Implications of biodiesel-induced land-use changes for CO_2 emissions

Case studies in tropical America, Africa and Southeast Asia.

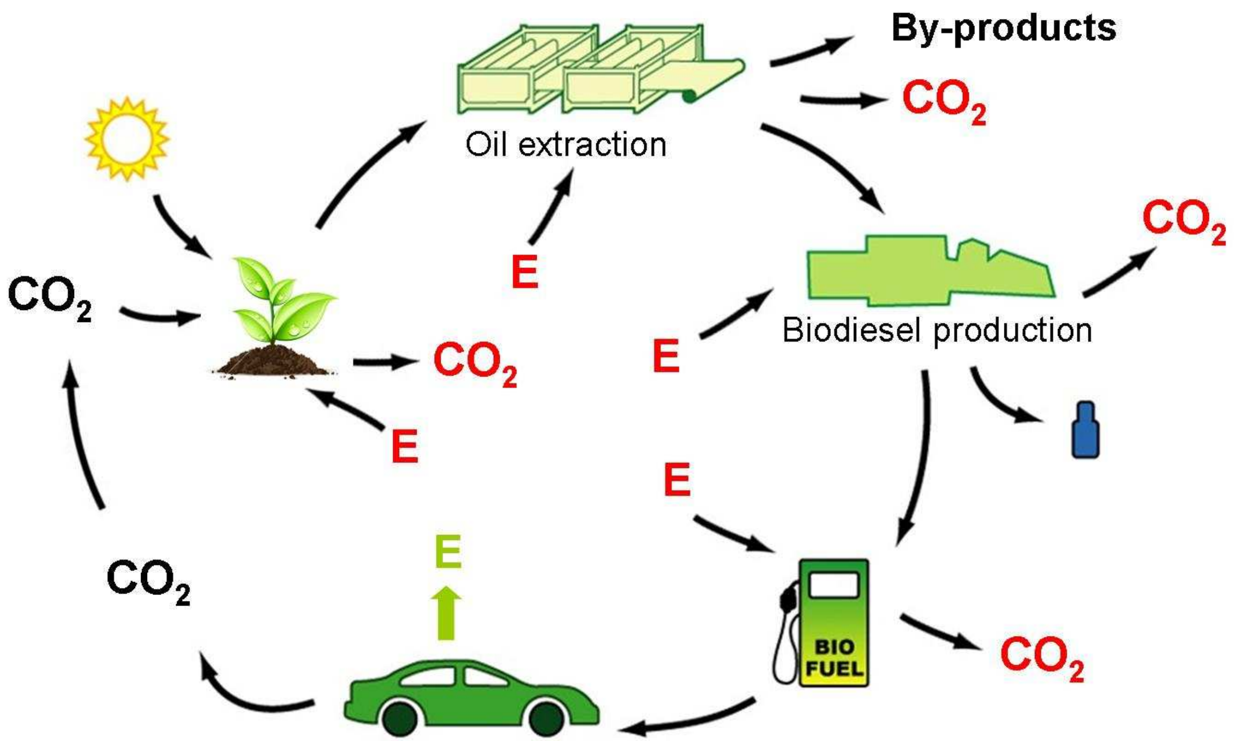
Achten W.M.J. & Verchot L.

Introduction

- Are biofuel environmentally sustanable?

→ Life cycle assessments (LCA)



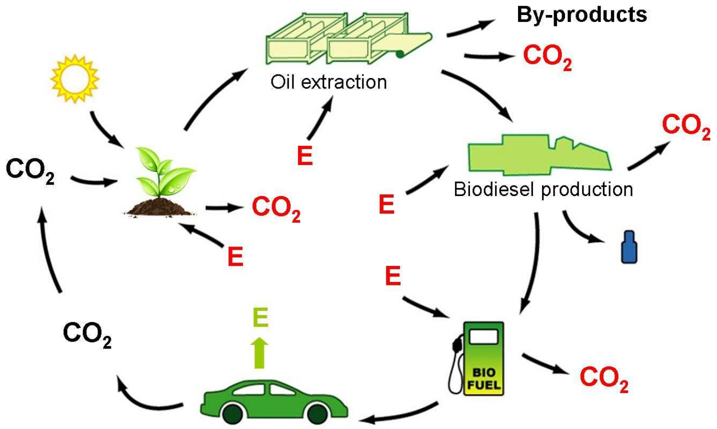
Introduction

- Are biofuel environmentally sustanable?

→ Life cycle assessments (LCA)

Reduction in CO_2-eq

- Oil palm: 38-79.5%
- Jatropha: 49 to 72%
- Soybean: 57 to 74%

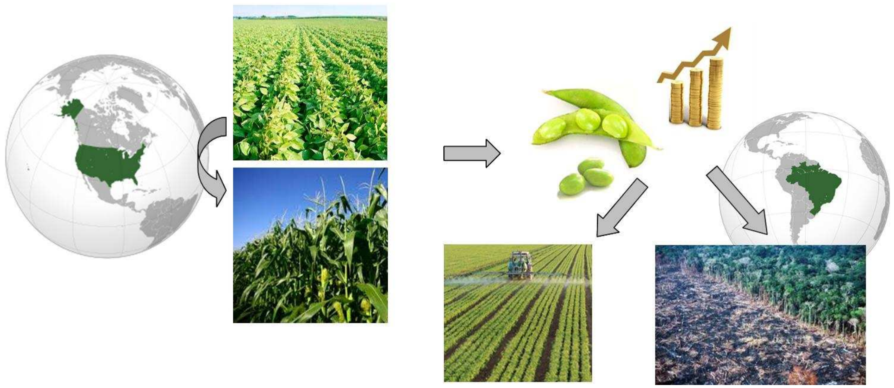


Introduction

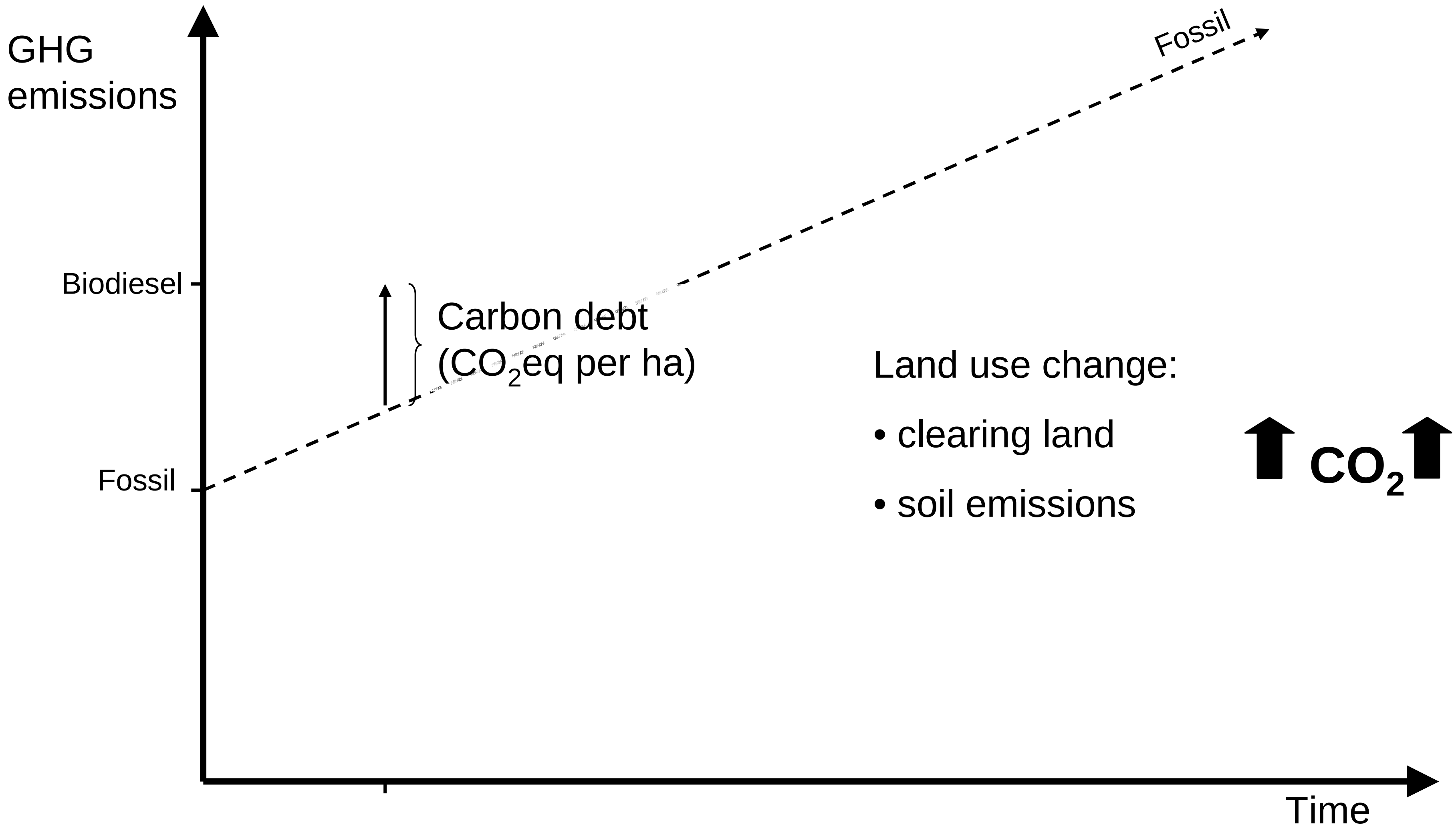
- Are biofuel environmentally sustanable?

→ Life cycle assessments (LCA)

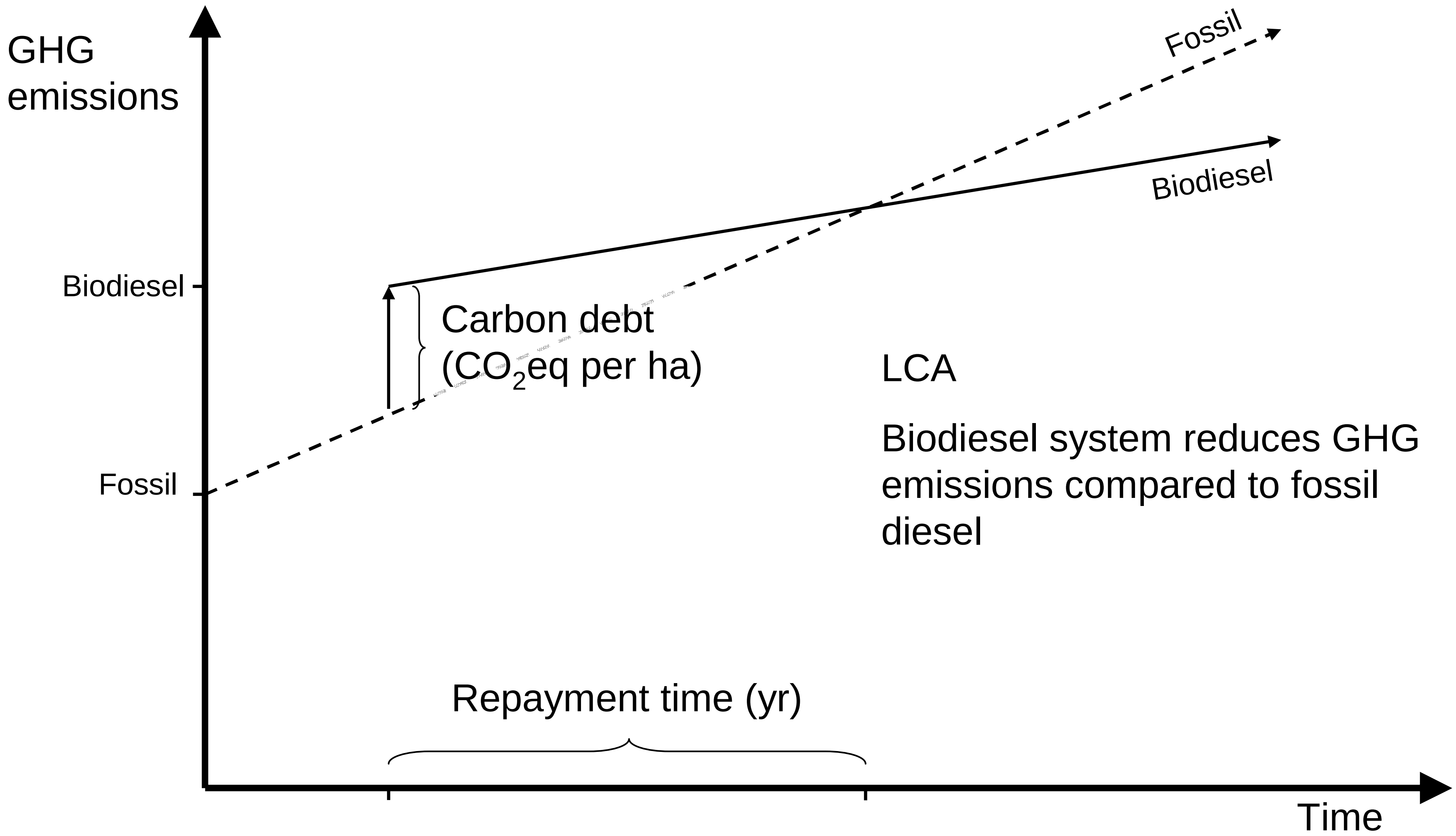
- LCAs often do not include land use change



Carbon debt & Repayment time

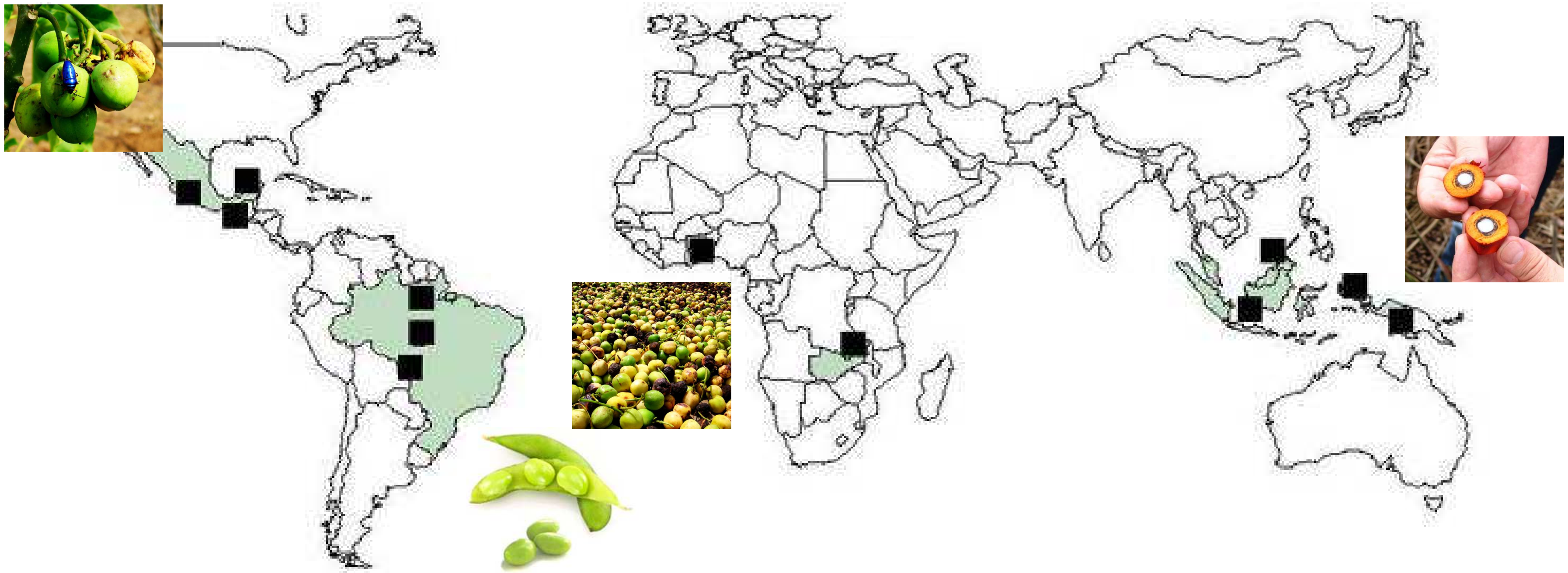


Carbon debt & Repayment time



Material and Method

- 3 feedstocks
- 6 countries
- 12 cases

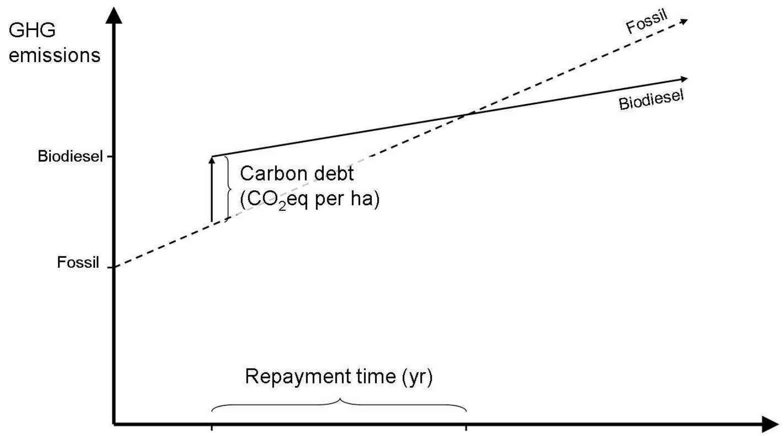


Achten and Verchot (submitted)

Material and Method

- Land use change
- Carbon debt (CD) [kg C ha^{-1}]
  - Loss of biomass carbon
  - Loss of soil carbon
- Allocation to biodiesel (A) [%]
- CO_2 emission reduction rate (CO_2RR) [kg C ha^{-1} yr^{-1}]
- Repayment time (RT) [yr]

$$RT = \frac{CD * A}{CO_2RR}$$



Fargione *et al.* (2008) *Science*

M&M: Land use change

- Direct land use change (dLUC)
  - Observed: Household surveys, remote sensing
  - Estimated: stakeholder interviews

- Indirect land use change (iLUC)
  - Observed: Household surveys
  - Estimated: Scenario's (based on Fritsche et al. 2010)
    - 25% of 'used' land in dLUC
    - 50% of 'used' land in dLUC
    - 75% of 'used' land in dLUC

Oil Palm	dLUC	Type of conversion	iLUC	Type of conversion
Beluran District, Sandakan Division, Malaysia	100%	Lowland tropical rainforest	0%	
Prafi,Manokwari, Indonesia	84%	Lowland tropical secondary rainforest	0%	
	16%	Agricultural land	N.A.	Lowland tropical secondary rainforest*
Kubu Raya, West Kalimantan, Indonesia	84%	Tropical peatland forest	0%	
	4%	Swamp		
[illegible]	[illegible]	[illegible]	[illegible]	
	25%	Fallow land†	N.A.	Secondary forest*
	50%	Permanent cropland (annuals)	N.A.	Secondary forest*
Chiapas, Mexico	5%	Secondary forest	0%	
	29%	Pasture	N.A.	Secondary forest*
	66%	Agricultural land (annual cropping)	N.A.	Secondary forest*
Chinsali & Mungwi, Zambia	24%	Mature miombo woodland	0%	
	61%	Permanent cropland (annuals)	34%	Miombo woodland
			19%	Fallow land†
	15%	Fallow land†	0%	
Soybean				
Sorriso, Brazil	50%	Cerrado forest	0%	
	50%	Pasture	N.A.	Cerrado forest
Guarantã do Norte & Alta Floresta, Brazil	100%	Degraded pasture	N.A.	Cerrado forest*
Santarém, Brazil	92%	Permanent cropland	N.A.	Amazon rainforest*
	8%	Amazon rainforest	0%	

N.A.: not assessed
* $iLUC_{Max}$=75%; $iLUC_{Medium}$=50%; $iLUC_{Low}$=25%; † fallow: 8-11 years old

Chinsali & Mungwi, Zambia	24%	Mature miombo woodland	0%	
	61%	Permanent cropland (annuals)	34%	Miombo woodland
			19%	Fallow land†
	15%	Fallow land†	0%	

Achten and Verchot (submitted)

M&M: Carbon debt

- Aboveground biomass carbon loss from former land use:
  - Measured (1 case)
  - Literature review (region specific)
- Belowground biomass carbon loss from former land use
  - Root/Shoot ratios: literature
- Soil carbon loss
  - IPCC tier 1

Carbon debt

Oil Palm	dLUC	Type of conversion	iLUC	Type of conversion
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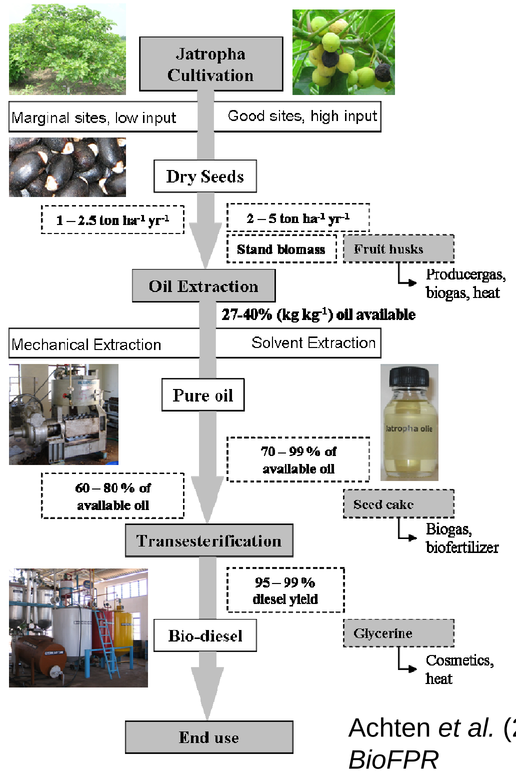
	16%	Agricultural land	N.A.	Lowland tropical secondary rainforest*
Kubu Raya, West Kalimantan, Indonesia	84%	Tropical peatland forest	0%	
	4%	Swamp		
	12%	Agricultural land	N.A.	Tropical peatland forest*
Boven Digoel District, Papua, Indonesia	98%	Lowland tropical primary rainforest	0%	
	2%	Agricultural land	N.A.	Lowland tropical primary rainforest*

	dLUC ha^{-1}		iLUC ha^{-1}			Total ha^{-1}	
Case study	**Mg C**	**Mg CO_2**		**Mg C**	**Mg CO_2**	**Mg C**	**Mg CO_2**
Oil Palm							
Beluran District, Malaysia	190.2	698.8		0.0	0.0	190.2	698.8
Prafi,Manokwari, Indonesia	69.0	253.6	**25%**	2.4	12.4	72.4	226.0
			50%	6.7	24.8	75.7	278.4
			75%	10.1	37.1	79.1	290.7
Kubu Raya, West Kalimantan, Indonesia	429.6	1578.9	**25%**	14.9	54.9	444.6	1633.8
			50%	29.9	109.8	459.5	1688.7
			75%	44.8	164.7	474.5	1743.7
Boven Digoel District, Papua, Indonesia	182.2	669.5	**25%**	0.7	2.7	182.9	672.2
			50%	1.5	5.3	183.6	674.9
			75%	2.2	8.0	184.4	677.5

Achten and Verchot (submitted)

M&M: Allocation

- Expressed in %
- Extracted from literature review



Achten *et al.* (2007) *BioFPR*

M&M: CO_2 emission reduction rate

- Based on comparative life cycle assessments
  - Literature review

Resulting repayment times

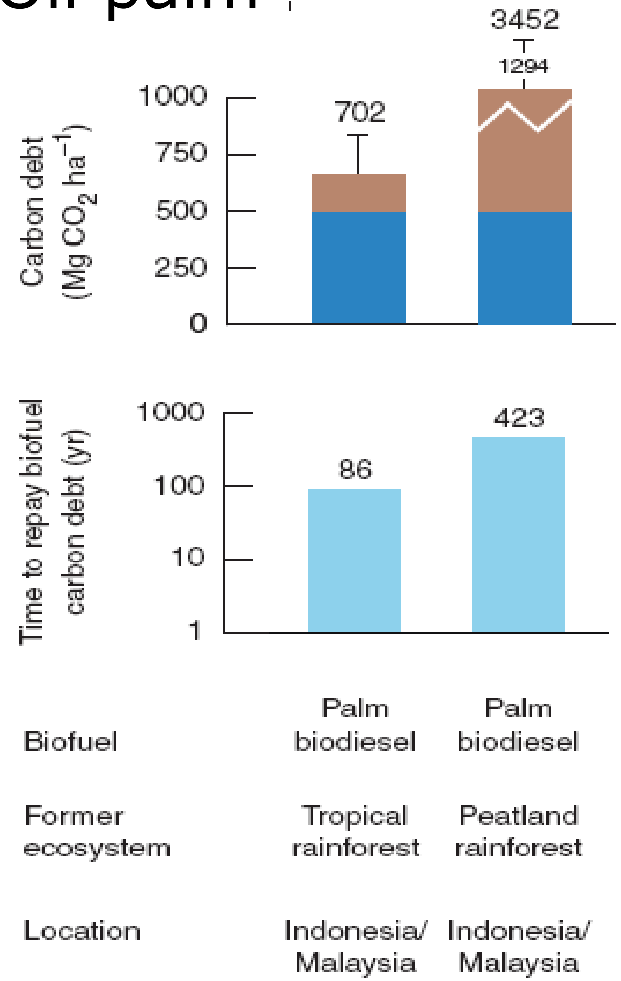
- Oil palm

Cases	**Malaysia**	**Manokwari Indonesia**	**West Kalimantan, Indonesia**	**Boven Digoel, Indonesia**
Carbon debt (dLUC + iLUC 25%) (Mg CO_2 ha^{-1})	698.8 + 0.0	253.6 + 24.8	1578.9 + 109.8	669.5 + 5.3
Repayment rate (Mg CO_2 ha^{-1} yr^{-1})	7.69	6.90	6.90	6.90
Repayment time (yr)	76 + 0 = **76**	32+ 2 = **34**	199 + 7 = **206**	84 + 1 = **85**

Secondary Forest **PEAT**

Resulting repayment times

- Oil palm



Fargione *et al.* (2008) *Science*

Peatland forest: Indonesia/Malaysia

423-918 years

Fargione *et al.* (2008) *Science; Gibbs et al.* (2008) *Environ. Res. Lett.* [accounted for 50 years of soil emissions]

169 years

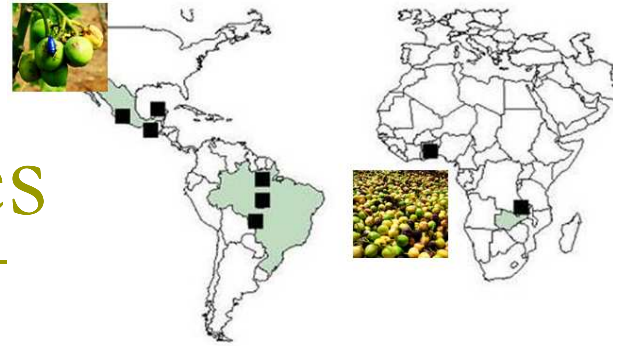
Wicke *et al.* (2008) *Biomass & Bioenergy* [accounted for 25 years of soil emissions]

Tropical rainforest: Indonesia/Malaysia

30-86 years

Wicke *et al.* (2008) *Biomass & Bioenergy;* Fargione *et al.* (2008) *Science*

Resulting repayment times



- Jatropha

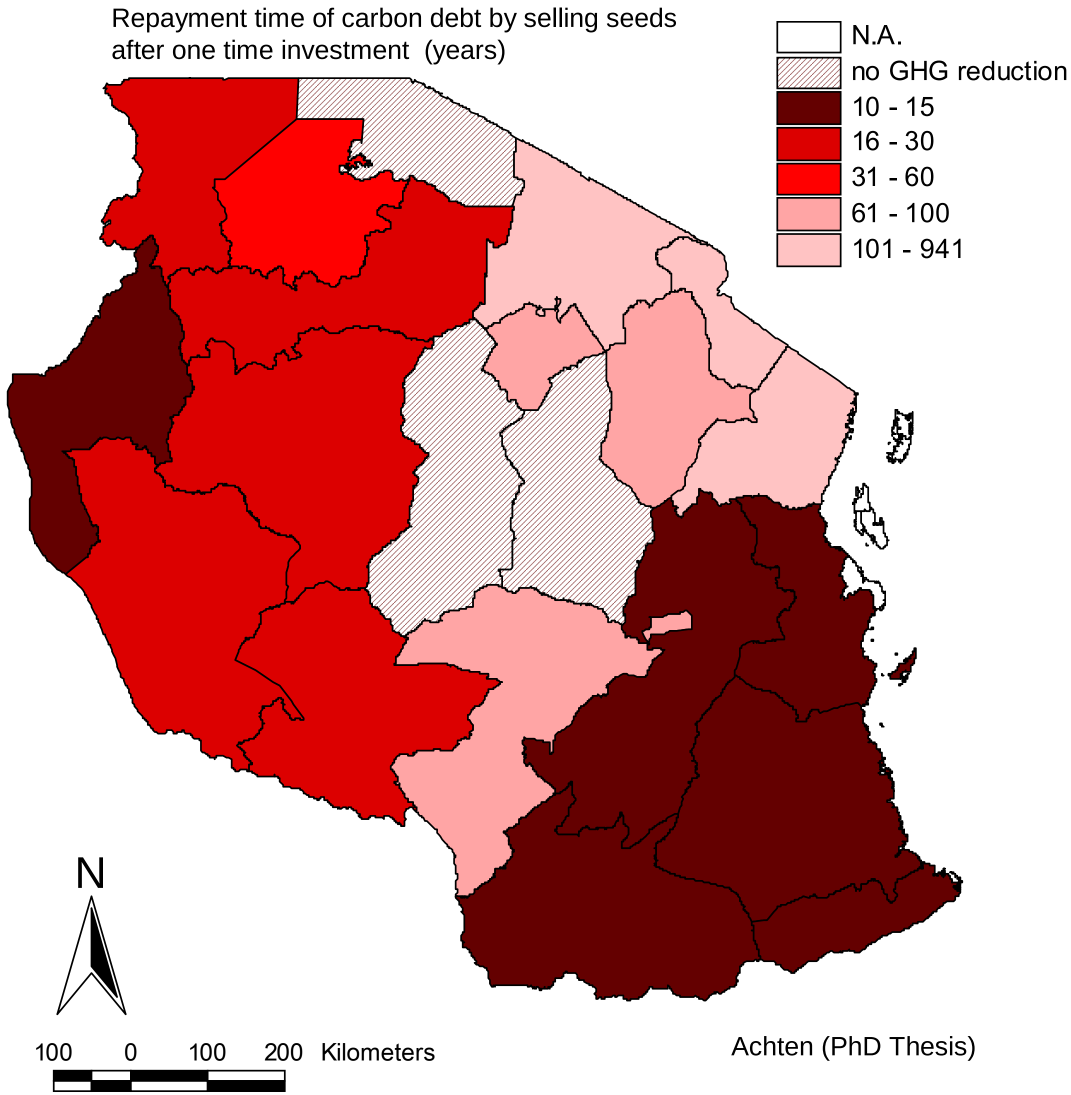
Cases	Ghana	Ycatan, Mexico	Michocan, Mexico	Chiapas Mexico	Zambia
Carbon debt (dLUC + iLUC 25%) (Mg CO_2 ha^{-1})	239.8 + 11.0	184.5 + 0	140.0 + 112.3	18.3 + 197.9	24.7 + 24.5
Repayment rate (Mg CO_2 ha^{-1} yr^{-1})	1.89 – 2.99	1.89 – 2.99	0.79 – 1.89	0.79 – 1.89	-0.32 – 0.79
Repayment time (yr)	90 + 4 = **94**	76 + 0 = **76**	105 + 84 = **189**	14 + 148 = **162**	95 + 94 = **188**

Woodland **Woodland** **Forest** **Forest** **Woodland**

Industrial scale **Smallholder systems**

Resulting repayment times

- Jatropha



Resulting repayment times

- Soybean

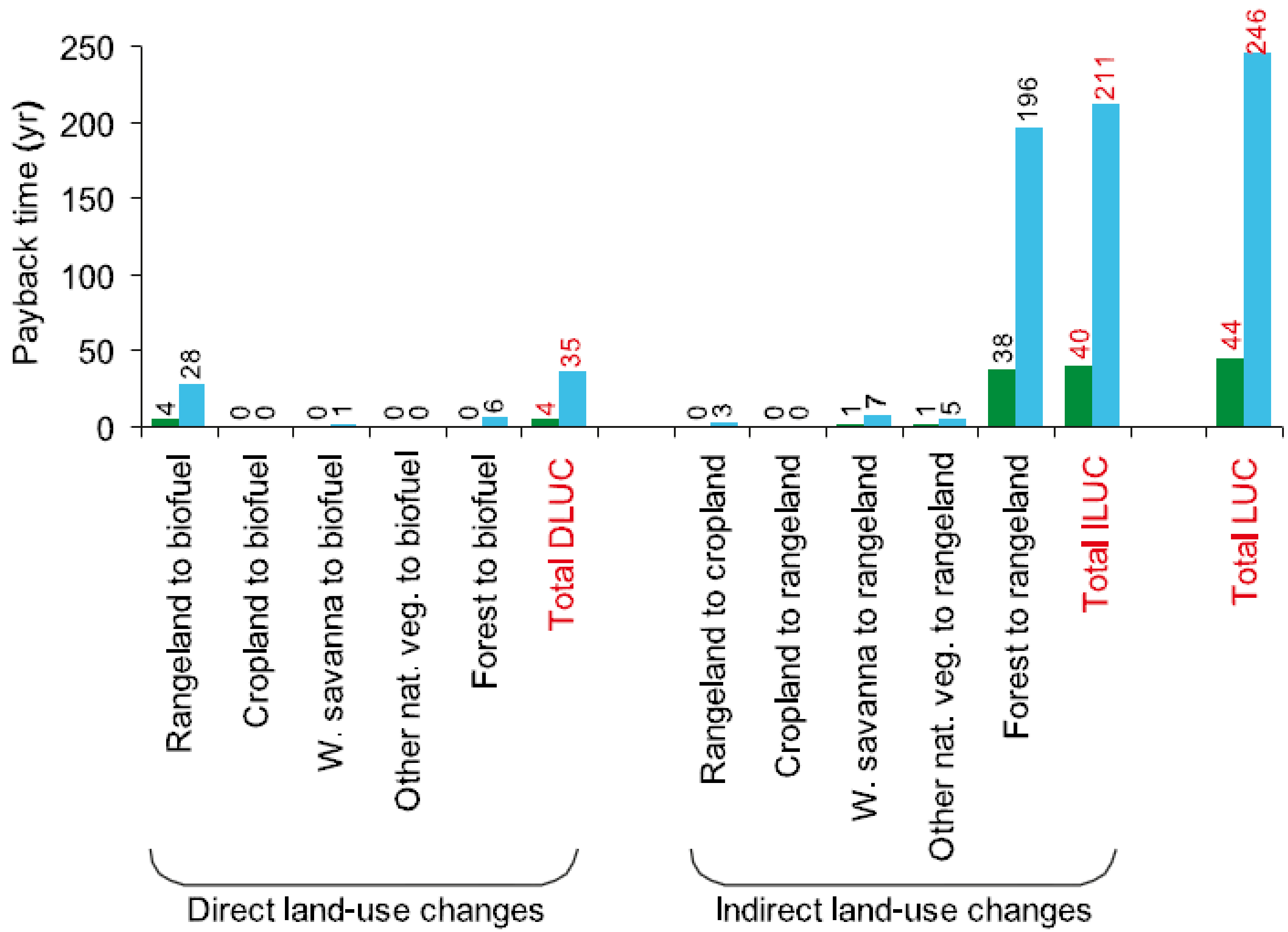
Cases	Sorriso, Brazil	Guarantã do Norte & Alta Floresta, Brazil	Santarém, Brazil
Carbon debt (dLUC + iLUC 25%) (Mg CO_2 ha^{-1})	134.5 + 0.0	23.5 + 33.6	55.3 + 159.1
Repayment rate (Mg CO_2 ha^{-1} yr^{-1})	0.87	0.87	0.87
Repayment time (yr)	41 + 0 = **41**	7 + 10 = **17**	16 + 47 = **64**

Cerrado Region

Amazon Region

Resulting repayment times

- Soybean



Lapola *et al.* (2008) *PNAS*

Discussion

- In our cases
  - Soybean < oil palm < Jatropha < oil palm on peat

- Final result mainly depends on
  - Carbon debt caused (direct and indirect)
  - Performance of biofuel crop

→ Very site specific
  - Land use deplaced
  - Potential crop yield

Discussion

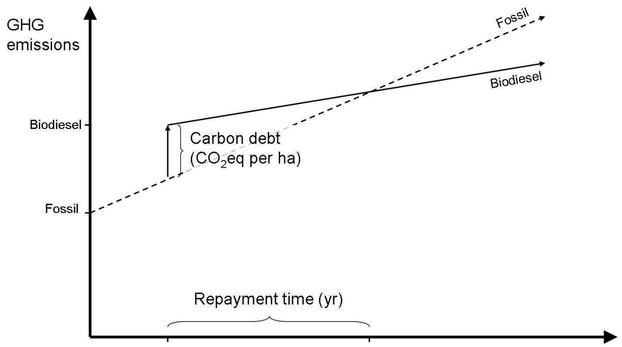
- Caution

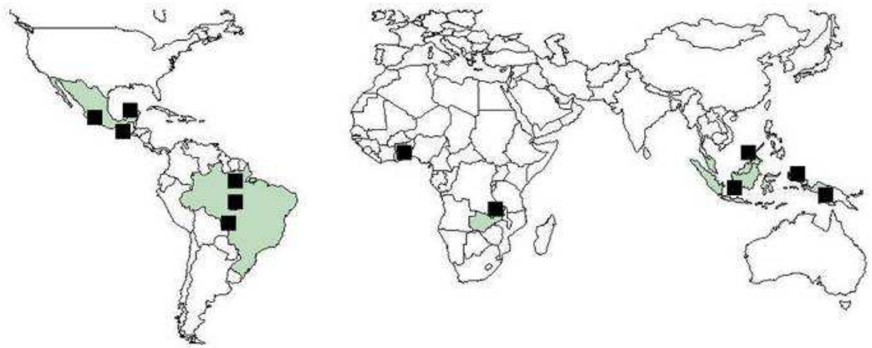
  - Land use change/dynamics are difficult to assess (uncertain)
  - Carbon content of land use types is based on literature

Conclusion

- Land use changes can negate the greenhouse gas balance of biofuels and postpone net greenhouse gas emission benefits for long periods
- Site specific
  - Type of land use changed
  - Performance of biofuel
- Biofuel climate mitigation potential
  - In areas with low carbon content
  - Areas not used in production systems
  - Areas where biofuel feedstock is sufficient performing

Thank you for your kind attention





Questions?