The electromagnetic fields could also disturb fish migration patterns by interfering with their capacity to orientate themselves in relation to Earth's magnetic field (Bergström et al. 2014).	
Non-indigenous species • Wind farms may introduce non-indigenous species that may potentially become invasive (Bergström et al. 2014, IUCN, 2010, Kerckhof et al., 2011).	

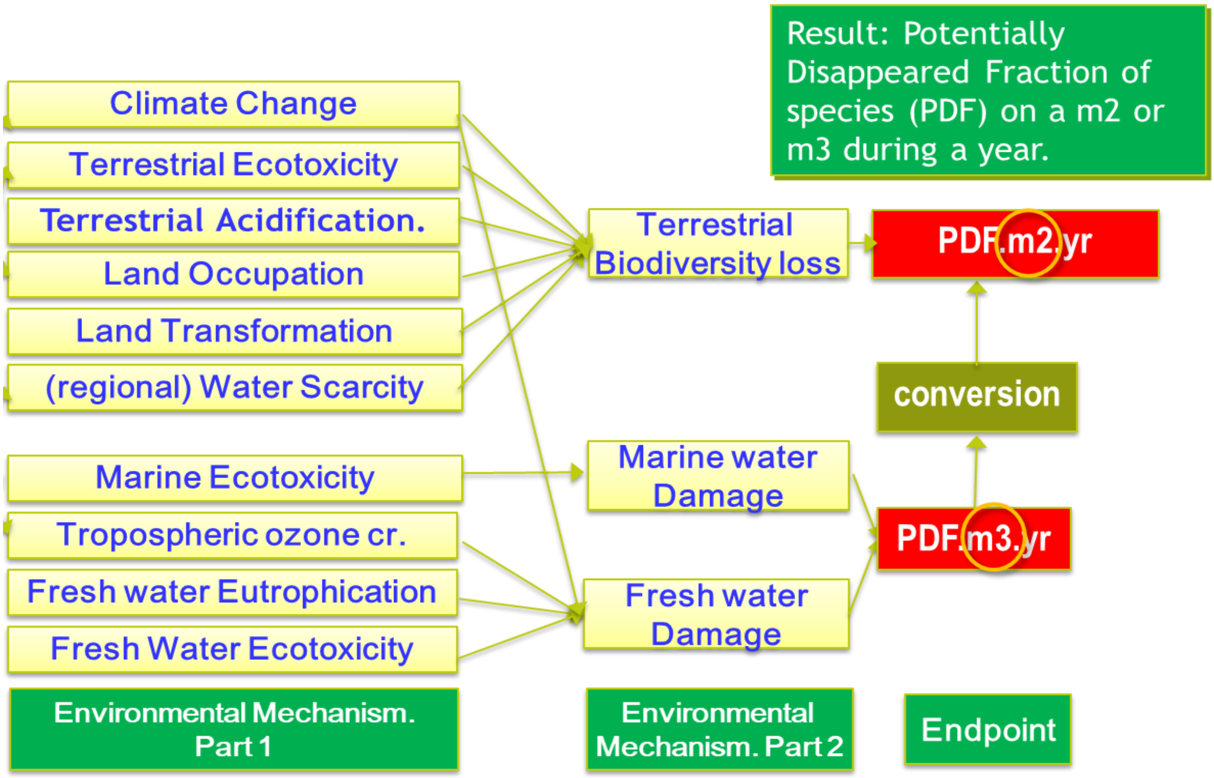
These impacts are difficult to determine in a quantifiable way as cause and effect mechanisms are not well enough established. However, by making these non-quantifiable impacts explicit, these impacts can still be addressed during the investment process (e.g. by requiring mitigating actions). The BFFI footprint calculation can only cover the following impacts:

1. The negative impacts of the production of the windmills and the materials used.
2. The increase in biodiversity below water, due to the no-fishing zones and the fact that the masts and foundations of the windmills are functioning as reefs, which creates small localized habitats. In some wind parks additional artificial reefs are created by adding cleaned shipwrecks, old train carriages or blocks.

4.2. Determining the positive impact under water.

The ReCiPe 2016 methodology has a number of impact categories for assessing the impacts in freshwater and marine water. In most calculations they do not receive much attention as most investments are land based. While the impacts on land are expressed per square meter (as $PDF.m^2.yr$), all impacts in water are expressed per cubic meter (as $PDF.m^3.yr$). The cubic and square meters can be converted into a unitless score by dividing them by the average species density on land and in water. These steps are shown in Figure 6. So for instance if there are on average 5 different species on a square meter, compared to a cubic meter ocean water, the impact of ocean water is divided by 5, as there are simply fewer impact species.

Figure 6: Schematic overview of the impact pathway from emissions and land use to the loss in biodiversity.

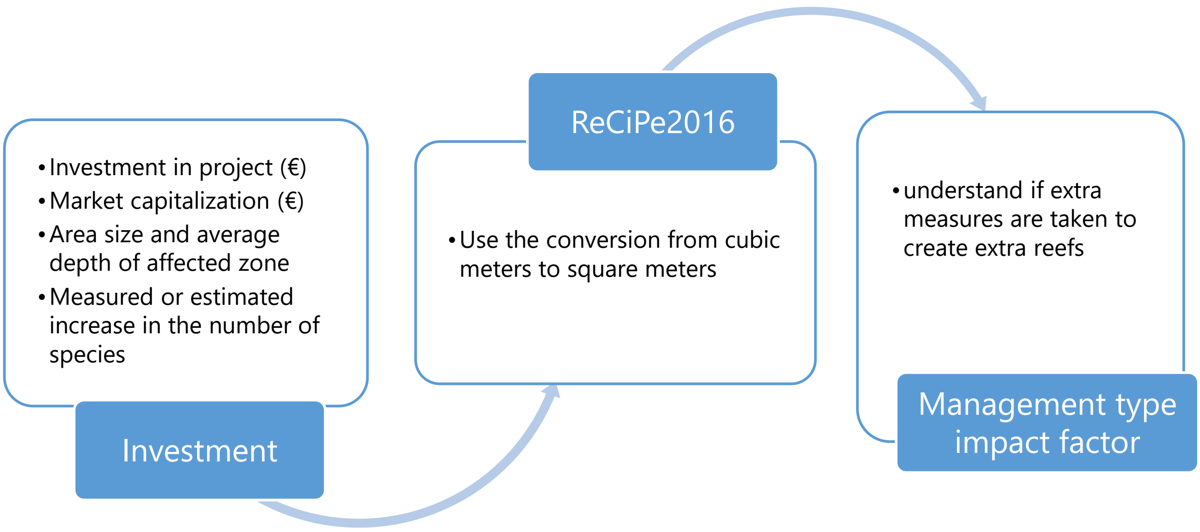


There is no equivalent mechanism to assess seawater occupation or transformation as there is for land-use, but we can add this especially for this project, if we have an estimate of the difference in species richness before and after the building of the wind park, as that can give us the basis of the PDF decrease.

The key question is again the reference. In order to be consistent with the methodology, the reference should be the biodiversity in the North Sea without fishing or any other intervention. We can also just look at the factor with which the biodiversity increases. If, for instance there are 5 times as many species in a wind park compared to the situation before the wind park was build, we can assume a PDF increase of 80%. This factor can also potentially be linked to management practices, such as creating additional artificial reefs.

The other factor we need is to understand the volume of water in which the biodiversity increases. This can be determined by multiplying the no-fishing-zone or the area size of the wind park with the average depth.

Figure 7: Schematic overview of the calculation steps and data sources of the impact of offshore wind energy on biodiversity.



4.3. Data needs for offshore wind projects

For the calculation on impacts on biodiversity from offshore wind projects, the following information should be collected.

1. Market capitalization of the project
2. Size of the area in Ha
3. Area size and average depth of affected zone
4. Measured or estimated increase in the number of species

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