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Towards the Assessment of an Ecological Index for Quantifying Sustainability of Day Life. A Case Study of the Environmental Consequences of Dietary and Transport in a Standard Workday

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Abstract: This article proposes a novel and simple methodology to evaluate eco-profiles of usual anthropic activities in order to promote the sustainable development. The case study refers to a standard work day, evaluating the sustainability of the life style of a hypothetical worker, in consideration of different standard meals provided by a canteen and a series of transport options from home to the work place. The eco-profiles of single products were evaluated with the Life Cycle Assessment (LCA) methodology, according to the LCA-food database given by the software SimaPro 7.2.4 [1]. The results of the LCA of single goods are hence linked to a sustainability index, assigned on the basis of the percentage of their impact in comparison with the most impacting option of each category between the considered meals and transportation options. The idea to summarize with a mark the eco-profile results of a LCA, aims to simplify the interpretation of results and gives to decision makers and single consumers a fast and comprehensive overview of the environmental consequences associated to different options. Considering this specific case, the results show clearly how dietary habits can largely affect the sustainability of single workers and how the combination of a vegetarian menu with the use of public transport is ever associated to low scores, indexes of very-low impacts.

Keywords: LCA food, LCA transportation, sustainability index.

1. Introduction

The issues concerning the environmental sustainability of industrial productions and life styles of developed and developing countries represent a critical urgency that have to be faced by the modern society, as underlined by many international institutions that are warning against the dramatic effects that future generations could suffer [2-6]. Within this contest one of the most powerful and universally accepted tool for sustainability investigation is represented by the Life Cycle Assessment (LCA) methodology. According to the directives reported by the European Platform for LCA [7], the life cycle approach seeks to identify possible improvements to goods and services, along the whole production chain, and aims to reduce impacts and use of resources. A rigorous LCA study has the purpose of evaluating the overall impacts "from cradle to grave", starting from the raw materials extraction until the end of life of the investigated product, and crossing through the phase of use [8].

Although the effectiveness of the life cycle approach is well accepted to quantify correctly the impacts and its potentiality of supporting the sustainable development is out of the question, a global consensus about the interpretation of results is not yet achieved. It is, as example, not still unanimously accepted which impact categories should receive more attention and higher priority from decision makers [9]. Eshun et al. [10] criticized how almost the totality of methods that aims to quantify the environmental impacts evidence the limit to evaluate these problems only considering how they manifest themselves in the western world, instead than globally, and cannot be easily adapted to different realities like the African countries. They particularly underline how critical aspects such as biodiversity loss or wood waste, that severely affect many countries of the third world, are scarcely considered by the most of the LCA studies. Moreover a second goal of the LCA would be the detection of social impacts on communities along the whole chain, which represent a problem very complex to be evaluated by the analytical approach of a standard LCA [11-13].

In reason of these aspects the LCA itself can be often not sufficient, at the moment, to support proficiently the best decisions. In addition the results of a LCA alone require a high level of competencies to be comprehended and can be often difficult to be correctly interpreted by final users or decision makers. In reason of that, the possibility to integrate the LCA study with additional information, complementary to the standard evaluation methods, can be a very effective tool. In regard of that Cunningham et al. [14] have recently developed an internal criterion at the Shell Group, associating their products with a score that summarises and quantify the high quantity of information, taking in consideration the environmental, the social and the economical aspects, that are provided by a life cycle analysis, in order to support the final decisions of their management.

The present work wants to analyse the environmental burden associated to daily behaviours of not-specified workers in a typical work day, in particular considering transportation and lunch. Different options of menus have been considered as well as different means of transportation. The study proposes the quantification of the environmental load with a sustainability index, which aims to summarize the results and offer to the reader a quick and comprehensible response about his daily behaviour and habits. It is in fact opinion of the Authors that the possibility to associate a mark, that synthesises the results of the LCA, can represent a simple and understandable tool to be shown to decision makers and single consumers, influencing their decision by taking also into account the aspect of sustainability. Moreover when sustainability indexes can be internationally known, the possibility to promote or reject a product or a behaviour as sustainable will be easier. Finally it has to be underlined that this study analyses only the environmental load related to the life cycle of the considered products and not the social and economical aspects that would require a more detailed investigation and further information.

2. Methodology

The LCA methodology was introduced with the aim of evaluating the environmental profiles of industrial processes, as well as the effects of anthropic activities on the environment. The LCA approach considers the environmental impact along the whole life cycle of a product, as well as the one of intermediary goods. According to ISO 14040:2006 [8], LCA is pursued in four main stages: goal and scope definition, life cycle inventory, life cycle impact assessment and interpretation and implementation of the results and of these stages only the first three are mandatory.

The definition of goal and scope in this kind of analysis aims to identify the objectives and the level of accuracy of the analysis. This phase has the purpose of defining the system boundaries, the assumptions of the study and the functional unit (a base-reference unit assumed to evaluate the impact). Moreover the whole process has to be defined at this stage, and a flow chart that considers inputs and outputs of each single step is required.

The Life Cycle Inventory (LCI) has the scope of reporting, in detail, the inputs and outputs (raw materials, energy consumption, energy sources, use of toxics etc.) that are involved in the whole process. The information that aims to fill the inventory can be principally divided in two main categories: primary data and secondary ones. Primary data that comes directly from the investigated process represent the best available option. However the possibility to have a direct access to all the primary data of a process represents a very optimistic and rare option, and in reason of that a considerable number of LCA databases are commercially available and normally used to integrate the missing data of the lifecycle (secondary data).

The Life Cycle Impact Assessment (LCIA) has the aim of analytically quantifying the environmental burdens of the overall chain, on the basis of a series of standard indicators. However, consensus has still not been reached concerning indicators that should be used to exhaustively quantify the environmental loads. The indicators that will be used in this work to quantify the environmental loads of a standard work day are:

- CED (Cumulative Energy Demand)
- GWP (Global Warming Potential)
- ODP (Ozone layer depletion)
- POCP (Photochemical oxidation)
- AP (Acidification Potential)
- EP (Eutrophication Potential)

The SimaPro 7.2.4 [1] software was employed to conduct the LCA analysis, and EPD 2008 (Environmental Product Declaration) [15] and CED v1.07 (Cumulative Energy Demand) [16] methods were used to evaluate the environmental impacts.

The stage of interpretation and implementation of results represents the final additional phase of a LCA study. The possibility to have a subsequent critical analysis of the results, possibly involving subjects with a different know-how, is a milestone for implementing and proficiently using the high number of information coming from the LCA, with the purpose to save energy and raw materials as well as to identify possible risks for the environment and human health.

This work aims to focalize its attention to this stage, and proposes an index to assess the sustainability of the different analyzed solutions for transportation and lunch, assigning to each option a score, and hence a mark. The Authors believe in fact that the possibility to present the environmental load with a simple index can be easy and quick understood by decision makers and single consumers. With an internationally-accepted simplification of the results of the LCA, it would be easier to identify the products which promotes or not sustainability and force institutions and companies to go through the route of sustainable development. Table 1 presents the environmental indexes proposed by the present study that offers a simple and quick interpretation, and assesses a scale of sustainability.

Table 1. Environmental indexes descriptions and values

Index	Description	Percentage
1	Very low impact	0% - 15%
2	Low impact	16% - 40%
3	Medium impact	41% - 60%
4	High impact	61% - 85%
5	Very high impact	86% - 100%

It has been assumed that an impact achieving 1 or 2 as index can be considered as a sustainability promoter, 3 represent the sufficiency while 4 or 5 do not promote sustainability. In this case the indexes have been assigned on the basis of the percent values obtained dividing each impact value by the highest one of the same category. As example, in order to assign a sustainability index to the Cumulative Energy Demand (CED) impact of a vegetarian menu, it is necessary to divide the CED impact of the vegetarian menu by the CED impact of the beef menu (highest value of the same category): the percentage is 53% and consequently the index is 3.

The two categories (food and transport) have been deliberately considered separately, in order to evidence the sustainable behaviours that can supply basic necessities. The total impacts of the considered menus and means of transportation are reported in the following tables.

Table 2. Impact values (EPD 2008 and CED v1.07) and impact percentages of the proposed menus

Menu	CED (MJ)	GWP ($kgCO_2eq$)	ODP (kgCFC-11eq)	POCP (kgC_2H_4eq)	AP ($kgSO_2eq$)	EP ($PO_4^{3-}eq$)
beef menu	17.75	5.60	4.28 E-07	1.93 E-03	4.53 E-02	4.58 E-02
poultry menu	11.21	0.90	1.28 E-07	4.90 E-04	6.90 E-03	3.57 E-03
pork menu	10.83	0.93	1.56 E-07	5.73 E-04	7.62 E-03	4.54 E-03
vegetarian menu	9.39	0.59	1.01 E-07	4.14 E-04	2.58 E-03	1.49 E-03
% beef menu	**100**	**100**	**100**	**100**	**100**	**100**
% poultry menu	**63**	**16**	**30**	**25**	**15**	**8**
% pork menu	**61**	**17**	**37**	**30**	**17**	**10**
% vegetarian menu	**53**	**11**	**24**	**21**	**6**	**3**

Table 2 shows the values of the single impacts associated to series of fully balanced menus that can be generally provided by a canteen, as well as the impact percentage.

Table 3 shows the single impact scores associated to different transport options, which can be normally used to cover the distance between home and the work place in a town. The data of table 3 are referred to a travel route of 10 km, having considered the hypothetical home 5 km away from the work place and taking in consideration the fact that the same way has to be covered twice (to go to work and to go home).

Table 3. Impact values (EPD 2008 and CED v1.07) and impact percentages of the proposed transport options

Transport option	CED (MJ)	GWP ($kgCO_2eq$)	ODP (kgCFC-11eq)	POCP (kgC_2H_4eq)	AP ($kgSO_2eq$)	EP ($PO_4^{3-}eq$)
passenger car (petrol)	31.42	1.82	2.14 E-07	2.95 E-03	4.93 E-03	1.41 E-03
passenger car (diesel)	28.83	1.65	2.07 E-07	1.65 E-03	4.77 E-03	1.50 E-03
Bus	16.78	1.04	1.52 E-07	1.54 E-03	6.07 E-03	1.58 E-03
Tram	11.90	0.26	1.96 E-08	1.73 E-03	1.10 E-03	6.23 E-04
Bicycle	0	0	0	0	0	0
% passenger car (petrol)	**100**	**100**	**100**	**100**	**81**	**89**
% passenger car (diesel)	**92**	**91**	**97**	**56**	**79**	**95**
% bus	**53**	**57**	**71**	**52**	**100**	**100**
% tram	**38**	**14**	**9**	**59**	**18**	**39**
% bicycle	**0**	**0**	**0**	**0**	**0**	**0**

3. Materials

3.1. Food

The menus were drawn up on the basis of indications given by the canteen at the Politecnico of Turin (Italy), proposing representative options as quantity and kind of dishes, in order to offer balanced and complete meals [17].

The environmental load attributable to the cooking process has been estimated on the basis of the natural gas and the electrical energy consumed by a canteen kitchen. Average transport values based on the information available from Sotral EPD [18] have been added to each menu.

Four different menus, proposing three different kinds of meat (beef, poultry or pork) have been proposed together with a vegetarian menu, where the meat has been substituted by peas [19].

- *Beef menu:* rice (100g), beef steak (120g), carrots (150g), bread (50g)
- *Poultry menu:* rice (100g), poultry (120g), carrots (150g), bread (50g)
- *Pork menu:* rice (100g), pork steak (120g), carrots (150g), bread (50g)
- *Vegetarian menu:* rice (100g), peas (120g), carrots (150g), bread (50g)

Table 4 shows the environmental load, expressed by the selected impact indicators (EPD 2008 and CED v1.07), and related to 1 kg of each food considered.

Table 4. Contribution of each type of food on the environment impact

Food (1kg)	CED (MJ)	GWP ($kgCO_2eq$)	ODP (kgCFC-11eq)	POCP (kgC_2H_4eq)	AP ($kgSO_2eq$)	EP ($PO_4^{3-}eq$)
rice	17.8	2.88	1.20 E-07	5.30 E-04	8.97 E-03	7.36 E-03
beef steak	72.1	42.19	2.88 E-06	1.32 E-02	3.60 E-01	3.72 E-01
poultry	17.6	3.04	3.79 E-07	1.20 E-03	4.03 E-02	1.95 E-02
pork	14.4	3.24	6.14 E-07	1.89 E-03	4.63 E-02	2.76 E-02
peas	2.4	0.48	1.59 E-07	5.60 E-04	4.28 E-03	2.16 E-03
carrots	0.5	0.06	3.05 E-08	1.07 E-04	4.69 E-04	2.75 E-04
bread	4.8	0.77	8.72 E-08	3.53 E-04	3.85 E-03	5.59 E-03
water	6.2 E-03	3.2 E-04	1.71E-11	1.64 E-07	1.21 E-06	8.74 E-07

3.1. Transport

The present study considers as options for the transport: cars, buses, trams and bicycles. For the car the fuel was considered also as additional parameter of distinction, taking into account petrol fuelled car and a diesel fuelled car. These two options have been considered separately, since they are the most common choices in Europe. Buses were considered to be diesel-fuelled, while trams were considered to be powered by electricity, according to the European average for this means of transport. The following aspects were considered for all the different types of mobility: type fuel (except in the bicycle case), vehicle production and maintenance, roads (rails in the tram case) construction and maintenance.

4. LCA Inventory

4.1. Food

The data on the environmental impacts of *rice* were taken from an LCA study [20] that evaluates the whole production chain operating in the Vercelli district (Italy). The data concerning *tap water* were provided by the Ecoinvent Database [16]. The data on *beef steak*, *chicken meat, pork steak, peas*, *carrots* and *bread* were taken from the LCA Food Database [21]. Data on *beef steak* are referring to information provided by three Danish slaughterhouses in 2001-2002, data on *chicken meat* are referring to eleven Danish slaughterhouses for the years 1997-1999, data on *pork steak* are calculated on the basis of information from Danish slaughterhouses for the years 1997-1998, data on *peas* and *carrots* are referring to Danish vegetables grown outdoors, and finally *bread* was produced by an industrial bakery, considering consumption related to the whole process. In each case the system boundaries are "from cradle to gate".

4.2. Transport

The data on the environmental impacts of *each transport mean* are provided by the Ecoinvent Database [16]. The impacts due to the processes concerning the operation of the vehicles, production, maintenance and disposal of the vehicles, construction and maintenance and disposal of the roads (rails in the *tram* case), were included in the case of *car, bus* and *tram*. Data concerning *passenger cars* are referred to the European average of the car fleet for the year 2010. Two different kinds of car were considered: petrol and diesel fuelled cars. Data concerning *buses* and *trams* are referred to the Swiss scenario, which can be considered extensible to the entire European scenario. The *buses* are considered diesel fuelled. Data concerning *bicycles* are estimated on the basis of the following hypothesis: the environmental loads pertaining to their use is zero, while the impacts due to the bicycle manufacturing are negligible, considering the entire life cycle of a bicycle. In each case the system boundaries are "from cradle to gate".

5. Results and discussion

Table 5 presents the sustainability indexes related to the fully-balanced menus of the canteen. It can be asserted how the beef menu can be totally rejected as promoter of sustainability, while the vegetarian menu represents the best available option for the environment with a average mark of 1.67. Between these two options there are instead the alternatives presenting pork or poultry in the menus, with sustainability index values around 2, that in the present work are still considered promoters of sustainability.

Table 5. Impact indexes related to the impact indicators of each menu

Menu	Average	CED (MJ)	GWP ($kgCO_2eq$)	ODP (kgCFC-11eq)	POCP (kgC_2H_4eq)	AP ($kgSO_2eq$)	EP ($PO_4^{3-}eq$)
beef menu	**5.00**	5	5	5	5	5	5
poultry menu	**2.00**	4	2	2	2	1	1
pork menu	**2.17**	4	2	2	2	2	1
vegetarian menu	**1.67**	3	1	2	2	1	1

Table 6 reports the sustainability marks related to the transport options considered by this study. As general consideration it is possible to assert that the private fuelled-options (petrol and diesel car) can be rejected as promoter of sustainability while the public options represent a more eco-friendly alternative. In particular the tram, in European countries, can represent a preferable option in comparison to the bus in urban areas. The bicycle, due to the negligible impacts of its life-cycle, is finally the best option ever and the possibility to promote the use of this solution in the town can be a very effective solution to sustain the environmental protection.

Table 6. Impact indexes related to the impact indicators of each transport option

Transport option	Average	CED (MJ)	GWP ($kgCO_2eq$)	ODP (kgCFC-11eq)	POCP (kgC_2H_4eq)	AP ($kgSO_2eq$)	EP ($PO_4^{3-}eq$)
passenger car (petrol)	**5.00**	5	5	5	5	5	5
passenger car (diesel)	**4.50**	5	5	5	3	4	5
Bus	**3.83**	3	3	4	3	5	5
Tram	**1.83**	2	1	1	3	2	2
Bicycle	**1.00**	1	1	1	1	1	1

Finally table 7 shows the sustainable behaviours of a hypothetical worker, combining menus and means of transportation. The choice of the beef at lunch never implies a sustainable behaviour and only when supported by the use of the bicycle achieves the sufficiency. On the other side, a vegetarian worker promotes the sustainability and, in particular when used together with the bicycle, produces a very low impact. Between these two dietary options, there are the menus having on poultry and pork, that when combined with public transport or with the bicycle represents a sustainable option, while when they are associated to a private car do not constitute a virtuous behaviour.

Table 7. Impact indexes of daily habits of hypothetic workers

	beef menu	poultry menu	pork menu	vegetarian menu
passenger car (petrol)	5.00	3.50	3.58	3.33
passenger car (diesel)	4.75	3.25	3.33	3.08
Bus	4.42	2.92	3.00	2.75
Tram	3.42	1.92	2.00	1.75
Bicycle	3.00	1.50	1.58	1.33

6. Conclusions

This work assesses the environmental sustainability of two basic need of the modern society, evaluating the environmental impact of different dietary and transport options. The possibility to reduce environmental impacts promoting more eco-friendly life styles, appears in fact as a very potent weapon for fighting against climate change and ecological damages. The main obstacle to adopt different behaviours is principally due to the necessity to break the mixture of conservatism, cultural heritage and indifference rooted in developed societies but, on the other hand, offers the advantage to have an immediate effectiveness and do not present any technological or economical drawback that can slow down their penetration in the market.

If the necessity to access food and transportation is a fundamental right for each citizen of modern society, a mature reflection about how we can supply them in a more responsible and social manner should represent as well a mandatory duty. The results here presented shows clearly how the possibility to prefer the use of public or ecological solutions, like tram or bicycle, as well as a wider diffusion of a vegetarian or at least beef-free dietary, can largely promote the environmental sustainability. In addition, this work proposes a simple and quick presentation of the LCA results with specific marks, which can facilitate the interpretation of the sustainability level of daily behaviours or industrial productions. The Authors proposed a scale to quantify the environmental burden resulting from a LCA analysis, believing how the establishment of internationally-accepted parameters defined by well known and respected institution, such as International environmental agencies, or governments agreement, will facilitate the penetration of the LCA adoption within companies and productive realities as well as increase the idea of sustainable development in the public opinion. It is important to underline that this paper has the aim to propose a method for simplifying LCA results interpretation and wants to be a baseline for further studies.

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Pré - Product Ecology Consultants. SimaPro 7.2.4 software; Amersfoort, The Netherlands, 2010.
2. FAO - Food and Agriculture Organization of the United Nations. *Livestock's Long Shadow Report. Environmental issues and options*, Rome, Italy, 2006. [WWWdocument]. URL: ftp://ftp.fao.org/docrep/fao/010/a0701e/a0701e.pdf (accessed on October 28th, 2011).
3. Mertens, B.; Poccard-Chapuis, R.; Piketty, M.G.; Lacques, A.E.; Venturieri, A. Crossing Spatial analyses and livestock economics to understand deforestation processes in the Brazilian Amazon: the case of Sao Félix do Xingu in South Para. *Agricultural economics* **2002**, 27 (3), 269-294.
4. Seidl, A.F.; Vila de Silva, J.d.S.; Moraes, A.S. Cattle ranching and deforestation in the Brazilian Pantanal. *Ecological Economics* **2001**, 36, 413-425.
5. WWF - Worldwide Fund for Nature. *Forest for Life. WWF's Global Annual Forest Report '97*, 1997.[WWWdocument].URL:http://wwf.panda.org/what_we_do/how_we_work/conservation/forests/publications/?3598/WWFs-Global-Annual-Forest-Report-97 (accessed on October 28th, 2011).
6. WWF - Worldwide Fund for Nature. *Living Planet Report 2010. Biodiversity, biocapacity and development*,2010.[WWWdocument].URL:http://wwf.panda.org/about_our_earth/all_publications/living_planet_report (accessed on October 28th, 2011).
7. European Commission - JRC Join Research Centre – Life Cycle Thinking and Assessment - Institute for Environment and Sustainability [WWWdocument]. URL: http//lca.jrc.ec.europa.eu (accessed on October 28th, 2011).
8. ISO - International Organization for Standardization. *ISO 14040: Environmental Management: Life Cycle Assessment, principles and guidelines,* Geneva, Switzerland, 2006.
9. Miettinen, P.; Hamalainen R.P. How to benefit from decision analysis in environmental life cycle assessment (LCA*). European Journal of Operational Research* **1997**, 102, 279-294.
10. Eshun, J.F.; Potting, J.; Leemans, R. LCA of the timber sector in Ghana: preliminary life cycle impact assessment (LCIA). *International Journal of Life Cycle Assessment* **2011**, 16, 625-638.
11. Dreyer, L.C.; Hauschild, M. Z.; Schierbeck, J. A Framework for Social Life Cycle Impact Assessment. *International Journal of Life Cycle Assessment* **2006**, 11 (2), 88-97.
12. Jørgensen, A.; Le Bocq, A.; Nazarkina, L.; Hauschild, M. Methodologies for Social Life Cycle Assessment. *International Journal of Life Cycle Assessment* **1997**, 13 (2), 96-103.
13. Weidema, B.P. The Integration of Economic and Social Aspects in Life Cycle Impact Assessment. *International Journal of Life Cycle Assessment* **2006** Special Issue 1, 11, 89-96.
14. Cunningham, B.; Battersby, N.; Wehrmeyer,W.; Fothergill, C. A Sustainability Assessment of a Biolubricant. *Journal of Industrial Ecology* **2003**, 7 (3-4), 179-192.
15. ISO - International Organization for Standardization. *ISO 14025: Environmental labels and declarations - Type III environmental declarations - Principles and procedures*, Geneva, Switzerland, 2006.

16. Frischknecht, R.; Jungbluth, N.; Althaus, H.J.; Bauer, C.; Doka, G.; Dones, R.; Hischier, R.; Hellweg, S.; Humbert, S.; Köllner, T.; Loerincik, Y.; Margni, M.; Nemecek, T. Implementation of Life Cycle Impact Assessment Methods. *Ecoinvent report No. 3*, Volume 2; Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland, 2007.
17. Politecnico di Torino, private documentation provided by the Canteen Management; Turin, Italy, 2010.
18. Sotral. *EPD - Environmental Product Declaration For The Logistic Service Applied To Meal Delivering In Public Catering*, 2008. [WWWdocument]. URL: http://www.sotral.it/public/sotral/Documenti/EPD_ENG_DEF.pdf (accessed on October 28th, 2011).
19. IOM - Institute of Medicine. *Nutrition Standards and Meal Requirements for National School Lunch and Breakfast Programs: Phase I. Proposed Approach for Recommending Revisions.* Washington, DC, The National Academies Press, 2008. [WWWdocument]. URL: http://www.fns.usda.gov/ora/menu/published/cnp/FILES/SchoolMealsIOMPhaseI.pdf (accessed on October 28th, 2011).
20. Blengini, G.A.; Busto, M. The life cycle of rice: LCA of alternative agri-food chain management systems in Vercelli (Italy). *Journal of Environmental Management* **2009**, 90, 1512-1522.
21. Nielsen, P.H.; Nielsen, A.M.; Weidema, B.P.; Dalgaard, R.; Halberg, N. *LCA food data base*, 2003. [WWWdocument]. URL: www.lcafood.dk (accessed on October 28th, 2011).