Regionalized LCIA – new software implementation and agricultural case study

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• Software enhancement:
  • Process locations extension
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Why regionalized LCIA?
Importance of regionalized LCA in agriculture

LCI:
- Wide variety of farming systems
e.g. USDA crop database

LCIA:
- Commonly analysed impact categories: land use, abiotic resource depletion, eutrophication, climate change, etc.
  ➔ Characterization factors (CFs) depend on site-specific characteristics:
  - Climate, soil type, water availability, soil erosion, etc.
Regional variation in impact assessment

- Withdrawal of 1l of water for agriculture

source: dennis140, aloe vera plantation, Fuerteventura (left); Gario, cows meadow, Texel (right)
Software enhancement
Software: openLCA

- Free, open source LCA software developed by GreenDelta since 2006
- Written in Java
- Regionalized LCIA implemented in a project supported by the US Department of Agriculture (USDA), National Agricultural Library
- www.openlca.org
Regionalised LCIA methods in openLCA

- Idea:
  - Parameterization of LCIA methods
Parameterization of LCIA methods

- Formulas for calculating the characterisation factors (CFs) can be defined
- Input and dependent parameters can be used as in the process data sets

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Flow property</th>
<th>Unit</th>
<th>Factor</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupation, arable</td>
<td>Area*time</td>
<td>m²*a</td>
<td>(0.60 \cdot \text{ratio}<em>\text{biom}/\text{SA}</em>\text{CF})</td>
<td>lognormal; gmean=1.36 g...</td>
</tr>
<tr>
<td>Occupation, construction site</td>
<td>Area*time</td>
<td>m²*a</td>
<td>(0.44 \cdot \text{ratio}<em>\text{biom}/\text{SA}</em>\text{CF})</td>
<td>lognormal; gmean=1.00 g...</td>
</tr>
<tr>
<td>Occupation, forest, intensive</td>
<td>Area*time</td>
<td>m²*a</td>
<td>(0.04 \cdot \text{ratio}<em>\text{biom}/\text{SA}</em>\text{CF})</td>
<td>lognormal; gmean=9.09E-1</td>
</tr>
<tr>
<td>Occupation, forest, intensive, clear-c...</td>
<td>Area*time</td>
<td>m²*a</td>
<td>(0.18 \cdot \text{ratio}<em>\text{biom}/\text{SA}</em>\text{CF})</td>
<td>lognormal; gmean=0.41 g...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Uncertainty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ratio_biom</td>
<td>1.0</td>
<td>uniform: min=0.21 max=1.97</td>
<td>from shapefile: ecoregions_with_biome_ratio</td>
</tr>
<tr>
<td>SA_CF</td>
<td>0.44</td>
<td>none</td>
<td>Settlement Area Characterization Factor</td>
</tr>
<tr>
<td>SA_EF</td>
<td>300.0</td>
<td>none</td>
<td>Settlement Area Ecofactor</td>
</tr>
</tbody>
</table>
Shapefiles containing regional characteristics

- Regional characteristics affecting the CFs can be defined with parameters: e.g. population density, precipitation variability, etc.
- Data for those characteristics is contained in shapefiles, which can be imported to openLCA
- Parameters are extracted during the shapefile import
- Shapefiles are stored in the database
Shapefiles containing regional characteristics
Binding shapefiles and LCIA method parameters

- Parameters of shapefiles can be bound to input parameters
- Default value of parameters is used for normal calculations and formula evaluation
- In regionalized assessment the parameter value derived from the shapefile is used for the formula evaluation
Extension of locations in openLCA (I)

Traditional approach:

- A list of locations available in the database level.
- The geographic information of the locations was limited to a pair of latitude, longitude data.
- The processes could only used locations from the pre-defined list.
  - Usually, only countries, global or group of countries (e.g. UCTE, EU, etc.)
Extension of locations in openLCA (II)

New approach:

- KML data can be added to each location (polygons, lines, points):
  - Import of kmz/xml files with geographic data.
  - Write coordinates in the “Text editor”.
  - Draw the polygons, lines or points in the KML editor.
- New locations can be defined in the process editor.
Extension of locations: **KML editor (map)**
Extension of locations: **KML editor (text)**
Calculation framework

Linking of process locations and LCIA methods spatial units

- GeoTools libraries integrated in openLCA

- The intersection between shapefiles features and process geometries is calculated.

→ A weighted mean calculated for each regional parameter

\[
\frac{\sum_{i=1}^{n}(p_{Fi}L_{Fi})}{\sum_{i=1}^{n}L_{Fi}} = p
\]

\[
\frac{\sum_{i=1}^{n}(p_{Fi}A_{Fi})}{\sum_{i=1}^{n}A_{Fi}} = p
\]

\[p_{Fi} = p\]
**Calculation framework**

**Regionalised LCIA calculation**

- Creation of a regionalised result matrix for the inventory (GR)
- Creation of a regionalised LCIA matrix (CR)
- Creation of the regionalised LCIA result (RR)

\[ RR = CR \times GR \]
Regionalised LCIA: **Calculation procedure**

- Select the “Regionalized LCIA” option in the calculation properties window:

  ➔ The impact method select must contain regionalised impact factors
Regionalised LCIA: Calculation procedure

To reduce the calculation time for complex systems, it is recommended to evaluate the intersections with the existing database locations when the impact method is defined:

Shape file parameters

<table>
<thead>
<tr>
<th>Location</th>
<th>C:\Users\Cristina\openLCA-data-1.4\databases\regionalised_example\olca...</th>
</tr>
</thead>
</table>

Evaluate for existing locations

Parameters of ecofactors_renamed

<table>
<thead>
<tr>
<th>Name</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical F</td>
<td>0.004</td>
<td>1646.6</td>
</tr>
<tr>
<td>Current F</td>
<td>0.0</td>
<td>761.0</td>
</tr>
<tr>
<td>Ecofactor</td>
<td>0.0</td>
<td>2.0E7</td>
</tr>
<tr>
<td>Normalize</td>
<td>0.0</td>
<td>2.614</td>
</tr>
</tbody>
</table>
Regionalised LCIA: Results
Case study: corn production in USA
Scope

- Functional unit: Production of 1kg of corn grain, at harvest in 2005; at farm; 85%-91% moisture
- Production in 5 estates of US: Illinois, Iowa, Minnesota, Nebraska and North Dakota
- System boundaries: Cradle to farm-gate
- Foreground system:
  - USDA crop database
  - KML data: US Census Bureau
- Background system:
  - ecoinvent 2.2. unit processes, GaBi 2012 full US
  - KML data: ecoinvent 3 geographies
Regionalized impact categories

- **Land use:**
  - de Baan et al. (2012), as implemented in Ecological Scarcity 2013:
    - *Parameter:* Ratio of species densities of biomes 1 to 4 to species density in biome 5
    - ➔ Generic: biome 5 values

- **Freshwater consumption:**
  - Ecological Scarcity 2013 (Frischknecht and Büsser Knöpfel 2013)
  - Pfister et al. (2009), as implemented in Enhanced Eco-Indicator 99:
    - *Parameter:* Water stress index (WSI). Data per country and watershed
Regionalized characterization factors

- WSI from Pfister et al. (2009)
- Eco-factor for land use (arable)
LCIA results: land use
LCIA results: land use

Highest LCI for occupation flows
LCIA results: land use

Highest LCI for occupation flows

Lowest CF

UBP

Illinois
Iowa
Minnesota
Nebraska
North Dakota

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LCIA results: freshwater consumption
LCIA results: freshwater consumption

Major contributor: corn production, at farm – US-MN
LCIA results: freshwater consumption

Major contributor: corn production, at farm – US-MN

Major contributor: crude oil, on shore – RME
LCIA results: freshwater consumption

Major contributor: corn production, at farm – US-MN

Major contributor: crude oil, on shore – RME

<table>
<thead>
<tr>
<th>Location</th>
<th>CF (UBP/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>610</td>
</tr>
<tr>
<td>Kuwait</td>
<td>200000000</td>
</tr>
<tr>
<td>USA</td>
<td>232</td>
</tr>
</tbody>
</table>

![Graph showing freshwater consumption by location and contribution]

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LCIA results: freshwater consumption

Results for Minnesota. Regionalized data per country
LCIA results: Ecological Scarcity 2013
Conclusions

- Regionalized LCIA in openLCA works successfully without affecting significantly the calculation time required.

- High variations in results due to different inventory and different characterization factors between locations. → Added complexity to results interpretation.

- The most suitable spatial resolution per parameter should be defined.

- Weighted aggregations might be useful for avoiding misleading values (e.g. emission proxies).
Outlook
Future software development

- Regionalized LCIA implementation in the Project level (i.e. comparative analysis)
- Further results views (e.g. contributions per location, etc.)
- Background processes tag: avoid data sets from generic databases when performing a regionalized LCIA

Other ideas:
- Geographic distributions of the processes when determining the location of each activity
- Consider geographic uncertainty per data set exchange and LCIA CF
- Transport pathways of emissions: does the impact occur in the process location?
- Seasonal variations of regional parameters
Thank you!

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