Sustainable biomass

Biomass, land use and development

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Hans Langeveld
Biomass Research

Biofuels, GHG and RED

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee},$$

E = total emissions from the use of the fuel;

e_{ec} = emissions from the extraction or cultivation of raw materials;

e_l = annualised emissions from carbon stock changes caused by land-use change;

e_p = emissions from processing;

e_{td} = emissions from transport and distribution;

Source: European Commission (2008) *Renewable Energy Directive*

Biofuels, GHG and RED

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GHG balance

¬ e_{ec} = crop cultivation (extraction)

¬ e_l = land use change

¬ e_p = biomass processing

¬ e_{td} = transport and distribution

Source: European Commission (2008) *Renewable Energy Directive*

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Background

- ¬ Tropical agronomy (Wageningen University)
- ¬ Biology & Society
- ¬ Farming systems and education
- ¬ Centre for World Food Studies
- ¬ Plant Research International

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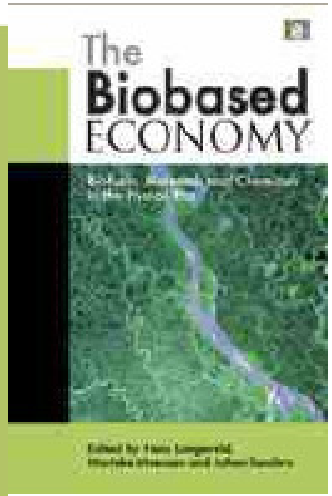
Background

- ¬ Farming & cropping systems
- ¬ Quantified analysis
- ¬ Land use modelling
- ¬ Nutrient flow analysis (emissions)
- ¬ Biofuels (sustainability)

Biomass Research

Background

- Since 2008
- Our motto:
  more facts & better interpretation = less speculation
- Our mission: provide quality information
- Research projects, factsheets, articles, books
- University, IEA Bioenergy, FAO, private companies



Malnutrition

Number underfed	1,000,000,000	(1 bln)
Additional food	1200 kcal pppd	(out of 1800 kcal total requirements)
Cereal requirements	350 g pppd	(wheat flour)
	128 kg pppy	(wheat flour)
Total	128 mln ton cereals	(wheat flour, 1 bln persons, 1200 kcal)
	192 mln ton cereals	(idem, 1800 kcal)

Cereal production (FAO, 2003)	1,885,611,618	(1.9 bln tonnes; not including beer)
Of which animal feed (idem)	720,267,840	(720 mln tonnes)
Of which waste (idem)	84,085,893	(84 mln tonnes)
75% of animal feed	540,200,880	(540 mln tonnes)
Equivalent of	4.22	(x 128 mln tonnes)
	2.81	(x 128 mln tonnes)
Waste ./. 128 mln ton	0.66	(x 128 mln tonnes)

Source: Langeveld. Cereal prod. data from FAOSTAT, accessed Feb. 15, 2010

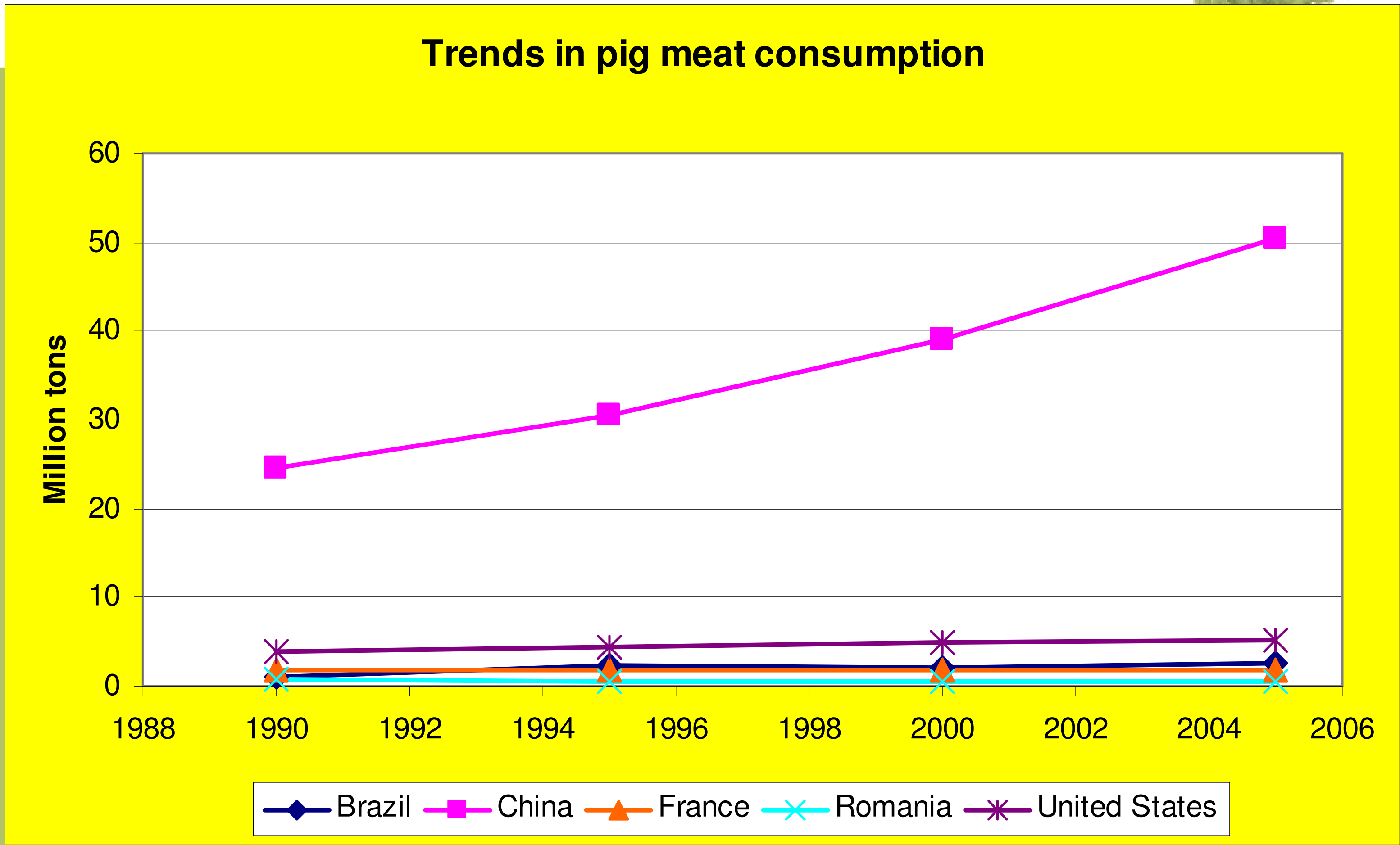
Malnutrition

Food consumption Quantity (1000 tonnes) | Soybeans

country		1990	1995	2000	2005
	Brazil	9,619.56	12,088.56	10,760.16	10,184.59
	China	13,105.50	18,727.91	24,395.47	50,957.45
	France	121.55	419.69	366.96	579.67
	Romania	299.98	41.66	41.21	150.65
	United States of America	18,203.21	21,743.56	27,548.35	25,261.75

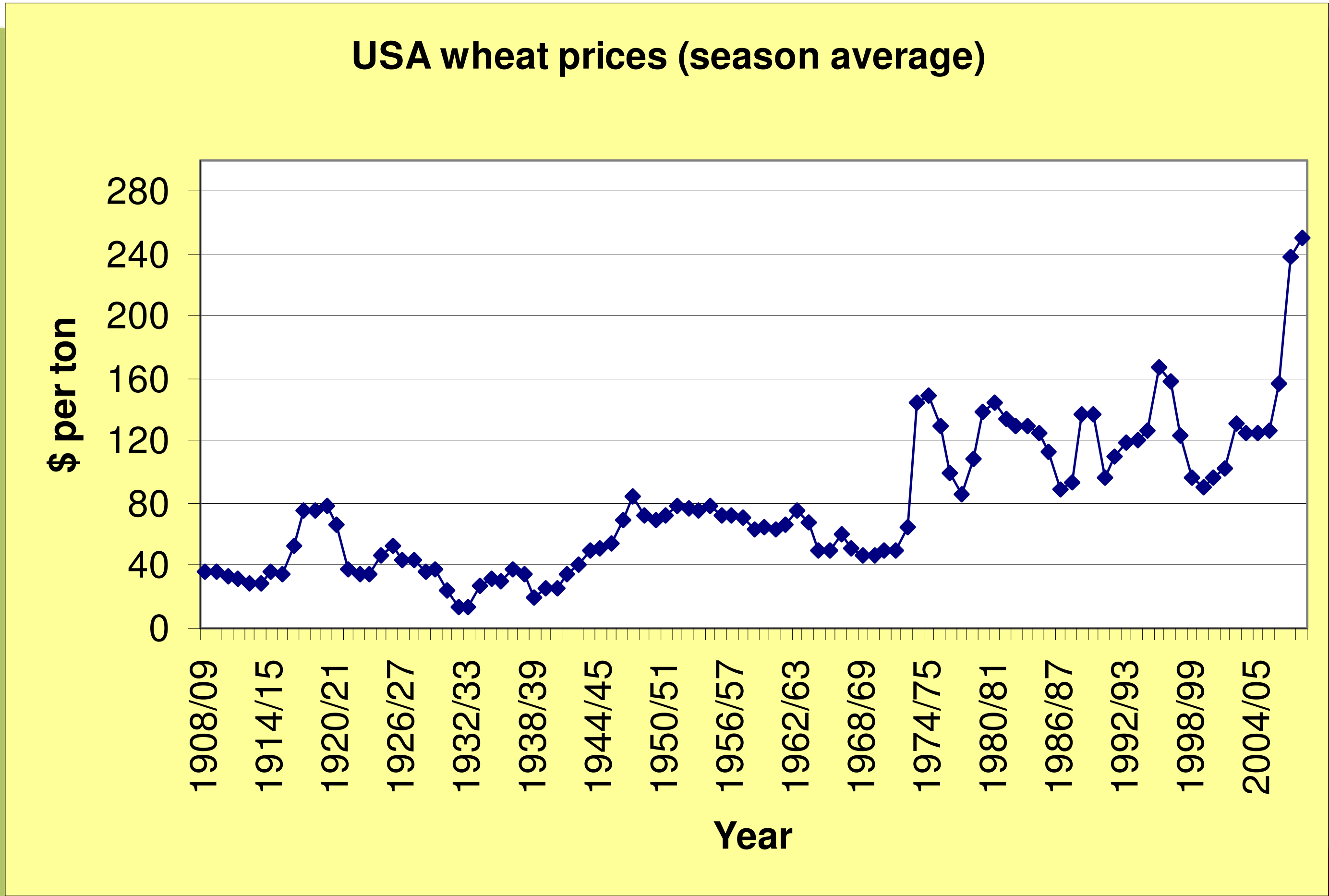
Source: FAOSTAT, accessed on Apr. 16, 2007

Meat consumption



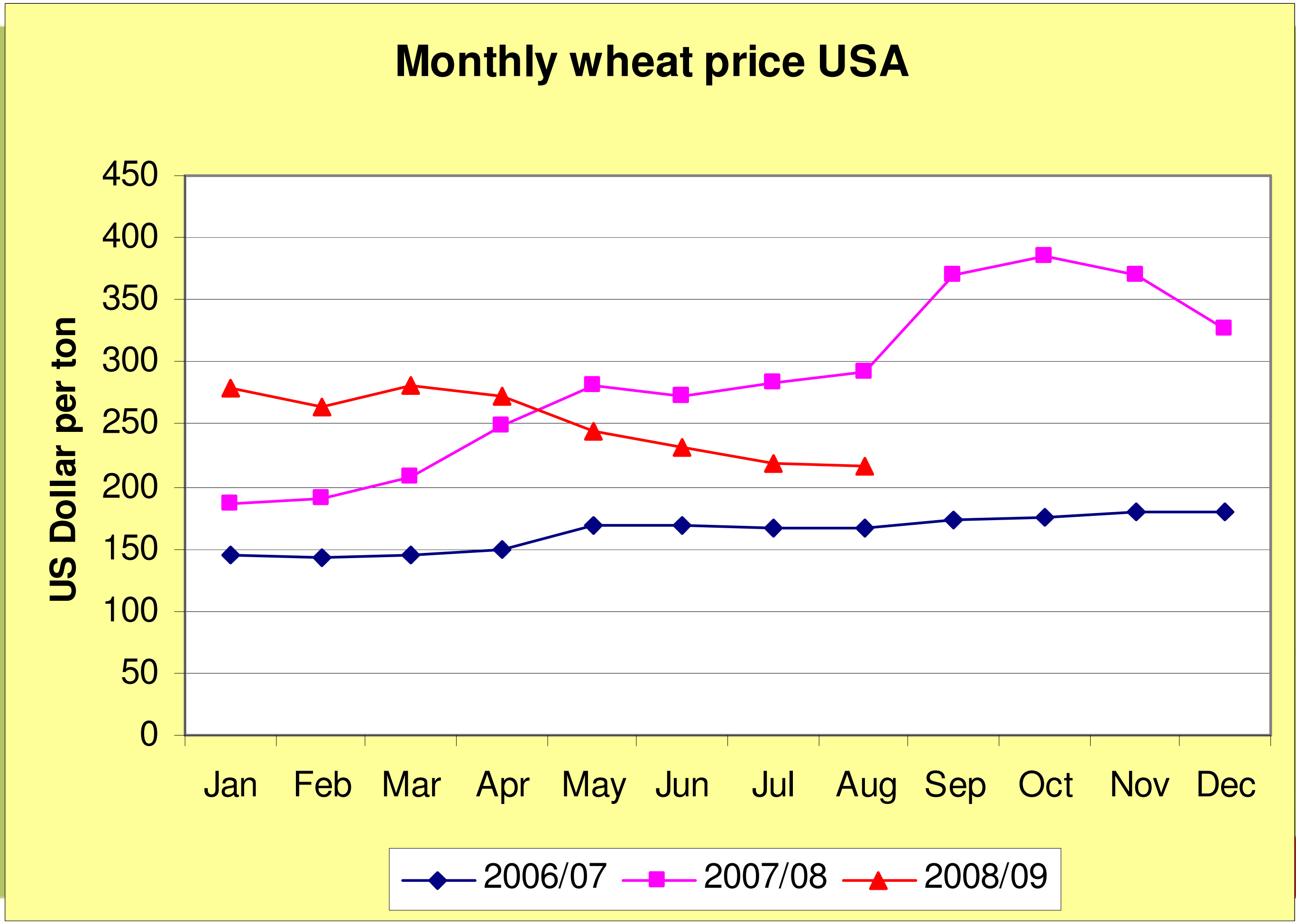
Source: FAOSTAT, accessed Apr. 16, 2007

Food prices



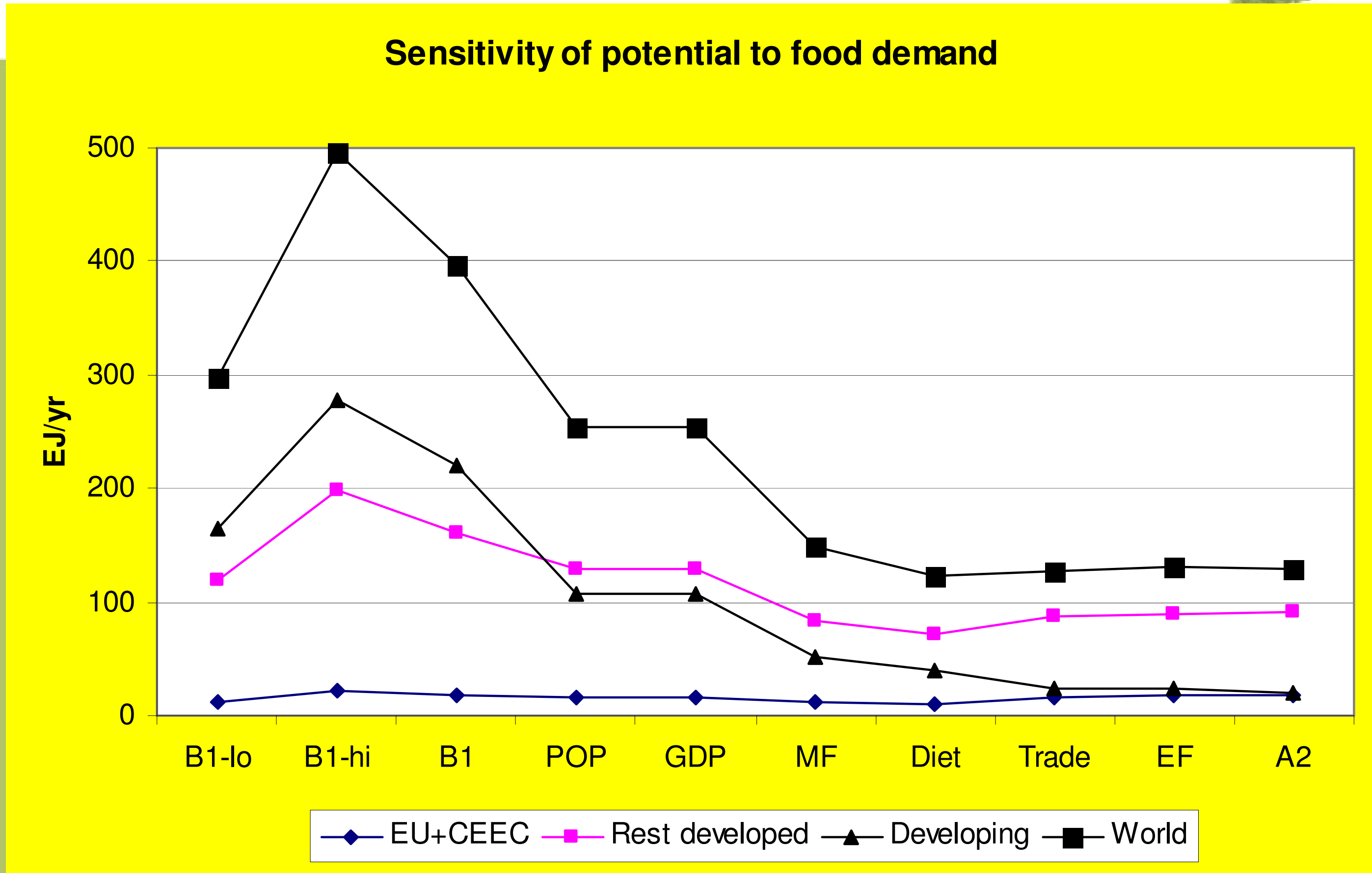
Source: www.ers.usda.gov/data/wheat/YBtable20.asp, accessed Aug. 24, 2008

Food prices



Source: www.ers.usda.gov/data/wheat/YBtable20.asp, accessed Aug. 24, 2008

Biomass potential



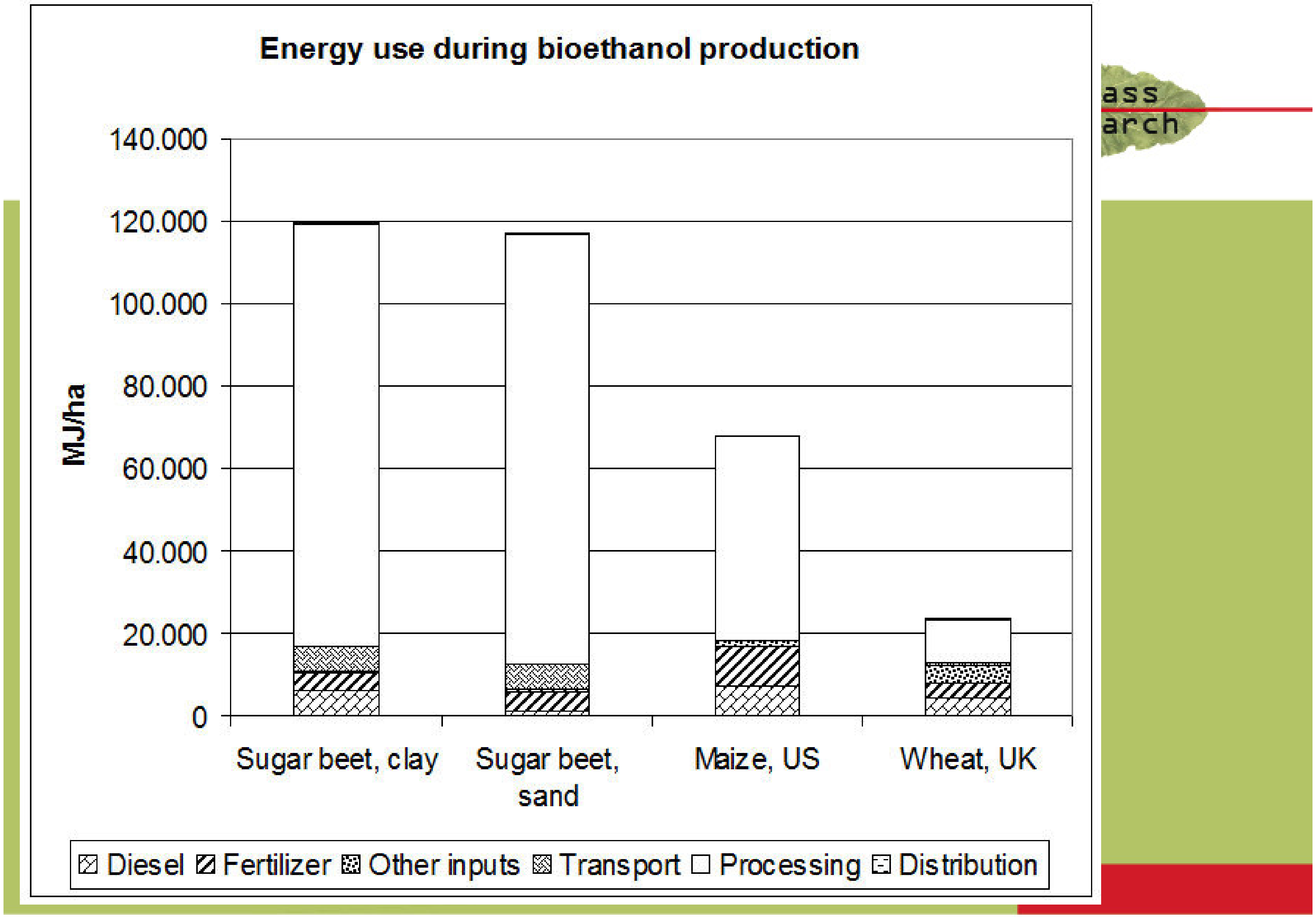
Source: Hoogwijk et al. (2005), *Biomass and Bioenergy.*

Figure 1. Chain of actions following increased biofuel production

Time →

Actors ↓	1	2	3	4	5	6
Producers	Biofuel production is increased.		Use of land and inputs increases.			Farmers decrease input, land use.
Markets		Less food, higher prices.	Demand for land increases.	Price of land, inputs increases. Food availability rises.	Land availability, food production increase, prices decline.	
Consumers			Poor cut back food purchases.	Poor look for cheaper food.		Poor consumers buy more food.
Policy				Public concern about increased food prices.	Actions to limit (effects of) biofuel production.	

Source: based on Langeveld and Sanders (2010)



Source: Energy and Research Group (2009); De Visser et al (2008); Mortimer et al (2004)

Crop cultivation

Mostly related to N-fertilization

¬ Artificial fertilizer production
¬ Nitrous oxide
¬ Efficiency varies but is improving
¬ Fertilizer application

Table 4.1 *Basic characteristics for major bioethanol crop production systems**

Crop	*Region*	*Area*	*Input level*	*Irrigation*	*Crop yield*	*Biofuel yield*
		mln ha		% of area	Tonne fresh weight/ha	l/ha
Wheat	Europe	9.1	High	No data	7.3	2600
Sugar beet	Europe	1.0	High	5–15	69.3	6700
Rapeseed	Europe	2.7	High	0	3.6	1200
Maize	USA	29.6	High	21	9.6	3500
Soy bean	USA	2.9	High	10	2.9	500
Switch grass	USA	No data	Moderate	No data	No data	10,800
Sugar cane	Brazil	22.2	High	14	73.5	6200
Soy bean	Brazil	5.9	Moderate	0	2.3	400
Wheat	China	23.5	High	No data	4.5	1600
Maize	China	27.1	High	40	5.4	2000
Sugar cane	China	1.2	Moderate	28	82.5	7000
Cassava	China	0.3	Moderate	0	16.2	7600
Sugar cane	India	4.2	No data	80	88.0	6600
Maize	India	7.6	Low	No data	1.9	700
Maize	Africa	26.1	Low	No data	1.7	700
Sugar cane	Africa	1.6	Varies	No data	57.1	4800
Cassava	Africa	12.1	Very low	0	10.1	3800

* Figures provide recent and representative values but cannot be considered as averages.

Source: Dixon et al (2009), except De Fraiture and Berndes (2009) irrigation.

Table compiled by: Langeveld and van de Ven (2010)

Processing

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Highest source of direct GHG emissions

¬ Heating
¬ Fossil fuel use
¬ Antique technologies
¬ CHP, bioenergy use

Table 4.4 *Improvements in production technology and their impact on energy and GHG balances*

Factor	Basic value	Options for improvement		Specification
	(100%)	Option 1	Option 2	
Maize yield variation in the USA 2003-2005	8.2 tonne/ha	13.6 (143%)		Highest county average as compared to national average
Conversion energy use for maize ethanol in the USA	13.9 MJ/l	9.0 (65%)	6.0 (43%)	Dry milling using natural gas (option 1), compared to average data (dry plus wet milling, using natural gas or coal).
Reduced wheat to ethanol energy requirement	17.2 GJ/tonne ehtanol	15.9 (93%)	10.8 (63%)	Replace gas boiler and electric grid by CHP with steam (option 1) or gas turbine (option 2)
Improved beet to ethanol energy yield	93 GJ/ha	140 (150%)	170 (182%)	Fermentation of by-product (option 1) and by-product plus leaves (option 2)
Reduced wheat to ethanol conversion emissions	1255 kg CO_2-eq/tonne ehtanol	1041 (83%)	587 (47%)	Replace gas boiler and electric grid by CHP with steam (option 1) or gas turbine (option 2)

Source: Mortimer et al (2004), Liska and Cassman (2008), De Visser et al. (2008)

Indirect land use

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Highly debated

¬ Searchinger etal.
¬ Displacement
¬ Land markets
¬ Criteria (RED)

Table 2. Soil carbon stocks, above ground carbon stocks, and changes in total carbon stocks in Cerrado and Amazon tropical forest (tons C/ha)

(tons/ha)	Carbon stocks			Carbon stock change; LUC to unburned sugarcane			Carbon stock change; LUC to sugarcane with burning
	soil[(a)]	above ground	total	soil[(a)]	above ground	total	total
Land cover							
Natural grassland[(b)]	56	1	57	-12	17	5	-5
Degraded grassland[(c)]	41	1	42	3	17	20	10
Cultivated grassland[(d)]	52	7	59	-8	11	3	-7
Soya bean	53	2	55	-9	16	7	-3
Maize	40	4	44	4	14	18	8
Cotton	38	2	40	6	16	22	12
Cerrado, typical savannah	46	26	72	-2	-8	-10	-20
Cerrado, woody savannah	53	34	87	-9	-16	-25	-35
Sugarcane with burning	35	17	52				
Sugarcane unburned	44	18	62				
Tropical forests	47[e]	150[f]	197			-135	-145

Source: Amaral et al. (2008) unless indicated otherwise.

Source: Amaral et al. (2008), Lilienfein et al. (2003), Fearnside and Barbosa (1998), Schaefer et al. (2008), Grace et al. (2006). Table compiled by Quist and Langeveld (*subm*)

GHG savings

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Background

¬ Tropical agronomy, farming systems
¬ Land use systems
  - Inputs, outputs
  - Efficiency, availability
¬ Nutrient emissions / GHG
¬ Biobased economy

Table 4.2 *Typical GHG emission reduction of biofuels and other biobased products compared to fossil products*

Product, feedstock	***Production system***	***GHG savings (%)***
Sugar cane	Brazil	85 (70-100)
	China	65
	Africa	65
Maize ethanol	USA	20 (-47-58)
	EU	56
Wheat ethanol	Europe	30-60 (18-90)
	China	27
Sugar beet ethanol	Europe	50 (32-65)
Rape biodiesel	Europe	40-60
Palm oil biodiesel	Various	10-80
	Europe	36
Waste oil biodiesel	Europe	88
Second generation fuels	Various	60-90
Switchgrass		92
*Corn PLA**	USA example	60-75

*Lower value compared to PET, higher to nylon

Source: calculated from Ogletree (2004), Patel (2008), Menichetti and Otto (2009), Dixon et al (2009), European Commission (2009) and SenterNovem (2009)

Table compiled by: Langeveld (2010)

GHG savings

Optie		1	2	3	4	5	6
Energieverbruik per ha (GJ)							
Landbouw		13.6	13.6	13.6	13.6	13.6	1.1
Transport		6.7	6.7	7.0	7.0	1.9	1.0
Proces		50.7	50.7	68.9	68.9	36.0	8.9
Pulpvergisting			−34.0		−34.0		
Totaal		71.0	37.0	89.5	55.5	51.5	11.0
Toegerekend aan pulp		-6.7		-6.8			
Toegerekend aan suiker/ethanol/biogas		64.3	37.0	82.7	55.5	51.5	11.0
Energieopbrengst	(kg ethanol/methaan)			5480	5480	4215	1050
Energieinhoud	(GJ)			144.1	144.1	235	58
Bruto energieopbrengst	(GJ)			175.9	175.9	237	59
Netto energieopbrengst	(GJ)			93.2	120.4	185	48
Rendement				0.53	0.68	0.78	0.81

Source: Corré and Langeveld (2008)

Discussion

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GHG balances

¬ Legislation
¬ Issue of allocation
¬ Indirect land use
¬ Deforestation / land use change

Good quantitative data

¬ Inventories
¬ Dynamic analysis
¬ Protocols
¬ Optimization procedures

Further activities

Cropping systems atlas

¬ Biofuel crops
¬ Global
¬ Use the right data

Standard for GHG balances

¬ Centre for European Normalisation
¬ TC383
¬ Working Group 2: GHG balances
¬ Concept: May 2010