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4th NEWSLETTER May2013

LC-IMPACT

Life Cycle Impact assessment
Methods for imProved sustAinability
Characterisation of Technologies

Editorial

By Mark Huijbregts, scientific coordinator – In the last 3.5 years, the LC-IMPACT project aimed to bring life cycle impact assessment (LCIA) to the next scientific level. We worked on advanced global environmental models with high spatial resolution and with information up to the level of damage to humans, ecosystems and resources. You can find the summary of outcomes and main conclusions for the individual work packages in this newsletter.

The question is whether we were successful in our work. My first answer would be yes indeed. For many resource extractions and emissions, including land occupation, water consumption, and priority air and water pollutants, we were able to substantially advance the current state of the art in LCIA, with models that cover the global scale with high spatial detail. We were also able to improve LCIA for specific interventions, such as emissions of pesticides and sound. Our work is not only presented in deliverables for the European commission, but also as scientific publications (now 30+ and the number is steadily growing), course materials and presentations at many congresses. You can find more information about this in the newsletter and our website (www.lc-impact.eu). Further note that a major share of the scientific work in LC-IMPACT was done by PhD-students. I expect that these young scientists, 14 in total, will provide the field with many new ideas in the forthcoming years.

Nevertheless, there are still challenges ahead of us. For humans, the endpoint is well-defined as years of life lost and disabled. For ecosystems, however, the assessment of global loss of biodiversity needs further development from a conceptual point of view. We also still need to find the right balance between high spatial resolution and feasibility for implementation in LCA practice. The case studies showed that it can be a difficult task to include spatial differentiated results into practice. So, we are not there yet.

At SETAC-Glasgow we will proudly present the highlights of the LC-IMPACT project results in a special session on Wednesday May 15th, from 16.30 to 18.30h (see program in page 7).

I am looking forward to meet you there!

Mark Huijbregts

Summary of outcomes and main LC-IMPACT conclusions of WP 1

By Stefanie Hellweg, Marijn van der Velde, Marisa Vieira

Work package 1 targeted at methods for the life cycle impact assessment of resource use, including impacts of land use, groundwater and surface water use, marine resources, and fossil and mineral resources. Methods are provided on the midpoint level as well as endpoint level, the latter referring to impacts to human health (in terms of DALYs), impacts to ecosystems (in terms of PDF*yr as well as absolute species loss) and impacts to resource scarcity (surplus cost in terms of US dollars per kg or m^3). The characterization factors of all methods except mineral and fossil resource use were developed in a site-dependent manner.

For land occupation, for the first time a spatially explicit method for biodiversity assessment with global coverage was developed (leading researcher: Laura de Baan). All characterization factors are provided in a site dependent manner (on biomes level) and include uncertainty information. In addition, a novel method to account using functional diversity instead of species richness was developed leading researcher: Danielle M. Souza). In the future, this method could help to establish links between species loss and key ecosystem functions. Moreover, various ecosystem services of land use were addressed. Muchada et al. calculated the changes in carbon sequestration due to forest wood extraction for biofuel production based on global forestry modeling and developed global, spatially-explicit method to quantify the impact on human health and ecosystem quality. Rosalie van Zelm and colleagues focused on impacts of crop cultivation on erosion using outputs from a global crop model and expressed damage in terms of extra costs due to soil loss. Montse Nuñez and colleagues developed a globally applicable, spatially differentiated Life Cycle Impact Assessment method to account for land occupation impacts in LCA, with a focus on soil erosion, and applied their model in Spain on impacts resulting from substituting traditional crops for energy crop rotations.

For water consumption, a comprehensive set of methodologies was developed addressing ecosystem impacts in rivers, wetlands and terrestrial ecosystems of both surface water and groundwater consumption (leading researchers: Francesca Verones, Rosalie van Zelm, and *Stephan Pfister)*. Both relative and absolute species loss can be used as indicator. Additionally, an existing method for the assessment of impact to human health was extended with uncertainty information. All methods are provided with spatial differentiation and are operational, most of them with global coverage. Main points for future research include the refinement of data, the extension to global coverage of all methods and the addition of uncertainty information.

To quantify overfishing, current level of spawning stock biomass and fishing mortality were compared with optimum levels, i.e. the present distance to Maximum Sustainable Yield (MSY). Three midpoint impact categories to account for overfishing in LCA are defined: *lost potential yield* (LPY), *overfishing through fishing mortality* (OF) and *overfishedness of biomass* (OB). Furthermore, a first method for addressing the impact on by-catch in LCIA was developed (leading researcher: Sara Hornborg).

For the assessment of mineral and fossil resource use, the endpoint life cycle indicator chosen was surplus cost meaning the increase in extraction/production costs caused by an increase in current fossil or mineral extraction, based on the issue of concern identified by decision makers (leading researcher: Marisa Vieira). This approach had already been taken in the ReCiPe method. However, the models and data used in the LC-IMPACT project are more sophisticated and harmonized between the two impact categories studied. We believe the work recently undertaken contributes to larger scientific robustness and consistency. Main points for future research include the extension of the method to further minerals and metals, including appropriate demand forecasts and cost data.

The publications produced by WP1 up to now are listed in page 6

Summary of outcomes and main LC-IMPACT conclusions of WP 2

By Ralph K. Rosenbaum, Peter Fantke, Laura Golsteijn, Ronnie Juraske, Anna Kounina, Mikolaj Owsianiak, Catherine E. Raptis, Serenella Sala

Work package 2 focused on improving the modelling of toxic impacts on humans and ecosystems and developing related normalisation factors for Europe and the world.

Terrestrial ecotoxicity of metals: LCIA models seldom consider terrestrial ecotoxicity and ignore metal speciation. Therefore, a new framework for modelling cationic metals in terrestrial environments was developed. It distinguishes two sides of metal availability in soil, solid-phase metal reactivity (represented as accessibility factor) and bioavailability of toxic metal forms in the aqueous phase due to speciation. Geographical differences in fate, accessibility, bioavailability, and terrestrial toxicity were assessed by combining the USEtox model, empirical regression models, and terrestrial biotic-ligand models, resulting in new empirical regression models estimating region-specific CFs of Cu and Ni from soil parameters.

Terrestrial ecotoxicity of organic chemicals: Terrestrial ecotoxicity essentially depends on the dissolved concentration in pore water. Based on sorption equilibrium, the chemical concentration in water and soil can be modelled with the equilibrium partitioning (EP) method. Consequently, aquatic toxicity tests can be used to estimate terrestrial toxicity. The goal was to analyse the validity and uncertainty of estimates of soil toxicity derived from the equilibrium partitioning method. A comparison between freshwater HC50 values from standard aquatic tests and pore-water HC50 values from terrestrial experimental data was performed for 48 organic chemicals, including uncertainty via Monte Carlo simulation.

Higher (warm-blooded) predator ecotoxicity of organic chemicals: CFs for warm-blooded predators at the end of freshwater food chains were developed for 1479 non-ionic chemicals, applying USEtox. Fate (FF) and exposure factors (XF) were calculated with USES-LCA 2.0. Bioaccumulation factors were calculated with the model OMEGA for chemical uptake via fresh water, food, and air. Effect factors (EF) were calculated from hazardous doses based on experimental and modelled toxicity data. Namely, the effect dataset was enlarged with interspecies correlation estimation model predictions.

Aquatic ecotoxicity of whole effluents: A new methodology addressing chemical mixtures, like industrial effluents, was developed using total organic carbon (TOC). FF is calculated with the USEtox model using average properties of the organic bulk. EF was estimated by attributing the total measured ecotoxicity to the organic and inorganic fraction of the effluent, applying whole effluent toxicity (WET) studies, the concentration addition concept of mixture toxicity and the free ion activity model.

Human toxicity of pesticides: A new dynamic plant uptake model was developed to characterize health impacts of pesticides applied to food crops. Crop-specific human toxicity CFs were provided for use in LCA along with analysing their variance between crop types, pesticides and application times. Crop leaf growth, initial spray drift and food processing are identified to be the main crop-related aspects driving the evolution of pesticide masses in the modelled system along with pesticide properties.

Spatial variability of toxicity of organic chemicals: The focus here was on identifying key drivers of spatial differentiation and selecting an appropriate model and spatial resolution balancing precision and data requirements. Studying intra-continental variation at a watershed scale with the spatial IMPACT 2002 Europe model, lead to the development of archetypes for freshwater ecotoxicity and human toxicity exposure to drinking water and fish, as a parsimonious simplification of detailed spatial resolutions. Comparing results from USEtox (parameterised for each continent respectively) with those from IMPACT World shows that the most important part of the impact occurs on the continent where the pollutant is emitted. When the emission location is known, a spatially differentiated model can improve the model accuracy up to 2-3 orders of magnitude. For persistent chemicals, the country/regional differentiation is relevant.

Based on USEtox CFs (recommended and interim), an extended set of human toxicity and ecotoxicity normalization factors for Europe and the World was developed for the reference year 2010. Extrapolation from European, US, Canadian, Japanese, and Australian emission data sources was based on GDP (gross domestic product) and CO_2 emission respectively. The result is the most updated set of normalization references for Europe and the World.

The publications produced by WP2 up to now are listed in page 6

Summary of outcomes and main LC-IMPACT conclusions of WP 3

By Philipp Preiss, Ligia B. Azevedo, Stefano Cucurachi, Nuno Cosme, and Thomas van Goethem

Work Package 3 developed new methodologies for impacts resulting from emissions of phosphorus and nitrogen, air pollutants (SO_2, NO_x, NH_3, NMVOC, primary particulate matter), and noise exposure. These are non-toxic pollutants that trigger aquatic eutrophication (in both freshwater and marine ecosystems), terrestrial acidification, tropospheric ozone formation, particulate matter formation and noise. All impacts were assessed at the endpoint level, globally and in a spatially-differentiated manner. Furthermore, the impact of noise on human health was assessed at the midpoint level at a European scale. Overall, the large spatial coverage, the introduction of spatially-dependent models, the inclusion of effect models, and the introduction of a LCIA frameworks for marine eutrophication and noise were the main innovations of WP3 compared with contemporary LCIA methodologies.

During the project, we came across important challenges in the development of the various effect models. For example, in the case of impacts of tropospheric ozone on natural ecosystems (lead researcher: Thomas van Goethem), we have detected that the sensitivity to ozone exposure depends on the type of plant. Another example is the case of eutrophication to freshwater ecosystems: we have observed that the species sensitivity to increased phosphorus concentrations availability depends on the type of freshwater ecosystem: lakes or streams (lead researcher: Ligia B. Azevedo).

Another relevant contribution of WP3 was the comparison between different types of effect models. We have shown that characterization factors may be influenced by the underlying assumptions of the effect model such as linear or non-linear changes in the potentially affected (PAF) or non-occurring fraction (PNOF) of species and inclusion or not of current background levels of pollution. For example, we have detected that eutrophication impacts in relatively unpolluted freshwaters may be overestimated if current levels of phosphorus are not taken into account.

Impacts to human health due to tropospheric ozone formation and particulate matter (lead researcher: Philipp Preiss) were assessed based on source-receptor-matrices derived from a global chemical transport model (TM5-FASST). The world was divided in 56 regions consisting of countries or groups of countries and we estimated spatially-differentiated impacts on morbidity and mortality. More information can be found on page 12.

The inclusion of spatial differentiation in the models was an important aspect in the development of new impact indicators. Spatially-differentiated models are more representative of the sensitivity of regions subjected to a human intervention. For that reason, the model of the transport of nitrogen into marine ecosystems includes processes such as denitrification, sedimentation, and advection, which encompass strong geographical variability (lead researcher: Nuno Cosme). For example, in the case of noise impacts indicator (lead researcher: Stefano Cucurachi), which is highly localized, spatially-explicit characterization factors were determined per archetype (e.g. day, rural, at 63 Hz frequency) and also by the option of using local customised conditions by the practitioner especially useful for any case of data availability.

The publications produced by WP3 up to now are listed in page 6

Summary of outcomes and main LC-IMPACT conclusions of WP 4

By Ulf Sonesson

Life cycle assessment is a tool for answering questions on the environmental impact of products and services, this is nothing new. But what it says is that any methods developed, how brilliant it might be, is not a good method until proven useful in applications. Hence, when developing methods the future application must be considered early in the process. In LC-Impact case studies (**Table 1**) have been performed as part of the project, and interaction between methods developer and case study practitioners have been intense as a way to secure that methods developed are relevant and applicable on real cases. We chose case studies in a way that all LC-Impact methods was covered by at least one case study, preferably more. The five products being studied are: Seafood products (Cod and herring), Margarine, Fresh tomato, car manufacture and operation, and paper production and printing. The case studies will apart from testing LCIA methods also deliver LCA results, including also already established LCIA methods.

In this newsletter I will briefly present some experiences. For information and results from specific case studies I refer to forthcoming project reports. A general conclusion is that it is very useful with the interaction, it benefited both practitioner and methods developer. The methods developer got hands on information about the use, and the practitioner had a better chance of understanding methods, hence could use it more efficiently. So one general conclusion is that integration between methods development and practice is key to move LCA forward.

On a more specific level I would like to highlight one specific difficulty that is relevant for the general development of LCA as a tool. It is about regionalisation and spatial resolution, which was applied in almost all LCIA method developed. Regionalisation is difficult, not only to develop regionalized characterization factors, which is difficult in itself, but the application turned out to be a challenge. The reasons being twofold; first it was often difficult to find inventory data with enough resolution, producers often do not know exactly where their supplies originate. Often the resolution on sourcing region was on country level but sometimes on a continental level. The second difficulty was that when performing an LCA you will have a large number of material and energy flows from the so called background system, i.e. supplementary flows where inventory data is not specifically inventoried. These flows are described by using LCA databases. Using databases is a prerequisite to make LCA studies possible; if you had to make primary inventories for all flows an LCA would be extremely more time demanding. But if regionalisation should be applied in a study then databases needs to be updated to accommodate this. Using methods with a high spatial resolution for some flows and global averages for others are not ideal. Of course this can be resolved by developing LCA databases, but we need to acknowledge that that will require both time and resources.

Table 1: Relevancy of the case studies for the newly developed impact assessment methodologies

Case study	Food			Printed matter		Transport
Impact category	Fish	Fresh tomatoes	Margarine	Paper	Printing	Car production and operation
Mineral resource use		+[1]	+[1]			+[2]
Fossil resource use	+[3]	+[4]				+[5]
Water use		+	+	+		+[12]
Land use	+[6]	+	+	+		+[12]
Marine resource use (fish)	+					
Ecotoxicity		+[7]	+[7]	+[8]	+[8]	+[9]
Acidification		+	+			+
Aquatic eutrophication		+	+			
Photoch. ozone formation					+	+
Fine part. matter formation		+	+		+[10]	+
Noise					+	+
Human toxicity		+[7]	+[7]		+[11]	+[9]

[1] phosphate used as fertiliser; [2] metals used in car production; [3] shipping; [4] greenhouse management; [5] car use; [6] seafloor disturbance; [7] pesticides; [8] whole effluent toxicity; [9] metal emissions; [10] indoor exposure to fine particles; [11] indoor exposure to solvents; [12] water and land use cause by biodiesel production.

Publications of LC-IMPACT

Work Package 1 – Resources use impacts

Amores MJ, Verones F, Raptis C, Juraske R, Pfister S, Stoessel F, Antón A, Castells F, Hellweg S, 2013. Biodiversity impacts from salinity increase in a coastal wetland. Environ Sci Techn. DOI: 10.1021/es3045423

de Baan L, Alkemade R, Koellner T, 2013. Land use impacts on biodiversity in LCA: a global approach. Int J LCA. DOI: 10.1007/s11367-012-0412-0

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Koellner T, Baan L, Beck T, Brandão M, Civit B, Goedkoop M, Margni M, Canals L, Müller-Wenk R, Weidema B, Wittstock B, 2012. Principles for life cycle inventories of land use on a global scale. Int J LCA, 1-13.

Núñez M, Antón A, Muñoz P, Rieradevall J, 2013. Inclusion of soil erosion impacts in life cycle assessment on a global scale: application to energy crops in Spain. Int J LCA 18, 755-767.

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Vieira MDM, Goedkoop MJ, Storm, P., Huijbregts, M.A.J., 2012. Ore Grade Decrease As Life Cycle Impact Indicator for Metal Scarcity: The Case of Copper. Environ Sci Techn 46, 12772-12778.

Work Package 2 – Ecotoxicity and human toxicity

Fantke P, Juraske R, Antón A, Friedrich R, Jolliet O, 2011. Dynamic Multicrop Model to Characterize Impacts of Pesticides in Food. Environ Sci Techn 45, 8842-8849.

Fantke P, Wieland P, Juraske R, Shaddick G, Itoiz ES, Friedrich R, Jolliet, O., 2012. Parameterization Models for Pesticide Exposure via Crop Consumption. Environ Sci Techn 46, 12864-12872.

Golsteijn L, van Zelm R, Hendriks AJ, Huijbregts MAJ, 2013. Statistical uncertainty in hazardous terrestrial concentrations estimated with aquatic ecotoxicity data. Chemosphere (just accepted)

Golsteijn L, Hendriks HWM, van Zelm R, Ragas AMJ, Huijbregts MAJ, 2012. Do interspecies correlation estimations increase the reliability of toxicity estimates for wildlife? Ecotox Environ Saf 80, 238-243..

Golsteijn L, van Zelm R, Veltman K, Musters G, Hendriks AJ, Huijbregts MAJ, 2012. Including ecotoxic impacts on warm-blooded predators in life cycle impact assessment. Integr Environ Assess and Manage 8, 372-378.

Owsianiak M, Rosenbaum RK, Huijbregt, MAJ, Hauschild MZ, 2013. Addressing Geographic Variability in the Comparative Toxicity Potential of Copper and Nickel in Soils. Environ Sci Techn 47, 3241−3250

Sala S, Marinov D, Pennington D, 2011. Spatial differentiation of chemical removal rates from air in life cycle impact assessment. Int J LCA 16, 748-760.

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Work Package 3 – Non-toxic pollutant impacts

Azevedo LA, Van Zelm R, Elshout PMF, Hendriks AJ, Leuven RSEW, Struijs J, de Zwart D, Huijbregts MAJ, In press. Species richness – phosphorus relationships for lakes and streams worldwide. Glob. Ecol. Biogeogr.

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Cross-cutting topics

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Mutel C., Pfister S., Hellweg S. 2012. GIS-based regionalized life cycle assessment: how big is small enough? methodology and case study of electricity generation. Environmental Science and Technology, 46 (2): 1096–1103.

Dissemination

By Anne Gaasbeek

The work of LC-impact is nearing its end, and we have been working hard on sharing and promoting the insights of the LC-impact project . This includes the public consultation to support the scientific enhancement of new methods for Life Cycle Impact Assessment, comments from the this have been processed and incorporated in the methodology. Through expert consultation we have assured the best quality and robustness of the methods developed within LC-impact and through the public consultation we have tried to assure the applicability of the developed methodology.

Our ambition is to build a community for those interested in the latest developments in the field of impact assessment. To initiate this, several course materials are being developed which can be used in training and communication. In the coming months, course materials will become available on the different impacts; Land use, water, marine resources, tox: metals, tox: pesticides, eutrophication, acidification, particulate matter & ozone formation, and noise.

Also two course materials will be developed on the principles of impact assessment. All courses will give an detailed description of the developed methodology , provide insight in bringing the methodology in to practice and where possibilities for further research lie. All course materials can be found at http://www.lc-impact.eu/.

All courses will be presented to various interested groups, it is free to join the courses. Keep an eye on the website to see when some of the courses take place. The first opportunity to gain insight into the methodologies is to join the special session, which is organized at the SETAC conference in Glasgow.

Wednesday May 15th
at SETAC Glasgow

Special Symposium: LC-IMPACT (meeting room Alsh 2)

16:30 - 16:45	Welcome and overview by the project coordinator Mark Huijbregts
16:45 - 17:10	Outcomes work package 1: resources
17:10 - 17:35	Outcomes work package 2: toxicity
17:35 - 18:00	Outcomes work package 3: non-toxic pollutants
18:00 - 18:25	Outcomes work package 4: case studies
18:25 - 18:30	Closure

LC-IMPACT is a 3.5 year project which runs until June 2013. It focuses on the development and application of life cycle impact assessment methods, characterization and normalization factors. LC-IMPACT involves 16 European partners from academia, industry, and SME's. The work of LC-impact entails:

New impact assessment methods for categories which are not (commonly) included in life cycle impact assessments, such as marine resource use (effects caused by seafloor disturbance, target catch and by-catch), and noise.

Spatially explicit characterization factors based on global scale models for land use, water exploitation, toxicants, priority air pollutants, and nutrients.

Assessment of parameter uncertainty and value choices for impact categories with high uncertainties involved, such as ecotoxicity and human toxicity. The improved decision support of the new characterization factors and normalization factors is demonstrated in the context of the following three case studies: i) food production (fish, tomatoes, margarine), ii) paper production and printing, and iii) automobile manufacturing and operation.

Agri-Environmental Modeling as Input in LCA

By Marijn van der Velde and Rosalie van Zelm

Improving the sustainable use of land is one of the most critical issues of our time. We have come to realize that local land use change is driven by globally teleconnected processes that straddle the socio-economic and environmental domains. This requires the development of spatially differentiated life cycle analysis methods in order to attribute these impacts to certain land uses across the globe. One way forward for life cycle impact assessment is to benefit from the increasing capacity of environmental modelers to represent biophysical processes and management operations in space and time. Recent advances in global crop modeling, for instance, can provide a coherent picture of current yields for a range of crops and environmental impacts as a function of (a.o.) the thermal requirements of crops, planting dates and growing season lengths, soil properties and the best available estimates of fertilizer applications (***Fig. 1***)

These types of simulations can contribute significantly to improve the land use impact category in LCA. One of the strengths of LCA is to integrate this information in a way that is meaningful to stakeholders that for example seek to improve the environmental balance of their products. However, to optimally benefit from the opportunities LCA can bring, communicating the limitations of the outputs of the agri-environmental model is essential. Indeed, uncertainties associated with global spatial information and environmental models need to be acknowledged. Even basic information such as the land cover and land use areas shows considerable differences between global state-of-the art maps, that can be several hundreds of Mha. The impact of these uncertainties on resulting characterization factors for LCA still needs to be assessed. Land use impacts such as soil erosion and carbon sequestration will depend on agricultural management intensity. Therefore, in LC-Impact, as a first step, we calculated global spatially explicit characterization factors for erosion due to crop cultivation associated with no input farming, fertilizer inputs, and fertilizer and irrigation management practices. Grid- and country specific characterization factors expressing the costs due to soil erosion worldwide (US $\$\cdot kg^{-1}$ agricultural product) were derived for cultivating wheat, rapeseed, cassava and sunflower for the three management scenario's. The high variability in characterization per crop, grid, and input scenario show the importance of the applied method.

In our forestry study (Muchada et al., *submitted*), we calculated the changes in carbon sequestration due to forest wood extraction for biofuel production and developed global, spatially-explicit method to quantify the impact on human health and ecosystem quality. Similarly, for crop cultivation, future work will focus on changes in carbon sequestration and subsequent effects on damage caused by climate change. Agri-environmental models will be parameterized to see for changes in impact due to tillage practices, crops (including e.g. soybean, sugarcane and corn as well), and to see for uncertainties due to parameter inputs. Importantly, a further integration of land use impact across different land cover types using a combination of dedicated and integrated models will be pursued.

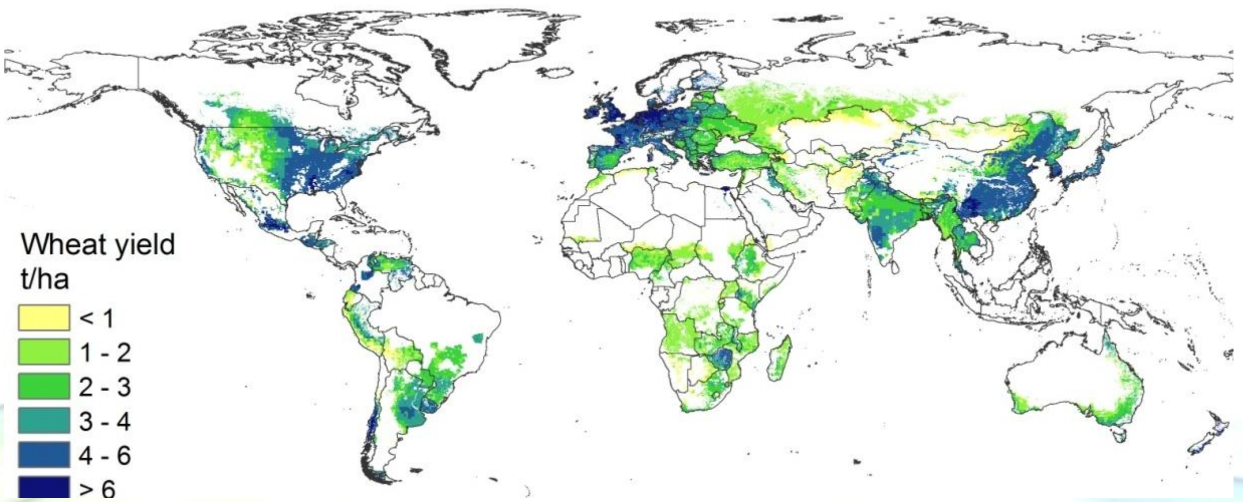

Fig. 1 *Spatial distribution of simulated average wheat yields (t ha^{-1})*

Muchada P, van Zelm R, van der Velde M, Kindermann G, Obersteiner M, Huijbregts MAJ, Submitted. Climate change related impacts from wood extraction for bio-energy on a global scale

Introducing DTU – Division for Quantitative Sustainability Assessment, Technical University Denmark

By Ralph K. Rosenbaum, Mikołaj Owsianiak, Nuno Cosme

The Division for Quantitative Sustainability Assessment (QSA) at the Technical University of Denmark (DTU) covers development of scientifically based engineering methods and tools for analysis and decision support concerning environmental and social sustainability, notably life cycle assessment (LCA) and risk assessment. Since the early nineties the core competence areas have been LCA and environmental and resource efficiency, development of cleaner technology, and technology and environment studies. Current research activities focus on developments in assessments of emerging technologies (nanomaterials and biofuels/materials) as well as emission modelling, planetary boundaries, life cycle management, and life cycle impact assessment. On the latter, research is notably related to human toxicity (exposure pathways like indoor, near-field/bystanders, or direct via consumer products), ecotoxicity (terrestrial and marine, or long-term impacts of metals), marine eutrophication, spatial differentiation, uncertainty management, and the USEtox model.

Within LC-IMPACT, part of our work focused on characterisation modelling of metals in terrestrial systems. Our method for calculating comparative toxicity potentials (CTP) of metals in soil captures the role of environmental chemistry parameters in environmental fate, accessibility, bioavailability, and terrestrial toxicity. For Cu and Ni, we showed that both magnitude and geographic variability in CTP can mainly be explained by variability in soil organic carbon, pH, and ionic composition of soil pore water. CTP of Cu and Ni apply to air emissions irrespectively of the emitted form of the metal. Our method allows capturing differences in reactivity for other contamination types, such as organic- and oxide-bound Cu applied as a biosolid, or Cu in mine spoils. We are planning to extend our model to other metals and contamination types.

Our research on non-toxic impacts within LC-IMPACT aimed at developing an endpoint model for marine eutrophication, as caused by nitrogen (N) emissions. The objective was to understand fate processes affecting N loadings to coastal waters and to define and estimate suitable factors for impact characterisation: fate factors for airborne and waterborne N emissions, incorporating export and loss rates; exposure factors based on the conversion of N into biomass in the photic zone and to dissolved oxygen consumption in the benthic habitat; and effect factors applying species sensitivity distributions to hypoxia, composing endpoint characterisation factors expressing species diversity loss. Spatial differentiation was essential to address geographical variation of impacts in the receiving ecosystems (LME - Large Marine Ecosystems), increasing discriminating power of the methodology and relevance of the results. N emissions to LMEs were quantified and their impact estimated for 214 country-to-LME combinations, 143 countries, 13 regions/continents, and a global default.

QSA has also been involved in the application and evaluation of the new methodologies from LC-IMPACT in a LCA case study on paper production and printing. This case study quantified and compared the potential environmental impact from generic paper and printing matter production on a model sheet-fed offset-printing company in Denmark (representing European average). The study applies and tests the newly developed LC-IMPACT models for land use, water use, whole effluent toxicity, indoor exposure to solvents, photochemical ozone formation, indoor exposure to fine particles, and noise.

Mikolaj Owsianiak

Nuno Cosme

Ralph Rosenbaum

Michael Hauschild

Overfishing and by-catch of sensitive species: previously un-assessed impacts in seafood LCAs

By Friederike Ziegler

Seafood LCAs have up until now excluded assessment of impacts on target fish stocks, or dealt with them in a qualitative way, and addressed by-catch in terms of total mass per landing. These are certainly the most direct impacts related to fisheries, and represent the focus of fisheries management and certification schemes. The aim of our research undertaken within LC-IMPACT has been to go from qualitative to quantitative assessment of biological impacts of fishing. One important goal has been to explain the procedure of how to calculate the characterization factors, as biotic impacts can never be static over time, since e.g. natural variability influences abundance. Anyone should easily be able to extend the methods to cover other stocks and years, by utilizing the same data sources and methodology provided.

To quantify overfishing, we compare current level of spawning stock biomass and fishing mortality in a projection model, with the corresponding target levels. This measure represents the present distance to Maximum Sustainable Yield (MSY), which is the current management goal for EU fisheries. We call this impact category **Lost Potential Yield (LPY)** and it can be subdivided into the two components of overfishing; **Overfishing by (too high) Fishing mortality (OF)** and **Overfishedness of Biomass (OB),** i.e. too small stock of reproducing biomass. All three ways of accounting for overfishing use the annual fishing mortality, which aggregates mortality caused by landings, and when relevant and possible also discards and unreported catches. By using the "real data", communicated by fisheries management on a stock-to-stock and year-to-year basis, we get the most relevant spatial and temporal resolution.

The same methodology could be applied to by-catches if data was available. However, the methods suggested for target stocks require availability of data from stock assessments, which only exist for the most important commercial species. Most by-catch species (some of which are landed and some discarded at sea) are data deficient. Two alternative approaches were therefore evaluated; 1) **Primary Production Required (PPR)** and 2) **Vulnerable, Endangered and Critically endangered species (VEC)**, according to the IUCN Red List of Threatened Species. PPR, i.e. the amount of carbon needed to produce a kilo of a species at a certain trophic level, has been applied before on feed in LCAs of aquaculture and applied to discards, it conveys important information on the composition of the discard in terms of different species. However, interpretation of PPR values is not completely straightforward: It is e.g. difficult to interpret PPR as measuring use of a limited resource in eutrophied coastal areas, or comparing values between different ecosystems and over time. In addition, it does not provide any information on fishing impacts in terms of effects on species' abundances and their sensitivity to fishing. Therefore, the IUCN Red List of Threatened Species is suggested as a complement to assess discards. Both by-catch methods request detailed discard data, which is still rarely available. However, the two methods combined illustrate well the discard impact of a fishery.

Altogether, the new mid- point indicators can complement traditional fisheries LCAs, and more comprehensively quantify relevant environmental impacts of fisheries, or aquaculture using marine feed inputs, such as salmon farming.

Hornborg S, Svensson M, Nilsson P, Ziegler F, Submitted. By-catch impacts in fisheries: utilizing the IUCN Red List Categories for enhanced product level assessment in seafood LCAs.

Introducing IRTA– Research and Technology for Food and Agriculture

By Assumpció Antón, Juan Ignacio Montero, Pere Muñoz, Eva Sevigne, Marta Torrellas

IRTA is a Research Institute depending on the Catalan Government. **IRTA´s general objectives** are to promote research and technological development in the agro-food sector, to assess scientific advances and to facilitate their implementation. Our team has been one of the pioneers of the development and application of **LCA methodology in agriculture**.

Our main task within the **LC-IMPACT project** is to apply and evaluate in detail the newly LCIA methods developed over the project in the **case study of fresh tomato production**. This case study was selected as representative of the agricultural practices applied in the Mediterranean region. In addition, we have been involved in the development of the new impact categories more related to agricultural systems, i.e. land use, water consumption and human toxicity assessment due to pesticides use.

Regarding **land use**, we focused on soil erosion impacts. Indicators were defined on the endpoint level of Natural resources and Ecosystems quality. Damage to resources is expressed as surplus energy needed to make the resource available at some point in the future. The effect of soil erosion on ecosystem quality is expressed using a growth-based value: NPPD (potential net primary production depletion) (leading researcher: Montse Nuñez).

In collaboration with ETH (Switzerland), and INRA and IRSTEA (France), we developed a method to include **soil-water consumption** (also termed green water) in LCA. In order to make the proposal operational in LCA, we estimated direct soil-water consumption of potential natural vegetation (PNV) adapted to local bio-geographic conditions on global dry lands at different ecological and administrative spatial aggregation levels (leading researcher: Montse Nuñez). In addition, in this project in cooperation with ETH (Switzerland) and URV (Tarragona, Spain) and specifically for our case study, we derived the first characterization factor (CF) for salinity impacts in a coastal wetland. (leading researcher: Maria José Amores).
IRTA also cooperated in the development of **human toxicity** through the modelling of pesticides intake, where our main task was the validation of the model with experimental trials (leading researcher: Eva Sevigne).

Finally, we applied the new CFs in our **case study** and judged the applicability of newly developed CFs in a case study, providing the required feedback to LCA method developers (leading researcher: Assumpció Antón). As an overall conclusion it can be said that for agricultural production systems the newly developed impact categories contribute to fill the most important gaps related to land use, water consumption, pesticides toxicity and non-toxic emissions mainly those linked to fertilizers use, on the one hand by incorporating new and important impact categories and on the other hand by improving existing methods with site-specific CFs, one of the main drawbacks in agricultural processes until now. The possibility of including biodiversity damage due to land use and influence of water consumption in wetlands mean an important scientific advance to a more actual environmental assessment for agriculture. Likewise, the developed dynamic crop model, to assess human toxicity due to pesticides residues in food, leads to a better praxis of pesticides application, which also brings benefits to ecosystems biodiversity.


Marta Torrellas


Eva Sevigne


Montse Nuñes


Pere Muñoz


Juan Ignacio Montero


Maria Jose Amores


Assumpció Antón

Application of global, spatially explicit characterisation factors for health impacts of exhaust-emissions of passenger cars

By Philipp Preiss

Within the case study on "car manufacturing and operation" exhaust-emissions from driving passenger cars per vehicle km have been assessed. The emissions of NOx, primary particulate matter and SO_2 per vehicle km are influenced by the driving speed and therefore, they are different for routes in urban and rural areas and on motorways.

The impact of emissions of the above mentioned pollutants towards human health depends on the number of people exposed to the corresponding primary and secondary particulate matter. The exposure is therefore also different for urban and rural sources. Moreover, the exposure is influenced by the stack height of releases. In case of exhaust-emissions the height of release is ca. ground level. In the following example we assessed the emissions per vehicle km of the "Euro V" passenger cars in 2010 in Germany. The shares of vehicle km on urban, rural and motorway routs are 26%, 54% and 20%, respectively.

Primary and secondary PM concentration is influenced by the transport and chemical transformation in the atmosphere because of spatially-variable background emissions and atmospheric conditions. Based on the TM5-FASST model a global, spatially explicit assessment of the air pollutants releases of primary particulate matter (PM), SO_2 and NO_x has been conducted with regard to primary and secondary particulate matter concentration change and the corresponding impacts to human health. Characterisation factors have been derived on an endpoint level, i.e. mortality and morbidity has been expressed as disability adjusted life years (DALY) per unit of pollutant emission. CFs have been derived for 56 regions consisting of countries or groups of countries. These CFs do not distinguish between urban or rural sources and they do not distinguish different stack heights, but represent average values for the corresponding regions. In order to estimate for each of the 56 regions the CFs for releases in urban and rural areas and for different stack heights an adjustment has been made according to the recommendation in the corresponding literature.

The result "Germany-adjusted" has been calculate as the activity-weighted average of using urban, rural and motorway specific exhaust-emissions and corresponding CFs (**Fig. 1**). The results "Europe-average" and "World-average" have been calculated by applying only European and world average CFs. The example shows that using only average CFs can lead to significant different results than using regional and spatial differentiated CFs.

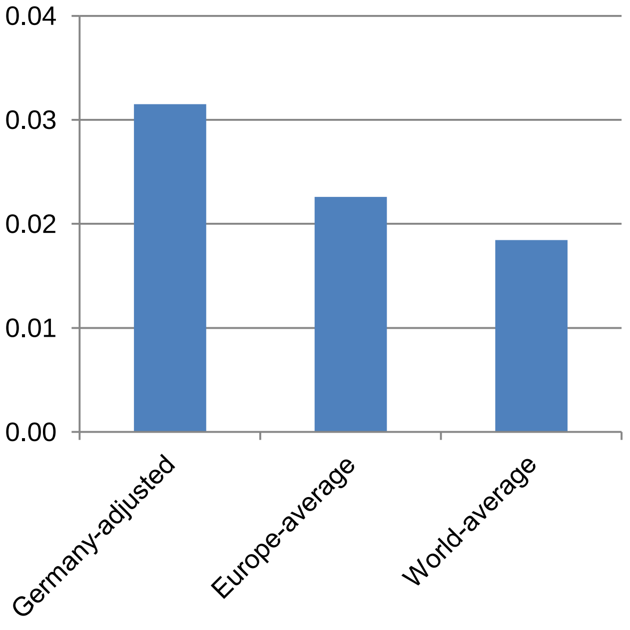

Fig. 1 *DALY per 1,000,000 vehicle km of certain passenger cars.*

Monday, May 13th

LCAS01 *Managing complexity, uncertainty and variability in LCA*
Platform presentation (Room **Dochart**)
ID 102 11:30 *Towards specific archetypes for the impact assessment of chemicals.* Ciuffo B, Sala S.

LCAS03 *Monetisation for weighting and aggregation of risks and impacts to human health and the environment*
Platform presentation (Room Dochart)
ID170 15:00 *Spatially explicit characterization factors for damage costs of soil erosion due to agricultural land occupation on a global scale.* Van Zelm R, Van der Velde M, Koellner T, Núñez M, Obersteiner M, Schmid E, Huijbregts MAJ.

Tuesday, May 14th (continues in the following page)

ET03 *Bridging the gap between lab and field - new approaches in the simulation of realistic exposure scenarios*
Platform presentations (Argyll 2 room)
ID 175 9:15 *Using observational field data for risk assessment of nutrients in freshwaters* Azevedo LB, Van Zelm R, Leuven RSEW, Hendriks AJ, Huijbregts MAJ.
ID 232 11:50 *Plant Species Sensitivity Distributions for ozone exposure*. Van Goethem TMWJ, Azevedo LB van Zelm R, Hayes F, Ashmore MR, Huijbregts MAJ.

ET08 *Wastewater effluents: chemical and ecotoxicological characterisation*
Poster (Exhibition Hall)
TU129 *How does effluent TOC differ between industries? A proposal to understand the nature of monitored organic sum-parameters in terms of their ecotoxicity.* Raptis C, Juraske R, Hellweg S.

EXM02 *Methods for linking chemical exposure to emissions*
Platform presentation (Boisdale)
ID 271 10:50 *Spatially resolved approach for linking emission to human exposure: a case study for Europe*. Sala S, Ciuffo B.

Tuesday, May 14th (cont. from previous page)

LCAS02 *Increasing the robustness in life cycle impact assessment methods I-III*

Platform presentations (Dochart room)

ID 208 8:15 *Climate change related impacts and benefits from wood extraction for bioenergy on a global scale*. Muchada, PAN, Van Zelm R, Van der Velde M, Kindermann G, Obersteiner M, Huijbregts MAJ.

ID 210 8:55 *Endpoint characterisation modelling for marine eutrophication in LCIA*. Cosme N, Larsen HF, Hauschild M.

ID 201 09:15 *Characterisation factors for the impact category human noise.* Cucurachi S, Heijungs R.

ID 212 9:35 *Land use in LCA: Global characterization factors based on regional and global species extinction*. de Baan L, Curran M, Hellweg S, Mutel CL, Koellner T.

ID 265 10:50 *Development of characterization factor to assess biodiversity damage due to salinity increase in a coastal wetland.* Amores MJ, Verones F, Raptis CE, Juraske R, Pfister S, Stoessel F, Anton A, Castells F, Hellweg S.

ID 266 11:10 *Developing an assessment methodology for the impact of consumptive water use on the biodiversity of wetlands of international importance.* Verones F, Pfister S, Saner D, Rondinini C, Baisero D, Hellweg S.

ID 267 11:30 *Towards including regionalized soil-water consumption in LCA*. Nuñez M, Pfister S, Roux P, Anton A.

ID 320 14:00 *Regionalised Global Assessment of Health Impacts of Non-Toxic Air Pollutants based on TM5-FASST* Preiss P, Van Dingenen R, Dentener F.

ID 322 14:40 *Spatial differentiation for toxic emissions in LCA: How well the (nested) USEtox model mimic a truly spatially differentiated model?* Kounina A, Margni M, Shaked S, Bulle C, Jolliet O.

Posters (Exhibition Hall)

TU239 *European characterization factors for damage to natural vegetation*. Van Goethem TMWJ, Preiss P, Azevedo LB, Roos J, Friedrich R, Huijbregts MAJ, van Zelm R.

TU244 *How and at which scale should we assess biodiversity? A comparison of three globally applicable land use LCIA methods in East Africa*. de Baan L, Visconti P, Rondinini C, Koellner T, Hellweg S

TU246 *Characterization factors for freshwater eutrophication: sensitivity towards emission location, effect model and species group*. Azevedo L, Henderson AD, Van Zelm R, Jolliet O, Huijbregts MAJ.

Poster corner (Exhibition Hall)

TUPC07 17:20 *Improvements and applicability of newly impact categories in the case study of greenhouse tomato production.* Anton A, Torrellas M, Nuñez M.

Wednesday, May 15th

Special Symposium LC-IMPACT

16:30 – 18:30, room Alsh 2

(See program in page 7)