



Indirect land use changes (iLUC)

- Life cycle inventory of the markets for land tenure

Arable land	Intensive forest land	Extensive forest land	Grassland
A1: Cropland already in use No emissions	IF1: Intensive forest already in use No emissions	EF1: Extensive forest already in use No emissions	G1: Pasture already in use No emissions
A2: Transformation from secondary forest to arable land	IF2: Transformation from primary forest to intensive forest	EF2: Transformation from primary forest to extensive forest	G2: Transformation from grassland to pasture
A3: Transformation from grassland to arable land	IF3: Transformation from secondary forest to intensive forest	EF3: Transformation from secondary forest to extensive forest	G3: Intensification Change in IF/EF/land application
A4: Intensification Change in IF/EF/land application	IF4: Intensification Not included	EF4: Intensification Not included	G4: Intensification Change in IF/EF/land application
A5: Crop displacement Consumers give up the use of crops	IF5: Forest displacement Consumers give up the use of forest	EF5: Forest displacement Consumers give up the use of forest	G5: Forest displacement Consumers give up the use of forest
A: Land tenure market: arable land $\sum (a_i \cdot p_i)$ No iLUC	IF: Land tenure market: intensive forest land $\sum (i_i \cdot p_i)$ No iLUC	EF: Land tenure market: extensive forest land $\sum (e_i \cdot p_i)$ No iLUC	G: Land tenure market: grassland $\sum (g_i \cdot p_i)$ No iLUC
X: Land production NPPs (kg C ha ⁻¹ y ⁻¹)			

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Aalborg 5th September 2013

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Content

- Overview of the inventory
 - Inputs to land tenure markets
 - Inventory of land transformation activities
 - Inventory of intensification activities
 - Summary of inventory and implementation in LCA

Global land use in 2010



Land use category	Main categories Area in 2010, million ha yr	Sub-divided categories Area in 2010, million ha yr	Comment
Forests (a)	4,033	-	FAO (2010, annex 3, table 2)
Primary forests (non-use) (b)		1,102	FAO (2010, p 55)
Secondary forests (non-use) (c)		1,799	Calculated as (a)-(b)-(d)-(e). Includes non-productive planted forests
Extensive forests (in use) (d)		931	Production forests (FAO 2010, p 89) minus intensive forests (e)
Intensive forests (in use) (e)		201	FAO (2010, p 90-91), 76% of planted forests are productive
Other wooded land (f)	1,145	1,145	FAO (2010, annex 3, table 2)
Agricultural land (g)	4,884	-	FAOSTAT (2010) data for 2008
Arable incl. permanent crops (h)		1,527	FAOSTAT (2010) data for 2008
Permanent meadows and pastures (i)		3,357	FAOSTAT (2010) data for 2008
Build-up land (j)	925	925	Ramakutti et al. (2006, p 25): 2-3% (assumed 2.5%) of global land area (l)
Other land (other non-wooded land, barren, ice caps etc.) (k)	2,624	2,624	Calculated as (l)-(a)-(f)-(g)-(j)
Total (l)	13,011	13,011	FAO (2010, annex 3, table 2)

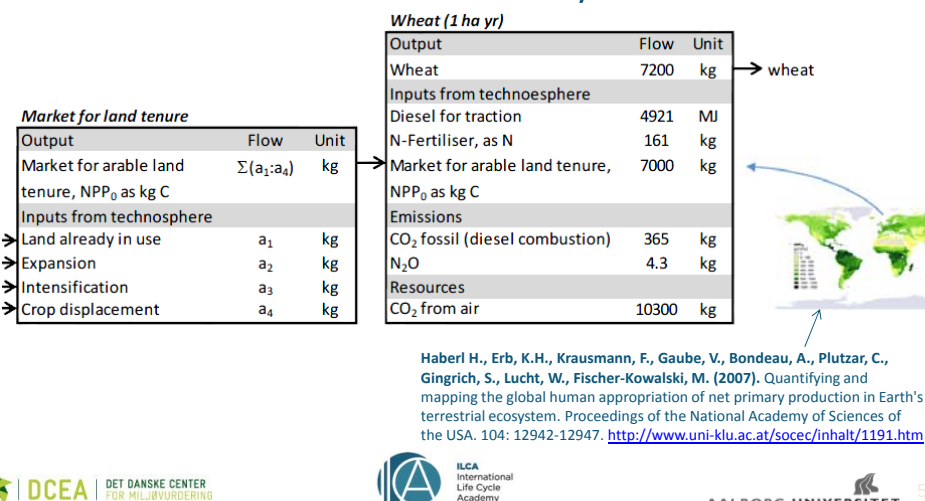
Inventory of iLUC

- Not very different from inventory in normal LCAs
- Just need to identify which processes to be inventoried
- Ecoinvent compliant

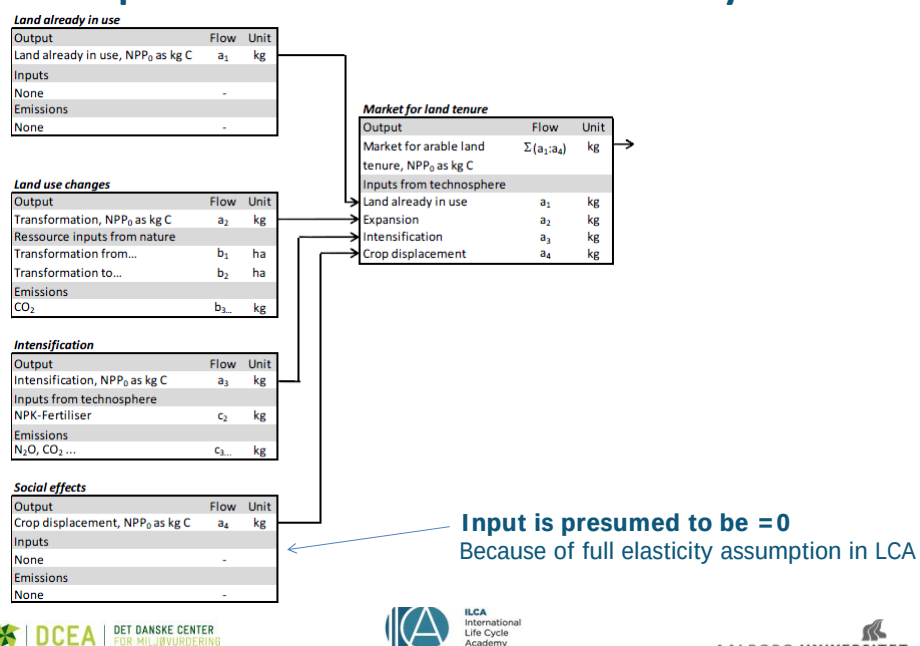


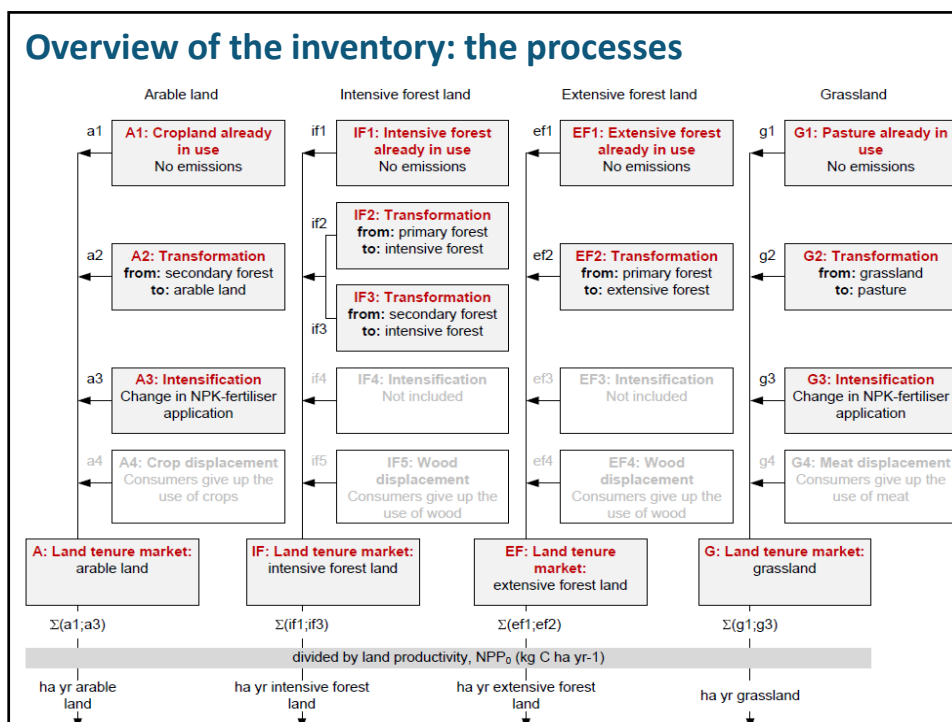
Land tenure as an LCA activity

- LCA activity with four principal inputs
- Mass balance of land tenure activity



The inputs to the land tenure LCA activity



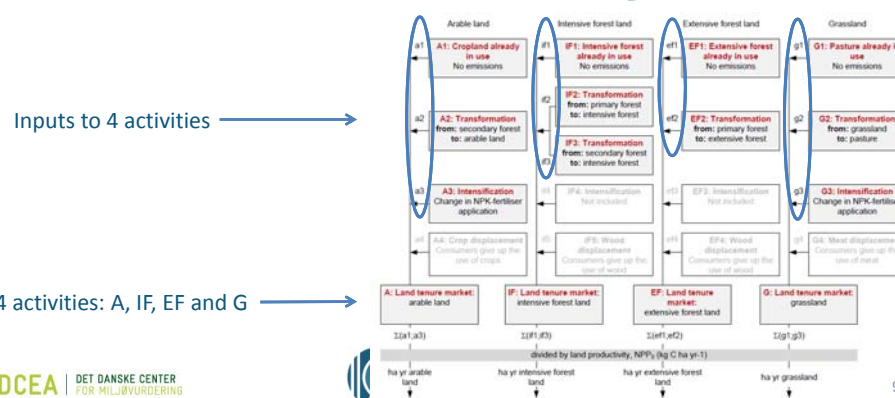


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Inputs to Market for Land tenure activities (1 of 8)

- 4 activities, each with inputs from
 - Land already in use (a_1 , if_1 , ef_1 and g_1)
 - Transformation (a_2 , $if_{2\&3}$, ef_2 and g_2)
 - Intensification (a_3 and g_3)
- next 7 slides



Inputs to Market for Land tenure activities (2 of 8)

- Inputs from **Land already in use** (a_1 , if_1 , ef_1 and g_1)

Table 2: Area and productivity of existing land in use and creation of new land. The productivity is based on Haberl et al. (2007a). Land not in use and build-up land (estimated) are also included to have a total area that adds up to the world's total land area.

Land use class	Existing land Area (million ha)	Existing land NPP ₀ (kg C ha ⁻¹)	Land tenure market	New land Area per year (million ha yr ⁻¹)	New land NPP ₀ (kg C ha ⁻¹)
Cropland	1,527	6,110	Arable land	13.0	6,940
Intensive forest	201	7,200	Intensive forestland	3.75	7,200
Extensive forest	931	7,200	Extensive forestland	3.86	7,200
Pasture	3,357	4,860	Grassland	4.59	4,860

Table 5: Inventory data for the four land tenure activities and their upstream inputs.

Flows	Arable land	Intensive forest land	Extensive forest land	Grassland
Output, NPP ₀ as million t C				
Land already in use	$a_1=9330$	$if_1=1447$	$ef_1=6703$	$g_1=16315$

Inputs to Market for Land tenure activities (3 of 8)

- Inputs from **Transformation** (a_2 , $if_{2\&3}$, ef_2 and g_2)
 - FAO (2010): 13 Mha yr^{-1} deforestation 2000-2010
 - of which 4.19 Mha yr^{-1} is primary forest
 - of which 8.81 Mha yr^{-1} is secondary forest
 - > Total deforestation (secondary to arable) => on arable land
 - > Step from primary to secondary => caused by forestry
 - 3.85 Mha yr^{-1} is extensive forest land
 - 0.38 Mha yr^{-1} is intensive forest land
 - > Transformation from secondary to intensive forest
 - Total annual planted productive forest: 3.75 Mha yr^{-1}
 - $3.75 - 0.38 = 3.37$ Mha yr^{-1} from secondary to intensive
 - > Transformation from grassland to pasture
 - FAOSTAT (2013), country level, all increase in pasture: 4.59 Mha

Inputs to Market for Land tenure activities (4 of 8)

- Inputs from **Transformation** (a_2 , $if_{2\&3}$, ef_2 and g_2)

Table 2: Area and productivity of existing land in use and creation of new land. The productivity is based on Haberl et al. (2007a). Land not in use and build-up land (estimated) are also included to have a total area that adds up to the world's total land area.

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Table 5: Inventory data for the four land tenure activities and their upstream inputs.

Flows	Arable land	Intensive forest land	Extensive forest land	Grassland
Output, NPP ₀ as million t C				
Transformation	$a_2=90.2$	$if_2=2.74$ $if_3=24.2$	$ef_2=27.8$	$g_2=22.3$

Inputs to Market for Land tenure activities (5 of 8)

- Inputs from **Intensification** (a_3 and g_3)
- Arable**: Proportion between expansion & intensification

Year	Production (Mn t DM)	Area (Mn ha)	Yield (t DS / ha yr)	Year	Crop from ΔY (Mn t DM)	Crop from ΔA (Mn t DM)	Total Δ crop (Mn t DM)
1997	2,991	1,188	2.52	1996 to 1997	42.8	4.0	46.9
1998	3,015	1,181	2.55	1997 to 1998	39.6	-15.9	23.7
1999	3,057	1,182	2.59	1998 to 1999	40.1	2.0	42.1
2000	3,054	1,183	2.58	1999 to 2000	-5.9	3.2	-2.7
2001	3,116	1,186	2.63	2000 to 2001	55.8	6.2	62.1
2002	3,093	1,179	2.62	2001 to 2002	-5.4	-17.8	-23.2
2003	3,186	1,208	2.64	2002 to 2003	18.3	75.7	94.0
2004	3,401	1,229	2.77	2003 to 2004	157.6	60.2	217.8
2005	3,419	1,251	2.73	2004 to 2005	-42.5	59.5	17.1
2006	3,446	1,243	2.77	2005 to 2006	49.7	-23.0	26.8
2007	3,614	1,262	2.86	2006 to 2007	115.3	53.8	169.1
2008	3,836	1,289	2.98	2007 to 2008	144.2	81.7	225.9
2009	3,802	1,278	2.98	2008 to 2009	0.1	-34.3	-34.2
2010	3,851	1,290	2.98	2009 to 2010	10.2	38.3	48.4
2011	4,038	1,304	3.10	2010 to 2011	146.5	42.9	189.3
FAOSTAT (2013)				1961 to 2009	1956	650	2606
DM% all crops: various ref					75%	25%	100%
				2000 to 2010	503	300	804
					63%	37%	100%



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Inputs to Market for Land tenure activities (6 of 8)

- Inputs from **Intensification** (a_3 and g_3)
- Pasture**: Proportion between expansion & intensification
 - pasture area increase:
 - FAOSTAT country level
 - => annual % increase area = 1.4%
 - pasture yield change:
 - FAOSTAT stock (head) density
 - => increase in no of heads from int.
 - => annual % increase yield = 11.5%
 - => Proportion: area 11% and yield 89%

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Inputs to Market for Land tenure activities (7 of 8)

- Inputs from **Intensification** (a_3 and g_3)
- Proportion between expansion & intensification

$$> \text{expansion } [NPP_0] \times (\text{proportion}_{\text{yield}} / \text{proportion}_{\text{exp}})$$

$$= \text{intensification } [NPP_0]$$

2 previous slides

Table 5: Inventory data for the four land tenure activities and their upstream inputs.

Flows	Arable land	Intensive forest land	Extensive forest land	Grassland
Output, NPP_0 as million t C				
Transformation	$a_2=90.2$	$if_2=2.74$ $if_3=24.2$	$ef_2=27.8$	$g_2=22.3$

Table 5: Inventory data for the four land tenure activities and their upstream inputs.

Flows	Arable land	Intensive forest land	Extensive forest land	Grassland
Output, NPP_0 as million t C				
Intensification	$a_3=151$			$g_3=188$



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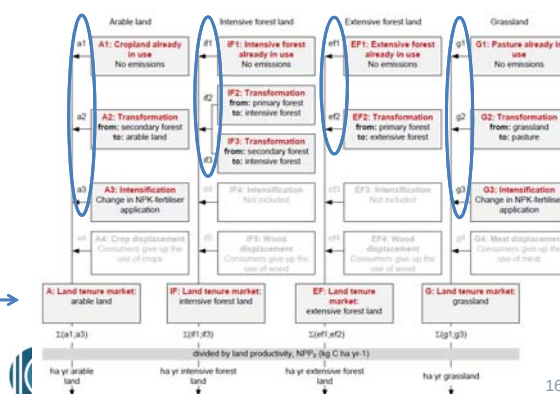
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Inputs to Market for Land tenure activities (8 of 8)

- 4 activities, each with inputs from
 - Land already in use (a_1 , if_1 , ef_1 and g_1)
 - Transformation (a_2 , $if_{2\&3}$, ef_2 and g_2)
 - Intensification (a_3 and g_3)

DONE!

4 activities: A, IF, EF and G



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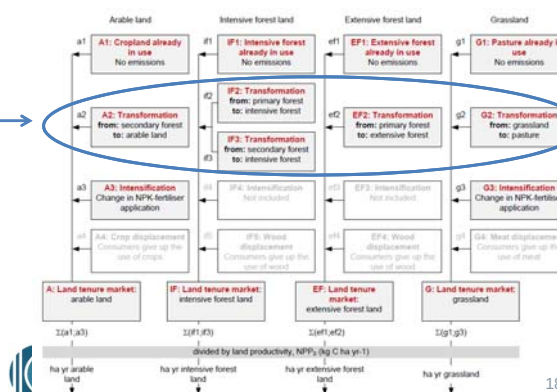
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Inventory of transformation activities (1 of 6)

- 5 activities
 - Transformation (A_2 , $IF_{2\&3}$, EF_2 and G_2) } next 5 slides

5 activities: A_2 , $IF_{2\&3}$, EF_2 and G_2 →



Inventory of transformation activities (2 of 6)

- Where does deforestation take place? (1000 ha)

Country	Net deforestation 2000-2010	Share of world	Share of world, accumulated
Brazil	-26,421	26%	26%
Australia	-5,620	5.5%	31%
Indonesia	-4,977	4.9%	36%
Nigeria	-4,096	4.0%	40%
United Republic of Tanzania	-4,034	3.9%	44%
Zimbabwe	-3,270	3.2%	47%
Democratic Republic of the Congo	-3,114	3.0%	50%
Myanmar	-3,095	3.0%	53%
Bolivia (Plurinational State of)	-2,895	2.8%	56%
Venezuela (Bolivarian Republic of)	-2,876	2.8%	59%
Argentina	-2,461	2.4%	61%
Cameroon	-2,200	2.1%	63%
Mozambique	-2,166	2.1%	66%
Ecuador	-1,976	1.9%	68%
Mexico	-1,949	1.9%	69%
Paraguay	-1,786	1.7%	71%
Zambia	-1,666	1.6%	73%
Cambodia	-1,452	1.4%	74%
Ethiopia	-1,409	1.4%	76%
Papua New Guinea	-1,407	1.4%	77%
Democratic People's Republic of Korea	-1,267	1.3%	78%

FAO (2010), Global Forest Resource Assessment 2010

- >80% takes place in tropical regions
- emissions are modelled as all deforestation was tropical



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Inventory of transformation activities (3 of 6)

- Where does deforestation of primary forests take place? (1000 ha)

Country	Deforestation, primary forest 2000-2010	Share of world	Share of world, accumulated
Brazil	-25,353	55%	55%
Papua New Guinea	-3,324	7.2%	62%
Gabon	-3,300	7.1%	69%
Indonesia	-2,034	4.4%	73%
Peru	-2,010	4.3%	78%
Bolivia (Plurinational State of)	-1,882	4.1%	82%
Russian Federation	-1,649	3.6%	85%
Republic of Korea	-1,320	2.8%	88%
Mexico	-1,159	2.5%	91%
Central African Republic	-765	1.7%	92%
Nigeria	-736	1.6%	94%
Guatemala	-472	1.0%	95%
Malawi	-396	0.85%	96%
Mongolia	-387	0.84%	97%
Madagascar	-178	0.38%	97%
Democratic People's Republic of Korea	-174	0.38%	97%
Colombia	-142	0.31%	98%
Suriname	-136	0.29%	98%
Cambodia	-134	0.29%	98%

Inventory of transformation activities (4 of 6)

- CO₂ emissions from deforestation based on carbon stocks
- $1 \text{ kg C} \times (44/12) \text{ kg CO}_2/\text{kg C} = 3.67 \text{ kg CO}_2$

Table 3: Carbon stocks in land use categories used in the iLUC model. Carbon stocks are based on IPCC (2006, chapter 4, 5 and 6): forests represent tropical regions, extensive and secondary forests are represented by an average of primary forest and intensive forests, and grassland represents average of tropical and sub-tropical scrubland/steppe. Unit: t C/ha.

Land use type	Above ground carbon	Below ground carbon
Land in use		
Cropland	6.3	64.7 (61% of initial land = secondary forest)
Intensive forest	70.5	26.1
Extensive forest	106	39.1
Pasture	4.09	11.8 (100% of initial land = grassland)
Land not in use		
Primary forest	141	52.2
Secondary forest	106	39.1
Grassland	25.2	11.8

Inventory of transformation activities (5 of 6)

- CO₂ emissions from deforestation

Table 5: Inventory data for the four land tenure activities and their upstream inputs.

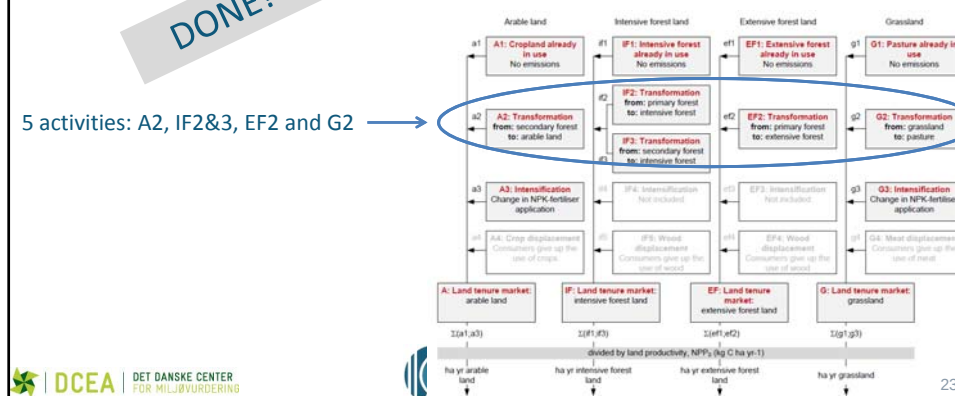
Flows	Arable land	Intensive forest land	Extensive forest land	Grassland
Output, NPP₀ as million t C				
Land already in use	a1=9330	if1=1447	ef1=6703	g1=16315
Transformation	a2=90.2	if2=2.74 if3=24.2	ef2=27.8	g2=22.3
Intensification	a3=151			g3=188
Land use change, million ha				
From primary forest		0.38	3.86	
From secondary forest	13.0	3.37		
From grassland				4.59
To cropland	13.0			
To intensive forest		3.75		
To extensive forest			3.86	
To pasture				4.59
Emissions related to transformation, million t				
CO ₂ (accelerated)	3,534	733	681	355
CO ₂ -eq. (time dependent GWP100)	26.9	5.59	5.19	2.71

Inventory of transformation activities (6 of 6)

- 5 activities
 - Transformation (A_2 , $IF_{2\&3}$, EF_2 and G_2)

DONE!

5 activities: A_2 , $IF_{2\&3}$, EF_2 and G_2 →



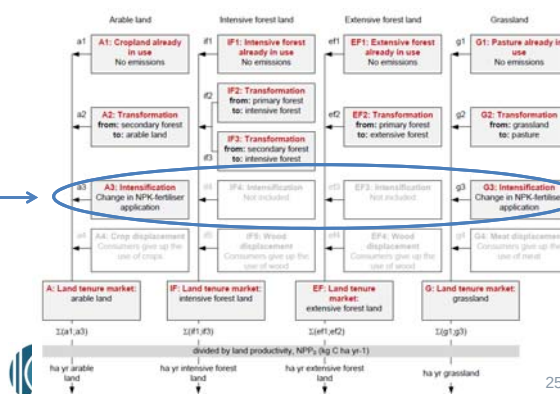
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Inventory of intensification activities (1 of 8)

- 2 activities
 - Intensification (A_3 and G_3) } next 6 slides
- Includes:
 - emissions
 - inputs of fertiliser

2 activities: A_3 and G_3



Inventory of intensification activities (2 of 8)

- Intensification of arable land: Which crops and where?

Table 4: Calculated average annual increase in crop production from intensification for the world (million tonne DM) based on 2000-2010. For each crop the relative contribution to yield increase by the most significant country is specified.

Crop	Production (million t dm)	Share	Most significant country
Maize	13.0	25%	USA (36%)
Rice, paddy	7.49	14%	India (20%)
Wheat	6.59	13%	China (27%)
Sugar cane	4.50	9%	Brazil (62%)
Oil palm fruit	2.04	4%	Malaysia (87%)
Cassava	1.82	3%	Thailand (18%)
Seed cotton	1.54	3%	India (51%)
Sugar beet	1.53	3%	Russia (25%)
Rapeseed	1.41	3%	Canada (22%)
Barley	1.31	2%	Russia (23%)
Other crops	16.8	21%	-
Total	58.0	100%	

- Intensification of pasture: Where?
 - Brazil accounts for 32% of pasture intensification 2000-2010

How to measure kg dm crops in terms of NPP₀? (3 of 8)

In order to convert the reference flow of the intensification activities to NPP₀ measured in kg C, a carbon content of biomass at ~50% (IPCC 2006, table 4.3), and a ratio of NPP₀ relative to harvested C (NPP_h minus residues not removed, i.e. 30% of NPP_h) at 2.95 is used (Harberl et al. 2007, table 2). The field emissions related to N-application are modelled based on IPCC

$$\begin{aligned} &\text{Intensification at 151 million t C (NPP}_0\text{)} \\ &= 151 \times 1/0.5 \times 1/2.95 = \underline{102 \text{ million t dm crops}} \end{aligned}$$

Inventory of intensification activities (4 of 8)

- Intensification: How?
 - More fertiliser
 - Pest management (pesticides, "natural" pest control, GMO)
 - Water management (irrigation, draining, GMO for drought resistance)
 - Plant material improvement
 - Cultivation practise (timing, soil preparation)

Assumed that

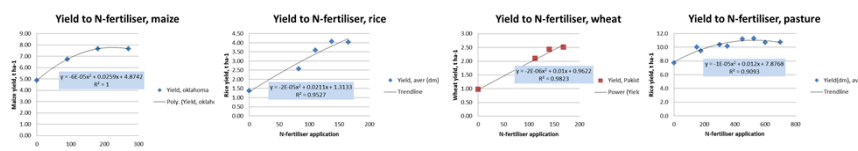
- fertiliser = endogenous (demand driven)
- other = exogenous (not demand driven – driven by technological development)

Inventory of intensification activities (5 of 8)

- How much yield from additional fertiliser?

- Fertiliser-yield dose-response relationships

(Units: yield as kg dm and N-fertiliser as kg N)



$$y_{maize}(N) = -0.000060N^2 + 0.0259N + 4.87$$

$$y_{rice}(N) = -0.000020N^2 + 0.0211N + 1.31$$

$$y_{wheat}(N) = -0.000020N^2 + 0.0100N + 0.962$$

$$y_{pasture}(N) = -0.000010N^2 + 0.0120N + 7.88$$

- Fertiliser level in relevant countries: IFA (2013) + manure fertiliser (inventory in creea.eu)

Inventory of intensification activities (6 of 8)

- Emissions from fertiliser? IPCC (2006, chapter 11)

Input parameters	Description	Unit	Maize, USA	Rice, India	Wheat, China	Pasture, GLO
area	Cultivated area in country with crop	ha	1	1	1	1
yield_act	Yield (kg actual weight/ha yr)	kg / ha yr	1	1	1	1
DM	Dry matter content of actual weight (0-1)	dimensionless	100%	100%	100%	100%
NFert	N-fertiliser: Synthetic fertiliser, as kg N/ha yr	kg N / ha yr	0.197	0.059	0.108	0.085
F_ON	Amount of animal manure, compost, sewage sludge and oth. kg N/ha yr	kg N / ha yr	0	0	0	0
F_SOM	Annual amount of N in mineral soils that is mineralised, in association with crop	kg N / ha yr	0	0	0	0
F_OS	Share of area of managed/drainage organic soils	%	0.0%	0.0%	0.0%	0.0%
F_PRP	Annual amount of urine and dung N deposited by grazing animals or kg N / ha yr	kg N / ha yr	0	0	0	0
slope	Crop specific constant to calculate AG_DM. Data are obtained from 1 dimensionless	dimensionless	1.03	0.95	1.51	0.3
intercept	Crop specific constant to calculate AG_DM. Data are obtained from 1 dimensionless	dimensionless	0.61	2.46	0.52	0
N_AG	N content of above ground residues for crop, kg N (kg dm)-1. Data of kg N / kg dm	kg N / kg dm	0.066	0.007	0.006	0.015
Frac_Remove	Fraction of above ground residues of crop removed annually for pur kg N / kg crop-N	kg N / kg crop-N	0	0	0	0
Frac_GASF	Fraction of synthetic fertiliser N that volatilises as NH3 and NOx, kg kg N volatilised / kg of N applied	kg kg N volatilised / kg of N applied	0.1	0.1	0.1	0.1
Frac_GASF	Fraction of applied organic N fertiliser materials (FON) and of urine kg N volatilised / kg of N applied or deposited	kg N volatilised / kg of N applied or deposited	0.2	0.2	0.2	0.2
Frac_LEACH	Fraction of all N added to/mineralised in managed soils in regions v. kg N / kg of N additions	kg N / kg of N additions	0.3	0.3	0.3	0.3
R_BGBO	Ratio of below-ground residues to harvested yield for crop, kg dm (kg dm / kg dm)	kg dm / kg dm	0.22	0.16	0.24	0.8
N_BG	N content of below ground residues for crop, kg N (kg dm)-1. Data of kg N / kg dm	kg N / kg dm	0.007	0	0.009	0.012
EF1	kg N2O-N (kg N input)-1, emission factor for N2O emissions from N kg N2O-N / kg N input	kg N2O-N / kg N input	0.01	0.01	0.01	0.01
EF2	kg N2O-N (kg N input)-1, emission factor for N2O emissions from drainage kg N2O-N / ha yr	kg N2O-N / ha yr	8	16	8	8
EF3	kg N2O-N (kg N input)-1, emission factor for N2O emissions from urine kg N2O-N / kg N input	kg N2O-N / kg N input	0.02	0.02	0.02	0.02
EF4	emission factor for N2O emissions from atmospheric deposition of 1 kg N-N2O / (kg NH3-N + NOx-N)	kg N-N2O / (kg NH3-N + NOx-N)	0.01	0.01	0.01	0.01
EF5	emission factor for N2O emissions from N leaching and runoff, kg N: kg N2O-N / kg N leached and runoff	kg N: kg N2O-N / kg N leached and runoff	0.0075	0.0075	0.0075	0.0075
EF	Annual emission factors (EF) for cultivated organic soils (IPCC 2006, 1 kg C/ha yr)	1 kg C/ha yr	5000	20000	5000	5000
Protein_content	(not IPCC parameter), Protein content (raw protein) of harvested crop kg protein / kg DM crop	kg protein / kg DM crop	0.09	0.097	0.113	0.2
N_content_prot	(not IPCC parameter), N content in raw protein (European Commission kg N / kg protein)	kg N / kg protein	0.16	0.16	0.16	0.16

Inventory of intensification activities (7 of 8)

• Emissions from fertiliser? N-balances

N-BALANCE			Maize, USA	Rice, India	Wheat, China	Pasture, GLO
Inputs						
Synthetic fertiliser	F_SN	kg N ha ⁻¹ yr ⁻¹	0.196850394	0.058616647	0.107851596	0.085324232
Organic fertiliser and manure	F_ON	kg N ha ⁻¹ yr ⁻¹	0	0	0	0
Urine and dung N deposited by grazing animals	F_PRP	kg N ha ⁻¹ yr ⁻¹	0	0	0	0
Crop residues returned to soils	F_CR	kg N ha ⁻¹ yr ⁻¹	0.004737382	0.016359	0.006407232	0
N in mineral soils that is mineralised	F_SOM	kg N ha ⁻¹ yr ⁻¹	0	0	0	0
Total inputs		kg N ha⁻¹ yr⁻¹	0.201587776	0.074975647	0.114258828	0.085324232
Outputs						
Harvested crop	crop * N_content	kg N ha ⁻¹ yr ⁻¹	0.0144	0.01552	0.0184	0.032
Crop residues removed from soils	calculated from F_CR	kg N ha ⁻¹ yr ⁻¹	0	0	0	0
N2O _N _direct	described under calculation of emissions	kg N ha ⁻¹ yr ⁻¹	0.002015878	0.000749756	0.001142588	0.000853242
N2O _N _indirect	described under calculation of emissions	kg N ha ⁻¹ yr ⁻¹	0.000650423	0.000227312	0.000364934	0.000277304
NO _x -N	described under calculation of emissions	kg N ha ⁻¹ yr ⁻¹	0.000318158	0.000118331	0.00018032	0.000134864
NH ₃ -N	described under calculation of emissions	kg N ha ⁻¹ yr ⁻¹	0.019368881	0.005743334	0.010604829	0.008397759
NO ₃ -N	described under calculation of emissions	kg N ha ⁻¹ yr ⁻¹	0.060476333	0.022452694	0.034277648	0.02559727
N ₂ -N	N ₂ -N = inputs minus calculated outputs	kg N ha ⁻¹ yr ⁻¹	0.104360103	0.03012422	0.049288498	0.018063993
Total outputs		kg N ha⁻¹ yr⁻¹	0.201587776	0.074975647	0.114258828	0.085324232
Inputs minus outputs			0	0	0	0

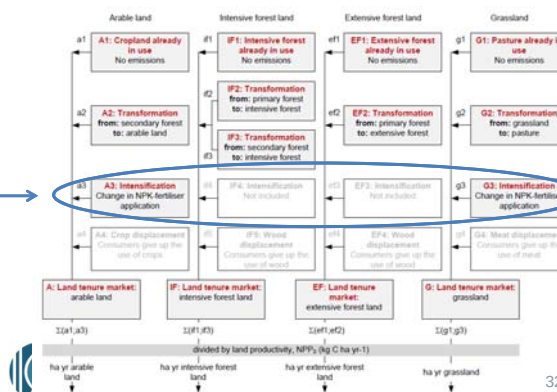
Inventory of intensification activities (8 of 8)

• 2 activities

– Intensification (A₃ and G₃) } next 6 slides

DONE!

2 activities: A3 and G3



Content

- Overview of the inventory
- Inputs to land tenure markets
- Inventory of land transformation activities
- Inventory of intensification activities
- ➔ Summary of inventory and implementation in LCA

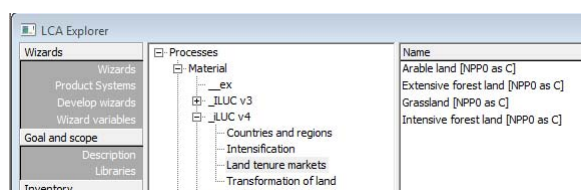
Inventory: Summary

Table 5: Inventory data for the four land tenure activities and their upstream inputs.

Flows	Arable land	Intensive forest land	Extensive forest land	Grassland
Output, NPP₀ as million t C				
Land already in use	a1=9330	if1=1447	ef1=6703	g1=16315
Transformation	a2=90.2	if2=2.74 if3=24.2	ef2=27.8	g2=22.3
Intensification	a3=151			g3=188
Land use change, million ha				
From primary forest		0.38	3.86	
From secondary forest	13.0	3.37		
From grassland				4.59
To cropland	13.0			
To intensive forest		3.75		
To extensive forest			3.86	
To pasture				4.59
Flows related to intensification, million t				
Fertiliser: Ammonia, as N	2.55			3.84
Fertiliser: Urea, as N	10.5			2.41
Fertiliser: Ammonium nitrate, as N	1.90			5.00
Fertiliser: Calcium ammonium nitrate, as N	0.00619			0.115
Fertiliser: Ammonium sulphate, as N	0.0605			0.210
Emission to air: Ammonia	1.79			1.38
Emission to air: Dinitrogen monoxide	0.329			0.241
Emission to air: Nitrogen oxides	0.0824			0.0600
Emission to water: Nitrate	21.1			15.4
Emissions related to transformation, million t				
CO ₂ (accelerated)	3,534	733	681	355
CO ₂ -eq. (time dependent GWP100)	26.9	5.59	5.19	2.71

Inventory: How to build in LCA software

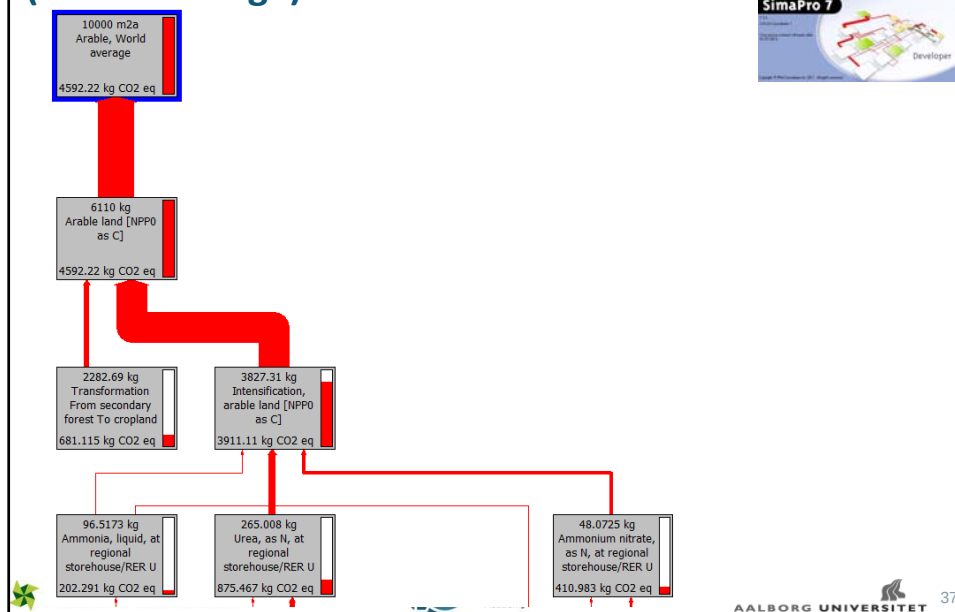
- Land tenure market activities
- Transformation activities
- Intensification activities
- User friendly country database



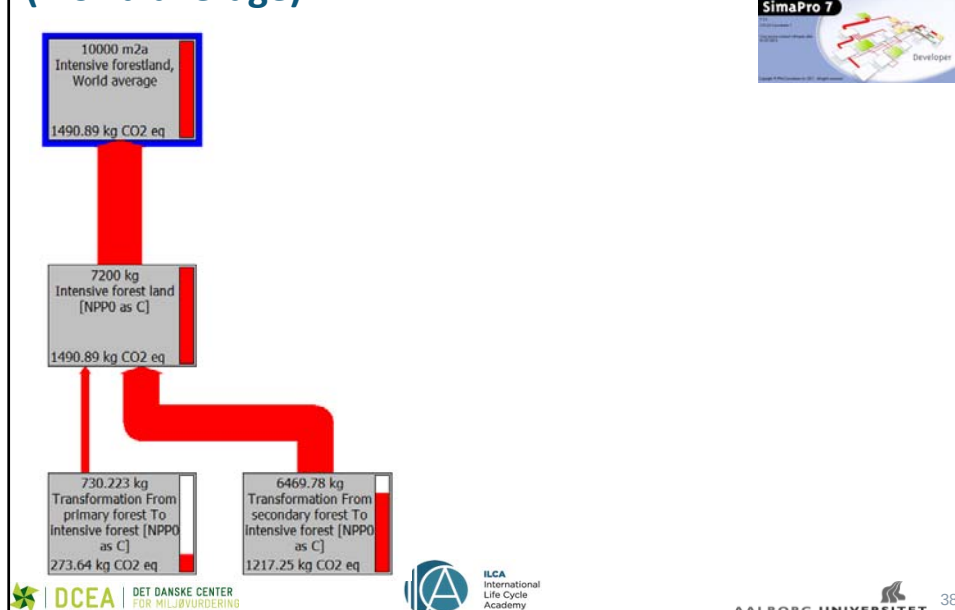
Contribution analysis



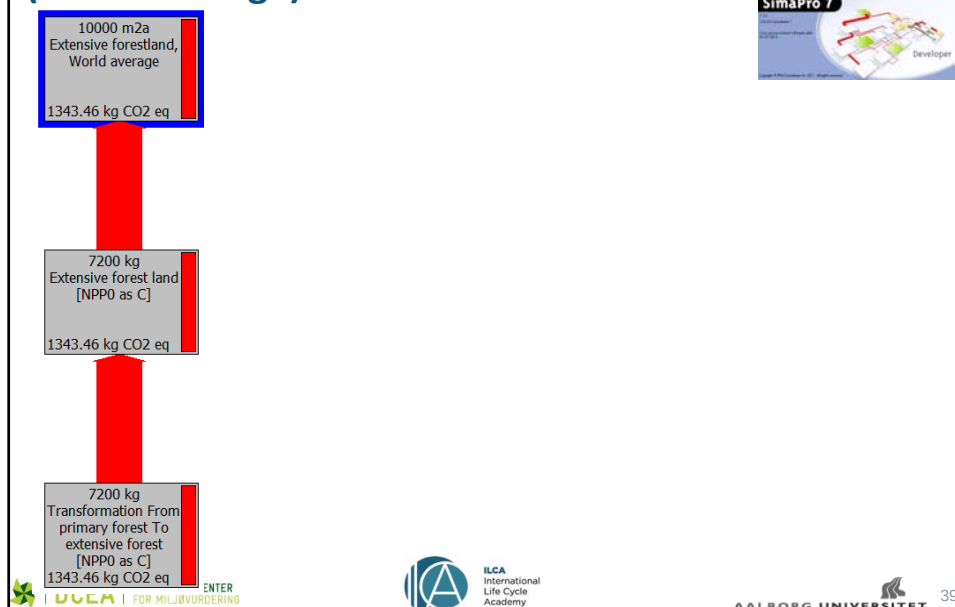
Market for land tenure: 1 ha yr arable land (world average)



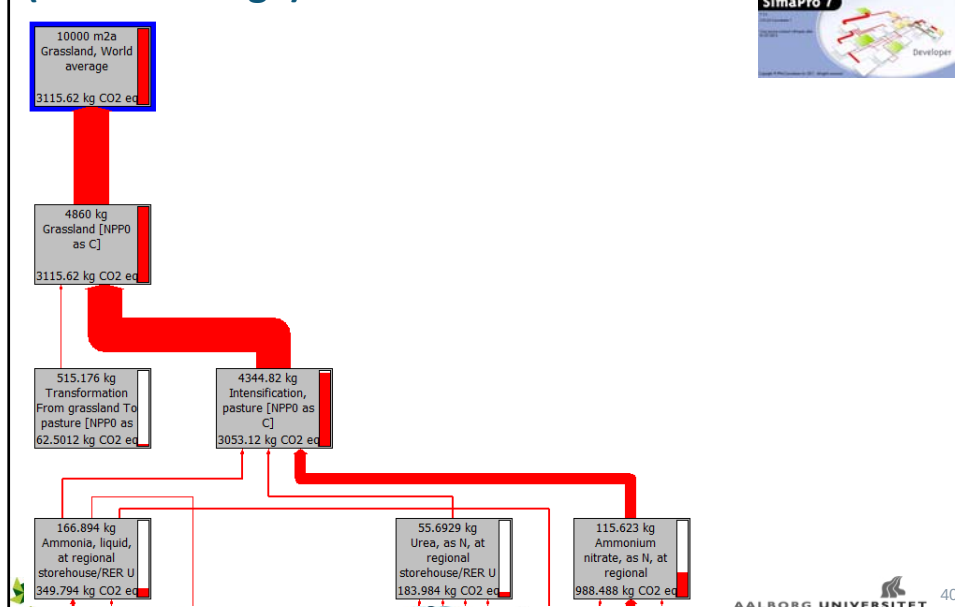
Market for land tenure: 1 ha yr intensive forest land (world average)



Market for land tenure: 1 ha yr extensive forest land (world average)

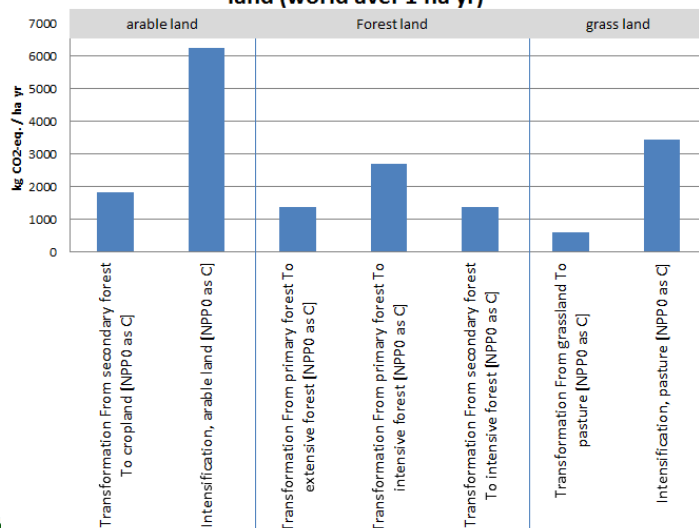


Market for land tenure: 1 ha yr grass land (world average)



Different sources of land: 1 ha yr (world average)

GHG-emissions from different sources of productive land (world aver 1 ha yr)



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