Expanding the coverage of ecosystem services in life cycle assessment: an interdisciplinary venture

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Summary

This thesis explores the incorporation of ecosystem services within the commonly used method of Life Cycle Assessment (LCA). As societies progress in their understanding and acknowledge that the natural environment provides us with vital and irreplaceable resources, so does the urgency to act for an improvement of human activities and avoid irreversible degradation of the environment. This work was motivated by the view that a comprehensive assessment of environmental impacts is indispensable in a transition towards more sustainable societies, which relies on identifying and assessing the multiple impacts caused by human activities. The overarching aim of this work is to bring forward a practical approach to characterize environmental impacts that are associated directly with ecosystem services in a compatible way with LCA.

In Chapter 1 we introduce the concept of ecosystem services, an approach that aims at identifying the multiple benefits that humans derive from the environment and from natural resources. We present the relevance of assessing anthropogenic impacts that affect ecosystem services within methods such as LCA, and provide a general introduction of a standardized framework. We highlight as well the importance of characterization factors, which are used during the impact assessment phase, translating Life Cycle Inventory (LCI) data into potential environmental impacts.

In Chapter 2, we first examined the extent to which ecosystem services have been incorporated within ReCiPe2016, a representative impact assessment method that is commonly used in LCA studies. For this we scrutinized both midpoint and endpoint impact categories, along with their impact characterization models and the ecological aspects considered within each model. We found a handful of impact categories that assess impacts on ecosystem services, and a general lack of guidance in the literature regarding which ecosystem services present compatibilities for future assessment within LCA studies. Addressing this gap, we derived a list of ecosystem service categories based on the Common International Classification of Ecosystem Services (CICES), that could be selected for future assessment in LCA. To achieve an optimal coverage, we recommend future efforts to target the development of new impact categories or the incorporation of ecosystem services in existing ones, which although time consuming, is an endeavor needed

to minimize negative trade-offs when comparing between environmental profiles.

Chapter 3 follows the recommendations derived in the Chapter 2, and targets the incorporation of an ecosystem service identified as missing while developing generalized recommendations for services that present similar characteristics. To do this, Chapter 3 dives into the characterization of land use impacts on pollinator abundance, a measure selected as representative of the state of pollinator communities, with land use identified as the main impact driver of pollinator impacts. Along with the support of an expert in the field of pollination, we successfully illustrate the proposed impact assessment model by deriving an exemplary set of characterization factors that allows to evaluate land use impacts on pollinator abundance in a compatible way to be used in LCA studies.

In Chapter 4, we target key data gaps found in Chapter 3 with an expert elicitation method, and present the first set of readily applicable characterization factors to assess land use impacts on pollinator abundance. To do this, we reached out to experts in the field of pollination which resulted in a panel composed of 25 researchers, spanning 16 nationalities and with a combined experience on more than 40 geographical regions across the globe. A Delphi expert elicitation method consisting of three consecutive rounds of survey was applied, and the statistical convergence of estimates was assessed through a coefficient of variation measure. This successful collaboration exemplifies clearly the way that interdisciplinary research is essential to overcome limitations that can hinder the assessment of key ecosystem services.

In Chapter 5, we explore the use of land system archetypes to characterize soil erosion impacts and assess the representation of intra-national differences in country specific characterization factors. From the characterization factors obtained, covering 263 countries and 8 land use types, the results indicate a high variability when all the archetypes within a country were accounted for. Hence, the impact characterization showed higher variability than when using solely the most predominant archetype within a country. An alternative reference state, the 'current land use mix' was used instead of the Potential Natural Vegetation, which allowed to account for prevailing soil degradation. With information derived from land system archetypes, we were able to identify vulnerable areas based on both biogeographical and socioeconomic aspects. The use of archetypes is recommended as a promising avenue of research to further

regionalize the characterization of land use impacts at compatible scales with LCI data.

Chapter 6 builds on the experiences and insights from the previous chapters to propose generalized recommendations to tackle the assessment of ecosystem services in LCA. Furthermore, we address in this chapter some of the challenges encountered during the characterization of land use impacts. We highlight as well the relevance of continuously improving and expanding the coverage of environmental impacts assessed in LCA studies. With the increasing acceptance of the LCA method, the demands for its representativeness to compare the environmental implications of product and service systems also increases and ecosystem services assessment should be one of them.

Altogether, we envision the work of this thesis to contribute to the body of knowledge aimed at a better coverage of environmental impacts, and supports future research by presenting a practical approach to tackle the development of new impact categories that address ecosystem services.