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Towards consensus on land use impacts on biodiversity in LCA: UNEP/SETAC Life Cycle Initiative preliminary recommendations based on expert contributions

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Abstract

The UNEP/SETAC Life Cycle Initiative organized two consensus-building workshops regarding Life Cycle Assessment (LCA) models and indicators for land use impacts on biodiversity. This article presents a synthesis of the main recommendations drawn from the opinions of the experts present, from the Initiative's perspective. The needs of LCA practitioners are crucial to determine what characteristics biodiversity assessment models should possess. Available models are mainly apt for impact hotspot detection in supply chains. If the goal is to assess the impacts of plot-level management practices they should be accompanied by other more detailed tools beyond LCA. Site-specific data are necessary to accurately assess biodiversity loss at regional and local scale, despite known constraints imposed by life cycle inventories. Examples of datasets are provided in this article. Species richness is a promising start for these models but it must be complemented with metrics for habitat configuration and intensity-based indicators. Finally, modelling results should be better coupled with policy decisions and existing strategic plans.

Keywords

Life Cycle Assessment; Life Cycle Impact Assessment; Land Use; Biodiversity; Ecology; UNEP/SETAC Life Cycle Initiative

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1 Introduction

Land use, including its resulting biodiversity impacts, is considered a priority impact category in LCA (Jolliet et al. 2014). In recent years substantial contributions were made in this topic, with the proposal of new models (e.g. Geyer et al., 2010a,b; Souza et al., 2013; Mueller et al., 2014) and mature discussions (Curran et al., 2011; Souza et al., 2015; Koellner et al., 2013a,b), but there is no significant consensus on the most suitable indicator and model elements/assumptions. The UNEP/SETAC Life Cycle Initiative is a platform promoting life cycle thinking for more sustainable societies. Under the efforts of its Phase III activities (2012-2017), the Flagship Project 1b targets consensus-building on existing environmental life cycle impact indicators/models within a set of impact categories that were previously prioritized as highly relevant and sufficiently developed methodologically within the field (Jolliet et al., 2014), including biodiversity impacts from land use. The aim of the biodiversity task force is to select and evaluate the most promising indicators and models to represent biodiversity features affected by land use. The final purpose is to provide feedback and recommendations from experts in ecology and conservation, as well as policy-makers from the public and private sector, on the integration of these indicators in Life Cycle Assessment (LCA). The mandate, initiated in 2014, targets a refinement of the cause-effect chain connecting land use to biodiversity impacts, the identification of important biodiversity features to be reflected in the indicator(s) used to model biodiversity change, and the comparison of existing land use models within and outside of LCA (Milà i Canals et al., 2014).

A key effort of the taskforce on land use and biodiversity is to bring into the discussion experts with different professional backgrounds related to ecology (conservation research, applied conservation, theoretical ecology, environmental management and policy, LCA etc.). To serve this end, two expert workshops were organized with a selection of experts based on prior work on the topic and institutional representation. The first 'Expert Workshop on Biodiversity Impact Indicators for Life Cycle Assessment' took place in San Francisco on October 7th, hosted by the US EPA. The workshop was attended by fourteen invited top experts in biodiversity metrics, LCA and ecology, as well as institutional and business partners. The second workshop took place in Brussels on November 18 and 19, hosted by the Confederation of European Paper Industries (CEPI). It was attended by twenty-four invited experts from equally diverse backgrounds.

The events included discussions centered around four topics pre-selected by taskforce members as key areas of disagreement or generalized lack of satisfaction within LCA (Milà i Canals et al., 2014). These topics are: (a) concept of biodiversity and modelling strategies, (b) data availability and feasibility, (c) desired characteristics of indicators, usability and consensus and (d) concerns and limitations about using biodiversity indicators in LCA. The last panel session (d) required input from the other sessions and as such was selected to close the event in Brussels, which ran for two days, and was absent from the San Francisco workshop due to time constraints. Both workshops started with introductory section designed to acquaint experts with the fundamentals of LCA, including the principles of life cycle inventory (LCI) and the framework of life cycle impact assessment (LCIA), mostly for the benefit of biodiversity experts without prior knowledge of LCA. The workshops consisted of discussion panels with different participants and as such, within each similar session, topics were handled differently. Figure 1 shows the session structure and summarizes the main topics tackled during each event. The topics for which some level of consensus can already be found (Milà i Canals et al., 2014) were left outside the scope of the discussions. These topics of widespread agreement are the land use assessment framework (Milà i Canals et al., 2007), the need for geographical differentiation in impact assessment (Souza et al., 2015), and the requirement for land cover/use class discrimination when assigning impacts (Koellner et al., 2013a).

This article presents the main learnings gathered by the taskforce during the two events. In the following sections we briefly narrate the taskforce interpretations of expert opinions and present key take-away messages. Divergent opinions from attendants in each workshop are duly noted. Recommendations drawn here will steer the goals of the taskforce going forward, namely in a systematic evaluation of biodiversity assessment models as well as in future recommendations of LCIA methods (Milà i Canals et al., 2014).

2 Conceptual discussion and modelling

The discussion in Brussels began with an attempt to understand why LCA is used and by which stakeholders, in order to design appropriate indicators tailored to user type. Within the broad sets of users, (*e.g.* public policy-makers, the private sector, consumers) three main uses of LCA can be defined: environmental improvements, product marketing and transparency/accountability. Two main questions were identified, corresponding to two different categories of users, namely comparative assertions ("is product A better than product B?"), and supply chain optimization/hotspot[1] detection ("what can we improve in our system?"). It was agreed that each category of user may require different modelling strategies and consequently data requirements might vary. The same idea was expressed in San Francisco, where participants highlighted the need to be clear about the kinds of decisions supported by LCA, and how reporting the results should be consistent with the accuracy and robustness of the LCA applications. This means that requirements for models addressing questions from the first user type, interested in comparisons, may be more stringent as they need to guarantee that different studies yield comparable results.

Experts then addressed how different causal pathways leading from land use to biodiversity change are and/or should be modeled in LCA. In San Francisco this discussion focused mainly on the need to go beyond taxonomic measures, such as species richness, which has extensively been applied in existing models (Souza et al., 2015). Important biogeographic concepts, such as habitat composition and configuration seem to be under-represented in impact assessment models. This lack is even more critical when the empirical Species-Area Relationship (SAR) underpins such models, as species abundance and distribution patterns can depend on the habitat configuration (Rybicki and Hanski 2013). Including habitat features in models is particularly crucial when quantifying impacts related to anthropogenic habitats, such as urban areas and, therefore, the capacity of human habitats to support species should be

1 The term "hotspot" refers to the steps in the supply chain responsible for the larger share of environmental damage, not "biodiversity hotspots" as used by some conservation organizations to describe highly species-diverse world regions.

considered. Experts conveyed that distribution-abundance relationships give important insights on inter-species relationships (*e.g.* competition) and may help predicting extinction risks (Verberk, 2011). In San Francisco the use of the matrix-calibrated SAR, developed by Koh and Ghazoul (2010), in LCA was also discarded due to a mathematical error. The countryside SAR (Pereira and Daly, 2006) is a promising alternative.

Both local intensity and regional state/pressure indicators require a reference against which impacts are measured. This reflects the desired direction of change for biodiversity in the region, and may be a fixed (semi-)natural state, such as the extensively used Potential Natural Vegetation (PNV), or a context-specific (current or historic) state. This choice of reference state was one topic of disagreement between attendants of each workshop. In Brussels, no conclusion was reached regarding a preference for the reference state in assessments. In San Francisco the use of current-historic reference states was reasoned as being more pragmatic and acceptable among the stakeholders, in comparison to the use of PNV. Participants in San Francisco considered that the latter is yet to be clearly defined, as high uncertainty is involved on the modeling of biodiversity recovery and resilience. One important observation made in Brussels was that the choice of reference has political implications. For example, a "current" reference state may disadvantage developing countries by penalizing future habitat loss whilst ignoring the historic loss that has taken place in developed countries.

Some final advices in San Francisco referred the need of drawing up a land use map including measures of fragmentation. Regarding the common problem when specific location of production is unknown it is advisable to provide uncertainties or at least a range of best and worst estimates. It is of crucial importance for model developers to provide not only values for different regions/countries but also for different agricultural practices and land uses/classes, and finally to be aware that the issues of scale are not really well contemplated in LCA.

3 Data availability and feasibility

A crucial limitation in any type of impact assessment model is data availability (Souza et al., 2015; Finnveden et al., 2009), as duly noted by participants in San Francisco. Experts agreed on the constraints imposed by currently existing links between inventory (LCI) elementary flows (previous and current land use, time of occupation) and impact assessment (LCIA), in the modeling of impacts on biodiversity. Current LCA operational models function without explicit consideration of geographic location and, withal software constraints, LCI data does not yet feature enough geographical information to feed into LCIA models. Likewise, the non-linear relationship between LCI data (e.g. land occupied/transformed in m^2.yr) and impact on biodiversity (e.g. potentially disappeared fraction of species locally) is impractical to implement in models that, in LCA, typically scale impacts up or down using simple proportionality. For biodiversity, however, the impact of converting *n* hectares of land is not necessarily the same as, or proportional to, *n* times the impact of converting one hectare. Additionally, one of the major concerns was related to the importance of background information and the difficulty to identify sourcing locations for some sectors (Earles and Halog, 2011), especially for the food industry. Therefore, the use of global/average values tacks on these matters and hinders modeling efforts.

Experts in both workshops thus discussed which properties an ideal biodiversity dataset should possess. In Brussels, a minimum set of desirable properties was reached: (1) global coverage of impacts, with high enough resolution to adequately represent local to regional changes (to assist supply chain management), (2) possible to aggregate at the spatial scale of life cycle inventories, (3) intuitive to interpret and sensitive to changes in land management, (4) up-to-date and temporally sensitive to relevant time-scales of environmental change, (5) carefully documented and transparent in terms of sources and methods description. Several available data sources were then discussed with reference to these properties, including product data sets (e.g. the Global Forest Watch), meta-analyses of the literature (e.g. the Convention on Biological Diversity's GLOBIO3 model), checklist data (e.g. WWF ecoregions and the WildFinder database), habitat-suitability and distribution models (e.g. the Map of Life project), various remote sensing and land cover data, national statistics (e.g. FAO), species information databases (e.g. the IUCN red list, extent of occurrence range maps, expert assessments). Due to single datasets not meeting all the desired properties listed above, combining datasets is likely the most desirable options based on their respective strengths and weaknesses.

Participants in San Francisco suggested the efforts to include biodiversity loss in LCA should be done in a stepwise manner, aiming at different sectors. Experts suggested that the first step in the development of impact assessment models should aim at identifying key commodities. Due to the high share of land used for agriculture, data from specific and relevant agricultural production sectors, followed by timber production, could be chosen as priority and impacts on biodiversity should be assessed by using land cover and area configuration. Focus on priority biodiversity areas, such as conservation hotspots, is a plausible alternative option.

4 Desired characteristics of indicators, usability and consensus

Moving on to particular indicators of biodiversity loss, participants in the Brussels workshop stressed that any indicator developed for LCA should be appropriately and transparently named to avoid misinterpretations (e.g. an indicator based solely on species richness should be defined as measuring “species richness” and not “biodiversity” as a whole). There was general support for a reduced set of quantitative indicators, even when this entails simplifications of the phenomena they depict. Indicators should always be fit for purpose (Mace and Baillie, 2007). Users interested in comparative assertions may use altogether different approaches and/or indicators from users interested in supply chain optimization within the same LCA framework. Indicators must also strive for communicability, be actionable, robust, and transparently acknowledge biases.

Participants in both workshops were unable to reach a decision on whether a single indicator can accurately depict changes to the state of biodiversity or if more are required. Experts present in Brussels were skeptical of the use of species richness loss as the main indicator for biodiversity in LCA, while experts in San Francisco considered species richness a good starting point. The latter understood the need to start with a simpler approach, yet able to attain the assessment of biodiversity impacts at different land covers/uses and geographic scales. Attendants stressed that model outcomes should deliver responses to land conservation policies and marginal decisions supported by LCA. Liaison with strategic plans and goals, such as the Aichi Biodiversity Targets, should be reflected on the results, enabling a more practical use of assessments. Brussels attendants asserted that if a single indicator is used, then a composite of multiple components would be necessary (Mueller et al., 2014). At minimum, the indicator set (either aggregated into a single index or kept separate) should reflect (i) the intensity of land use (i.e. local impacts in the occupied/transformed land), (ii) the geographic location of land use and the intrinsic conservation value (state) of biodiversity in the region (e.g. irreplaceability, intactness, endemism, evolutionary distinctness) and (iii) the vulnerability of biodiversity affected given existing pressures (e.g. threat intensity and sensitivity of biodiversity features). These indicators should be chosen at a relevant scale for the analysis, likely matching the system boundaries (i.e. global if the supply chain or production process is global). Current models in LCA have some of the desirable properties mentioned above (e.g. local and regional impacts, reflections of vulnerability), but likely require further development involving collaborations with conservation researchers.

5 Concerns and limitations about using biodiversity indicators in LCA

Experts agreed that for all purposes in LCA some level of validation of results, albeit indirect, is crucial. Validation using direct or indirect field evidence is complex in LCA, which mostly deals in potential impacts. Consequently, participants expressed worries about what uses can be expected from present (and, to some extent, all possible) LCA biodiversity models. There was consensus that available LCA models are sufficient for detection of potential hotspots of damage in supply chains. As a quantitative environmental footprint tool, LCA models should instead be used in combination with a suite of other more appropriate tools. This is the case, for example, if the practitioner uses LCA to compare products or optimize environmental outcomes, and it is particularly important when the LCA study involves assessment of farm management practices. The interpretation of results from an LCA biodiversity assessment should then lead to a deeper assessment using more detailed tools (likely beyond the scope of LCA) that account for local specificities (e.g. management practices and mitigation potential).

Participants believe good indicators of land use intensity should account for the land use practice/land cover class involved, relevant information from the inventory for other unit processes and agricultural inputs (e.g. fertilizer use) or some output measures (e.g. yield, HANPP). The inclusion of Net Primary Production (NPP) or Human Appropriation of NPP (HANPP), following Haberl et al. (2004, 2005), had already been suggested in San Francisco, since both are directly related to species richness and to biomass stocks, despite some ecosystems being notable outliers. These pressure measures should be related to state indicators such as (changes in) local species richness and similarity, evenness, abundance or classic diversity. Participants also believed land use intensity should be related to impact using non-linear functions.

Regarding particular modeling strategies in LCA, there was widespread agreement that it is already beneficial to go beyond inventory land use data (*i.e.* land area occupied/converted, land use/cover class) into an impact assessment model of biodiversity impacts (although specific LCA models were not considered in detail during the workshop).

6 Recommendations and conclusions

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UNEP/SETAC Life Cycle Initiative's Phase III will select and evaluate indicators and models to determine biodiversity impacts from land use (Jolliet et al., 2014). Interdisciplinary meetings are crucial opportunities to obtain clarifications and critical reviews from experts and institutions on the relevance and accuracy of methods and models in LCA. The Life Cycle Initiative's taskforce asked two groups of experts to team up in San Francisco and Brussels and contribute to its mandate of finding consensus on the inclusion of land use and biodiversity in LCA. The experts clarified many important points and also uncovered several new challenges that can move the field forward. The present article relays the main messages recorded during the event as understood by the taskforce in what relates to its goals.

The main messages that the Life Cycle Initiative's taskforce took away from the San Francisco meeting were the following. It remains problematic to reach an agreement on a single suitable indicator or set of indicators that fit the multitude of purposes for which LCA is used and that grasp the complexity of biodiversity. Species richness is a good starting point for assessing biodiversity loss, with the additional advantage that it is an indicator often used by LCIA developers. However, complementary metrics need to be considered in modeling, such as habitat configuration, including fragmentation and vulnerability, and intensity-based indicators (NPP/HANPP). Site-specific data are necessary to accurately assess biodiversity loss at regional and local scale, despite known constraints imposed by LCI data. Finally, modeling results should be better coupled with policy decisions and existing strategic plans.

In Brussels, there was a general agreement that an explicit modeling framework to estimate biodiversity loss is superior to basic inventory data for land occupation, and that available models are mainly apt for impact hotspot detection in supply chains – their use as quantitative biodiversity "footprint" must be accompanied by other more detailed tools. A good model should possess three components: (i) a representative, quantitative indicator(s) for local land use impacts, (ii) a state component at the regional level expressing intrinsic biodiversity values relative to other areas and (iii) a pressure component expressing regional threats to biodiversity relative to other areas. Specific indicators for the three components were discussed, but no agreement could be found. Finally, from the experts pointing out the limitations of existing LCA models, and recommending further developments, the taskforce took note of the need to incentivize explicit cooperation between LCA researchers and conservation researchers/organizations.

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Figure caption:

Figure 1 - Simplified scheme of major topics discussed during each section in each workshop. LC – Life Cycle; LCA – Life Cycle Assessment; LCIA – Life Cycle Impact Assessment; LCI – Life Cycle Inventory.