ACCOUNTING LAND AS NATURAL RESOURCE FOR ENERGETIC AND EXERGETIC LCA: A NEW METHOD

Rodrigo Augusto Freitas de Alvarenga [1*], Jo Dewulf [1], Herman Van Langenhove [1]

[1] Department of Sustainable Organic Chemistry and Technology, Ghent University, Belgium.
* Corresponding author: E-mail: Rodrigo.Alvarenga@UGent.be. Telephone: (++32) 9 264 99 25. Fax: (++32) 9 264 62 43. Address: Coupure Links, 653 – Blok B – 9000 Gent, Belgie.

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ABSTRACT

Life Cycle Assessment (LCA) is an environmental assessment methodology that considers the life cycle perspective of products (goods and services). It is divided in four steps, and in the Life Cycle Impact Assessment (LCIA) stage is where the potential environmental impacts are raised [1, 2]. Some other assessment methodologies can be considered as LCIA methods when the life cycle approach is considered. For energetic and exergetic analysis, three resource-based LCIA methods are found in literature: Cumulative Energy Demand (CED) [3], Cumulative Exergy Demand (CExD) [4], and Cumulative Exergy Extraction from the Natural Environment (CEENE) [5]. These methods are well structured for evaluation of fossil fuels, but for biofuels there is still room for some advances regarding the biotic resources, which in the one way are accounted by the energy or exergy content in biomass (in CED and CExD, respectively), while in other way the land area where the biomass is grown is accounted (CEENE). There is no consensus in which is the best approach, but the methods are flexible, and the researcher can decide what to account (the energy/exergy of the biomass or the land for growing). When this happens, special attention has to be given because only one way should be chosen; otherwise double-counting may occur. The way of accounting for land in the CEENE method (by solar radiation) can also be found in other energetic and exergetic analysis [6], but might be considered misleading, since the fraction of solar radiation used for photosynthesis is influenced by several factors, including water availability, soil quality, temperature, etc. The objective of this paper is to introduce a way of accounting for land through its potential Net Primary Production (NPP). NPP is the amount of biomass production of a certain area and it represents how much energy is available to transfer from plants to other trophic levels in the ecosystem [7, 8]. It is an output indicator influenced by several factors [9] and it is in accordance with ecosystem thermodynamics theory [10, 11]. The potential NPP is an estimation of the possible natural biotic production that would occur in a certain area if there was no land use or land use change. A regionalized database over the World is available [8]. Therefore, regarding the challenge of considering regional aspects in LCA [12], to account for land occupation through potential NPP might give better results since other site-dependent factors would be considered. In NPP data, the unit usually considered is mass of carbon (gC/m^2a) or dry matter ($kgDM/m^2a$), but since the aforementioned resource-based LCIA methods produce single score results (in energy or exergy), the units of NPP have to be transformed. This obstacle may be overlapped through the creation of generic energy/exergy conversion factors for biomass, which may be regionalized in biome level. This new approach was applied in a sugarcane case study from Brazil and the results were confronted with the three original LCIA methods. The analysis was considered until the farm gate ("cradle-to-gate"), and we used data from ecoinvent database. CED and CExD presented a slight increase on the total value (around 1%), while CEENE had a decrease of 42%. The Potential NPP appears to be a good indicator for accounting land as natural resource, having advantage of availability of a regionalized database. It is important to point that the potential NPP mentioned here is the "natural" NPP, considering that no land use change would have occurred; not a potential NPP "produced" by men through forestry or agricultural practices.

Keywords: Land, NPP, LCA, Resource

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RESULTS AND DISCUSSION OF THE CASE STUDY

In order to visualize the changes that would occur by considering the approach aforementioned, we applied it in one case study of sugarcane, considering its production in the state of Sao Paulo, Brazil. The changes occurred are presented in Figure 1.

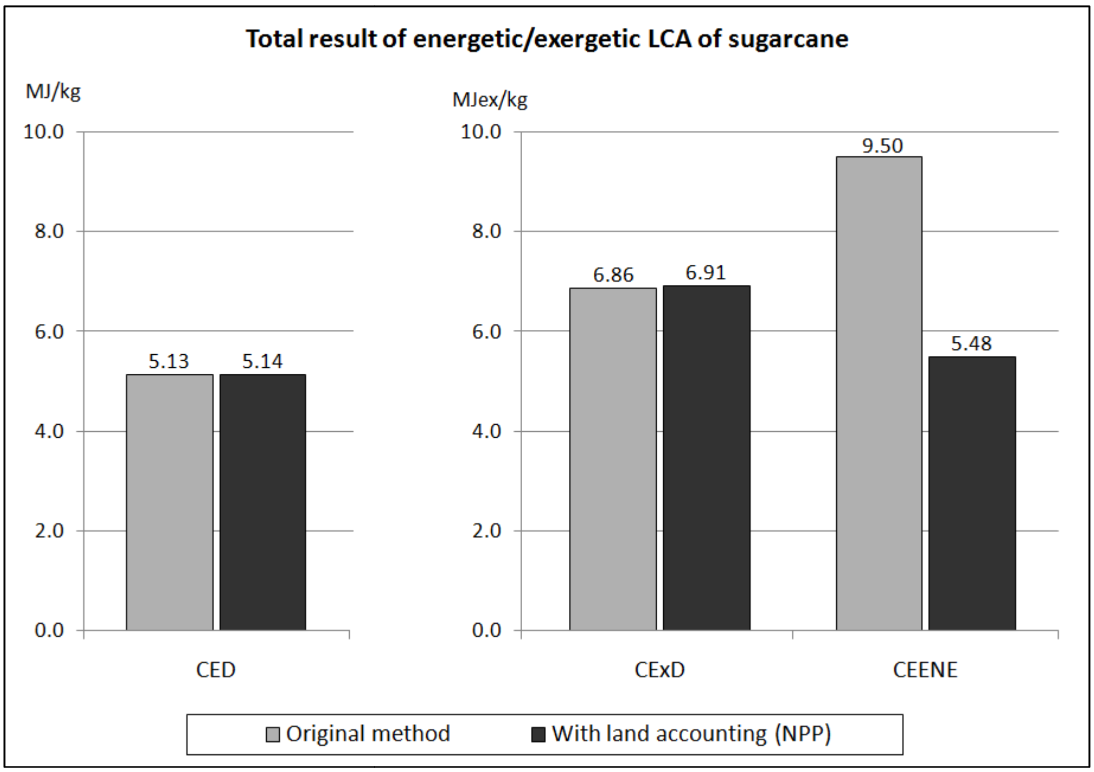

Figure 1: Total result of energetic (CED) and exergetic (CExD and CEENE) LCA of sugarcane, from cradle-to-gate, by the original method and by land accounting through potential NPP

In light gray is presented the values of CED, CExD, and CEENE for 1 kg of sugarcane, at the farm gate. In black are presented the values if the approach would be implemented, which was done by two ways: (a) For CED and CExD we neglected the value of the energy and exergy of the sugarcane and considered the potential NPP of the area needed to grow the crop; (b) For CEENE we neglected the exergy of 2% of solar radiation for the area of land occupied, and considered the potential NPP of the same area. For all of them it was considered an average value of potential NPP, from the north of Sao Paulo state, of 900 gC/m^2a

The differences between the original methods and with the new approach were small for CED and CExD mainly because sugarcane has a high fraction of its total above-ground biomass [6]. This means that the value of energy/exergy on the sugarcane is approximate to the value of total NPP, for the same area. If other crops were considered (e.g. soybean) higher values would appear. The variation on the CEENE method could be higher if the 2% of solar radiation considered would be from the state of Sao Paulo, instead of an average value of Western Europe as it is considered originally in the method (which characterization factors are site-generic).

REFERENCES

1. International Organization for Standardization (ISO), ISO International Standard 14044: Environmental management — Life cycle assessment — Requirements and guidelines. In International Organization for Standardization: Geneva, Switzerland, 2006; p 54.
2. International Organization for Standardization (ISO), ISO International Standard 14040: Environmental management — Life cycle assessment — Principles and framework. In International Organization for Standardization: Geneva, Switzerland, 2006; p 28.
3. Hischier, R.; Weidema, B.; Althaus, H.-J.; Doka, G.; Dones, R.; Frischknecht, R.; Hellweg, S.; Humbert, S.; Jungbluth, N.; Loerincik, Y.; Margni, M.; Nemecek, T.; Simons, A. *Implementation of Life Cycle Impact Assessment Methods: Final Report ecoinvent v2.1.*; Swiss Centre for Life Cycle Inventories: St. Gallen, Switzerland, 2009.
4. Bösch, M.; Hellweg, S.; Huijbregts, M.; Frischknecht, R., Applying cumulative exergy demand (CExD) indicators to the ecoinvent database. *The International Journal of Life Cycle Assessment* **2007,** *12*, (3), 181-190.
5. Dewulf, J.; Bosch, M. E.; Meester, B. D.; Vorst, G. V. d.; Langenhove, H. V.; Hellweg, S.; Huijbregts, M. A. J., Cumulative Exergy Extraction from the Natural Environment (CEENE): a comprehensive Life Cycle Impact Assessment method for resource accounting. *Environmental Science & Technology* **2007,** *41*, (24), 8477-8483.
6. Brehmer, B.; Struik, P. C.; Sanders, J., Using an energetic and exergetic life cycle analysis to assess the best applications of legumes within a biobased economy. *Biomass and Bioenergy* **2008,** *32*, (12), 1175-1186.
7. Erb, K.-H.; Krausmann, F.; Gaube, V.; Gingrich, S.; Bondeau, A.; Fischer-Kowalski, M.; Haberl, H., Analyzing the global human appropriation of net primary production -- processes, trajectories, implications. An introduction. *Ecological Economics* **2009,** *69*, (2), 250-259.
8. Haberl, H.; Erb, K. H.; Krausmann, F.; Gaube, V.; Bondeau, A.; Plutzar, C.; Gingrich, S.; Lucht, W.; Fischer-Kowalski, M., Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. *Proceedings of the National Academy of Sciences* **2007,** *104*, (31), 12942-12947.
9. Costanza, R.; Fisher, B.; Mulder, K.; Liu, S.; Christopher, T., Biodiversity and ecosystem services: A multi-scale empirical study of the relationship between species richness and net primary production. *Ecological Economics* **2007,** *61*, (2-3), 478-491.
10. Dewulf, J.; Van Langenhove, H.; Muys, B.; Bruers, S.; Bakshi, B. R.; Grubb, G. F.; Paulus, D. M.; Sciubba, E., Exergy: Its Potential and Limitations in Environmental Science and Technology. *Environmental Science & Technology* **2008,** *42*, (7), 2221-2232.
11. Doka, G.; Hillier, W.; Kaila, S.; Köllner, T.; Kreißig, J.; Muys, B.; Quijano, J. G.; Salpakivi-Salomaa, P.; Schweinle, J.; Swan, G.; Wessman, H. *The Assessment of Environmental Impacts caused by Land Use in the Life Cycle Assessment of Forestry and Forest Products: Guidelines, Hints and Recommendations.*; Final Report of Working Group 2 “Land use” of COST Action E9: 2001; p 92.
12. Hauschild, M., Spatial Differentiation in Life Cycle Impact Assessment: A decade of method development to increase the environmental realism of LCIA. *The International Journal of Life Cycle Assessment* **2006,** *11*, (0), 11-13.