10 years of iLUC modelling

Jannick Schmidt & Michele De Rosa

15th November 2017

2.-0 LCA consultants
Rendsburggade 14, room 4.315B
9000 Aalborg, Denmark
www.lca-net.com

jannick.schmidt@lca-net.com
michele.derosa@lca-net.com
Agenda

Welcome and introduction
- What is direct and indirect land use changes?
- The 2.0 LCA iLUC model
  - Key assumptions
  - Markets for land and reference flow
  - Temporal issues of land use changes (avoiding arbitrary impact allocation)
- How to use the model and application examples
- New developments
- What is next?
Background

- **High impact**: 11% of global GHG emissions

- **Causes**
  - Global increased demand for land
  - A change in demand for land \(\Rightarrow\) land-use changes

- **Challenges**
  - Ascribing the land use changes to their drivers
  - What is the role of energy/food/fibers?
Global land use

Global land cover 2014

- Other land: Savannah, barren, build (43%)
- Pasture (35%)
- Crops (17%)
- Water (5%)
- Forest (42%)
  - Naturally regenerated (26%)
  - Primary (13%)
  - Planted (3%)
Land use change impacts

- 11% of global GHG emissions
- 9% of forests lost since 1961
- Current species extinction <7% and 18-35% by 2050
- 260,000-600,000 per year mortality attributed to landscape fires

Johnston F H, Henderson S B et al. (2012). Estimated global mortality attributable to smoke from landscape fires. Environmental Health Perspectives. 120(5); 695-701
Will iLUC be less relevant in the future?

- Population growth by 2050: **9 billion** people
- Economic growth
  - food consumption per capita
  - share of meat
- Biofuels
Members of the iLUC crowdfunded project

- Aalborg University, Department of Planning and Development, AAU (plan.aau.dk)
- Aarhus University, Department of Agroecology - Agricultural Systems and Sustainability (scitech)
- Arla Foods (arla.com)
- Asplan Viak (asplanviak.no)
- Concito (concito.dk)
- CSIRO (csiro.au)
- DuPont Nutrition and Health (dupont.com)
- DONG Energy (dong.dk)
- ecoinvent (ecoinvent.org)
- Mahidol University, Department of Civil and Environmental Engineering (http://www.eg.mahidol.ac.th)
- IFP Energies nouvelles (http://www.ifpen.fr/)
- Miljögräff (miljograff.se)
- National Agricultural Research Center, Japan (naro.affrc.go.jp)
- Niras (niras.dk)
- NSW Department of Primary Industries (http://www.dpi.nsw.gov.au/)
- PRé Consultants (https://www.pre-sustainability.com/)
- PT SMART (https://www.smart-tbk.com)
- Round Table on Sustainable Palm Oil, RSPO (rspo.org)
- Sustainability Consortium (sustainabilityconsortium.org)
- Swedish University of Agriculture Sciences, SLU (slu.se)
- TetraPak (tetrapak.com)
- Unilever (unilever.com)
- United Plantations Berhad (unitedplantations.com)
- University of Copenhagen, The Faculty of Life Sciences, LIFE (life.ku.dk)

More info at:
https://lca-net.com/clubs/iluc/

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Direct and indirect Land-Use Changes

- Effect of 1 ha additional rapeseed field somewhere?

Indirect effects:
Land for displaced crops?

Indirect intensification

Somewhere else – at the frontier

Direct land use changes (dLUC)

Indirect land use changes (iLUC)
Why is current practice wrong?
- PAS2050, GHG protocol, PEF Guideline

Example: 1 ha year crop
- Choose amortization period – (e.g. 20 years)
- Determine to include or exclude LUC
- If LUC included, identify C stock before and after LUC
- GHG-emissions from LUC = ΔC x (44/12) x (1/20)

Limits of this approach:
- Amortization period in the past or future?
- Amortisation period is arbitrary (why 20 years?)
- Arbitrary reference scenario (historical C-stock)
- Ignoring trade with crops/animal products

Implications: overestimating LUC at the frontier, while ignoring iLUC for established arable land
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The model in five bullets

- **Key assumptions**

1. Land use changes are **caused** by the **demand** for land

2. There is a **market** for land i.e. for land’s **capacity for growing biomass**

3. The market for land is **global**:
   - crops can be grown in different **regions**
   - Food/biomass is **substitutable** and traded on the global market

4. Different markets for land can be distinguished: **arable, forest, range**

5. **Change** in demand for land **cause**:
   - Transformation of land
   - Intensification of land already in use
   - Crop displacement
     (reduced consumption)
iLUC – “the mass balance proof”

Implications from using land: 1 t crop from land $a$

Before land use change $\Sigma = 10$ t

<table>
<thead>
<tr>
<th>Region X</th>
<th>10 t</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_{\text{before}}$</td>
<td></td>
</tr>
</tbody>
</table>

After land use change $\Sigma = 11$ t

| Region X | 10 t - 1 t = 9 | 1 t |
|-----------|---------------|
| $a_{\text{after}}$ |

Direct land use changes (can be controlled)

$\text{Direct land use changes}$

$\text{a}_{\text{before}}$ $\rightarrow$ $\text{a}_{\text{after}}$

Indirect land use changes (cannot be controlled)

$\text{Indirect land use changes}$

$\text{B}_{\text{before}}$ $\rightarrow$ $\text{B}_{\text{after}}$

$\text{Intensification}$

$\text{Change in food consumption}$

Transformation of non-cultivated land to cultivated land

Region Y

Region Y

Region Z

Increased fertiliser etc.

Change in food consumption

Implications from using land: 1 t crop from land $a$
What is land?

- Land = asset input
- Crop cultivation requires
  - Tractors
  - Combine harvester
  - ... and **land**
Land... what is land?
- Functional unit considerations

- **Functional unit**
  - For each market: Capacity for biomass production from 1 ha*year global average

- **Functional unit**
  - Barren land: Area for non-biomass purposes 1 ha*year global average
Global potential net primary production ($NPP_0$) - How to weight land use in different locations?

1 ha*year in the Aalborg area expressed as pw ha*year (GLO aver. arable is 5680 kg C ha$^{-1}$ year$^{-1}$)

$$NPP_{0,DK} = 6150 \text{ kg C ha}^{-1}\text{ year}^{-1}$$
$$\text{Factor}_{DK} = \frac{6150}{5608} = 1.08$$

From ha*year to pw ha*year:
Factor = $NPP_0$ / $NPP\_GLO$ aver.

Life cycle inventory
- Market, transformation and intensification

**Land use changes**

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<td>ha*year eq.</td>
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<td>Ressource inputs from nature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transformation from</td>
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<td>ha</td>
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<td>Transformation to...</td>
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**Intensification**

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<td>Inputs from technosphere</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel for traction</td>
<td>$c_1$</td>
<td>MJ</td>
</tr>
<tr>
<td>N-Fertiliser, as N</td>
<td>$c_2$</td>
<td>kg</td>
</tr>
<tr>
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**Land market activity**

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<td>Changes in consumption</td>
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**Wheat LCA activity (1 ha yr)**

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<tr>
<td>Wheat</td>
<td>7,296</td>
<td>kg</td>
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<td>Inputs from technosphere</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>1.08</td>
<td>ha*year eq.</td>
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<tr>
<td>Diesel for traction</td>
<td>3,306</td>
<td>MJ</td>
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<td>N-Fertiliser, as N</td>
<td>198</td>
<td>kg</td>
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<tr>
<td>P-Fertiliser, as P$_2$O$_5$</td>
<td>46</td>
<td>kg</td>
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<tr>
<td>K-Fertiliser, as K$_2$O</td>
<td>84</td>
<td>kg</td>
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<tr>
<td>Emissions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO$_2$ fossil (diesel combustion)</td>
<td>245</td>
<td>kg</td>
</tr>
<tr>
<td>N$_2$O</td>
<td>4.15</td>
<td>kg</td>
</tr>
<tr>
<td>Resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO$_2$ biogenic from air</td>
<td>11,370</td>
<td>kg</td>
</tr>
</tbody>
</table>

Social effects

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Changes in consumption</td>
<td>$a_3$</td>
<td>ha*year eq.</td>
</tr>
<tr>
<td>Inputs</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Emissions</td>
<td>n.a.</td>
<td></td>
</tr>
</tbody>
</table>

Not included
Occupation and transformation
- Accelerated deforestation

Effect of occupation (1 ha yr)

1) General trend for forest cover
   Forest area (ha)

2) Effect on forest cover from demand for 1 ha
   Forest area (ha)

3) Effect on forest cover from occupation
   Forest area (ha)

Net effect
+ CO₂ year 1
– CO₂ year 2

Same as moving CO₂ from year 2 to year 1

Net effect
+ CO₂ year 1
– CO₂ year 2

Same as moving CO₂ from year 2 to year 1
IPCC's global warming potential (GWP)

- The global warming potential
  - Originally used to differentiate different GHG-emissions (unit: CO$_2$-eq)
    
    \[ GWP_i = \frac{\int_0^{TH} RF_i(t)dt}{\int_0^{TH} RF_{CO_2}(t)dt} \]

  - TH = time horizon
  - RF = Radiative forcing (W/m$^2$)
IPCC's global warming potential (GWP) - time dependant

- Effect of emitting CO$_2$ in year $\Delta t$:

$$GWP_{CO_2,\Delta t} = \frac{\int_{\Delta t}^{100} CO_2,fraction(t - \Delta t) \, dt}{\int_{0}^{100} CO_2,fraction(t) \, dt}$$

- Effect of emitting 1 kg CO$_2$ in year 0 instead of year 1:

$$GWP_{CO_2,t=1 \rightarrow 0}^{100} = 1 - 0.9922 = 0.00783 \text{ kg CO}_2\text{-eq.}$$

![Fraction of CO$_2$ pulse remaining in atmosphere over time](image)
Global temperature potential (GTP)

- Measures temperature effect from a pulse emission at specified time (H)
- Closer to end-point than GWP
- Indicator has same unit as GWP; CO$_2$-eq.

Effect of emitting 1 kg CO$_2$ in year 0 instead of year 1:

\[
GWP_{100}^{CO_2,t=1\rightarrow 0} = 1 - 0.9922 = 0.0078 \text{ kg CO}_2\text{-eq.}
\]

\[
GTP_{20}^{CO_2,t=1\rightarrow 0} = 1 - 0.9978 = 0.0022 \text{ kg CO}_2\text{-eq.}
\]

Difference = factor 3.5!
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Using the model, in practice

What does the model provide?

- **Simple**: Elementary flows per unit of land use (pw ha*year-eq.)
- **Advanced**: iLUC effects of land using activity, linking foreground activities to model in LCA software

Input data:

1. Land occupation → How much land is used per FU?
2. Market → Identify market segment (arable, forest or range)
3. Productivity factor → Identify the productivity factor of land

<table>
<thead>
<tr>
<th>Acronym for country/region</th>
<th>Country/region</th>
<th>NPP0 for each land cover, normalized to global NPP0 (ha-eq/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Arable</td>
</tr>
<tr>
<td>GLO Global</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>AT Austria</td>
<td></td>
<td>1.14</td>
</tr>
<tr>
<td>AU Australia</td>
<td></td>
<td>0.90</td>
</tr>
<tr>
<td>BE Belgium</td>
<td></td>
<td>1.11</td>
</tr>
<tr>
<td>BG Bulgaria</td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>BR Brazil</td>
<td></td>
<td>1.51</td>
</tr>
<tr>
<td>CA Canada</td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>CH Switzerland</td>
<td></td>
<td>1.14</td>
</tr>
<tr>
<td>CN China</td>
<td></td>
<td>0.94</td>
</tr>
<tr>
<td>CY Cyprus</td>
<td></td>
<td>0.72</td>
</tr>
<tr>
<td>CZ CzechRepublic</td>
<td></td>
<td>1.10</td>
</tr>
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Using the model, in practice

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Input data:
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Calculations
- Calculate the weighted productivity of land [pw ha*year]
- Multiply the pw with global iLUC LCI per pw ha*year
The model in SimaPro - Example: Wheat

### Land use changes

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<td>Transformation</td>
<td>( a_1 )</td>
<td>ha*year eq.</td>
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<td>Resource inputs from nature</td>
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<td>e.g. CO₂</td>
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### Intensification

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### Wheat LCA activity (1 ha yr)

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Not Included
The model in SimaPro - Example: Wheat
The model in SimaPro
- Example: Wheat
Examples of application

- Vegetable oils (palm, rapeseed, sunflower, peanut, soybean)
- Milk (Germany, Denmark, Sweden and United Kingdom)
- Chicken
- Specialty food ingredients
- Canteens (eco-labelled and conventional)
- Nature conservation in Kalimantan
- Global food consumption
- Biofuels (liquid and solid)
- Electricity models
- Structural timber
- Aggregates
- Buildings
- Apparels
- Corporate footprints for large, multinational companies, e.g. Arla Foods, Novo Nordisk, Nordic Alcohol Monopoly, and many others
- Danish consumption footprint
- Municipal level production and consumption footprint
- Global input-output table (the model is integrated in a special version of Exiobase v3)
- And many more...

All examples can be accessed here:
Case with palm oil industry:

- Palm oil at United Plantations

- Detailed LCA studies since 2004

![Diagram showing GHG emissions (incl. ILUC) and plantations]

**GHG emissions (incl. ILUC)**

- Installation:
  - Biogas plant, Jendarata
  - Biomass boiler, Jendarata

- Installation:
  - Biogas plant, Pt. Surya Sawit Sejati

**Picture:** Jannick Schmidt, United Plantations, Lada Estate
Different crops - and the role of iLUC

![Graph showing CO2e/kg for different crops.

Results extracted from LCA data in:
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New developments - Global model

Integration with:
Multi-regional hybrid input-output model

Supply of land

Use of land

Global market for land

Input data

- Time-series for all crops, all countries of:
  - Area
  - Yield
  - Production

- 3 markets for land: Arable, forest, range

Output of the model (next slide...)
Examples of results (1/2)
- Raw milk and iLUC

- Exiobase v3, hybrid version inclusive iLUC

www.exiobase.eu
Examples of results (2/2)  
- Cereals and iLUC

- Exiobase v3, hybrid version inclusive iLUC

Per kg dry matter

Wheat, kg CO2e/kg

Cereals nec, kg CO2e/kg

www.exiobase.eu
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What is next?
What is next?

We currently work on:

- Cross checking with satellite remote sensing (De Rosa et al. 2017)
- LUC: particulates from forest fires
- Better carbon stock and biodiversity data
- Module for nature conservation modelling

Potential developments?

- Annual update of background data
- More complete modelling of intensification: Not only additional fertilizer, also irrigation, pesticides...
- To further investigate sub-divide (and regionalize) markets for land
Thank you for your attention

Jannick Schmidt
Michele De Rosa

https://lca-net.com/clubs/iluc/