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CO_2 and N_2O emissions from palm oil plantations: impacts of land use and LUC

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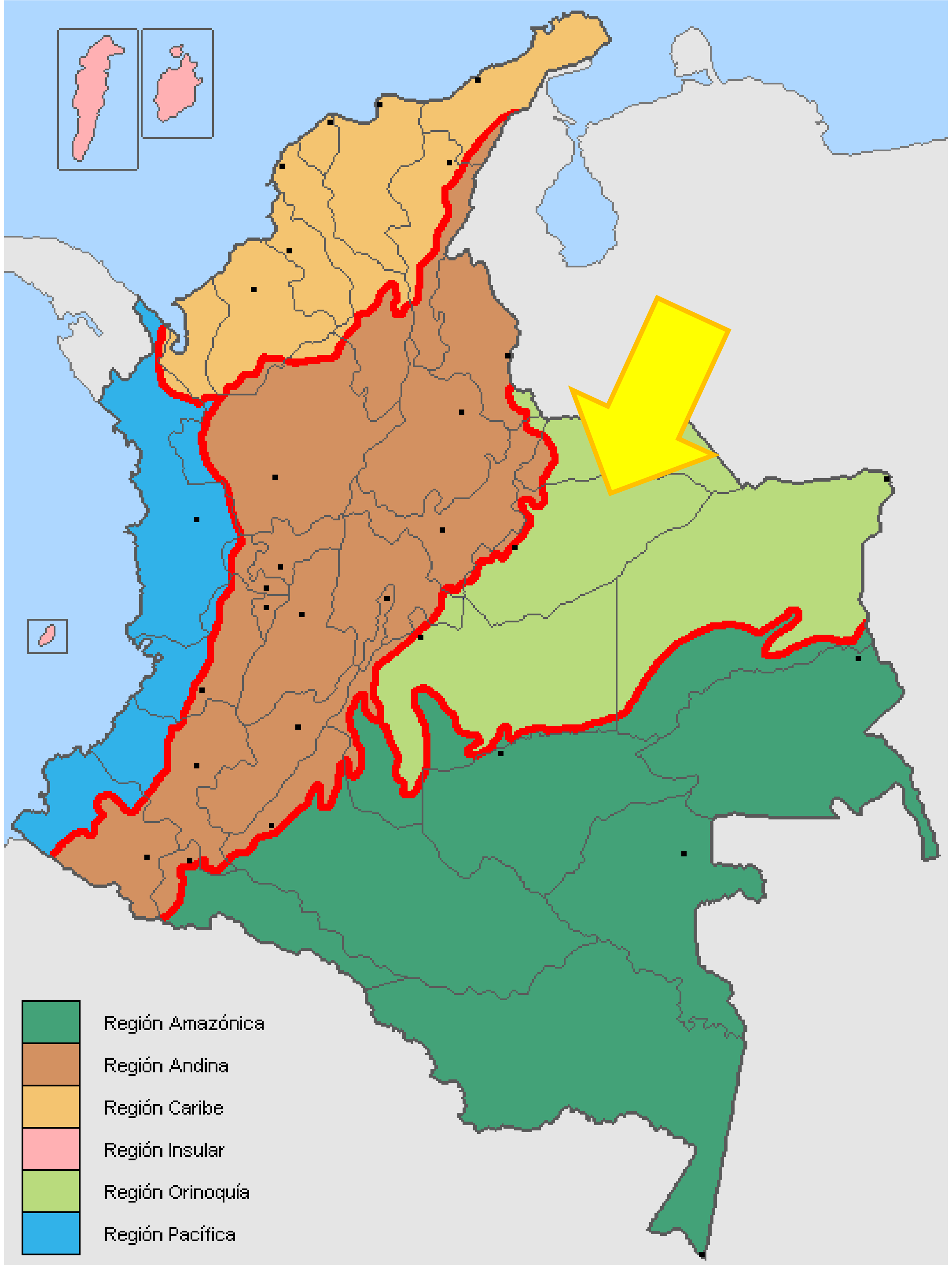
Motivation and Goal

- The calculation of GHG emissions related with land use and LUC has been a focus of controversy.
- LC GHG studies for palm oil, most of the research is for Malaysia and Indonesia (Wicke *et al*., 2008; Reijnders and Huijbregts, 2008; Schmidt, 2010).
- The production in Latin American countries has been treated rarely and does not include emissions from LUC.

Main goal: To evaluate the CO_2 and N_2O emissions of Colombian palm oil plantations for different LUC scenarios and various types of N-fertilizer production.

Palm oil plantation in Colombia

A palm oil plantation LC model has been implemented based on data collected for a specific plantation in the Orinoquía Region of Colombia



Life Cycle Inventory and Modelling

Inputs, per kg FFB	
Fertilizer, as N	0.007 kg
Fertilizer, as P_2O_5	0.003 kg
Fertilizer, as K_2O	0.013 kg
Diesel	0.003 kg
Gasoline	0.1 g

Yield = 19 tonnes of fresh fruit bunches (FFB) per hectare and year.

Direct CO_2 emissions due to conversion of the previous land use

Land use change

Direct CO_2 and N_2O emissions from fertiliser application and fossil energy use

Fertilizers

Diesel

Gasoline

Palm oil planting and fresh fruit bunches (FFB) harvesting

1 kg FFB

Indirect CO_2 and N_2O emissions from the production of fertilisers and fossil fuels

Indirect LUC emissions - not included

Scenarios definition

Scenario		
	Reference Land use	
L1	**Tropical forest**	***Tropical rain forest***
L2		***Amazon***
L3		***Colombian primary forest***
L4		***Forest plantations***
L5	**Grassland, including savannahs**	***Savannahs***
L6		
L7		***Improved grassland***
L8		
L9		***Moderately degraded grassland***
L10		***Severely degraded grassland***

Above ground living biomass obtained from

EC Decision defaults
Colombian Amazon
A model statistics by vegetation class for Colombia
EC Decision defaults

The Orinocos plains in Colombia
A model statistics by vegetation class for Colombia

Medium input, where no additional management inputs have been used
High input, where one or more additional management inputs/improvements have been used

Scenario	Synthetic N-fertilizer scenarios				
	Type	N-content	Emission factor, per kg fertilizer (as N)		Source
			kg CO_2	kg N_2O	
AS	Ammonium sulphate	21%	2.64	0.00003	Davis and Haglund (1999)[a]
AN1	Ammonium nitrate	35%	2.89	0.0189	
AN2			2.78	0.0140	Davis and Haglund (1999)[b]
AN3		33.5%	2.74	0.0145	Kramer et al. (1999)
AN4			1.90	0.0153	Elsayed et al. (2003)
AN5			1.49	0.0176	Kuesters and Jenssen (1998)
CAN1	Calcium ammonium nitrate	26.5%	3.00	0.0189	Davis and Haglund (1999)[a]
CAN2			2.98	0.0152	Davis and Haglund (1999)[b]
CAN3		27.9%	2.64	0.0138	Kramer et al. (1999)
CAN4		27.6%	3.24	0.0173	Davis and Haglund (1999)[c]
CAN5		27.2%	3.19	0.0211	
U1	Urea	46%	3.16	4.13×10^{-5}	Davis and Haglund (1999)[a]
U2			3.92	1.35×10^{-5}	Davis and Haglund (1999)[b]
UAN1	Urea ammonium nitrate	32%	2.94	0.0095	Davis and Haglund (1999)[a]
UAN2			1.34	0.0078	Kuesters and Jenssen (1998)
UAN3			3.41	0.0076	Davis and Haglund (1999)[b]
	Organic N-fertilizer scenario				
	Type	**N-content**	**Emission factor, per kg of poultry**		**Source**
			kg CO_2	**kg N_2O**	
P	Poultry manure, dried	4.6%[d]	0.1	2.2×10^{-6}	Nemecek and Kägi (2007)

CO_2 emissions from LUC

Land use change - affects the carbon stocks in biomass, in dead organic matter and in soil:

Tier 1 - IPCC guidelines (2006) and Commission Decision of 10 June 2010

Carbon stock change due to LUC = $Cs_{reference\ LU} - Cs_{actual\ LU} - e_B$

$$CS_i = SOC + C_{VEG}$$

$$C_{VEG} = C_{BM} + C_{DOM}$$

SOC **- Soil organic carbon:**

$$SOC = SOC_{ST} \times F_{LU} \times F_{MG} \times F_I$$

C_{DOM} **- Carbon stock in dead organic matter:**

$$C_{DOM} = C_{DW} + C_{LI}$$

C_{BM} ***- Above and below ground vegetation carbon stock in living biomass:***

$$C_{BM} = C_{AGB} + C_{BGB} = (B_{AGB} \times CF_B) + (B_{AGB} \times CF_B) \times R$$

Factors reflecting the difference in SOC compared to the SOC_{ST} use

Reference land use, R (Scenarios)		Land use F_{LU}	Management F_{MG}	Input F_I
Forest land	L1	Native forest (1)	n/a	n/a
	L2	Native forest (1)	n/a	n/a
	L3	Native forest (1)	n/a	n/a
	L4	Managed forest (1)	All (1)	All (1)
Grassland, including savannahs	L5	Savannah (1)	Nominally managed (1)	Medium (1)
	L6	Savannah (1)	Nominally managed (1)	Medium (1)
	L7	Savannah (1)	Improved (1.17)	Medium (1)
	L8	Savannah (1)	Improved (1.17)	High (1.11)
	L9	Savannah (1)	Moderately degraded (0.97)	Medium (1)
	L10	Savannah (1)	Severely degraded (0.7)	Medium (1)
Actual land use, A		**Land use F_{LU}**	**Management F_{MG}**	**Input F_I**
Oil palm plantation		Perennial crop (1)	Reduced tillage (1.15)	Medium (1)

Carbon stock calculations - values for AGB, BGB and DOM

<table>
<tr><th colspan="2" rowspan="2">Reference land use, R (Scenarios)</th><th>B_{AGB}</th><th>R</th><th>C_{DW}</th><th>C_{LI}</th><th>C_{VEG}</th></tr>
<tr><th>tonnes d.m. ha^{-1}</th><th>tonnes root d.m. tonne shoot d.m.$^{-1}$</th><th colspan="3">tonnes C ha^{-1}</th></tr>
<tr><td rowspan="4">Forest land</td><td>L1</td><td>-</td><td>-</td><td>-</td><td>-</td><td>198[a]</td></tr>
<tr><td>L2</td><td>291</td><td>0.24</td><td>0</td><td>2.1</td><td>139.1[b]</td></tr>
<tr><td>L3</td><td>264</td><td>0.20</td><td>0</td><td>2.1</td><td>126.4[b]</td></tr>
<tr><td>L4</td><td>-</td><td>-</td><td>-</td><td>-</td><td>79[a]</td></tr>
<tr><td rowspan="3">Grassland, including savannahs</td><td>L5</td><td>37</td><td>0</td><td>0</td><td>0</td><td>17.4[b]</td></tr>
<tr><td>L6</td><td>21</td><td>0</td><td>0</td><td>0</td><td>9.9[b]</td></tr>
<tr><td>L7, L8, L9, L10</td><td>-</td><td>-</td><td>-</td><td>-</td><td>8.1[a]</td></tr>
<tr><th colspan="2">Actual land use, A</th><th>B_{AGB}</th><th>R</th><th>C_{DW}</th><th>C_{LI}</th><th>C_{VEG}</th></tr>
<tr><td colspan="2">Oil palm plantation</td><td>-</td><td>-</td><td>-</td><td>-</td><td>60[a]</td></tr>
</table>

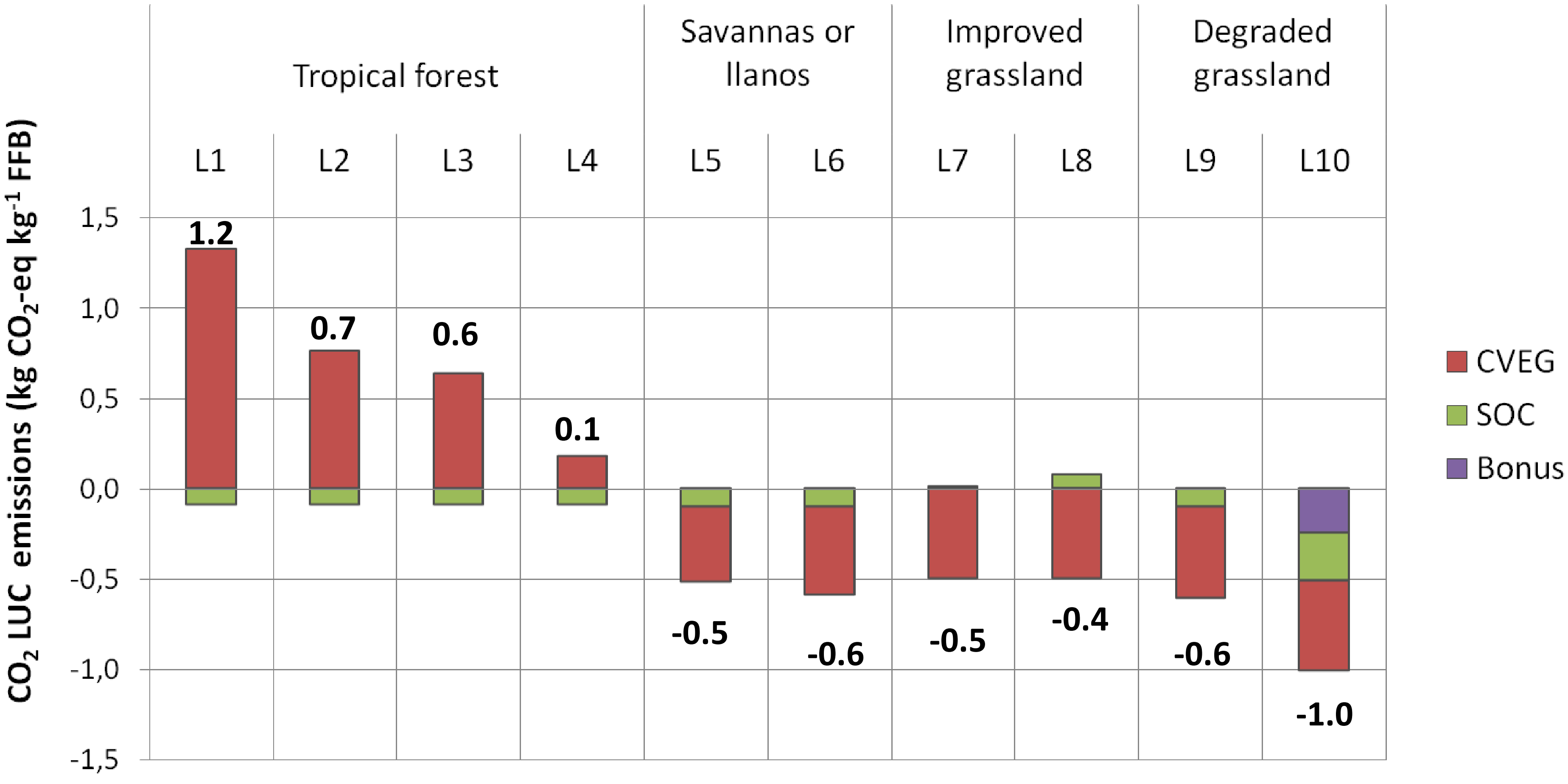
Calculating CO_2 and N_2O emissions

- CO_2 emissions from **fossil fuels production and used** have been calculated based on IPCC Guidelines (2006) and Jungbluth (2007).
- CO_2 and N_2O emissions from **N-fertiliser production** are calculated using different emission factors depending on the type and N-content of fertilizer (scenarios).
- The emission factors for **diammonium phosphate production** are given by Davis & Haglund (1999) and for **potassium chloride production** by Kongshaug (1998) and Aktiengesellschaft (2001).
- The direct and indirect N_2O emissions that result from **N-fertiliser application** are calculated based on the IPCC Guidelines (Tier 1) and Nemecek and Kägi (2007)
- For **urea application**, an emission factor of 1.57 kg of CO_2 kg^{-1} urea-N has been assumed.

Results and discussion

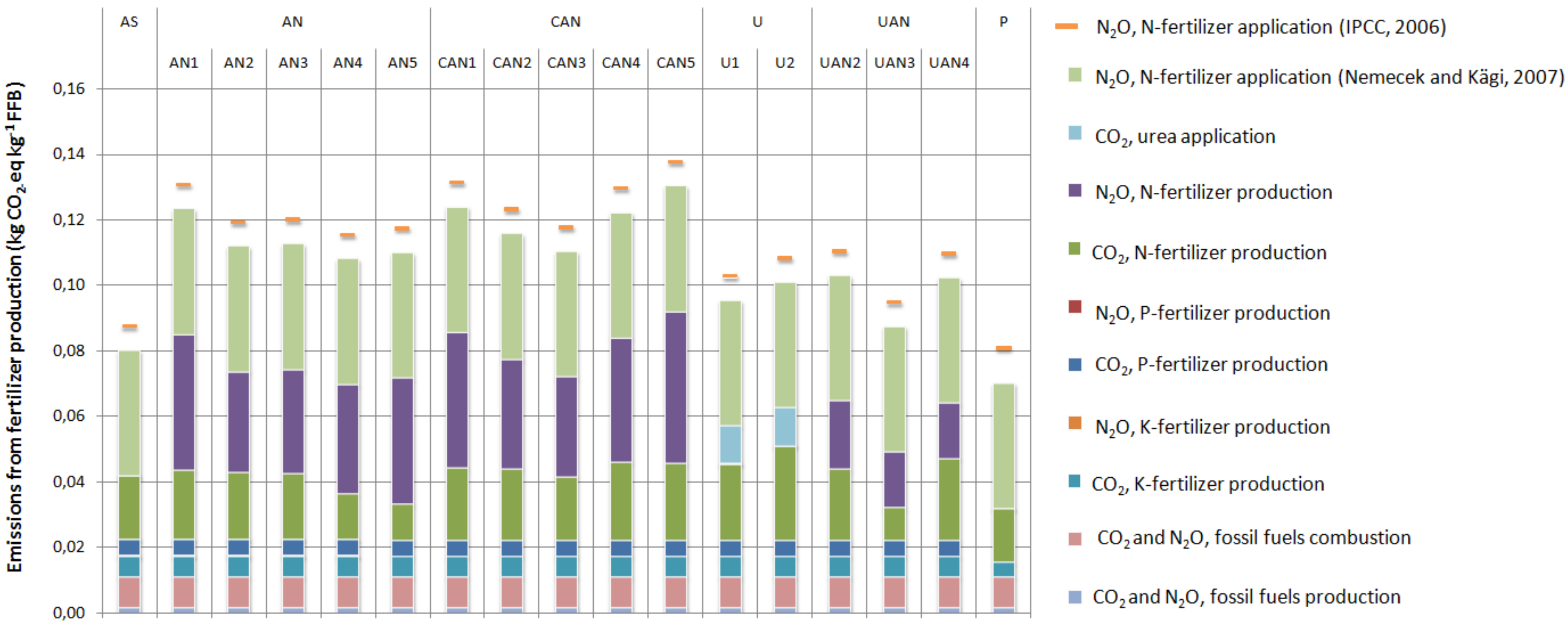
CO_2 emissions due to the LUC

Partial contribution of carbon stock changes



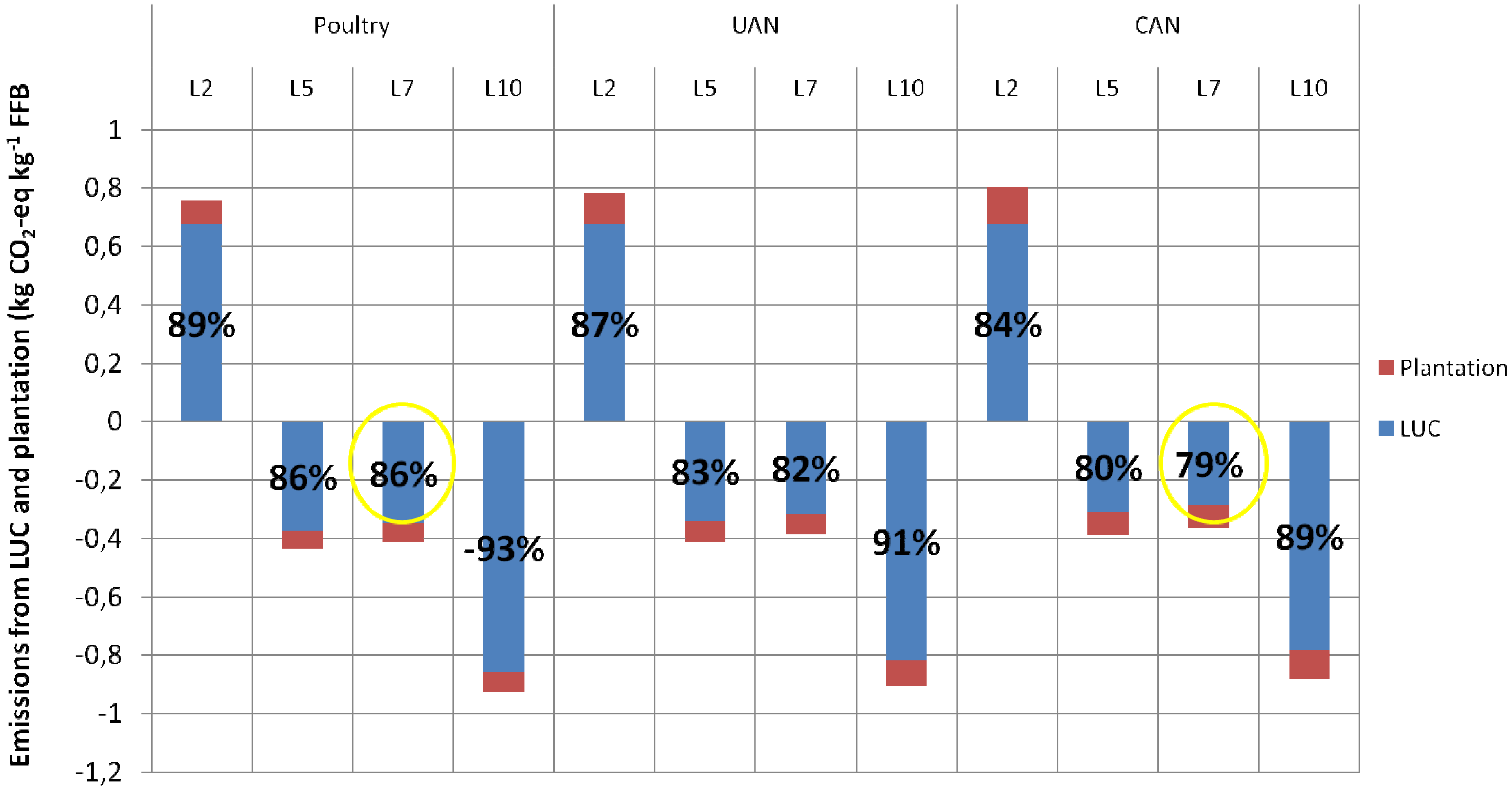
Results and discussion

Palm oil plantation CO_2 and N_2O emissions



Results and discussion

Contribution of LUC and palm oil plantation



Conclusions

- The original land use is a critical issue and large variations can be observed between the various LUC scenarios.
- To assure the sustainability of palm oil plantations, degraded land should be preferably used for palm oil cultivation, followed by savannas or *llanos*.
- Emissions due to the LUC dominate the total CO_2-eq emissions in the scenarios where tropical forest is converted.
- Fertilizer production and application emissions represent more than 70% of the overall emissions when the LUC emissions are not considered.
- The lowest emissions occur in the scenarios where poultry manure and AS are used as N-fertilizer.

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- •PTDC/TRA/72996/2006 Biofuel systems for transportation in Portugal: A "well-to-wheels" integrated multi-objective assessment

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