

# GreenDELTA

sustainability consulting + software

## Regionalized LCIA – new software implementation and agricultural case study

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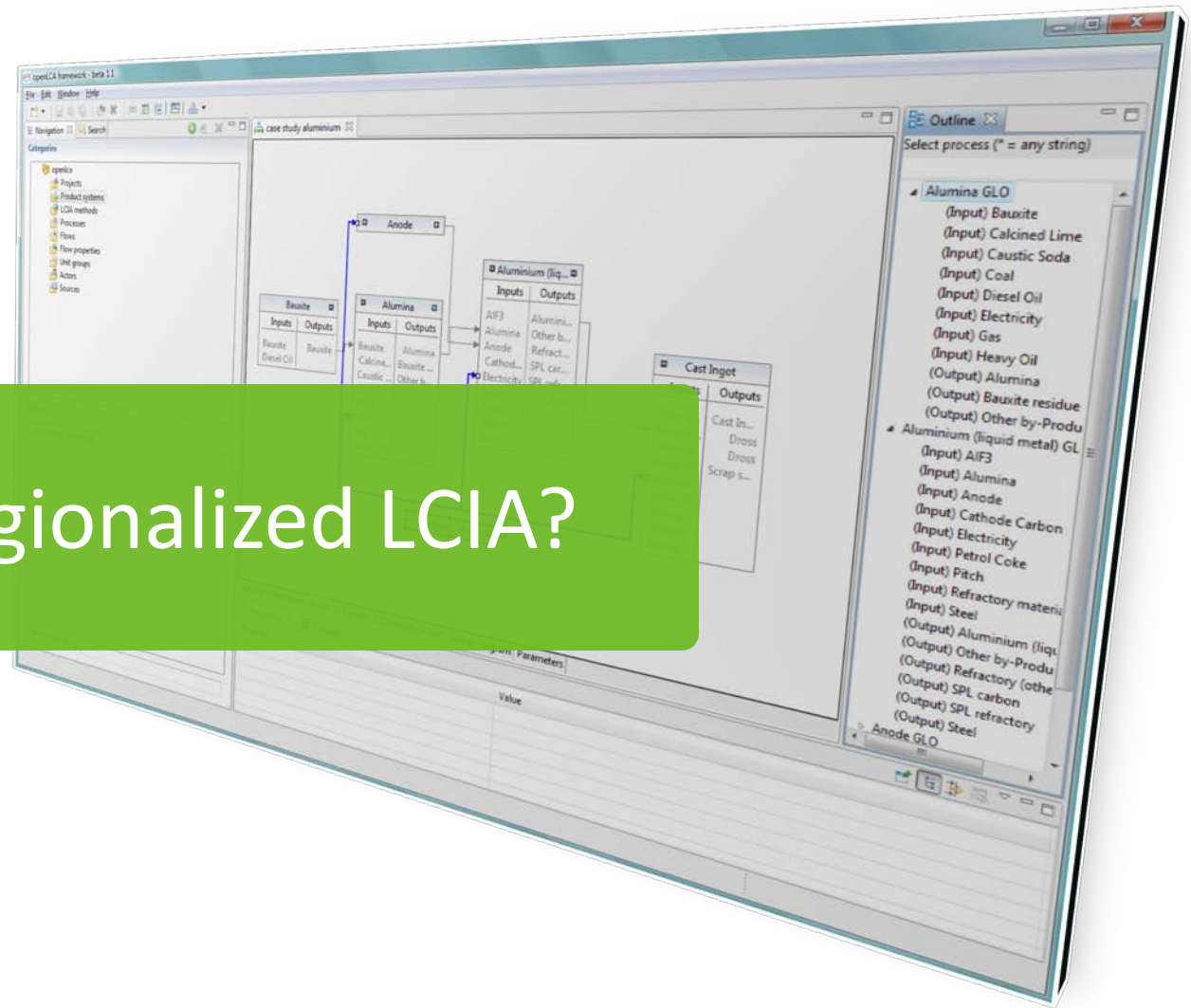
October 8, 2014

San Francisco, USA

# Content

- Importance of regionalized LCIA in agriculture
- Software enhancement:
  - Process locations extension
  - New approach for LCIA methods
  - Calculation framework
- Case study: corn production in USA
- Conclusions
- Outlook

# Why regionalized LCIA?



# Importance of regionalized LCA in agriculture

## LCI:

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

## LCIA:

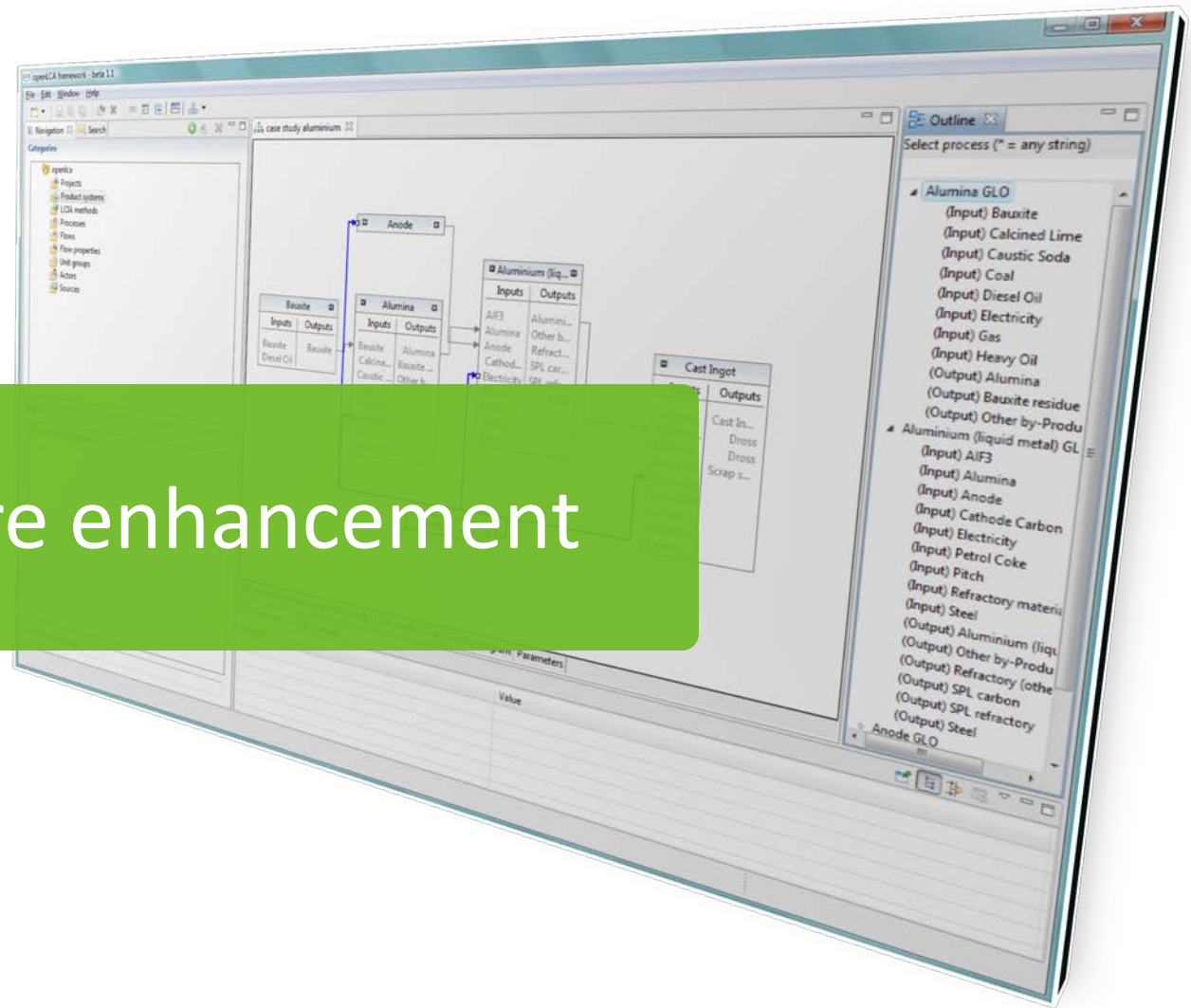
- Commonly analysed impact categories: land use, abiotic resource depletion, eutrophication, climate change, etc.
  - Characterization factors (CFs) depend on site-specific characteristics:
    - Climate, soil type, water availability, soil erosion, etc.

# Regional variation in impact assessment

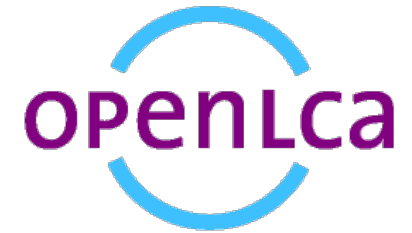
- Withdrawal of 1l of water for agriculture



Software enhancement



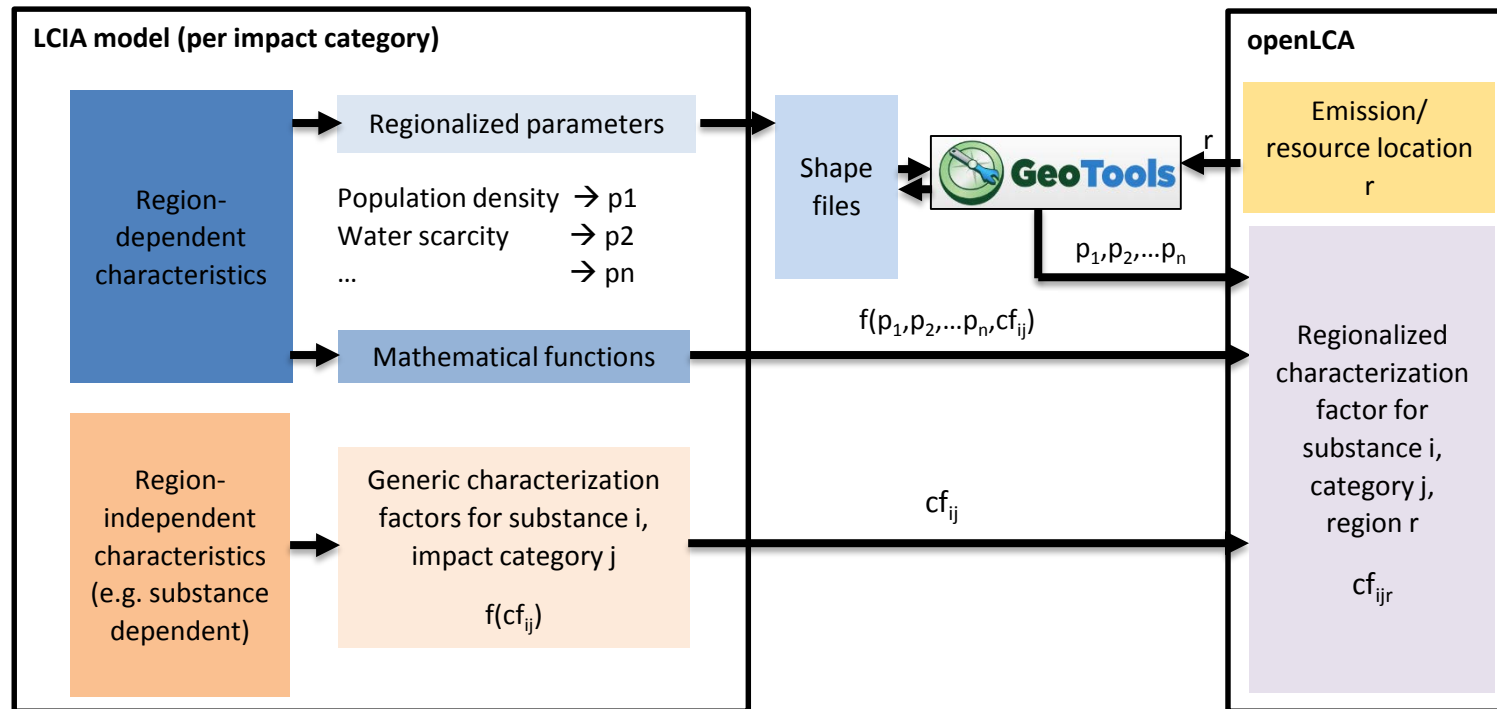
# Software: openLCA



- 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](http://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

▼ 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


# 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

## Shape file parameters

### ▼ Files

Location  C:\Users\Cristina\openLCA-data-1.4\databases\regionalised\_example\olca\_...

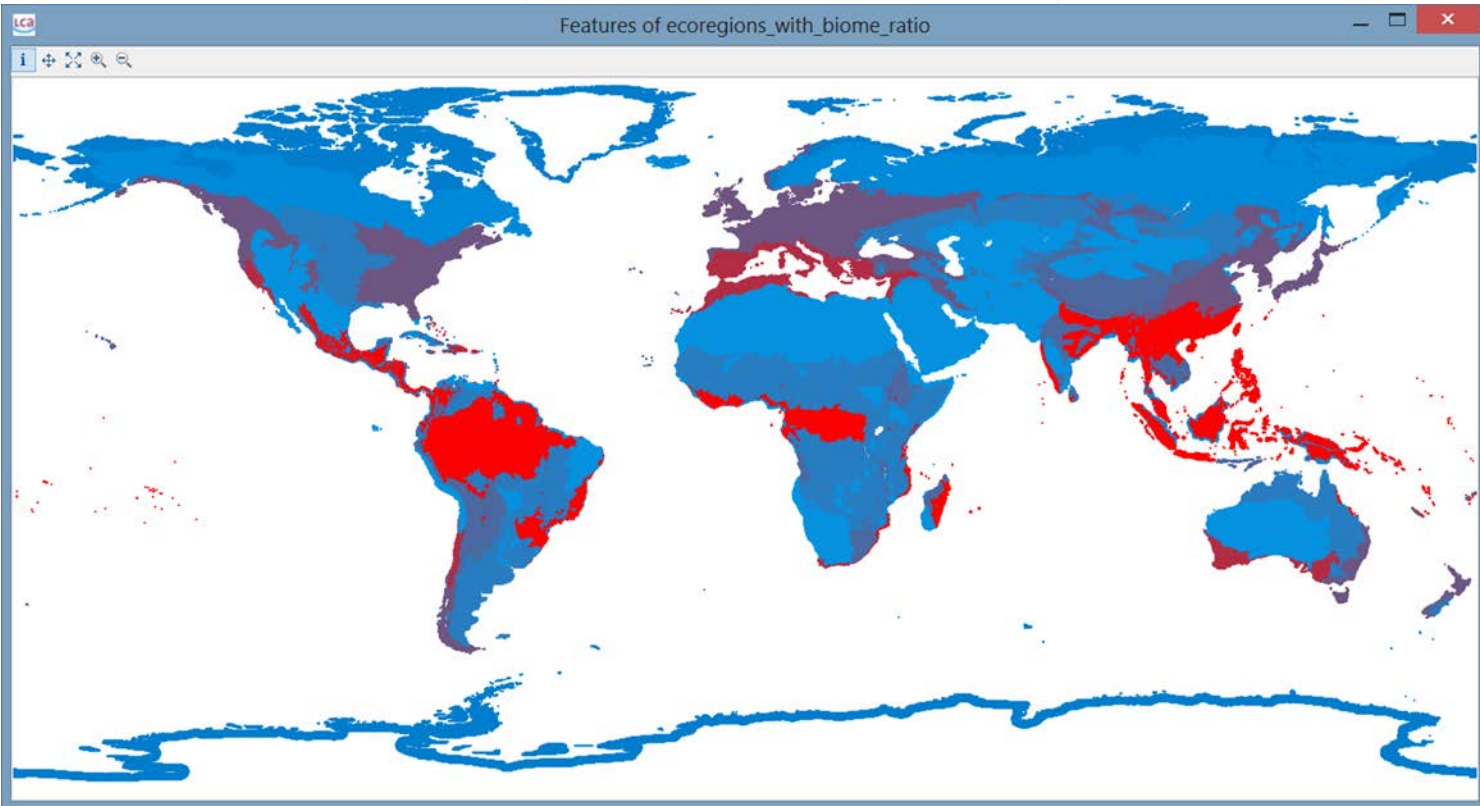
 Import...

 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 evaluation

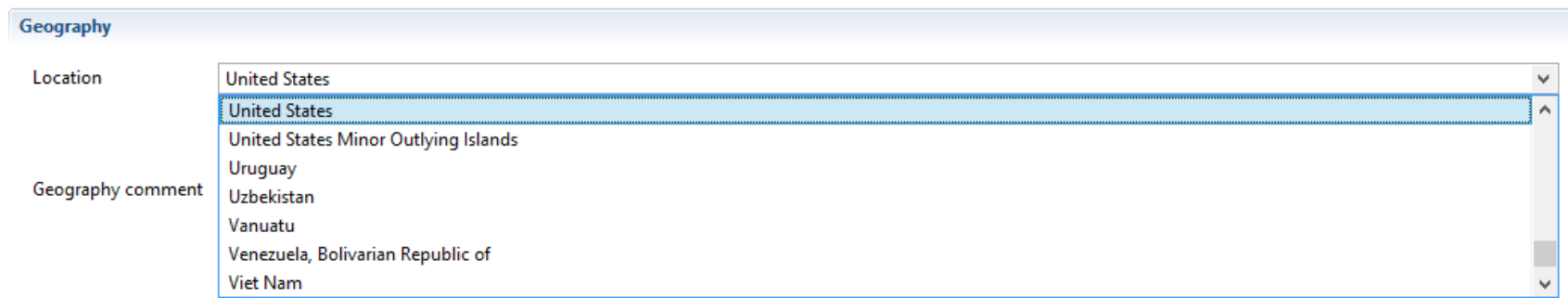
▼ Input parameters					
Name	Value	Uncertainty	Description	External source	
ratio_biom	1.0	none			
Ecofactor	610.0	none			

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 countries (e.g. UCTE, EU, etc.)



The screenshot shows a software interface with a 'Geography' section. It contains two input fields: 'Location' and 'Geography comment'. The 'Location' field has a dropdown menu open, displaying a list of countries and regions. The 'Geography comment' field is empty.

Field	Value
Location	United States
Geography comment	

The dropdown menu for 'Location' contains the following items:

- 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.
- New locations can be defined in the process editor.



▼ Geography

Location

KML

Description



# Extension of locations: KML editor (text)

KML Editor

Map Text

```
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 -155.91817847,19.486977029999988 -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 -155.89494991,19.91325592 -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 -155.8226395999999,20.113037009999999
```

Update location Clear

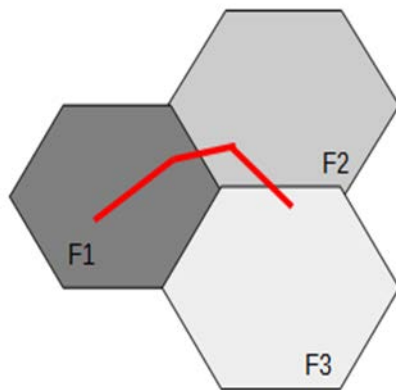


# Calculation framework

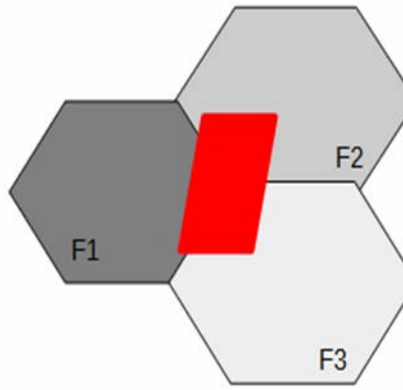
## Linking of process locations and LCIA methods spatial units

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

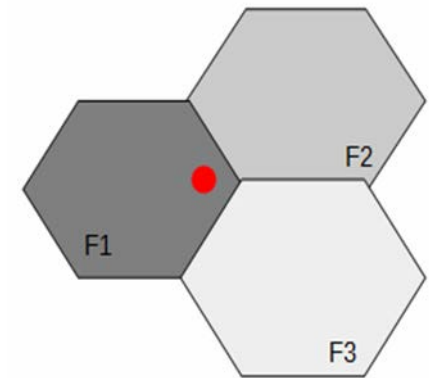
→ A weighted mean calculated for each regional parameter



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



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



$$p_{Fi} = p$$

# Calculation framework

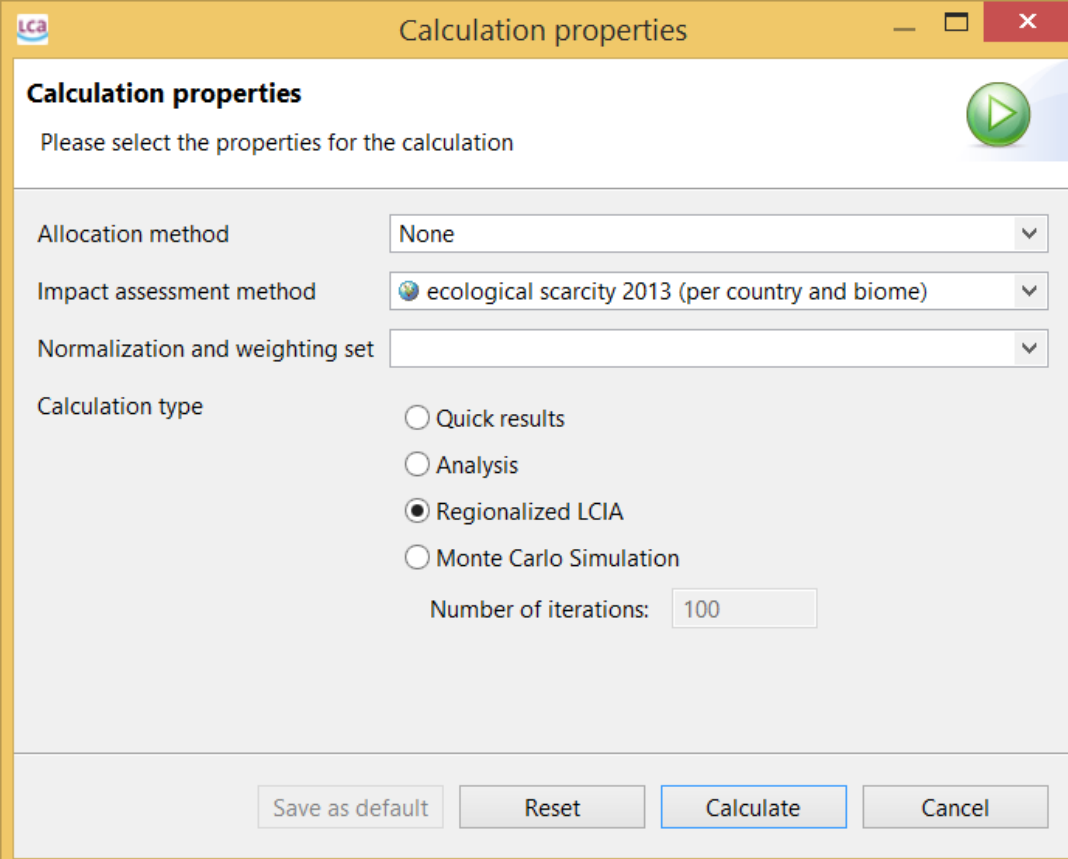
## Regionalised LCIA calculation

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

$$RR = CR * GR$$

# Regionalised LCIA: Calculation procedure

- Select the “Regionalized LCIA” option in the calculation properties window:
  - The impact method select must contain regionalised impact factors



**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


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

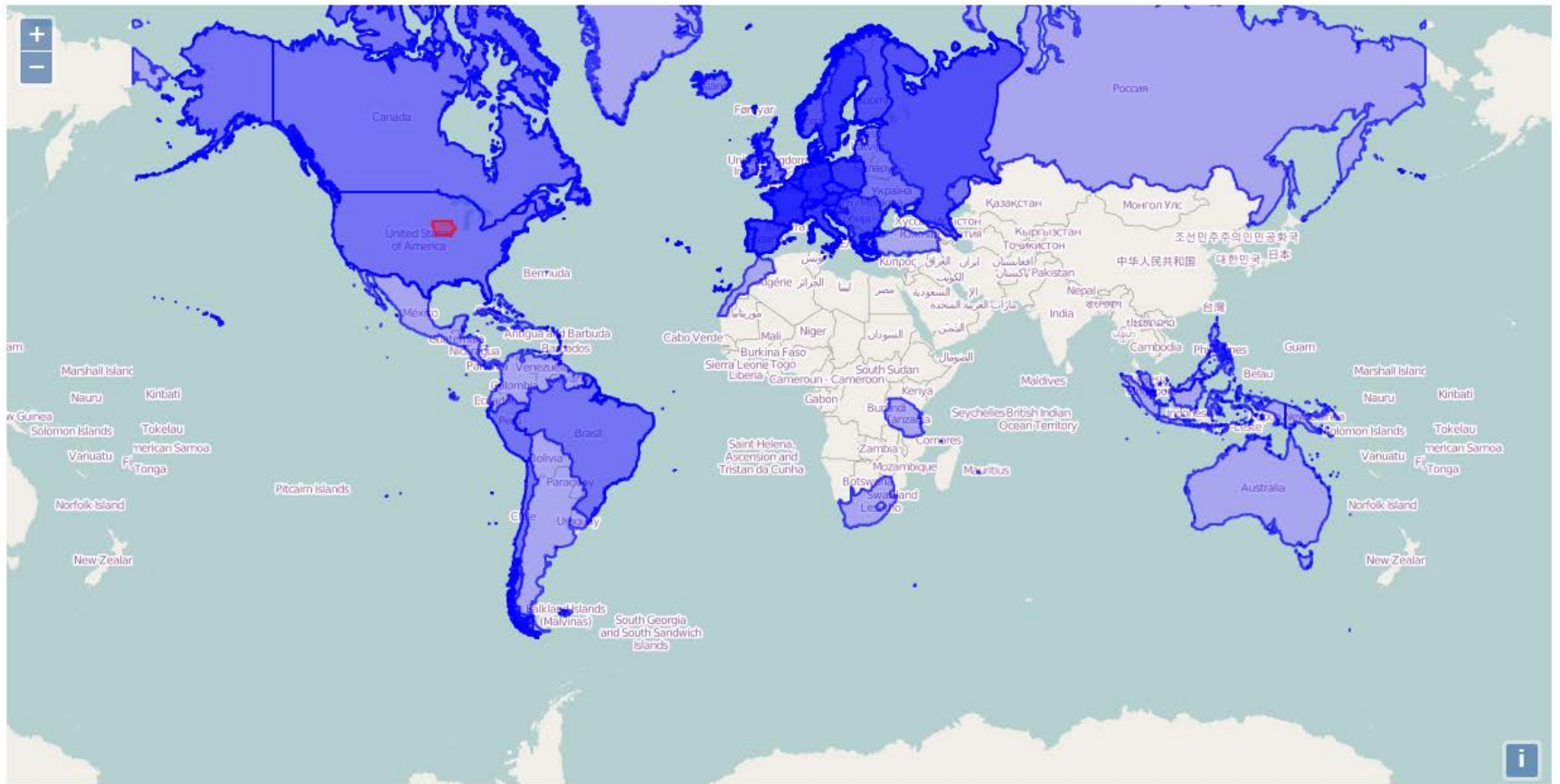
### Parameters of ecofactors\_renamed

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	
$f$ . Normalizat	2 614	2 614	

# Regionalised LCIA: Results

## Result map

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



# 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

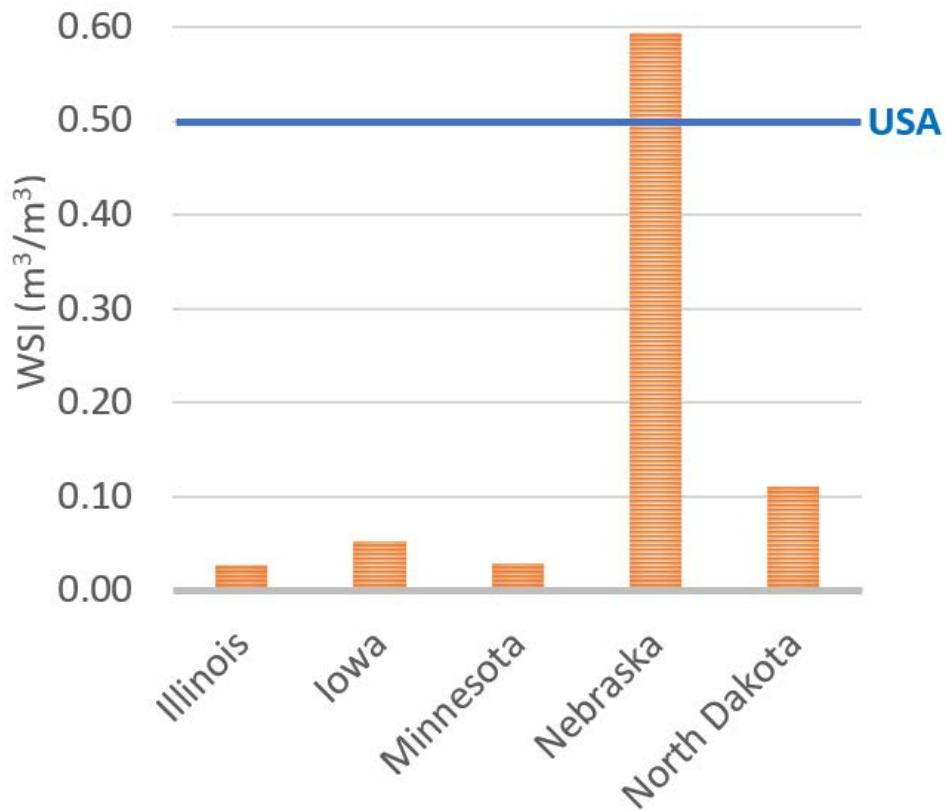
# Regionalized **impact categories**

- **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

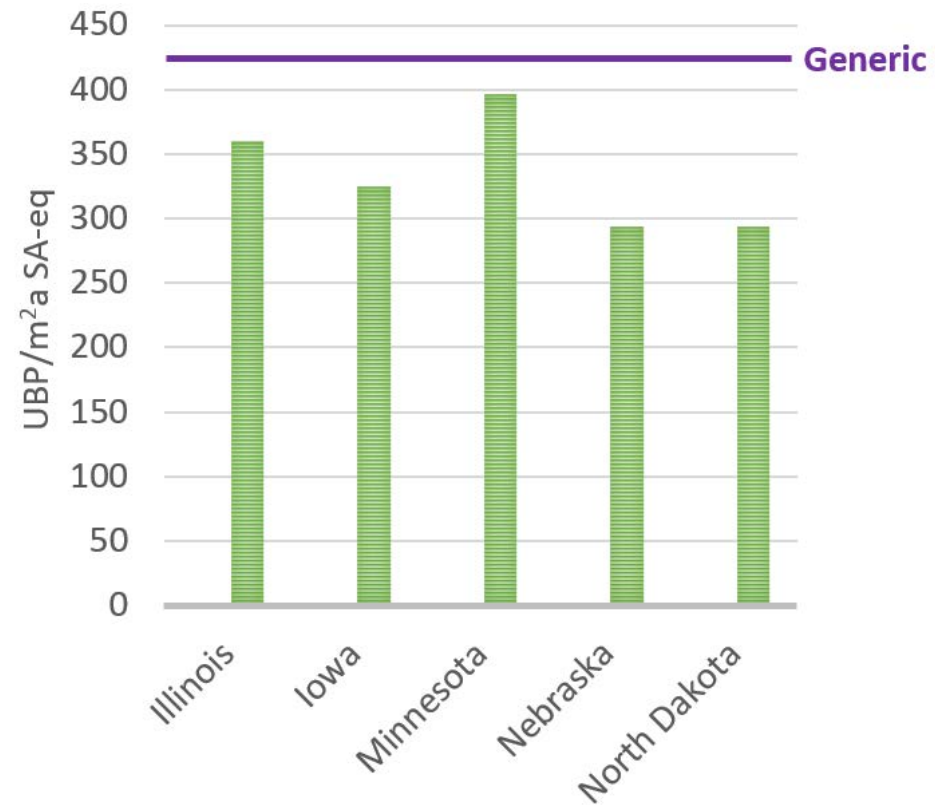


# Regionalized characterization factors

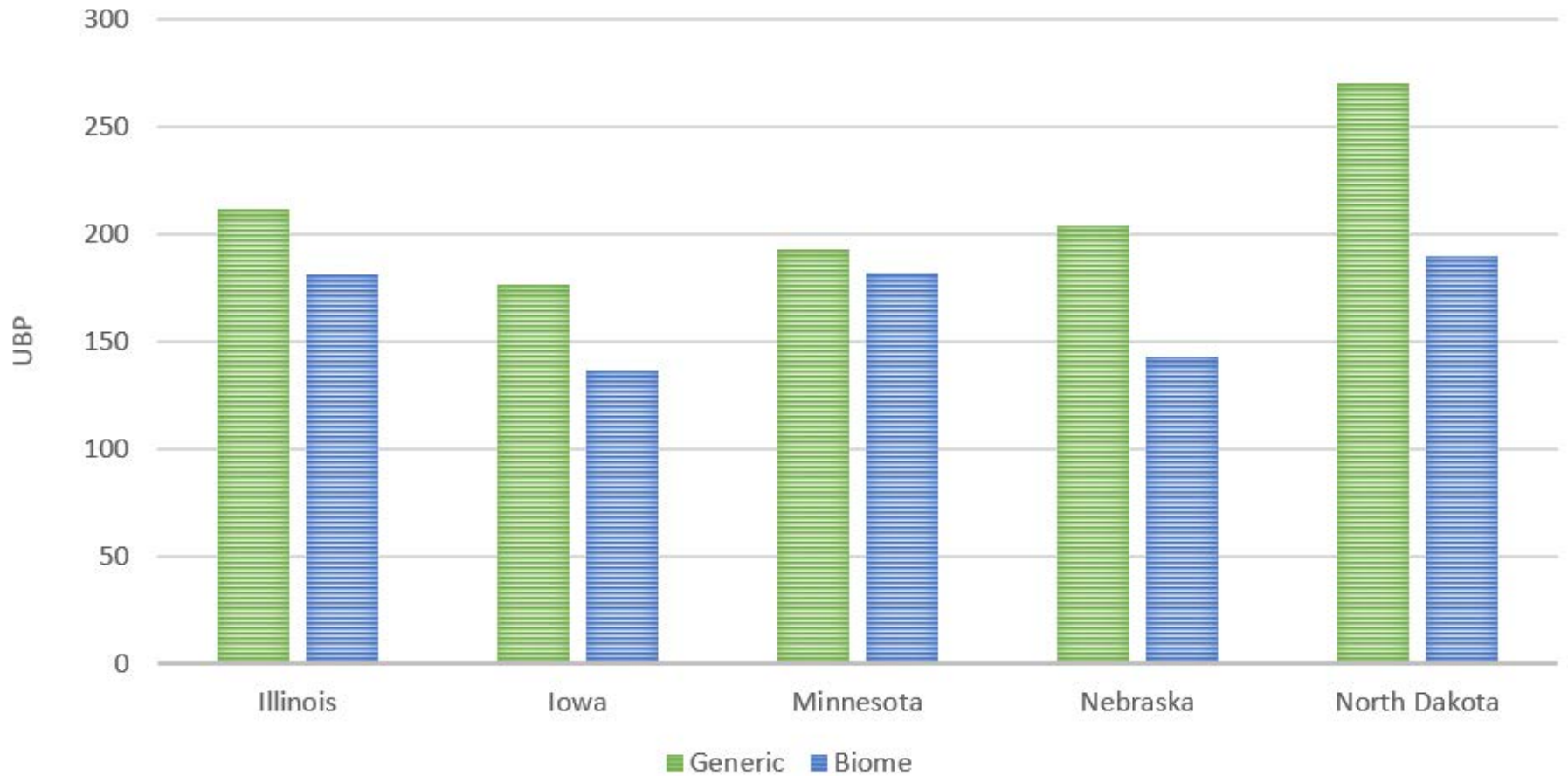
- WSI from Pfister et al. (2009)



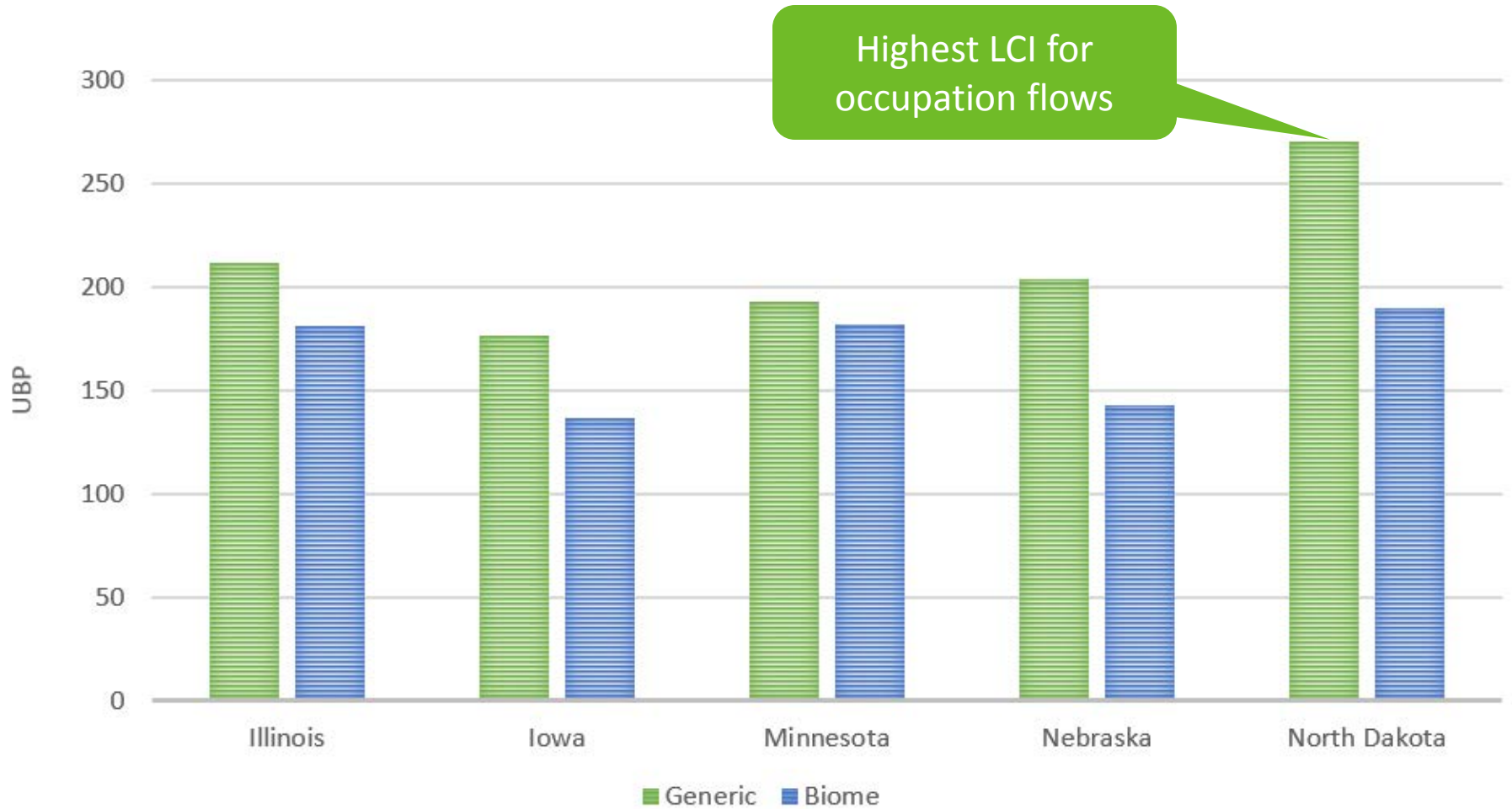
- Eco-factor for land use (arable)



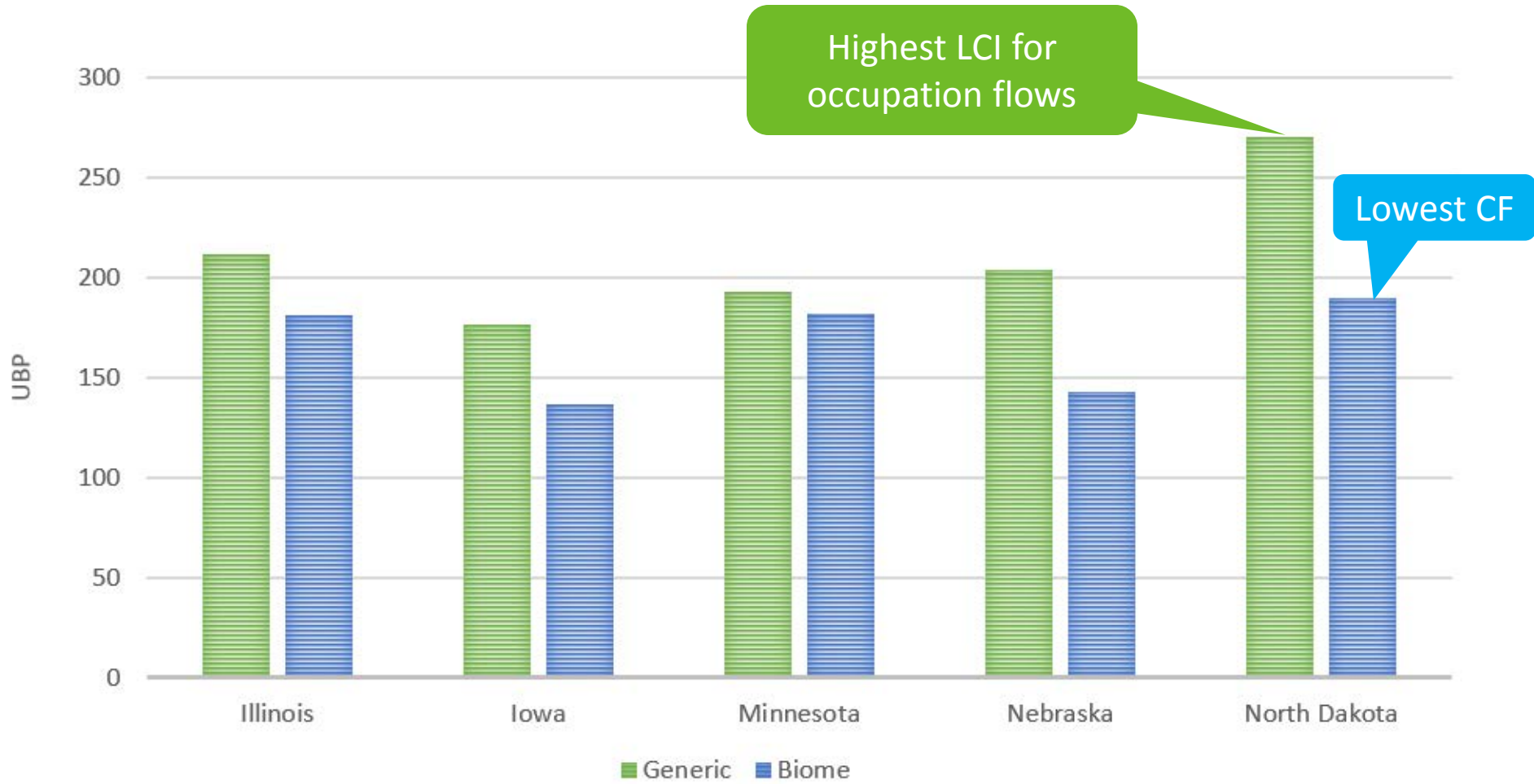
# LCIA results: land use



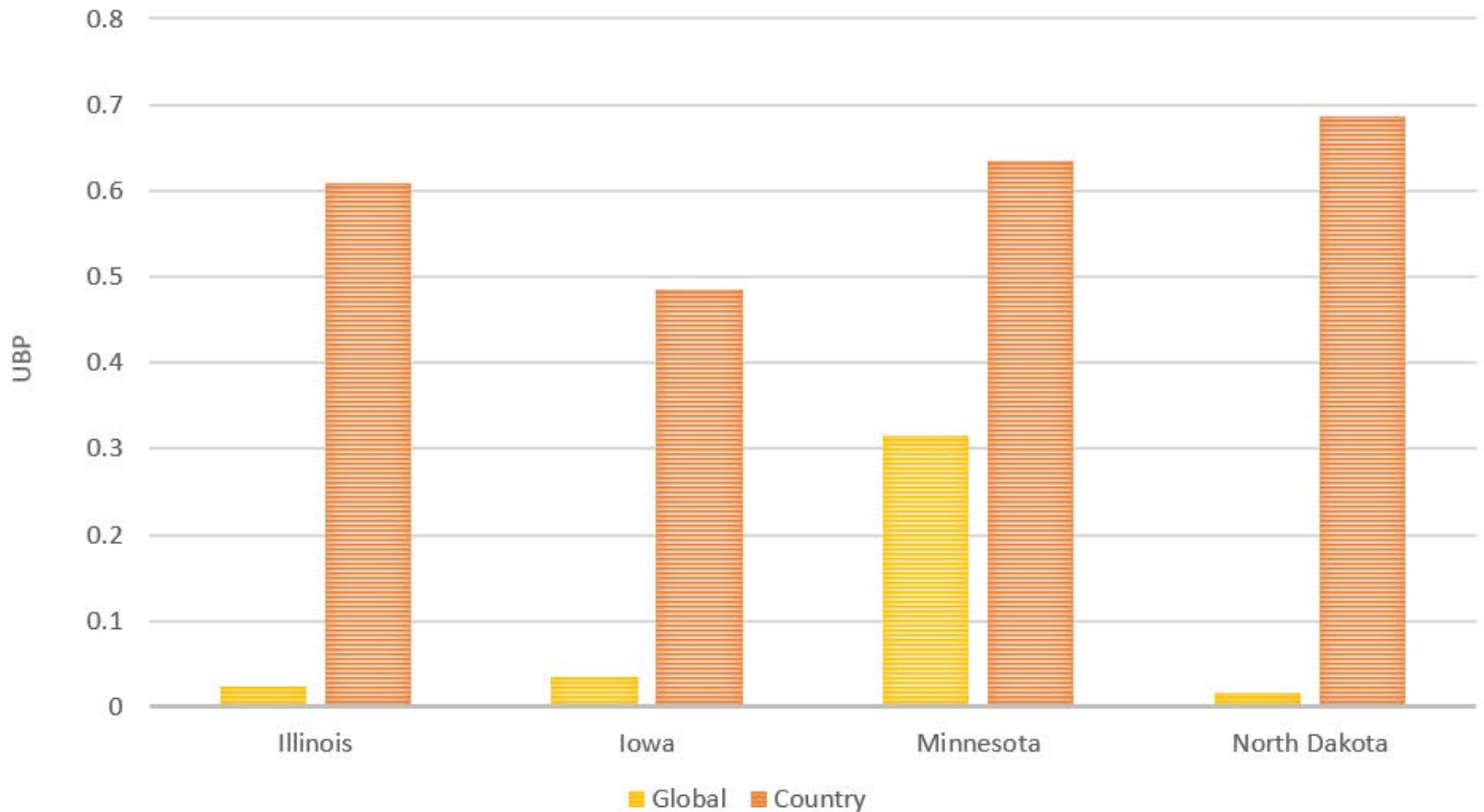
# LCIA results: land use



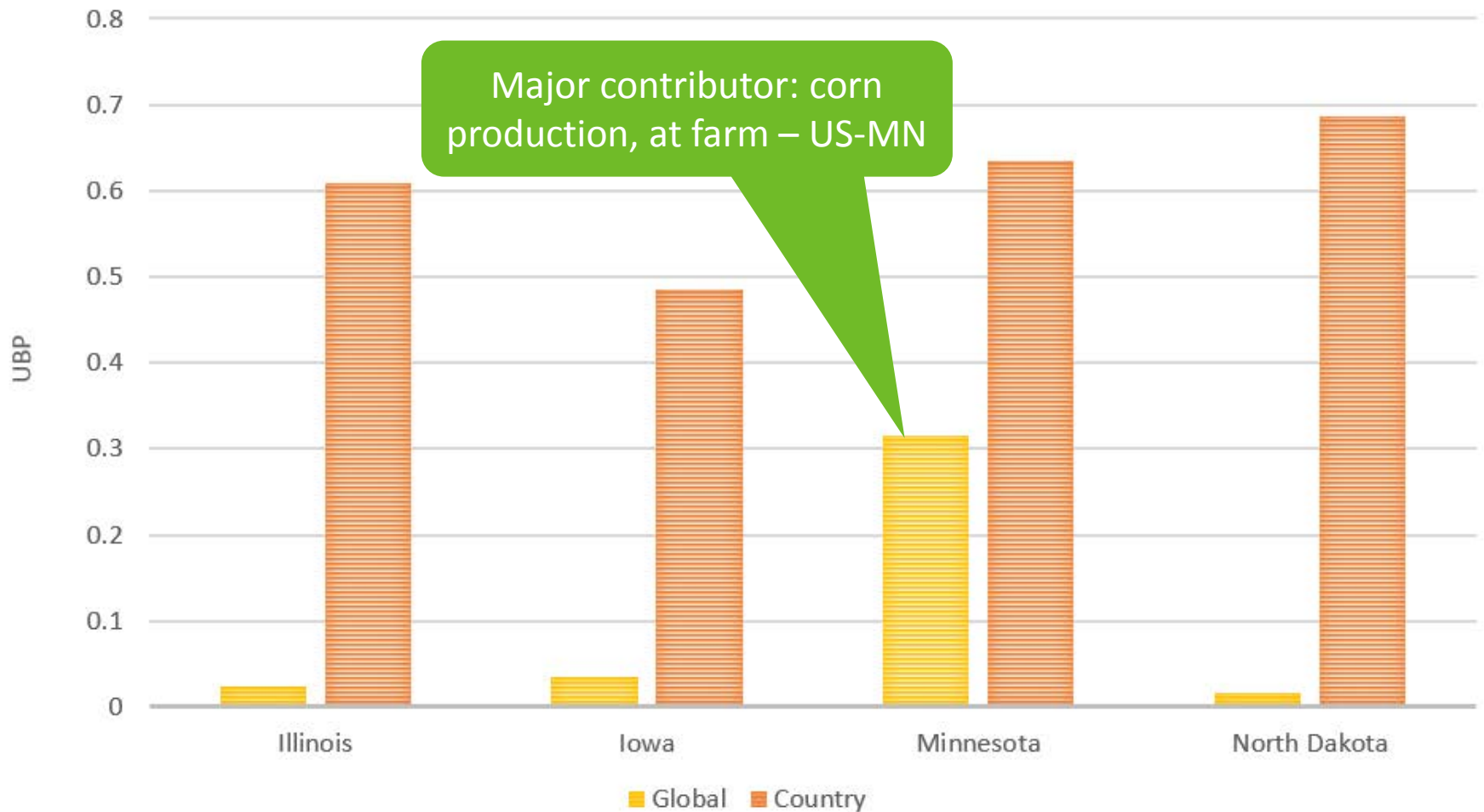
# LCIA results: land use



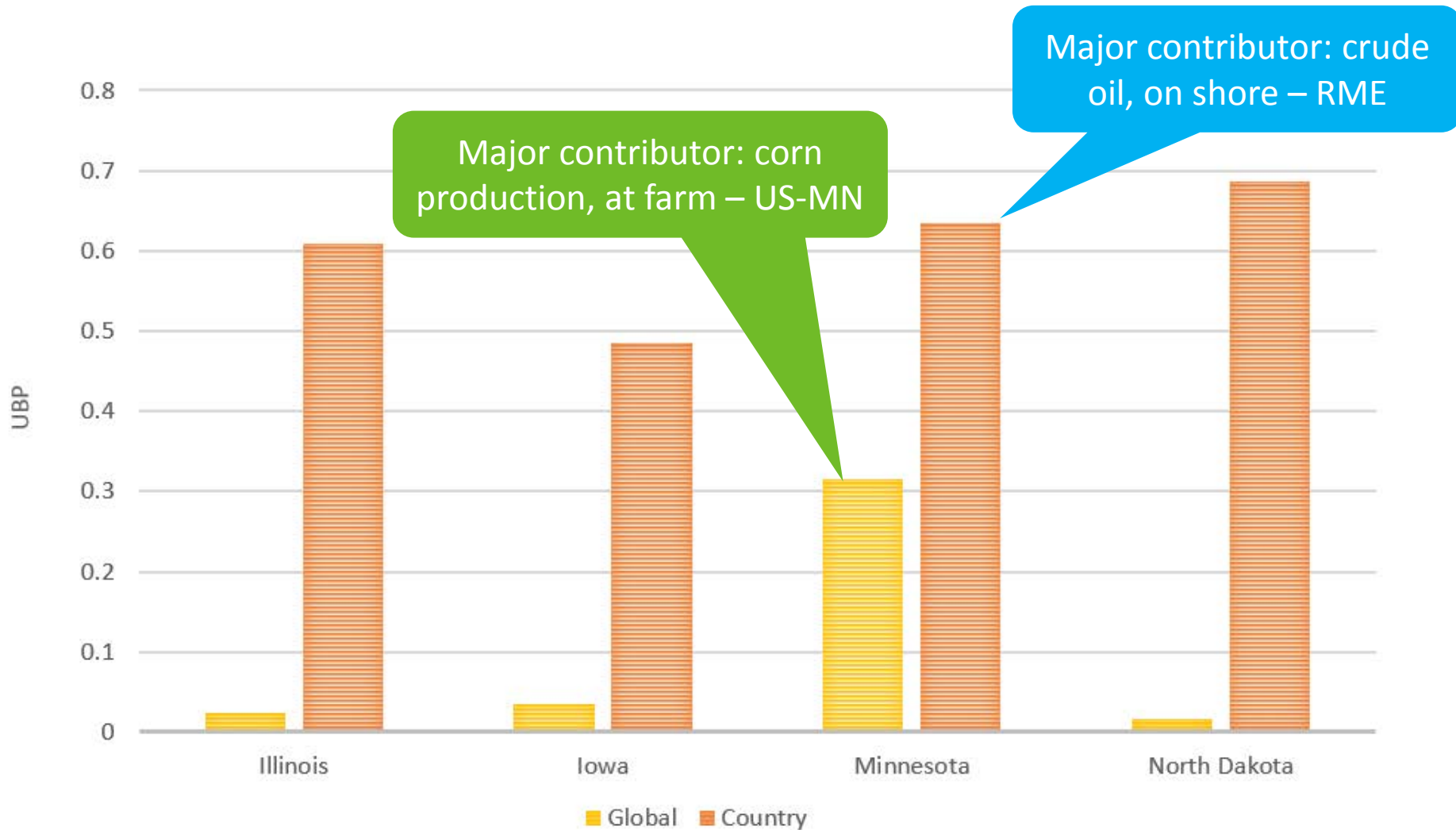
# LCIA results: freshwater consumption



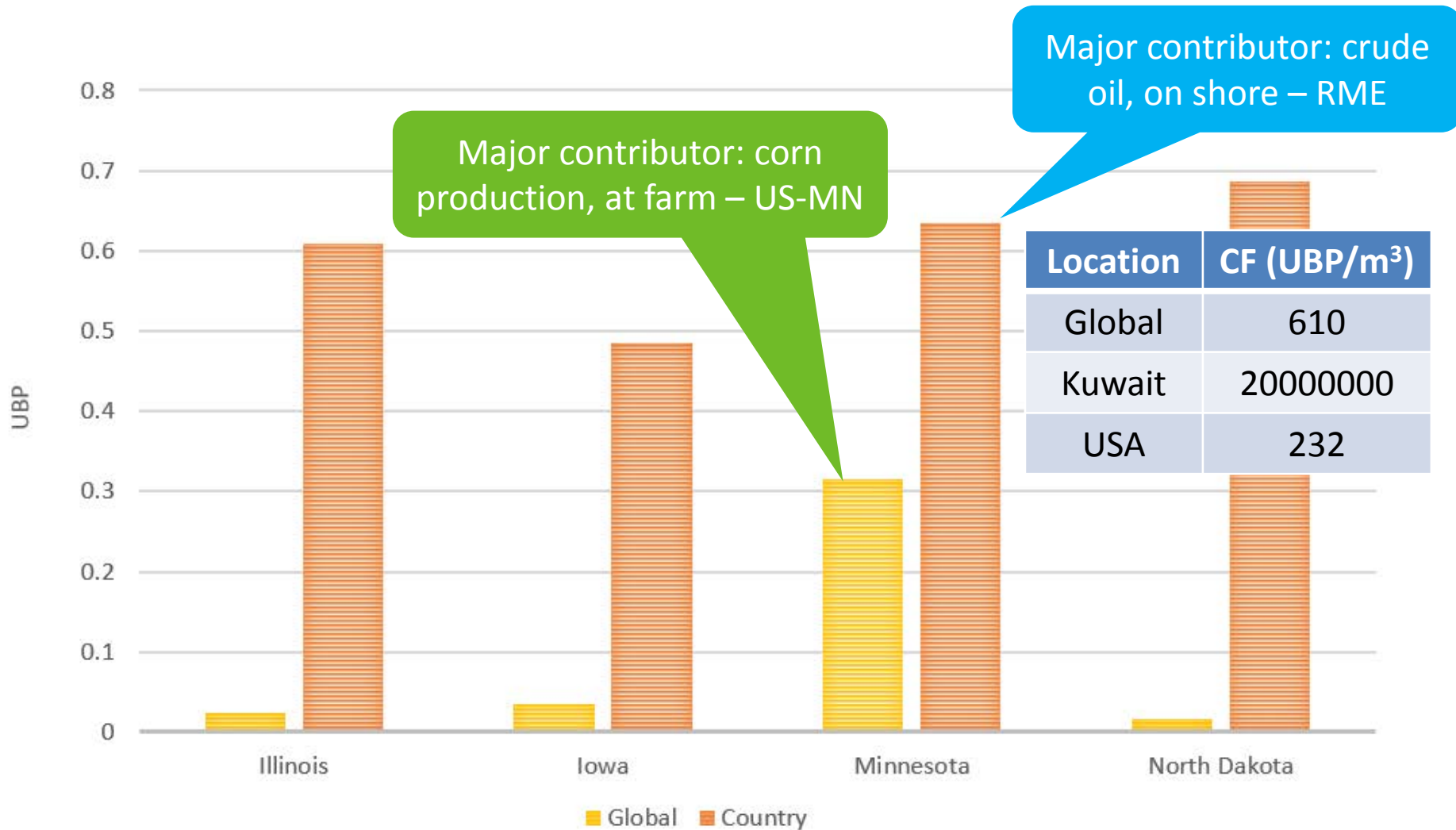
# LCIA results: freshwater consumption



# LCIA results: freshwater consumption



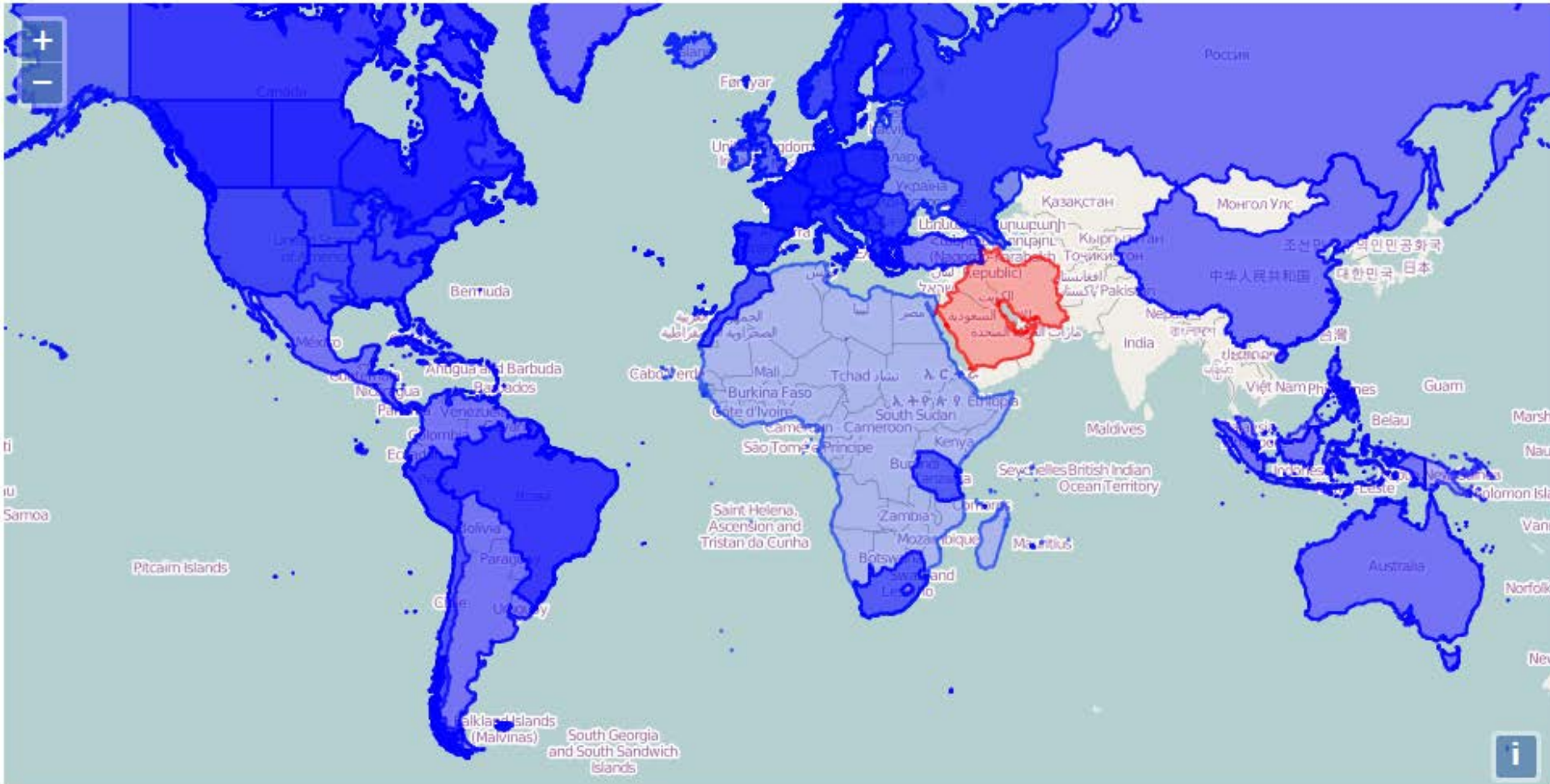
# LCIA results: freshwater consumption





# LCIA results: freshwater consumption

● Impact categories  total - Water resources 

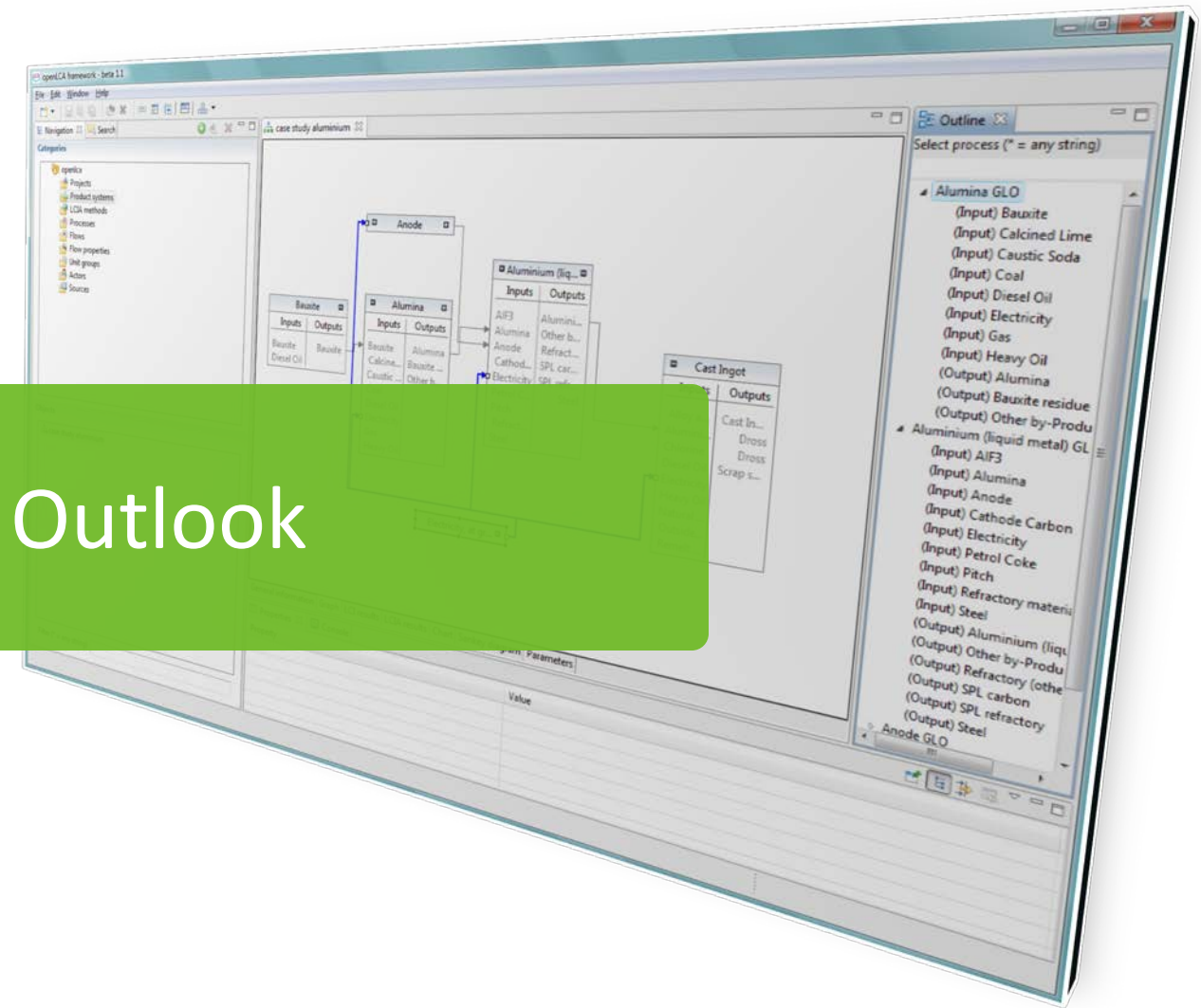


Results for Minnesota. Regionalized data per country



# 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!

**GreenDELTA**

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