

GreenDELTA

sustainability consulting + software

Linking regionalized LCIA methods and LCA databases: concept and practical demonstration of implementation in LCA software

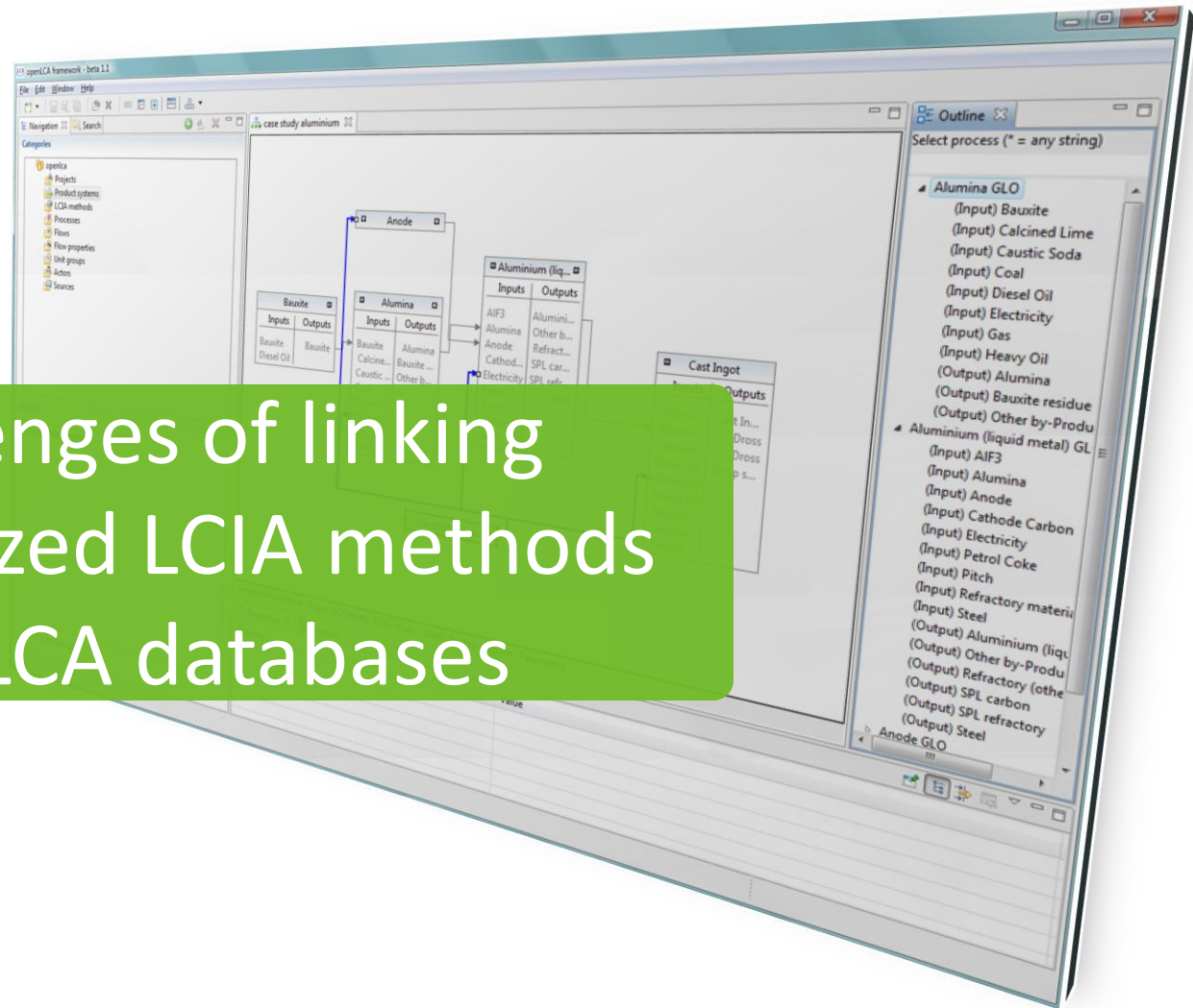
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GreenDelta GmbH

October 9, 2014
San Francisco, USA

Content

- Challenges of linking regionalized LCIA methods and LCA databases
- New concept for regionalized LCIA implementation in openLCA
- New concept implementations:
 - Parameterization of LCIA methods
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 - Calculation framework
- Application example
- Conclusions
- Outlook

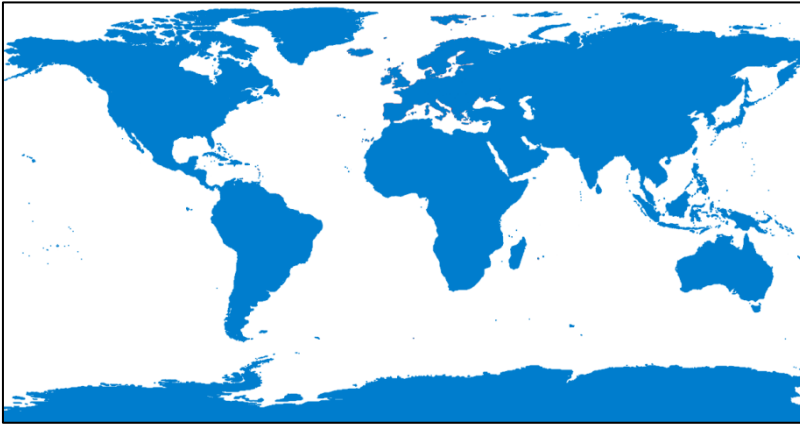
Challenges of linking regionalized LCIA methods and LCA databases



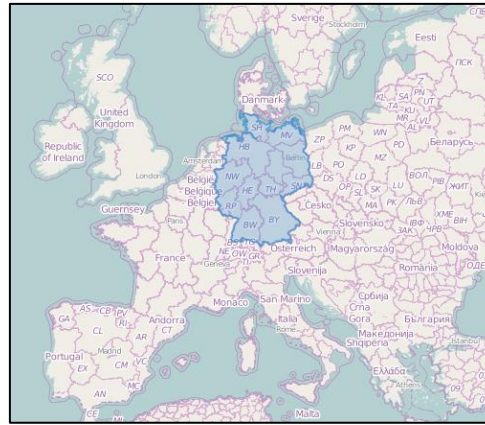
Several levels of regionalization in a life cycle

Foreground processes

Site-generic



Site-dependent



Site-specific

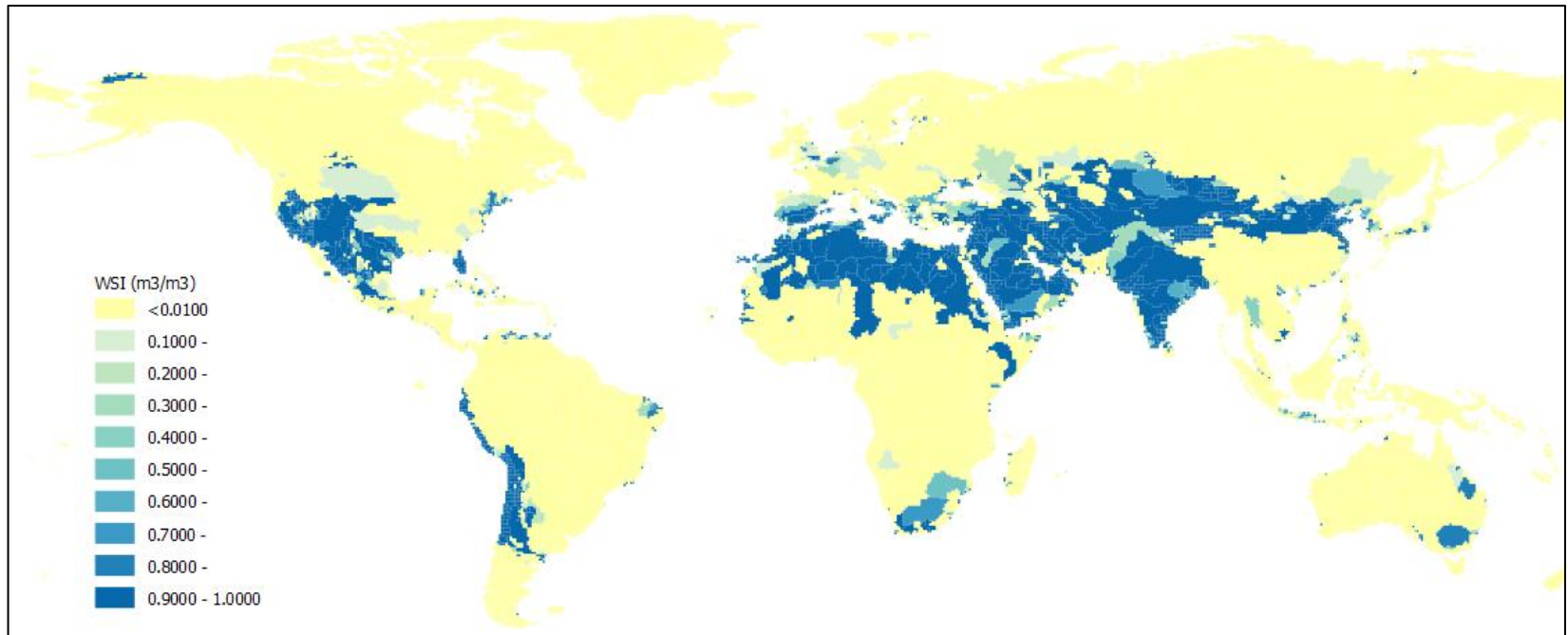


Most common in LCA databases

Background processes

Different spatial units per impact category

- e.g. biomes, watersheds, etc.



WSI per m3 water consumed (Source: El99+)

Spatial uncertainty

- High spatial resolution might add precision to results but decrease relative accuracy
- Spatial uncertainty of inventory and CFs should be considered
 - What is the likelihood of an activity occurring in a specific location?
 - What is the real area of impact of an emission?

Amount of data

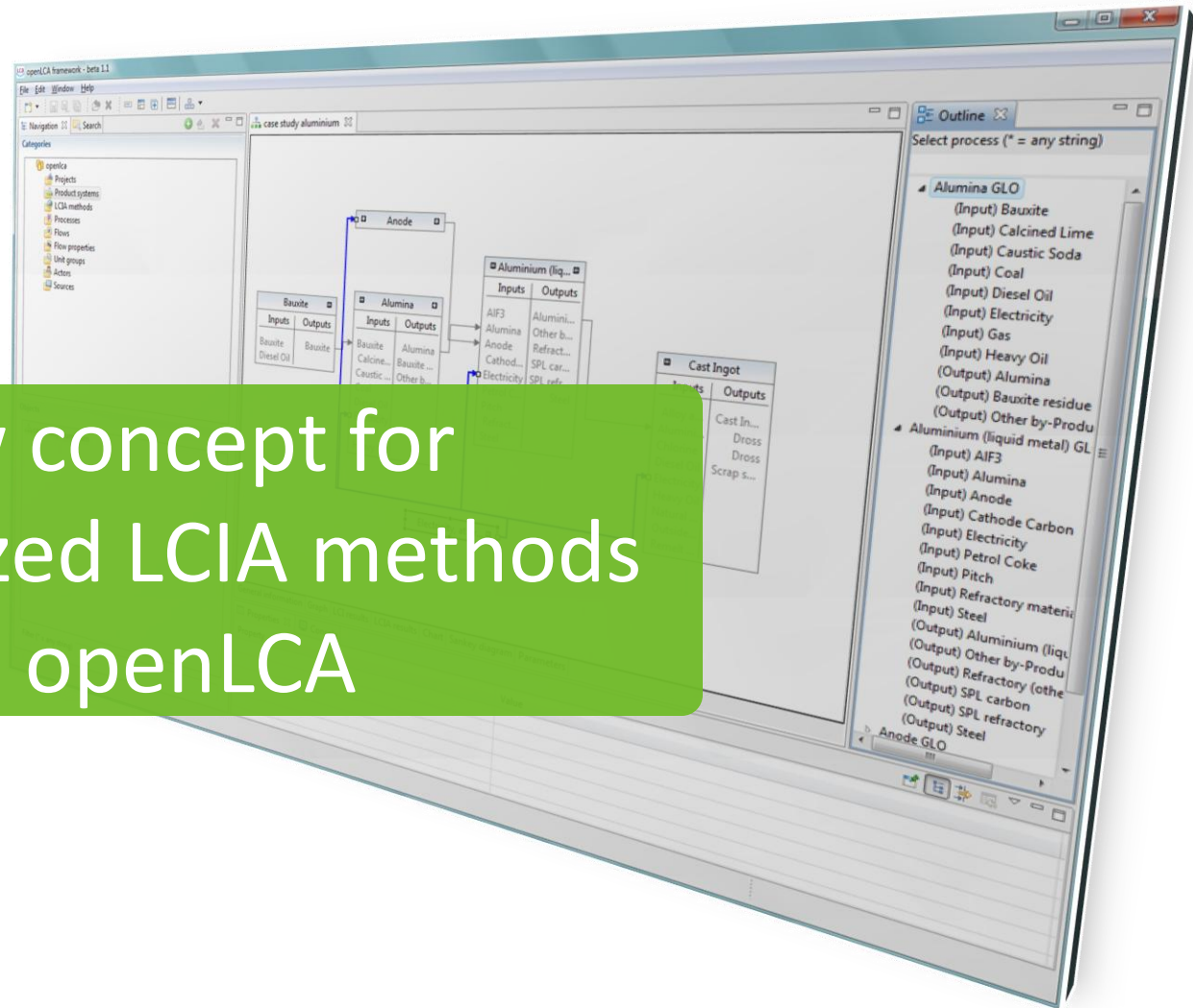
- High amount of data:

$\text{fhprocesses} * \text{elementary exchanges} * \text{locations}$

- Data storage capacity
- Computing power
- Interpretation of results by non-expert users

→ GIS (Geographic Information Systems)

New concept for regionalized LCIA methods in openLCA

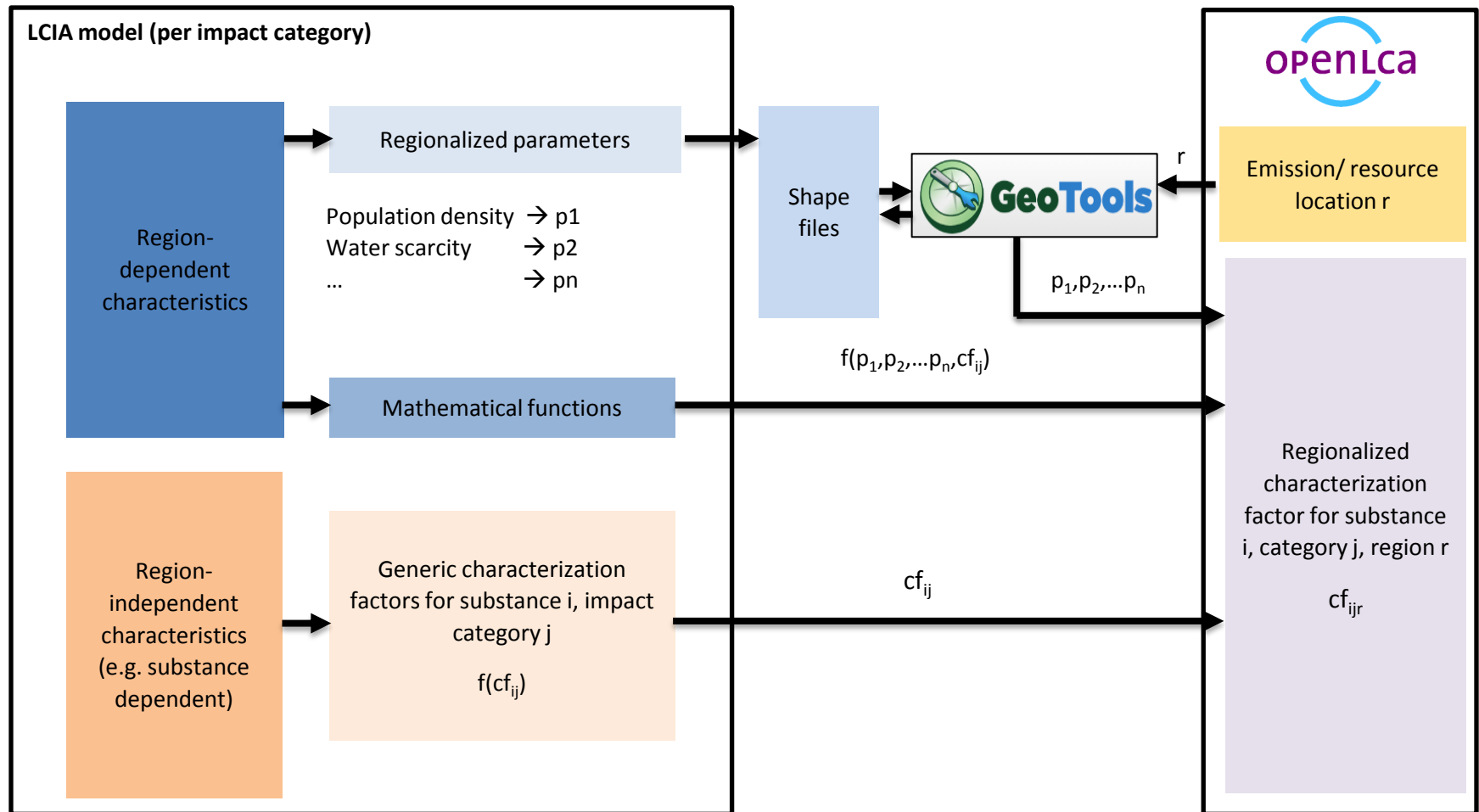


Software: openLCA

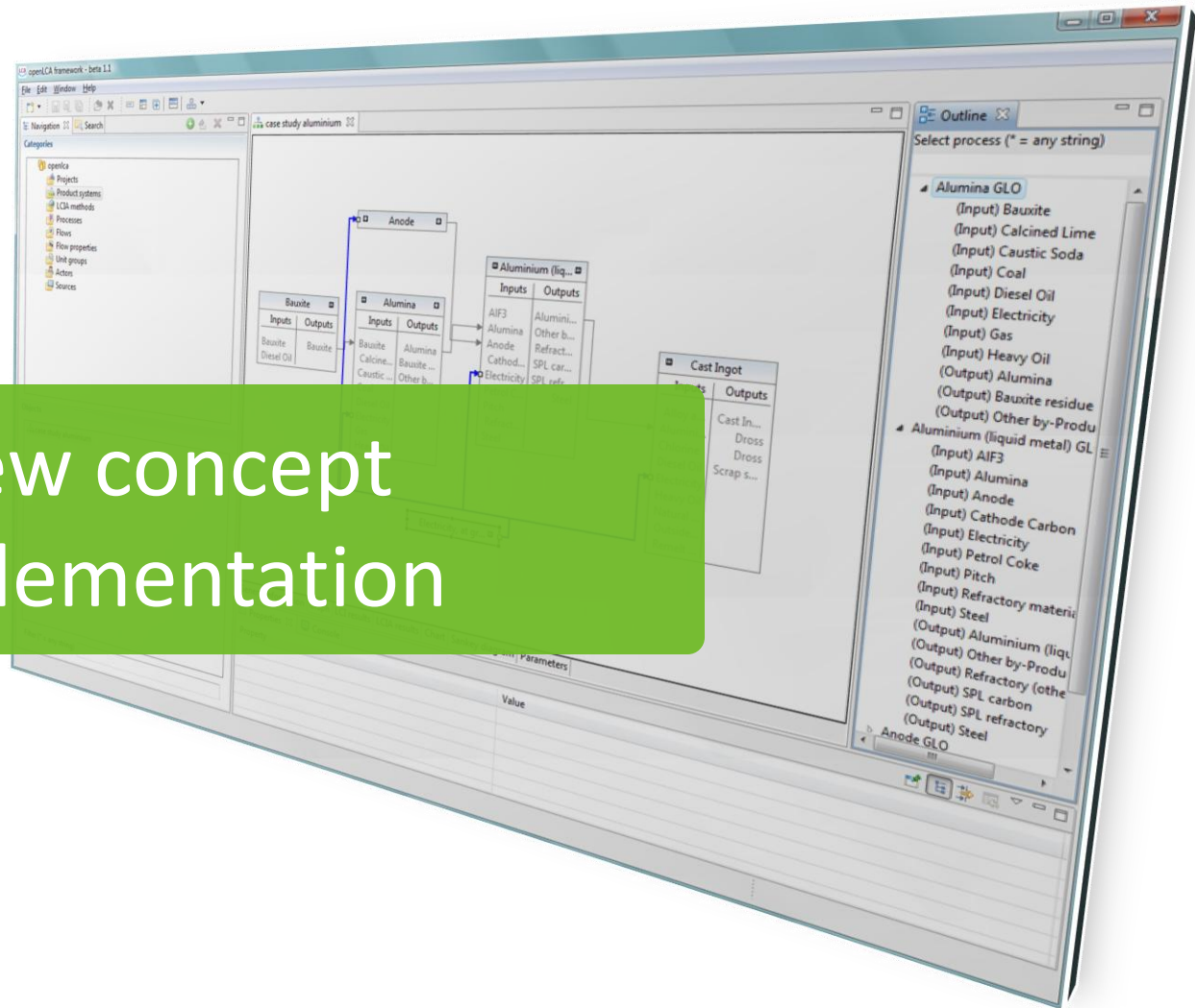


- Free, open source LCA software developed by GreenDelta since 2006
- Written in Java
- Regionalized LCIA implemented in a project supported by the US Department of Agriculture (USDA), National Agricultural Library
- www.openlca.org

Parameterization of LCIA methods




New concept
implementation



Parameterization of LCIA methods


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

Impact factors					
Impact category  Land use					
Flow	Category	Flow property	Unit	Factor	Uncertainty
Occupation, arable	resource/land	Area*time	m2*a	$(0.60 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=1.36 g...
Occupation, construction site	resource/land	Area*time	m2*a	$(0.44 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=1.00 g...
Occupation, forest, intensive	resource/land	Area*time	m2*a	$(0.04 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=9.09E-...
Occupation, forest, intensive, clear-c...	resource/land	Area*time	m2*a	$(0.18 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=0.41 g...

Parameters

Global parameters

Input parameters

Name	Value	Uncertainty	Description
 ratio_biom	1.0	uniform: min=0.21 max=1.97	from shapefile: ecoregions_with_biome_ratio
SA_CF	0.44	none	Settlement Area Characterization Factor
SA_EF	300.0	none	Settlement Area Ecofactor


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

Shape file parameters

▼ Files

Location  C:\Users\Cristina\openLCA-data-1.4\databases\regionalised_example\olca_...

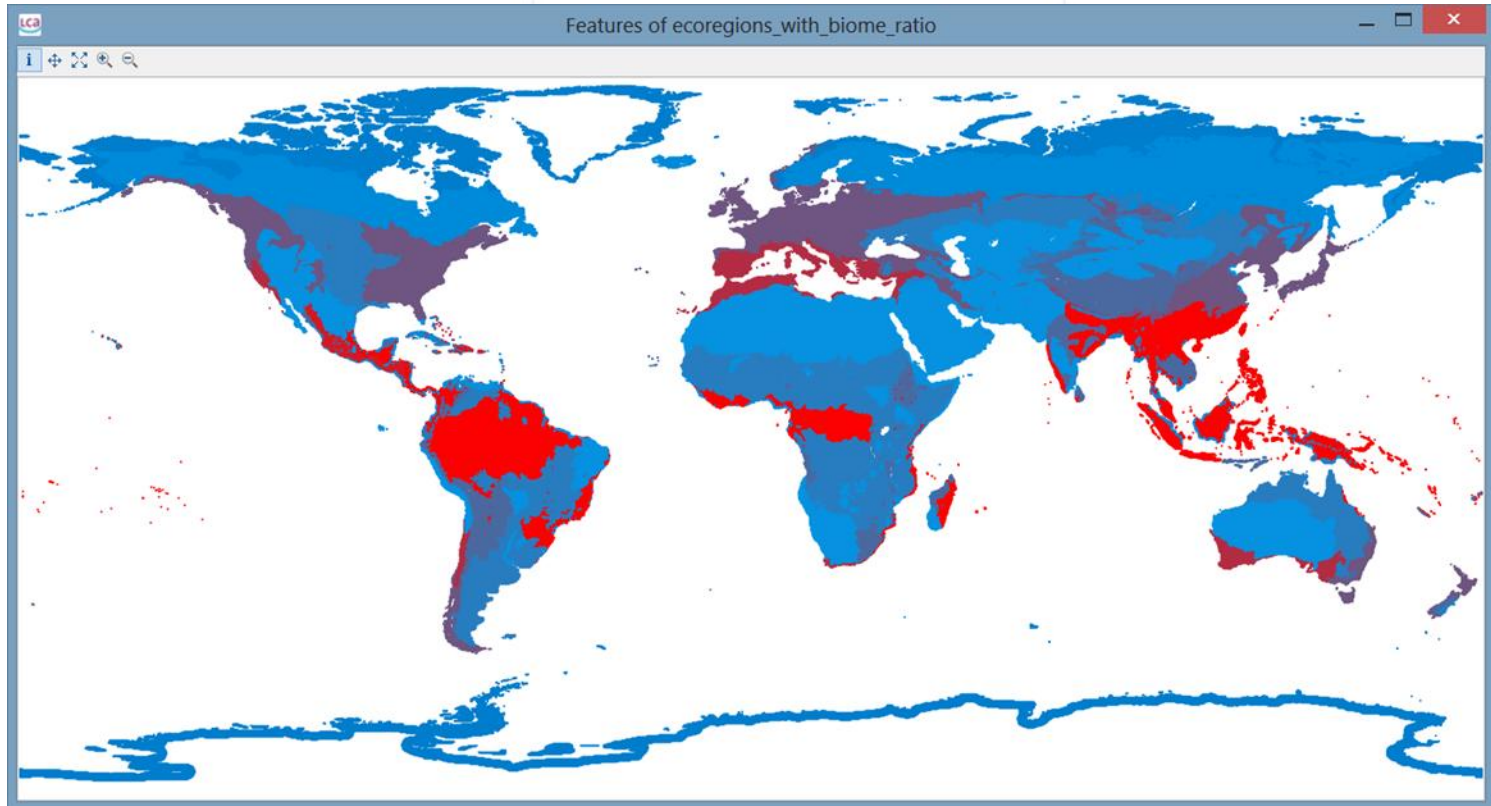
 Import...

 Evaluate for existing locations

Shapefiles containing regional characteristics

Parameters of ecoregions_with_biome_ratio

Name	Minimum	Maximum
CLS_CODE	0.0	1144.0
ECO_ID_U	10000.0	17109.0
ECO_NUM	1.0	99.0
ratio_biom	0.20929077	1.96750671



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

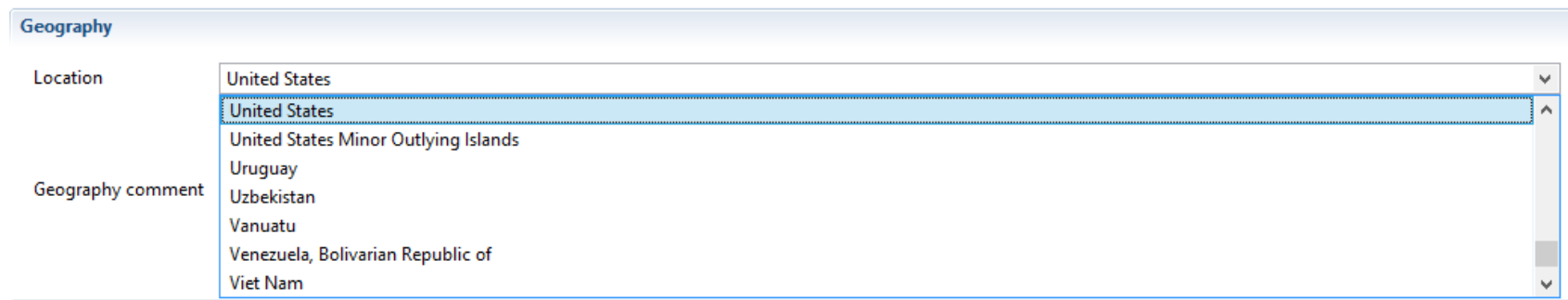
▼ Input parameters					
Name	Value	Uncertainty	Description	External source	
ratio_biom	1.0	none			
Ecofactor	610.0	none			

ecoregions_ratio_biomes

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 use locations from the pre-defined list.
 - Usually, only countries, global or group of



The screenshot shows a software interface titled "Geography". It contains two labels: "Location" and "Geography comment". The "Location" label is positioned to the left of a dropdown menu. The dropdown menu is open, displaying a list of locations. The first two items, "United States" and "United States Minor Outlying Islands", are highlighted in blue. Below them are "Uruguay", "Uzbekistan", "Vanuatu", "Venezuela, Bolivarian Republic of", and "Viet Nam". The "Geography comment" label is to the left of the list, but no text is entered. The interface has a light blue header bar and a white background for the list.

Location	Geography comment
United States	
United States Minor Outlying Islands	
Uruguay	
Uzbekistan	
Vanuatu	
Venezuela, Bolivarian Republic of	
Viet Nam	

Extension of locations in openLCA (II)

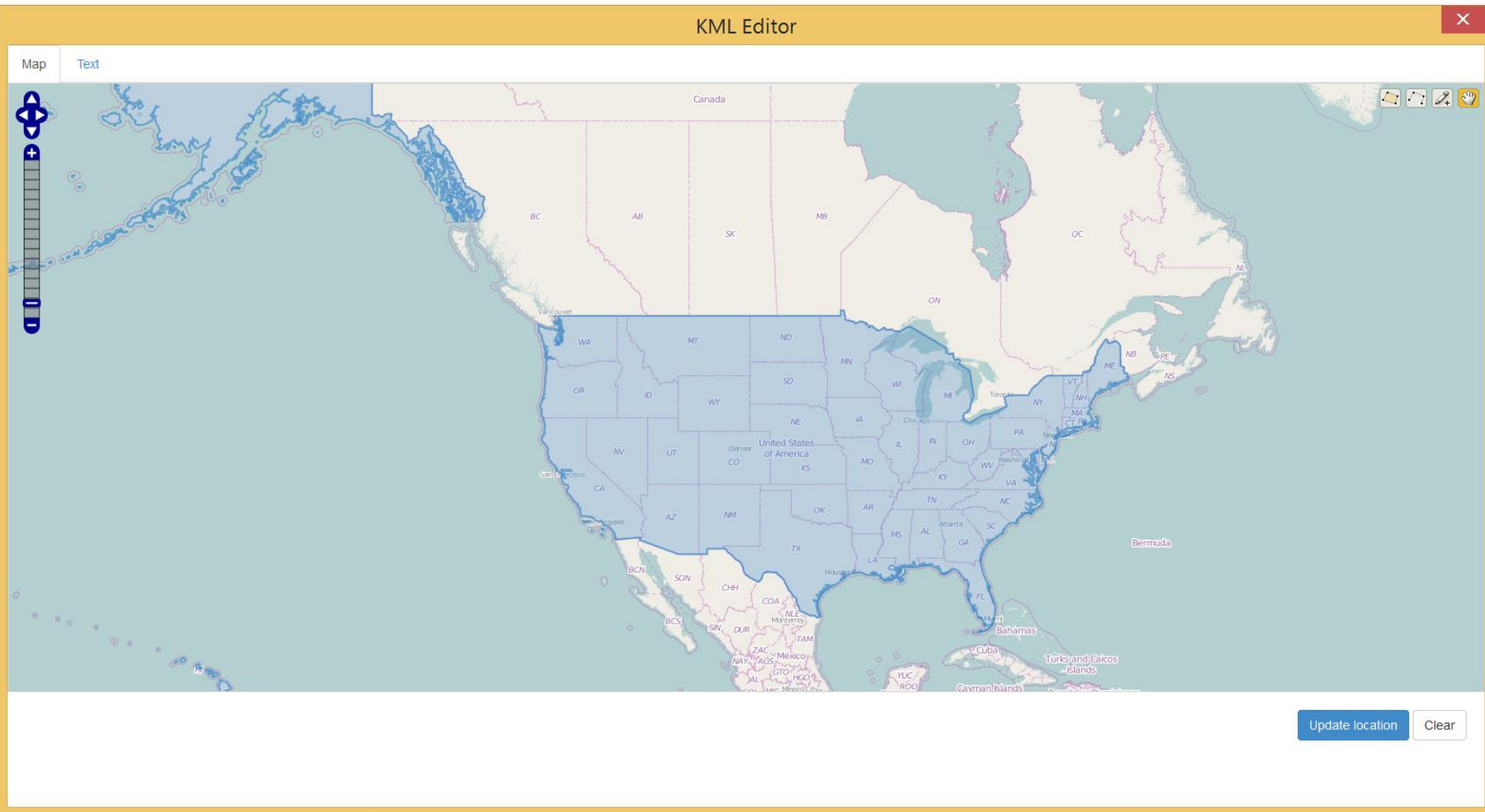
New approach:

- 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.

The screenshot shows the 'Geography' panel in the openLCA software. It contains the following fields and controls:

- Location:** A dropdown menu with 'Switzerland' selected.
- KML:** A text field containing 'Polygon [8.60,47.77 ... 8.60,47.77] (location)'. Below this field are two buttons: 'Map editor' (with a globe icon) and 'Text editor' (with a code icon).
- Description:** A text field containing 'European average values'.

Extension of locations: **KML** editor (map)



Extension of locations: KML editor (text)

KML Editor

MapText

```
1 <?xml version="1.0" encoding="UTF-8"?>
2 <kml xmlns="http://earth.google.com/kml/2.1">
3   <Folder>
4     <name>OpenLayers export</name>
5     <description>Exported on Tue Oct 07 2014 20:37:00 GMT+0200</description>
6     <Placemark>
7       <name>OpenLayers_Feature_Vector_35130</name>
8       <description>No description available</description>
9       <MultiGeometry>
10        <Polygon>
11          <outerBoundaryIs>
12            <LinearRing>
13              <coordinates>-155.59328873999996,20.139185279999996 -155.58013709,20.131201269999995 -155.5692592,20.134043480000003 -155.55928565,20.14047719 -155.54889868,20.142957660000015
-155.527194579999999,20.135102840000002 -155.49014258,20.112830299999985 -155.445726690000001,20.10520803 -155.336896120000003,20.062859189999994 -155.20630977,19.99947805
-155.172668420000004,19.97420827 -155.088306640000004,19.8843688 -155.07946997,19.866824649999995 -155.07593014,19.844707129999993 -155.07593014,19.765616350000016 -155.06877295,19.743912249999997
-155.05768836,19.739158019999998 -155.017613280000003,19.745669249999988 -154.99311865,19.743188779999983 -154.98125891,19.734352110000007 -154.97637549,19.717402240000002
-154.96826229,19.666759340000006 -154.96169938,19.653220110000014 -154.92149512,19.613739319999997 -154.86987036,19.587436009999998 -154.79478451,19.543045959999997
-154.79765255,19.522117000000005 -154.80527482,19.499973649999999 -154.81623023,19.479561460000003 -154.82889095,19.463929339999996 -154.91084977,19.419797670000012
-154.9182395,19.408635559999993 -155.00717464,19.332102759999987 -155.024098669999997,19.327348529999988 -155.04921342,19.324661359999999 -155.06869544,19.317865910000002
-155.10324113,19.299391580000016 -155.17147986,19.284353739999997 -155.18892066,19.275517069999992 -155.26775305,19.278927710000001 -155.28589148,19.274483540000006
-155.29819047,19.269470930000004 -155.32237504,19.252262679999994 -155.3545953,19.221980290000005 -155.367049320000004,19.217484439999996 -155.383379069999996,19.213479510000003
-155.39769344,19.203686299999988 -155.42167131,19.179915669999986 -155.43588232,19.169632059999999 -155.48683529,19.142398579999995 -155.501847289999997,19.137566829999999
-155.54520382,19.098008520000001 -155.5544539,19.082428080000014 -155.569414229999998,19.025687360000006 -155.61349422,18.965820210000004 -155.627421019999999,18.957396950000003
-155.637937179999997,18.953133649999998 -155.65617896,18.934349260000005 -155.66840043,18.930137630000008 -155.66902055,18.935589499999995 -155.686099610000004,18.964269919999996
-155.708708050000004,18.985198870000005 -155.744313109999998,19.006050310000002 -155.78495662,19.023026019999996 -155.82262874,19.032508649999999 -155.85510738,19.030519099999999
-155.863608149999998,19.032508649999999 -155.86885331,19.041836239999998 -155.87133378,19.055582169999994 -155.87595882,19.068036190000004 -155.887792729999997,19.073513900000002
-155.89983333,19.082428080000014 -155.9049493,19.103692929999999 -155.90399329,19.187150370000012 -155.87823259,19.346494649999997 -155.87787085,19.354633689999993 -155.88184994,19.36695852
-155.895415,19.38964447 -155.918850260000003,19.471344909999996 -155.91957373,19.476150820000001 -155.91817847,19.486977029999998 -155.918850260000003,19.49183462 -155.92231258,19.492558090000013
-155.935696780000003,19.49111115 -155.93931413,19.49183462 -155.951406410000003,19.52674205 -155.95298254,19.535914610000003 -155.95432613,19.559220679999996 -155.958305220000003,19.581053979999997
-155.96471309,19.601827900000007 -155.97347225,19.622162580000012 -155.99693335,19.656088160000003 -156.02339168,19.68513031 -156.04377804,19.717040510000018 -156.04917822,19.759337670000002
-156.03786108,19.782902120000003 -156.01649288,19.800911360000004 -155.99577063,19.814269710000005 -155.98649471,19.824217429999997 -155.98109452,19.843131 -155.96698686,19.854086410000001
-155.92505143,19.868581639999998 -155.90487179,19.901887110000008 -155.89449991,19.91325592 -155.85678687,19.96821381 -155.84993974,19.975138449999992 -155.8183396,19.99947805
-155.80896033,20.012578020000007 -155.808624429999998,20.029915469999998 -155.81924394,20.04950083 -155.82262874,20.053583270000015 -155.872263959999997,20.113037009999999
```

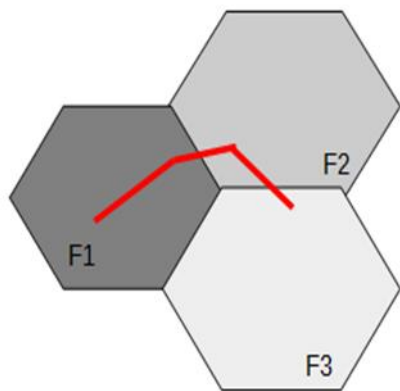
Update location

Clear

Calculation framework

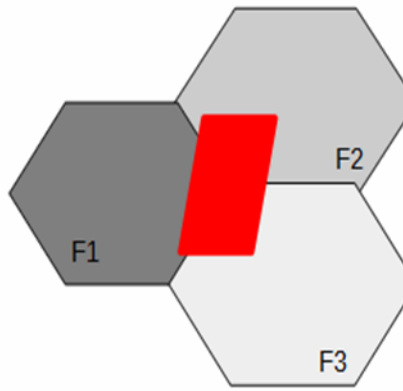
Linking of process locations and LCIA methods spatial units

- GeoTools libraries integrated in openLCA
 - The intersection between shapefiles features and process geometries is calculated.



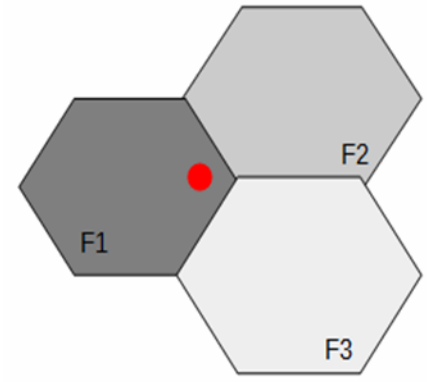
$$\frac{\sum_{i=1}^n (p_{Fi} L_{Fi})}{\sum_{i=1}^n L_{Fi}} = p$$

ed me



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

or ea



$$p_{Fi} = p$$

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)

$$RR = CR * GR$$

Regionalised LCIA: Calculation procedure

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

→ The i regional

Calculation properties

Please select the properties for the calculation

Allocation method: None

Impact assessment method: ecological scarcity 2013 (per country and biome)

Normalization and weighting set:

Calculation type:

- ☐ Quick results
- ☐ Analysis
- ☒ Regionalized LCIA
- ☐ Monte Carlo Simulation

Number of iterations: 100


Buttons: Save as default, Reset, Calculate, Cancel


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

Files

Location  C:\Users\Cristina\openLCA-data-1.4\databases\regionalised_example\olca_...

 Import...

 Evaluate for existing locations

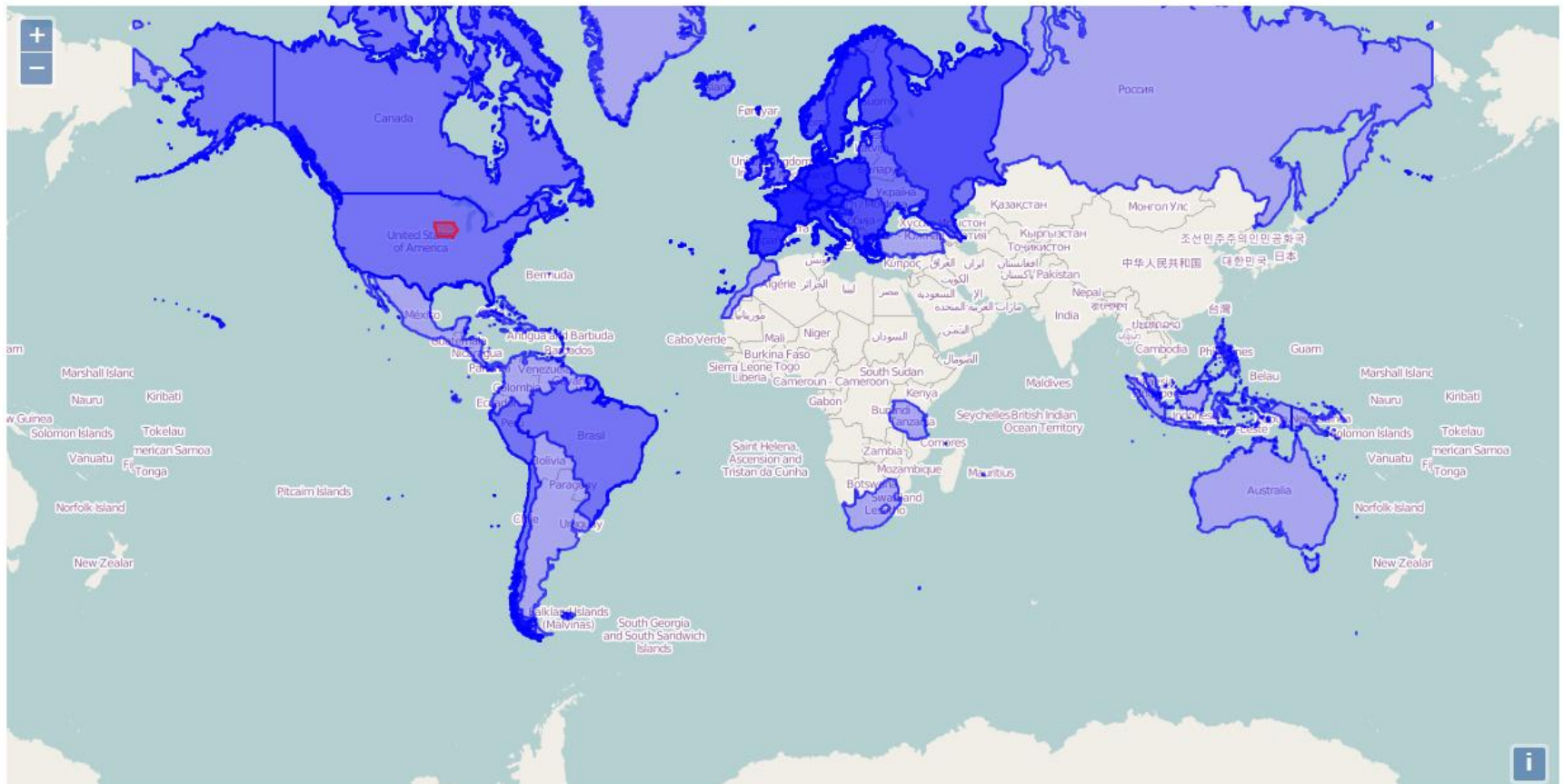
Parameters of ecofactors_renamed

Name	Minimum	Maximum
f_x Critical F	0.004	1646.6
f_x Current F	0.0	761.0
f_x Ecofactor	0.0	2.0E7
f_x Normalizat	2 614	2 614

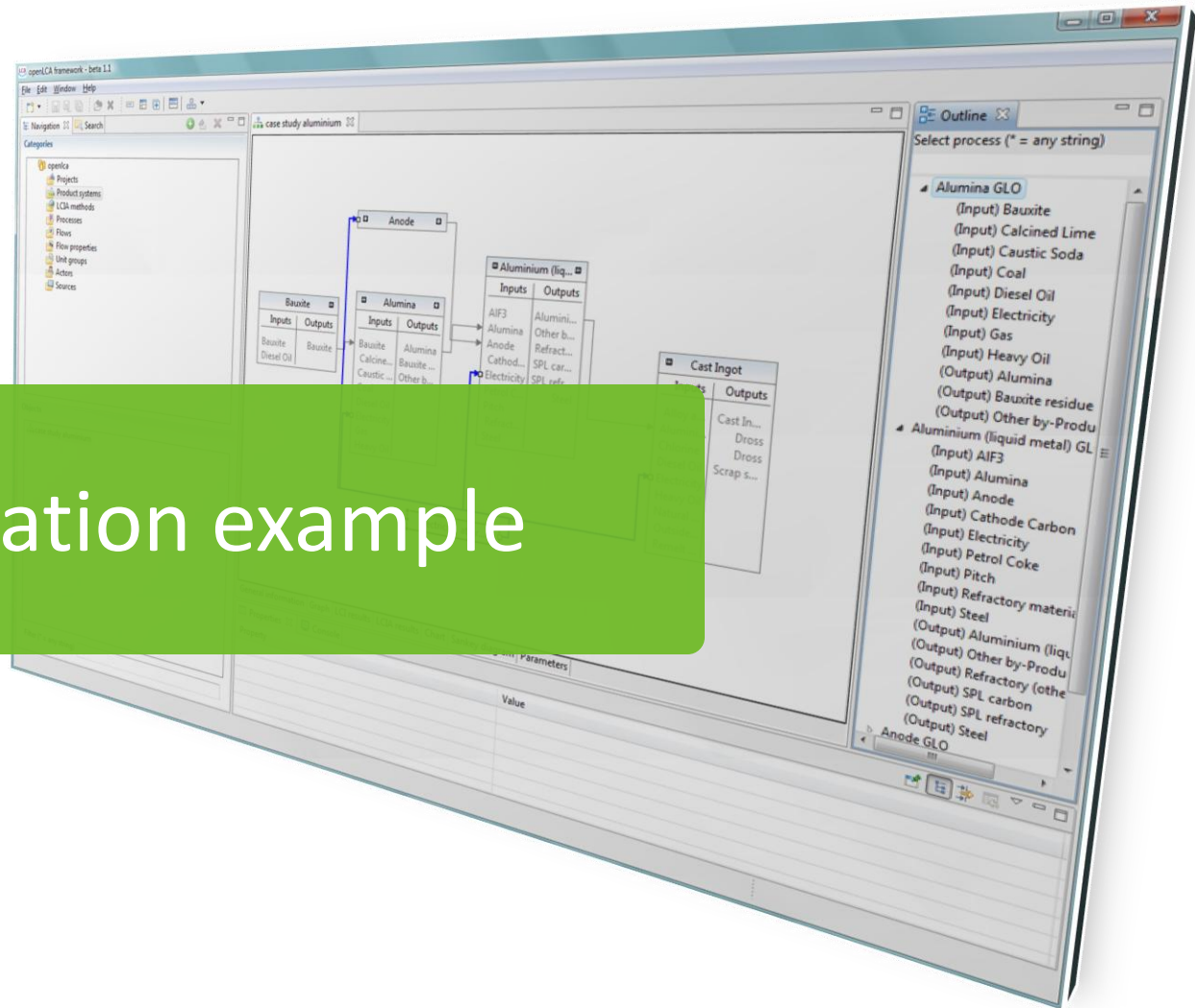
Regionalised LCIA: Results

Result map

- ☐ Flows Hydrogen-3, Tritium - water/ocean
- ☒ Impact categories total - Land use



Application example



Case study

- 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 category

- Land use:
 - de Baan et al. (2012), as implemented in Ecological Scarcity 2013:

$$Eco - factor^{Region_1} = K^{Region_1} \cdot \frac{1 \cdot UBP}{F_n^{CH}} \cdot \left(\frac{F}{F_k} \right)^2 \cdot c$$

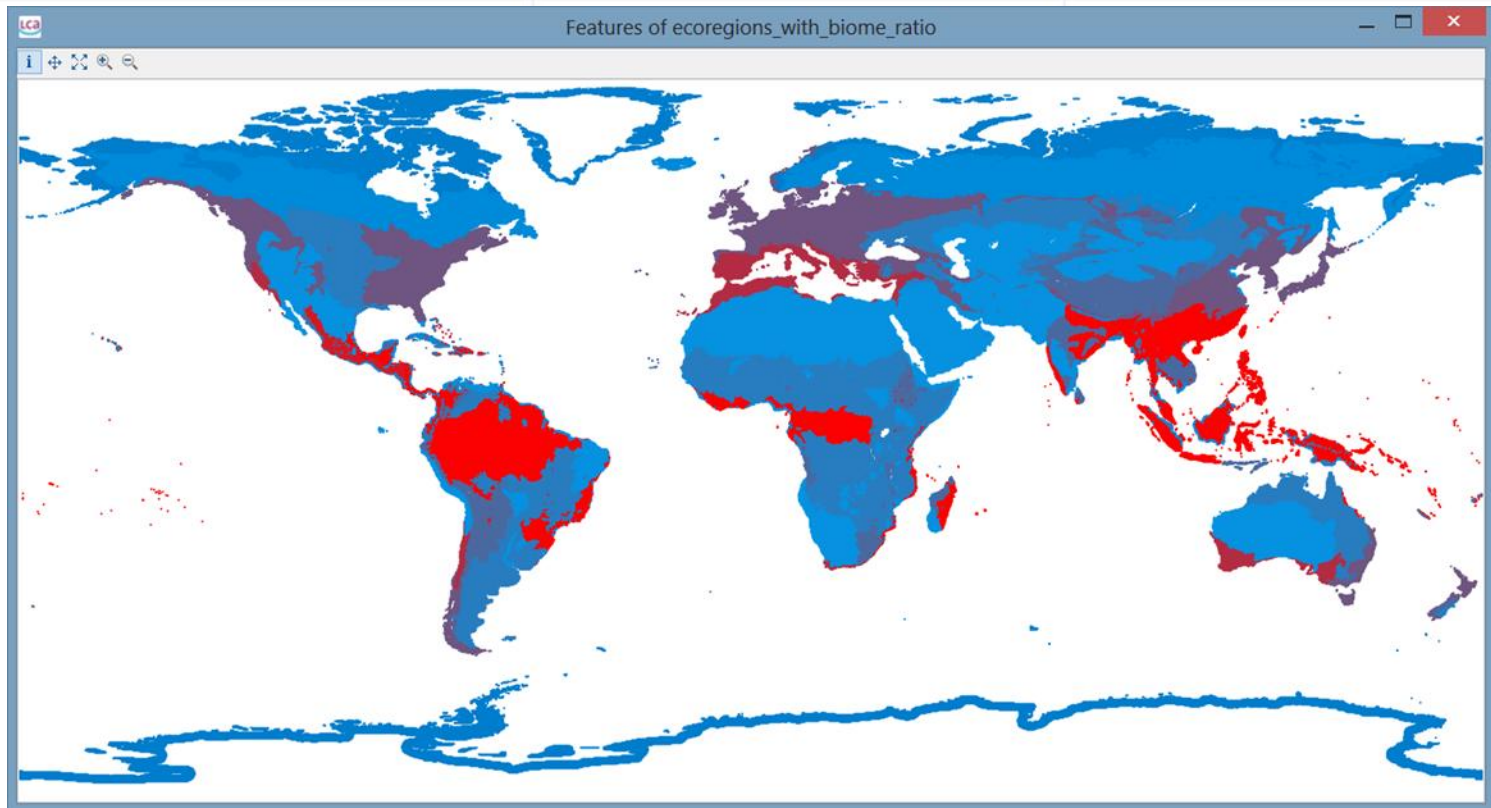
$$K^{biome_i} = \frac{BDP^{biome_i}}{BDP_settlement_area_biome5} = \frac{BDP^{biome5}}{BDP_settlement_area_biome5} \cdot \boxed{ratio^{biome_i_to_biome5}}$$

Regionalized parameter


Land use regionalized parameter

Parameters of ecoregions_with_biome_ratio

Name	Minimum	Maximum
CLS_CODE	0.0	1144.0
ECO_ID_U	10000.0	17109.0
ECO_NUM	1.0	99.0
ratio_biom	0.20929077	1.96750671




Land use parameterized formulas

▼ Impact factors 1.23					
Impact category  Land use					
Flow	Category	Flow property	Unit	Factor	Uncertainty
Occupation, arable	resource/land	Area*time	m2*a	$(0.60 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=1.36 g...
Occupation, construction site	resource/land	Area*time	m2*a	$(0.44 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=1.00 g...
Occupation, forest, intensive	resource/land	Area*time	m2*a	$(0.04 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=9.09E-...
Occupation, forest, intensive, clear-c...	resource/land	Area*time	m2*a	$(0.18 * \text{ratio_biom}) / \text{SA_CF}$	lognormal: gmean=0.41 g...

Parameters

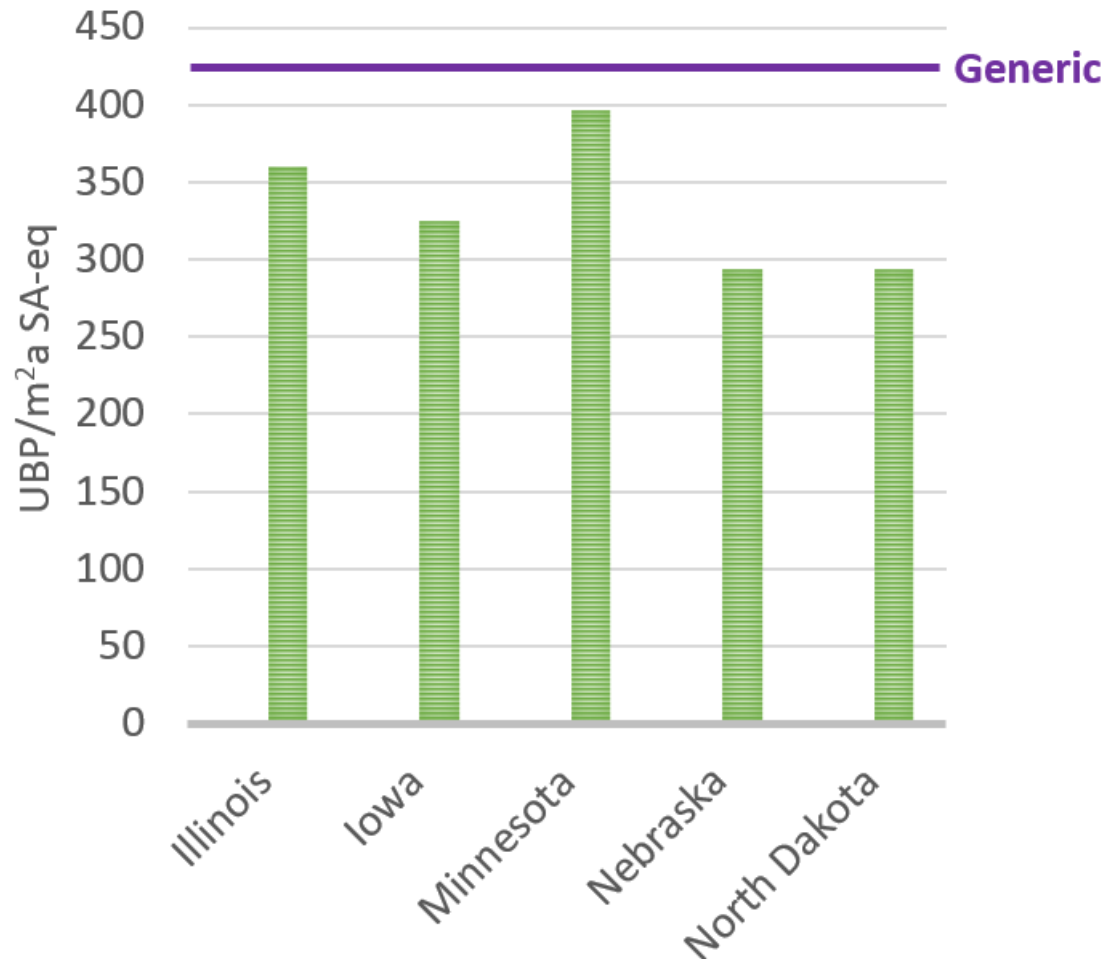
► Global parameters

▼ Input parameters

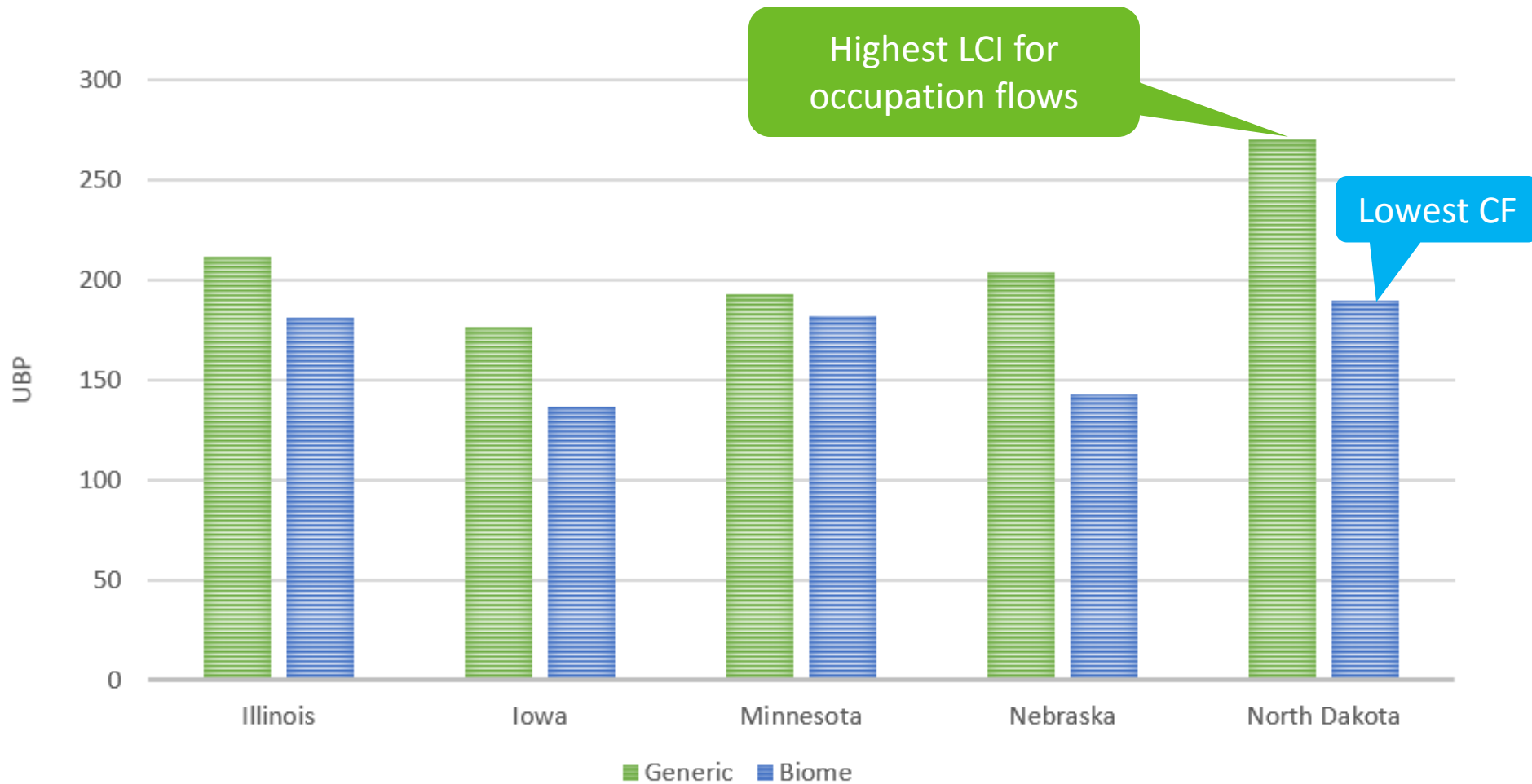
Name	Value	Uncertainty	Description
 ratio_biom	1.0	uniform: min=0.21 max=1.97	from shapefile: ecoregions_with_biome_ratio
SA_CF	0.44	none	Settlement Area Characterization Factor
SA_EF	300.0	none	Settlement Area Ecofactor

Regionalized characterization factors

- Eco-factor for land use (Occupation, arable)

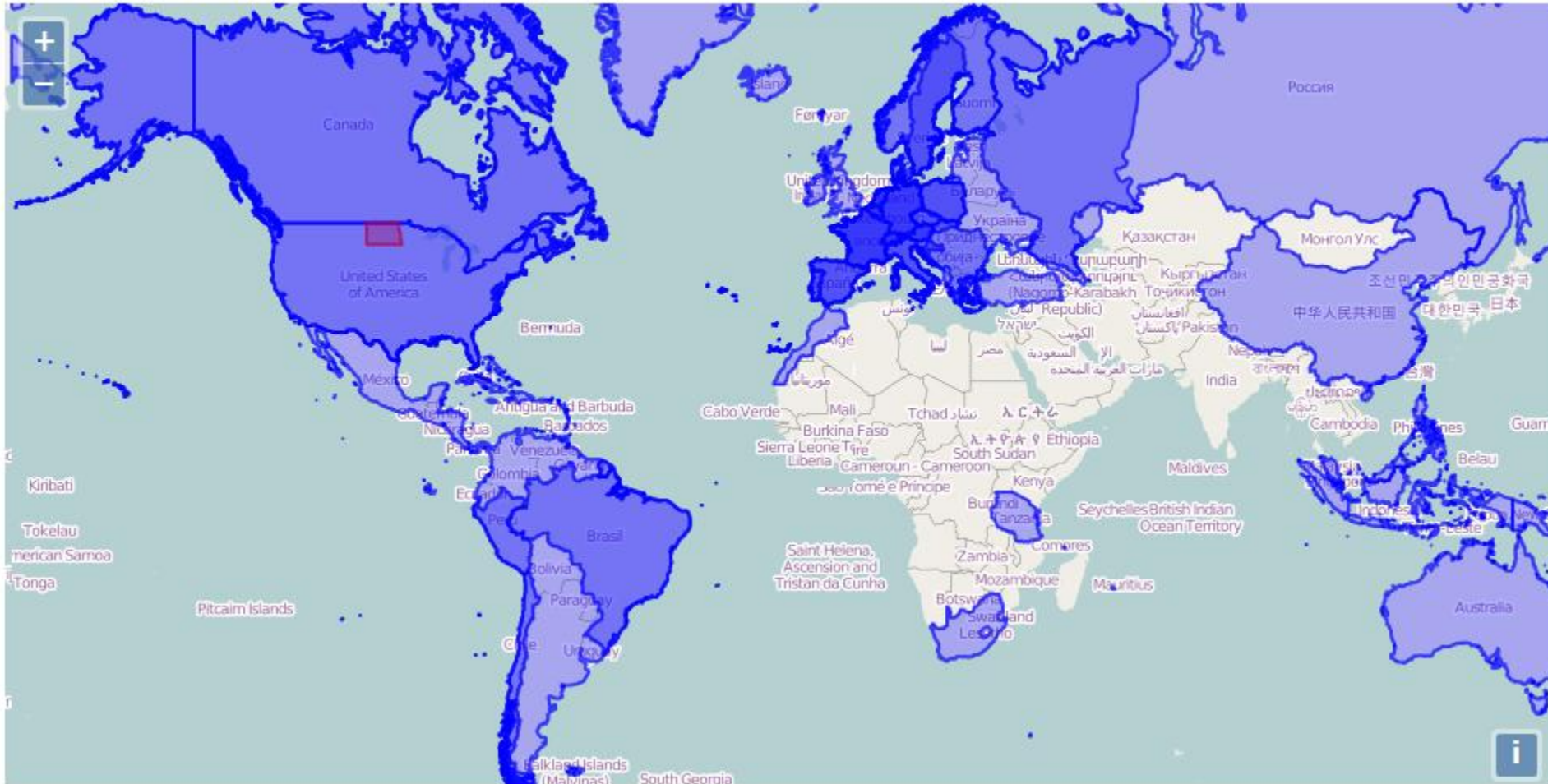


LCIA results: land use



LCIA results: land use

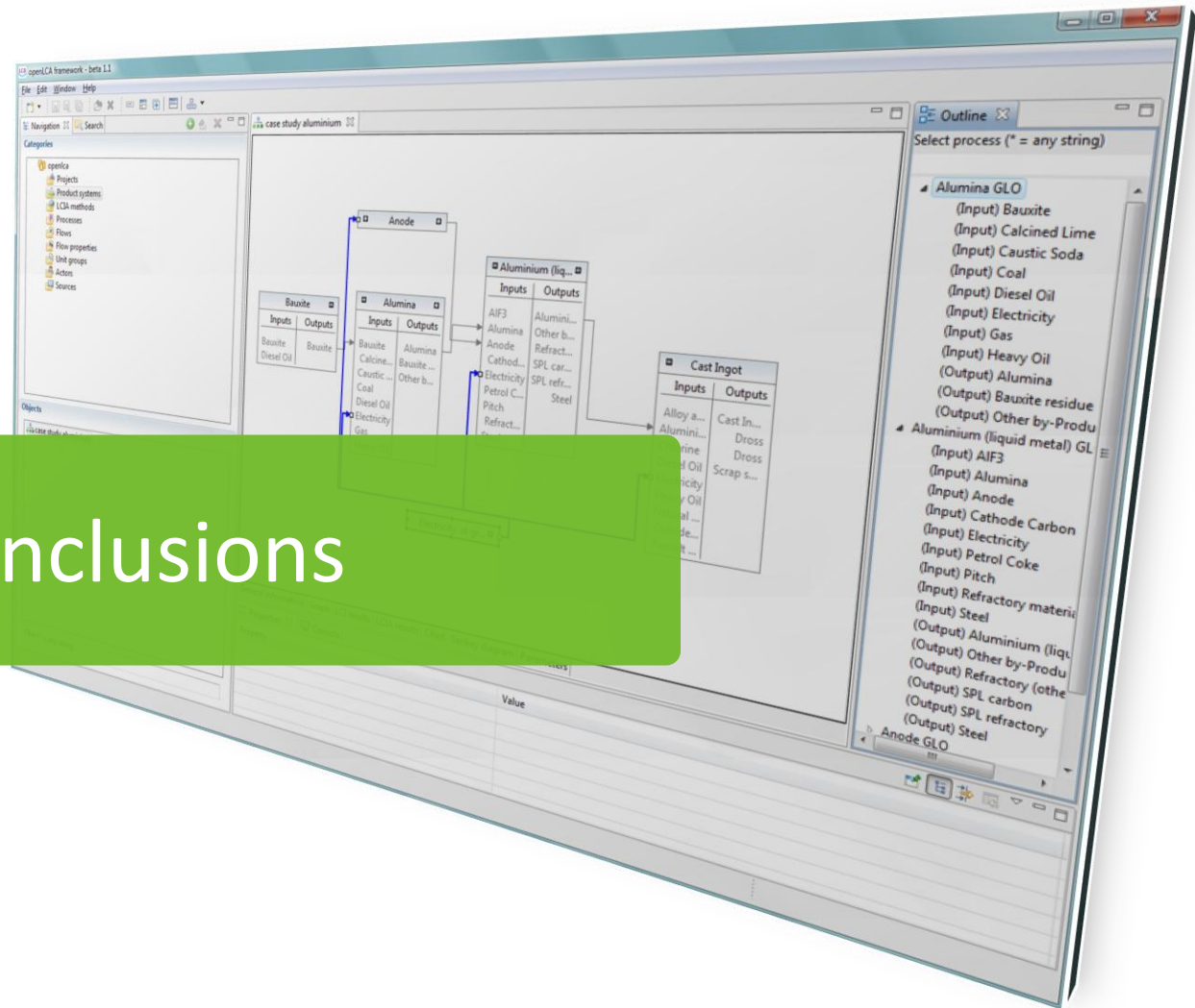
Impact categories  total - Land use ▼



Results for North Dakota

GreenDelta

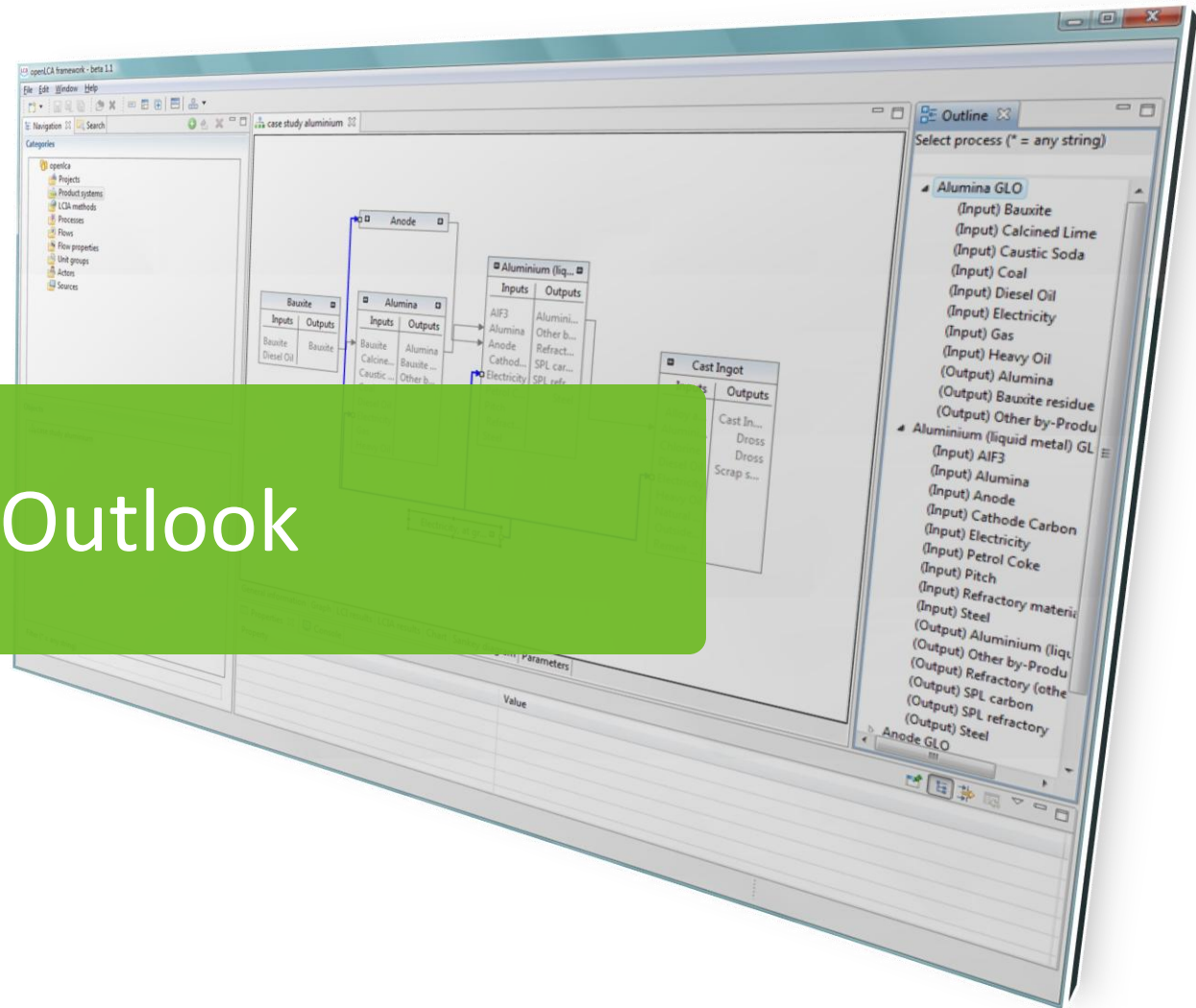
Conclusions



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
- Include transport pathways of emissions
- Seasonal variations of regional parameters

Thank you!

The logo consists of a green rectangular box containing the text 'GreenDelta' in white. Below the box, the words 'sustainability consulting + software' are written in a smaller, grey font. To the left of the box is a vertical line with blue, red, and green segments.

GreenDelta

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