Bioenergy demand driven large scale land-use changes in Brazil

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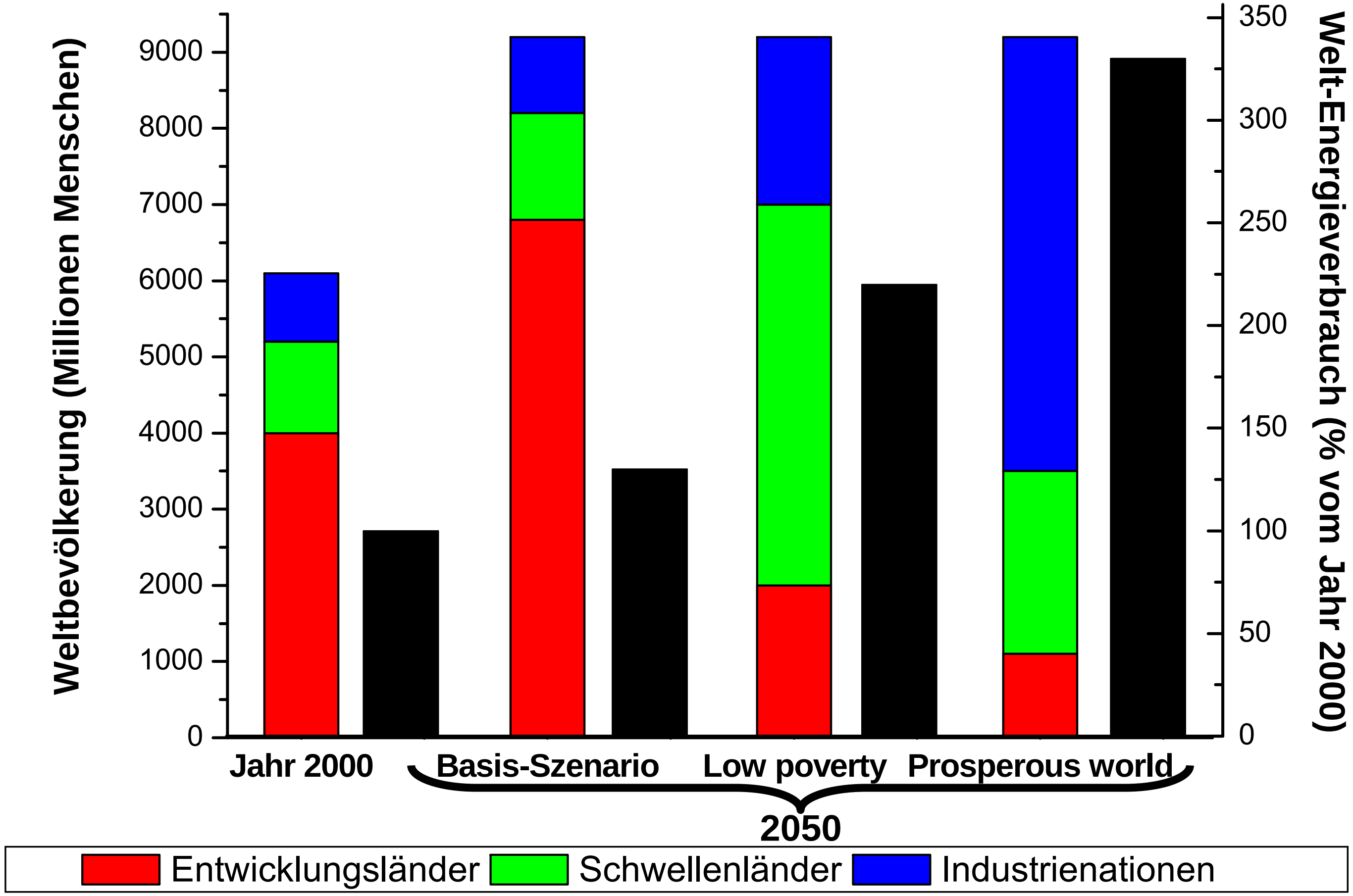
Motivation (1):

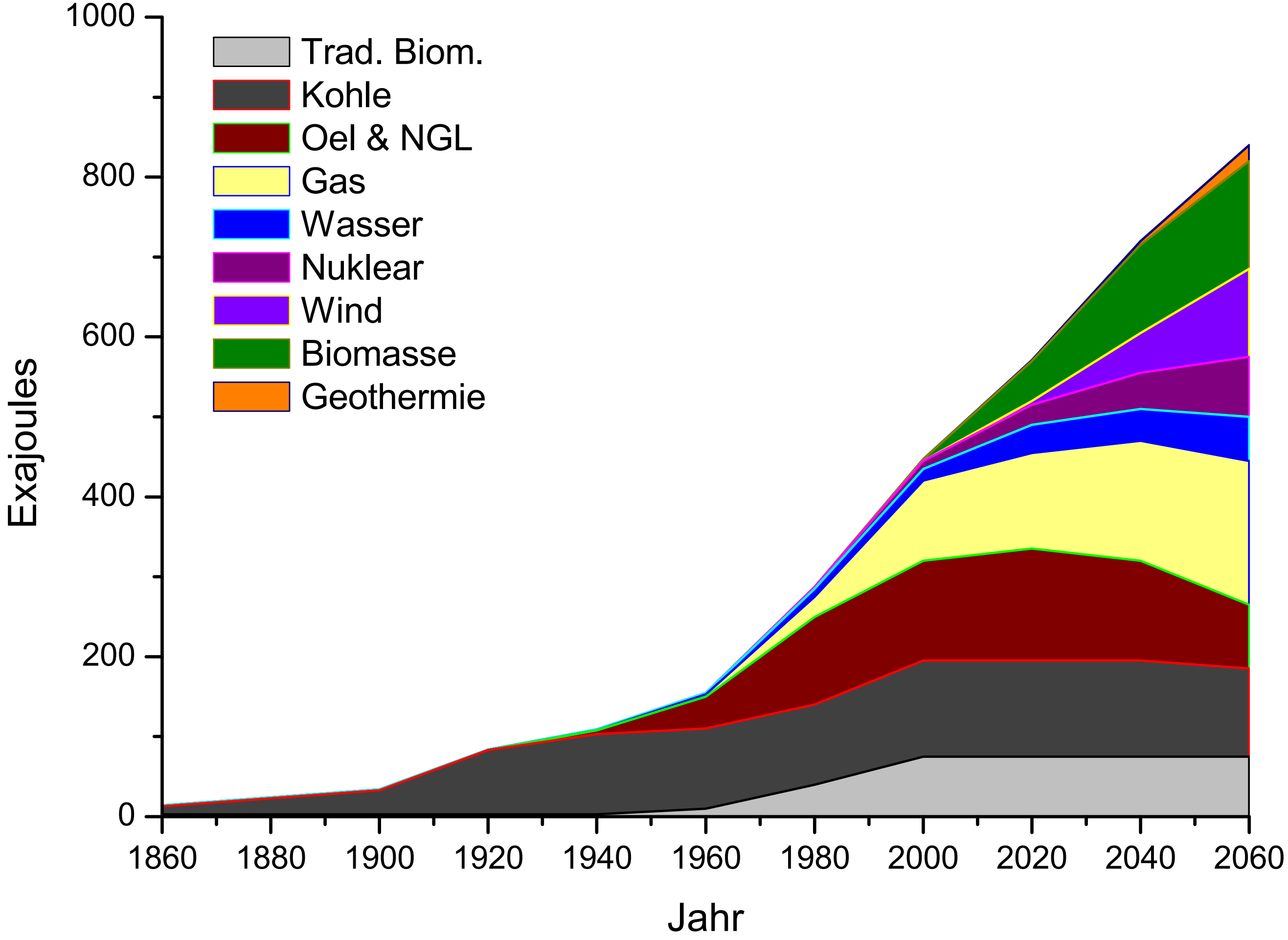
Increase in world population and prosperity results in an increasing energy demand



Data from World Business Council Sustainable Development - 2004

Motivation (2):

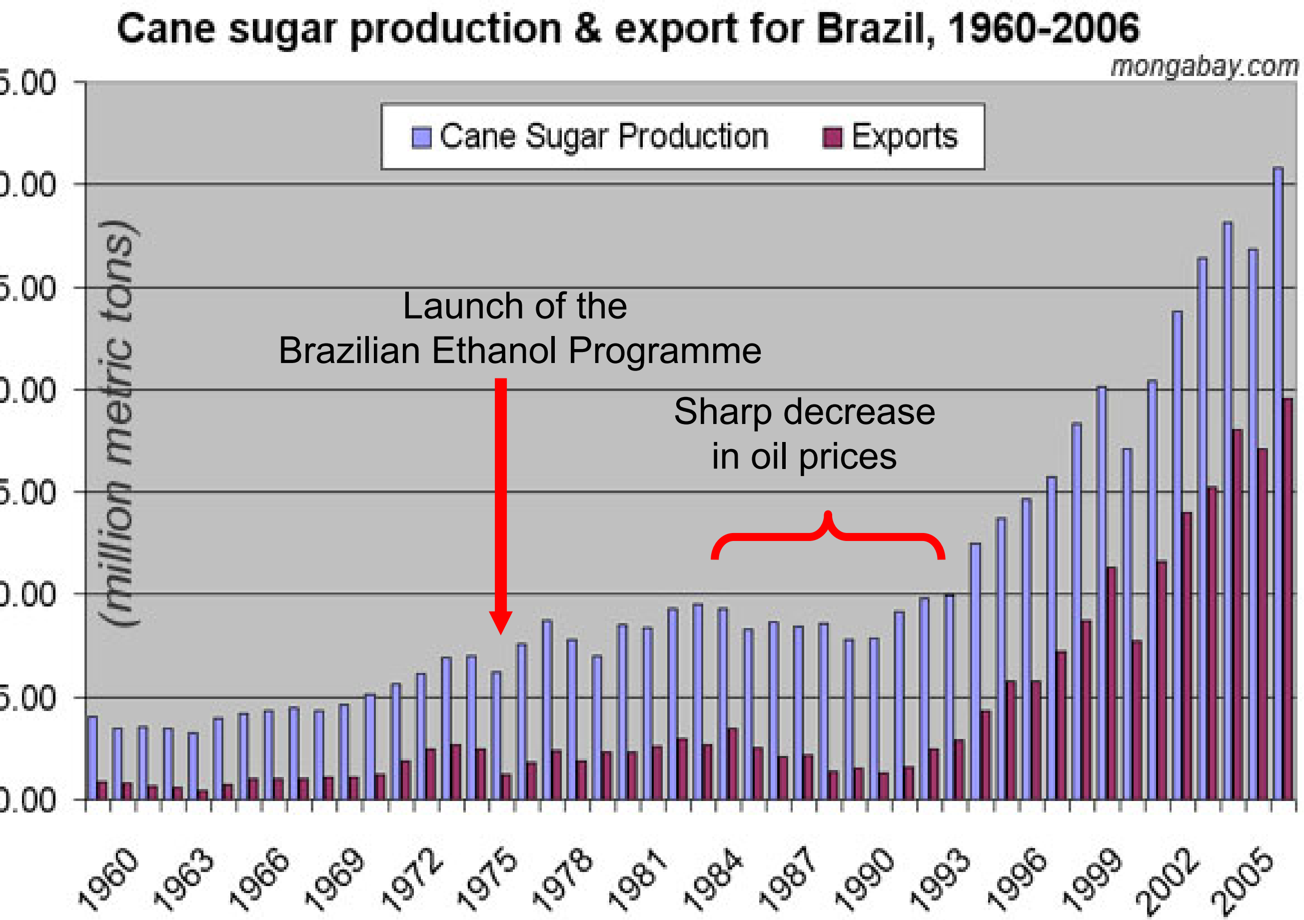
The increasing energy demand cannot be met by fossil fuels. Biofuels are at present intensively discussed as an alternative.

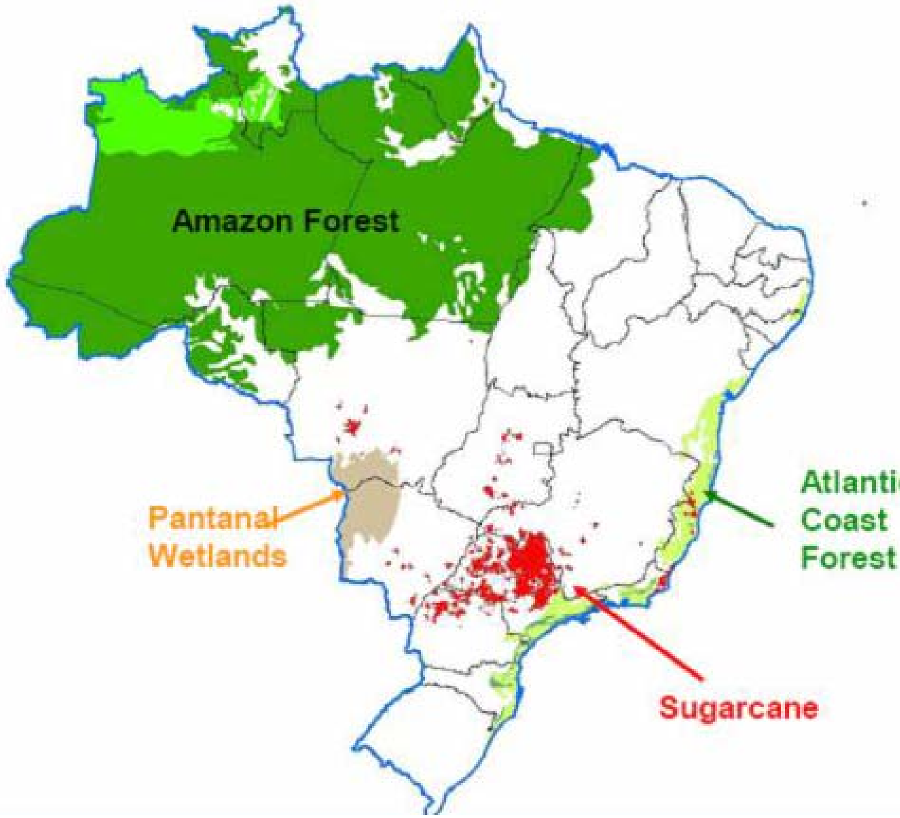


Shell world energy supply scenario: 2000-2060

Bio-Ethanol and Brazil

Brazil has already launched a national Ethanol Programme following the first oil crisis. Brazil is now the #1 exporter for Bio-Ethanol.





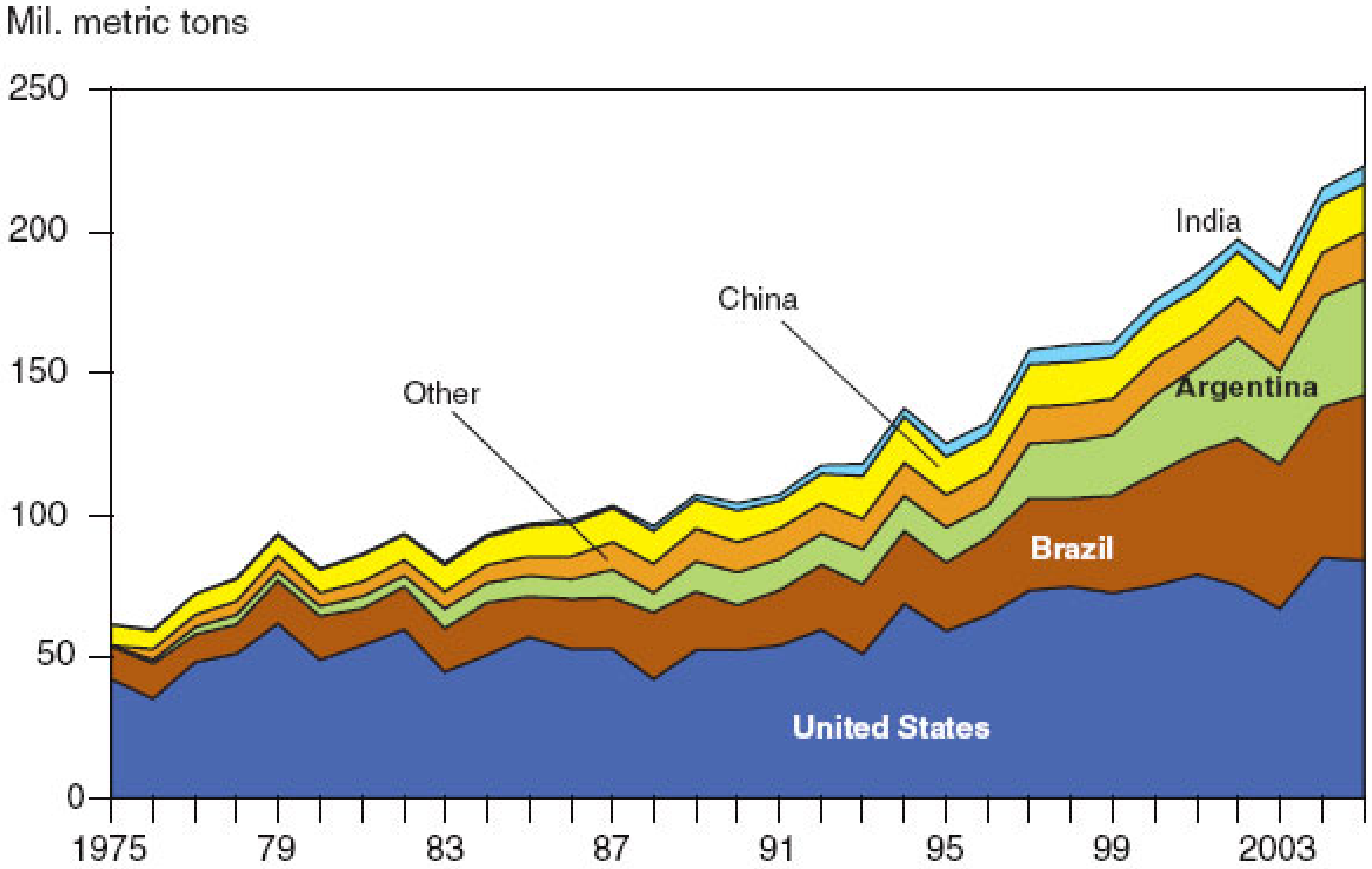
Source: USDA & Mongabay.com

[note 1 ha sugarcane ≈ 5800-6500 l ethanol]

Bio-Diesel and Brazil

Brazil is developing own industries for Biodiesel production. Main crops used for current and future Biodiesel production are soy beans and cotton (seeds).

South American soybean production has grown rapidly since 1980



Source: U.S. Department Agriculture, Foreign Agricultural Service, PS&D database.

Biofuels and land use change in Brazil

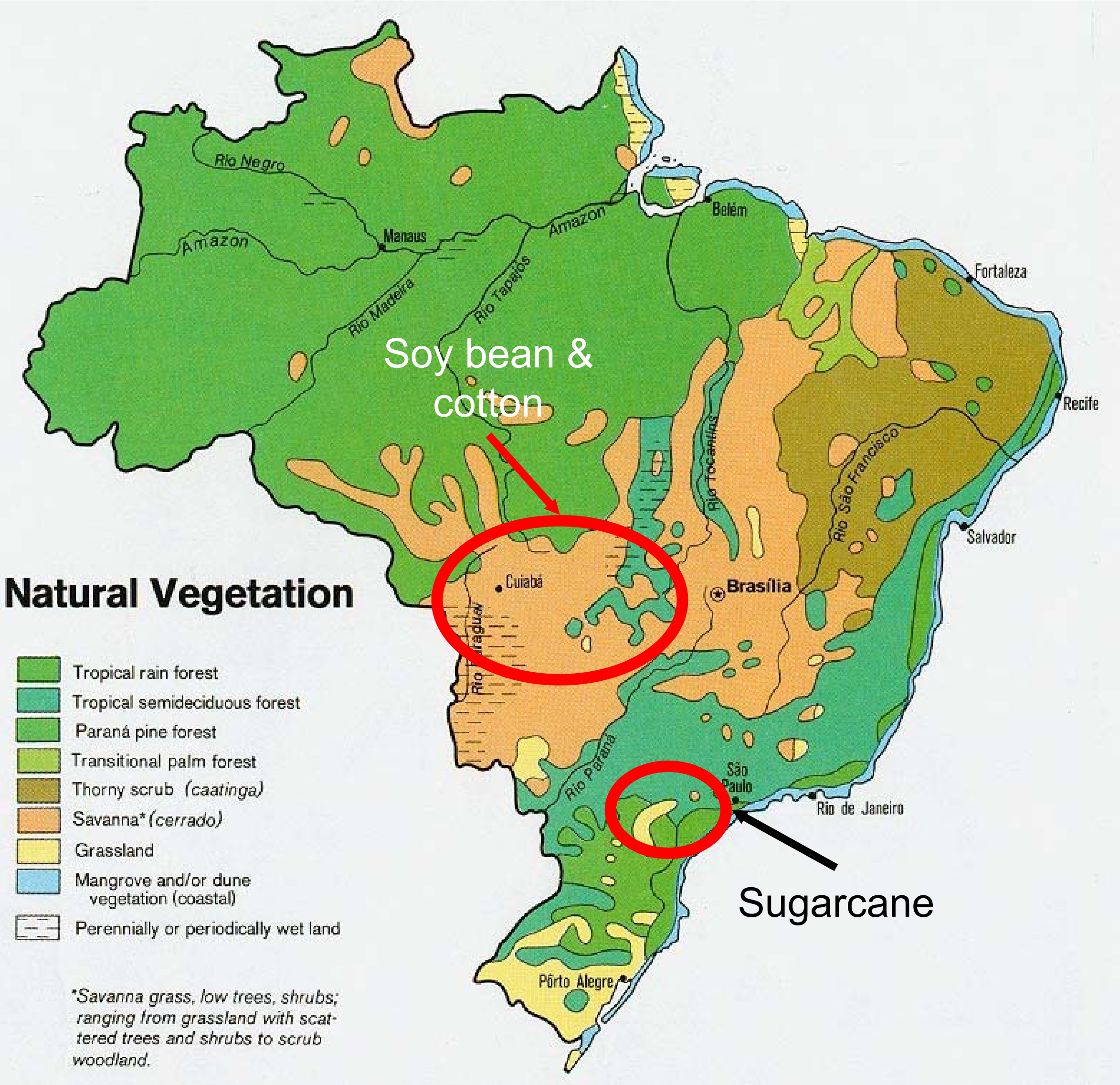
Brazil is largely expanding its cropland on costs of natural rainforest or Savanna (Cerrado) areas or by the conversion of rangelands or other landuses (e.g. coffee plantations) into croplands.

"The primary concern is that the biofuels push will directly or indirectly increase the loss to Brazil's remaining natural high biodiversity areas, such as the Cerrado," (John Buchanan, Conservation International)

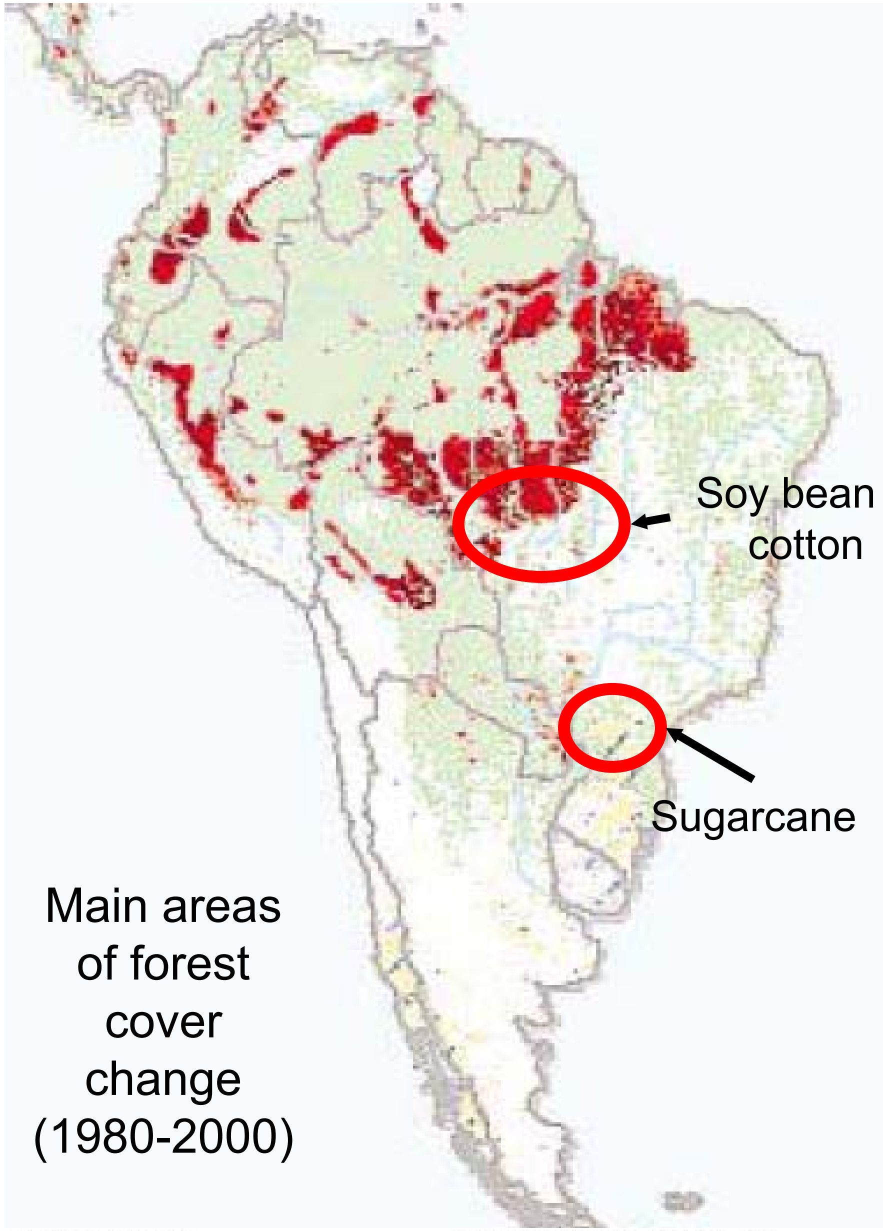
„Most of the expansion required will affect the Cerrado ecosystem and the Amazon, which are already being destroyed because of cattle ranching and soybean farming," (Leonardo Lacerda, WWF-Brazil)

„Growth in Amazon cropland may impact climate and deforestation patterns," (M. Bettwy, Goddard Space Flight Center, Sept 2006)

Hot spots of land use change in Brazil



Recent trends of land use change in South America



Forest cover change
- Hotpsot (low certainty)
- Hotspot (high certainty)

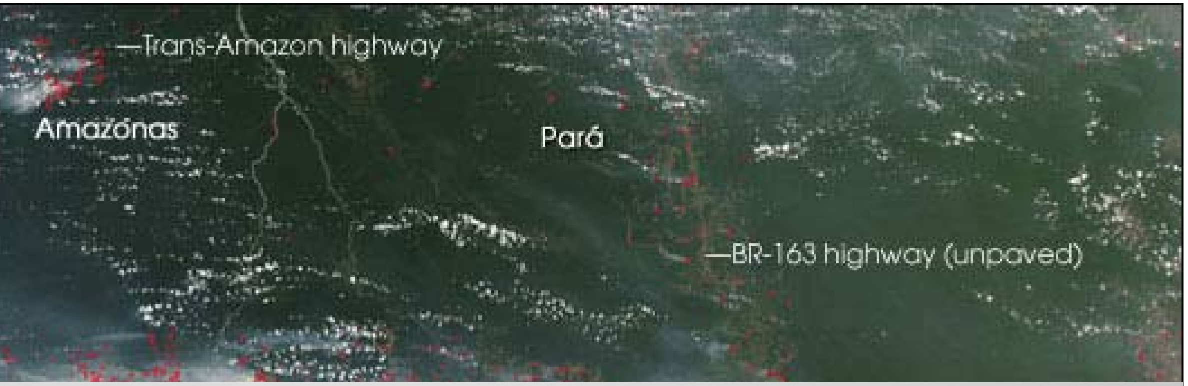
Average annual deforestation rate
- 2.01–3%
- 1.01–2%
- 0.01–1%
- No change or increase in forest

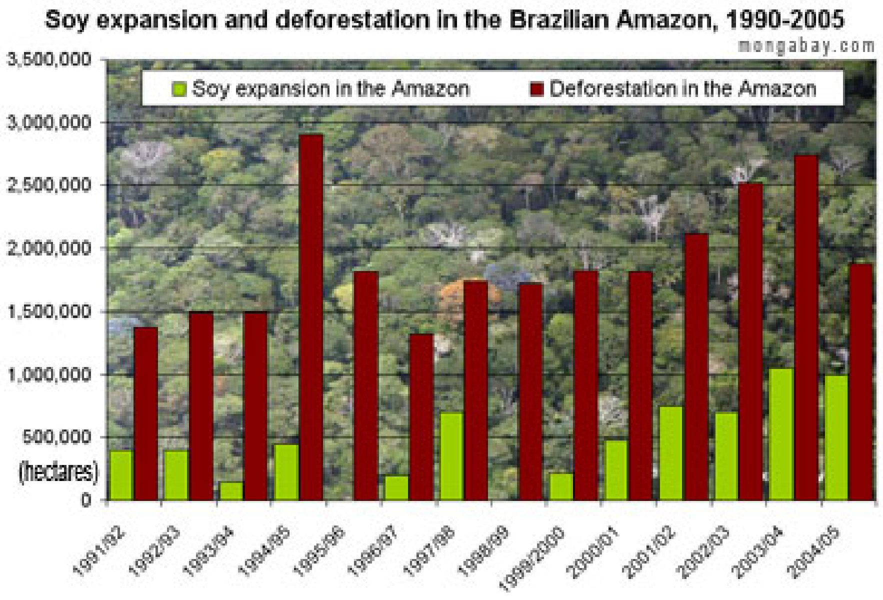
Increase in cropland area
- Hotspot (low certainty)
- Hotspot (high certainty)

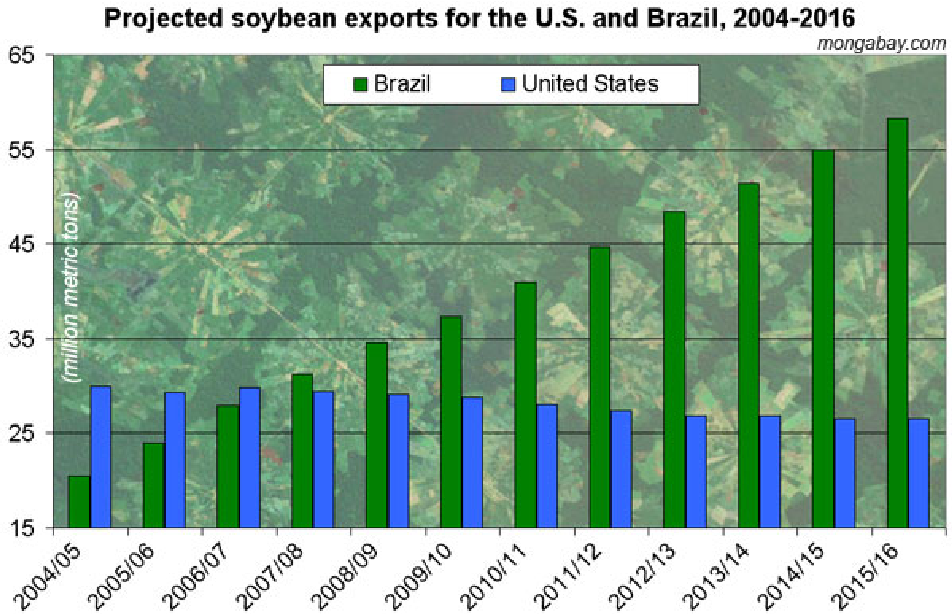
Decrease in cropland area
- Hotspot (low certainty)
- Hotspot (high certainty)

Lepers et al., 2005, BioScience

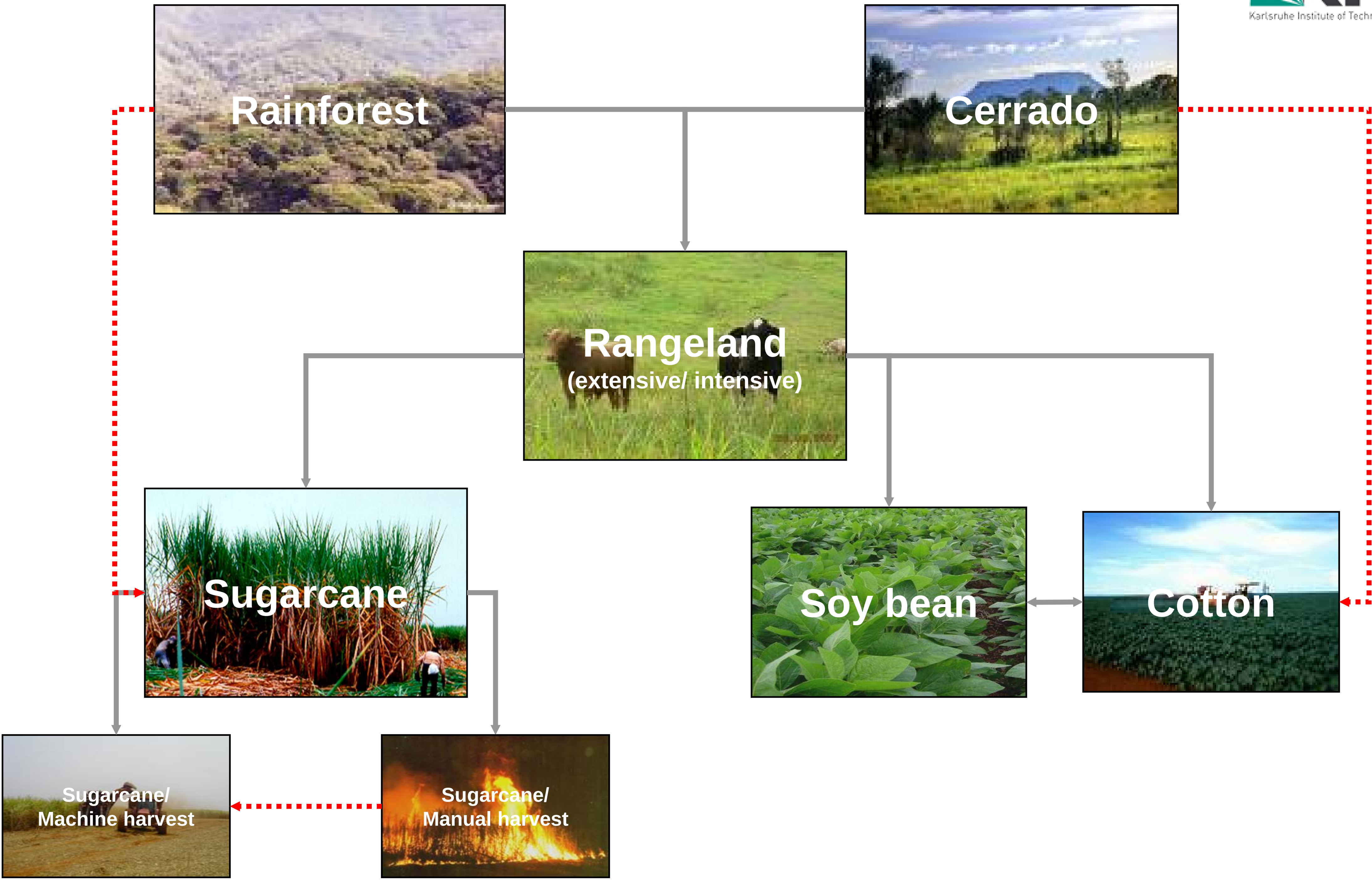
Biomass burning and land use change, Mato Gross, Brazil





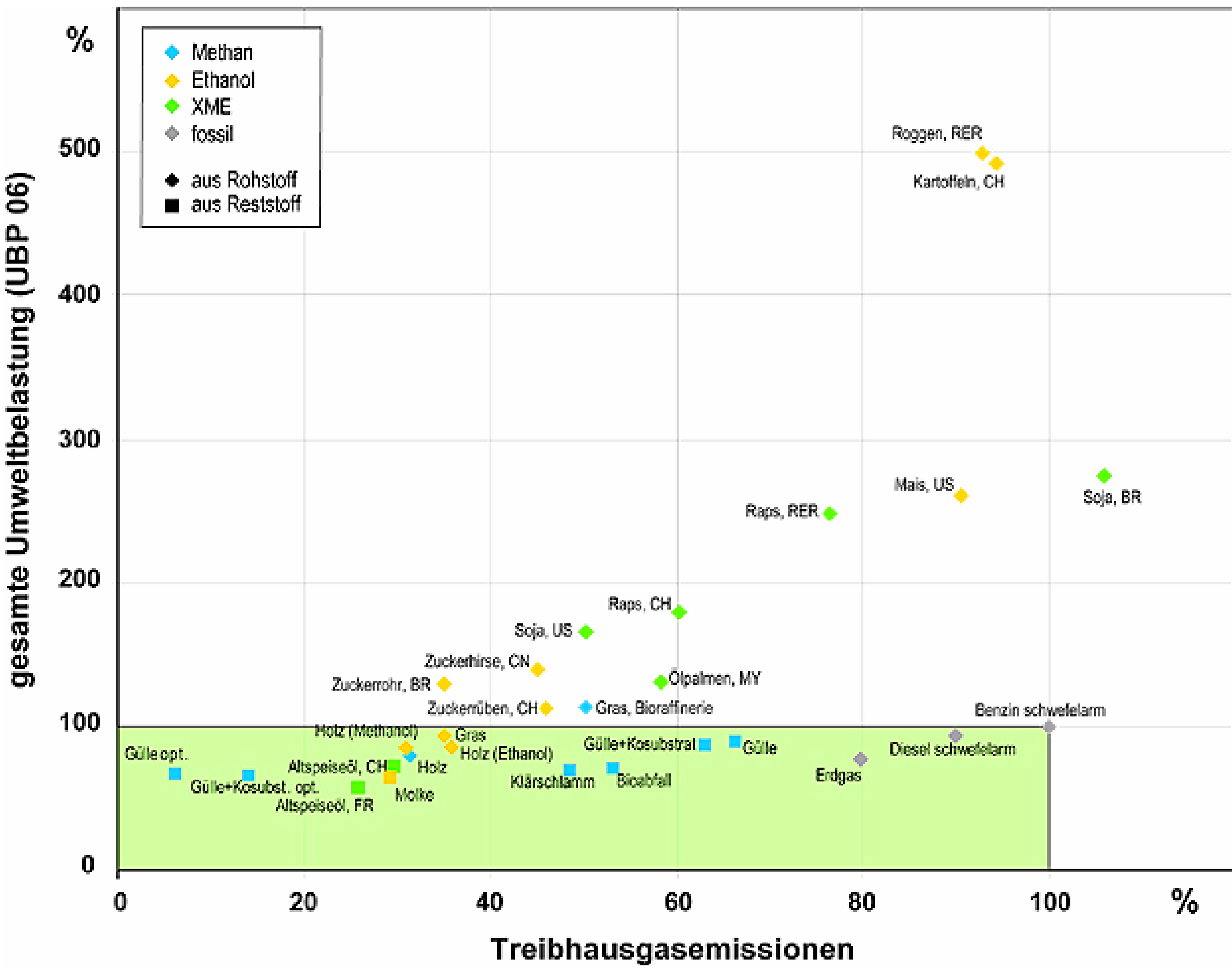


Current trends in land use change dynamics in Brazil



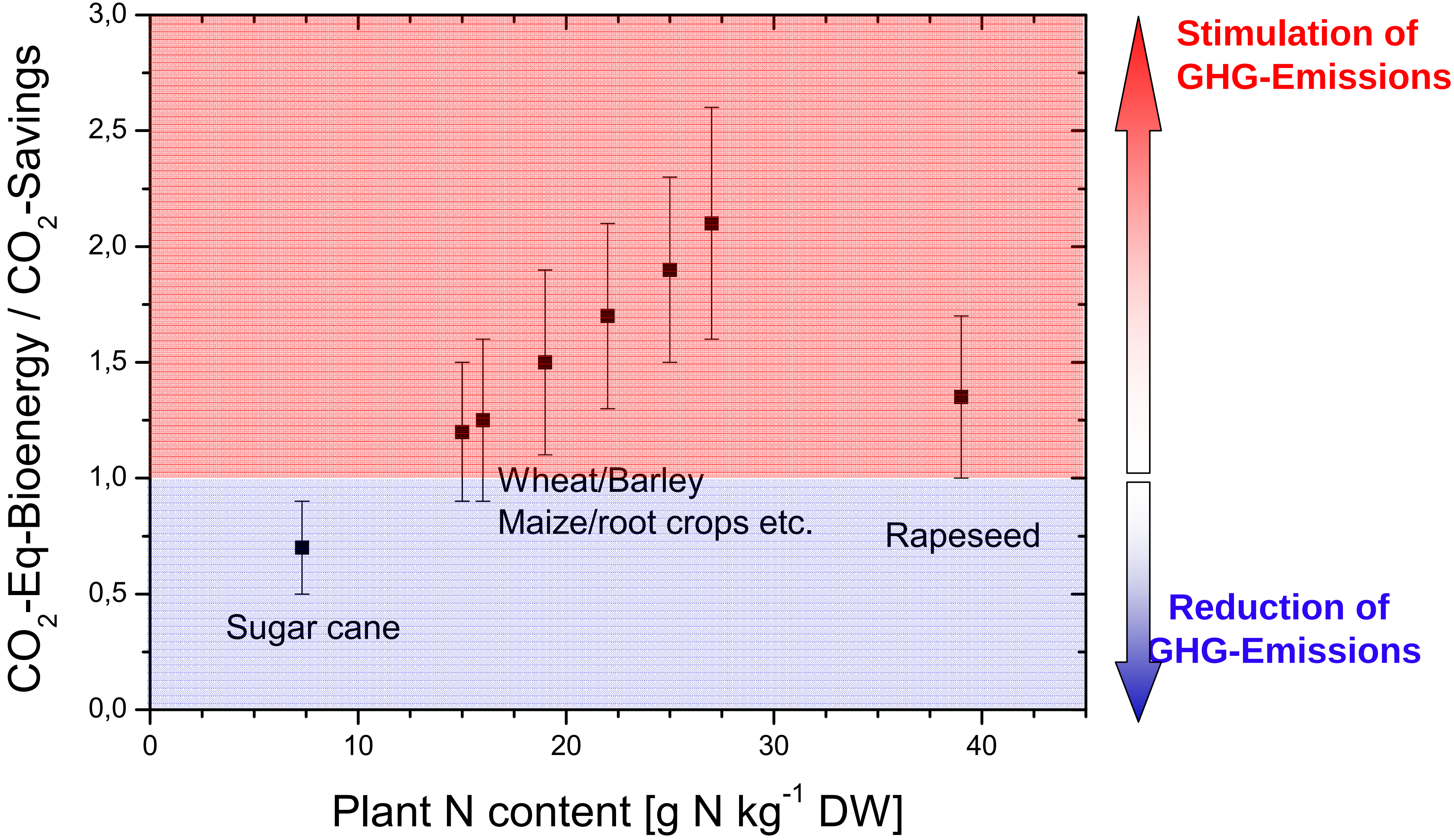
Hypothesis

Sustainability of ethanol production from sugarcane (net reduction of GHG emissions as compared to fossil fuels, environmental impact [e.g. water quality]) requires improved management



Zah et al. 2007, Ökobilanz von Energieprodukten, empa, CH
Discussion in Scharlemann and Laurance, Nature 319, 43-44

C-neutrality of biofuels



Crutzen et al., 2007

C, N and H_2O footprint for ethanol production (case study: São Martinho Sugar Mill, São Paulo State, Brazil)

Karlsruhe Institute of Technology

São Martinho Sugar Mill

- Second largest in Brazil
- Modern facility
- Processes 40 kt sugarcane d⁻
- Pioneer in mechanized
- unburned harvest

C, N and H_2O footprint for ethanol production
(case study: São Martinho Sugar Mill, São Paulo State, Brazil)

Assessing ecological sustainability:

- Quantifying major C and N fluxes in the soil-plant system
  - ➢ Plant production
    (incl. yield and residue management [filtercake, ash, vinasse])
  - ➢ Fertilizer application and biological N_2 fixation
  - ➢ Losses in form of N_2, NO_3, DOC/ DON
- GHG emissions during sugarcane production from the plant soil system
  - ➢ Soil C and N changes on decadal time scales (isotope studies)
  - ➢ CO_2 and non-CO_2 (CH_4/N_2O) exchange (EC, chamber)
- GHG emissions and nutrient losses during industrial ethanol production
- Changes in regional hydrology and water quality
- Simulation of water, C and N fluxes on regional scales
  - ➢ Biogeochemical and hydrological modelling
  - ➢ Scenario studies
- Ecological assessment for São Martinho plant

São Martinho Sugar Mill: knowns and unknowns

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Knowns:

- Soil and landuse (50 yr retrospective) data (GIS)
- Meteorology for 30 years (longer for other stations in the vicinity)
- Plant production: crop performance, fertilizer use and varieties
- Vinasse application (1l Ethanol = 12-16 l Vinasse) and spatial distribution

Preliminary data:

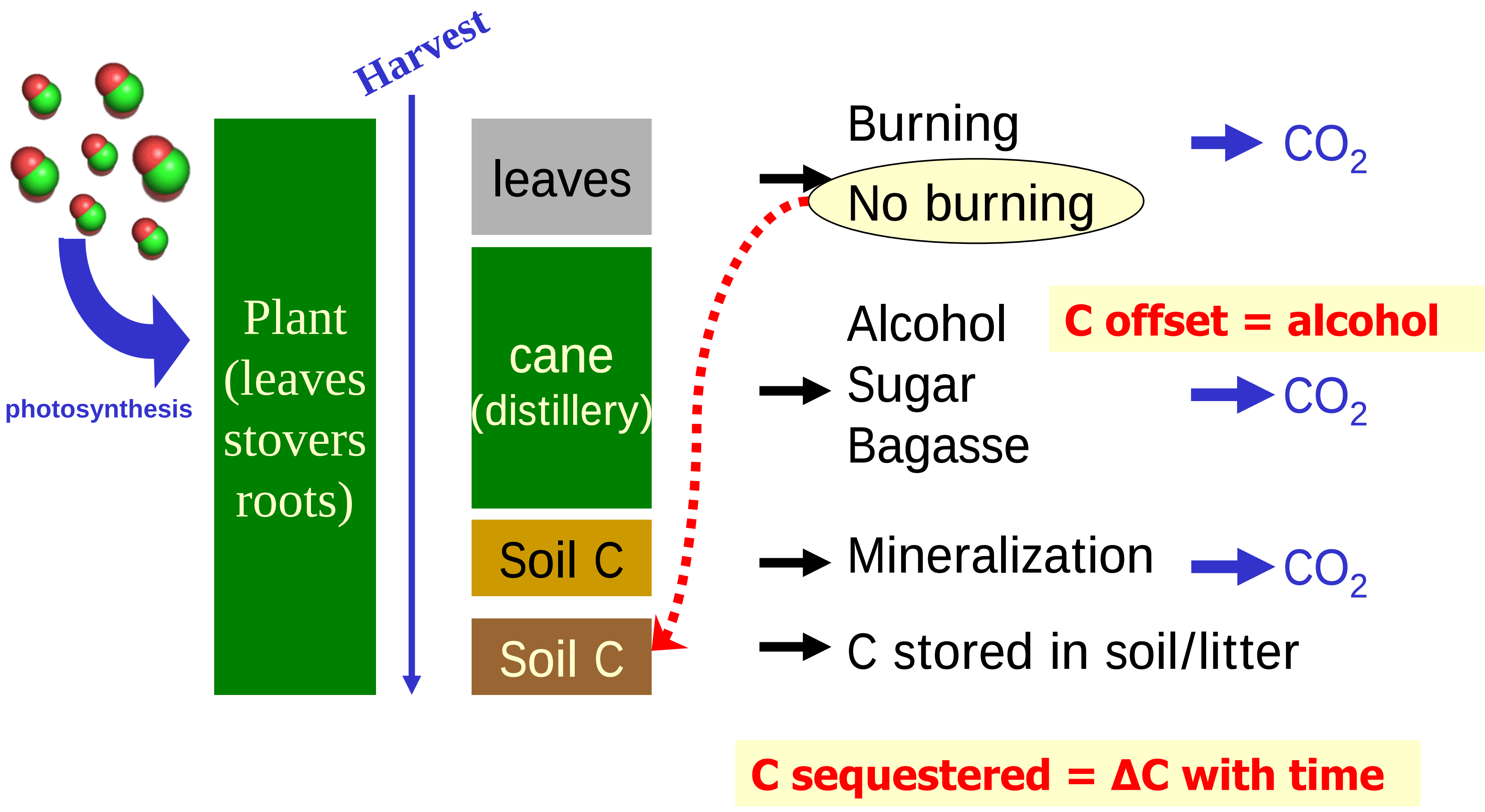
- Soil C/N changes
- N_2O emissions

Unknowns:

- Other gaseous N losses and details of GHG fluxes
- Management related losses (Vinasse, filter cake, biogas plant)
- Biological N_2 fixation
- Leaching losses

São Martinho Sugar Mill: knowns and unknowns

CO_2 balance for sugarcane agrosystem



GHG balance [C-CO_2 equivalents]

With burning	No burning
	 
Combustion	—
Soil mineralization	Soil mineralization
—	Litter mineralization

Manual versus mechanized harvesting

C-exchange [C-CO_2eq (kg.ha^{-1}.yr^{-1})]

With burning		No burning
		
0	Soil-litter C	-1311
4748	Yield and crop cycle	300
4748	**Final balance**	**-1011**

Manual versus mechanized harvesting

Karlsruhe Institute of Technology

N_2O and CH_4 fluxes [C-CO_2eq ($kg.ha^{-1}.yr^{-1}$)]

With burning	No burning
	

Yield: Immediate release of GHG (kg C-CO_2 eq.ha^{-1}.yr^{-1})

	With burning			No burning
CH_4	180	4549	CH_4	0
N_2O	4369		N_2O	

Crop cycle: fluxes at the soil-litter-atmosphere level (kg Ceq.ha^{-1}.yr^{-1})

	With burning		No burning	
CH_4	- 48.4	CH_4	31.5	-5 - +3.5 kg CH_4-C ha^{-1} yr^{-1}
N_2O	247.7	N_2O	268.9	1.8 – 2.2 kg N_2O-N ha^{-1} yr^{-1}

Missing data

a) Vinasse application

b) Hotspots & hot moments

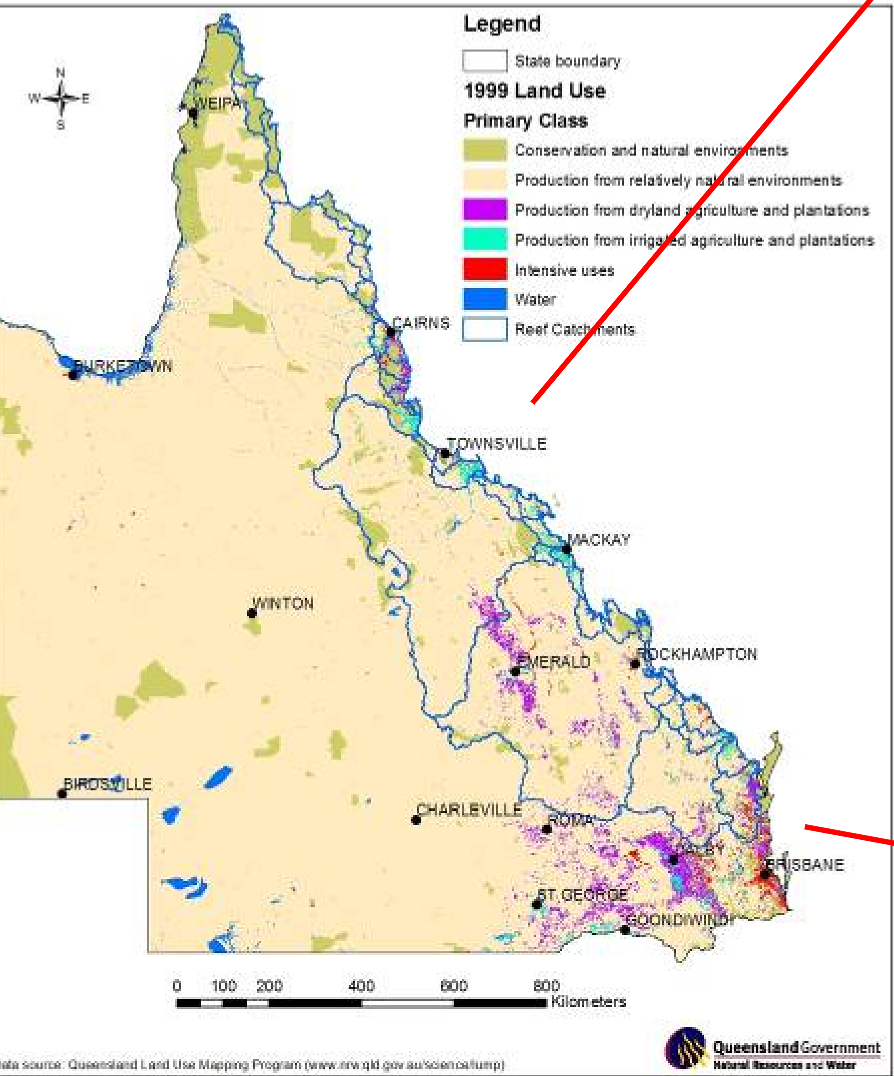
- **Filter cake**
- **Fertilizer application**
- **Rainfall events**

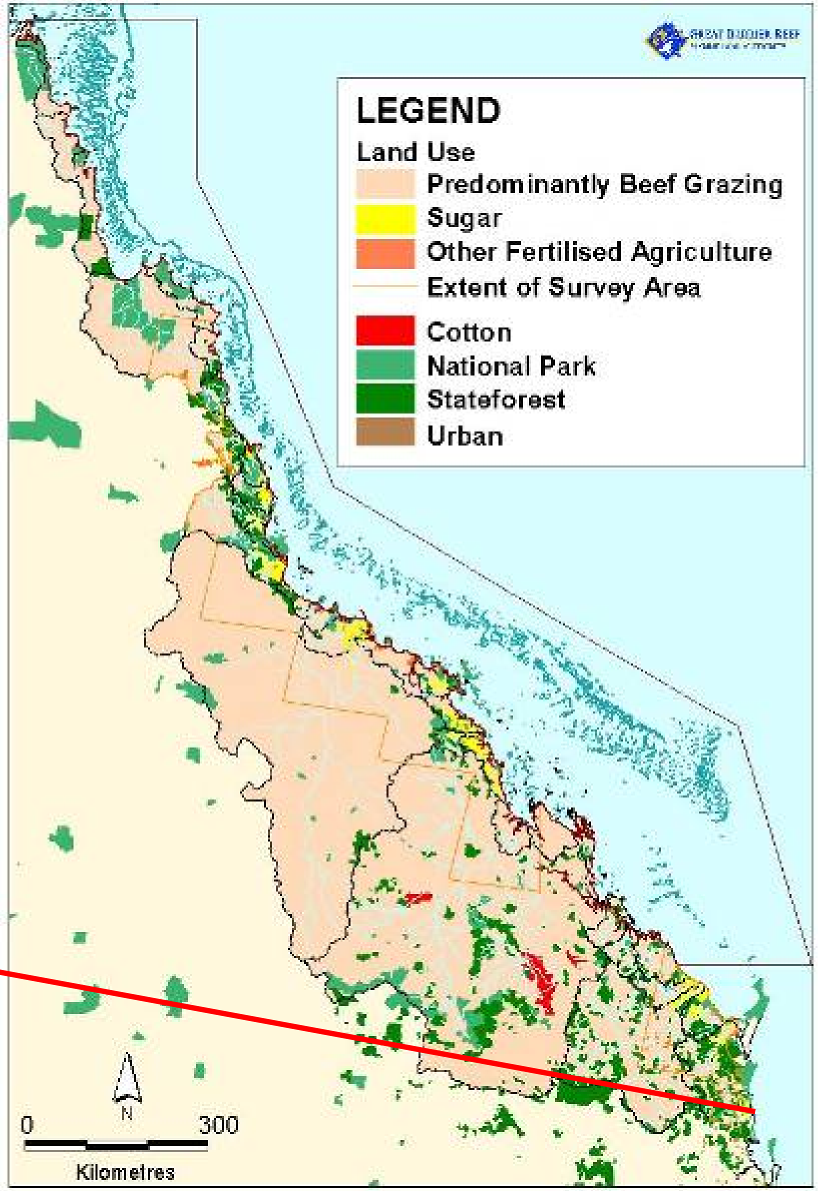
c) Leaching losses & water quality

Conclusion: → at least for N_2O current estimates are to low

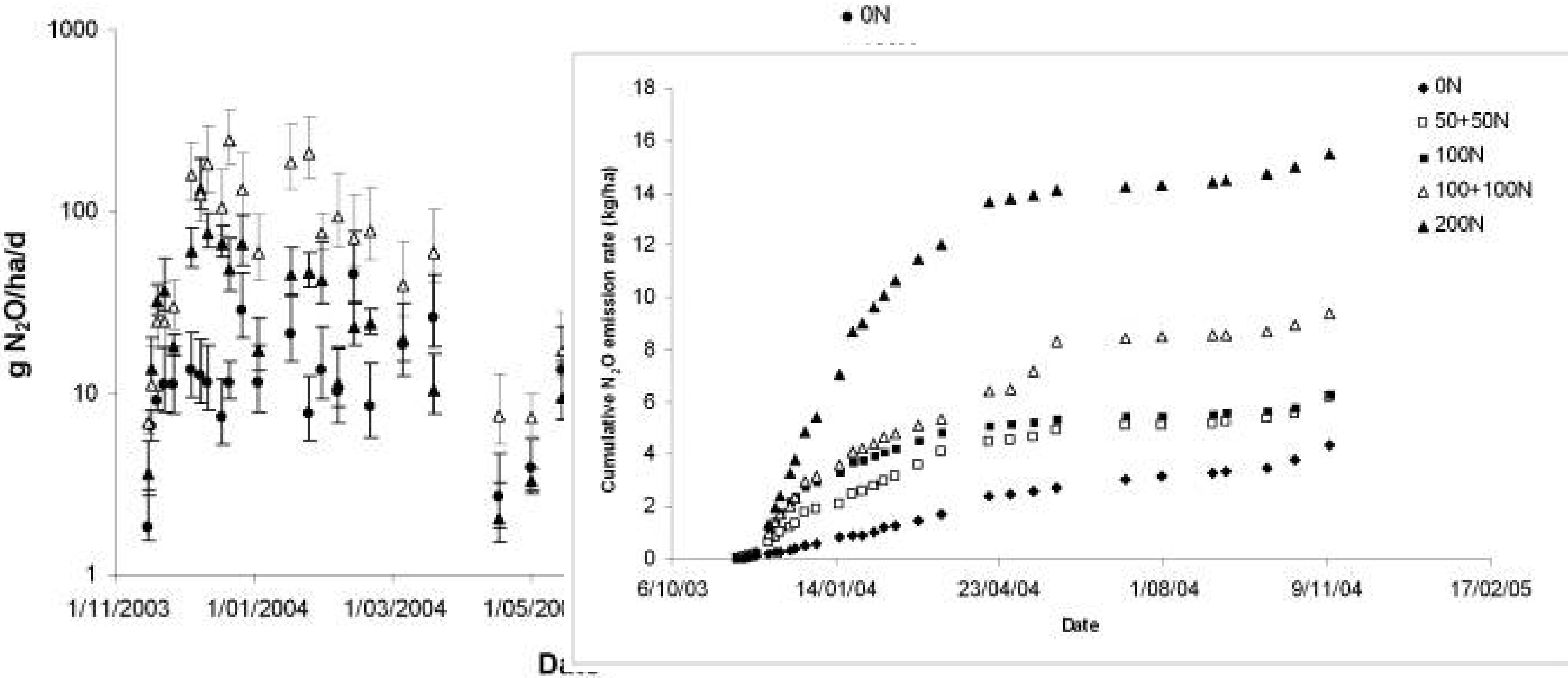
Sugar cane area > 500 000ha, approx 20% of total cropping area

Australia





N_2O losses from sugarcane in Australia 4-16 kg N_2O-N



Courtesy of Diane Allen, Agric. Departm. Queensland, Australia

Allen, D.E., Kingston, G., Rennenberg, H., Dalal, H., Schmidt, S. 2008. Nitrous oxide emissions from sugarcane soils as influenced by waterlogging and split N fertiliser application. Australian Society for Sugarcane Technologists, (accepted)

Outlook

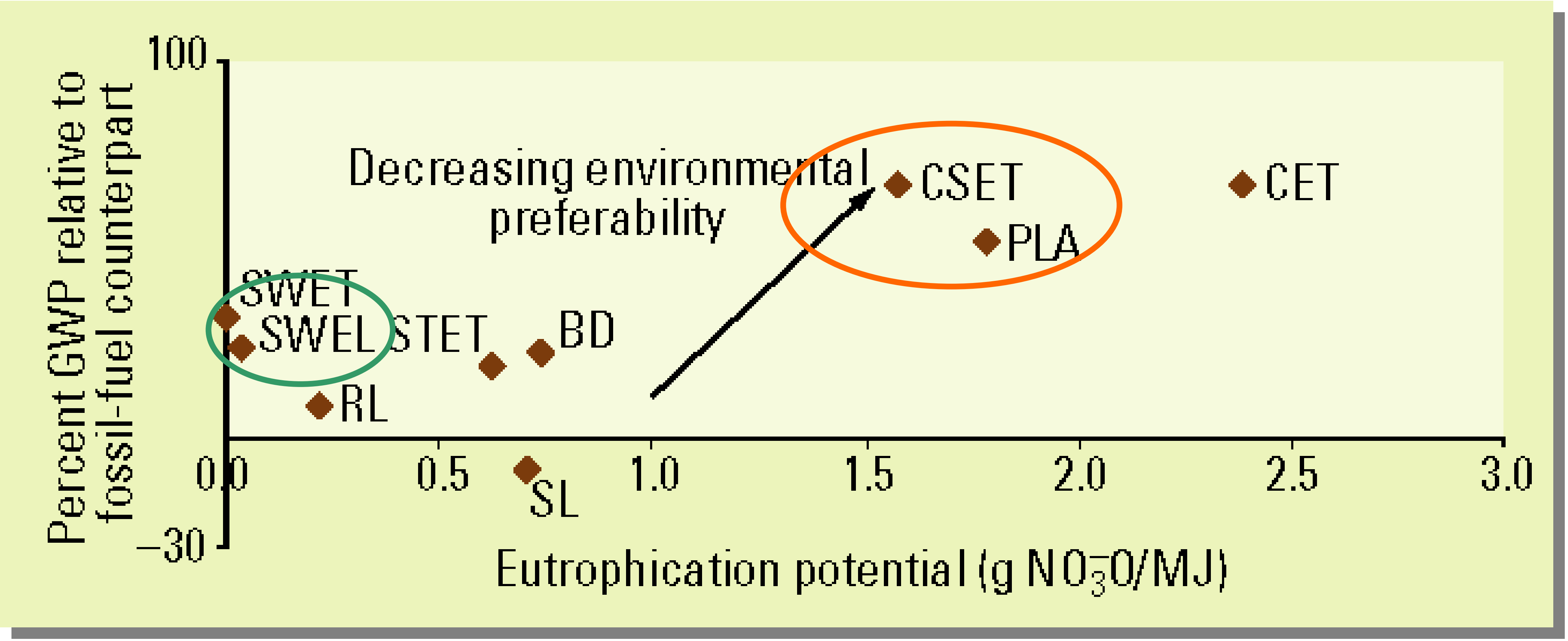
- ***Sugarcane (Sao Paulo State)***
  - Urgent need for more detailed measurements spanning entire years
  - No information on N losses by leaching/ water quality
  - Modeling and system analysis is pending

- ***Soy bean/ cotton (Mato Grosso)***
  - Contacts established
  - Potential sites available
  - First measurements start 2008

- ***Studies need to include other potential bioenergy crops (e.g. switch grass)***

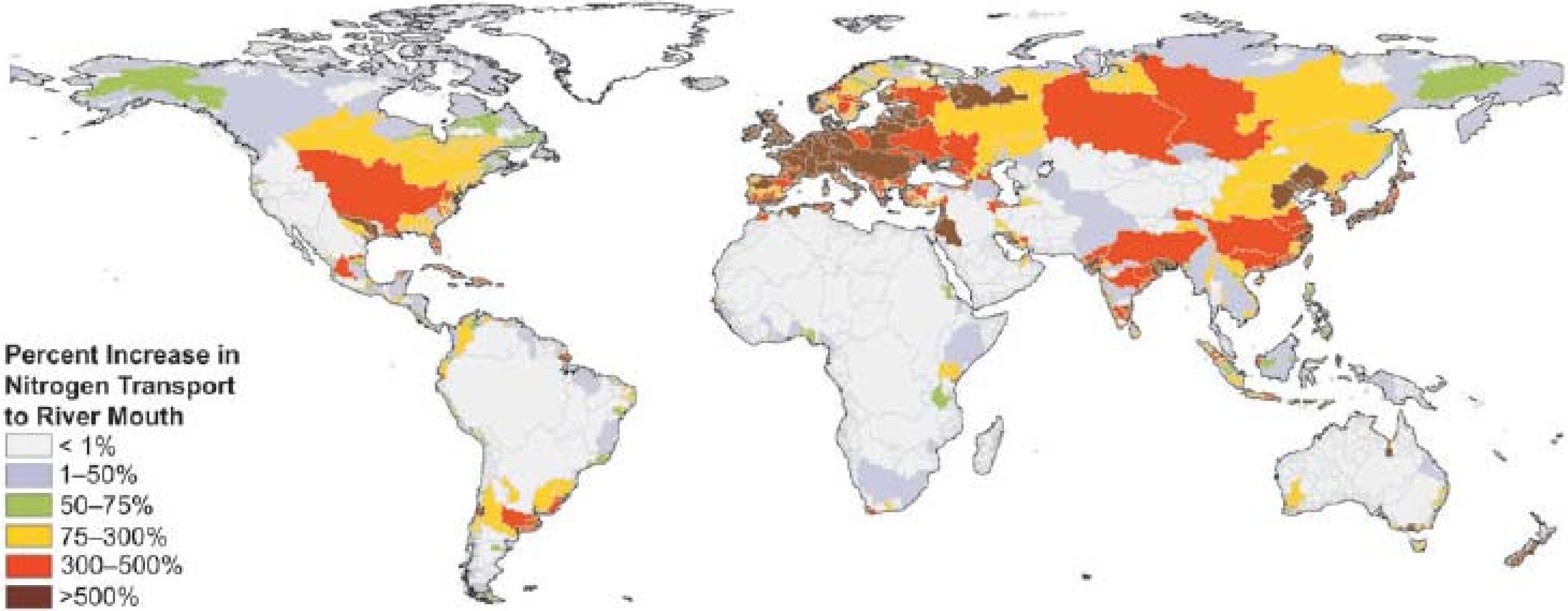
Ressources and additional partners

Eutrophication vs relative global-warming potential (GWP)



CET corn ethanol; CSET corn and stover ethanol; PLA polylactic acid from corn (polystyrene);
RL rapeseed lubricant; SL soybean lubricant; STET stover ethanol; BD biodiesel;
SWEL switchgrass electricity; SWET switchgrass ethanol

Miller et al. 2007, Environ Sci Technol 41:5176-5183


Percent Increase in Nitrogen Transport to River Mouth
< 1%
1–50%
50–75%
75–300%
300–500%
>500%