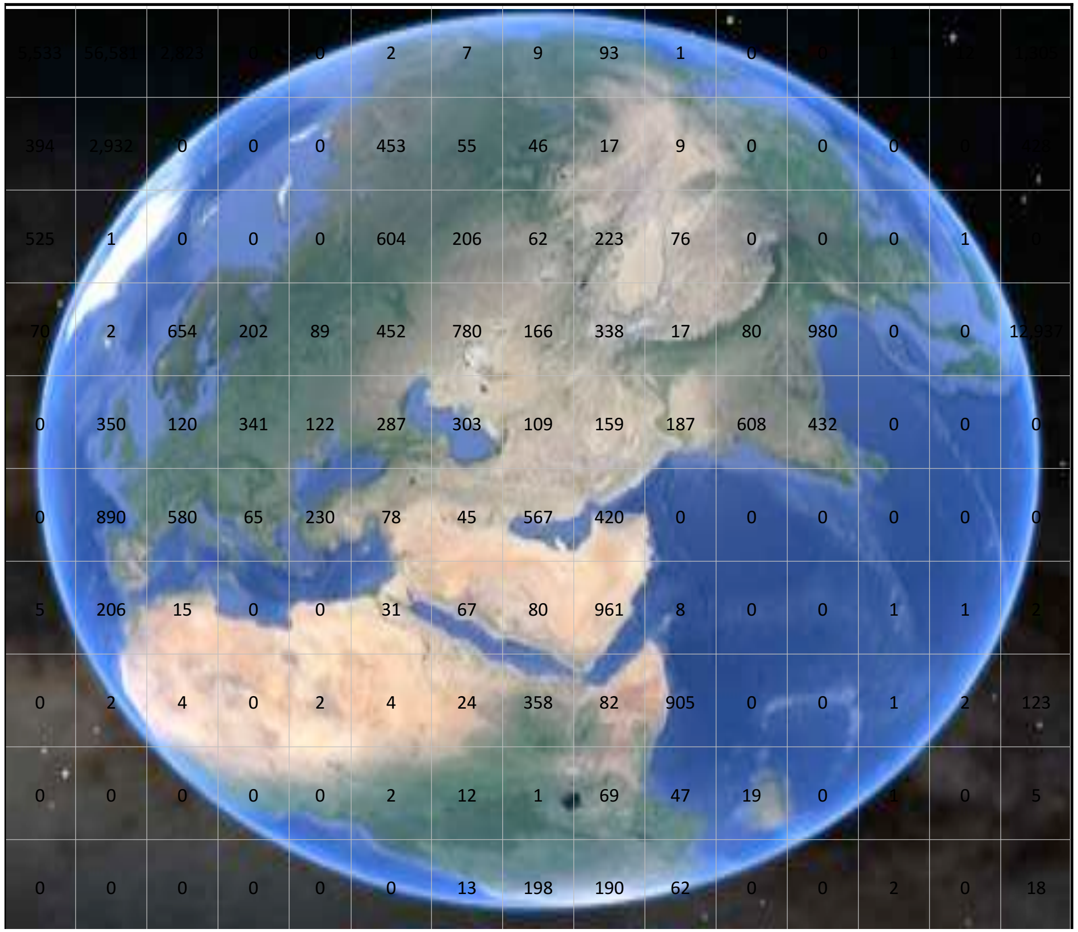
10 years of iLUC modelling



Jannick Schmidt & Michele De Rosa

15th November 2017

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2-0 LCA consultants

Agenda

- ➡ Welcome and introduction
- What is direct and indirect land use changes?
- The 2.-0 LCA iLUC model
  - Key assumptions
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Central Kalimantan, April 2014

Background

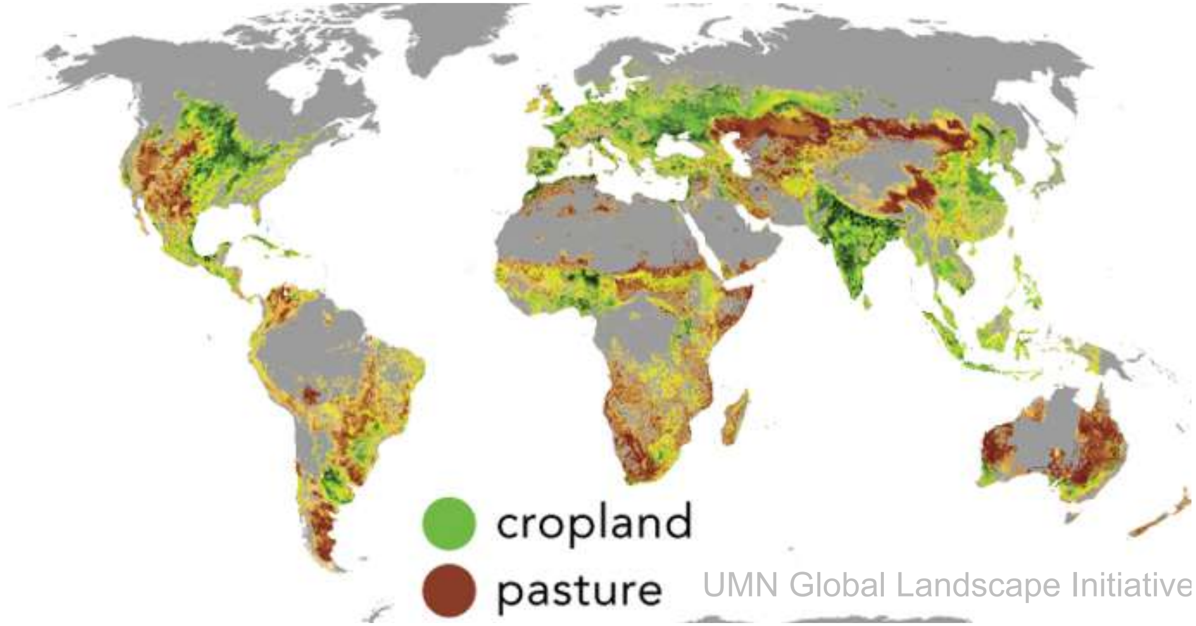
- **High impact:** 11% of global GHG emissions
- **Causes**
  - Global increased demand for land
  - A change in demand for land ⇨ land-use changes
- **Challenges**
  - Ascribing the land use changes to their drivers
  - What is the role of energy/food/fibers?

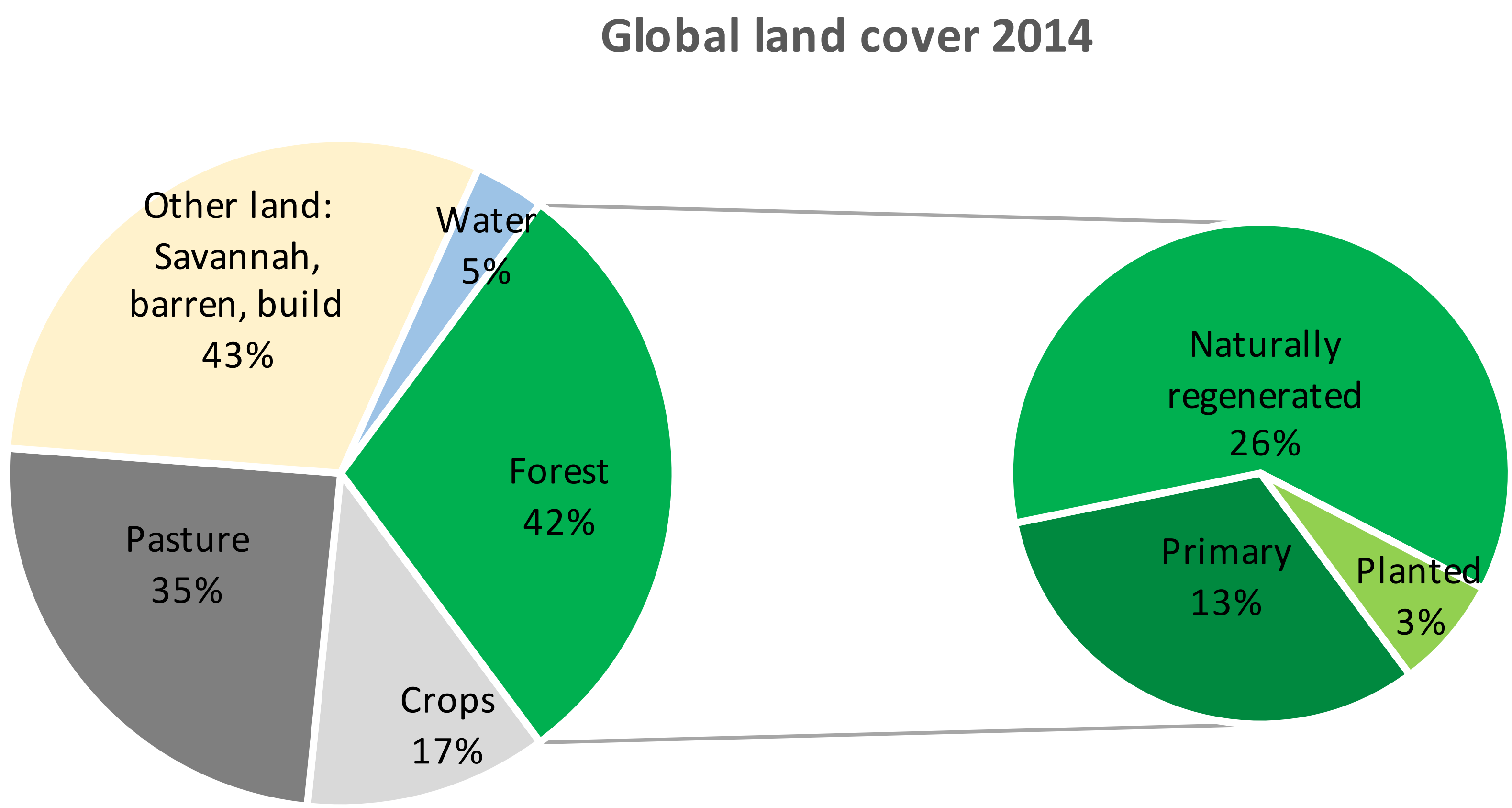

Pangkalanbuun, Central Kalimantan April 2014


Bukit Lawang, Sumatra November 2013


Perak, Malaysia, April 2014

Global land use





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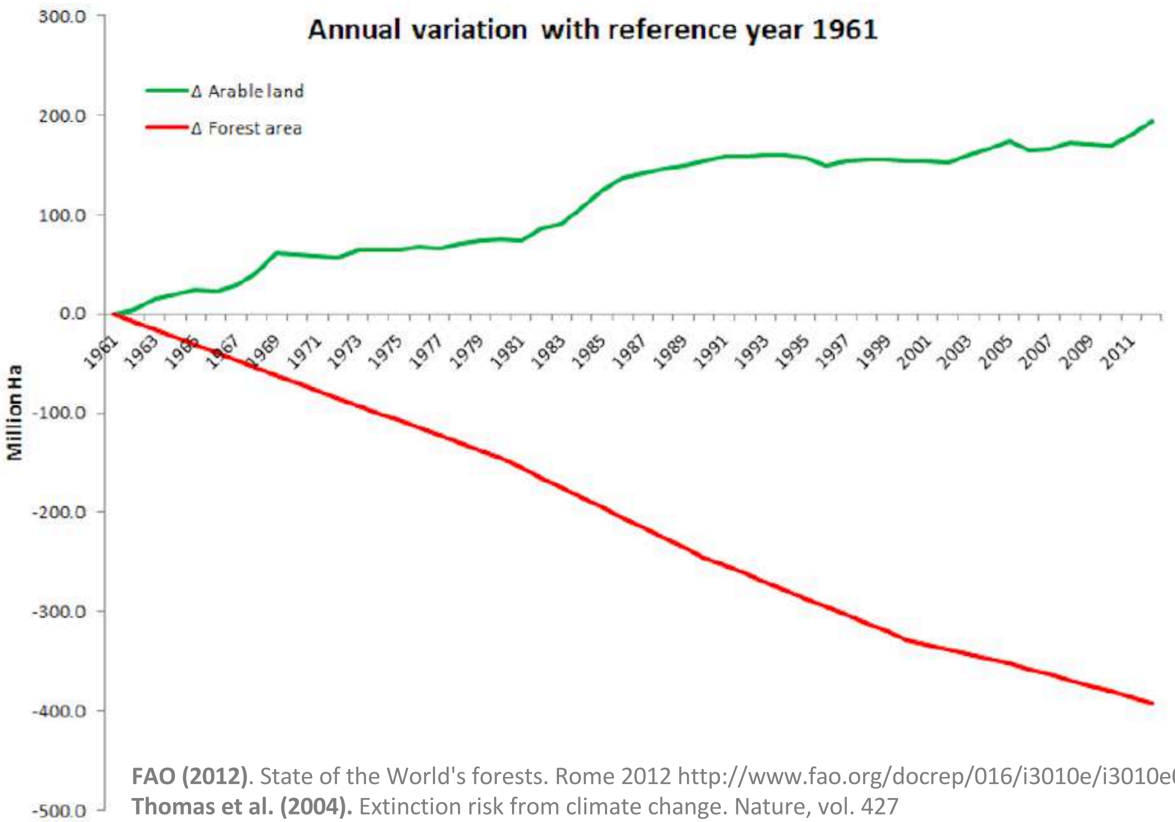
Land use change impacts

- 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



FAO (2012). State of the World's forests. Rome 2012 http://www.fao.org/docrep/016/i3010e/i3010e00.htm

Thomas et al. (2004). Extinction risk from climate change. Nature, vol. 427

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.

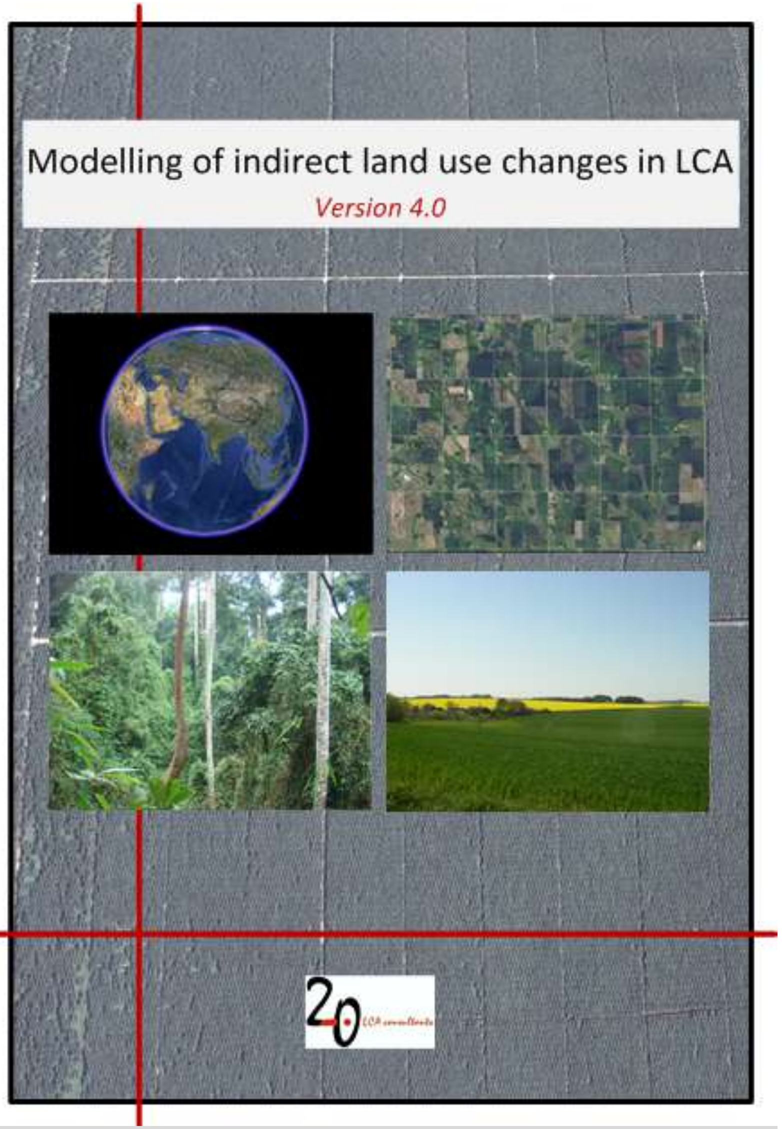
Johnston F H, Henderson S B et al. (2012). Estimated global mortality attributable to smoke from landscape fires. Environmental Health Perspectives. 120(5); 695-701

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.mahid
- 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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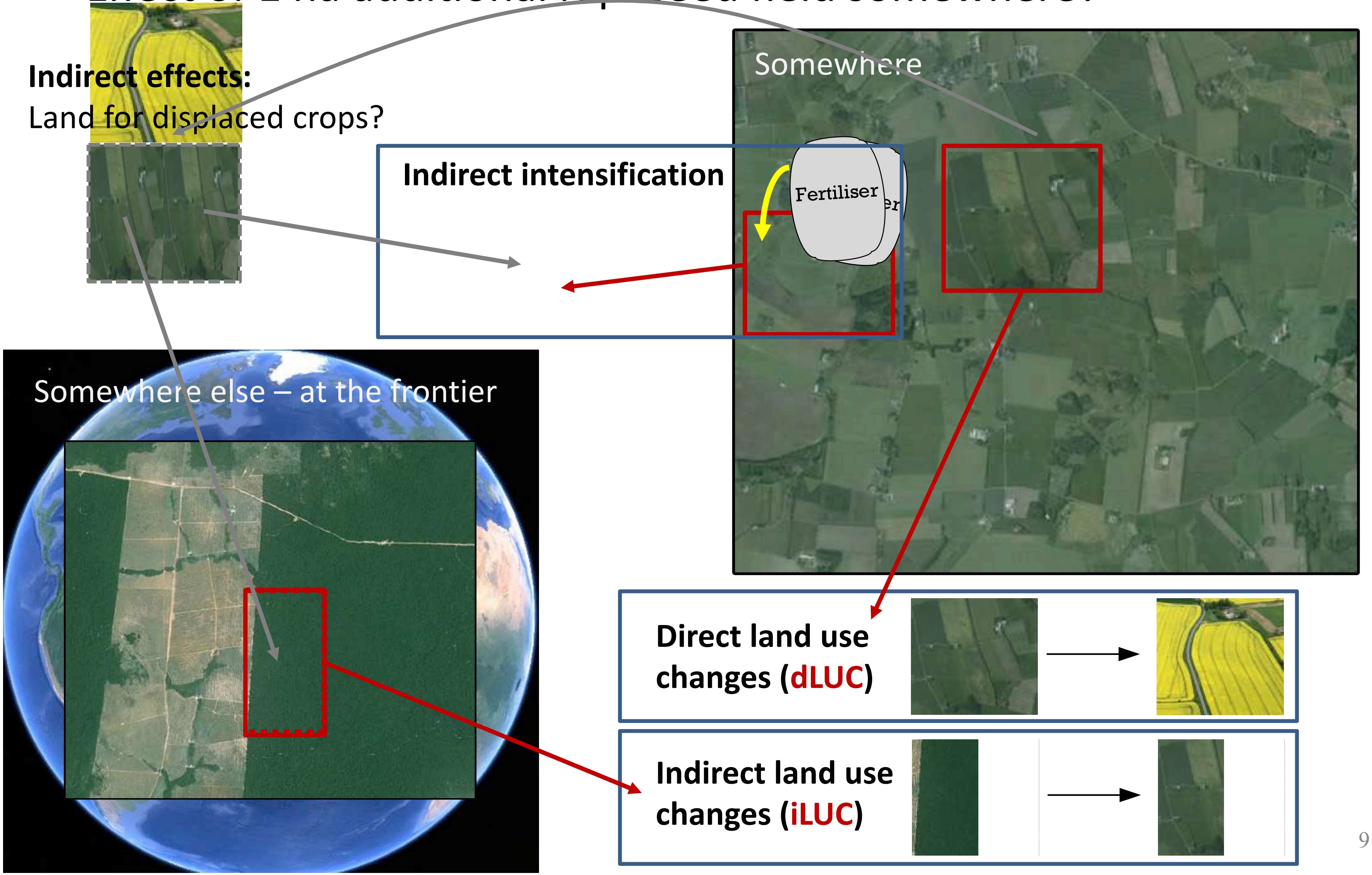
Central Kalimantan, April 2014

Direct and indirect Land-Use Changes

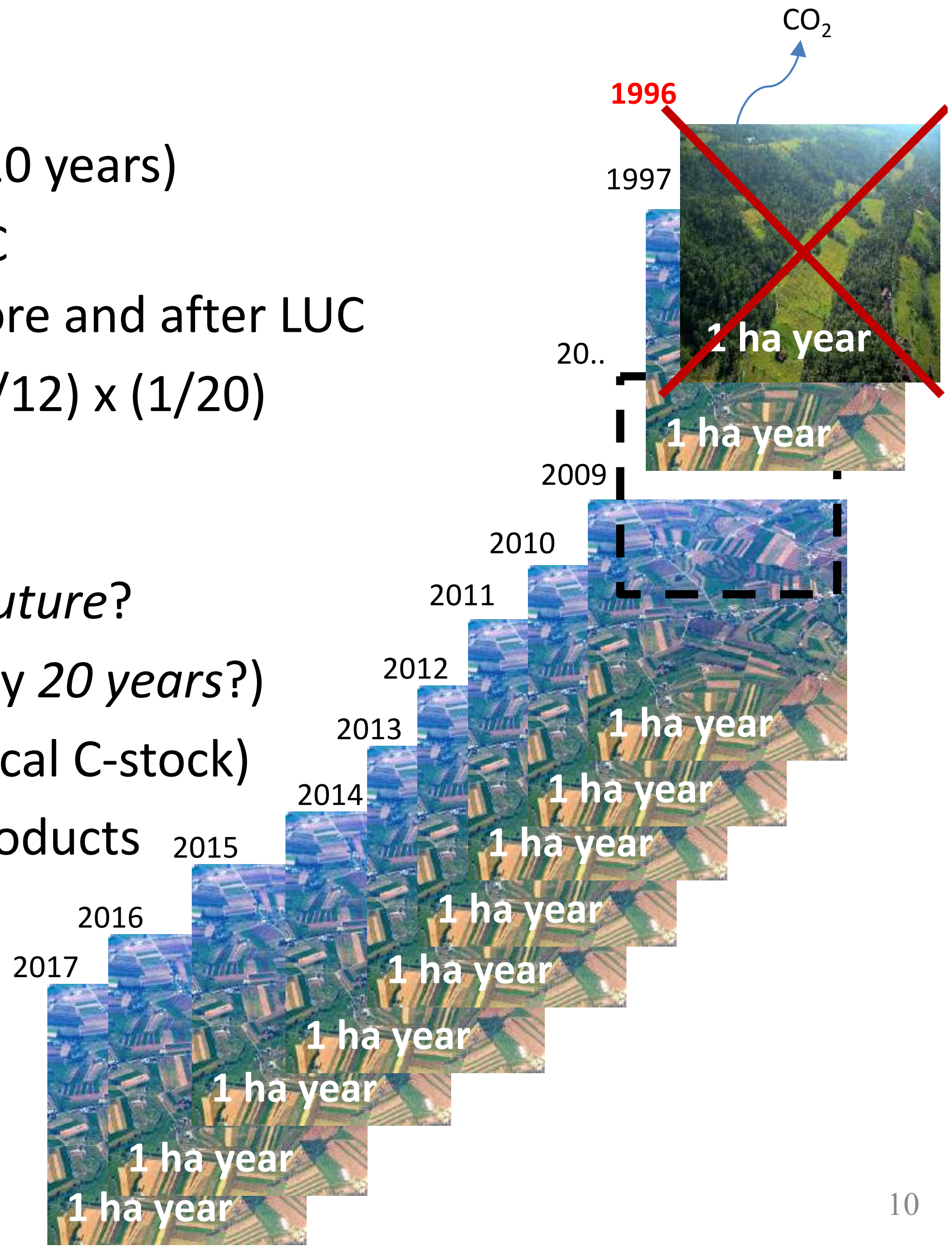
- Effect of 1 ha additional rapeseed field somewhere?



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 = 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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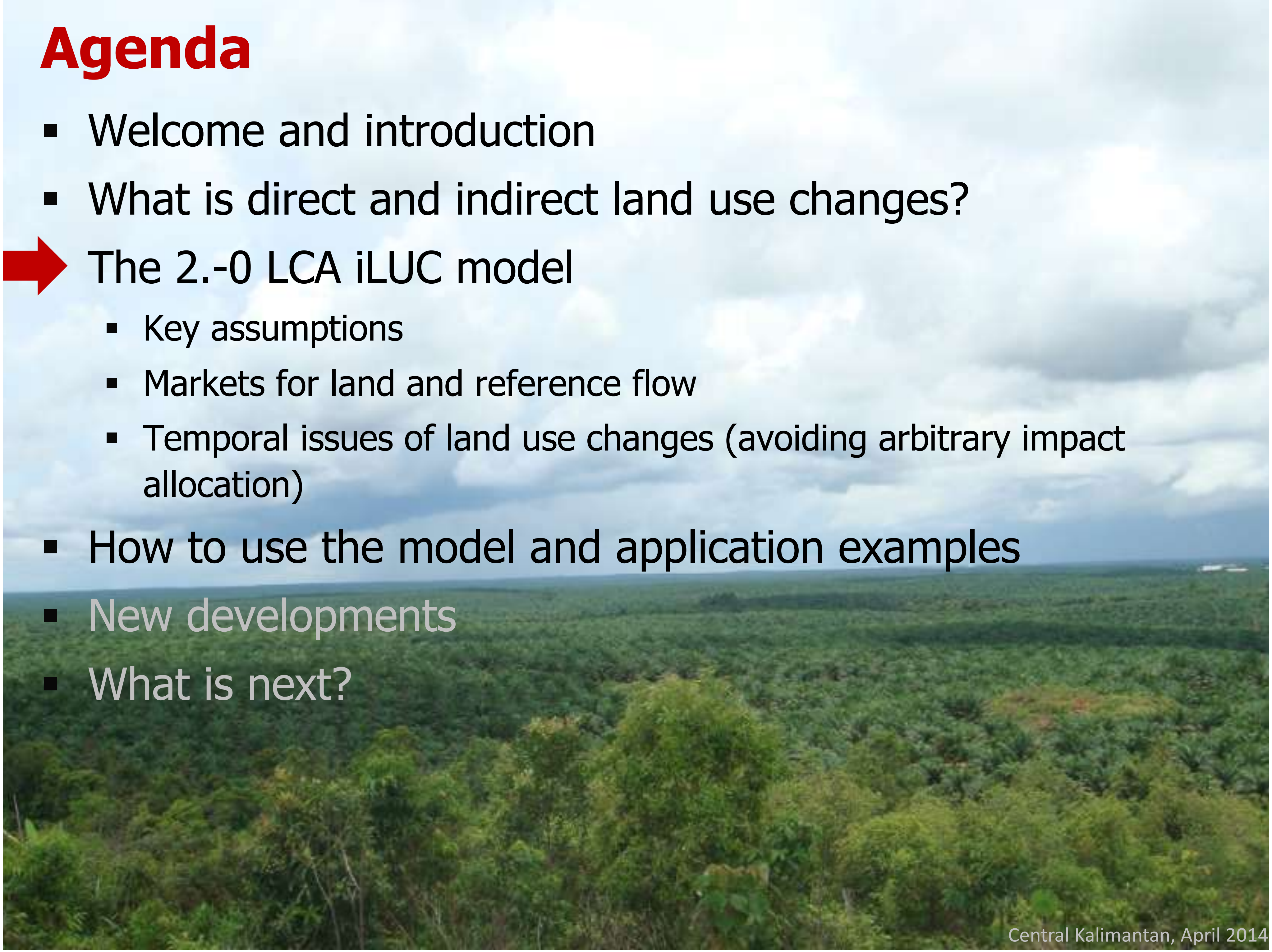

Central Kalimantan, April 2014

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)

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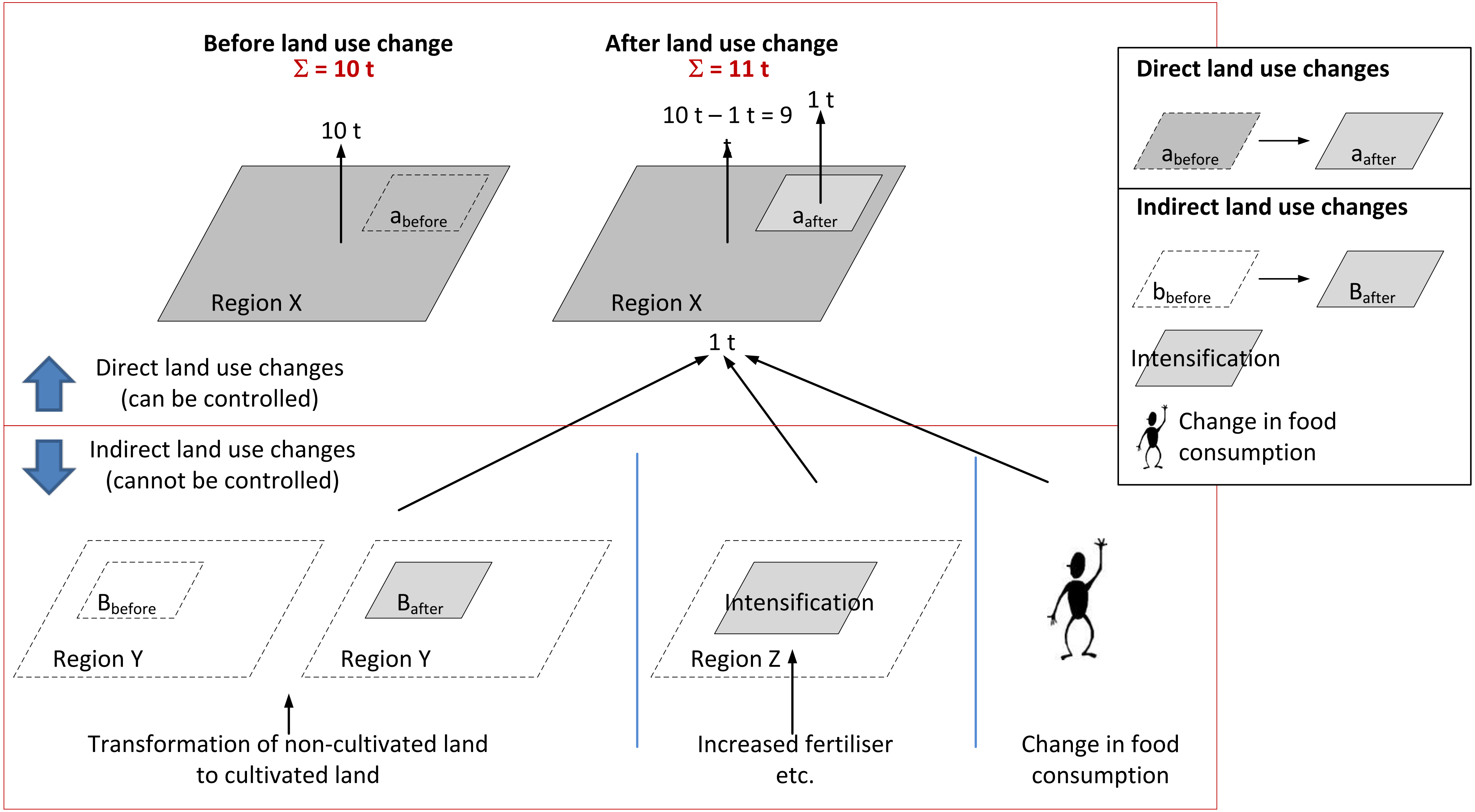
iLUC – "the mass balance proof"

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



What is land?

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

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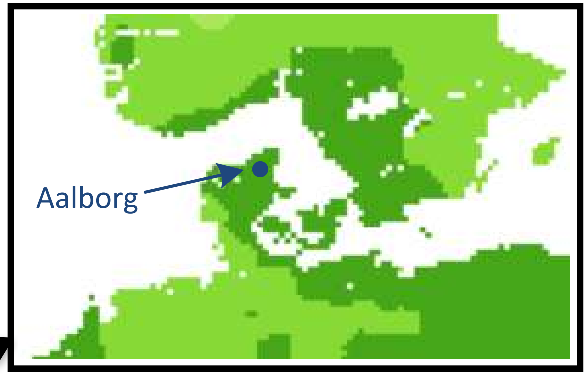
Land... what is land?
- Functional unit considerations

	Markets for land
	Market for arable land (fit for arable and other)
	Market for intensive forest land (fit for intensive/extensive forestry and grazing)
	Market for extensive forest land (fit for extensive forestry and grazing)
	Market for grassland (fit for grazing)
	Market for barren land (not fit for biomass production)

- 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?

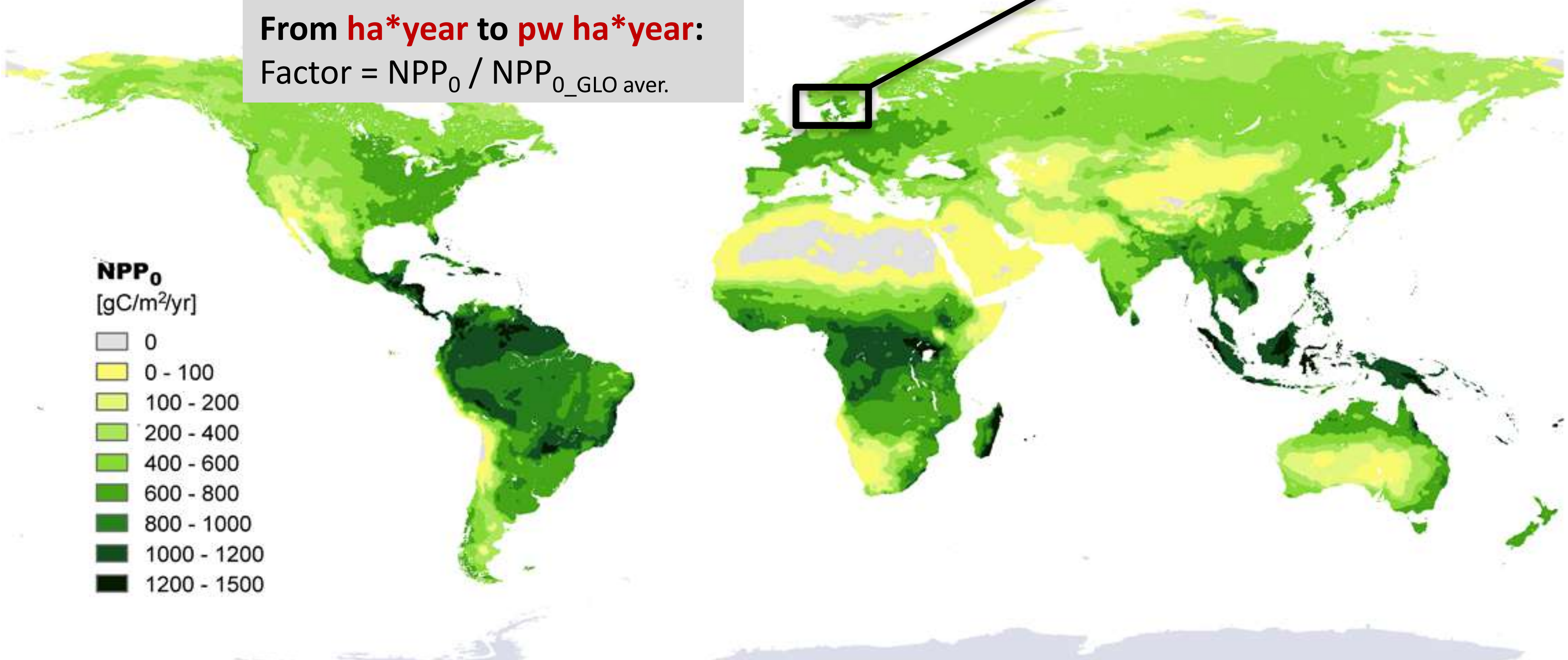


1 ha*year in the Aalborg area expressed as pw ha*year
(GLO aver. arable is 5680 kg C ha^{-1} $year^{-1}$)

$NPP_{0,DK}$ = 6150 kg C ha^{-1} $year^{-1}$

$Factor_{DK}$ = 6150/5608 = 1.08

From ha*year to pw ha*year:
Factor = NPP_0 / $NPP_{0\_GLO\ aver.}$



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: 12942-12947. http://www.uni-klu.ac.at/socec/inhalt/1191.htm

Life cycle inventory
- Market, transformation and intensification

Land use changes

Output	Flow	Unit
Transformation	a_1	ha*year eq.
Ressource inputs from nature		
Transformation from…	b_1	ha
Transformation to…	b_2	ha
Emissions		
e.g. CO_2	$b_{3...}$	kg

Intensification

Output	Flow	Unit
Intensification	a_2	ha*year eq.
Inputs from technosphere		
Diesel for traction	c_1	MJ
N-Fertiliser, as N	c_2	kg
Emissions		
e.g. N_2O, CO_2	$c_{3...}$	kg

Not included

Social effects

Output	Flow	Unit
Changes in consumption	a_3	ha*year eq.
Inputs		
n.a.	-	
Emissions		
n.a.	-	

Land market activity

Output	Flow	Unit
Land	$\Sigma (a_1:a_3)$	ha*year eq.
Inputs from technosphere		
Transformation	a_1	ha*year eq.
Intensification	a_2	ha*year eq.
Changes in consumption	a_3	ha*year eq.

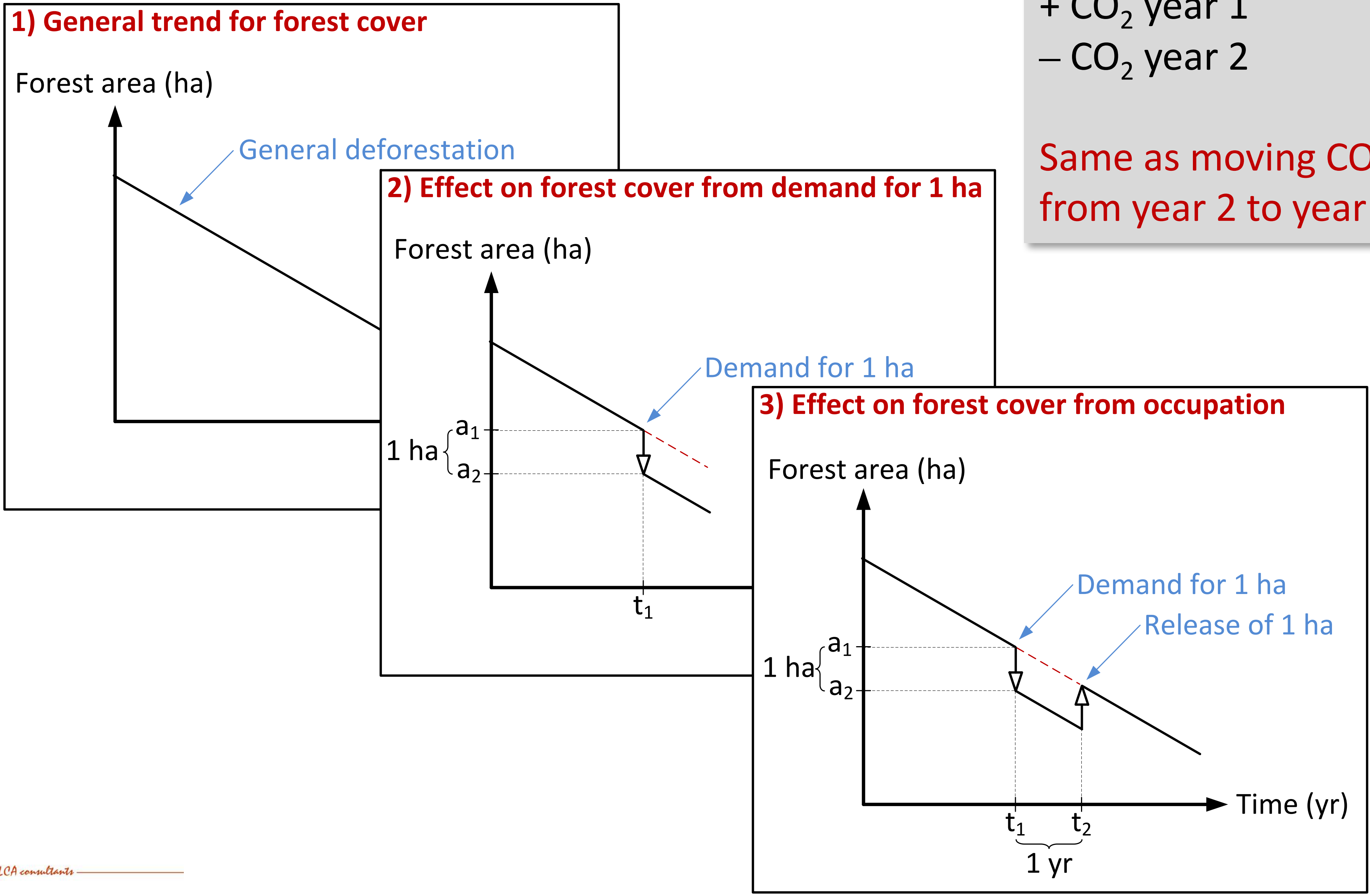
Wheat LCA activity (1 ha yr)

Output	Flow	Unit
Wheat	7,296	kg
Inputs from technoesphere		
Land	1.08	ha*year eq.
Diesel for traction	3,306	MJ
N-Fertiliser, as N	198	kg
P-Fertiliser, as P_2O_5	46	kg
K-Fertiliser, as K_2O	84	kg
Emissions		
CO_2 fossil (diesel combustion)	245	kg
N_2O	4.15	kg
Resources		
CO_2 biogenic from air	11,370	kg

→ wheat

Occupation and transformation
- Accelerated deforestation

Effect of occupation (1 ha yr)



Net effect

+ CO_2 year 1

– CO_2 year 2

Same as moving CO_2 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)

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Formulas: IPCC (2013) Climate Change 2013 - The Physical Science Basis, 8SM p 15-16.

IPCC's global warming potential (GWP)
- time dependant

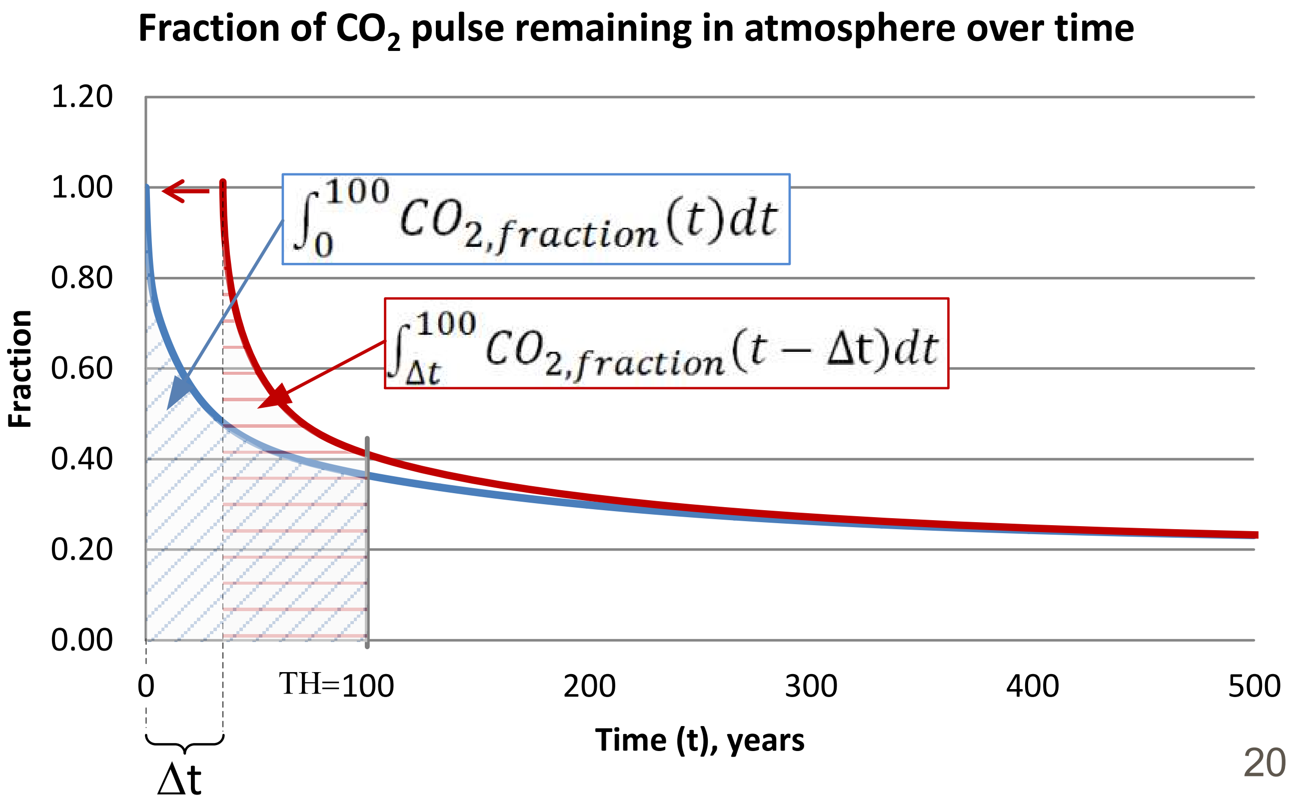
- Effect of emitting CO_2 in year Δt:

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

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

Effect of emitting 1 kg CO_2 in year 0 instead of year 1:

$GWP100_{CO2,t=1\rightarrow 0}$
$= 1 - 0.9922$
$= 0.00783$ kg CO_2-eq.



Global temperature potential (GTP)

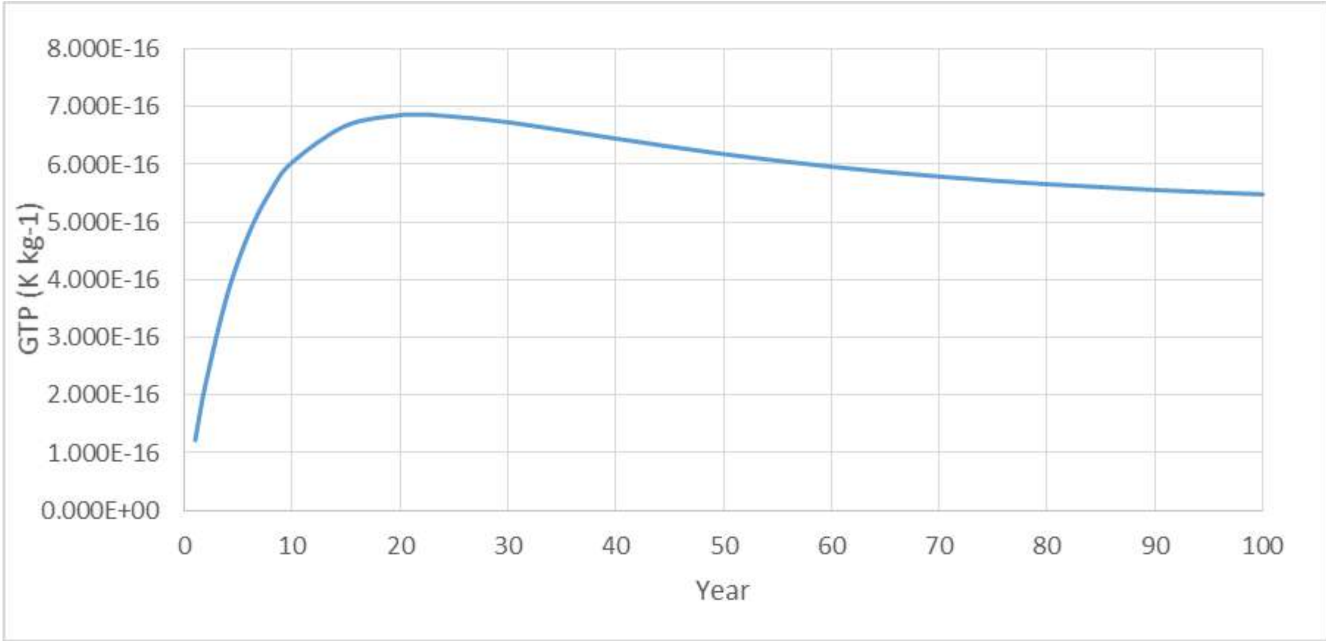
- Measures temperature effect from a pulse emission at specified time (H)
- Closer to end-point than GWP
- Indicator has same unit as GWP; CO_2-eq.

Effect of emitting 1 kg CO_2 in year 0 instead of year 1:

GWP100$_{CO2,t=1\rightarrow 0}$
= 1 – 0.9922
= <u>0.0078 kg CO_2-eq.</u>

GTP20$_{CO2,t=1\rightarrow 0}$
= 1 – 0.9978
= <u>0.0022 kg CO_2-eq.</u>

Difference = factor 3.5!



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Central Kalimantan, April 2014

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

Acronym for country/region	Country/region	NPP0 for each land cover, normalized to global NPP0 (ha-eq/ha)		
		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
CH	Switzerland	1.14	0.77	1.23
CN	China	0.94	0.81	0.84
CY	Cyprus	0.72	0.57	1.05
CZ	CzechRepublic	1.10	0.84	1.62

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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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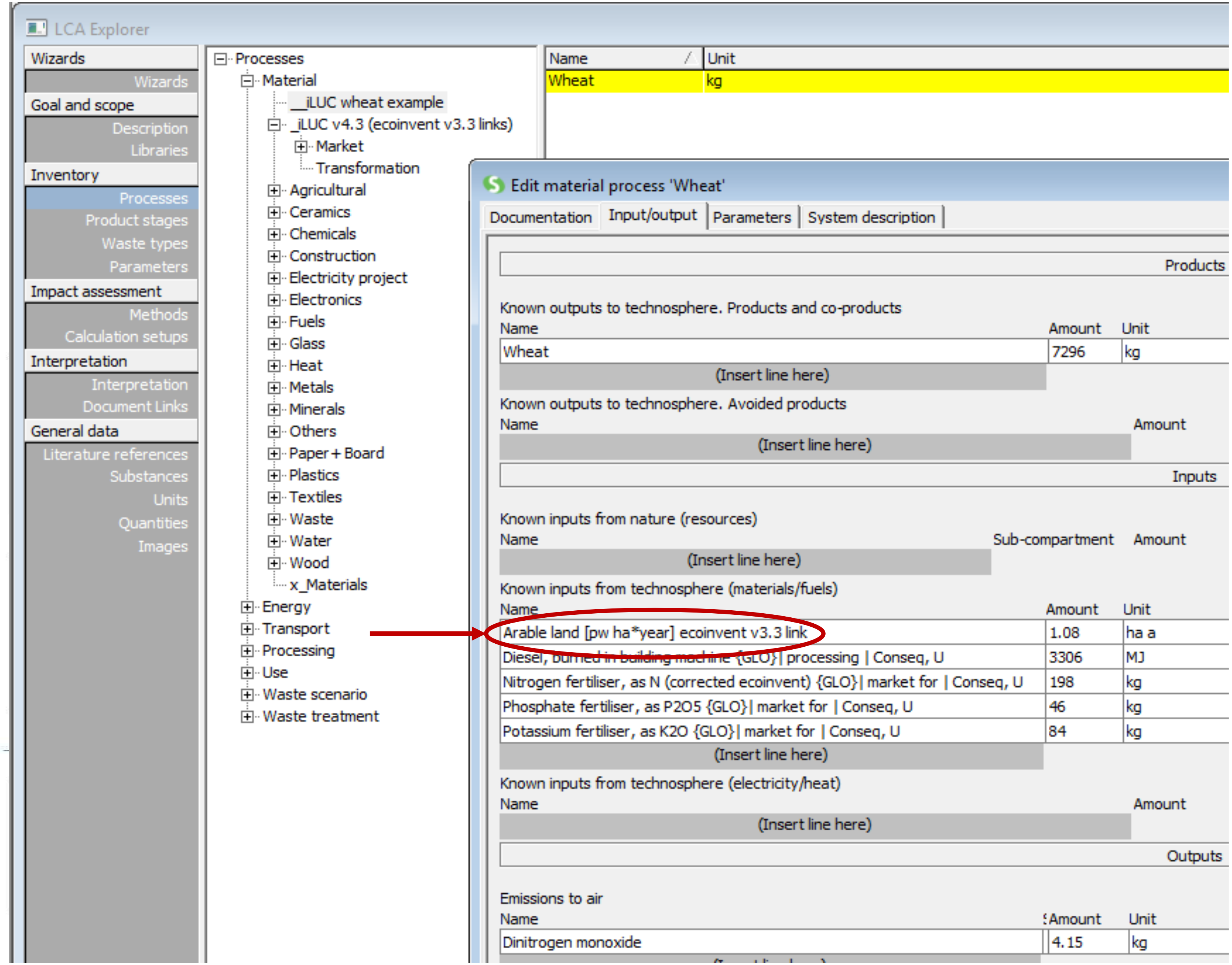

The model in SimaPro
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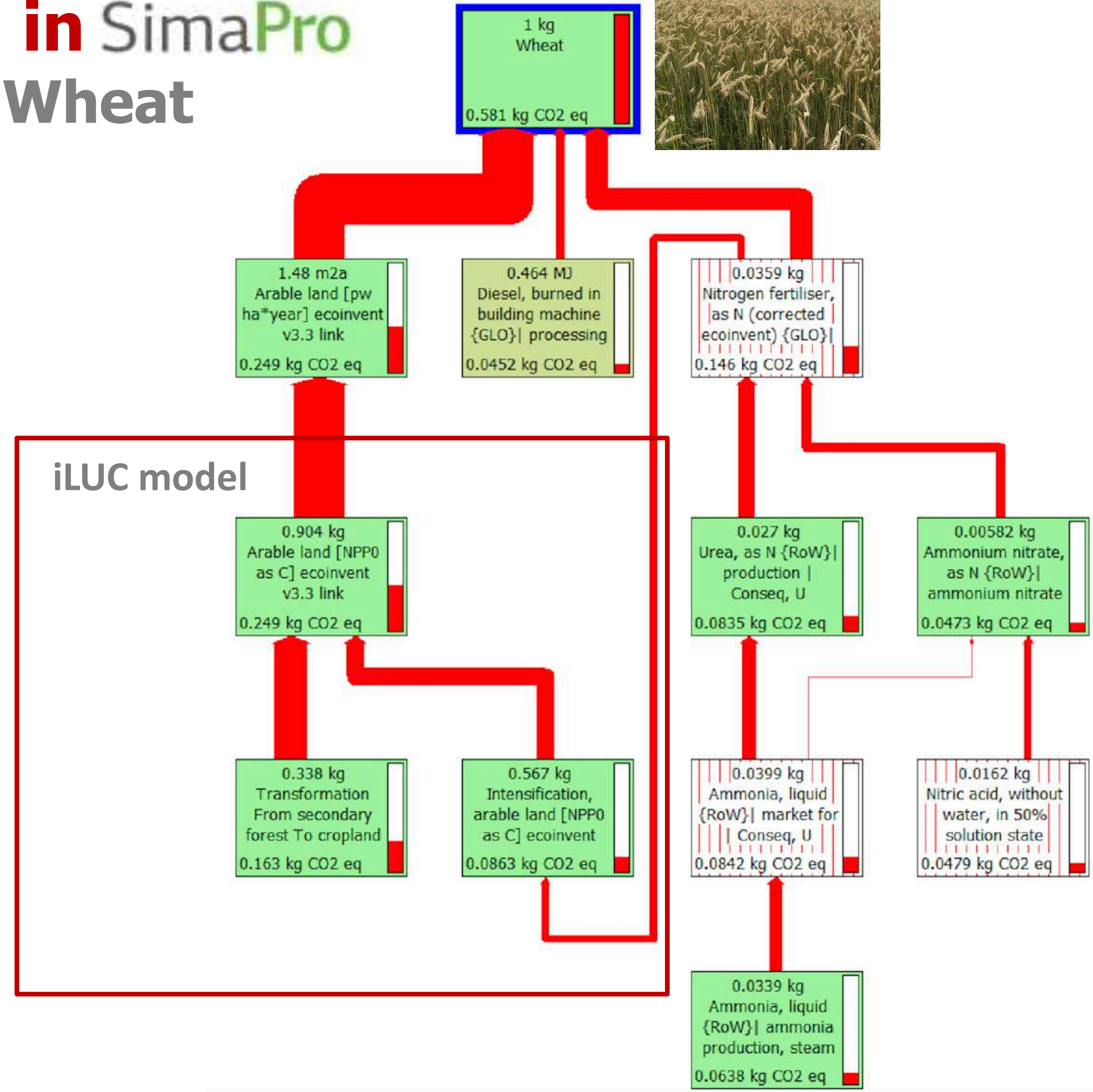


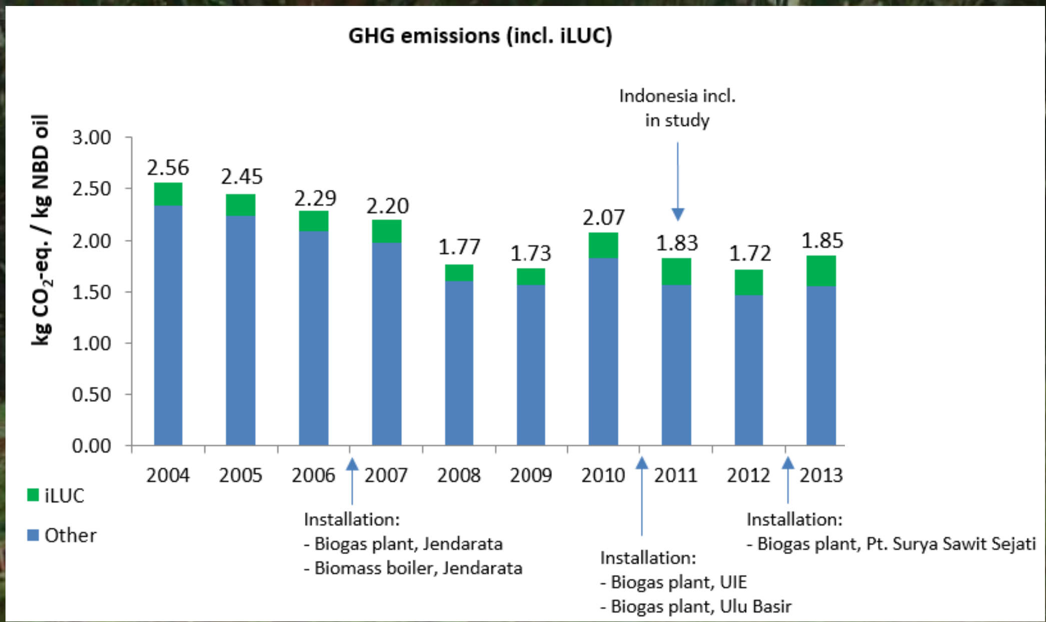
Examples of application

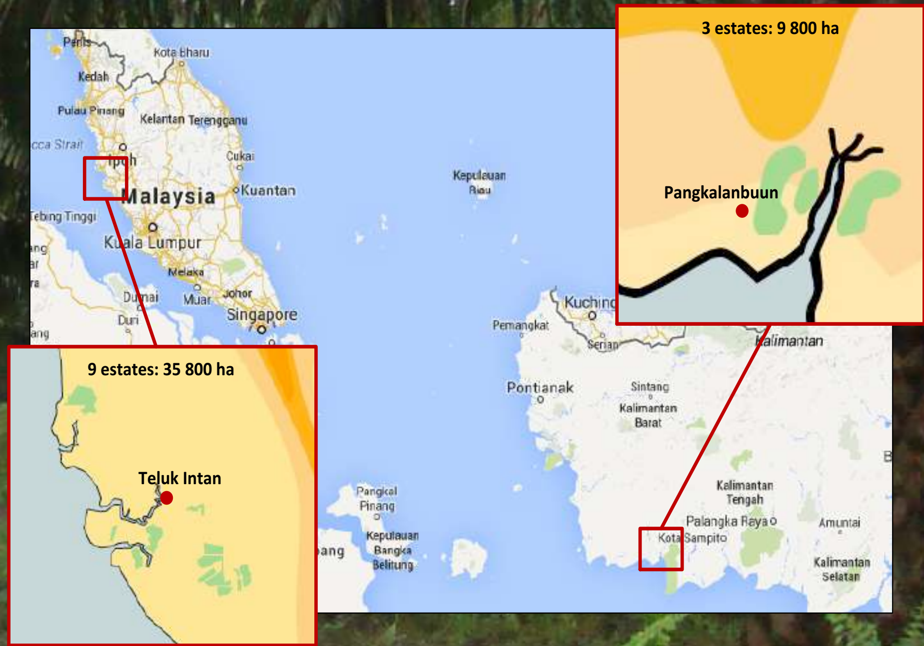
- Vegetable oils (palm, rapeseed, sunflower, peanut, soybean)
- Milk (Germany, Denmark, Sweden and United Kingdom)
- Chicken
- Specialty food ingredients
- Canteens (eco-labelled and conventional)
- Nature conservation in Kalimantan
- Global food consumption
- Biofuels (liquid and solid)
- Electricity 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

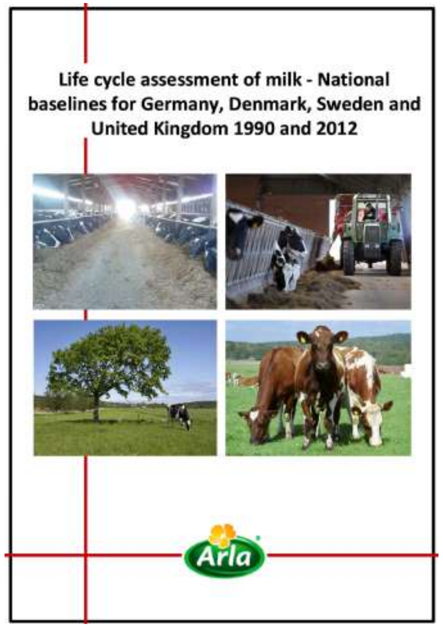
- Detailed LCA studies since 2004

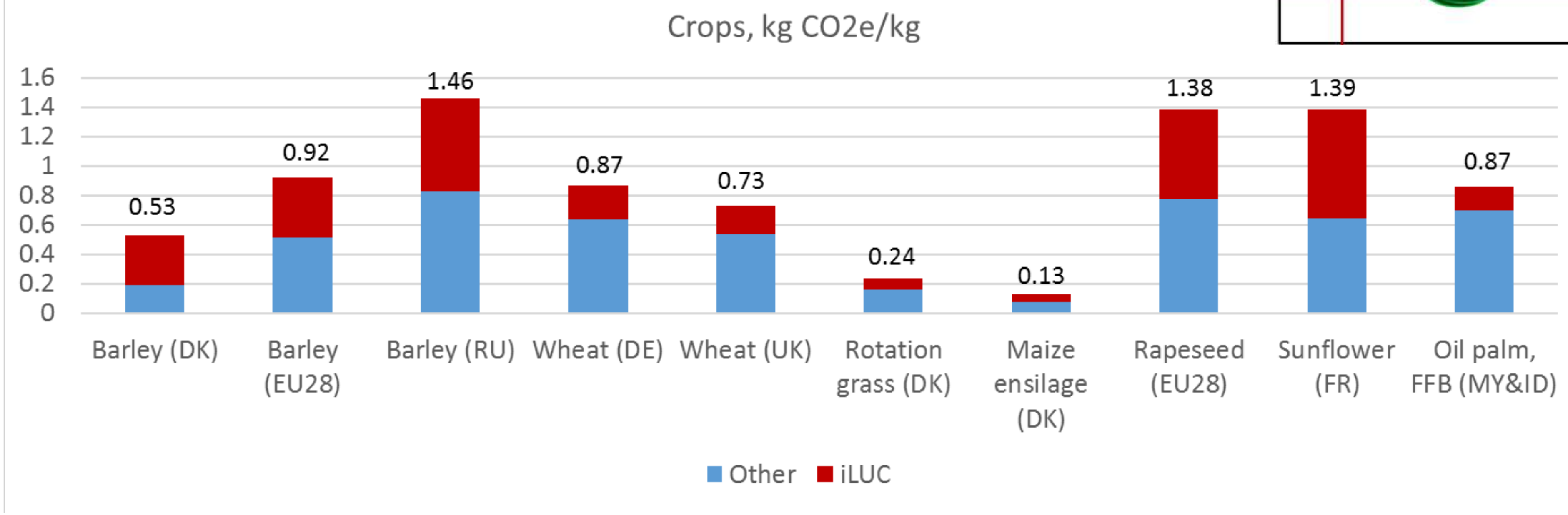




Picture: Jannick Schmidt, United Plantations, Lada Estate

Different crops
- and the role of iLUC





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

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New developments
- Global model

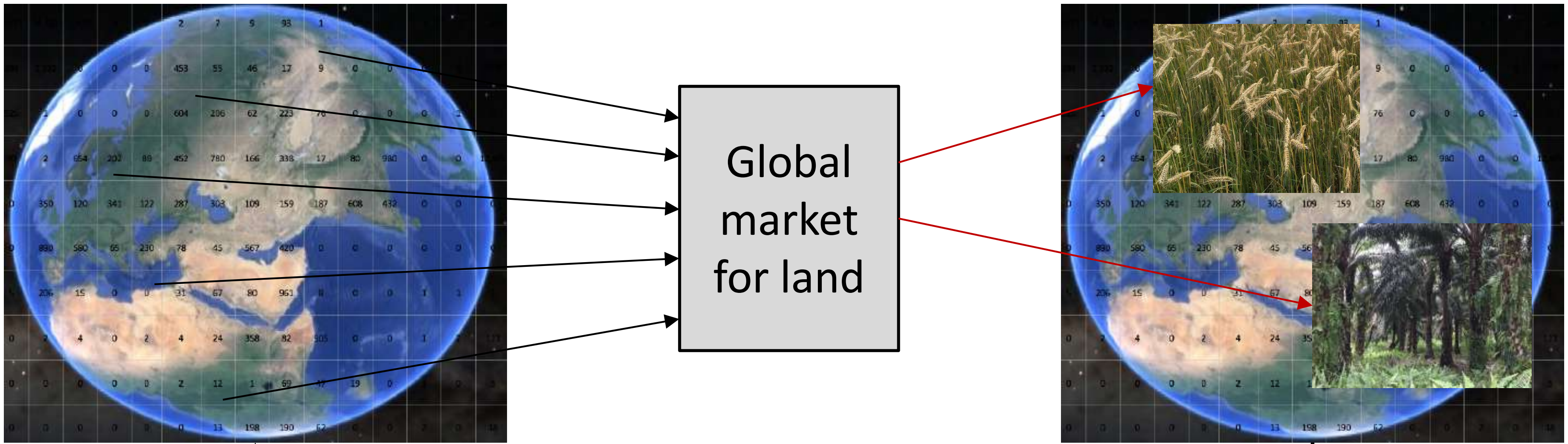
Integration with:

Multi-regional hybrid input-output model

exiobase

Supply of land

Use of land



Input data

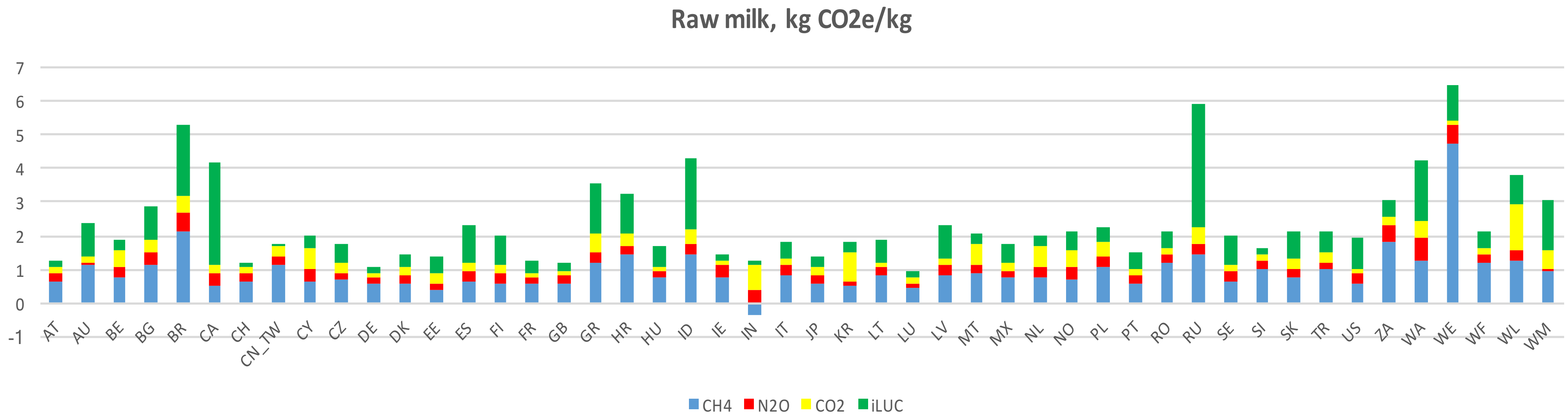
- Time-series for all crops, all countries of:
  - Area
  - Yield
  - Production
- 3 markets for land: Arable, forest, range

Output of the model

(next slide…)

Examples of results (1/2)
- Raw milk and iLUC

- Exiobase v3, hybrid version inclusive iLUC



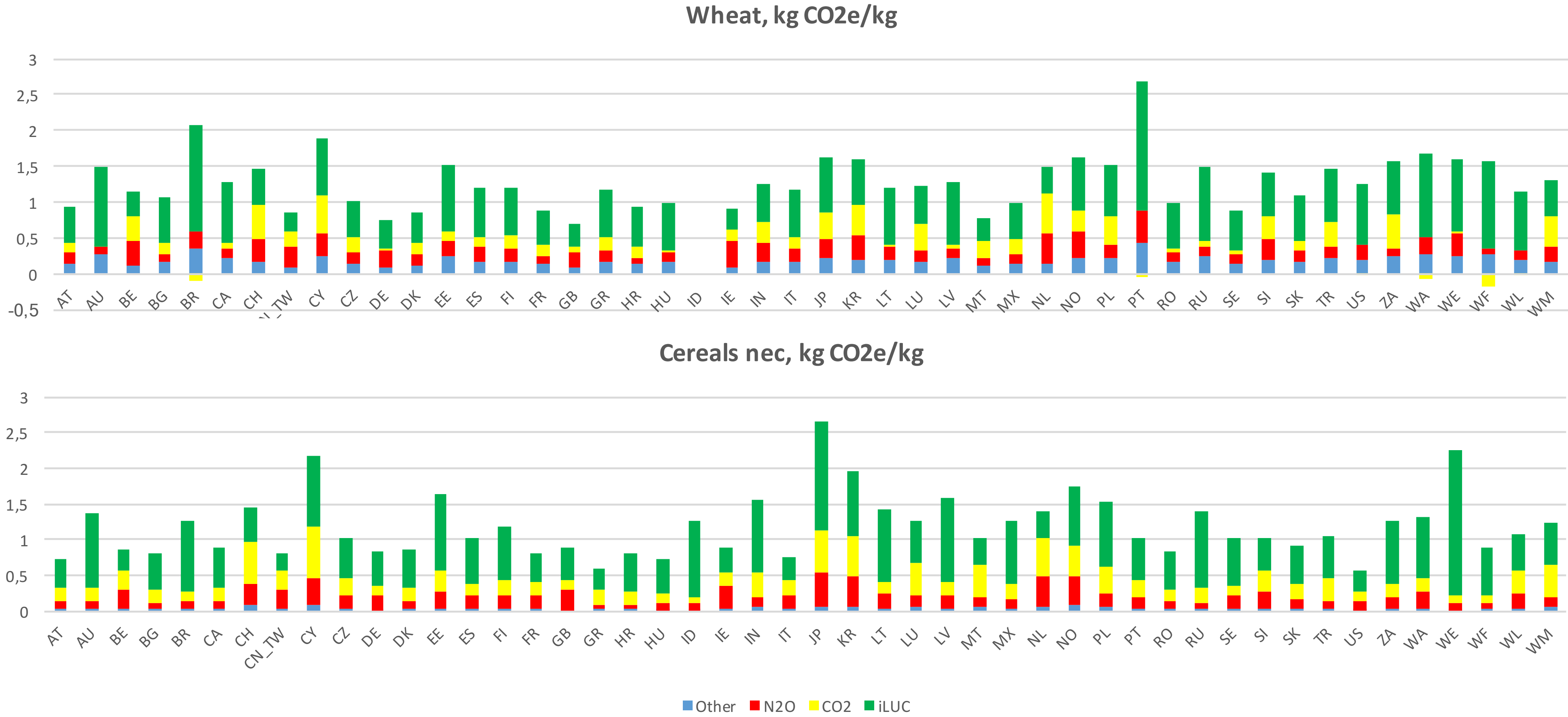
www.exiobase.eu

Examples of results (2/2)

- Cereals and iLUC

- Exiobase v3, hybrid version inclusive iLUC

Per kg dry matter



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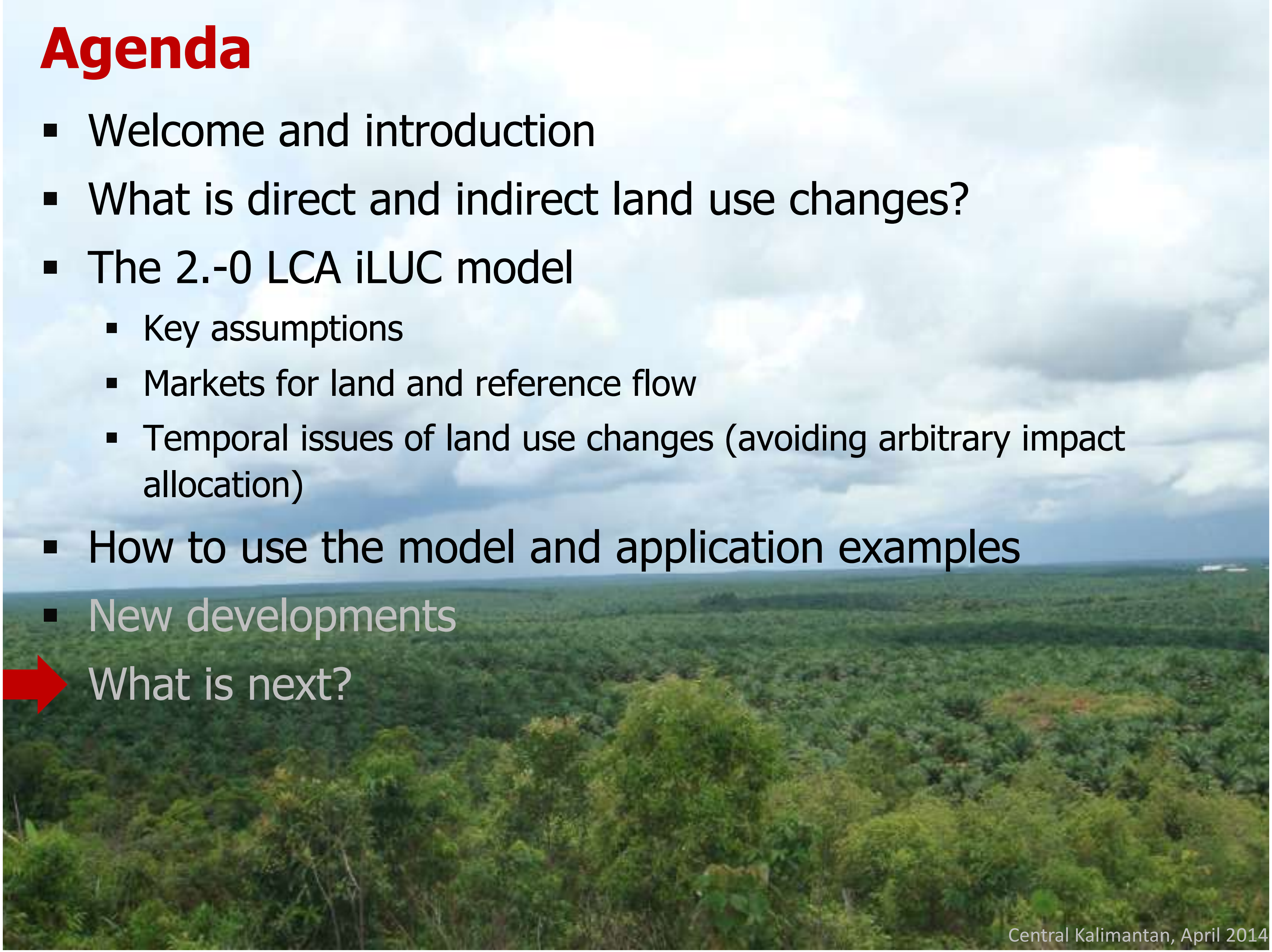

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What is next?

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

Field work, Central Kalimantan, April 2017

Field work, Central Kalimantan, April 2017

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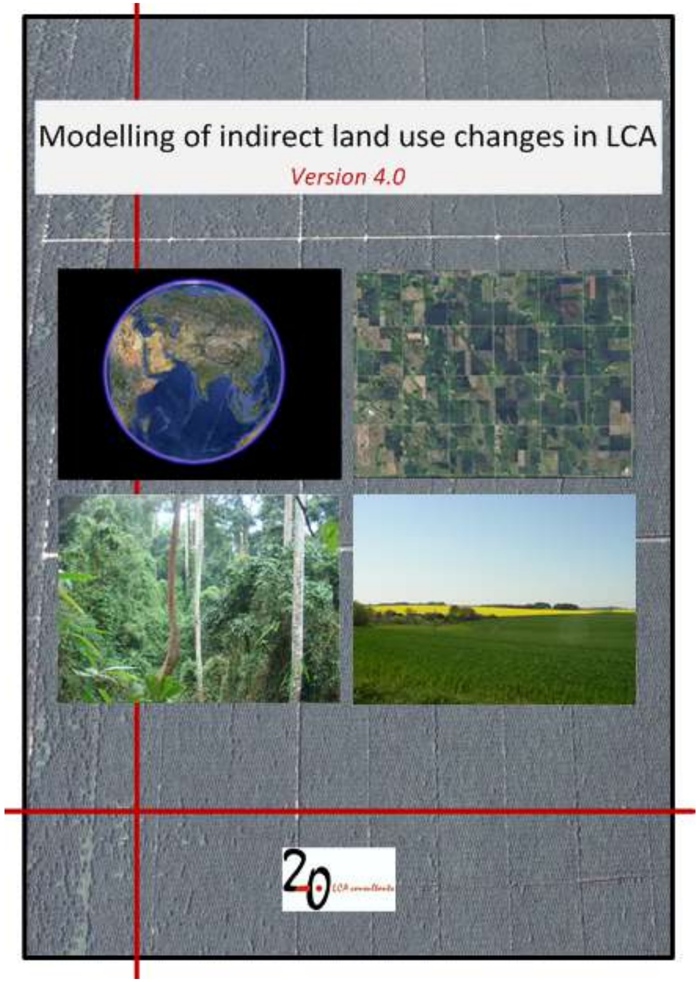
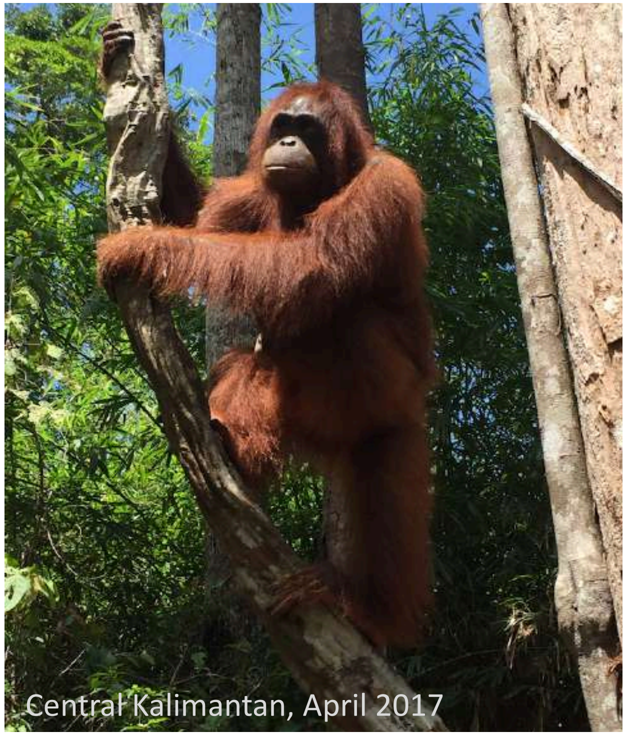


Thank you for your attention

Jannick Schmidt

Michele De Rosa

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



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