Biodiversity in LCA

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1 Introduction

Biodiversity together with global warming and impacts caused by emissions of nitrogen compounds was back in 2009 identified as the most important areas of concern for the sustainable future of humankind (Rockström et al., 2009). Now, the decline of biodiversity in the world is high on the political agenda as our livelihoods and well-being all depend on healthy ecosystems and recent studies report that global biodiversity is declining at rates unprecedented in human history (Dasgupta, 2021; IPBES, 2019). Thus, when assessing environmental impact of products and systems, including biodiversity impacts are of high importance.

Research to develop a suitable method to include biodiversity in life cycle assessment (LCA) has been and is on-going. However, the current Product Environmental Footprint (PEF) methods do not include an impact category named "biodiversity". However an assessment of the relevance of biodiversity when developing a PEFCR shall be made and if biodiversity is relevant, then a description shall be included of how this biodiversity impact shall be assessed (European Comission, 2018). Suggestions are to use a certification scheme as proxy or to state how much of the materials in the study that comes from ecosystems where biodiversity is maintained and/or are increased, and to set a level of how much the biodiversity can be affected, e.g. 15% loss of species richness due to disturbance. It would be beneficial for the comparability of PEF studies if one method were used for biodiversity instead of having the option to choose method. There are working groups set up by the European commission that is currently reviewing biodiversity methods with the aim to recommend an approach to be included in the PEF guidelines.

The report is prepared by the NordPEF group and briefly reviews the ongoing work on biodiversity methods for inclusion in LCA and include case studies from the Nordic countries using some of these methods. The benefits and drawbacks with the methods and suggest improvements from a Nordic perspective is also included, however not on detailed methodological level. The NordPEF group works on issues regarding the implementation of Product Environmental Footprint (PEF) in agricultural sector in the Nordics. The group consist of Anna Woodhouse, RISE (Sweden); Sanna Hietala, LUKE (Finland); Troels Kristensen, Aarhus University (Denmark) and Hanne Møller, NORSUS (Norway). The work is funded by the Nordic Council of Ministries and national ministries (MMM/FI) and environmental protection agencies (EPA/SWE) via the Nordic Environmental Footprint (NEF) group. This report is not exhaustive within this topic and descriptions are based on experiences that the participants of the group have as LCA practitioners.

2 Framework

There are several methods developed for quantifying biodiversity impact in LCA, however most of them have limited geographical scope (restricted to certain locations, or global without meaningful results) and are restricted to only one taxonomy group. Some characterisation method in LCA includes biodiversity linked to land occupation ass for example the ILCD /ReCiPe method, which includes loss of species expressed in Potential Disappeared Fraction of species (PDF) as an endpoint indicator (Goedkoop et al., 2009). However, it is not sufficient to include biodiversity only by using a characterisation method and it is necessary to use specific impact methods for this.

Several frameworks are developed for a specific purpose and not generally applicable. In recent years, several studies and methods have been published, including two publications from de Baan in 2013 on global (de Baan, Alkemade, et al., 2013) and regional assessment (de Baan, Mutel, et al., 2013). A UNEP–SETAC guideline on biodiversity in LCA was published by Koellner et al. (2013). This was followed up by a UNEP-SETAC initiative (UNEP/SETAC, 2016), a global forum to ensure a science-based, consensus-building process to support decisions and policy making. The outcome was a consensus workshop (Pellston) and a review by Curran et al. (2016), where the model by Chaudhary et al. (2015)was recommended for hotspot analysis, but not for comparative studies or product labelling. Chaudhary et al. published updated framework in 2018, better adjusted for product level assessments. For a review of methods see e.g. (Crenna et al., 2020; Curran et al., 2016; V. M. Gabel et al., 2016).

A method for assessing biodiversity in LCA should be applicable for farm level and up to a global scale, distinguish between different agricultural intensities, e.g., when assessing organic agricultural products using LCA, the omission of biodiversity is problematic, because organic systems are characterized by higher species richness at field level compared to the conventional systems (J. Bengtsson et al., 2005; M. Bengtsson & Steen, 2004; Hole et al., 2005). A biodiversity method for LCA inclusion should also have data available in existing data (databases etc.) and it should be possible to related to a functional unit. Published methods follow some common characteristics that have been listed below:

- Species richness most used indicator, often only one taxonomy group, sometimes combined with vulnerability index
- Characterization factors available for occupation and/or transformation
- Global, regional or local level
- Sometimes applied on products
- BDP (biodiversity damage potential) most used impact, expressed as PDF (potentially disappeared fraction) or species loss per m^2 or alike
- Reference land use important, often “semi-natural”

At the global level, there are good methods, but they do not provide sufficient information to distinguish between production forms (pasture/ feed concentrates or conventional /organic farming). Teixeira et al. (2016) recommended that the ideal biodiversity dataset should reflect changes in land management, and that species richness seems to be the best option for a start but that one of the crucial limitations was data availability. Table A1 in appendix provides an overview of some selected methods that have been published since 2013 and their main features in terms of structure, scope and included elements.

3 Description of methods

3.1 Global scale

The UNEP-SETAC Life Cycle Initiative (UNEP/SETAC, 2016) have recommended the biodiversity method by Chaudhary et al. (2015). The FAO guidelines for quantitative assessment of biodiversity in the livestock sector (FAO, 2020) have recommended the method by Chaudhary & Brooks (2018), which is an updated version the first mentioned method. The Chaudhary & Brooks (2018) appears so far to be the best method that meets the most important criteria for quantifying biodiversity in LCA , as proposed by Gabel et al. (2016): global applicable and associated characterisation factors that includes production intensity.

The method by Chaudhary and Brooks (2018) provides characterization factors for potential biodiversity loss in 804 different ecoregions for mammals, birds, amphibians, reptiles, and plants, and for taxa aggregated. The method covers forest, cropland, pasture and urban land use, at different levels of land use intensity. The characterization factors are developed based on e.g., data in global land use intensity maps, WWF Wildfinder database and International Union for Conservation of Nature (IUCN) red list habitat classification scheme.

The method provides characterization factors for land transformation (e.g., for deforestation situations) and land occupation, and these reflect the potential biodiversity loss of human disturbance as in comparison to natural (primary) vegetation in the chosen ecoregion. The ecoregions are categorized within 14 biomes and eight biogeographic realms based on Olson et. al. (2001) to facilitate representation, see Figure 1. The terrestrial biomes, also called major habitat types (MHT) are broad, typically large-scale aggregations of ecoregions of similar moisture, physiognomy, and latitude.

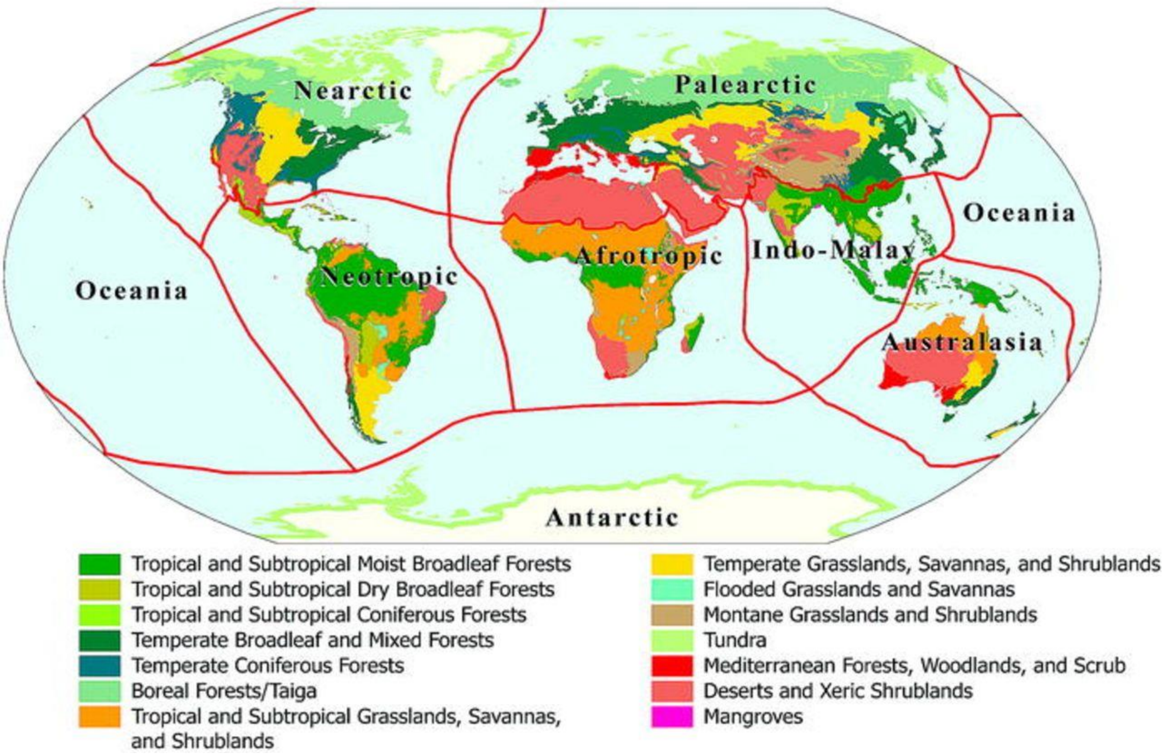

Figure 1 Map showing 14 biomes and eight biogeographic realms (Olson et al., 2001).

The method by Chaudhary & Brooks (2018) was used in Moberg et al (2020) to analyse the impacts of Swedish food consumption on biodiversity loss. The method is also discussed in Hayashi (2020) which points out that the method is suitable at a ecoregion level, however it is not adapted for local assessment or to distinguish between conventional management and integrated pest management. Also Maier et al. (2019) describes that the methods cannot be used for assessing specific land use management.

In addition to Chaudhary et al. (2015) and Chaudhary & Brooks (2018), also the methods developed by Lindner et al. (2019) and Maier et al. (2019) aim at being globally applicable (see further description in section 3.2).

3.2 Management practices

Several methods have been published that aim at considering agricultural management practices. These include the SALCA-BD method (Swiss Agricultural LCA—Biodiversity) as described in Jeanneret et al. (2014) and other methods proposed by Knudsen et al. (2017), Lindner et al. (2014, 2019), (Meier et al., 2015) and Maier et al. (2019). Most of these methods include several different management practices, most frequently the level of nitrogen input in fertilisers and pesticide use, as described in Table A1. Other less frequently covered management practices include for example crop diversity or crop rotation and the presence of seminatural area or small landscape structures. The method of Knudsen et al. (2017) differs the most from the others by not including individual management practices but differentiating between conventional and organic production.

The **SALCA-BD method (Jeanneret et al. 2014)** is valid for grasslands, arable crops and semi-natural habitats of the farming landscape. Impacts on eleven indicator-species groups (flora of crops and grasslands, birds, mammals, amphibians, snails, spiders, carabids, butterflies, wild bees, and grasshoppers) are included. At first, the method was validated for use in Switzerland and neighbouring regions, but recently Lüscher et al. (2017) have validated the parametrization of four indicator-species groups (arable crop flora, grassland flora, spiders, and wild bees) based on ground surveys for eight European regions located in Austria, Bulgaria, Switzerland, Germany, France, UK, Hungary and Norway. In SALCA-BD, the impact of each management option on an indicator-species group is rated on a scale from 1 to 5, where 1 is the most damaging option and 5 the most favourable one (Jeanneret et al. 2014). The result of the assessment is an overall species diversity score (OSD score) for each indicator-species group per land use class and practice, ranging from 0 to 50 (Lüscher et al. 2017). An OSD score of 0 means that the land use class is no habitat for the considered indicator-species group. An OSD score of 50 means that the land use class and the practice is of primary importance for the considered ISG, and that the impact of the practice is positive. The method has been used in many case studies, however, the method does not include any ready characterization factors, but the assessment must be made separately each time. This means that the quality of the results is largely dependent on the expertise and experience of the expert team making the assessment (Mungkung et al., 2019). Also, the results cannot be reported along with the other LCA impact categories because it uses a scale where high values are beneficial for environment, which is the opposite than the conventional practice in other LCA methodologies (Knudsen et al., 2019).

The Biodiversity method proposed by **Lindner et al. (2014)** is based on previous work by Michelsen (2007) and considers an ecoregion factor and the regional biodiversity potential in the location of the land use. The ecoregion factor is calculated based on species richness, ecoregion scarcity, normalized uniqueness of endemic species and the value of threat. The required data can be obtained from the WWF wildfinder database for each ecoregion. The regional biodiversity potential, in turn, is defined by expert judgement for each ecoregion. Experts evaluate which parameters (e.g., fertilisation and biomass production level) are important for each ecoregion's biodiversity potential regarding land use. For the ecoregion 'Western European Broadleaf Forests' the authors defined fertiliser nitrogen input level, ecotoxicity potential, presence of small landscape structures, and share of harvested biomass as the critical parameters for the regional biodiversity potential. The method is also applicable for assessment of forestry systems and has been further developed in several case studies related to forestry practices (Lindqvist et al., 2016; Myllyviita et al., 2019; Rossi et al., 2018).

The method proposed by **Lindner et al. (2019)** is based on the needs of different stakeholders similarly as in some multi-criteria decision methods. The method allows differentiation between sites (biomes and ecoregions) and between practices (land use classes and management parameters). Many parameters related to farm management practices are included: diversity of weed species, presence of seminatural area, field size, crop rotation, ground cover, intensity of soil movement, intensity of fertilization, share of organic fertilizers and the application of plant protection agents and mechanical weed control. The variability of the impacts of management practices between different biomes can be considered. The calculation result is not a physical measurement but a philosophical quantity.

The method developed by **Meier et al. (2015)** is based on regression models that describe species diversity on landscape level as a function of land use intensity and landscape structure including parameters that refer not only to the farm under consideration but also to the surrounding landscape: nitrogen input on the agriculturally used area, diversity of the crop rotations within the overall landscape, and the proportion of semi-natural area within the landscape. The method is based on empirical data on the species diversity of vascular plants, birds and arthropods collected in Central Europe (France, Belgium, Holland, Germany, Switzerland, Czech Republic and Estonia). The impact on farmland biodiversity is expressed as the biodiversity damage potential (BDP), normalized to a dimensionless index with values between zero and one in which lower values indicate land use that is better for encouraging species diversity. So far, the method has only been published in German language. The method has been used in Gabel et al. (2018).

The **Land Use Intensity Index proposed by Maier et al. (2019)** is an additive index which consists of a summary of different management parameters and the standardization of existing values either by a maximum value, mean value or as z-standardization. The method is based on data in the PREDICTS database which contains more than 3 million data entries from over 21,000 sites globally. It covers more than 38,000 species, including vertebrates and plants but also invertebrates. For croplands, parameters related to management practices included in the method include fertilization level, the level of mechanization, the level of pesticide application per year and the level of irrigation. More specific instructions or values for the estimation of different parameter values are not given.

3.3 Organic and conventional

The **Biodiversity Damage Potential method of Knudsen et al. (2017)** includes characterization factors expressing the Potentially Disappeared Fraction (PDF) of plant species to estimate land occupation impacts on biodiversity in the 'Temperate Broadleaf and Mixed Forest' biome. This model provides characterization factors for the potentially damaged fraction of plant species per square meter for different types of land uses, but does not include other taxa as reptiles, mammals and birds. The calculations are based on a dataset derived from field recording of plant species diversity in farmland across six European countries. The CFs can distinguish between different land use types such as pastures (monocotyledons or mixed), arable land and hedges) and management practices (organic or conventional production systems) across countries. Mixed pastures are those with both perennial monocotyledonous grasses and biannual/perennial broadleaved herbaceous species, whereas monocotyledons pasture only contain perennial monocotyledonous grasses. The applicability of the method is however limited to central European countries and only the southernmost part of Scandinavia. The method by Knudsen et al. (2017) has been used in Knudsen et al. (2019) comparing production of organic and conventional milk in Western Europe. The method was also used in a life cycle sustainability assessment of organic and conventional pork (Zira et al., 2021). Since only plant species are included in this method, a sensitivity analysis was performed by using the method by Chaudhary & Brooks (2018). However, that model is set on a larger spatial scale and does not specifically capture the differences in organic and conventional production. The use of different biodiversity models in this study clearly shows that the choice of impacts methods influences the results.

3.4 Pasture and grassland

As far as we know, none of the methods have specific focus on pastures. Natural- and semi-natural pastures can be defined as grasslands or sparse woodlands that are neither ploughed, nor fertilised, but grazed by domestic animals. Usually, these are land areas that traditionally have not been suitable for crop cultivation. There have been numerous studies investigating the effects of grazing on biodiversity in natural and semi-natural pastures. The studies have found that moderate grazing generates less homogeneity regarding species richness, species composition and state of succession in comparison to other management regimes (such as mowing and burning) or to abandoned pastures (Oldén et al., 2016; Pykälä, 2003; Tälle et al., 2016).

The high biodiversity is due to the activity by the grazing animals. Grazing affects the species composition of plants since some plants are more attractive to the grazers than others. Usually grazing favours smaller and more opportunistic species at the expense of the generalists (Klimek et al., 2007; Middleton et al., 2006). In addition, the mixtures of biotopes in the natural pastures affects where the animals can graze thus create a mosaic structure that favours diversity. Furthermore, the tramping, movement patterns and the manure of the animals' favour seed-dispersal, certain fungus species, mosses, insects and soil living organisms (Cederberg et al., 2018; Linkowski, 2010; Middleton et al., 2006; Oldén et al., 2016) Finally, a more open and heterogenic landscape also benefits birds and pollinators, among others because it creates wildlife corridors and islands (Cederberg et al., 2018; Linkowski, 2010; Pykälä, 2003).

The diversity of natural pastures is affected by the grazing-pressure and it is vital that the pastures are continuously grazed but not overgrazed. A combination of different grazing regimes as well as different types of animals on the same pastures is beneficial for the biodiversity. For example is late-time grazing conducive for seed production and seed establishment of flowering plants (Fredriksson, 2017; Hall-Diemer et al., 2013; Klimek et al., 2007; Wissman, 2006).

4 Land use effects on biodiversity for steers and bulls in Sweden

Below follows an example of a case study from Sweden using the method for assessing biodiversity impact by Chaudhaury and Brooks (2018).

Since there is evidence that grazing semi-natural and natural pastures increase biodiversity it would be good if there was a methodology that could quantify these positive effects. The method of Chaudhaury & Brooks (2018) was tested on a case study of steers and bulls bred in Sweden where steers grazed semi natural pastures for one or two seasons and the bulls were kept indoors due to restrictions on keeping bulls outdoors.

All feeds were assumed to originate from the Västra götaland region in Sweden. From the slaughter weight, 68% was assumed as meat product based on Hansson (1989). Table 1 shows the land used for producing feed for bulls and also grazing for steers. The longer the lifespan of the animal, the higher land use as more feed is needed. Also, for the steers more land is needed as grazing is less efficient than feeding concentrate feed.

Table 1 Land use for production of feed, and for pasture in the different Swedish meat systems (m^2 per kg bone free meat).

	Steers				Bulls			
	Dairy x beef breed 21 months	Dairy x beef breed 28 months	Pure-bred dairy 21 months	Pure-bred dairy 28 months	Dairy x beef breed 15 months	Dairy x beef breed 18 months	Pure-bred dairy 15 months	Pure-bred dairy 18 months
Silage	30	46	36	50	6	14	7	8
Pasture	12	25	15	30	0	0	0	0
Barley	1	1	1	1	18	20	19	22
Grain legumes	0	0	1	1	2	1	2	2
Rapeseed cake	0	0	1	1	0	0	0	0
Sum	44	73	53	83	26	34	29	32

Figure 2 shows the results of the Chaudhary & Brooks (2018) method. If comparing results between steers and bulls, bulls have a lower negative impact on biodiversity than steers. However, if the grazing period were excluded from the results, the 21 months old steers, both dairy and beef breed, would have similar results to the bulls of 18 months. As there is evidence for grazing to have a positive impact on biodiversity for semi-natural and natural pastures, perhaps this is a more fair comparison for assessing biodiversity impact. It also shows that the method of Chaudhaury & Brooks method would benefit from updating characterization factors for semi-natural pastures to capture the beneficial impacts grazing can have on biodiversity.

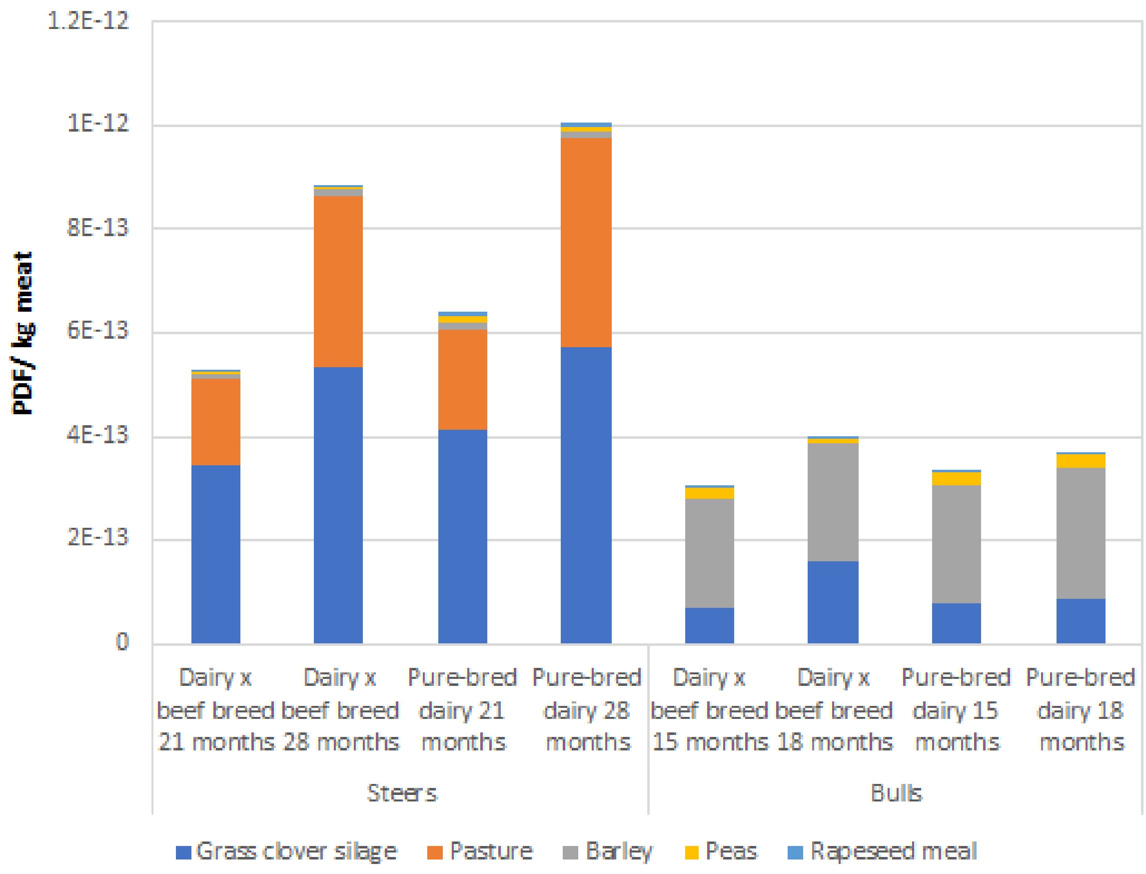

Figure 2 Impact of land use on biodiversity (potential disappeared fraction, PDF) for steers and bulls in Sweden.

5 Applicability for Nordic conditions

When choosing a biodiversity method, it is important to clarify the goal and scope of the study in question. Is the purpose of the study to get an overview of a global value chain, an assessment at the regional level between different types of grazing and roughage practice, or compare conventional and organic production? Based on the description of the methods in this report, it is clear that some methods are more suitable for a certain goal and scope than others.

Currently, none of the above-mentioned methods can directly be taken into use in assessing the biodiversity impact of agricultural production in Northern European conditions. Knudsen et al. (2017) applies to the “Temperate Broadleaf and Mixed Forest biome” and thus includes only Denmark and the southern part of Sweden of the Nordic region. Meier et al. (2015) present characterization factors or calculation equations that can be directly applied but also this method is only validated for use in Central Europe. The SALCA-BD method (Jeanneret et al. 2014) and the method proposed by Lindner et al. (2014) require additional expert evaluation for the definition of the calculation equations. The method proposed by Lindner et al. (2019) seems promising, but it contains a large number of different parameters and should first be tested in a case study to find out whether all the parameters are really needed and if the workload related to the data collection could be reduced by reducing the number of parameters.

If the scope is global or regional, the method by Chaudhary & Brooks (2018) is relatively easy to use because it includes the characterisation factors and it provides a good overview of the value chain. However, the method is not suitable for distinguishing between organic and conventional production or product systems at the local level. In this report we displayed a case study for beef production. For production systems where the feed is produced from feed crops, such as cereals, oilseeds and legumes, the method of Chaudhaury & Brooks (2018) is currently the best available method and can reflect where in the life cycle the largest impacts on biodiversity originates. It is important to note that Chaudhaury & Brooks (2018) is not taking into account the impact of land use on insects which may lead to an underestimation of the impacts in this model. No method to date can account for positive impacts on biodiversity in an optimal way e.g., when semi-natural areas are used for grazing.

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Appendix

Table A1 Selected methods published since 2010 (not exhaustive) and description of the main elements.

Method	Description	Indicator	Geographical scope	Reference condition	Taxa included	Land use types and management practices included	Empirical /theoretical basis	Data availability
de Baan, Mutel, et al. (2013)	The potential global extinction of species is used to assess irreversible, permanent impacts	Potentially lost species / m^2/ year	Regional level used on a global scale	Site specific natural reference habitat	Mammals, birds, plants, amphibians, reptiles and an aggregated value	Management intensity for 4 land use types, the impacts of individual options are evaluated separately for each species group.	Based on an adapted, matrix-calibrated species-area relationship model	Characterization factors available in supplementary material
de Baan, Alkemade, et al. (2013)	A global approach to include land use effects on biodiversity	Biodiversity Damage Potential (BDP)	World regions, 14 WWF biomes	Semi natural reference state	Arthropods, vertebrates, birds, vascular and herbaceous plants, trees, mosses	Occupation and semi natural reference state. Forest, not used Secondary vegetation Forest, used. Pasture/meadow, Annual Crops, Permanent Crops, Agroforestry Artificial areas	Based on GLOBIO3 database, and national biodiversity monitoring data of Switzerland	Characterization factors available in supplementary material
de Souza et al. (2013)	Land use impacts on biodiversity in LCA: proposal of characterization factors based on	Functional Diversity Index (FDI)	North, Central and parts of South America	Natural or close-to-natural state: primary forest	Mammals, birds, plants	13-15 land use types according to Koellner et al., 2013, e.g. forest, agricultural land etc	Data compiled by previous regional meta-analysis on species richness and functional	Characterization factors available in supplementary material

Method	Description	Indicator	Geographical scope	Reference condition	Taxa included	Land use types and management practices included	Empirical /theoretical basis	Data availability
	functional diversity						diversity, in different land use types in the Americas	
Mueller et al. (2014)	Compare conv and org milk in Sweden	Potentially Disappeared Fraction of species (PDF)	Regional	Semi-natural land	Only vascular plants included.	Occupation and transformation, compared to semi-natural land	Direct land use change data derived from FAO statistical database, other data from literature	Characterization factors available in supplementary material
Jeanneret et al. (2014)	Scoring system to estimate impacts of agriculture on biodiversity	Biodiversity score (dimensionless)	Austria, Bulgaria, Switzerland, Germany, France, UK, Hungary and Norway	The proposed method does not refer to an initial or reference biodiversity condition, but instead estimates the impacts of various farming practices in a relative manner.	Eleven indicator-species groups or ISGs (flora of crops and grasslands, birds, mammals, amphibians, snails, spiders, carabids, butterflies, wild bees, and grasshoppers)	Management intensity, the impacts of individual options are evaluated separately for each species group. Grasslands, arable crops and semi-natural habitats of the farming landscape	Based on empirical data on the diversity of 11 species groups: vascular plants, birds, small mammals, amphibians, snails, spiders, carabid beetles, butterflies, wild bees and grasshoppers	Scoring system available in supplementary material
Meier et al (2015)	Agricultural land use related impacts on farmland biodiversity	Biodiversity damage potential (BDP)	Central Europe	Landscape level allocated to a specific farm level	Vascular plants and birds	N input, crop diversity, number of pesticide applications, animal density	Based on empirical data on the diversity of plants, arthropods, and birds	Data for specific areas
Chaudhary et al. (2015)	Quantifying Land Use Impacts on Biodiversity: Combining	Species loss/year/ha	Global	The natural, undisturbed habitat of the same region	Mammals, birds, reptiles, amphibians, and vascular plants	“Intensive forestry”, “extensive forestry”, “annual crops”, “permanent crops”,	Species–area relationships (SAR) model	Characterisation factors are available

Method	Description	Indicator	Geographical scope	Reference condition	Taxa included	Land use types and management practices included	Empirical /theoretical basis	Data availability
	Species– Area Models and Vulnerability Indicators			that is assessed		"pasture", and "urban"		
Chaudhary & Brooks (2018)	Updated method for quantifying land use impacts on biodiversity	BDP (biodiversity damage potential)/ Potential species loss/m^3	Global	No reference situation	Mammals, birds, amphibians, and reptiles	Five broad land use types (managed forests, plantations, pasture, cropland, urban) under three intensity levels (minimal, light, and intense use)	Species– area relationships (SAR) model	Characterisation factors are available
Knudsen et al. (2017)	Organic and conventional production	Potentially Disappeared Fraction (PDF) of plant species	'Temperate Broadleaf and Mixed Forest' biome in Central Europe	Semi-natural woodland	Plants	Organic and conventional production	Based on empirical data on the diversity of plant species	Average number of different plant species counted (organic or conventional) in six European countries
Lüscher et al. (2017)	Biodiversity assessment on field and farm scale in Europe	overall species diversity score (OSD score)	8 regions in Europe	Calculated SALCA-BD species diversity scores compared to field records.	Arable crop flora, grassland flora, spiders, and wild bees	Arable land, grassland and seminatural land, all divided into sub groups.	SALCA-BD (Swiss Agricultural LCA—Biodiversity	Method available in supplementary material
Maier et al (2019)	Framework for biodiversity Assessments in global value chains	Land Use Intensity Index (LUI)	Global	Theoretical framework - synthesizing existing global	Covers more than 38,000 species, including vertebrates and	Primary vegetation, secondary vegetation, cropland, pasture, plantation, urban	Based on empirical data on the diversity of plants, vertebrates and invertebrates	Method not yet available

Method	Description	Indicator	Geographical scope	Reference condition	Taxa included	Land use types and management practices included	Empirical /theoretical basis	Data availability
				conservation schemes to create a global uniform risk map that covers biodiversity priority areas for different taxa and at all scales	plants but also invertebrates	N input, level of mechanisation, pesticide input, level of irrigation		
Lindner et al., (2014)	Propose unified biodiversity impact assessment method	Regional bio-diversity potential	Ecoregion 'Western European Broadleaf Forests'	-	-	Nitrogen input, ecotoxicity potential, presence of small landscape structures, share of harvested biomass	Based on expert evaluation	
Lindner et al. (2019)	Method for incorporating biodiversity into life cycle impact assessment.	land use-specific biodiversity value (BV_{LU})	Global	Naturalness	-	N input, crop rotation, pesticide use, presence of seminatural area, diversity of weed species, field size, share of organic fertilizers, ground cover and intensity of soil movement	Based on expert evaluation	
Turner et al. (2019)	BioImpact, a method for incorporating biodiversity into an LCA, on four production systems in Australia	BioImpact score	Regional to be applied on a global level	None	Vascular plants, invertebrates, birds	Native forestry, plantation softwood timber production, cropping and rangeland grazing	Based on expert evaluation	Semi quantitative questions

Method	Description	Indicator	Geographical scope	Reference condition	Taxa included	Land use types and management practices included	Empirical /theoretical basis	Data availability
Scherer et al. (2020)	A framework for developing characterization factors for functional diversity as affected by land use.	Functional diversity index, Potentially disappeared fraction of functional diversity (PDFFD)	Temperate regions and larger scale	Depends on situation. Broad leaved forest, coniferous forest or mixed forest	Plants	Non-irrigated arable land, pasture, complex cultivation pattern	Based on empirical data on the diversity of plants, vertebrates and invertebrates	Characterization factors in article