Biocombustibles: Beneficios y Costos Ambientales

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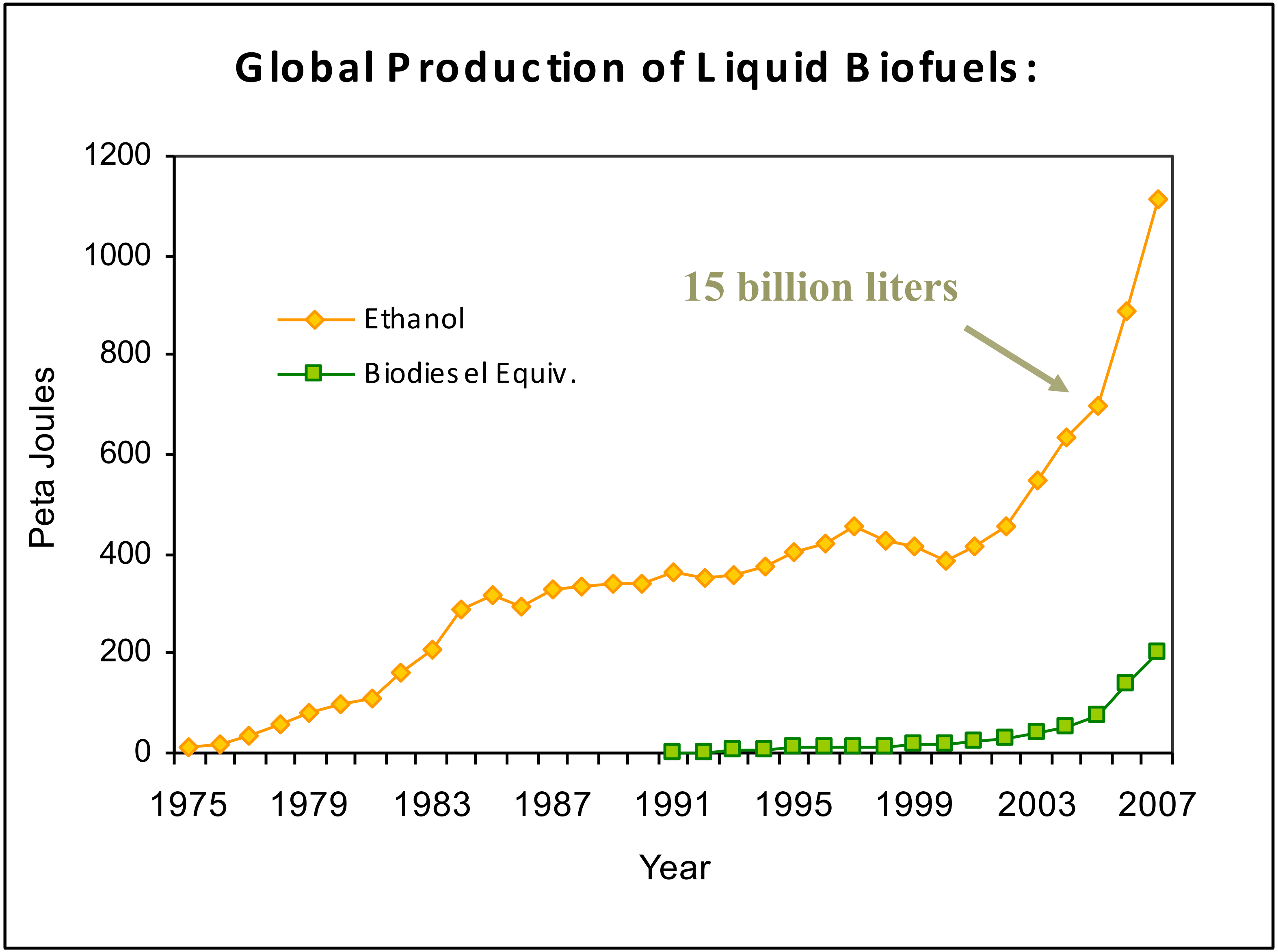
Biofuels

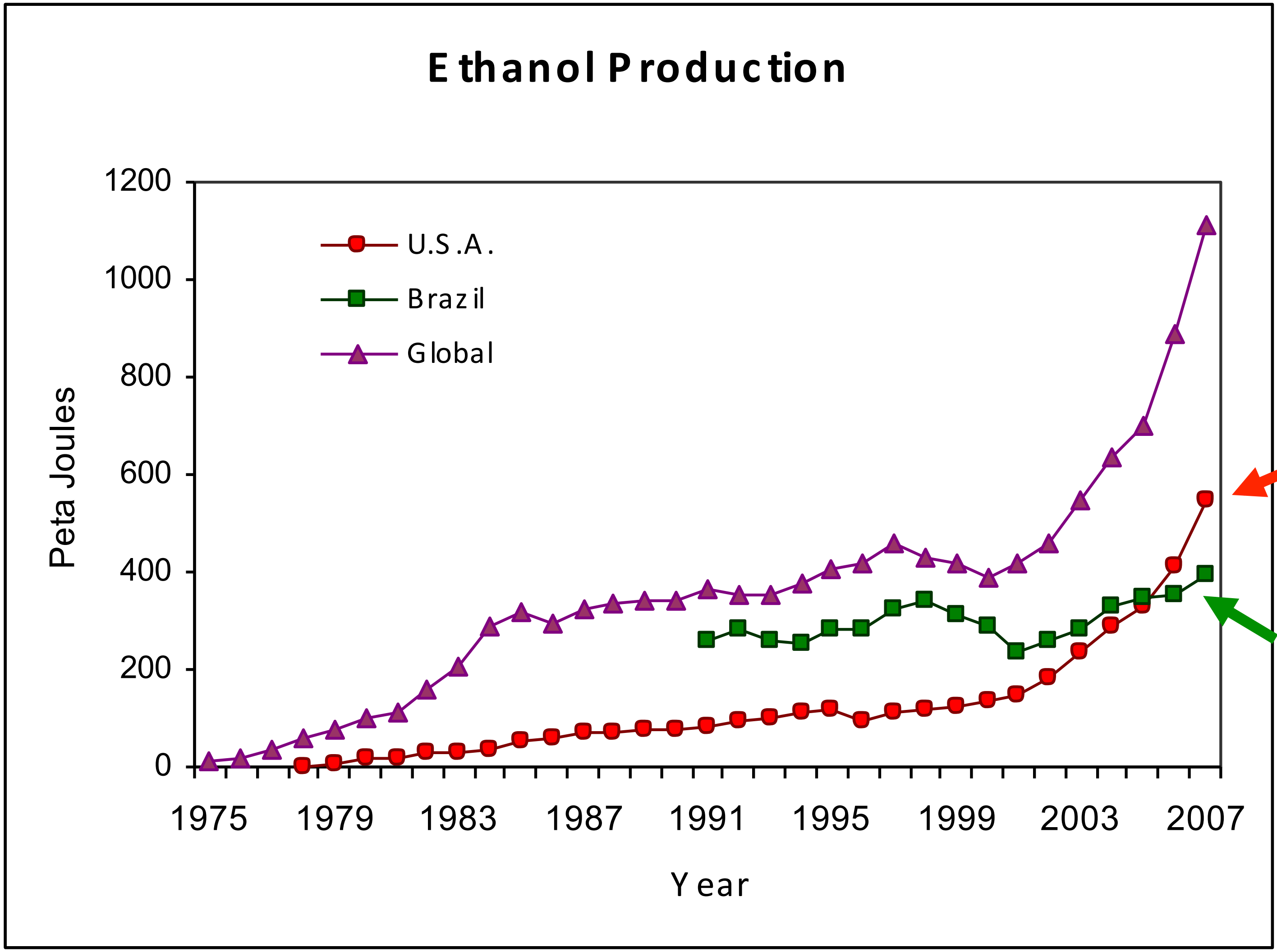
- Combustible materials derived directly or indirectly from biomass, usually from plants but also from organic wastes

Biofuels

- Magnitude of the issue and trends



Howarth et al. 2009



Almost all corn

Almost all sugar cane

Howarth et al. 2009

Magnitude of Liquid Biofuel production in year 2007

United States -- 26% of corn to produce ethanol for 1.1% of total liquid fuel use (transportation and other).

Brazil -- 60% of sugar cane harvest to produce ethanol for 7.5% of liquid fuel use.

Future Magnitude of Biofuels

- Many countries have ambitious biofuels targets or mandates, with goals to use biofuels for 10% or more of liquid transportation fuels in 10 to 20 years.

- In 2007, liquid biofuels contributed 1.8% of global liquid transportation fuels.

- Biofuel production in 2007 required 6% of all grain harvest globally (including rice, as well as corn, wheat, etc.), 8% of vegetable oil, and 28% of sugar can harvest.

- It will be difficult at best to meet biofuel targets using traditional crops.

Biofuels

COSTS

BENEFITS

Motivation for Biofuels and Renewable Energy

1. Climate change mitigation
2. Energy security
3. Economic development

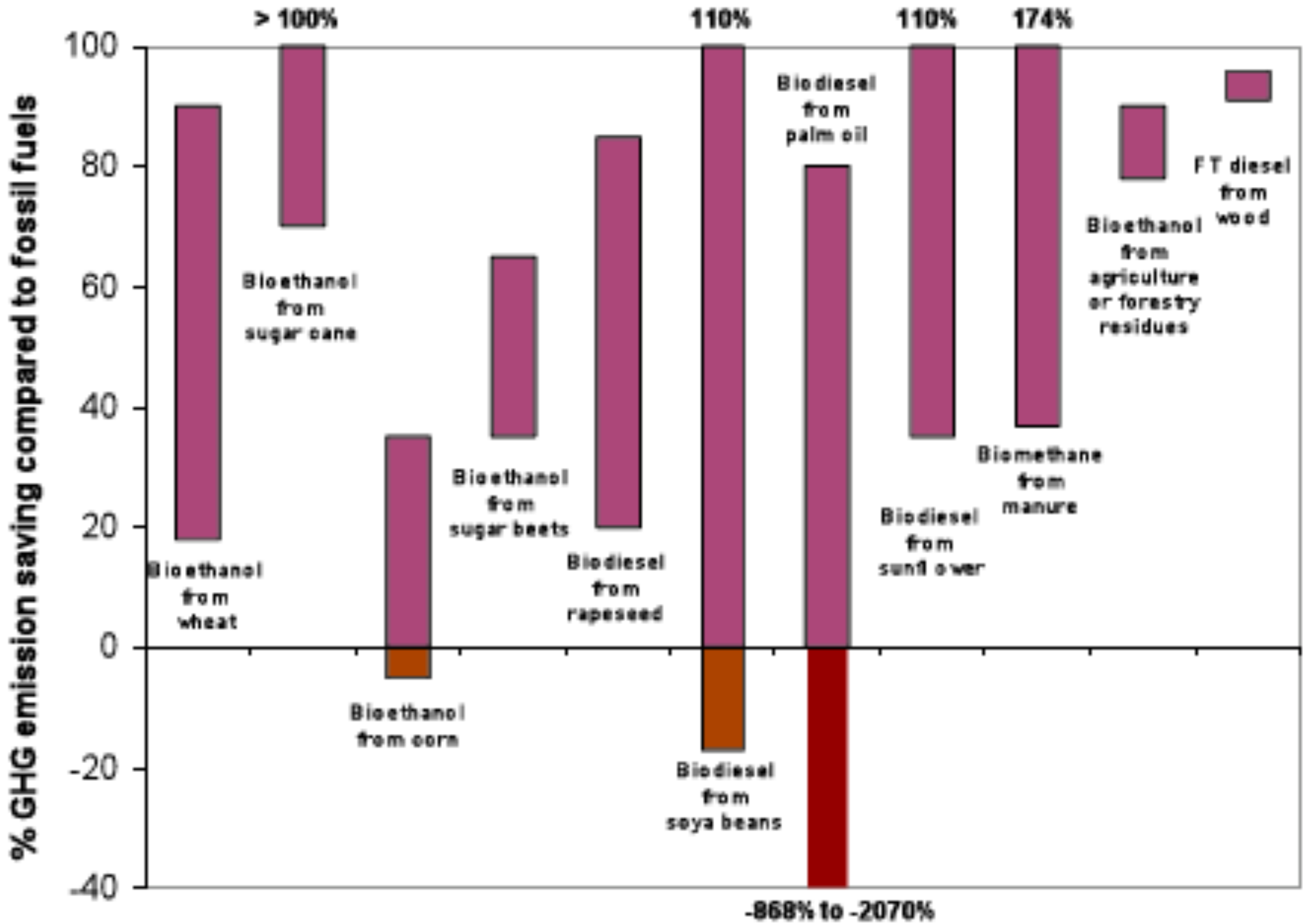
Biofuels Costs

- Energy Consumption
- Food production
- Biodiversity loss
- Nitrogen pollution
- Fresh water
- Clean air

Environmental effects (including greenhouse gas emissions) vary, depending upon issues such as:

- Which feedstocks
- Which biofuel
- Where the feedstocks are grown
- Where the fuels produced
- Conversion methods
- What energy powers these conversions and transportation
- Interactions with other drivers for land use and land cover changes

Figure 4.4: Greenhouse gas savings of biofuels compared to fossil fuels.



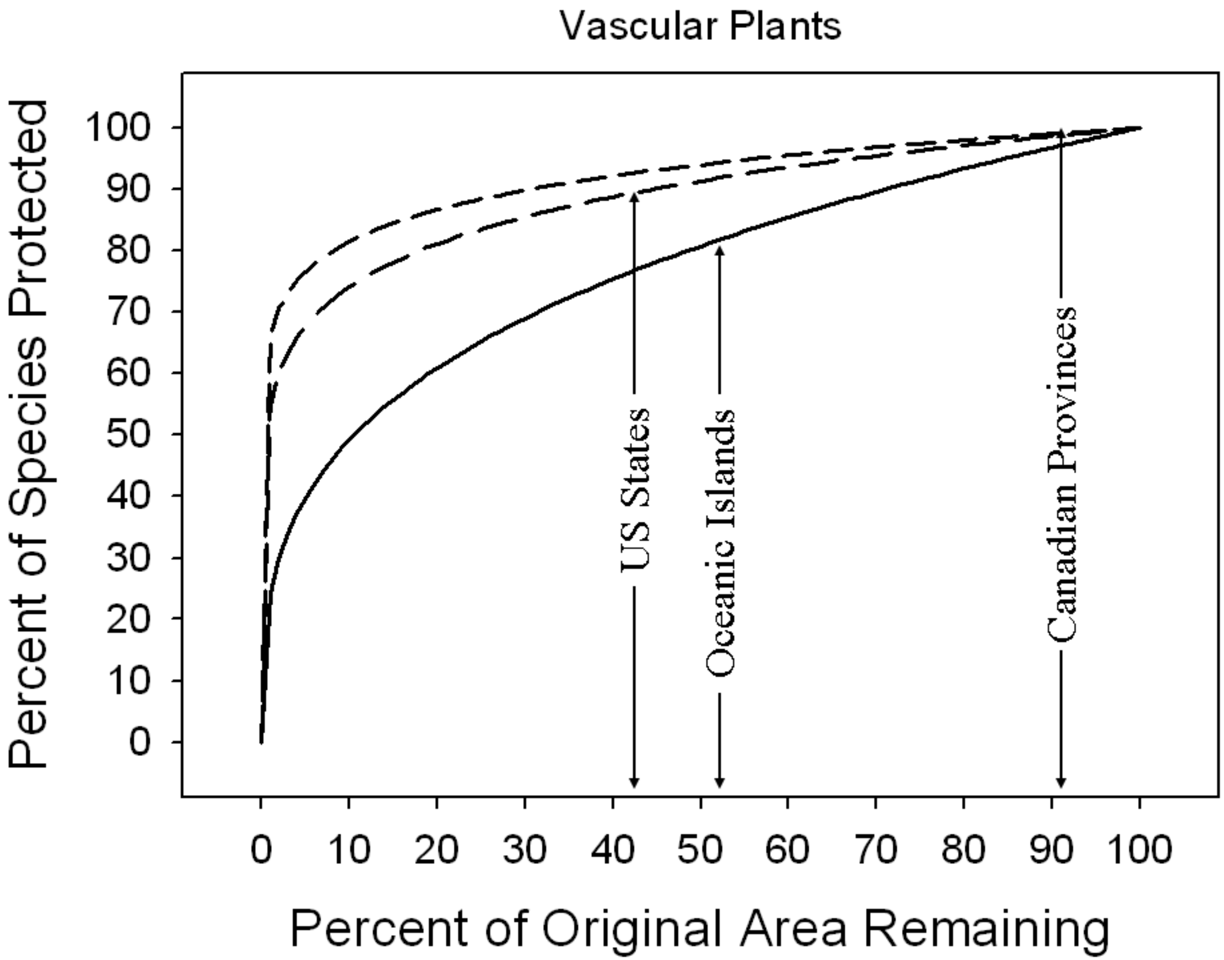
Unpublished; International Panel on Sustainable Resource Use

The Biofuel Effect on Biodiversity

- (1) Total land area = Agriculture land + Conservation land + Urban Areas
- (2) Total land area = Food production + Biofuel production + Conservation + Urban
- (3) $S = c\,A^z$

Future Demand of Agricultural Land

- By 2050 demand for food crops will increase by 3321 megatons over current 3906 megatons (Global Orchestration)
- Demand for cereals alone will increase by 73%
- Demand for livestock will increase by 63%
- From 1997 to 2050 increases in agricultural land range from 0.01% per year to 0.34% per year
- This rate of increase means an increase of agricultural land of 137 million hectares by 2050



Sala et al 2009

Effects of Biofuel Production on Vertebrate Diversity

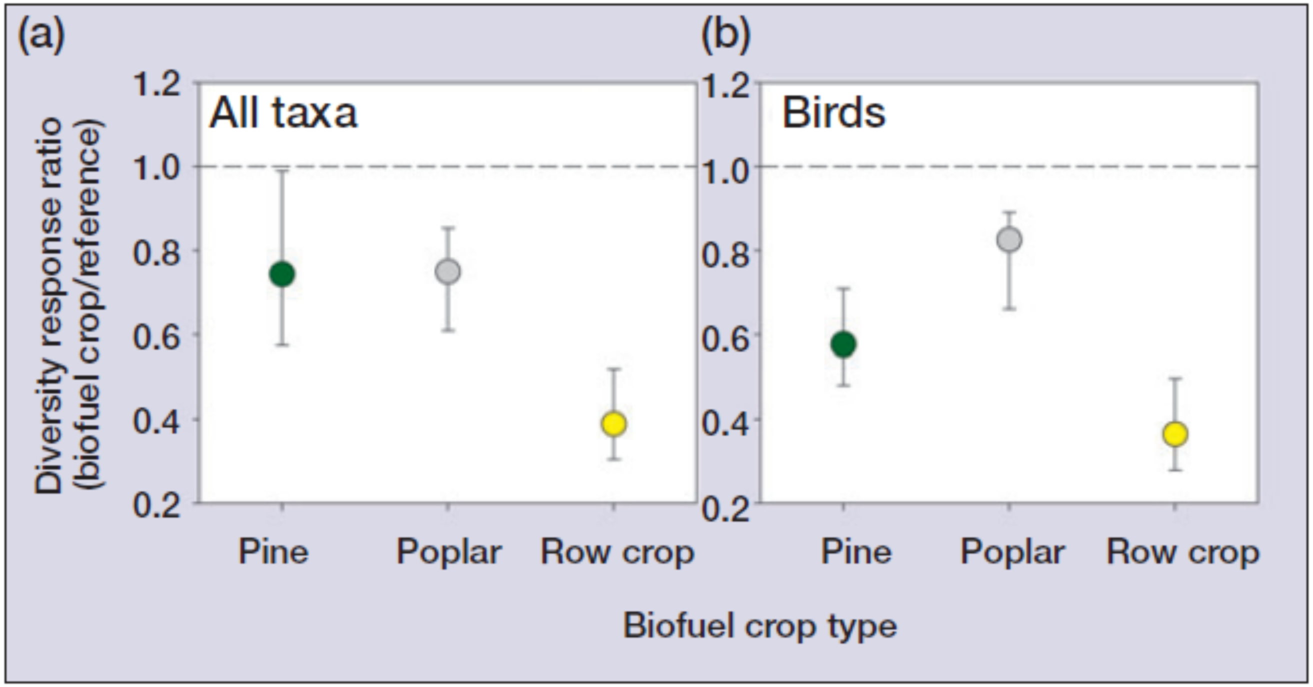


Figure 2. *Effect sizes (response ratios ± 95% confidence intervals) of metrics of diversity for each biofuel land use for (a) all taxa combined and (b) for birds only. Responses are considered significant if confidence intervals do not overlap the dashed lines.*

Fletcher et al 2010, Frontiers

Effects of Biofuel Production on Vertebrate Abundance

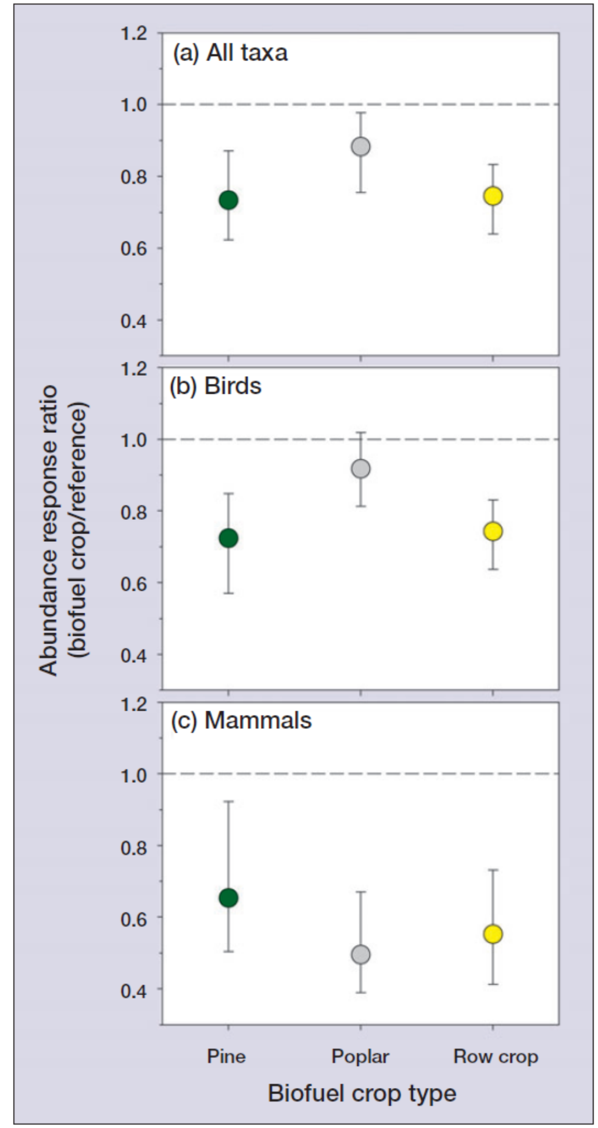


Figure 3. *Effect sizes (response ratios ± 95% confidence intervals) of metrics of abundance for each biofuel land use for (a) all taxa combined, (b) birds, and (c) mammals. Responses are considered significant if confidence intervals do not overlap the dashed lines.*

Fletcher et al 2010, Frontiers

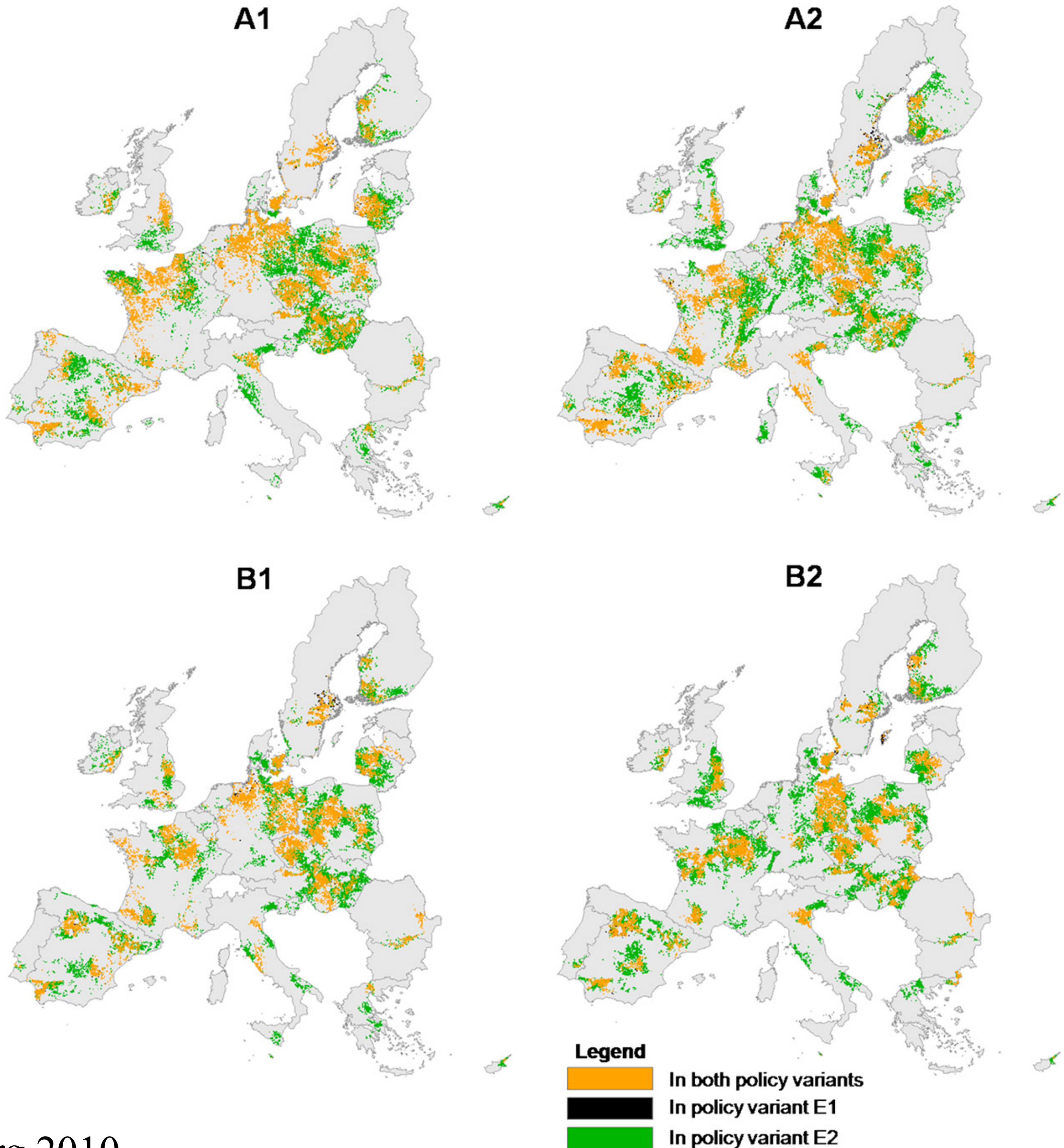
The Cascading Effect

- Accounting for the effect of biofuel production on land-use change in distant location
- Comprehensive carbon balance

Table 1. Comparison of corn ethanol and gasoline greenhouse gasses with and without land-use change by stage of production and use (grams of GHGs CO_2 equivalents per MJ of energy in fuel) (*28*). Figures in total column may not sum perfectly because of rounding in each row. Land-use change was amortized over 30 years. Dash entries indicate "not included."

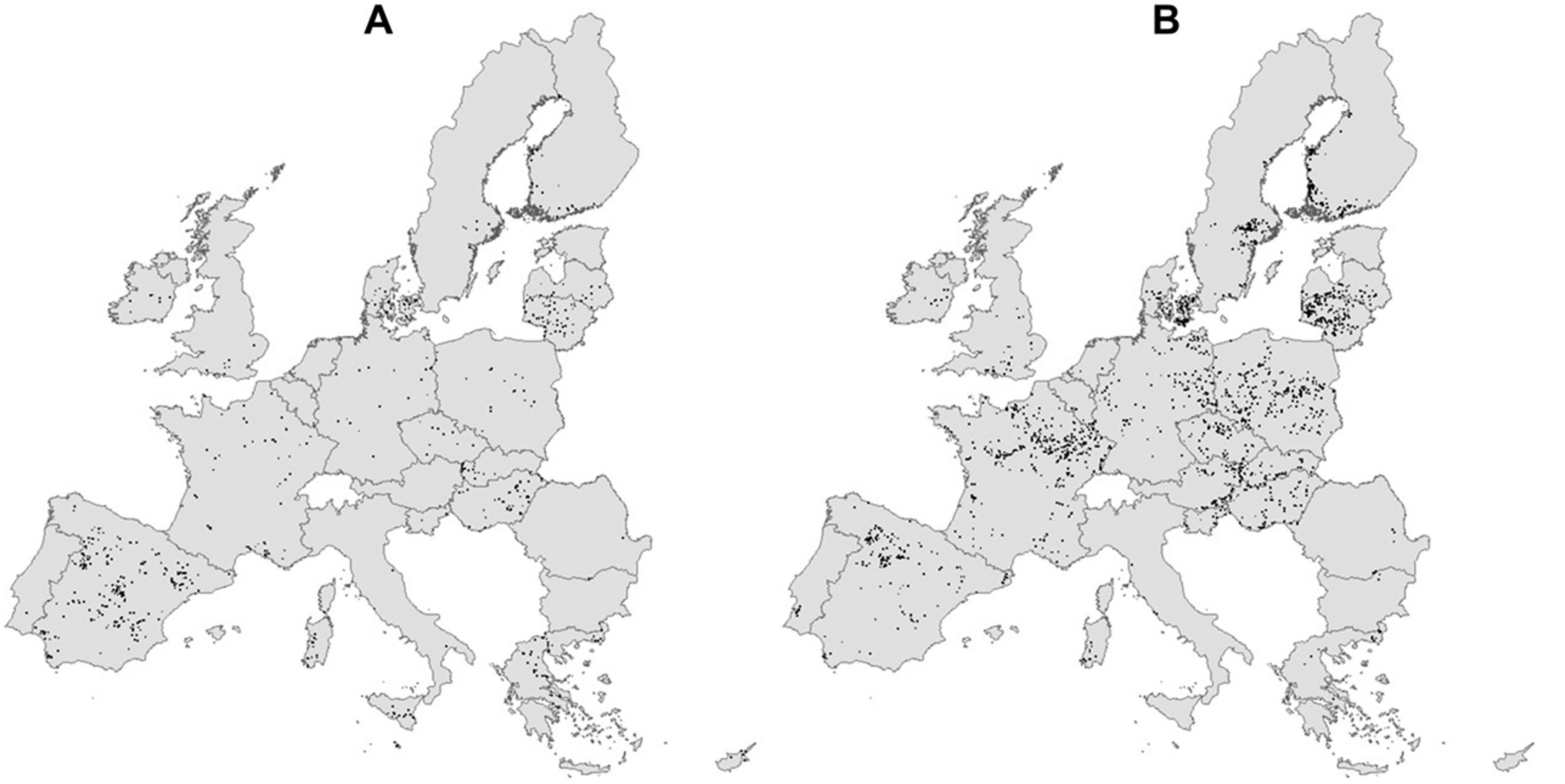
Source of fuel	Making feedstock	Refining fuel	Vehicle operation (burning fuel)	Net land-use effects: Feedstock carbon uptake from atmosphere (GREET)	Net land-use effects: Land-use change	Total GHGs	% Change in net GHGs versus gasoline
Gasoline	+4	+15	+72	0	–	+92	–
Corn ethanol (GREET)	+24	+40	+71	−62	–	+74 +135 without feedstock credit	−20% +47% without feedstock credit
Corn ethanol plus land use change	+24	+40	+71	−62	+104	+177	+93%
Biomass ethanol (GREET)	+10	+9	+71	−62	–	+27	−70%
Biomass ethanol plus land use change	+10	+9	+71	−62	+111	+138	+50%

Searchinger et al 2008



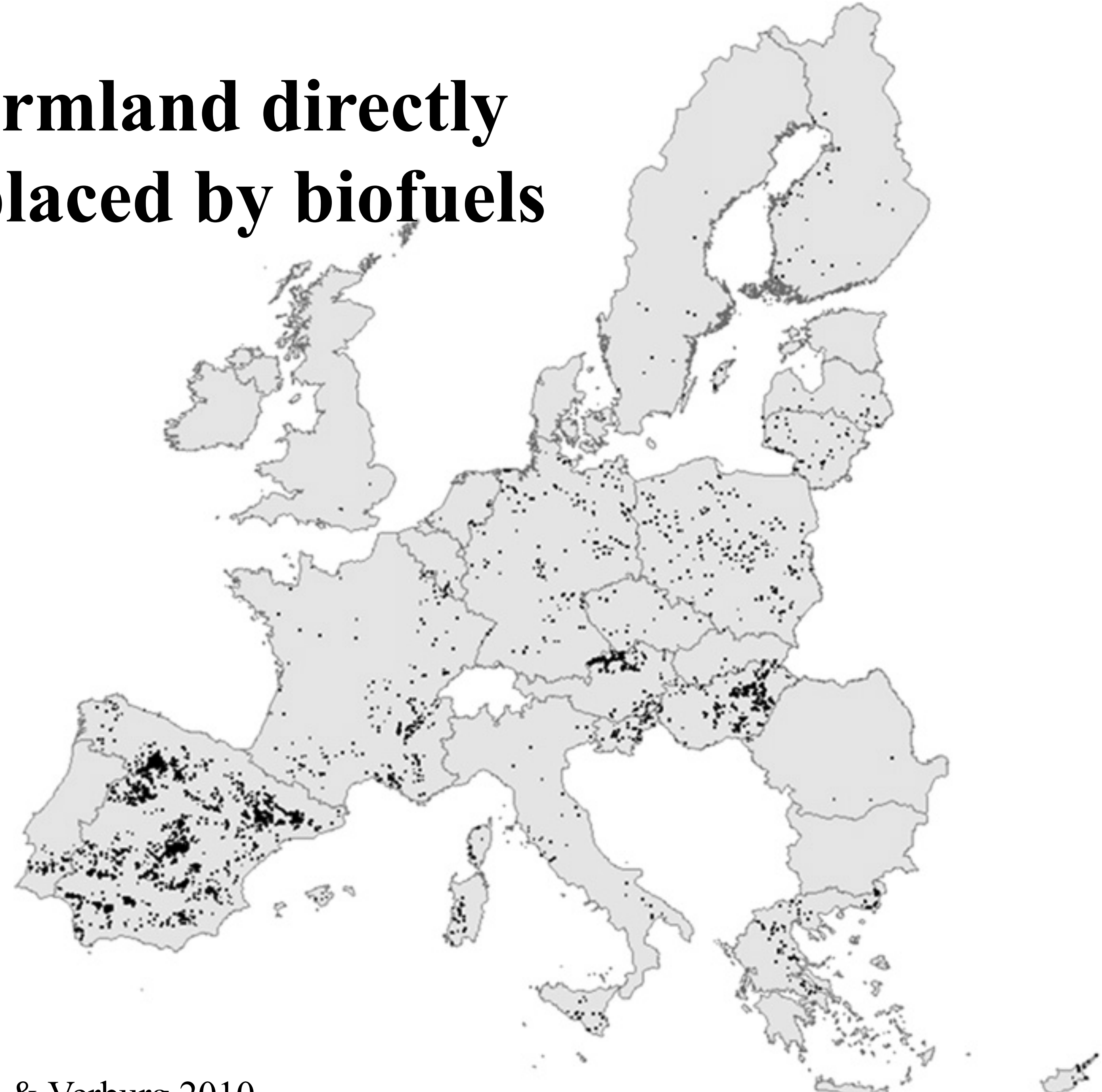
Hellmann & Verburg 2010

Semi-natural and forest replaced by biofuels



Hellmann & Verburg 2010

Farmland directly replaced by biofuels



Hellmann & Verburg 2010

Nitrogen Pollution

•**Releases of <u>nitrous oxide</u>, a much more powerful greenhouse gas than carbon dioxide, often increase with increased use of nitrogen fertilizer and crop burning, both of which are common in biofuels production. Poor management of nitrous oxide emissions can either decrease or eliminate the greenhouse gas benefits of a biofuels operation.**

Atmos. Chem. Phys. Discuss., 7, 11191–11205, 2007
www.atmos-chem-phys-discuss.net/7/11191/2007/

Atmospheric Chemistry and Physics Discussions

N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels

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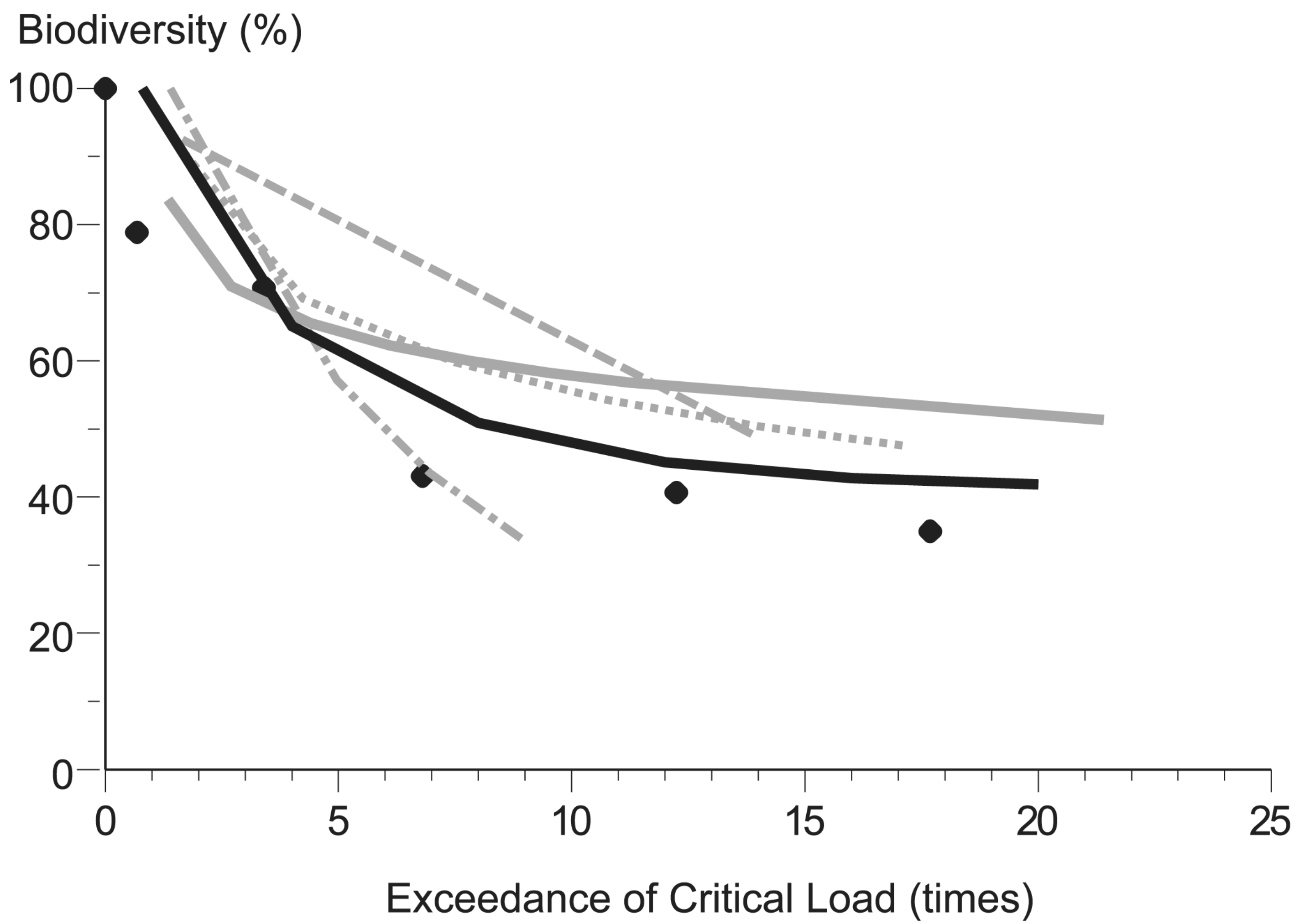
~ 4% of all nitrogen added to the environment by humans ends up in atmosphere as N_2O (Galloway et al. 2004).

Emission is often far from site of original application of fertilizer!

	Concentrations[b] and their changes[c]		Radiative Forcing[d]	
Species[a]	2005	Change since 1998	2005 ($W\ m^{-2}$)	Change since 1998 (%)
CO_2	379 ± 0.65 ppm	+13 ppm	1.66	+13
CH_4	1,774 ± 1.8 ppb	+11 ppb	0.48	-
N_2O	319 ± 0.12 ppb	+5 ppb	0.16	+11

Per molecule, N_2O is 280-fold more potent greenhouse gas than CO_2.

Forster et al. (2007) -- IPCC



Sala et al 2009

Sept. 19, 2008 -- Piracicaba/SP /Brazil

(Luiz Martinelli)

Water Pollution

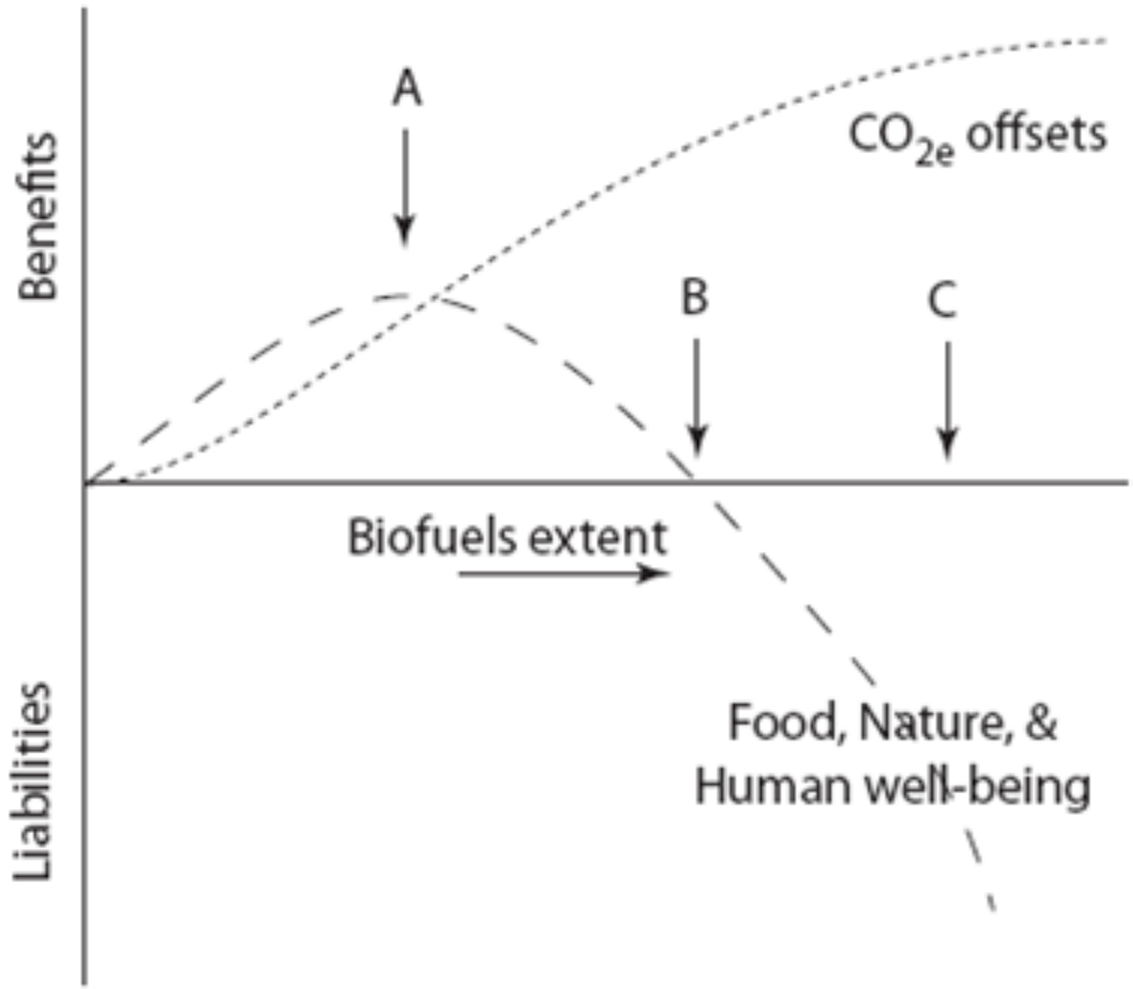
- **Severe <u>water pollution</u> can result from runoff from agricultural fields and from wastes produced during the production of biofuels. Nutrient losses from corn fields and organic wastes from sugar cane processing are particular problems.**
- **When perennial crops such as switchgrass are used instead of annual ones such as corn, water pollution is much less.**

Freshwater

- **Freshwater is increasingly in short supply and may not meet future demands for food production in many regions. Using irrigation to grow biofuel crops will aggravate these shortages, reducing water available for other uses and further impacting freshwater (and in some cases coastal marine) ecosystems. Roughly 45 billion cubic meters of irrigation water were used for biofuels production in 2007.**

•**Using wastes and agricultural and forest residues for biofuels is also likely to produce greenhouse gas benefits, but care must be taken to assure that enough residuals are left behind to protect soil health and carbon levels.**

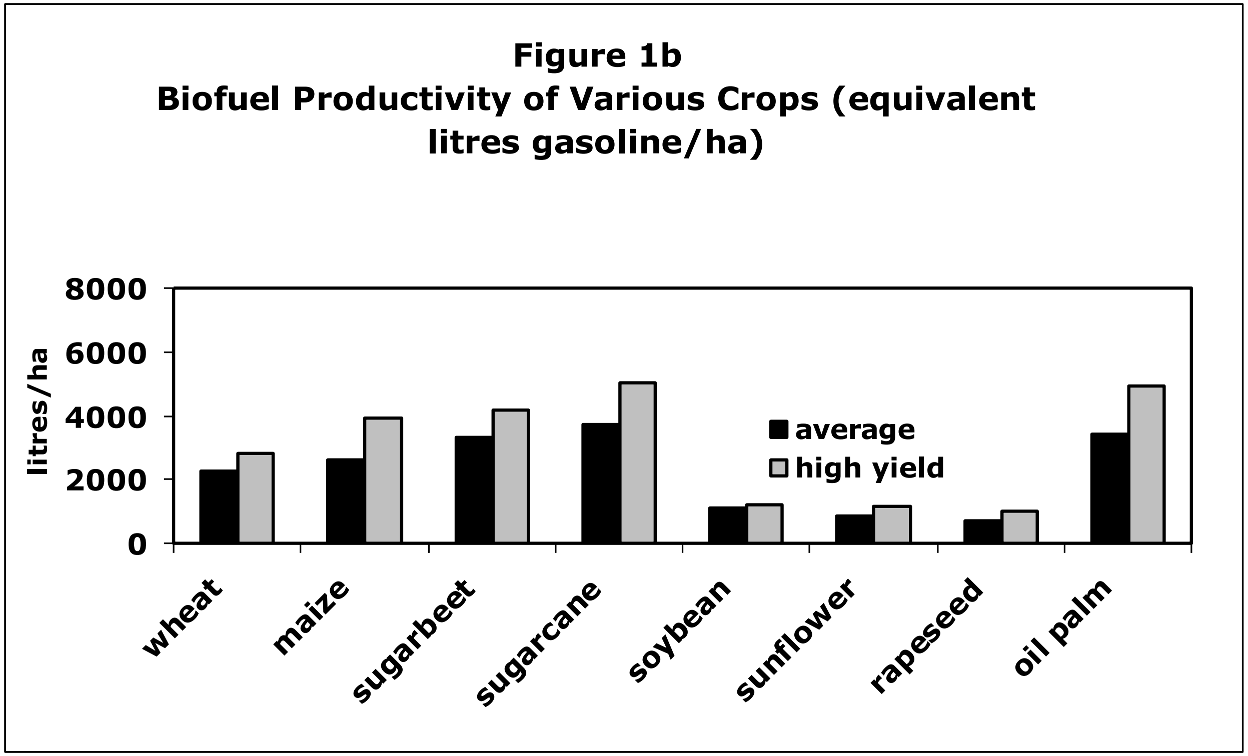
Costs, Benefits and Extent



The Future of Biofuels

- New Crops
- New Regulations
- New Technologies
- New Locations

Biofuel productivity of different crops



Connor and Hernández, 2009

What about novel crops (ie, cold pressed oil from jatropha)?

“Second-generation” biofuels, using cellulose as feedstock (from switchgrass, corn stover, wood, etc.)?

-- cellulosic ethanol

Unproven and developing technologies,
great uncertainty.

Should we move towards cellulosic ethanol?

Ethanol is <u>not</u> a desirable fuel:

- **corrosive (difficult and expensive to transport and store)**
- **must be distilled to remove water (energetically costly)**
- **low energy density (35%) less than gasoline**
- **high in oxygen, leading to greater nitrogen emissions**

Current Mandates and Targets

Current mandates and targets for liquid biofuels should be reconsidered in light of the potential adverse environmental consequences, potential displacement or competition with food crops, and difficulty of meeting these goals without large-scale land conversion.

“Advanced biofuels:”

> **Potentially better fuels in development, such as pure-hydrocarbon biofuels with no oxygen (“biomass to liquid fuels,” or BtL, similar to gasoline, diesel, etc., but with far less toxicity and more uniform composition)**

Alternatively, why not use direct combustion of solid biofuels (woods, grasses)?

Generate electricity or heat, or co-generate electricity and heat.

<u>Much greater efficiencies</u>. Probably much smaller greenhouse gas emissions and fewer environmental problems, since less need for land.

Focus on liquid biofuels because of price differential between solid and liquid fuels, driven by demand for transportation fuels (gasoline and diesel)…. But this could change as electric and fuel-cell driven vehicles become available.

The way forward….

- **Energy plans must start with conservation, greater efficiency, and reduction in demand.**

- **Biofuels are not able to replace oil.**

Non-food biomass should be preferentially used for material purposes, and the energy content recovered after several rounds of use: the "cascading principle."

Direct use of biomass for electric power and heat generation can be more efficient than conversion to liquid biofuels for transport. These alternatives may be the best use of biomass for energy, particularly as electric vehicles and vehicles powered by hydrogen fuel cells become commercially viable in future decades.

Comprehensive land use guidelines are needed that target biofuels production on marginal and degraded lands, and preserve areas for agriculture, forestry, settlements, and nature conservation on the regional, national and international levels to avoid unintended consequences.

Biofuels policies will be most successful if integrated in comprehensive plans for climate, food, and energy security. Plans should address conservation and efficiency as well as new sources of energy.

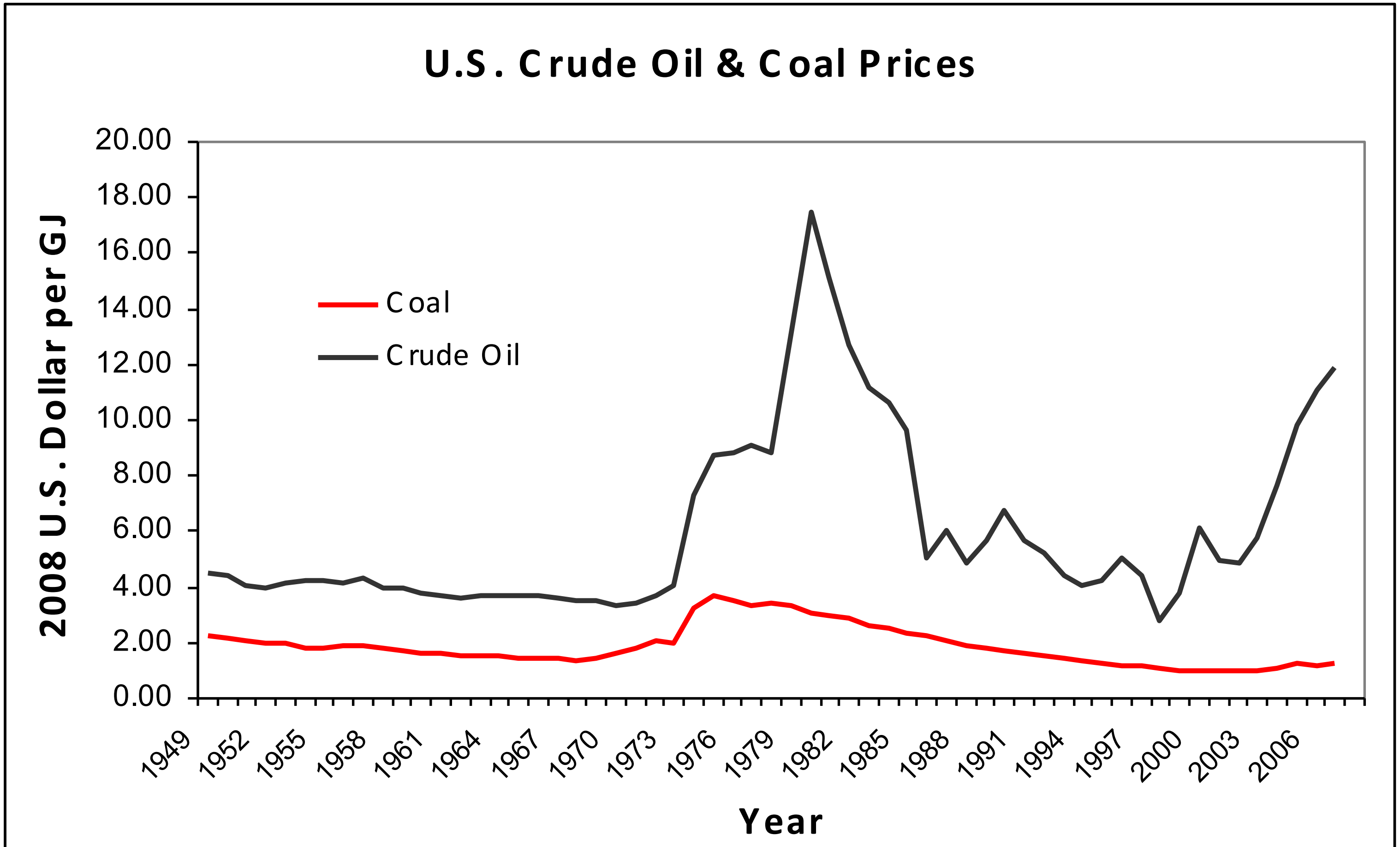
Biofuels based on low input cultivation of non-food crops offers promise in developing countries as a source of energy, in part because energy use is often very low at present. Biofuel markets can serve as an opportunity to trigger additional investments that could lead to increased production of food as well as biofuel crops by small-scale farmers. Further research on the use of indigenous non-food crops should be encouraged.


(photo by Jeff McNeely)
Enkoping, Sweden: First European
town powered by bioenergy

From Biofuels to Liquid Biofuels

- Why focus on liquid biofuels?

Why emphasis on liquid fuels – premium in price for use in transportation



(Howarth et al. 2009)

Model T Fords were powered by ethanol; diesel engine designed for peanut oil

Corn is a particular problem for nitrogen pollution, due to shallow root system and short active period of nutrient uptake (~ 60d)

Tile drainage and lack of winter cover crops aggravate nitrogen pollution.

Corn-ethanol goals in US predicted to increase nitrogen inputs to Mississippi River by 37%. National goal is to reduce nitrogen by at least 40% to mitigate the “dead zone“ in Gulf of Mexico.

Biodiversity

- **<u>Biodiversity</u> is greatly threatened by deforestation and conversion of grasslands and savannas to biofuel crops. Conservation reserve lands are also threatened with conversion to agriculture in support of biofuel production. On the other hand, natural grasslands and forests may be managed for harvest of biofuel material at moderate levels, providing reasonable protection for biodiversity.**

Searchinger et al. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land use change. ***Science*** 10.1126/science.1151861

- **Previous "analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels."**

- **"… corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse gas emissions …."**

- **"Biofuels from switchgrass, if grown on U.S. corn lands, increase emission by 50%."**

•If biofuels are grown on cleared forests or grasslands, the release of greenhouse gases from soils and vegetation almost always exceeds decades worth of fossil fuel offsets from using biofuels.

•If global warming is the primary concern, leaving natural ecosystems (particularly forests) alone is often a better strategy than clearing them to grow crops.

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- **Diverting land previously used for food crops to biofuels can result indirectly in clearing of forests or grasslands, as farmers clear other lands for food production.**

- **The greenhouse gas emissions from this clearing, sometimes in different countries or continents, can be quite large.**

- **These indirect consequences make many biofuel systems net releasers of greenhouse gases over several decades as biofuel production is increasing.**

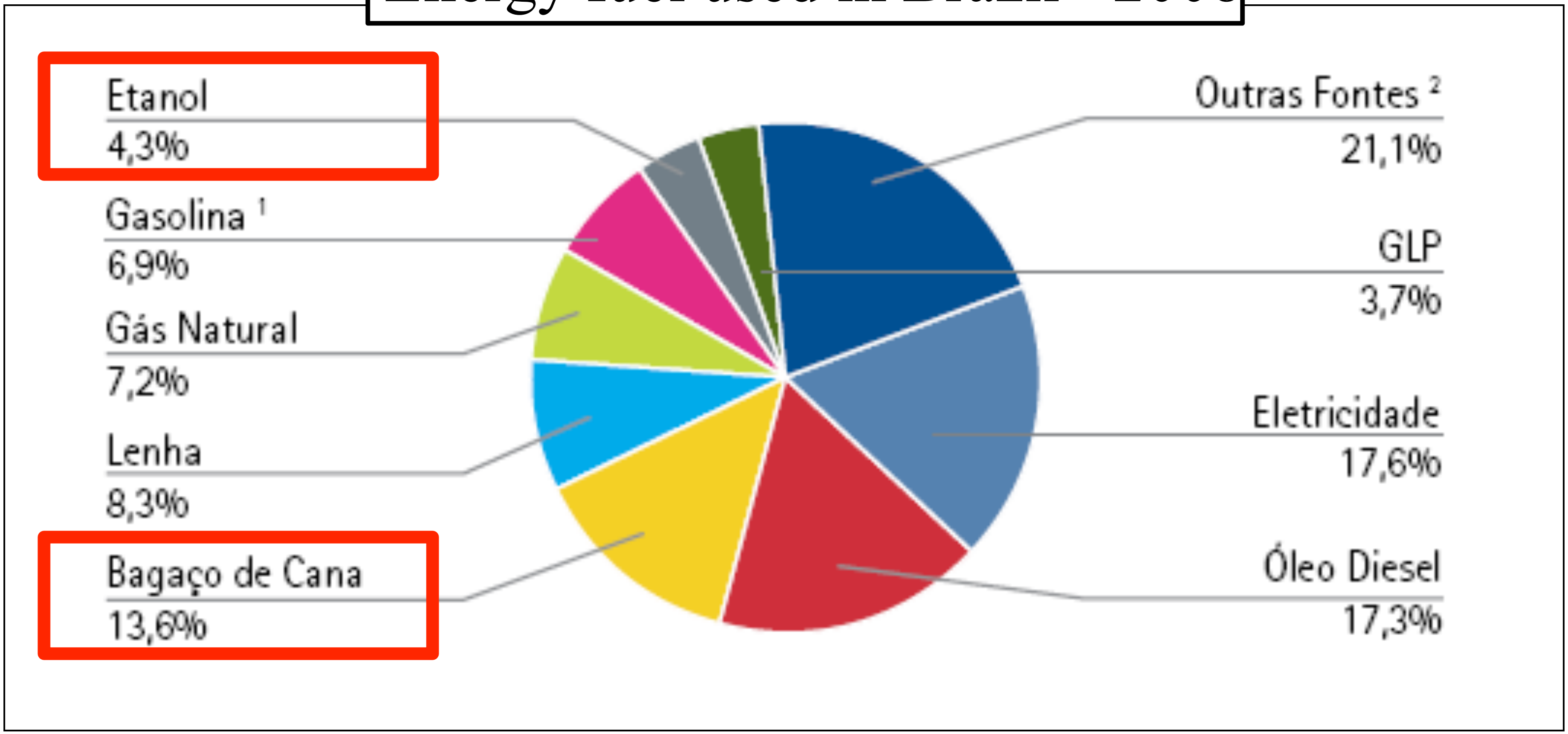
- **Biofuel crops offer their greatest promise for greenhouse gas benefits if grown on abandoned, degraded, or marginal lands. On these lands, carbon losses from conversion to biofuels are often small.**

- **Of course, if the lands have the potential to revert to forests, conversion to biofuels represents a lost opportunity for carbon storage.**

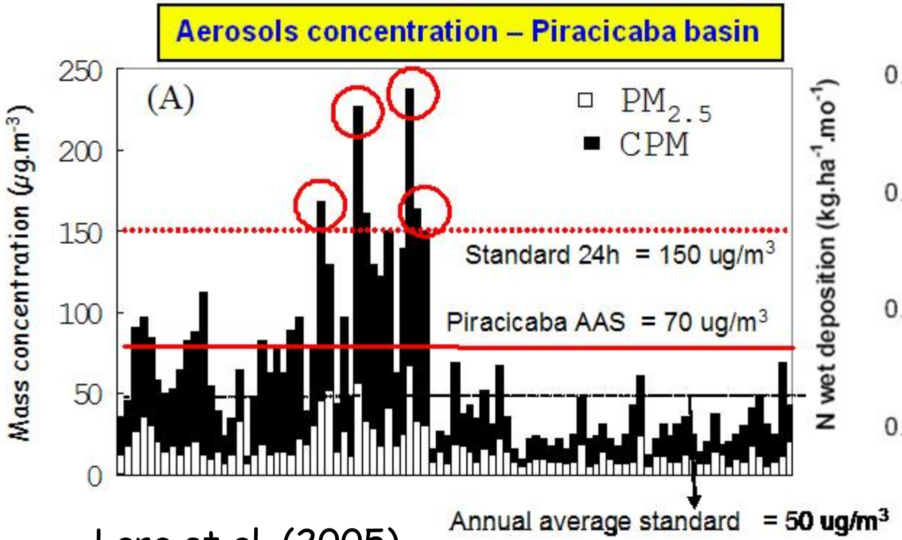
- **The environmental consequences of inputs required to make degraded and marginal lands productive must also be considered.**

Large areas of marginal and degraded lands exist in many areas, often on abandoned farmland. These areas provide an opportunity to produce crops for biofuels while also restoring the landscape. However, often this land needs substantial investment in irrigation and fertilizer. Some of these regions include areas of high biodiversity. There is substantial uncertainty over the magnitude of lands that could be farmed in a sustainable, environmentally beneficial way for biofuels.

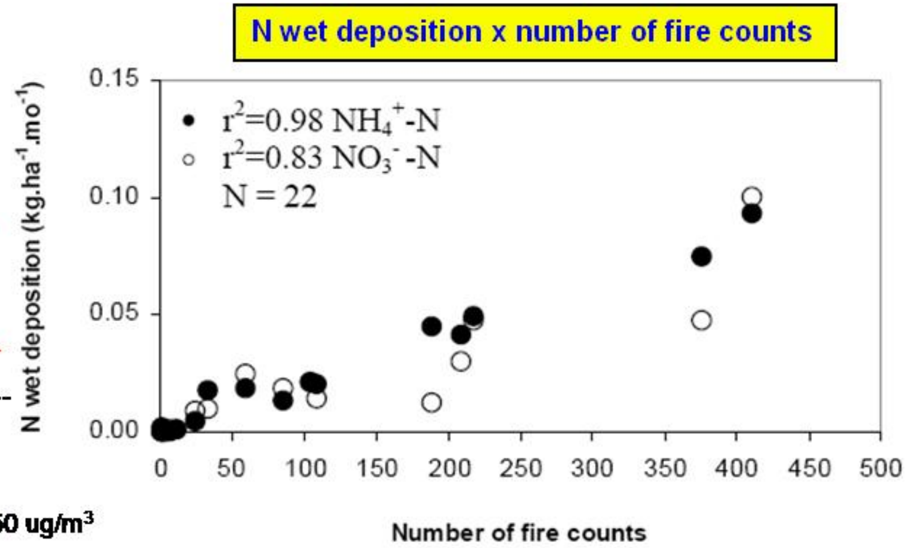
Energy fuel used in Brazil - 2008

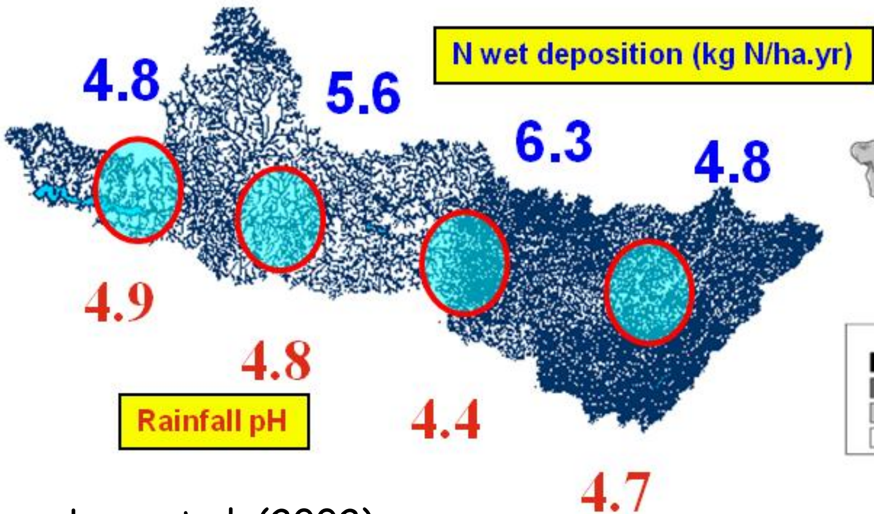


(Courtesy of Luiz Martinelli)

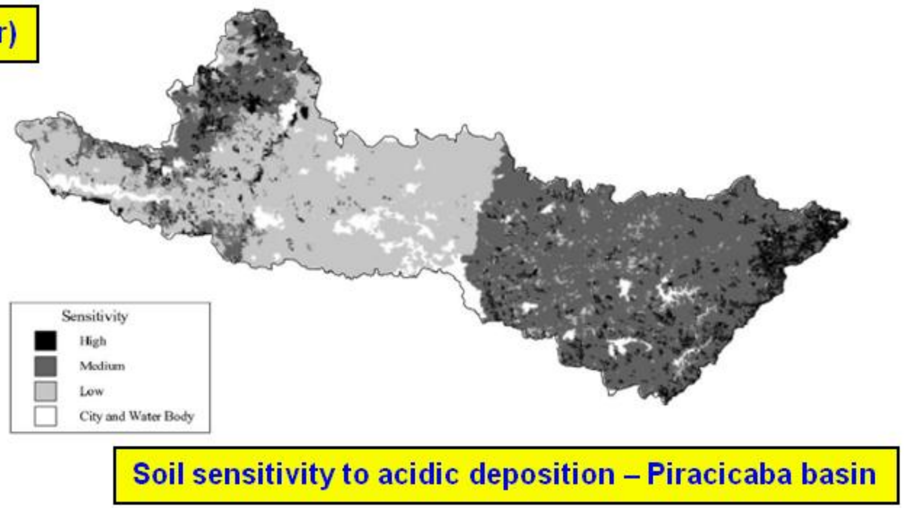


Lara et al. (2005)





Lara et al. (2002)



Krusche et al. (2003)