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Arnaud Hélias[1,2,3], Reinout Heijungs[4,5]

[1]LBE, Montpellier SupAgro, INRA, Univ Montpellier, Montpellier, France
[2]Elsa, Research group for Environmental Life cycle and Sustainability Assessment, Montpellier, France
[3]Chair ofSustainable Engineering, Technische Universität Berlin, Berlin, Germany
[4]Institute of Environmental Sciences (CML), Department of Industrial Ecology, Leiden University, Einsteinweg 2, 2333 CC Leiden, The Netherlands.
[5] Department of Econometrics and Operations Research, Vrije Universiteit Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands.
E-mail contact: arnaud.helias@supagro.fr

1. Introduction

This extended abstract is based on elements of a recently published article [1]. In LCIA, the resource issue is still debated and remains the least consensual area of concern. The currently popular assessment models for resource depletion are based on "heuristic" considerations. This paper deals with the use of a stock dynamic model to address the resource depletion by marginal approach. It shows how the Abiotic Depletion Potential [2] anticipated the result and gives us ideas for managing the dissipative use of resources.

2. Materials and methods

2.1. Abiotic depletion potential

Guinée and Heijungs [2] published a "proposal" for the construction of Characterization factors (CFs) for abiotic and biotic resources on the basis of an abiotic depletion potential (ADP). Based on heuristic reasoning ("both reserves and deaccumulation ... should somehow be included in an equation ... indicating the seriousness of depletion") and formal mathematics (unit independence), they offer a formula for assessing resource depletion on the basis of a CF that has deaccumulation (similar to production) P_f in the numerator, and reserve (measured in some way) R_f squared in the denominator: $CF_{AD,f} = const \times P_f / {R_f}^2$

For the constant $const$, they used the same expression for a reference flow which was antimony for abiotic depletion. The resulting score was then expressed in kg Sb-equivalent. Recently, CFs for biotic resource depletion based have been proposed [3, 4]. They are defined by a marginal approach used on a fish stock model $CF_{fish} = const_f \times P_f / {R_f}^2$ (see Fig 1 for an overview of the approach). With the similarities between both CFs, it is interesting to look at the parallel we can draw.

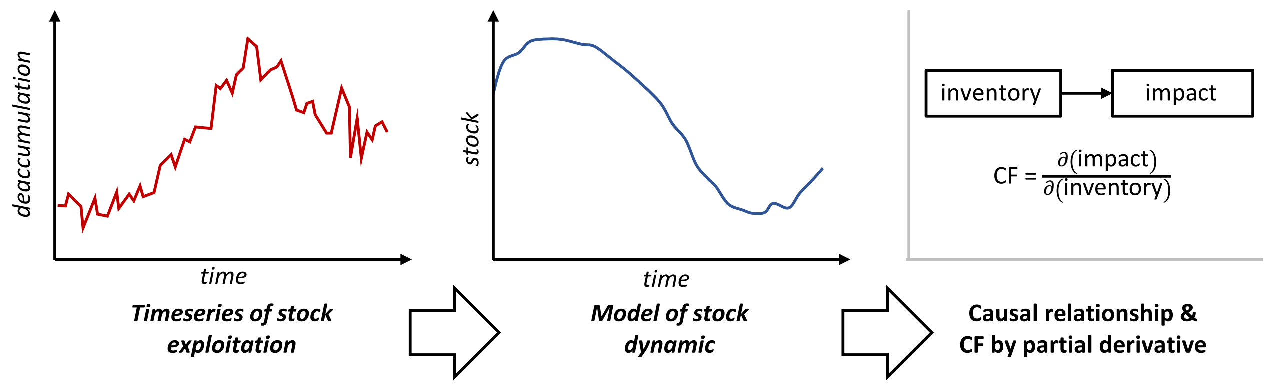

Figure 1. Schematic of the CF derivation from bottom-up model.

2.2. Marginal depletion potential

The fish population dynamics model in [4] is based on the very common logistic function. In use for nearly two centuries, the logistic curve is applied in many domains such as stock management, ecology, biology, chemistry and economics. This is also the relation used in the Hubbert peak theory [5]. In the Hubbert curve model, the extraction rate P_f is a function of the current (R_f) and the initial ultimately extractable (U_f) reserves.

We use the shape of the model to describe the current depleted resource fraction ($DRF_f = 1 - R_f/U_f$). This fraction equals to zero for a never exploited resource and tends towards one with the depletion. Note that there is, from a conceptual point of view, an analogy with the potential affected fraction of species (PAF) and indirectly with the potential disappeared fraction of species (PDF) used for the ecosystem quality.

DRF_f is taken as the impact to assess for the resource depletion. The inventory flow is then a mass of extracted resource, removed from the current reserve R_f. The use of the marginal approach relates the marginal change of the impact according to the marginal change of the inventory. The use of partial derivative therefore makes it possible to define the CF of the resource depletion on the basis of the Hubbert theory (where we have changed the subscript AD from the classical abiotic depletion to HD for the one based on the Hubbert peak theory): $CF_{HD,f} = -\frac{\partial DRF_f}{\partial R_f} = const_f \times P_f/{R_f}^2$

3. Results and discussion

3.1. Empirical comparison

The difference between the two approaches, $CF_{AD,f}$ and $CF_{HD,f}$, lies in the constant part of the equations with a fixed (antimony-based) unit conversion factor for CF_{AD} and a resource-specific parameter for CF_{HD}. The two CF values are thus not directly comparable, but we can study them with data coming from the same source [6]: $CF_{AD,f}$ and $CF_{HD,f}$, are highly correlated ($r = 0.99$ with p-value $\ll 0.001$, based on the Pearson correlation between the logarithms of the two sets of CFs). Considering ADP as a marginal approach applied on resource dynamic models offers interesting perspectives. This implies that the CF design is based on a model which was developed in the relevant research fields, like it is for other impact categories.

3.2. Perspectives for dissipative use

With ADP being seen as a marginal approach of the resource de-accumulation, the next step is an assessment of more complex models, combining the extraction and the recycling dynamics. The resulting balance represents the dissipation of the resource. This changes the assessed stock: it would be a wider one, merging the extractable reserve in the environment and the quantity usable in the technopshere (anthropogenic stock). The definition of the CF dealing with this stock must be made with particular attention to the dynamics: the evolution of the dissipation rate depends on the recyclability of the resource but is also determined by the market. The cost of extracting the resource contributes to the price and therefore to the commercial interest of recycling. This extraction cost is also partially determined by the availability of the resource (DRF_f). This means that representing the dissipation of a resource requires a complete modelling of stock dynamics to define the CF through a marginal approach.

4. Conclusions

If theoretically Hubbert theory-based ADPs have a better theoretical foundation than the more heuristic original ADPs, we show here that the original ADP is a very good estimator for the CF derived as a marginal depletion characterization factor from the Hubbert curve. The models we have discussed suggest a similar approach for biotic and abiotic resources. This could contribute to a more consensual pathway for the resource area of concern, which is a hot topic in LCA. Moreover, the resource depletion potential design now fits better in the overall framework of LCIA, where CFs are partial derivatives from dose-response type of models

5. References

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