The environmental performance of native grassland based livestock production systems

Donal Murphy-Bokern

Photo: International Livestock Research Institute

DFID Department for International Development

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Background
Native grasslands are a key resource in poor communities

200 million pastoral households
1,000 million head of livestock
ca 3,000 million ha

675 million rural poor depend on livestock
300 million dependent on natural grassland

Sources:
FAO 2003, The state of food insecurity
Ellis and Ramankutty 2008, Frontiers in ecology and environment
Hatfield and Davies 2006, Global review of the economics of pastoralism.

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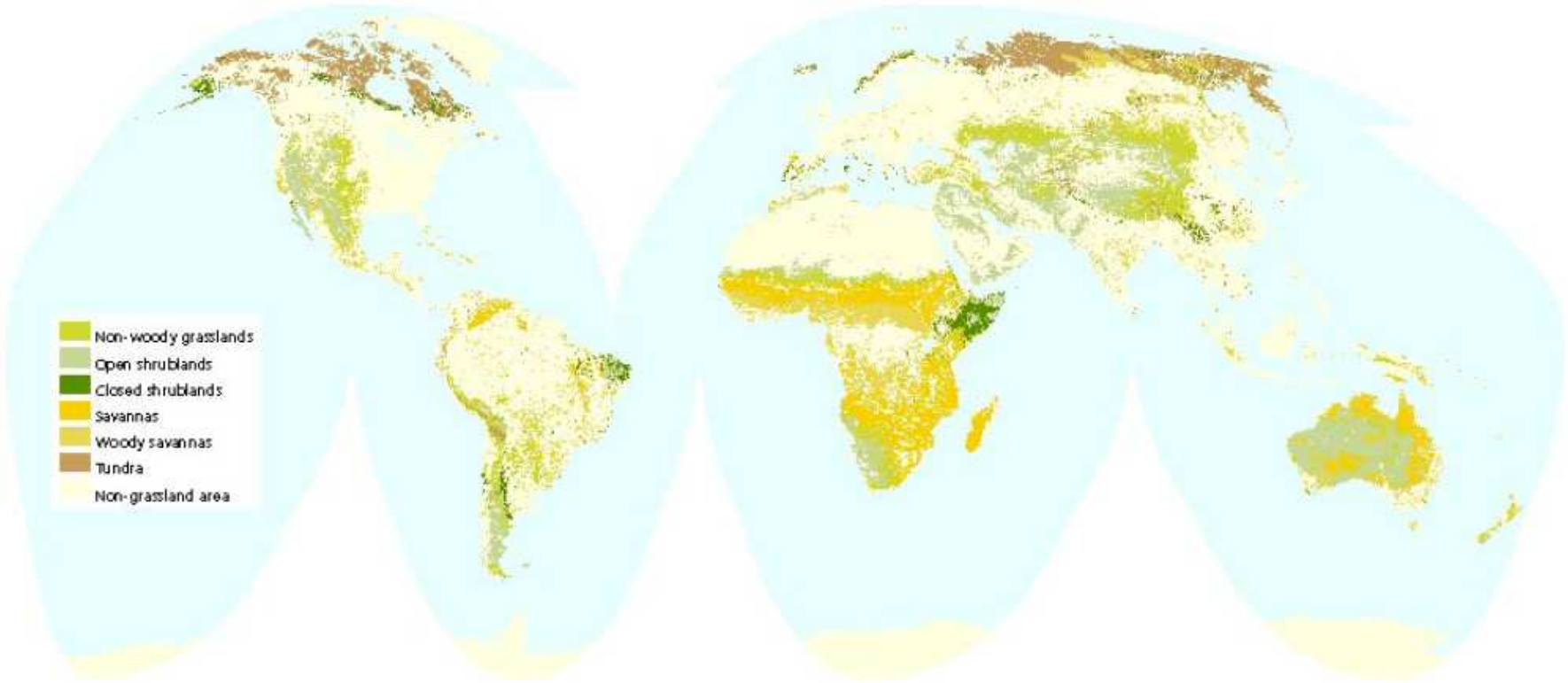
Background
Native grasslands are a key resource in poor communities



GLCCD. 1998. Global Land Cover Characteristics Database, Version 1.2. Data available online at: http://edc2.usgs.gov/glcc/gifs.php.
Olson, J.S. 1994a. *Global Ecosystem Framework-Definitions*.
USGS EROS Data Center Internal Report. Sioux Falls: USGS EROS Data Center. 37pp

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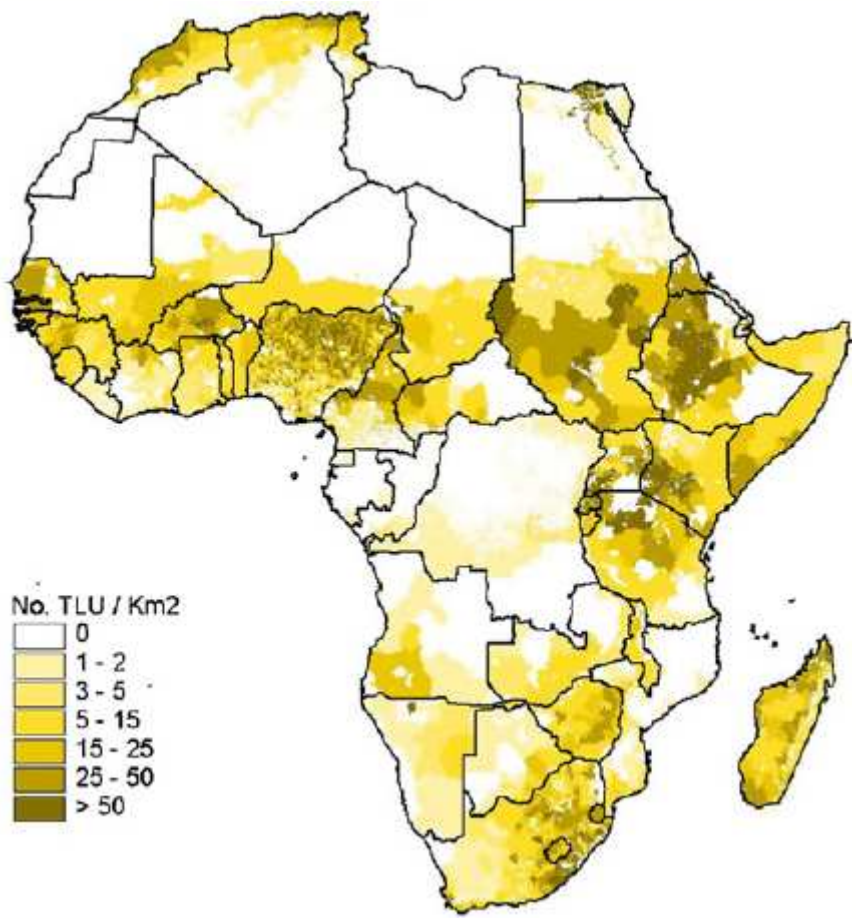
Background
Native grasslands are a key resource in poor communities

Tropical livestock units/100 ha



M. Herrero a,b,*, P.K. Thornton, Kruska R. and Reid, R.S., 2008.
Systems dynamics and the spatial distribution of methane emissions from African domestic ruminants to 2030. Agricultural systems and environment 126: 122-137.

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Background

Native grasslands are a key resource in the developing world

The top 28 grassland based countries

Country	Region[b]	Total Land Area (km^2)	Grassland Area (percent)
Benin	Sub-Saharan Africa	116,689	93.1
Central African Republic	Sub-Saharan Africa	621,192	89.2
Botswana	Sub-Saharan Africa	579,948	87.8
Togo	Sub-Saharan Africa	57,386	87.2
Somalia	Sub-Saharan Africa	639,004	86.7
Australia	Oceania	7,704,716	85.4
Burkina Faso	Sub-Saharan Africa	273,320	84.7
Mongolia	Asia	1,558,853	83.9
Guinea	Sub-Saharan Africa	246,104	83.5
Mozambique	Sub-Saharan Africa	788,938	81.6
Namibia	Sub-Saharan Africa	825,606	80.6
Angola	Sub-Saharan Africa	1,252,365	79.9
Zimbabwe	Sub-Saharan Africa	391,052	76.8
Nigeria	Sub-Saharan Africa	912,351	76.7
Guinea-Bissau	Sub-Saharan Africa	34,117	73.9
Senegal	Sub-Saharan Africa	196,699	73.5
South Africa	Sub-Saharan Africa	1,223,084	73.5
Lesotho	Sub-Saharan Africa	30,533	73.5
Afghanistan	Middle East & N. Africa	642,146	73.4
Ethiopia	Sub-Saharan Africa	1,132,213	72.9
Zambia	Sub-Saharan Africa	754,676	69.8
Tanzania, United Republic	Sub-Saharan Africa	945,226	69.7
Madagascar	Sub-Saharan Africa	594,816	69.4
Kenya	Sub-Saharan Africa	584,453	68.6
Ghana	Sub-Saharan Africa	240,055	64.2
Cote d'Ivoire	Sub-Saharan Africa	322,693	62.3
Turkmenistan	Asia	471,216	62.1
Kazakhstan	Asia	2,715,317	61.5

[1] Olson, J.S. 1994a. *Global Ecosystem Framework-Definitions*. USGS EROS Data Center Internal Report. Sioux Falls: USGS EROS Data Center. 37pp.
[2] Olson, J.S. 1994b. Global Ecosystem Framework-Translation Strategy: USGS EROS Data Center Internal Report. Sioux Falls: USGS EROS Data Center. 39pp.
[3] GLCCD. 1998. Global Land Cover Characteristics Database, Version 1.2. Data available online at: http://edc2.usgs.gov/glcc/gifs.php.

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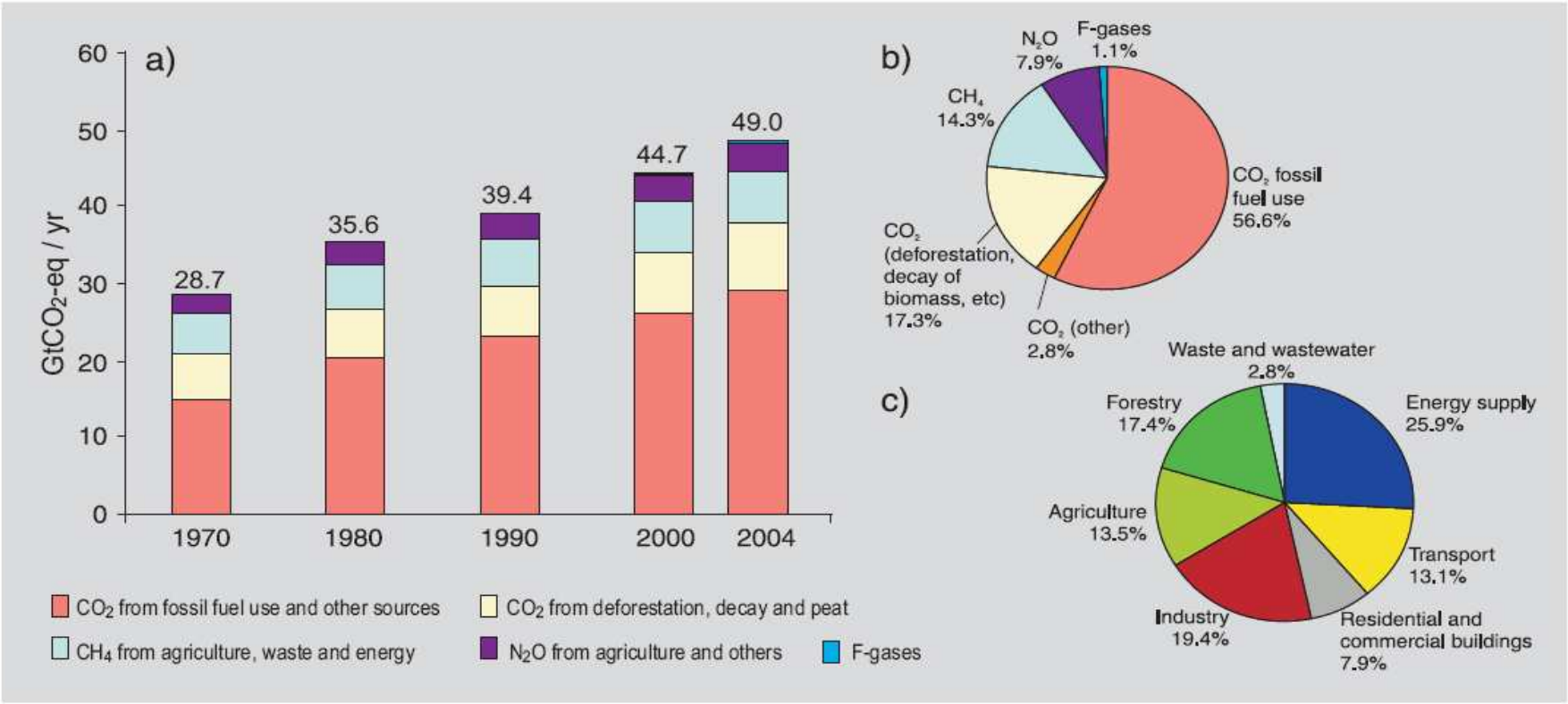
Food production is a major source of greenhouse gas emissions

ca one third of all emissions on a life-cycle basis (including Land-use change)



Source: IPCC Fourth Assessment Report

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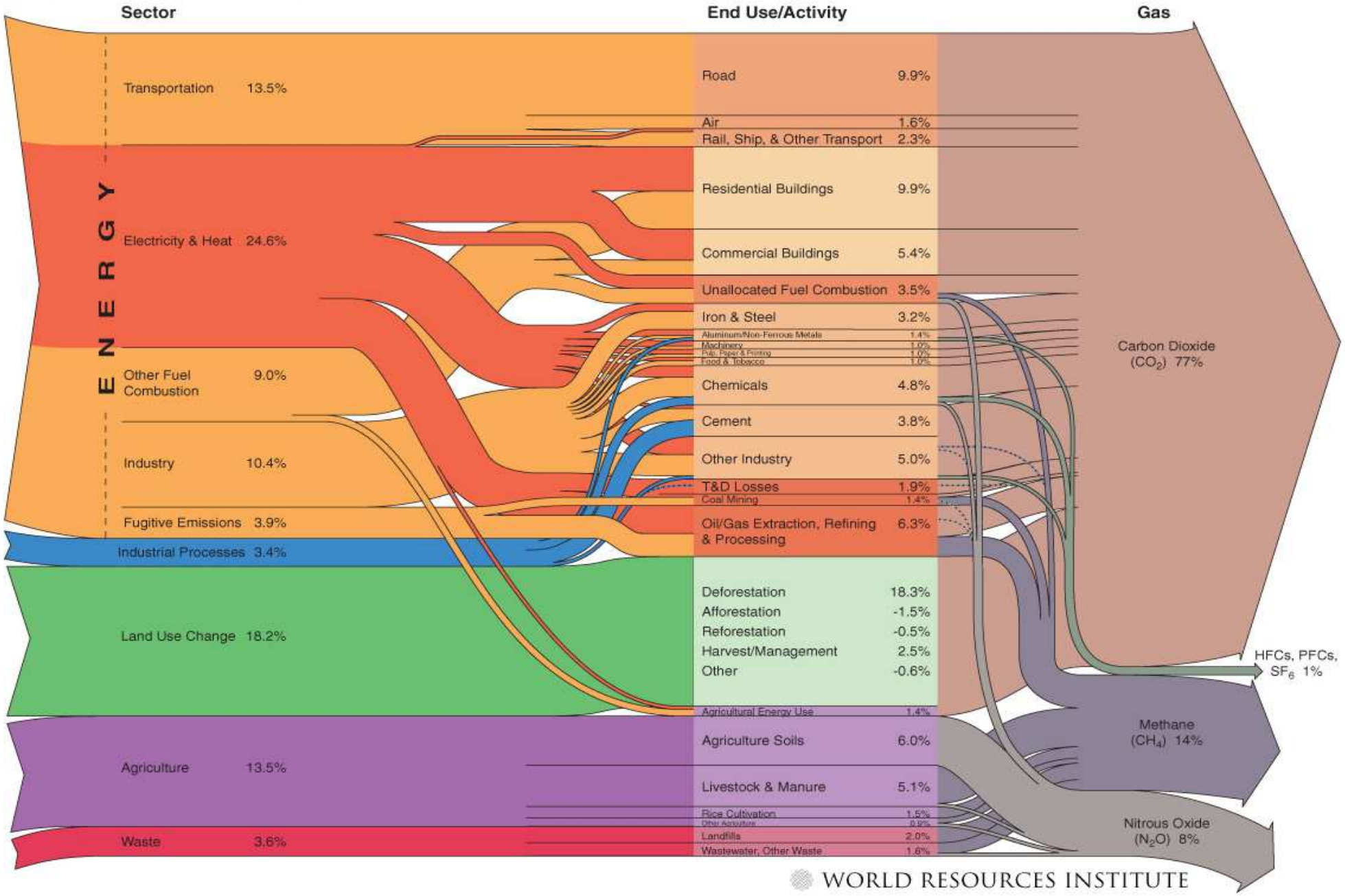
World GHG Emissions Flow Chart



Environmental benefits for grassland based production claimed (and disputed)

	GWP_{100} $kgCO_2eq/ha$		GWP_{100} $kgCO_2eq/kgMS$	
	NZ	UK	NZ	UK
CO_2				
Energy	1,145 [1]	2,825	1.37 [1]	3.47 [2]
CH_4				
Fermentation and manure mgmt	5,320	5,310	6.36	6.52
N_2O				
Direct emissions N fert. input to soil	320	815	0.39	1.00
Direct emissions N excretion to soil	1,360	1,150	1.63	1.42
Indirect emissions atm. decomposition fert. N and excretion	390	280	0.47	0.35
Indirect emissions leaching fert. N and excretion	305	1,120	0.36	1.38
Total (100% allocation to milk)	**8,840**	**11,505**	**10.58**	**14.13**
Total (85% allocation to milk)	**7,530** [3]	**9,775**	**9.01** [3]	**12.01**

[1] Landed at a UK port
[2] Adjusted from original report where it was 2.92 based on 8.4 per cent MS to 3.47 based on 7.1 per cent MS
[3] Includes 100 per cent of shipping CO_2 emissions

Saunders and Barber 2007, Comparative energy and greenhouse gas emissions of New Zealand's and the UK's dairy industry

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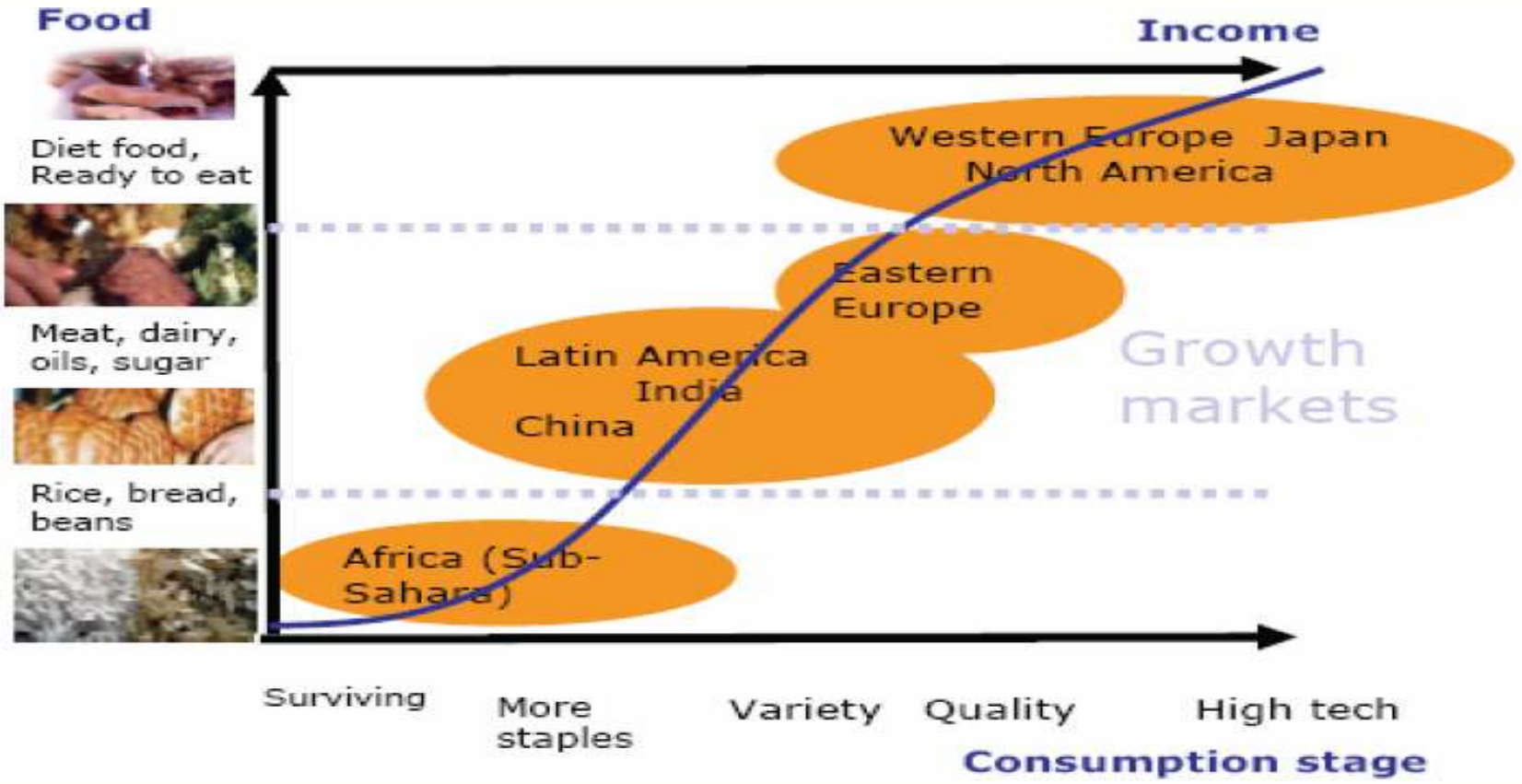
Demand for livestock products is increasing



Source: Zwanenberg, Robobank

The demand for meat and dairy products will double by 2050

	2000 (population 6 bn)	2050 (population 9 bn)
Average *per capita* global demand - meat (tonne)	0.0374	0.052
Average *per capita* global demand - milk (tonnes)	0.0783	0.115
Total demand – meat (tonnes)	228	459
Total demand – milk (tonnes)	475	883

Source: FAO 2006 (World Agriculture towards 2030/2050) data presented by Tara Garnet

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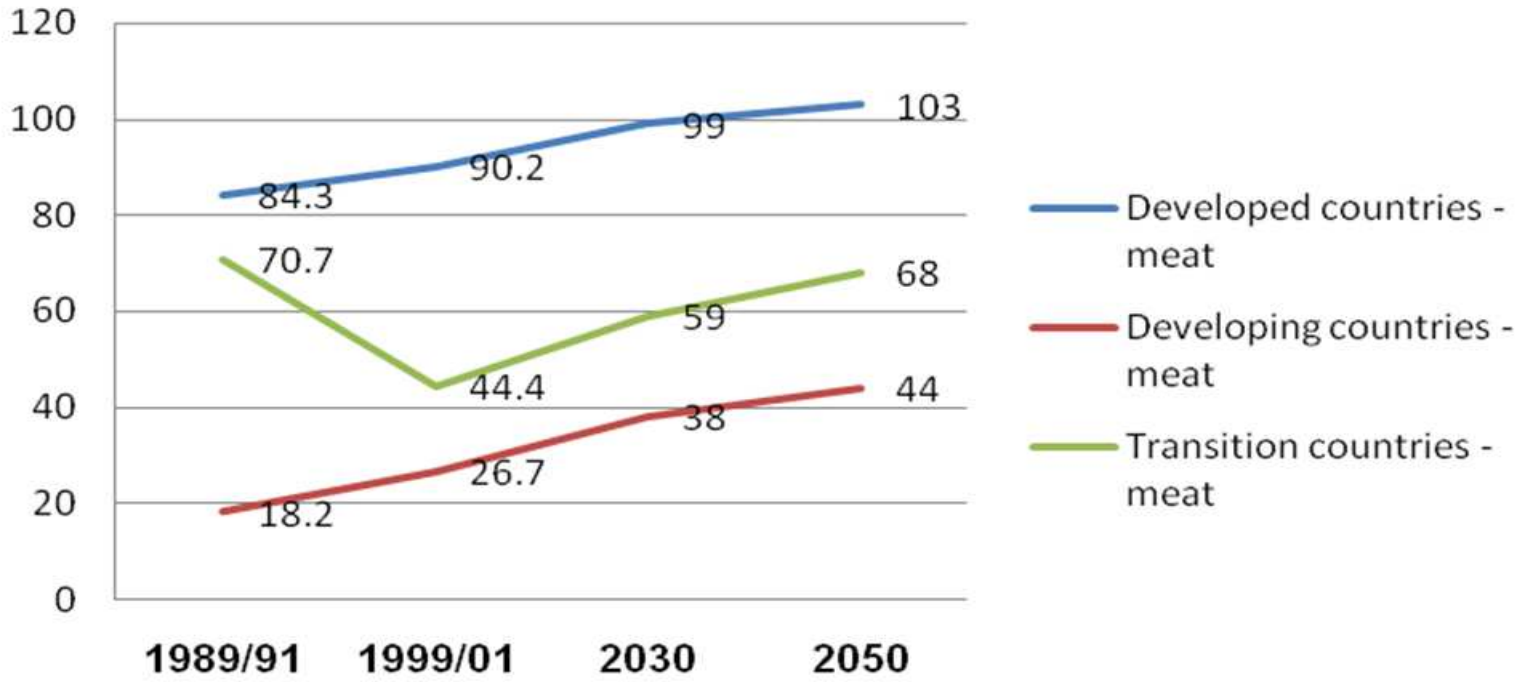
But the consumption gap will remain

Projected trends in per capita consumption of meat products to 2050, kg/person/yr



Source: *World agriculture: towards 2030/2050* Interim report Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations, Rome, June 2006. Presented by Tara Garnet

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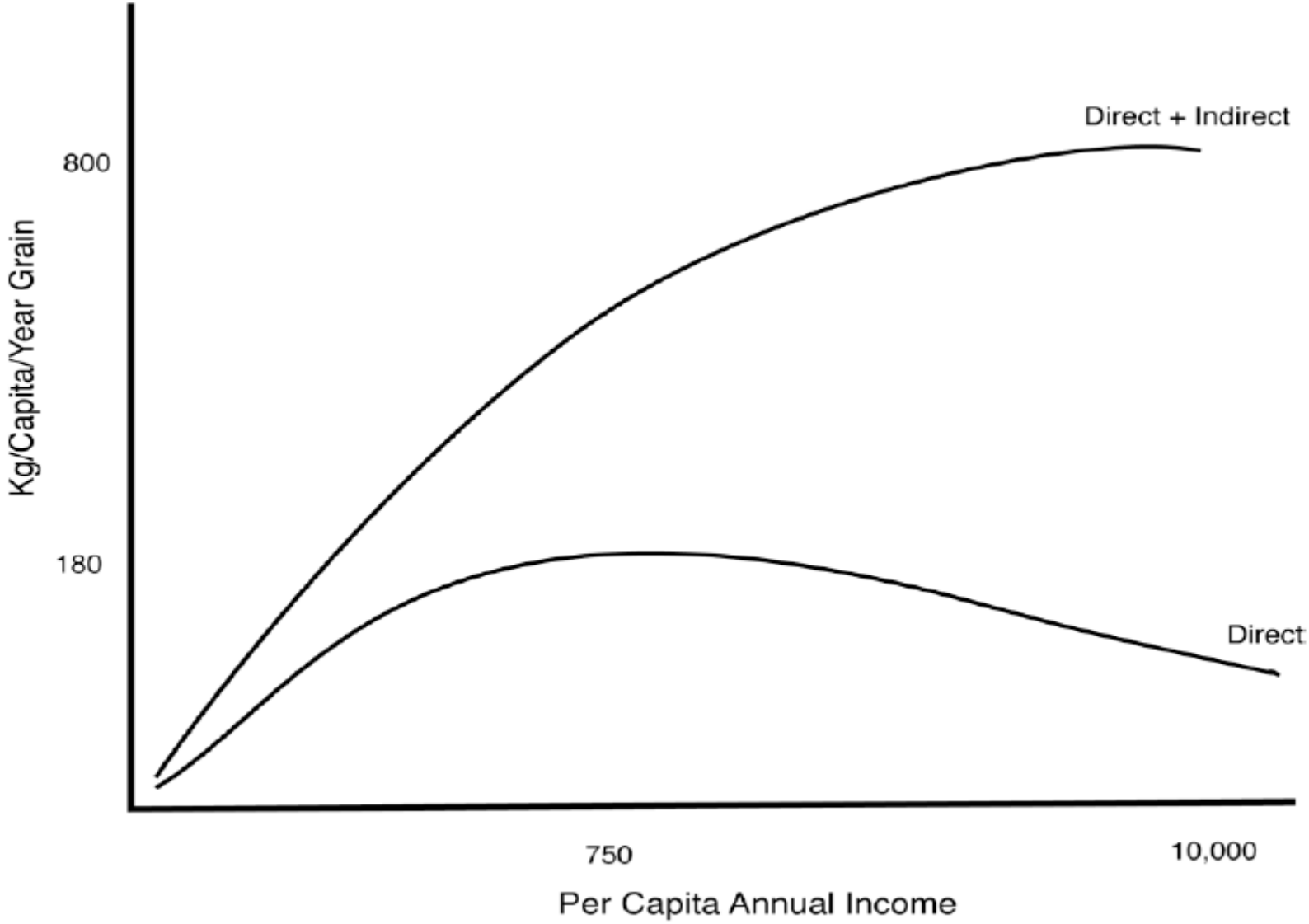
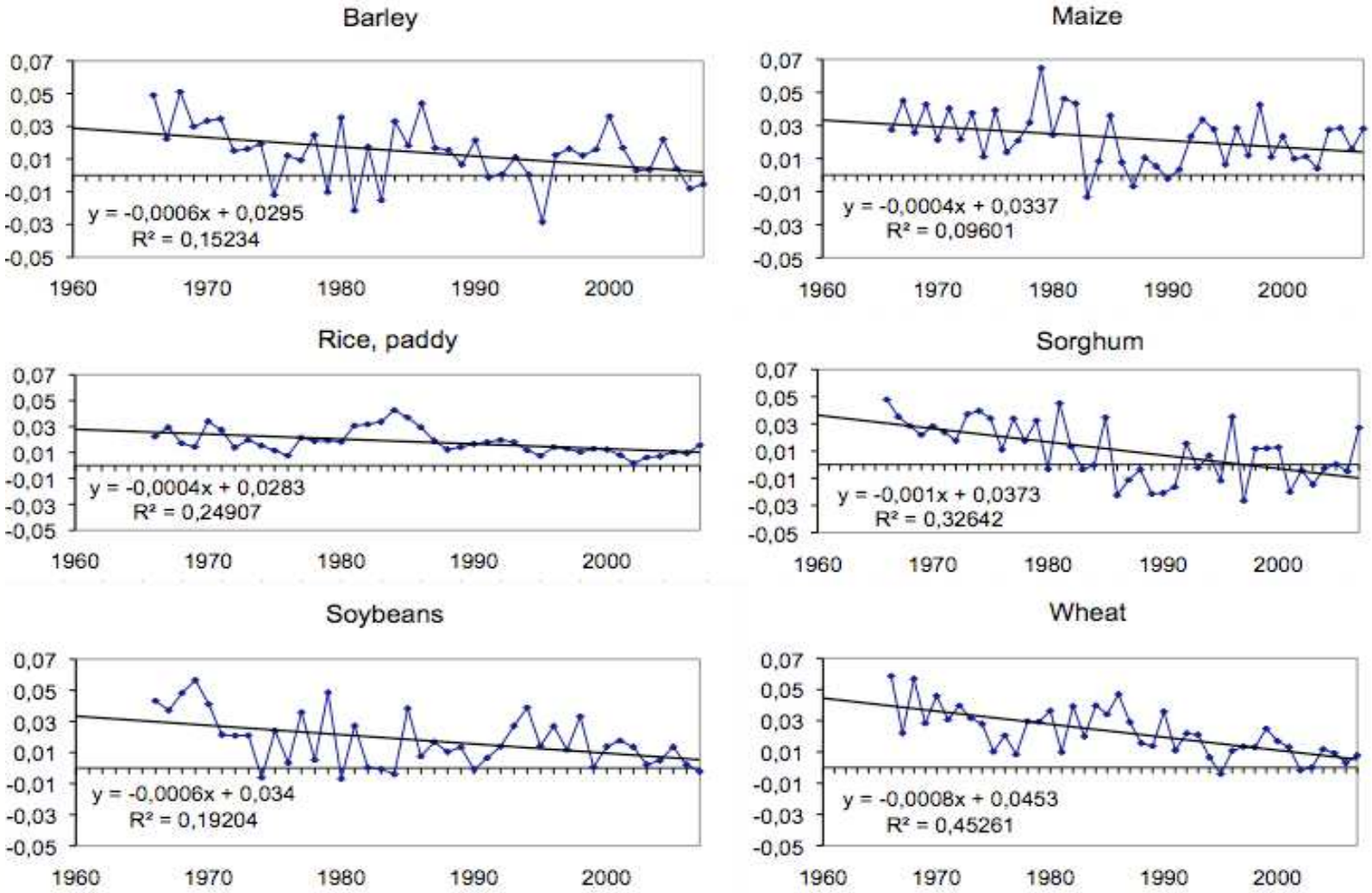
Growth in livestock means growth in demand for crops



Relative yield growth is slowing

5 year moving averages



Source: based on FAOSTAT online data 2008 presented by Dr Stefan Bringezu.

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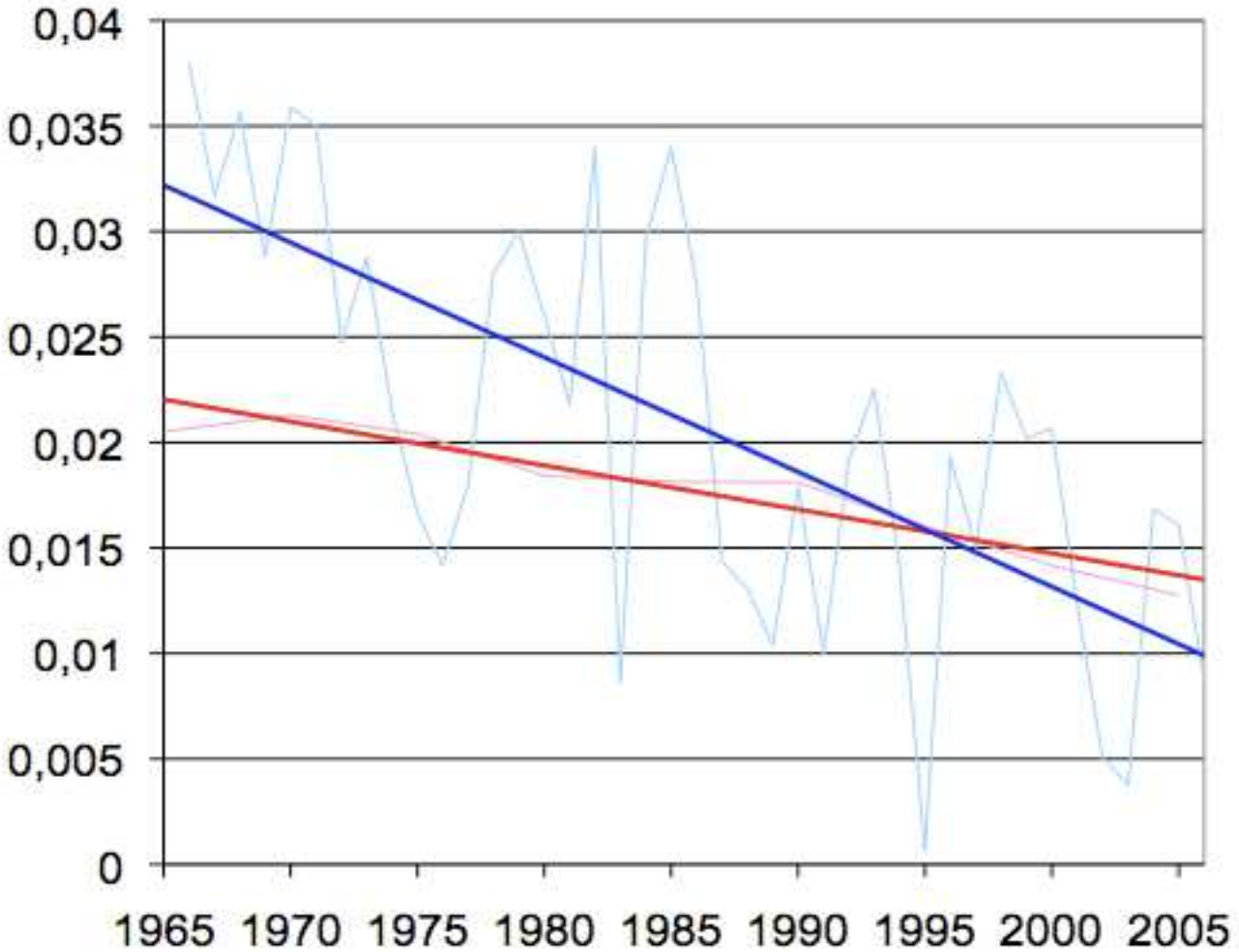
and Energy

Population growth now exceeds crop yield growth



Population
Cereal yields
Linear(Population)
Linear(Cereal yields)

y = -0.0002x + 0.0222
R2 = 0.937

y = -0.0005x + 0.0327
R2 = 0.4608

Source: UN population statistics online; FAOSTAT online, presented by Dr Bringezu

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for Climate, Environment
and Energy

Interim conclusion I

There must be either:

An expansion in cropland

or

Increased rate of growth in agricultural productivity

But there are constraints…..

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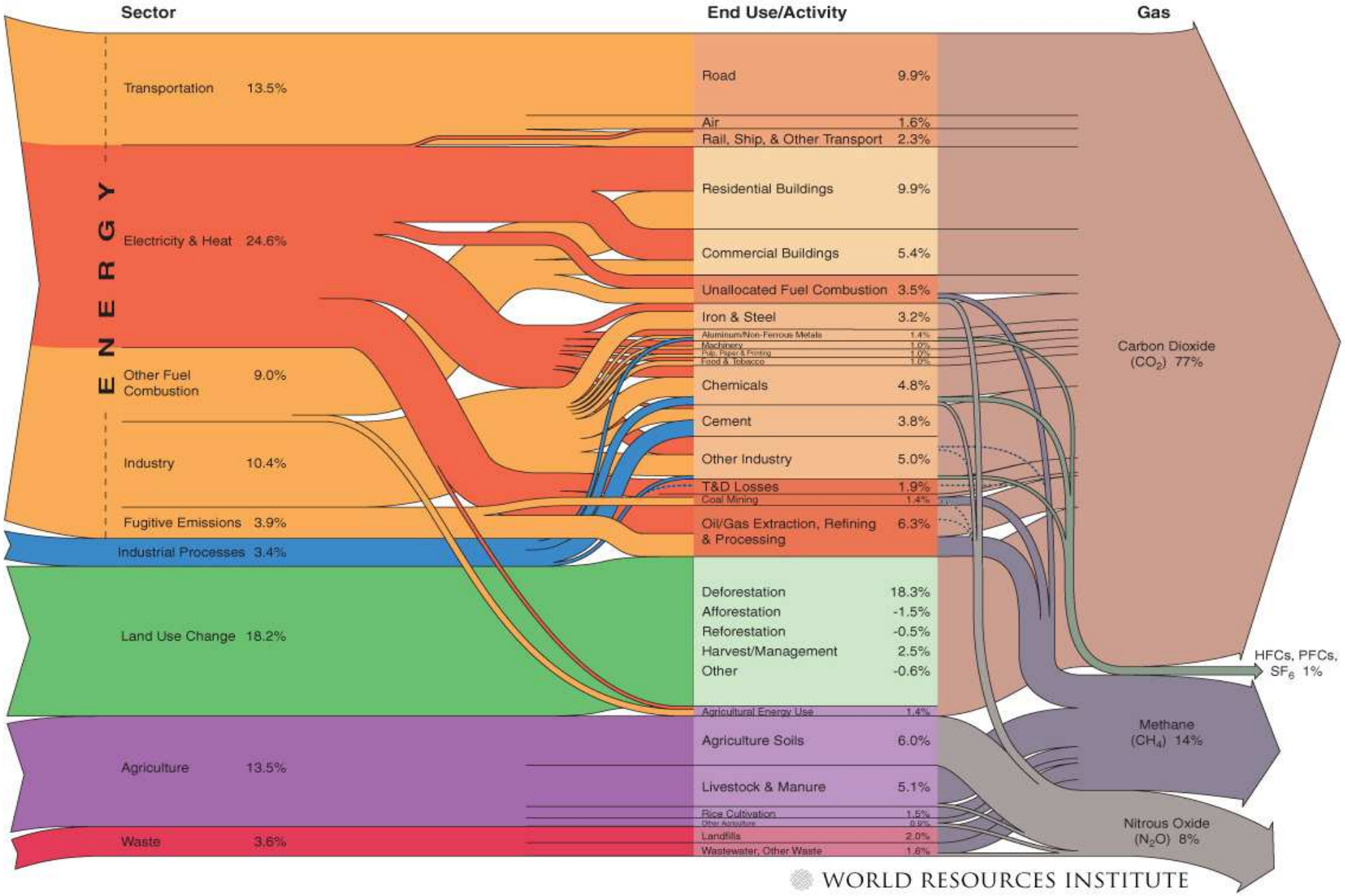
“Climate change is probably the greatest long-term challenge facing the human race.”

Tony Blair – Climate Change: The UK Programme 2006 (Defra)

World GHG Emissions Flow Chart



Land-use change is responsible for ca 18% of GHG emissions

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Reasons are complex – but growth in demand for meat is a key underlying driver

The forest frontier in Mato Grosso de Sol, Brazil

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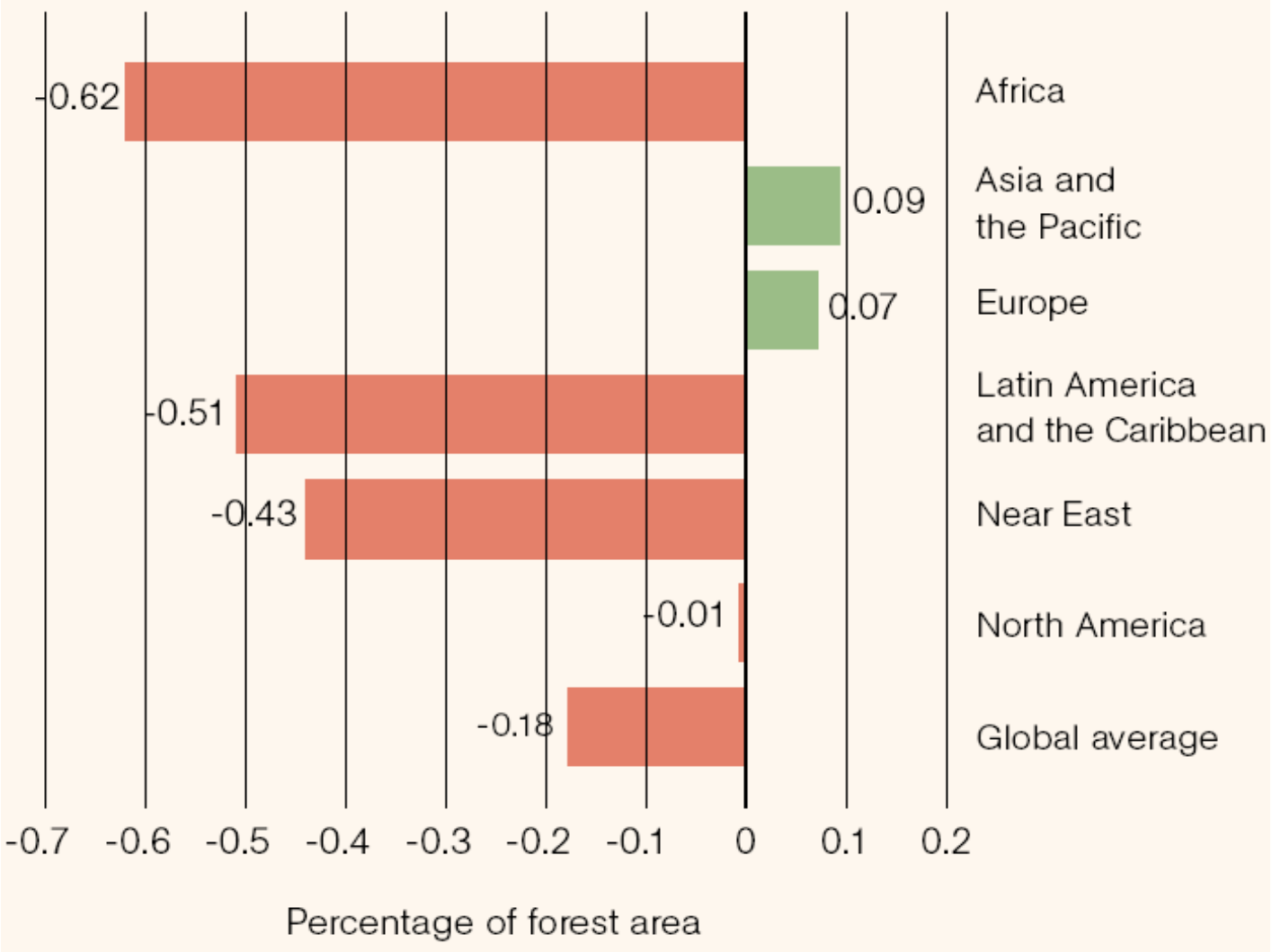
Annual net change in forest area 2000-2007



Source: FAO 2006, State of the world's forests

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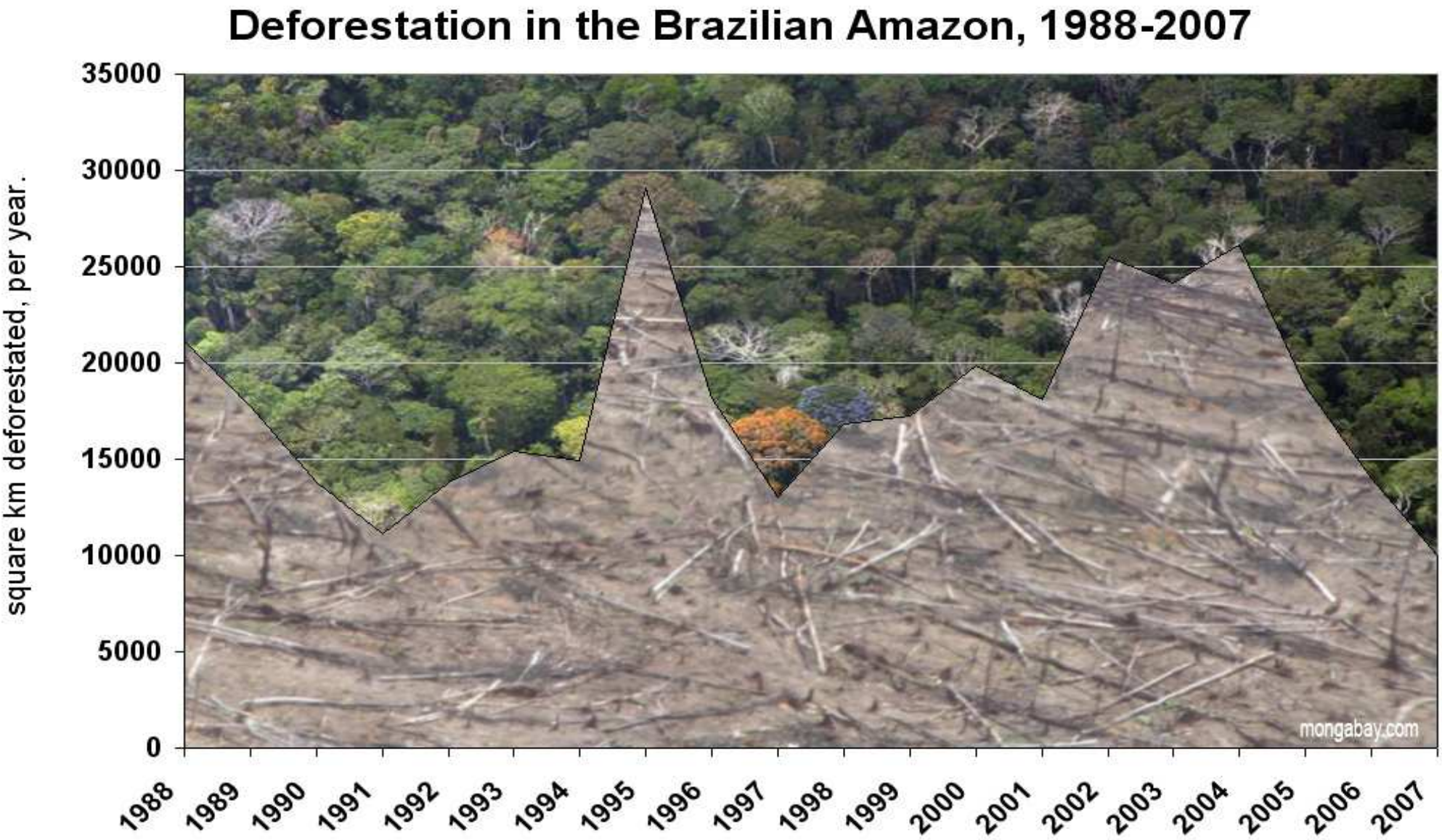
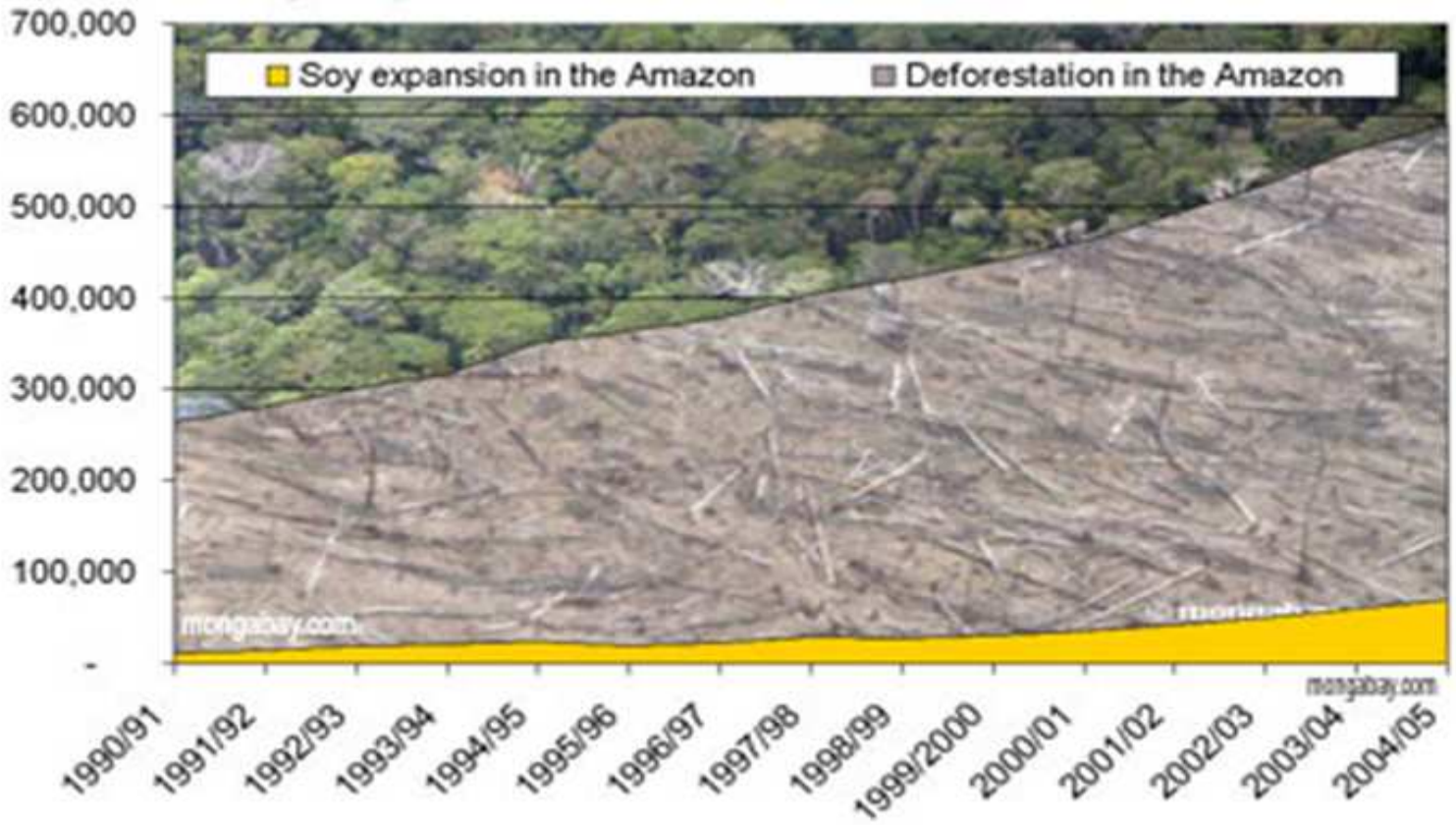


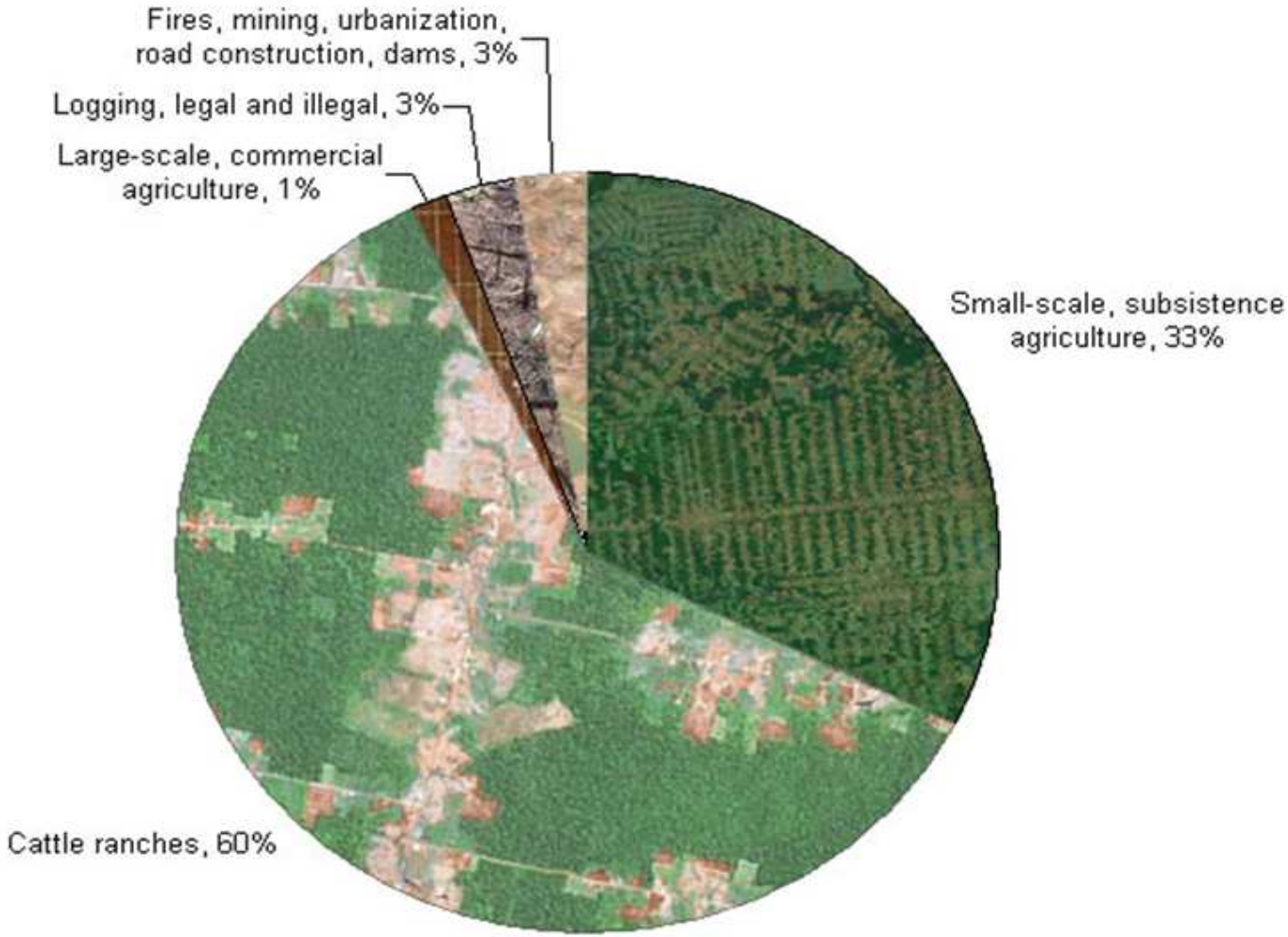
Source: Mongabay.com

Soy expansion in the Amazon in 2000-2005



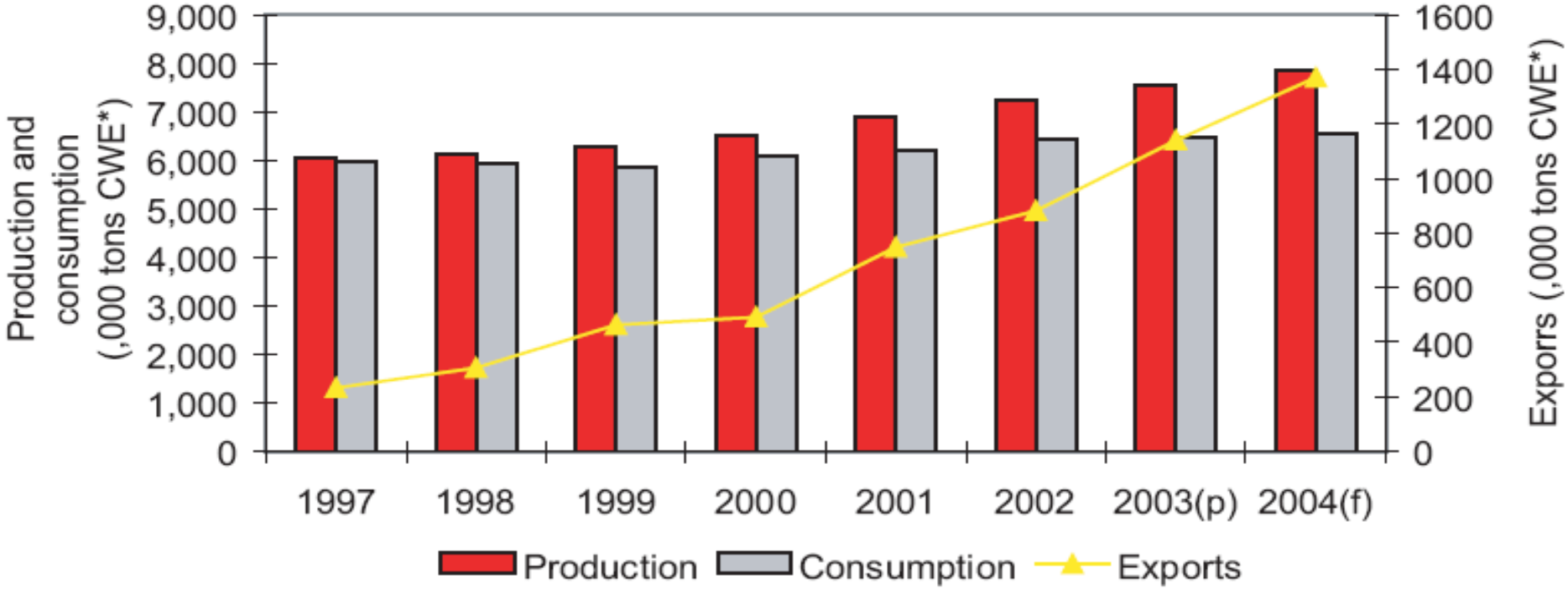
Source: Mongabay.com

Use of land in the Amazon deforested in 2000-2005



Source: Mongabay.com

Changes in Brazilian beef production and consumption between 1997 - 2004



Source: United States Department of Agriculture (USDA),

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Hamburger Connection Fuels Amazon Destruction[1]

Cattle ranching and deforestation in Brazil's Amazon

CENTER FOR INTERNATIONAL FORESTRY RESEARCH
David Kaimowitz, Benoit Mertens, Sven Wunder and Pablo Pacheco

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Interconnected commodity markets driving agriculture north

Credit Aliança da Terra

Source: Paula Fridman/Carbis, Business Week May 22, 2008

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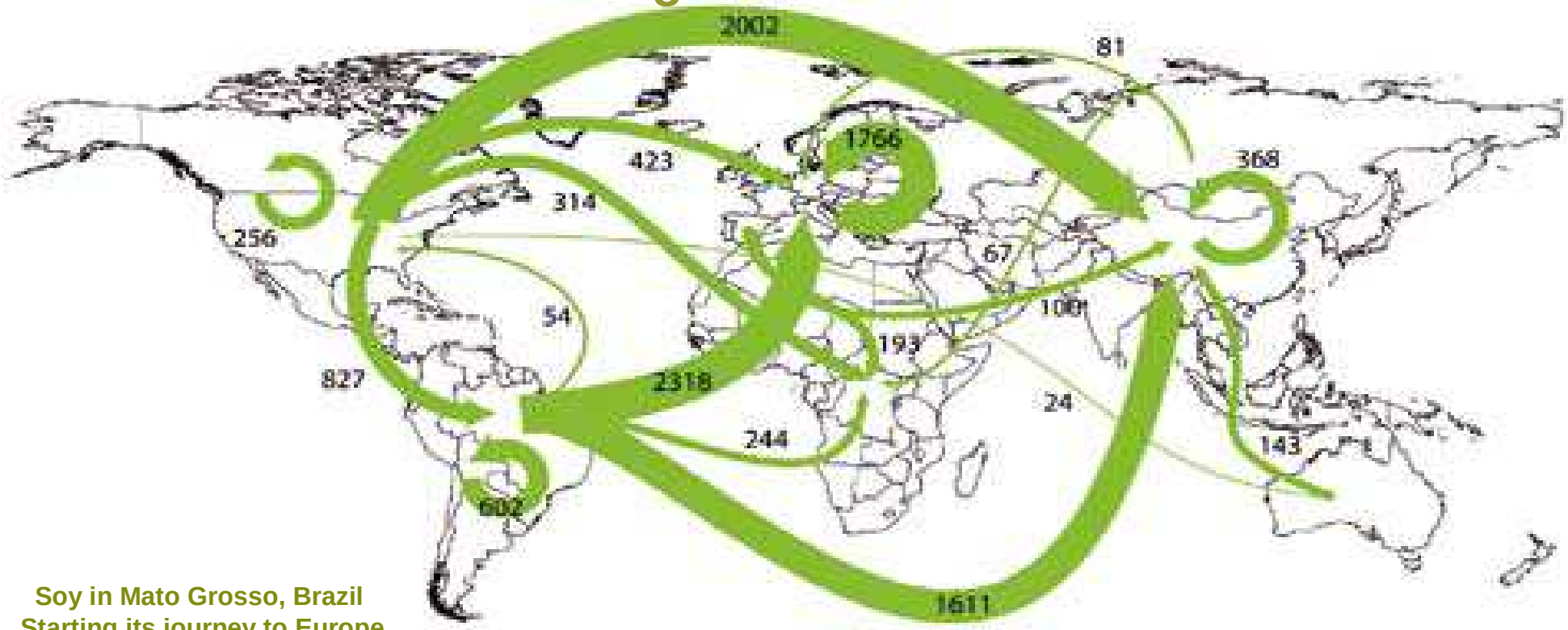
Nitrogen contained in internationally traded crops
‘Nitrogen miles’



Soy in Mato Grosso, Brazil
Starting its journey to Europe

Source: Lalo de Almaida for the New York Times

2004 data in thousands of tons of N; minimum requirement for drawing a line is 20,000 tons N. The total amount of nitrogen transferred in the trade of crop commodities was 11.5 million tonnes in 2004.
(From Braun, 2007).

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Pastoralism is at the nexus of development issues

Economic activity based on sustainable management of natural resource

Food security

Diet quality

Greenhouse gas emissions

Global resource use

Land-use change

Sustainable consumption and production - LCA

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Life-cycle assessment

Life-cycle assessment links emissions to products – key to sustainable consumption

Attributional Life-Cycle Assessment is an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying energy and materials used and wastes released to the environment, and to evaluate and implement opportunities to affect environmental improvements. (SETAC, 1990)

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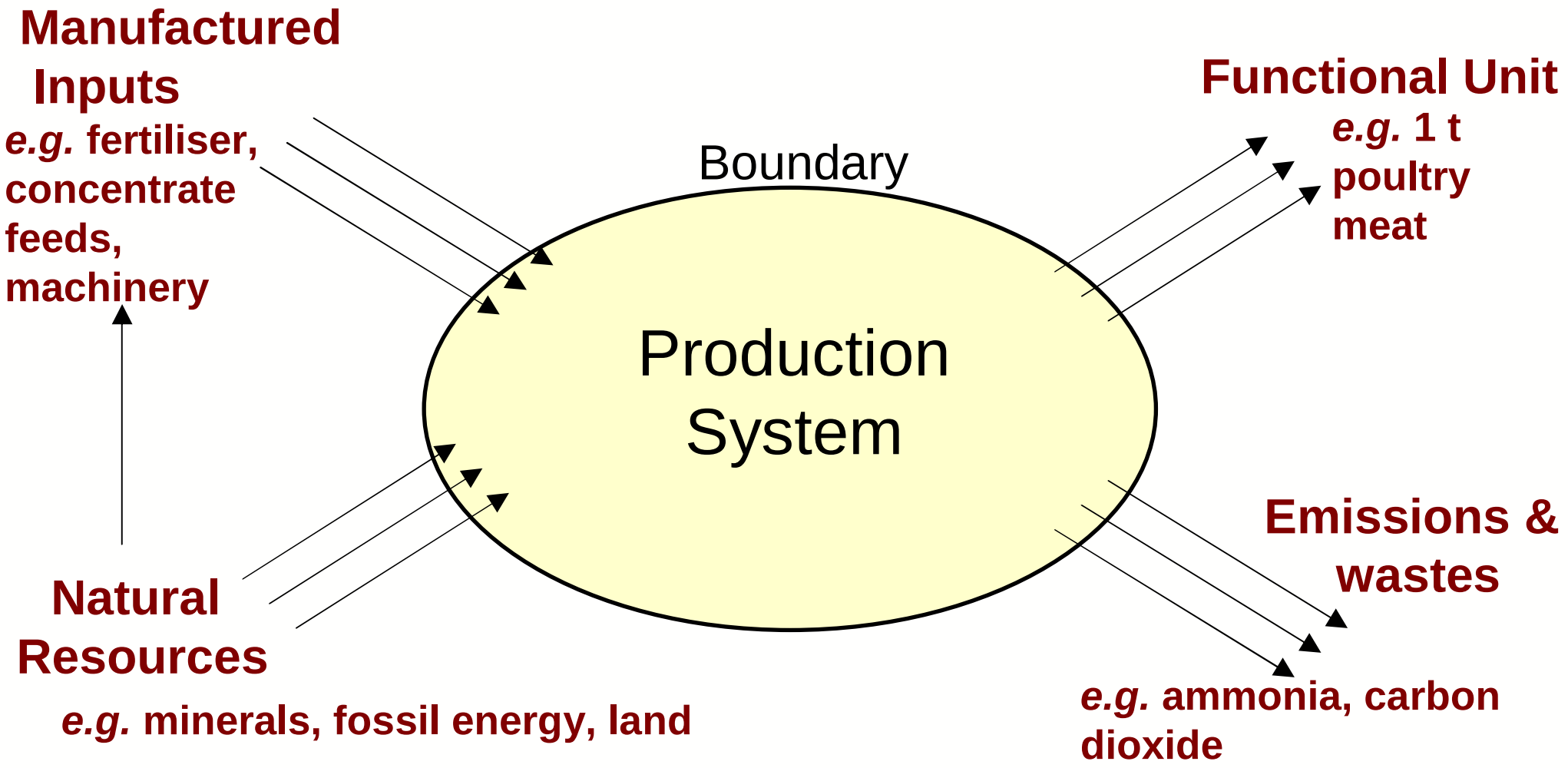
Analysis of a production system

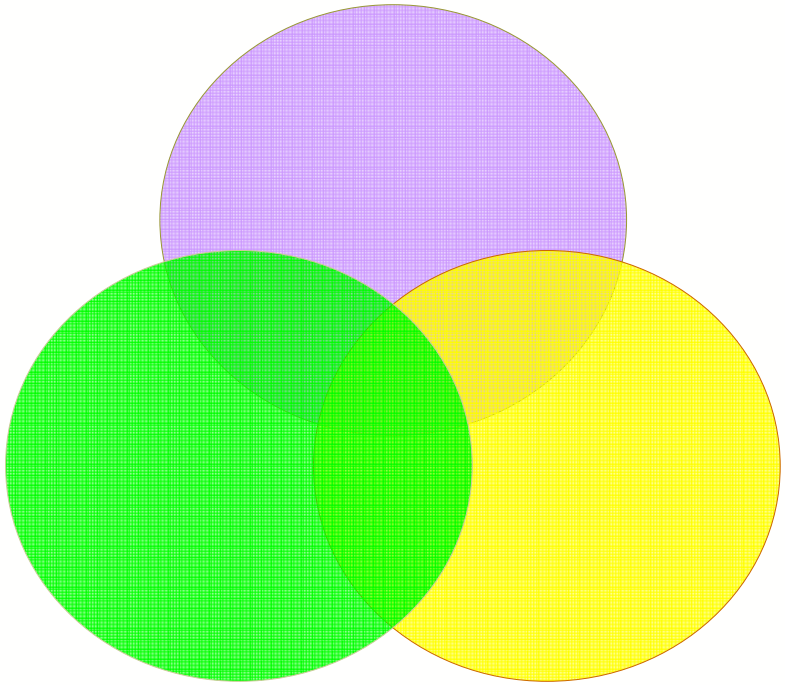
Inputs = Outputs

Mass flows measured at the system boundary must balance



What can you do with an assessment?

Policymakers



Producers

- ‘Eco-design’ of production

Consumers

- Sustainable consumption

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The ‘Cranfield’ Study (Defra project IS0205)

- Industry structure models
- Soil, crop & livestock process models
- Provides ability to address a wide range of questions

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Land use by UK sheep and cattle is higher than for pigs and poultry

Primary energy and land use in UK animal production 1 tonne of carcass meat, milk dry matter, 20,000 eggs

Commodity	Primary energy used, MJ	Grade 2, ha	Grade 3a, ha	Grade 3b, ha	Grade 4, ha	Grade 1, ha	Grade 5, ha
Pig meat	23043	0.00	0.65	0.00	0.00	0.00	0.01
Poultry	16696	0.00	0.61	0.00	0.00	0.00	0.00
Beef	30210	0.03	0.63	0.81	0.65	0.00	1.32
Sheep meat	21834	0.07	0.49	1.32	1.06	0.00	2.65
Milk	26596	0.22	0.96	-0.06	-0.05	0.03	-0.10
Eggs	15710	0.00	0.54	0.00	0.00	0.00	0.01

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Emissions from UK sheep and cattle are higher than for pigs and poultry

Emissions in UK animal production 1 tonne of carcass meat, milk dry matter, 20,000 eggs

Commodity	GWP100, kg CO2	Eutroph-ication potential, kg PO4 eqv.	Acid-ification potential, kg SO2 eqv.	NO3-N, to water, kg	NH3-N, to air, kg	N2O-N, to air, kg	Total N emitted, kg	CH4, to air, kg
Pig meat	4006	66	241	30	41	3	87	34
Poultry	2687	32	96	27	17	3	55	2
Beef	12114	121	296	104	64	9	185	239
Sheep meat	14605	207	495	191	36	10	286	310
Milk	10078	50	143	51	40	6	112	220
Eggs	2932	40	140	27	27	3	70	4

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But UK sheep and cattle use less soy

Primary energy use, emissions and soy use in UK animal production 1 tonne of carcass meat, milk dry matter, 20,000 eggs

Commodity	Primary energy used, MJ	GWP100, kg CO2	Soy use t/t
Pig meat	23043	4006	0.85
Poultry	16696	2687	0.62
Beef	30210	12114	0.14
Sheep meat	21834	14605	0.15
Milk	26596	10078	0.21
Eggs	15710	2932	0.52

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Qualifications on (attributional) LCA

- **Steady states - not transition**
- **Soil C not included**
- **N_2O/methane could be calculated by other methods**
- **Uncertainty in emissions data**
- **Activity data are limited**
- **Not about environmental performance of individual farms or biodiversity**
- **Burdens, not impacts**
- **Examines products statically – does not examine effects of change**

- **Land-use change (e.g. deforestation) not included**

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Assessing the environmental performance of African grassland based production

Giocomo Pirozzi/PANOS

The productivity – tonnes in 2005

Country	Beef and buffalo meat	Cows milk	Sheep and goat meat	Ruminant meat trade kg/ha pasture
Burundi	5,800	16,800	3,900	0.0
Eritrea	16,650	39,200	11,400	0.0
Ethiopia	350,000	1,580,000	124,000	0.0
Kenya	390,000	3,500,000	75,000	0.0
Rwanda	22,000	120,000	5,300	0.1
Sudan	340,000	5,300,000	334,000	0.0
Tanzania	247,000	850,000	40,850	0.0
Uganda	106,000	795,000	34,800	0.1
South Africa	704,950	2,870,870	151,747	0.9
Mongolia	47,000	300,000	102,000	0.0
India	2,833,850	95,619,000	762,000	0.0
Kazakhstan	345,000	4,749,000	117,700	0.0
Kyrgystan	90,850	1,197,660	46,374	0.0
Turkmenistan	100,000	1,400,000	96,500	0.0
Uzbekistan	518,100	5,004,879	736,000	0.0
New Zealand	632,378	15,841,624	574,755	65.9
United Kingdom	850,000	14,450,000	330,000	53.1

Source: FAOSTAT

The livestock resource – in 2005

Country	Number of cattle and buffalos	Number of sheep and goats	Pasture (ha)	Rainfall index (mm)
Burundi	395,741	1,142,933	950,000	1042
Eritrea	1,950,000	3,950,000	6,967,000	323
Ethiopia	40,390,098	37,097,961	20,000,000	1050
Kenya	13,019,000	23,916,500	21,300,000	998
Rwanda	1,004,100	1,734,000	520,000	1115
Sudan	40,468,000	92,323,000	117,180,000	741
Tanzania	17719,091	16,071,000	43,000,000	1116
Uganda	6,770,000	9,400,000	5,112,000	1401
South Africa	13,790,000	31,690,000	83,928,000	640
Mongolia	1,841,600	23,924,400	129,294,000	156
India	279,712,000	187,760,000	11,040,000	1432
Kazakhstan	5,212,900	13,409,100	185,098,000	277
Kyrgystan	1,034,890	3,773,617	9,291,000	419
Turkmenistan	2,024,500	15,089,000	30,700,000	104
Uzbekistan	6,571,400	11,351,900	22,800,000	264
New Zealand	9,510,802	40,034,660	13,863,000	1248
United Kingdom	10,378,000	35,345,048	11,000,000	1129

Source: FAOSTAT

Animal output – in 2005

Country	Cattle and buffalo meat (kg/animal)	Sheep and goat meat (kg/animal)	Milk yield per cow kg/cow
Burundi	15	3	294
Eritrea	9	3	196
Ethiopia	9	3	200
Kenya	30	3	482
Rwanda	22	4	480
Sudan	8	4	366
Tanzania	14	3	174
Uganda	16	4	350
South Africa	51	5	2,975
Mongolia	26	4	407
India	10	5	109
Kazakhstan	66	9	198
Kyrgystan	88	12	214
Turkmenistan	49	6	139
Uzbekistan	79	7	158
New Zealand	67	14	3,553
United Kingdom	82	9	7,190

Source: FAOSTAT

Enteric methane emissions

Enteric fermentation emission factors (EF) for cattle (kilogram CH_4 per head per year) by production system and world region. Tier 2 based estimates compared to tier 1 emission factors

Region	Dairy cattle				Other cattle				
	Grazing	Mixed	Weighted EF	Tier 1 EF	Grazing	Mixed	Industrial	Weighted EF	Tier 1 EF
Sub-Saharan Africa	79	39	60	36	44	27	-	36	32
Asia excluding China and India	79	53	54	56	66	38	-	38	44
India	70	45	45	46	41	17	-	18	25
China	102	63	84	56	85	38	-	49	44
Central and South America	93	62	78	57	58	33	23	47	49
West Asia and North Africa	91	60	61	36	49	31	-	32	32
North America	115	100	100	118	50	33	26	35	47
OECD excluding North America	102	97	98	100	45	27	26	32	48
Eastern Europe and the CIS	-	59	59	81	-	45	24	41	56
Other developed	96	129	99	36	45	27	28	45	32

Estimates of enteric methane emission from livestock in different world regions (from Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Hann, Cees. 2006. Livestock's Long Shadow. FAO).

Nitrous oxide emissions from manure

Region/country	N_2O emissions from manure management, after application/deposition on soil and direct emissions						
	Dairy cattle	Other cattle	Buffalo	Sheep and goats	Pigs	Poultry	Total
	million tonnes per year						
Sub-Saharan Africa	0.06	0.21	0.00	0.13	0.01	0.02	**0.43**
Asia excluding China and India	0.02	0.14	0.06	0.05	0.03	0.05	**0.36**
India	0.03	0.15	0.06	0.05	0.01	0.01	**0.32**
China	0.01	0.14	0.03	0.10	0.19	0.10	**0.58**
Central and South America	0.08	0.41	0.00	0.04	0.04	0.05	**0.61**
West Asia and North Africa	0.02	0.03	0.00	0.09	0.00	0.03	**0.17**
North America	0.03	0.20	0.00	0.00	0.04	0.04	**0.30**
Western Europe	0.06	0.14	0.00	0.07	0.07	0.03	**0.36**
Oceania and Japan	0.02	0.08	0.00	0.09	0.01	0.01	**0.21**
Eastern Europe and CIS	0.08	0.10	0.00	0.03	0.04	0.02	**0.28**
Other developed	0.00	0.03	0.00	0.02	0.00	0.00	**0.06**
Total	**0.41**	**1.64**	**0.17**	**0.68**	**0.44**	**0.36**	**3.69**
Livestock Production System							
Grazing	0.11	0.54	0.00	0.25	0.00	0.00	**0.90**
Mixed	0.30	1.02	0.17	0.43	0.33	0.27	**2.52**
Industrial	0.00	0.08	0.00	0.00	0.11	0.09	**0.27**

from Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Hann, Cees. 2006. Livestock's Long Shadow. FAO).

Primary energy use and direct emissions from UK livestock production

Commodity (1 tonne carcase meat or raw milk)	Primary energy use (MJ)	Global warming potential (kg CO2)	N2O (kg)	CH4 (kg)	Fossil fuel CO2 (kg)	Land-use change CO2 (kg)
UK livestock emissions without land-use change						
Beef	30210	12114	13.50	239	1837	0
Sheep meat	21834	14605	15.70	310	1381	0
Milk	2660	1008	0.94	22	169	0
UK livestock emissions in CO2 equivalents						
Beef	30210	12114	3996 (33%)	5497 (45%)	1837 (15%)	0
Sheep meat	21834	14605	4647 (32%)	7130 (49%)	1381 (9%)	0
Milk	2660	1008	278 (28%)	506 (50%)	169 (17%)	0

(From Defra project report IS0205, using data updated in 2009)

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Primary energy use and direct emissions from UK and African livestock production

Commodity (1 tonne carcase meat or raw milk)	Primary energy use (MJ)	Global warming potential (kg CO2)	N2O (kg)	CH4 (kg)	Fossil fuel CO2 (kg)	Land-use change CO2 (kg)
UK livestock emissions in CO2 equivalents without land use change						
Beef	30,210	12,114	3,996	5,497	1,837	0
Sheep meat	21,834	14,605	4,647	7,130	1,381	0
Milk	2,660	1,008	278	506	169	0
African livestock emissions in CO2 equivalents						
Beef	0	39,887-60,403	15,392	24,495-45,011	0	0
Sheep/Goat meat	0	38,347-56,310	26,640	11,707-29,670	0	0
Cows milk	0	5,718	888	4,830	0	0

Primary energy use and emissions incl. LUC from UK and African livestock production

Commodity (1 tonne carcase meat or raw milk)	Primary energy use (MJ)	Global warming potential (kg CO2)	N2O (kg)	CH4 (kg)	Fossil fuel CO2 (kg)	Land-use change CO2 (kg)
UK livestock emissions in CO2 equivalents						
Beef	30,210	42,114	3,996	5,497	1837	20,000
Sheep meat	21,834	44,605	4,647	7,130	1381	20,000
Milk	2,660	3,008	278	506	169	2,000
Extensive production from natural grassland in Africa						
Beef	0	39,887-60,403	15,392	24,495-45,011	0	0
Sheep/Goat meat	0	38,347-56,310	26,640	11,707-29,670	0	0
Cows milk	0	5,718	888	4,830	0	0

Interim conclusion II

Biogenic emissions from African production are likely to be high on a per unit output basis

There are huge uncertainties in the data – but we can conclude African produce cannot be marketed as ‘low carbon’ on the basis on conventional attributional LCA

But policy is about change – the question then is: will market development improve the global environment compared with business as usual?

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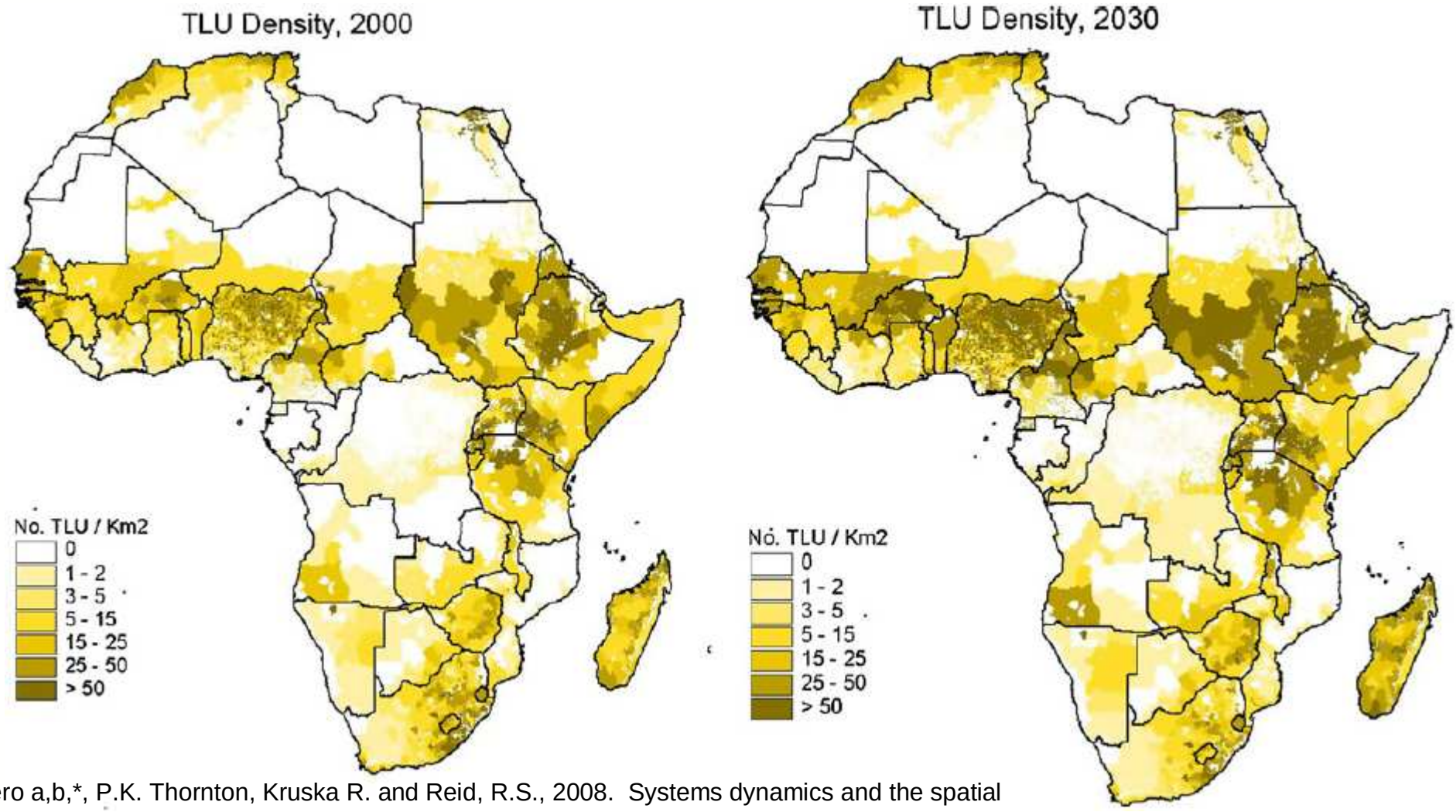
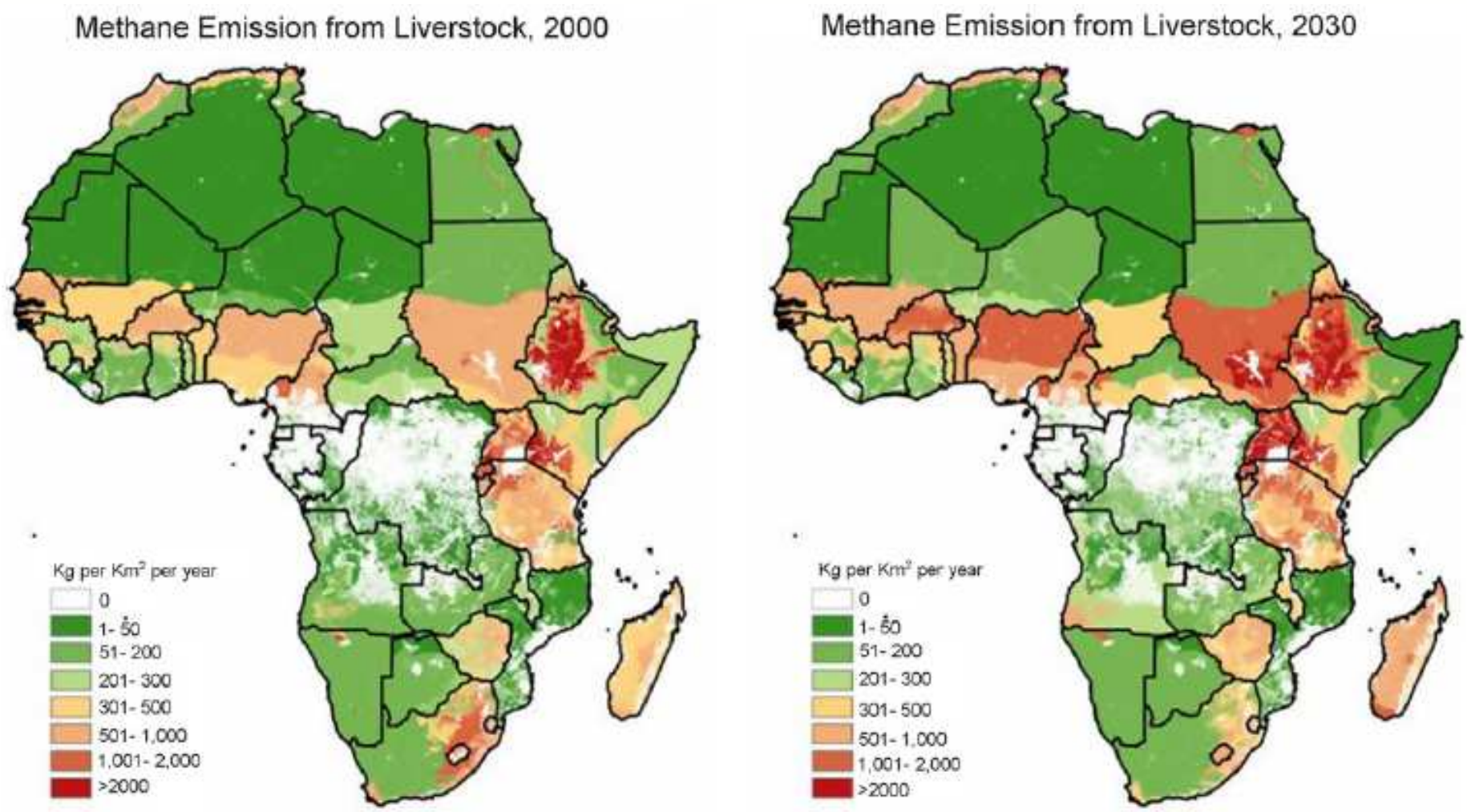
Influencing change – livestock numbers under business as usual



M. Herrero a,b,*, P.K. Thornton, Kruska R. and Reid, R.S., 2008. Systems dynamics and the spatial distribution of methane emissions from African domestic ruminants to 2030. Agricultural systems and environment 126: 122-137.

Influencing change – methane emissions under business as usual



M. Herrero a,b,*, P.K. Thornton, Kruska R. and Reid, R.S., 2008. Systems dynamics and the spatial distribution of methane emissions from African domestic ruminants to 2030. Agricultural systems and environment 126: 122-137.

Final conclusions

Native grasslands are a huge agricultural resource at the nexus of many development and environmental issues

Developed country livestock production systems are eco-efficient as assessed by conventional LCA

Products from native grasslands have higher methane and nitrous oxide emissions – these exceed the GHG benefits of low energy inputs

Attributional LCA cannot adequately assess the environmental implications of development policy for native grasslands. The system needs to be expanded to examine the effect of change on emissions in relation to business as usual and especially indirect land-use change effects.

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Final conclusions

There are huge uncertainties in the data – larger land-use change charges for commercial production and/or revision downwards of estimates for emissions from grassland based production would change the picture.

There is a strong case for using international mechanisms to finance change to reduce emissions – the linked products are low carbon even if their direct emissions are high when the result is improvement.

The other benefits are substantial – biodiversity, soil carbon sequestration, water.

Marketing will need to be linked to local approaches to environmental improvement and stewardship – the customer must be sure that the supply chain results in real improvements in all areas – social, economic, GHGs, biodiversity, animal welfare.

Animal welfare could be a deal maker/breaker.

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The environmental performance of native grassland based livestock production systems

Acknowledgements

A number of individuals gave freely on their time in discussing this work:

Dr Adrian Williams, Cranfield University,
Ms Tara Garnett, University of Sussex;
Prof. Ian Scoones, University of Sussex; UK;
Mr Joe Phelan, Ireland and formally FAO;
Mr Robert Sherriff, Teagasc and Gorta, Ireland.

The consideration of land-use change effects drew on work being conducted by Matthew Brander of Ecometrica in the UK for WWF UK. The study also drew on other work funded by the WWF UK

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