10 years of iLUC modelling

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Jannick Schmidt & Michele De Rosa

15th November 2017

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

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

CA consultants

Agenda

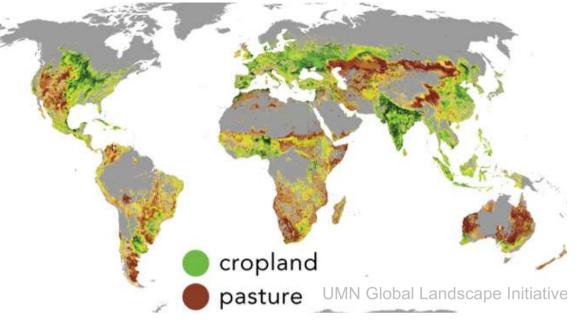
- Welcome and introduction
- What is direct and indirect land use changes?
- The 2.-0 LCA iLUC model
 - Key assumptions
 - Markets for land and reference flow
 - Temporal issues of land use changes (avoiding arbitrary impact allocation)
- How to use the model and application examples
- New developmentsWhat is next?

Background

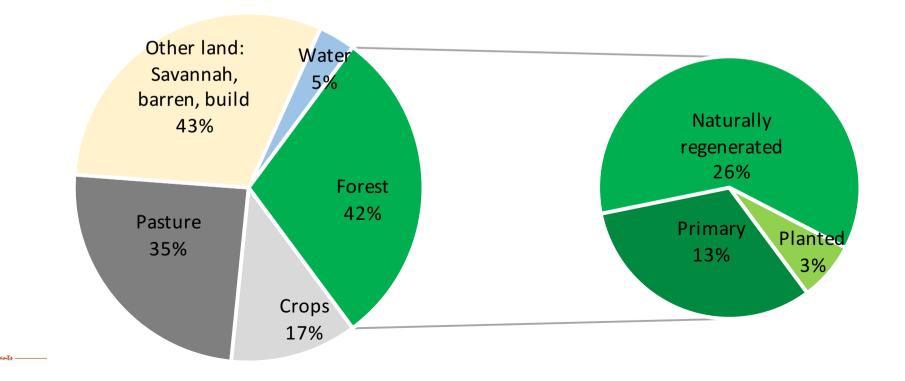
- **High impact:** 11% of global GHG emissions
- Causes
 - Global increased demand for land
 - A change in demand for land \Rightarrow land-use changes
- Challenges
 - Ascribing the land use changes to their drivers
 - What is the role of energy/food/fibers?



Global land use

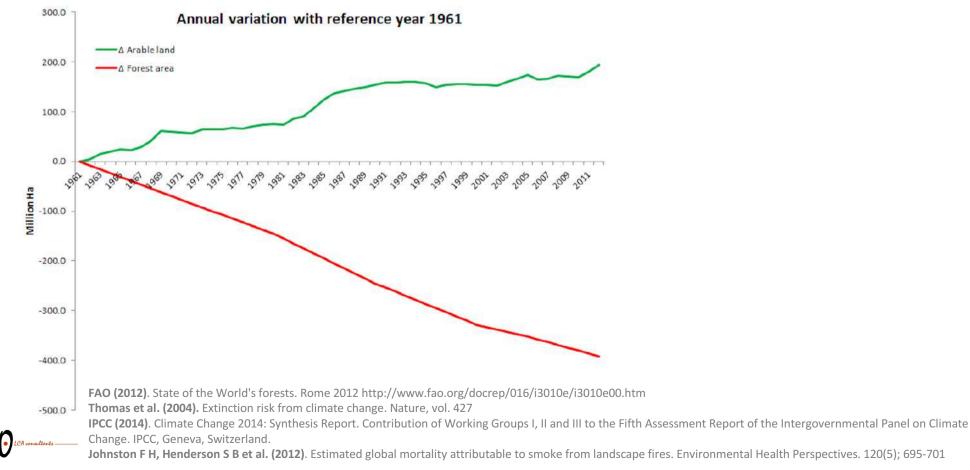


Global land cover 2014



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



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



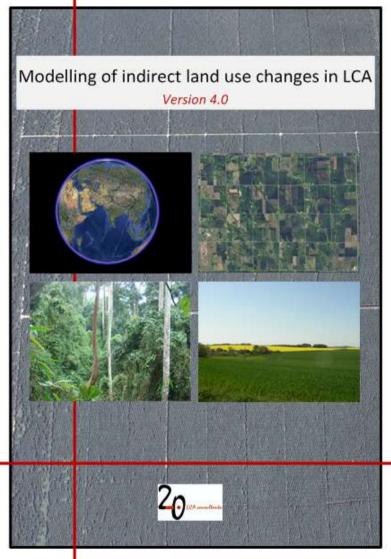
Members of the iLUC crowdfunded project

- 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.eg.m
- IFP Energies nouvelles (http://www.ifpen.fr/)
- Miljögiraff (miljogiraff.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/

Schmidt J, Weidema B P, Brandão M (2015). A framework for modelling indirect land use changes in life cycle assessment. Journal of Cleaner Production 99:230-238

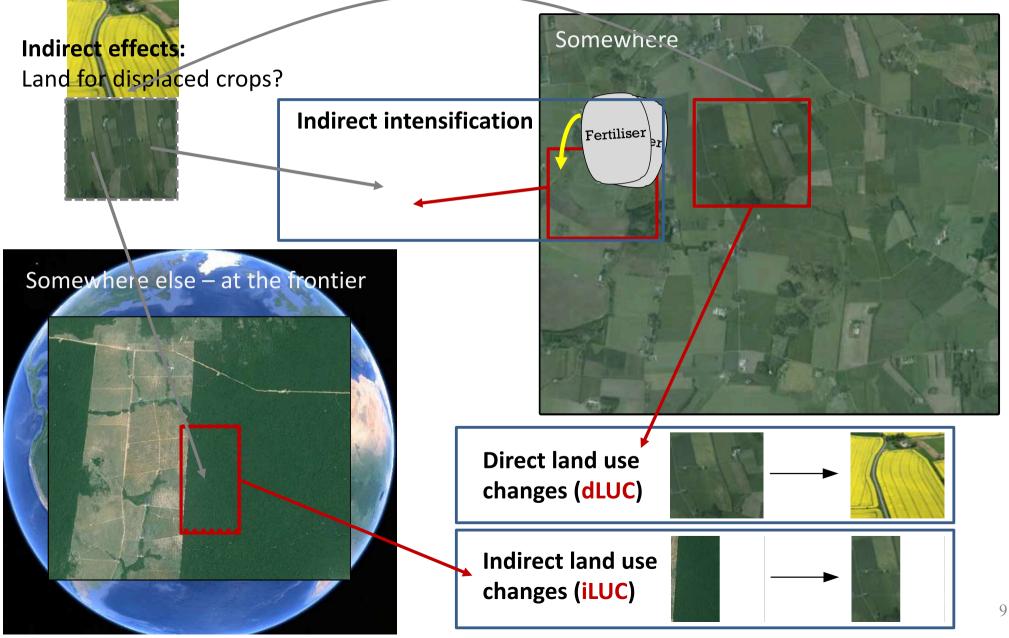


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Direct and indirect Land-Use Changes

Effect of 1 ha additional rapeseed field somewhere?



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 = $\Delta C \times (44/12) \times (1/20)$

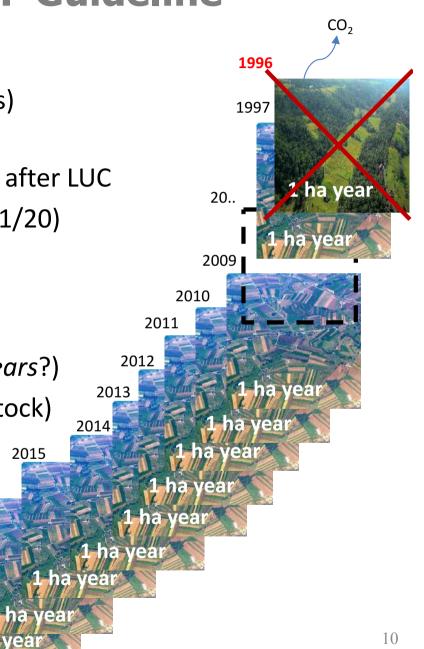
Limits of this approach:

- 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 2015

2016

2017

Implications: overestimating LUC at the frontier, while ignoring iLUC for established arable land



Agenda

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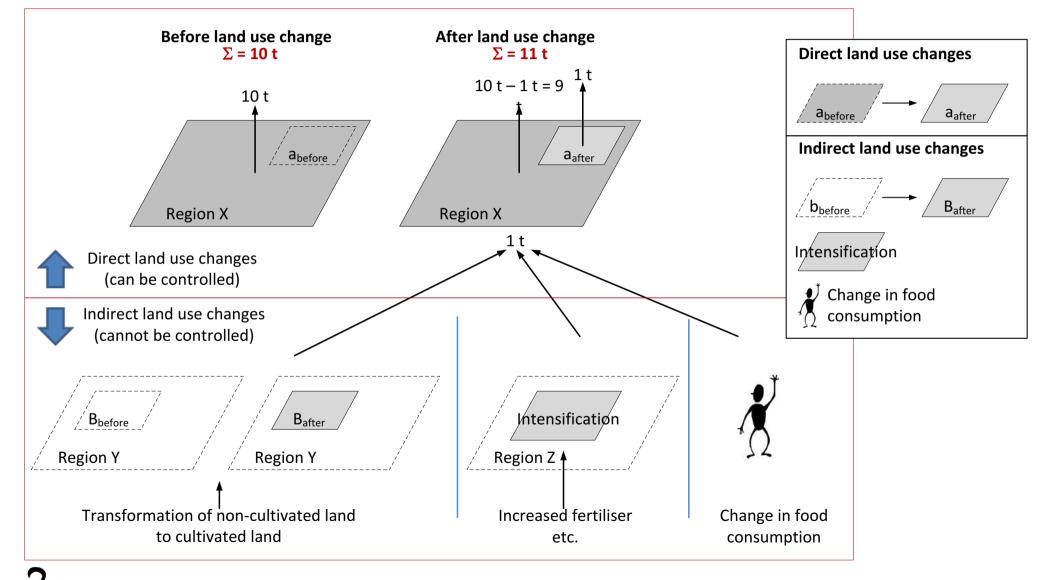
The model in five bullets

- 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**



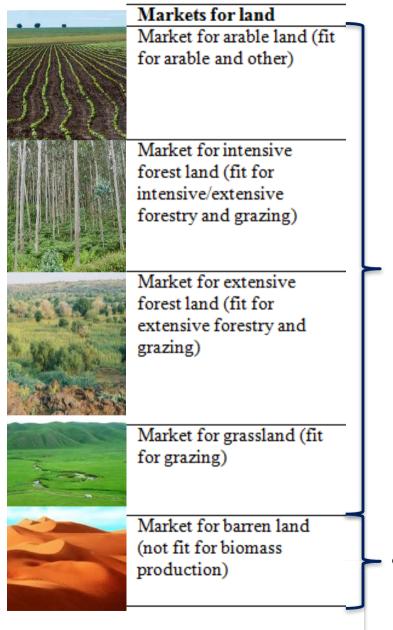
What is land?

- Land = asset input
- Crop cultivation requires
 - Tractors
 - Combine harvester
 - ... and **land**



Land... what is land?

- Functional unit considerations

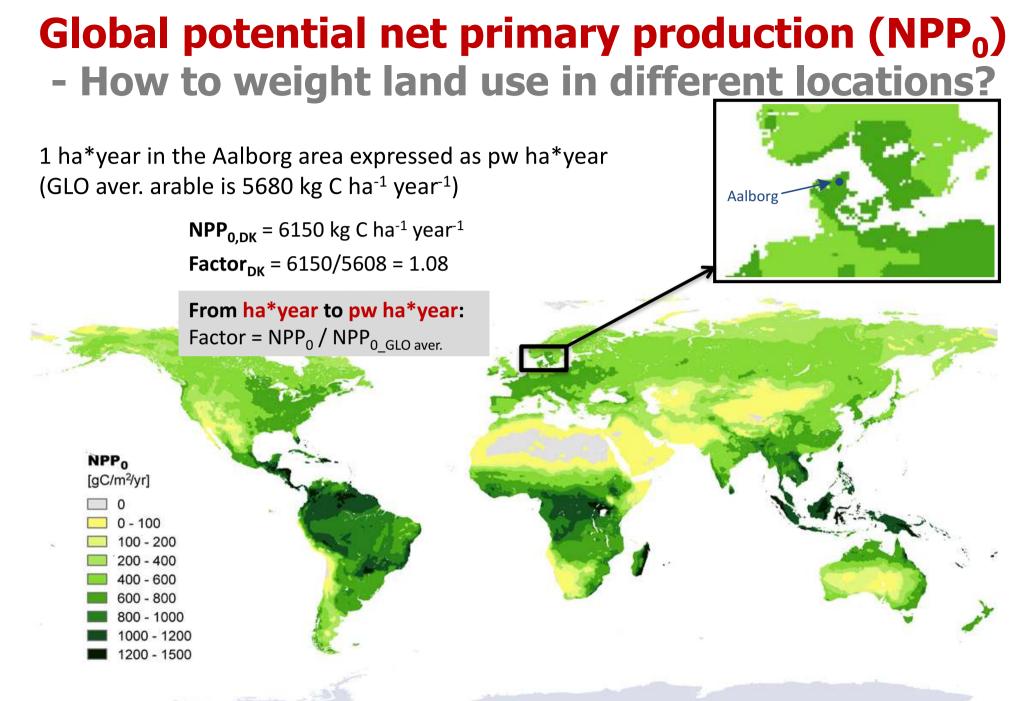


Functional unit

 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



Haberl H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., Fischer-Kowalski, M. (2007). Quantifying and mapping the global human appropriation of net primary production in Earth's terrestrial ecosystem. Proceedings of the National Academy of Sciences of the USA. 104: 12942-12047. http://www.uni-klu.ac.at/socec/inhalt/1191.htm

Life cycle inventory

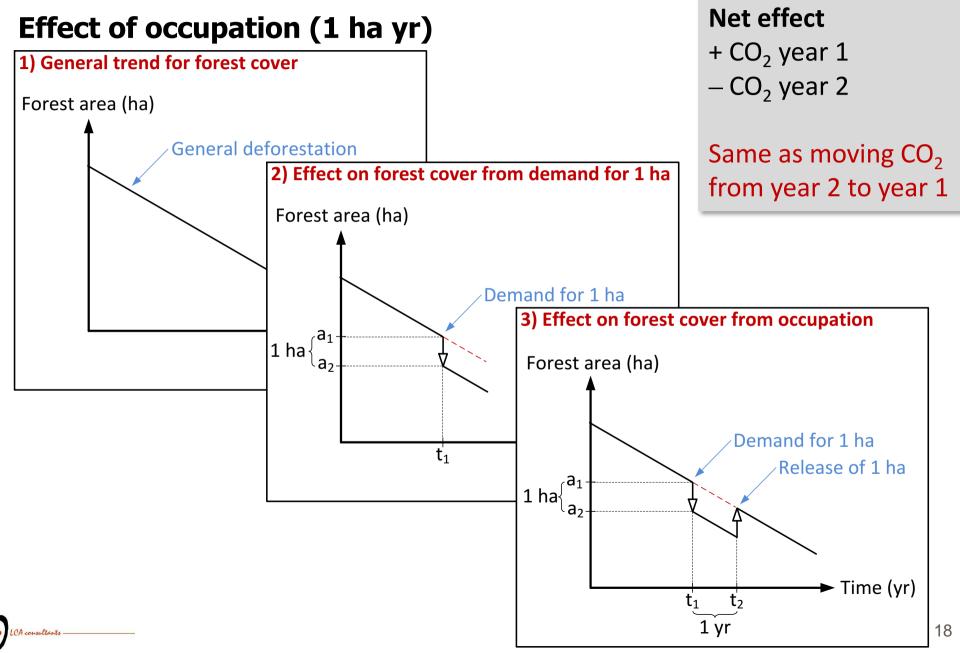
- Market, transformation and intensification

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missions	Inputs									
	n.a.	-								
.a. –	Emissions									

Wheat LCA activity (1 ha yr)

Occupation and transformation

- Accelerated deforestation



IPCC's global warming potential (GWP)

- The global warming potential
 - Originally used to differentiate different GHG-emissions (unit: CO₂-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/m²)

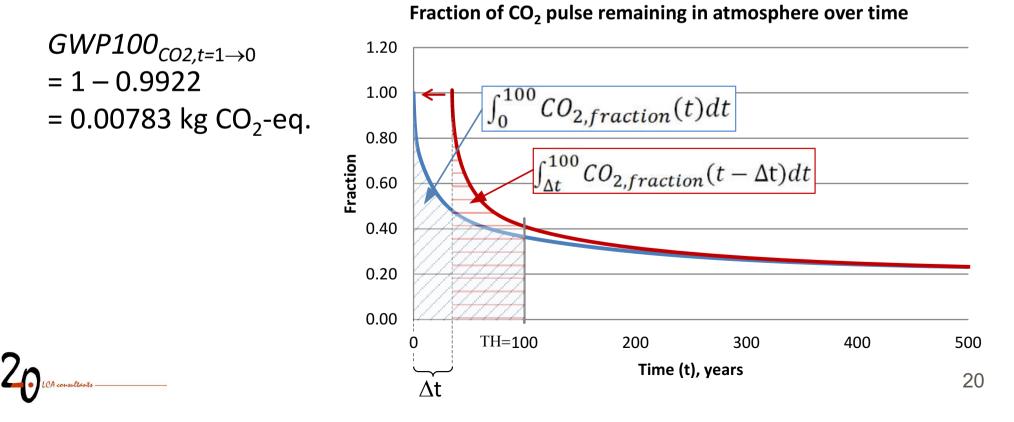
IPCC's global warming potential (GWP)

- time dependant
- Effect of emitting CO_2 in year Δt :

$$GWP_{CO2,\Delta t} = \frac{\int_{\Delta t}^{100} CO_{2,fraction}(t - \Delta t)dt}{\int_{0}^{100} CO_{2,fraction}(t)dt}$$

 $GWP_{CO2, \Delta t=0} = 1$ $GWP_{CO2, \Delta t=1} = 0.9922$

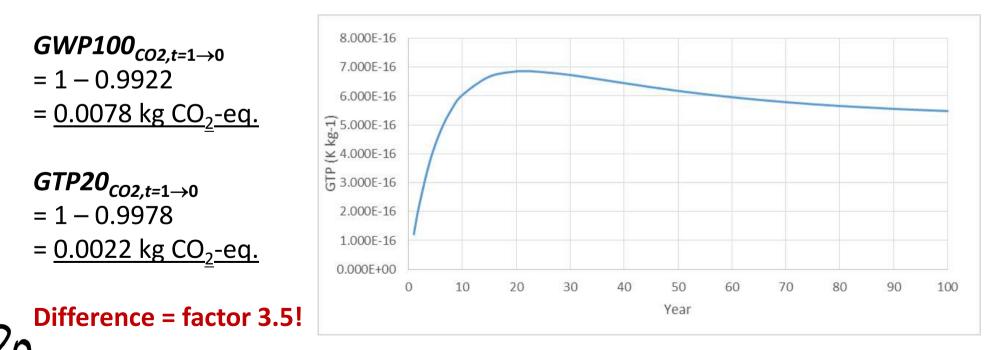
Effect of emitting 1 kg CO₂ in year 0 instead of year 1:



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; CO₂-eq.

Effect of emitting 1 kg CO₂ in year 0 instead of year 1:



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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.
- Market 2.

Land occupation \longrightarrow How much land is used per FU?

- Identify market segment (arable, forest or range)
- 3. Productivity factor *I* Identify the productivity factor of land

		NPP0 for each land cover, normalized to global NPP0 (ha-eq/ha)						
Acronym for country/region	Country/region	Arable	Forest	Grassland				
GLO	Global	1.00	1.00	1.00				
AT	Austria	1.14	0.86	1.37				
AU	Australia	0.90	0.91	1.19				
BE	Belgium	1.11	0.82	1.57				
BG	Bulgaria	0.95	0.75	1.39				
BR	Brazil	1.51	1.25	2.27				
CA	Canada	0.99	0.70	0.58				
СН	Switzerland	1.14	0.77	1.23				
CN	China	0.94	0.81	0.84				
СҮ	Cyprus	0.72	0.57	1.05				
cz	CzechRepublic	1.10	0.84	1.62				

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

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

						Output	Flow	U
			Land market activity			Wheat	7,296	k
			Output	Flow	Unit	Inputs from technoesphere		
Land use changes			Land	Σ (a1:a3)	ha*year eq.	> Land	1.08	ha*yea
Output	Flow	Unit	Inputs from technosphere			Diesel for traction	3,306	M
Transformation	a1	ha*year eq.	Transformation	a1	ha*year eq.	N-Fertiliser, as N	198	ke
Ressource inputs from n	ature		Intensification	a ₂	ha*year eq.	P-Fertiliser, as P ₂ O ₅	46	ke
Transformation from	b ₁	ha	Changes in consumption	a ₃	ha*year eq.	K-Fertiliser, as K ₂ O	84	kg
Transformation to	b ₂	ha	he		(22)	Emissions		
Emissions						CO ₂ fossil (diesel combustion)	245	kg
e.g. CO ₂	b ₃	kg				N ₂ O	4.15	kg
						Resources		
Intensification						CO ₂ biogenic from air	11,370	kg
Output	Flow	Unit						
Intensification	az	ha*year eq.						
Inputs from technosphe	re							
Diesel for traction	C ₁	MJ						
N-Fertiliser, as N	C ₂	kg						
Emissions								
e.g. N ₂ O, CO ₂	C3	kg						

Wheat LCA activity (1 ha yr)

Not included

Output	Flow	Unit
Changes in consumption	a3	ha*year eq.
Inputs		
n.a.	÷	
Emissions		
n.a.	-	

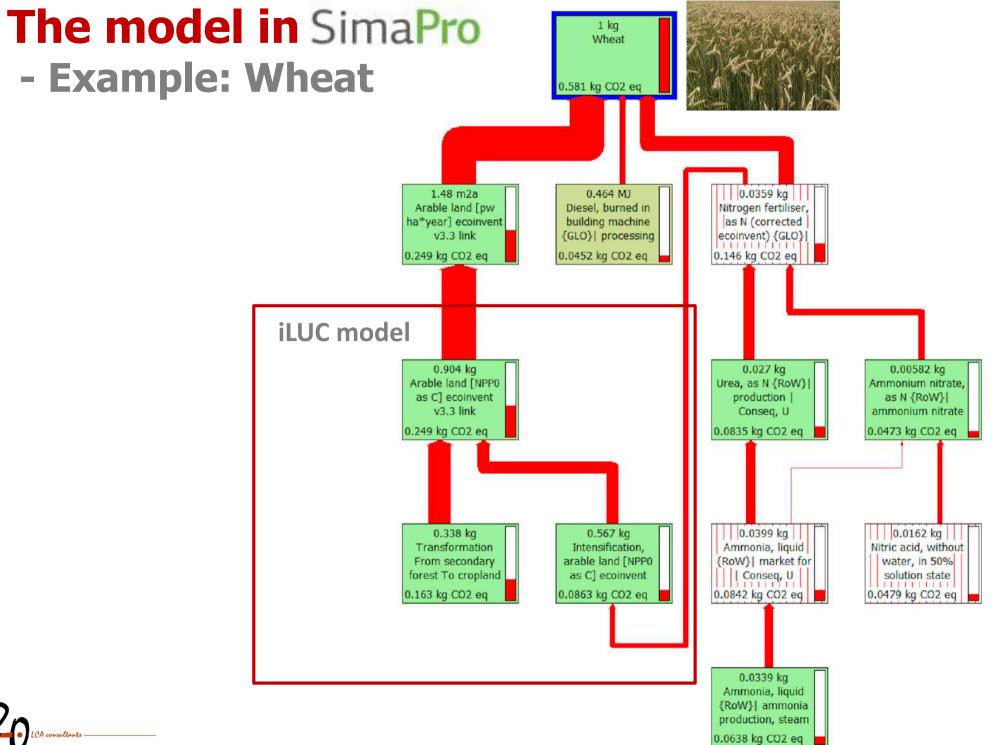
> wheat

The model in SimaPro

- Example: Wheat

multants

LCA Explorer					
Wizards	-Processes		Name 🛆 Unit		
Wizards	 ⊡ · Material		Wheat kg		
Goal and scope	iLUC wheat example				
Description	□ _iLUC v4.3 (ecoinvent v3.3 lin	ks)			
Libraries	⊡ Market				
Inventory	Transformation				
Processes	🗄 Agricultural	🌖 Edit	material process 'Wheat'		
Product stages	Ceramics	Docume	entation Input/output Parameters System description		
Waste types					Products
Parameters	. Electricity project				Products
Impact assessment		Know	n outputs to technosphere. Products and co-products		
Methods		Name		Amount	Unit
Calculation setups		Whea		7296	ka
Interpretation		whice	(Insert line here)	7250	Ng
Interpretation	• Metals		. ,		
Document Links			n outputs to technosphere. Avoided products		
General data	. ⊕. Others	Name	(Terret Providence)		Amount
Literature references	Paper + Board		(Insert line here)		
Substances	Plastics				Inputs
Units	. Textiles				
Quantities		Knowr	n inputs from nature (resources)		
Images		Name		mpartment	t Amount
	itwood		(Insert line here)		
	····· x_Materials	Knowr	n inputs from technosphere (materials/fuels)		
	i Energy	Name		Amount	Unit
		Arabl	e land [pw ha*year] ecoinvent v3.3 link	1.08	ha a
	Processing	Diese	, burned in building machine {GLO} processing Conseq, U	3306	LCW
	⊡ Use		gen fertiliser, as N (corrected ecoinvent) {GLO} market for Conseq, U	198	kg
			whate fertiliser, as P2O5 {GLO} market for Conseq, U	46	kg
	Waste treatment	<u> </u>	sium fertiliser, as K2O {GLO} market for Conseq, U	84	ka
		rotas	(Insert line here)	01	Ng
			n inputs from technosphere (electricity/heat)		
		Name			Amount
			(Insert line here)		
					Outputs
			ons to air		
		Name		{Amount	Unit
		Dinitro	ogen monoxide	4.15	kg
			Are a Port A		



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...

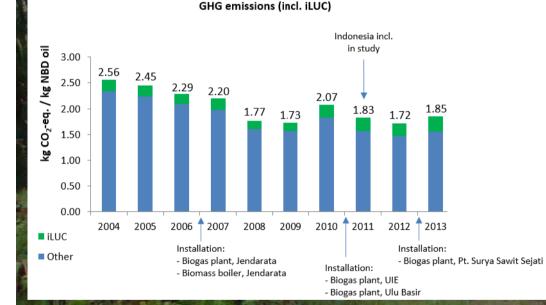
All examples can be accessed here:

https://lca-net.com/projects/show/indirect-land-use-change-model-iluc/



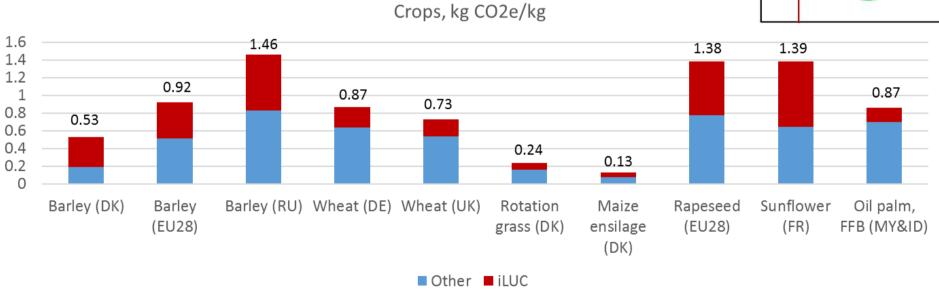
Case with palm oil industry: - Palm oil at United Plantations

Detailed LCA studies since 2004



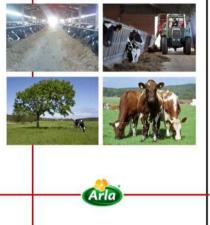


Picture: Jannick Schmidt, United Plantations, Lada Estate



Different crops - and the role of iLUC

Life cycle assessment of milk - National baselines for Germany, Denmark, Sweden and United Kingdom 1990 and 2012



Results extracted from LCA data in:

Dalgaard R, Schmidt J, Cenian K (2016). Life cycle assessment of milk - National baselines for Germany, Denmark, Sweden and United Kingdom 1990 and 2012. Arla Foods, Aarhus, Denmark http://lca-net.com/p/2324 30

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

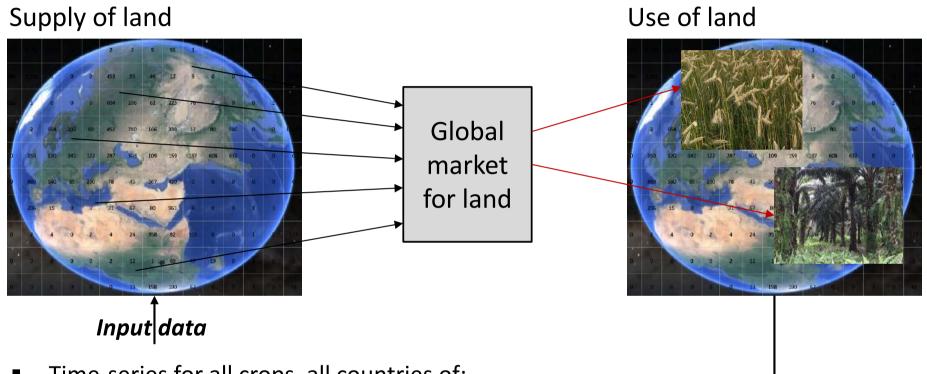
New developments What is next?

New developments - Global model

Integration with:

Multi-regional hybrid input-output model



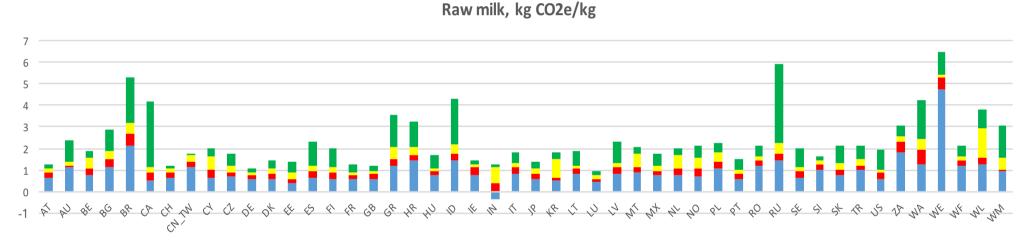


- Time-series for all crops, all countries of:
 - Area
 - Yield
 - Production
- 3 markets for land: Arable, forest, range

Output of the model (next slide...)

Examples of results (1/2)

- Raw milk and iLUC
- Exiobase v3, hybrid version inclusive iLUC



■CH4 ■N20 ■CO2 ■iLUC

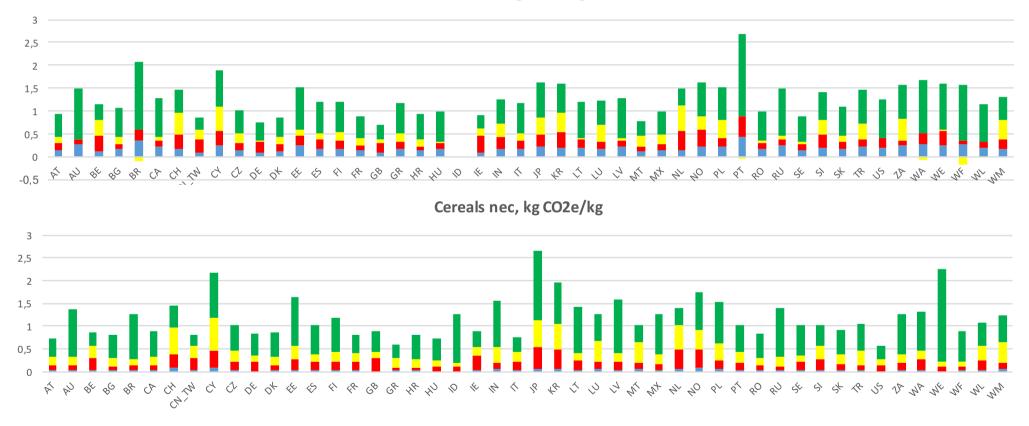


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Examples of results (2/2) - Cereals and iLUC

Exiobase v3, hybrid version inclusive iLUC

Per kg dry matter



Wheat, kg CO2e/kg

Other N20 C02 iLUC

www.exiobase.eu

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exiobase

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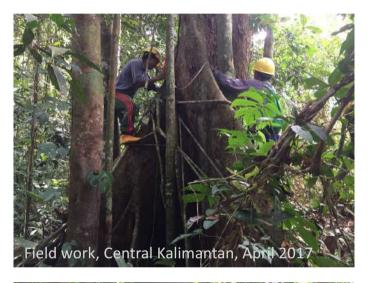
What is next?

We currently work on:

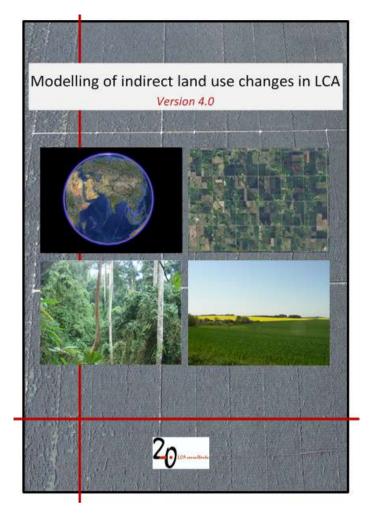
- Cross checking with satellite remote sensing (De Rosa et al. 2017)
- LUC: particulates from forest fires
- Better carbon stock and biodiversity data
- Module for nature conservation modelling

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/

