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COMMENTARY AND DISCUSSION ARTICLE

Comment to "Marginal and non-marginal approaches in characterization: how context and scale affect the selection of an adequate characterization factor. The AWARE model example"

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1 Introduction

Life cycle assessments and life-cycle-thinking-based footprints aim at supporting management decisions (ISO 2006), traditionally at the level of products and processes, and increasingly at larger scales such as organizations, sectors, and territories (Hellweg and Milà i Canals 2014; ISO 2014; Forin et al. 2019a). Such large systems often come along with large-scale inventories, according to the reference flow or reporting unit chosen. At the same time, several impact assessment methods use a marginal characterization approach, which assumes "sufficiently small" inventories that do not change the background situation, without providing alternatives for "larger" inventories that might affect the background.

The article "Marginal and non-marginal approaches in characterization: how context and scale affect the selection of an adequate characterization factor. The AWARE model example" (Boulay et al. 2019) acknowledges that marginal characterization approaches are not suitable for large-scale inventories (which potentially affect the background) and suggests using average characterization factors to overcome this problem in the case of retrospective assessments. This procedure is in line with the current discussion and the recommendations of the Life Cycle Initiative hosted by UN Environment (Verones et al. 2016, 2017). In addition, the authors make explicit that the average approach helps to avoid the drawbacks typical to marginal factors (dependence on inventory size and non-additivity), which, in the case of water scarcity footprint, fueled the scientific dispute in the community in the last years (Hoekstra 2016: Pfister et al. 2017).

In an outlook paragraph, the authors offer insights into integrative LCA (also called *incremental* in Guinée and Lindeijer (2002)), suggesting its use for non-marginal, prospective assessments (i.e., with water consumption taking place in the future) using non-linear characterization functions. In the same context, the incremental/integrative approach is defined as the generalization of marginal and average approaches (which provide constant characterization factors, thus not requiring a case-by-case calculation).

The article raises attention on the often-neglected assumptions underlying impact assessment methods, thus providing a valuable contribution for LCA method developers and practitioners. Such assumptions have become more visible while considering large-scale inventories but are relevant to all system types and sizes. The aim of this comment is to add further considerations on how the context of the study should be accounted for when selecting the most appropriate characterization approach. We argue that (i) value choices made within the goal and scope phase, and not the inventory size, should be decisive for the choice between an average and an incremental/integrative approach (with the marginal approach being a special case of the latter) (Section 2) and (ii) the retrospective or prospective character of the assessments is not a discriminant for the choice of the characterization approach (Section 3). Following this reasoning, we suggest an alternative algorithm for selecting the characterization approach (Section 4) and provide conclusions (Section 5).

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2 Incremental/integrative vs. average approach

The incremental/integral approach calculates the integral below the "final part" of the derivative of the impact curve (from the working point backwards), thus taking into account only the impact of the system under study considered as the last user (Fig. 1, left). It represents the maximal impact a user in that basin can have, thus reflecting the precautionary principle. The additivity paradox still holds, like for the marginal special case: if all inventories in a certain basin are characterized at the end of the curve, the sum of the surface areas provides an overestimation. This could theoretically be solved by assigning different users to different intervals of the *x*-axis. Which user should then be considered the first one (and have a lower impact per unit of water consumed) and which user the last one (taking a higher burden)? A decision on the field of water user prioritization would be arduous, for both ethical reasons and for the effort needed, e.g., for a case study of a complex product using water from several basins. The average approach, instead, prevents from both overestimation and prioritization by dividing the whole impact at the working point by the basin inventory and is applicable regardless of the inventory size (Fig. 1, right).

The average approach is good for more than solving the additivity dilemma. For example, if category indicator results at a large scale (e.g., for organizations or sectors) were used to mitigate the water scarcity hotspots along product life cycles or organizations' value chains by engaging also other water users at the basin level (e.g., integrated water resource management or water stewardship), using an average approach would reflect the burden sharing mindset needed to engage in common water scarcity mitigation measures. In other words, the notorious goal and scope can influence the choice of the impact assessment approach in several ways (as indicated by the influence of *decision contexts* on modeling approaches by Boulay et al. (2019)) and multi-user mitigation initiatives such as water stewardship as an emerging field of application for resource footprints (Forin et al. 2019b) should be taken into account.

To sum up, the choice between the incremental/integral approach (with marginal CFs as a special case thereof) and average CFs is not solely dependent on the size of the life cycle inventory—it rather depends on the value choice whether the study intends to analyze the maximum impact at a basin's current stage or the average impact of all users, which accumulated over time.

3 Retrospective vs. prospective assessments

The reasoning above applies for both retrospective and prospective assessments. Boulay et al. (2019) express reservations for the use of average characterization for future consumption, acknowledging literature that argues with the lack of underlying land use change models. At the same time, the incremental/integral characterization approach proposed in the outlook section also lacks underlying land use change models but simply follows the characterization function beyond the reference state. With a similar exercise, average characterization can be performed as well, i.e., by calculating the integral of the derivative impact function between 0 (or a target value as suggested by Huijbregts et al. (2011)) and the assumed total future consumption (present consumption plus additional consumption). The underlying value choice is, as for retrospective assessments, whether (present and future) users share the burden with other basin users or are considered as last users following the precautionary principle. The disadvantage is only on the practitioners' side: category indicator results need to be calculated case-by-case and cannot be easily inserted in software products or retrieved in table format.

Still, we acknowledge that temporal discrepancies between the data underlying impact assessment models and inventory data might lead to less meaningful results. However, this applies to both retrospective and prospective assessments. The AWARE method, for example, is based on hydrological data from the WaterGAP model dating back to 2010 (Flörke et al. 2013), thus not reflecting changes in water availability or water consumption that took place in the last decade. Should prospective assessments be then the default option? If yes, the same reasoning should be applied to other characterization methods too, which would strongly change the way of doing LCA. Moreover, without more up-to-date hydrological models, it is not possible to guess the development of water availability and whether the water consumption reflected by the inventory substitutes past water consumption or should be considered additional. This said, we encourage method developers to update their methods and to develop specific ones for future assessment taking into account, e.g., future land use and climate change scenarios.

4 The water scarcity characterization algorithm

Figure 1 summarizes our considerations and illustrates the choice hierarchy we suggest. First, it should be considered whether the assessment should be performed (i) next to the working point (incremental/integral, with marginal as a special case), with the advantage of reflecting the precautionary principle and the disadvantage of non-additivity (which would lead to overestimation of impacts), or (ii) at an average level, following a burden-sharing approach. This initial decision can be applied to both retrospective and prospective assessments, by simply shifting the integral limits.

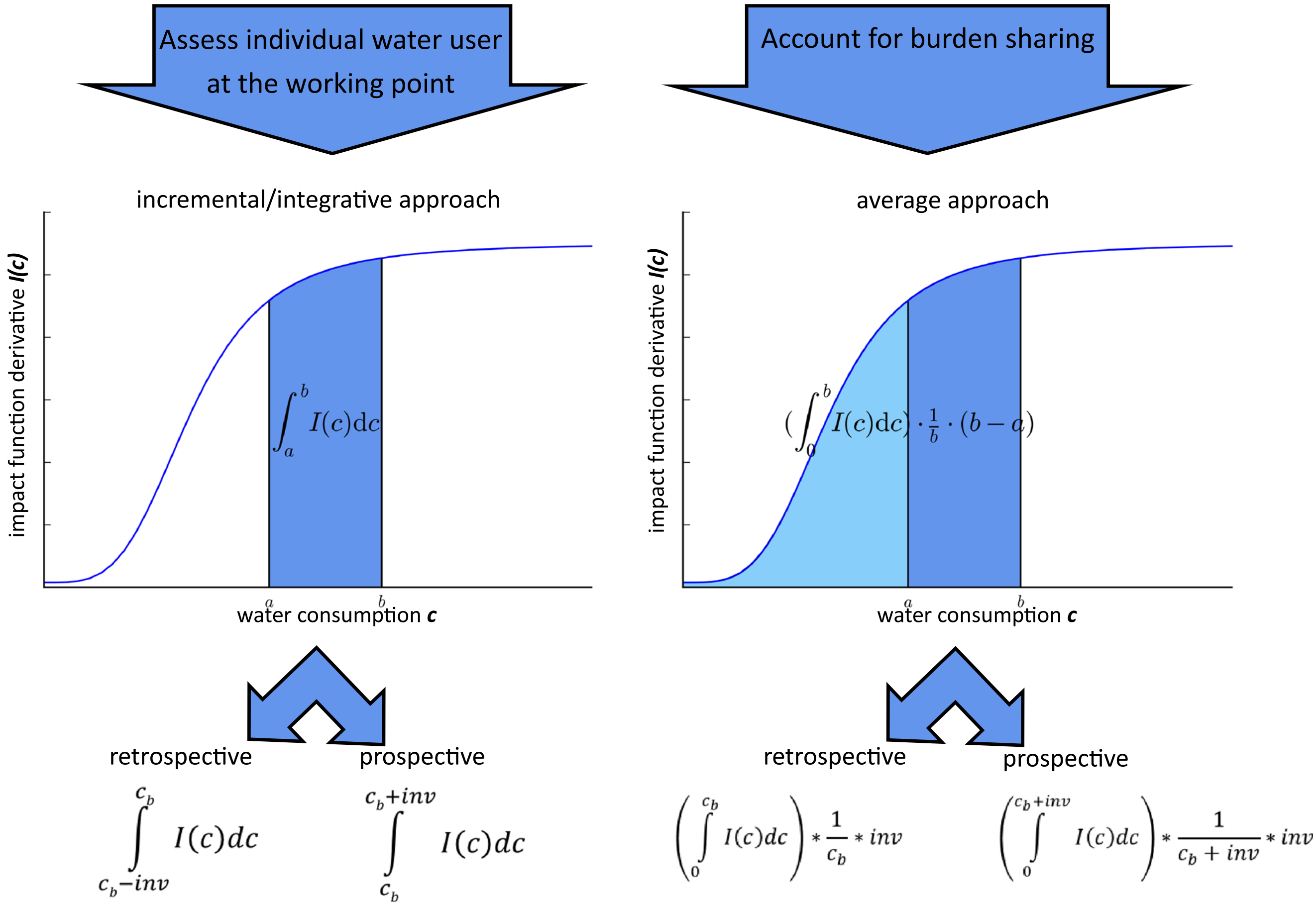

Fig. 1 Illustration of the characterization algorithm for a generic logistic derivative of a water scarcity impact function $I(c)$ as function of water consumption c. The equations to calculate the category indicator result for the generic cases and in detail for the retrospective and prospective case are made explicit, where c_b is the present basin-level water consumption (equivalent to b for retrospective assessments and to a for prospective assessments) and inv = inventory = $b - a$

5 Conclusions

To sum up, according to Table 1 in Boulay et al. (2019), the choice of the characterization approach (marginal, average, or incremental/integrative) is mainly a matter of scale, or inventory size (and therefore affected by the functional unit or reporting unit), and of timing (retrospective vs. prospective water consumption). While agreeing that these factors are relevant, we argue that the decisive distinction line should be drawn between the following: (i) approaches taking into account a single user next to the working point (incremental/integrative and marginal as a special case for small inventories) and (ii) the average approach, which implicitly considers all water users within one basin as equally damaging, or, in a mitigation perspective, as sharing the burden originated by the impact. By adding this additional perspective on the context-dependence of the choice based on the burden-sharing vs. last-user dichotomy, inventory size and timing assume a subordinate role in the choice of the characterization approach. For small inventories, the incremental/integrative option can be approximated by a marginal characterization; timing influences only the integral limits (and therefore the resulting numerical values) but does not affect the choice between the burden-sharing approach (average CFs) and the precautionary principle (incremental/integral approach or marginal CFs).

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