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Comprehensive approach for evaluating different resource types – Case study of abiotic and biotic resource use assessment methodologies

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ABSTRACT

Due to steadily increasing resource demand and accompanying raising public awareness, a variety of assessment methodologies evaluating resource use and its consequences were published in the last years. Existing methodologies are typically developed considering the specific characteristics of one particular resource type and as consequence are not suitable for cross-cutting assessment of different resource types. This paper proposes an 3-step approach for combining different resource use assessment methodologies allowing for a consistent assessment of product systems using different resource types. The first steps evaluate if the considered dimensions, categories, indicators, indicator models and underlying data are consistent. When this is the case, they can be included in the combined methodology without further adjustments. Differences are identified simultaneously and addressed in the subsequent steps. Within the steps guidance is provided on how the dimensions, categories and indicators of the methodologies can be adjusted to fit in the combined methodology. In a case study the proposed approach is applied to two methodologies developed by the authors assessing abiotic (ESSENZ method) and biotic resources and raw materials (BIRD method). The ESSENZ method consists of four dimensions, which are quantified by overall 21 categories and indicators. The BIRD method takes into account five dimensions and 24 corresponding categories and indicators. As none of the considered dimension of the two methodologies match, comparison of the considered resource types as well as application in a case study is not possible. By applying the proposed approach all five dimensions and 25 of the overall 27 categories and indicators can be integrated in the combined approach for a consistent assessment of abiotic and biotic resources and raw materials. The obtained combined methodology is then applied to three shelves made out of metal, wood and plastic. It could be shown that the introduced approach provides meaningful guidance on how to combine different resource use assessment methodologies and increases the findings gained from a combined and consistent assessment.

1. Introduction

Continuing global industrial and technological development has steadily increased the demand for resources. Their use has therefore been a topic of discussion throughout the last decades with regard to competition on resources (availability of resources and raw materials as well as related vulnerabilities of companies and countries) and corresponding environmental (e.g. climate change) as well as social aspects (e.g. working conditions). With that also the need to assess resource use and its related impacts has been growing. This led to the publication of a variety of assessment methodologies for evaluating resource use (mostly for abiotic resources and raw materials (e.g. Schneider et al. (2016), van Oers and Guinée (2016) and Berger and Sonderegger (2017)) as well as water (e.g. Pfister et al. (2009), Berger et al. (2014) and Núñez et al. (2016)), but also for biotic resources and raw materials (e.g. Oakdene and Faunhofer (2014) and Bach et al. (2017)) as well as land (e.g. Beck et al. (2010) and Koellner et al. (2013)). So far, almost all of these methodologies are developed explicitly for one type of resource only.

The term resource refers to entities, which can be extracted from nature and transferred to the anthroposphere. This includes abiotic and biotic resources, abiotic and biotic raw materials as well as water, land, and the natural environment (European Commission, 2005; Schneider et al., 2016; Sonderegger et al., 2017). Based on the specific characteristics of the considered resource or raw material, relevant aspects (and corresponding indicators) are defined. For instance, availability constraints are mostly associated with abiotic resources and raw materials (Dewulf et al., 2016), renewability rates with biotic resources (Crenna and Sala, 2017), scarcity for water (Pfister et al., 2017), etc. The development of methodologies for specific resource types allows

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accounting for relevant aspects in a consistent way. However, these methods do not allow for the assessment of any other resource types besides the one they are developed for. Some of the specific dimensions, categories and indicators applied cannot be transferred to other resource types and/or are not valid for these resources. This makes it challenging to assess different resource types in a consistent way. Following challenges occur in current assessments of several resource types:

- Dimension(s) and corresponding categories and indicators considered represent only the intersecting set (and therefore often only a small amount of dimensions, categories and indicators) and thus do not comprehensively reflect all aspects of resource use and its related implications (e.g. as shown by Ritthoff et al. (2002), Zabalza Bribián et al. (2011), Alvarenga et al. (2013) and Klinglmair et al. (2014)). For example, even though biofuels are made from renewable resources, which cannot be consumed in the same way as fossil fuels can, their use is limited by land and phosphorus availability (Hein and Leemans, 2012; Rulli et al., 2016; March et al., 2016). However, currently phosphorus and land use are often not addressed in the assessment of biotic materials (Rack et al., 2013; Finkbeiner et al., 2014; Mousavi-Avval et al., 2017). An adequate assessment of different resource types together can therefore not be achieved.
- Inadequate comparison of dimensions, categories and indicators occurs, when different aspects of the various resource types are addressed. For example: Acidification can be determined with different indicators (using different models and underlying data). Thus, even though results are provided for the category acidification within two methodologies, these results cannot be compared due to the differences in the applied indicators. If there are compared anyways, the comparison is inadequate.

This methodological gap is addressed in this paper, which has the aim of providing guidance for combining different resource use assessment methodologies and thus achieving a more comprehensive assessment and adequate comparison of different resource types.

In the next section, the proposed approach including a user-friendly flow chart for easy application is introduced (Section 2). Next, the approach is applied to a case study (Section 3), where two methodologies developed by the authors (one for the assessment of abiotic resources and raw materials and one for biotic ones) are combined according to the proposed approach. The combined methodology is then applied for an exemplary product system considering three sorts of shelves (made out of wood, plastic and metal). Further, challenges of the proposed approach are discussed (Section 4) and conclusions are drawn (Section 5).

2. Method

In this section the proposed approach to combine methodologies evaluating different resource types is introduced. To apply the proposed approach, it is assumed that the practitioner is familiar with the methodologies and aware of their shortcomings. The proposed approach can be applied for methodologies assessing resource use, independently from the number of aspects and indicators considered. However, as the goal of the approach is to combine multi indicator methodologies, the focus is on methodologies taking into account several categories and indicators (e.g. Graedel et al. (2012), European Commission (2014) and Bach et al. (2016a)) instead of methodologies considering only one or few indicators (e.g. van Oers et al. (2002), Valero et al. (2014) and Finnveden et al. (2016)). As indicators are designed differently depending on the level considered (micro (product), meso (company) or macro (company) level), methodologies can only be combined when they address the same level. The approach can be applied to combine two or more methodologies. For the sake of simplicity, this paper describes the combination of two methodologies.

The introduced approach consists of three steps, which guide the user to identify equal and different dimensions, categories and indicators applied within the considered methodologies. Step 1) and 2) have three possible outcomes: i) comparison of dimensions, categories and/or indicators is possible; ii) comparison is possible, because dimensions, categories and/or indicators can be rearranged, renamed and/or (re) calculated; iii) comparison is not possible, because rearranging, renaming and/or (re) calculating is not feasible and the user is guided to a subsequent step 3). Within this step, dimensions, categories and indicators are addressed, which could not be matched within step 1) and 2).

For non-experts in the field of life cycle assessment, life cycle impact assessment and sustainability assessment, a more detailed procedure is provided in the supplementary materials, including a user-friendly flow chart. Within the detailed approach the same principles are considered as within the 3-step approach, but are broken down to a more detailed level (Section 4 Supplementary Materials).

In the following, the 3-step approach is introduced and described in detail:

1) Check if the considered dimensions address the same aspects and categories

a. Yes, comparison is possible without adaptation
b. No, dimensions do not consider the same aspects and categories, but can be rearranged and/or renamed
c. No, dimensions do not consider the same aspects and categories and cannot be rearranged and/or renamed → they need to be further analyzed in step 3

2) Check if indicators, their models and underlying data are comparable

a. Yes, comparison is possible without adaptation
b. No, indicators, their models and underlying data are not comparable, but can be renamed and/or (re) calculated
c. No, indicators, their models and underlying data are not comparable and cannot be rearranged and/or (re) calculated → they need to be further analyzed in step 3

3) Check if missing categories and corresponding indicators are relevant for the evaluated resource and raw material

a. No → set indicator value to zero
b. Yes, categories are relevant and findings of other studies can be used to determine results of missing categories
c. Yes, but applying results of other studies is not possible → categories have to be excluded from the combined approach

In step 1) the user determines if the considered dimensions of the methodologies are equivalent by comparing their naming as well as addressed aspects and categories. Possible dimensions could be the classical sustainability dimension: environmental, economic and social (Giddings et al., 2002) as well newly developed dimensions like criticality (Sonnemann et al., 2015). If the same dimensions and categories are addressed, they can be considered in the combined approach without adaptation.

However, when the methodologies do not consider the same dimensions and categories, it has to be analyzed if they can be rearranged and/or renamed. For example: human health impacts are often considered as part of the environmental dimension, because impacts are determined as part of an Life Cycle Assessment (LCA) case study. Sometimes though these categories are seen as part of human well-being and are placed in the social dimension. These dimensions can be rearranged and renamed to be combined in a consistent way by shifting the assessment of human health impacts from the environmental dimension to the social dimension. Before dimensions and categories are