Proposal of a unified biodiversity impact assessment method

Jan P Lindner[1,*], Briana Niblick[1], Ulrike Eberle[2], Ulrike Bos[3], Eva Schmincke[4], Sebastian Schwarz[4], Rainer Luick[5], Martin Blumberg[6], Anja Urbanek[6]

[1] Fraunhofer Institute for Building Physics, Dept. Life Cycle Engineering
[2] Corsus – corporate sustainability
[3] University of Stuttgart, Chair of Building Physics, Dept. Life Cycle Engineering
[4] PE International
[5] University of Applied Forest Sciences Rottenburg
[6] Brands & Values
[*] Corresponding author. E-mail: *jan-paul.lindner@ibp.fraunhofer.de*

ABSTRACT

The LCA community is moving forward in developing methods to address biodiversity in impact assessments and the required inventory data. However, biodiversity is a notoriously fuzzy topic. Underlying preferences and perspectives on biodiversity vary considerably among stakeholders. The method presented herein allows for both broad-brush and detailed assessments of critical processes. The goal is to enable LCA users to generate product-related biodiversity impact information and manage biodiversity along value chains. The method represents the impact category "biodiversity" in the UNEP-SETAC land use impact assessment framework. It is inspired by the method proposed by Michelsen (2008) in that it employs region-specific characterization models yet allows aggregation across regions. Preliminary results for a western European ecoregion show that landscape structure and pesticide use contribute to the biodiversity impact. Fertilizer input is relevant, but a low dose is tolerable.

Keywords: biodiversity, land use, impact assessment, method integration, landscape ecology, normative aspects

1. Introduction

Many international declarations and studies have built a strong case for protecting global and local biodiversity (e.g. UNEP 1992, MA 2005, TEEB 2010). The LCA community is moving forward in developing methods to address biodiversity in impact assessments and the required inventory data. In this paper we present an impact assessment method for terrestrial biodiversity. The method bears structural resemblance to the Michelsen (2008, 2013) method and takes advantage of expert judgment. It also aligns with the UNEP-SETAC land use LCIA framework (Milà i Canals et al. 2007, Koellner et al. 2013). Other LCIA methods for biodiversity, namely those that rely on statistical analyses of species inventories, lack the flexibility that our method offers. The statistical methods better suit unknown supply chains, i.e. background systems. Future unification of the various approaches may be possible.

2. Methods

Creating a biodiversity impact assessment category builds on previous work in developing an LCIA category for land use and land use change. Figure 1 shows a simplified schematic of land use change as described by the UNEP-SETAC land use framework (Milà i Canals et al. 2007, Koellner et al. 2013). A given land use impact can be described by Equation 1.

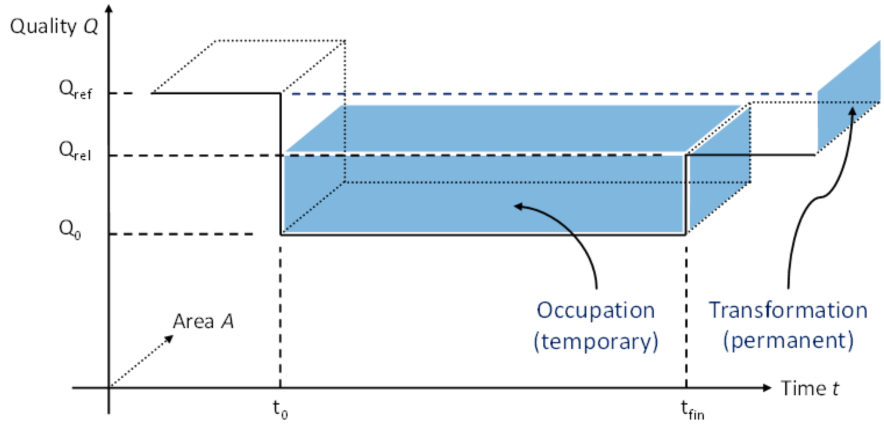

Figure 1. Simplified schematic of land use change as described by the UNEP-SETAC Framework. (Simplified from Milà i Canals et al. 2007, Koellner et al. 2013.)

$$\text{Impact} = \Delta Q \times A \times \Delta t \qquad \text{Eq. 1}$$

where:

Q = land quality (or other impact category)
A = area affected
t = time

In this description, the land use impact is the product of the land quality Q, the area of land directly affected A, and the duration time t of the impact. "Quality" on the y-axis represents applies to any impact category considered: in the UNEP-SETAC Framework, the y-axis refers to land quality, whereas here it refers to biodiversity quality.

The overall quantification of biodiversity is composed of two factors: an ecoregion factor and the actual assessment of the state of biodiversity at the given location. Biodiversity can be expressed via Equation 2 while the impact on biodiversity can be expressed via Equation 3:

$$\text{Biodiversity} = EF \times BP \qquad \text{Eq. 2}$$

where

EF = ecoregion factor
BP = biodiversity potential

$$\text{Biodiversity impact} = EF \times (1 - BP) \qquad \text{Eq. 3}$$

The biodiversity potential corresponds to a point in a multidimensional parameter space. The user obtains the function's value by entering a handful of parameter values x_i into (an ecoregion-specific version of) Equation 4. The scalar result can be interpreted in a similar manner as a potential function in field theory (e.g. a pressure potential that forces a fluid through a porous medium). The parameters are specific to each ecoregion, as is their combination in the biodiversity potential function. The values of these parameters are specific to processes in each ecoregion.

2.1. Ecoregion factor

The ecoregion factor is based on globally acknowledged biodiversity parameters, including total species richness, endemism, and vulnerability. Pertinent data, or proxies for the data, are obtained via online databases such as the World Wildlife Fund's WildFinder (WWF 2006). Michelsen (2008) does not call it an ecoregion factor but describes essentially the same methodological element as the combination of ecosystem scarcity (i.e. inverse area, or "smallness") and ecosystem vulnerability (i.e. inverse pristine fraction remaining, or "anthropogenic encroachment"). This factor makes impacts comparable across ecoregions by assigning a weighting factor to each region. We use a similar but refined system, in which the ecoregion factor is calculated using the area of a given ecoregion, combined with the species richness, endemic species richness, and conservation status. (Brethauer 2013) The calculation details of the ecoregion factor are beyond the scope of this paper; this paper focuses instead on the biodiversity potential functions. (For calculation details, see Brethauer 2013).

Each data point is processed through a function to yield a contribution. The contributions are combined through compromise programming, which uses a behavioral model to aggregate the various ecoregions and compute the ecoregion factor. Table 1 lists sample input data and corresponding ecoregion factors. Ecoregion factors typically range from 0.4 to 2.2. Approximately 75% of all ecoregions are assigned a factor between 1.2 and 2.1, indicating that most biodiversity impact potentials would be doubled (at most) after applying the ecoregion factor.

Table 1. Sample ecoregion factors and their required data inputs.

Code	**Ecoregion name**	**Area [km²]**	**Total species**	**Endemic species**	**Conservation status**[a]	**Ecoregion factor**
AT0117	Madagascar Lowland Forest	111,760	509	230	1	1.99
NA0612	Northern Canadian Shield Taiga	617,319	182	0	3	0.58
PA0445	Western European Broadleaf Forests	493,836	381	0	1	1.37

[a] Conservation status is a measure of threat to an ecoregion assigned by the WWF.

2.2. Regional biodiversity parameters and contribution functions

Regional biodiversity parameters form the building blocks of the biodiversity potential functions. A contribution function for each parameter links the value of the parameter to a biodiversity contribution value. The contribution values lie between zero and one, where zero corresponds to the minimum contribution and one to the maximum contribution. The closer the contribution value is to one, the closer the considered state of biodiversity is to "good". The term "good" is left deliberately undefined to accommodate varying conservation goals across ecoregions.

Picking appropriate parameters and defining the respective contribution functions require the developer to review the literature and to conduct a few expert interviews. National biodiversity strategies serve as a good starting point since every country participating in the Convention on Biological Diversity is required to have such a strategy document (UNEP 1992); reports from the International Union for Conservation of Nature (IUCN) and WWF reports are also good resources. The set of chosen parameters should include a mix of descriptive and management parameters, also known as pressure and state indicators, respectively, in the Driving-Force, Pressure- State- Impact- Response (DPSIR) Framework.

The expert interviews consist of a qualitative and a quantitative discussion of the parameters' relation to biodiversity. First, the qualitative discussion: the developer and the experts being interviewed identify the general form of each contribution function. The parameter value is measured on the x-axis and the state of biodiversity on the y-axis. A large parameter value, indicating a good state of biodiversity, would be reprepresented by a point along the curve in the upper right corner. A factor detrimental to biodiversity would be indicated by a downward slope along the x-axis.

Second, the quantitative discussion: once the general shape of each function has been determined, a mathematical description of the curve can be developed. Each parameter x_i is related to its biodiversity contribution y_i through the function $y_i(x_i)$. A few general equations, each with some extra variables for curve-fitting, usually suffice. Most contribution functions thus far have been straight lines, s-shapes or u-shapes (upward or downward). The specific equations, graphs, and critical points are presented to the experts being interviewed and adjustments are made when necessary. The curve can also be critiqued by a wider audience, e.g. in a webinar or via an online questionnaire, to avoid overdependence on a few selected experts (this has not been done yet in our ongoing project).

2.3. Regional biodiversity potential functions

Once the relevant parameters for a given ecoregion have been identified and their respective contribution functions have been determined, the biodiversity potential function for the given ecoregion can be constructed. The biodiversity potential function combines *n* parameter contribution functions and normalizes the sum to the (0, 1) interval, as shown in Equation 4.

$$BP = \frac{1}{n} \times \left[y_1(x_1) + y_2(x_2) + y_3(x_3) ... + y_n(x_n) \right] \qquad \text{Eq. 4}$$

Equation 4 would be appropriate for a situation in which the parameters impact biodiversity independently from one other and in which all parameters have the same degree of influence. If this is not the case and instead some parameters are deemed more important than others, the more important parameters can be given a higher weight (greater than 1/n) and others a correspondingly lower weight.

When the interaction between parameters is more complex, two or more contributions functions can combined in other ways. They could be multiplied together so that both y-values must be large to reach a large total contribution. Instead of multiplying the functions, a fuzzy intersection can also be suitable in such a situation. When parameters compensate each other’s contribution, a fuzzy union may be the best operational choice.

The result *BP* is the biodiversity potential function for a given ecoregion. It uses parameters as defined above as inputs and produces a scalar biodiversity value as the output.

3. Results

Parameters for the ecoregion PA0445 Western European Broadleaf Forests have been derived from the German National Strategy on Biodiversity (BMU 2007) and from expert discussions. Overall, nature conservation in Germany aims at producing and protecting low-intensity cultural landscapes (rather than pristine wilderness as in other parts of the world). The biodiversity contribution curves $y_i(x_i)$ are represented schematically in Figure 2.

Keeping the German context in mind, biomass removal is selected as the first parameter and is used as a proxy for management intensity. It is measured in multitudes of biomass production per harvest year. For example, a meadow from which all regrown biomass is harvested each year receives a parameter value of one. If half of the regrown biomass is removed, the parameter value is 0.5. A forest that is allowed to grow for 50 years and is then completely removed in a clear-cutting fashion receives a parameter value of 50 (probably not 50 because not all biomass remains to be harvested). These parameter values are the x-values of the contribution function. The function curve begins at large y-values, though not at the maximum. As the x-values increase, the biodiversity contribution rises to the top of the curve and then drops, eventually reaching a y-value close to zero (Figure 2, curve a).

The second parameter is fertilizer application, measured in kg N-surplus per hectare per year. Typically, ecosystems in the PA0445 ecoregion can cope with some N-surplus but an oversupply will allow fast-absorbing generalist plant species to outcompete the diversity of rarer niche species that are valued relatively high in conservation regulations. Fertilizer’s contribution curve is s-shaped, starting at the high end of the y-axis before descending and leveling out close to zero at high x-values (Figure 2, curve b).

The third parameter is pesticide application. The experts interviewed agreed that every bit of pesticide is too much. The contribution function therefore is a curve that begins at the high end of the y-axis but declines sharply from the onset, eventually leveling out near zero (Figure 2, curve c). As a possible measurement that allows capturing of the variety of pesticides, eco-toxicity scores make for a good starting point (e.g. “comparative toxic units, ecotoxicity” or CTUe from the USEtox model).

The fourth and final parameter was chosen to be small landscape structures, measured in total covered area. In open landscapes, the structures could be walls made from loosely stacked stones separating fields, hedgerows, groups of trees or even single trees, strips of alluvial forest alongside bodies of water, etc. The contribution curve begins with low y-values, rises to the maximum, and drops again as the x-values increase (Figure 2, curve d). The curve levels out with small y-values. This curve illustrates that an overly structured landscape will not allow for as much biodiversity as a spacious landscape with some small structures sprinkled throughout. Conversely, too few small structures would characterize an overly homogenous landscape.

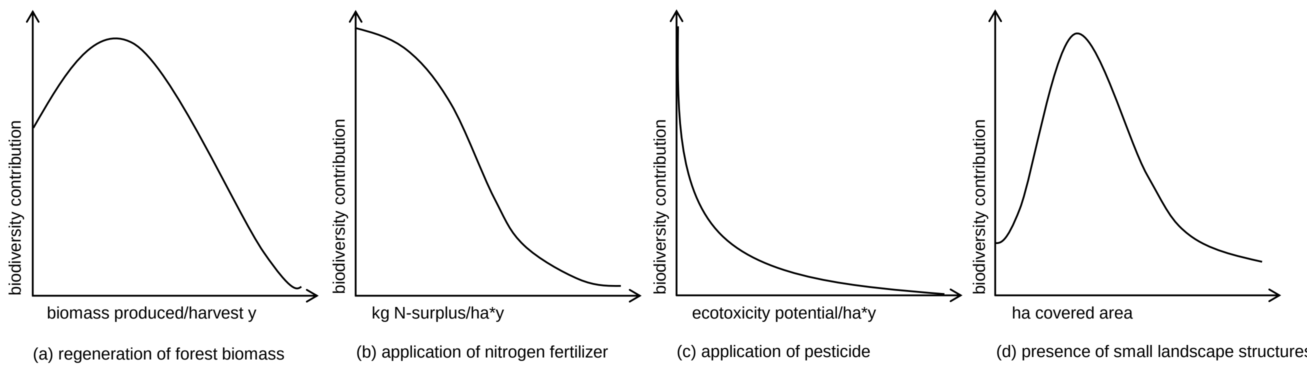

Figure 2. Biodiversity contribution curves of various parameters in ecoregion PA0445 Western European Broadleaf Forests (schematic).

The functions were combined via summation. This very simple function combination process is to be understood as a first iteration and will likely be revised in future developments of the method.

4. Discussion

As far as we can tell at this point, the methodological framework generally functions as intended. It is possible to capture a range of differing interpretations of biodiversity as a conservation target. If desired, the potential field function can be replaced by a regionally agreed-upon method and integrated into the overall framework (hence the word “unified” in the title). With all input parameters on a continuous scale—as opposed to categorized by land use classes—differences in management practices that would otherwise go unnoticed can be captured and evaluated.

Our method trades consistency for comprehensiveness. Its structure tries to mimic an expert’s impression of the overall state of biodiversity on an observed patch of land. Other methods that focus on particular measurable aspects of biodiversity (e.g. species diversity) are more consistent, however such methods (1) fail to capture biodiversity “as a whole” within a given region and (2) fail to acknowledge the varying interpretations of biodiversity across the globe. The method presented here is rooted in the conviction that a fuzzy subject like biodiversity requires an impact assessment capable of fuzzy analysis.

The reference state—a critical element for anything that uses the UNEP-SETAC land use framework—is implicitly defined as a byproduct of identifying the biodiversity parameters per ecoregion. For every parameter, there is a maximum biodiversity contribution. Anything below the maximum contribution is considered an impact. This means that the reference state represents a desired state of biodiversity as defined in national strategy documents. It acknowledges that whenever the term biodiversity makes the leap from a statistic to a political goal, it picks up a heavy normative load. We cannot define biodiversity as a conservation subject without naming what kind of biodiversity is actually desired. This defining task falls to governmental bodies, likely with the support of respected experts and conservation organizations.

Obviously, our biodiversity impact assessment method requires land use impact information that is typically only available for foreground systems. This challenge can be managed in two ways: (1) Archetypal combinations of parameter values can be developed that represent the majority of operations in a given ecoregion (e.g. “medium-sized cattle grazing operation in PA0445”), similar to archetypal emission profiles for industrial plants or vehicles. (2) Other more top-down biodiversity LCIA methods may be used for background system information, e.g. de Baan et al. (2012).

In regions with poorly defined conservation targets, hemeroby may serve as a surrogate since it is essentially a measure of naturalness. In absence of a specific “cultural” definition for biodiversity, such as the German one, naturalness seems like a good default. Michelsen and Coelho used hemeroby in a case study of the Michelsen method in New Zealand with moderate effort. As a composite index, hemeroby is not too different from the biodiversity potential described in this paper.

For more flexibility in the application of the method, distinguishing mandatory and optional parameters could help accommodate various types of activities. Parameters with general relevance for a given ecoregion would be mandatory while others would be selected from a list relevant only to certain activities.

5. Conclusion

This paper presents a method for biodiversity impact assessment in LCA. The first version of the method is currently being tested and is expected to undergo revisions over the course of the research project. Preliminary results, however, are promising and demonstrate the method's basic feasibility.

Inherent to the method is the concept of biodiversity as a fuzzy subject, both quantitatively and qualitatively. Depending on regional definitions and conservation goals, a regional biodiversity potential is defined. How much of this potential is conserved depends on regionally specific input parameters. The regional impact is weighted by the ecoregion factor to enable global aggregation. Other biodiversity LCIA methods are seen as contributors rather than competitors. This is especially true for regionally-specific methods, while the role of other methods as sources of background system information has been described as well.

To operationalize this method, the parameter list for PA0445 Western European Broadleaf Forests needs to be expanded and refined, and biodiversity potential functions for other regions need to be developed. Five case studies on various industry products are currently underway and are expected to offer further insight into the feasibility and accuracy of the method. Readers are encouraged to contact the corresponding author with criticism and other comments.

6. Acknowledgements

This work has been funded by the German Federal Agency for Nature Conservation (BfN). Further information about the project can be found at http://www.ibp.fraunhofer.de/de/Kompetenzen/ganzheitliche-bilanzierung/projekte.html (description in German, downloads in English).

7. References

BMU (2007) National Strategy on Biological Diversity. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Public Relations Division, Berlin

Brethauer L, Lindner JP (2013) Development of a method for assessing location characteristics concerning biodiversity in LCA. Poster at the 7th International Conference of the International Society for Industrial Ecology. Ulsan, South Korea

de Baan LR, Alkemade R, Koellner T (2012) Land use impacts on biodiversity in LCA: a global approach. Int J Life Cycle Ass 18: 1216-1230

Koellner T, de Baan L, Beck T, Brandao M, Civit B, Margni M, Milà i Canals L, Saad R, de Souza DM, Mueller-Wenk R (2013) UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA. Int J Life Cycle Ass 18: 1188-1202

MA (2005) Millenium Ecosystem Assessment: Ecosystems & human well-being – synthesis. Island Press, Washington

Michelsen O (2008) Assessment of Land Use Impacts on Biodiversity. Proposal of a new methodology exemplified with forestry operations in Norway. Int J Life Cycle Ass 13: 22-31

Michelsen O, Coelho CRV (2013) Land use impacts on biodiversity from kiwifruit production in New Zealand assessed with global and national datasets. Int J Life Cycle Ass 19: 285-296

Milà i Canals L, Bauer C, Depestele J, Dubreuil A, Freiermuth Knuchel R, Gaillard G, Michelsen O, Müller-Wenk R, Rydgren B (2007) Key Elements in a Framework for Land Use Impact Assessment within LCA. Int J Life Cycle Ass 12: 5-15

Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, D'Amico JA, Itoua I, Strand HE, Morrison JC, Loucks CJ, Allnutt TF, Ricketts TH, Kura Y, Lamoreux JF, Wettengel WW, Hedao P, Kassem KR (2001) Terrestrial ecoregions of the world: A new map of life on earth. BioScience 51: 933-938

TEEB (2010) The Economics of Ecosystems and Biodiversity. Ecological and Economic Foundations. Earthscan, London and Washington (all TEEB reports available at www.teebweb.org, last accessed 27 May 2014)

UNEP (1992) Convention on Biological Diversity. Treaty Series, No. 30619, United Nations, New York

World Wildlife Fund (2006) WildFinder: Online database of species distributions. Version January 2006 (available at www.worldwildlife.org/wildfinder, last accessed 27 May 2014)

This paper is from:

Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector

LCA Food 2014

8-10 October 2014 - San Francisco

Rita Schenck and Douglas Huizenga, Editors
American Center for Life Cycle Assessment

The full proceedings document can be found here:
http://lcacenter.org/lcafood2014/proceedings/LCA_Food_2014_Proceedings.pdf

It should be cited as:

Schenck, R., Huizenga, D. (Eds.), 2014. Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2014), 8-10 October 2014, San Francisco, USA. ACLCA, Vashon, WA, USA.

Questions and comments can be addressed to: staff@lcacenter.org

ISBN: 978-0-9882145-7-6