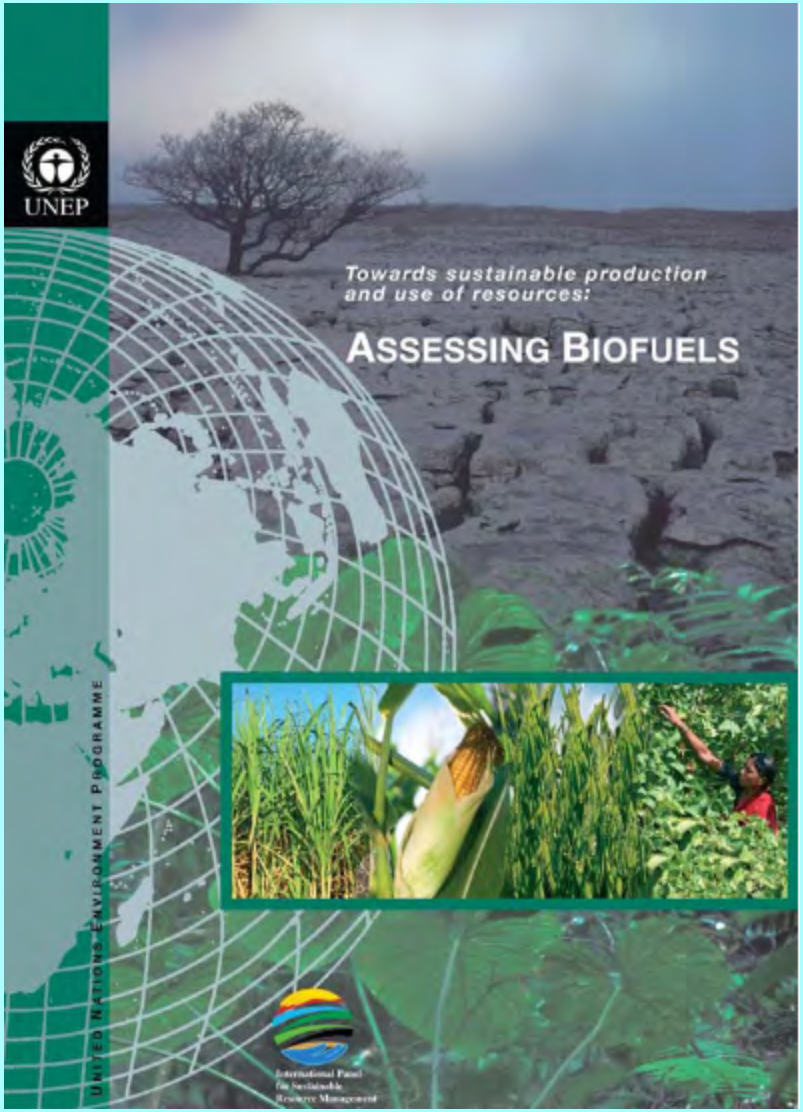
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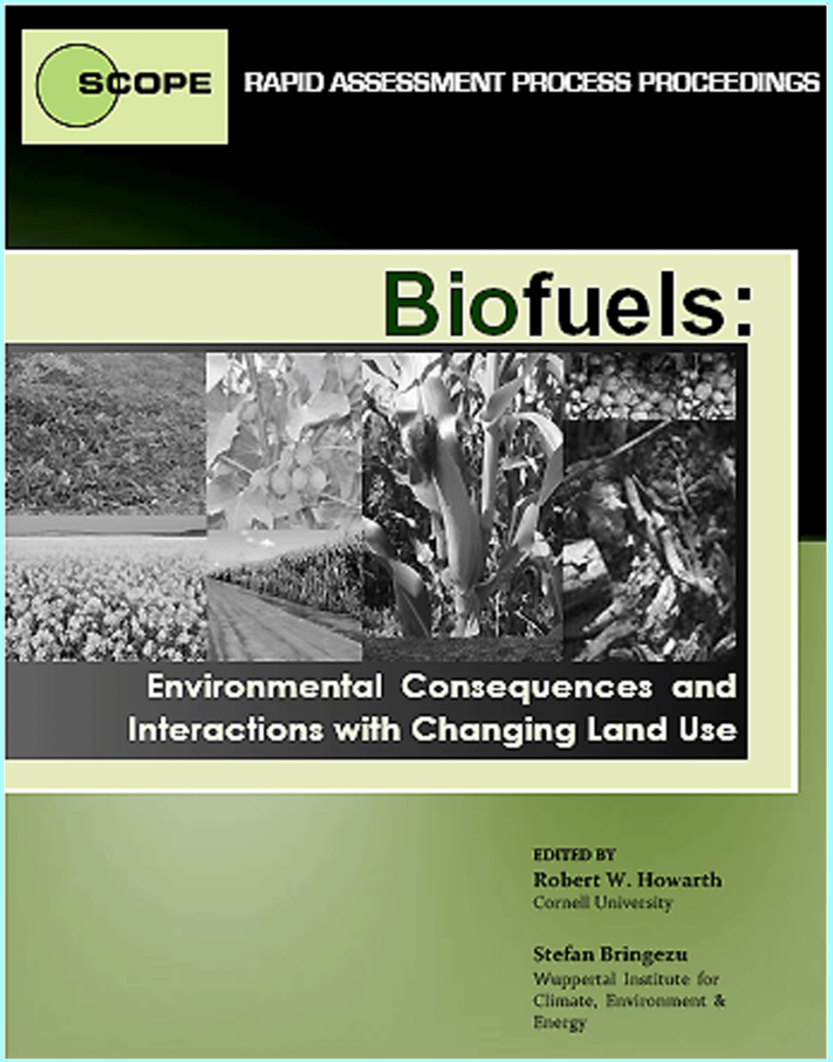
Biofuels: Environmental Sustainability and Interaction with Food Systems



Bob Howarth
(Cornell University, USA)
Chair, International SCOPE
Biofuels Project

November 3, 2010
CIIFAD Colloquium


UNEP
Towards sustainable production and use of resources:
ASSESSING BIOFUELS
UNITED NATIONS ENVIRONMENT PROGRAMME
International Panel for Sustainable Resource Management


SCOPE
RAPID ASSESSMENT PROCESS PROCEEDINGS
Biofuels:
Environmental Consequences and Interactions with Changing Land Use
EDITED BY
Robert W. Howarth
Cornell University
Stefan Bringezu
Wuppertal Institute for Climate, Environment & Energy



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Governments and industry focused on liquid biofuels (ethanol and biodiesel for transportation)

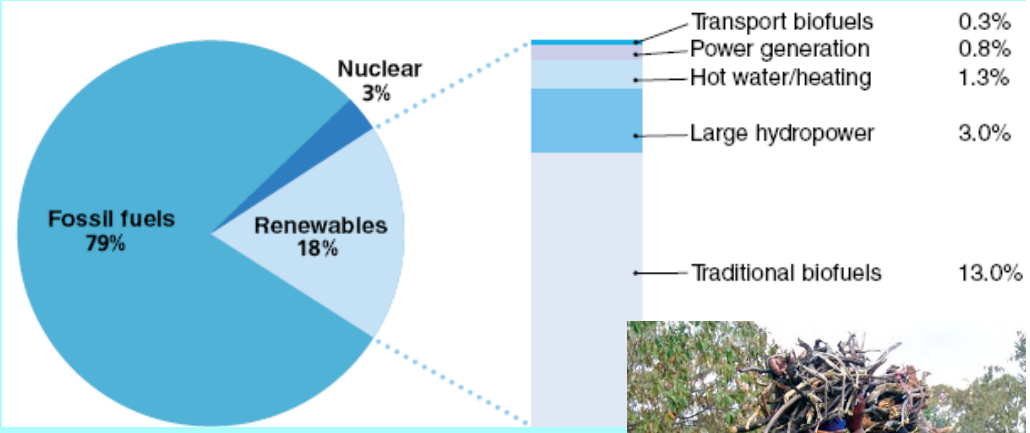
- Global climate change
- Energy security
- Rural development

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Governments and industry focused on liquid biofuels

- Global climate change
- Energy security
- Rural development



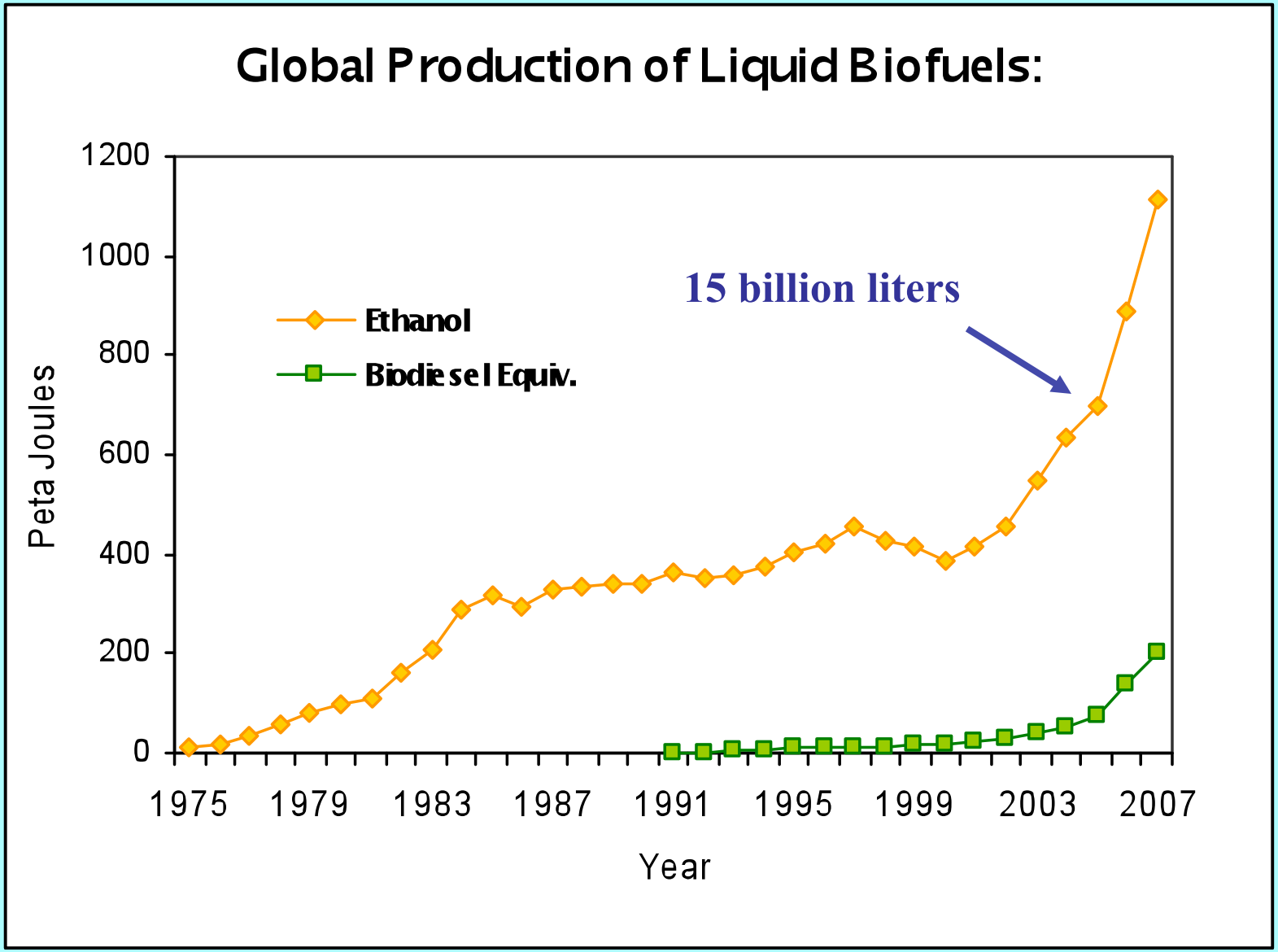


Global energy use from all sources:

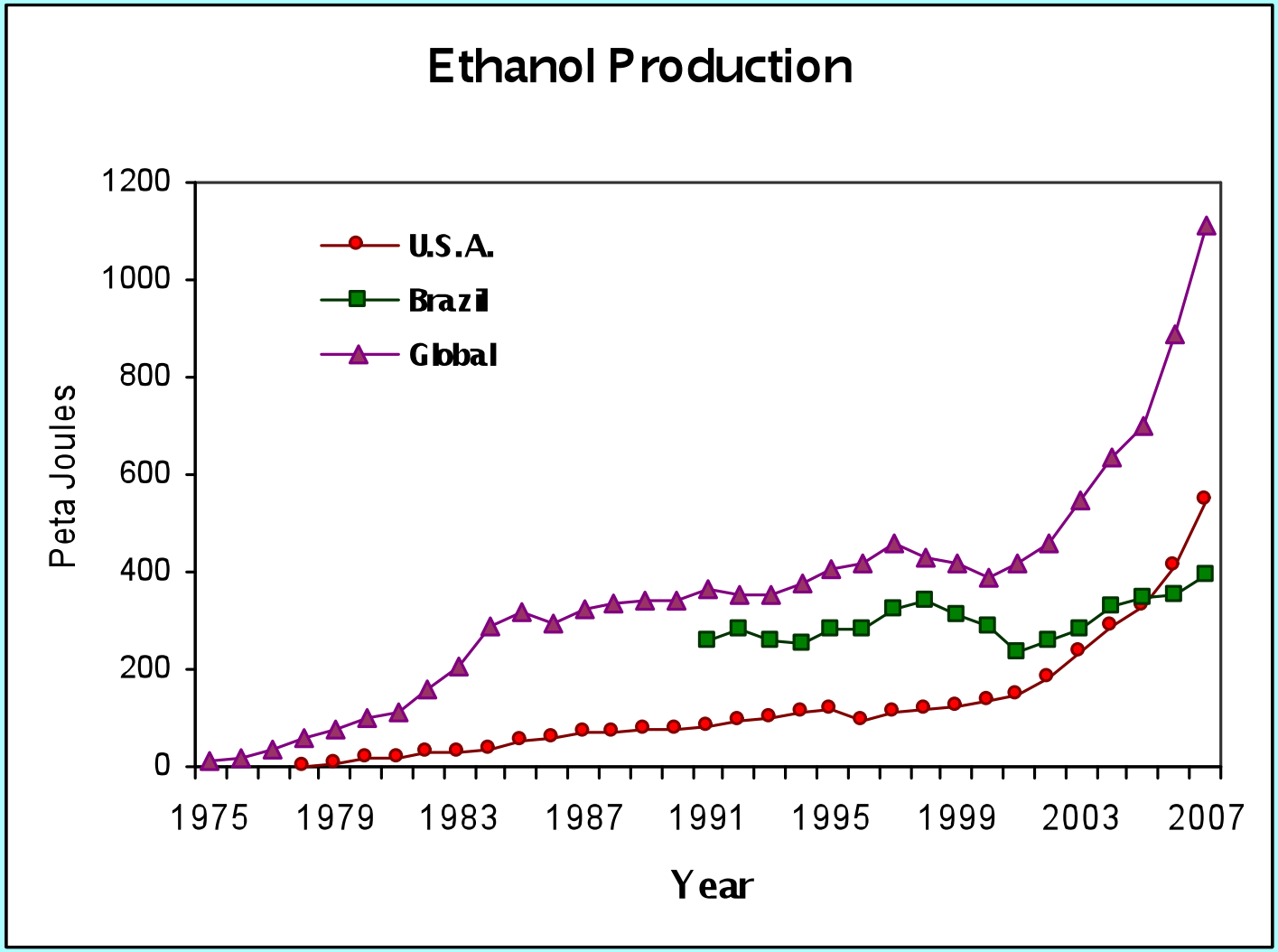
- **0.4% liquid biofuels**
- **10-13 % solid biofuels (wood, charcoal, dung)**



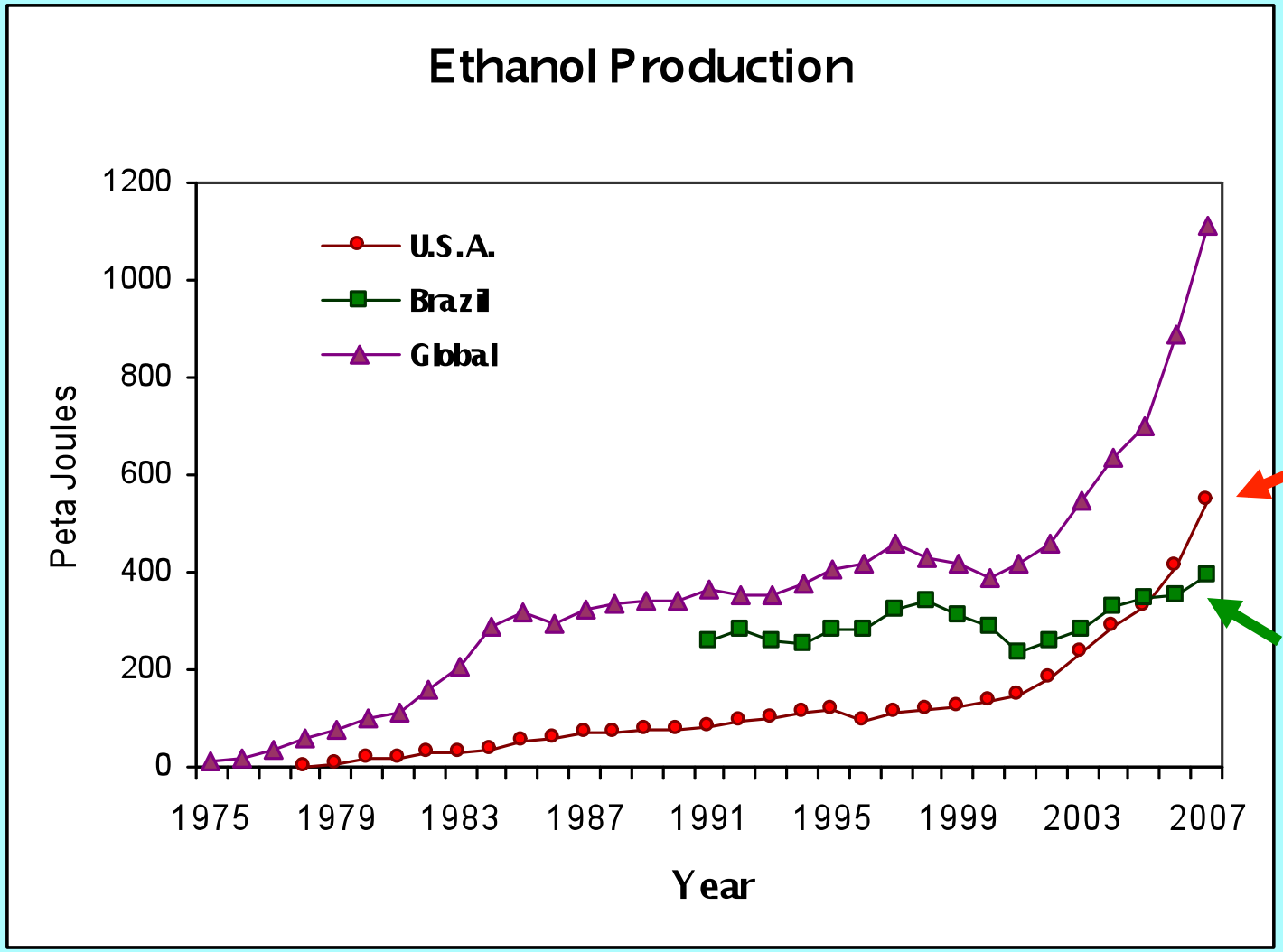
Model T Fords were powered by ethanol; diesel engine designed for peanut oil



Howarth et al. 2009



Howarth et al. 2009





Almost all corn

Almost all sugar cane



Howarth et al. 2009



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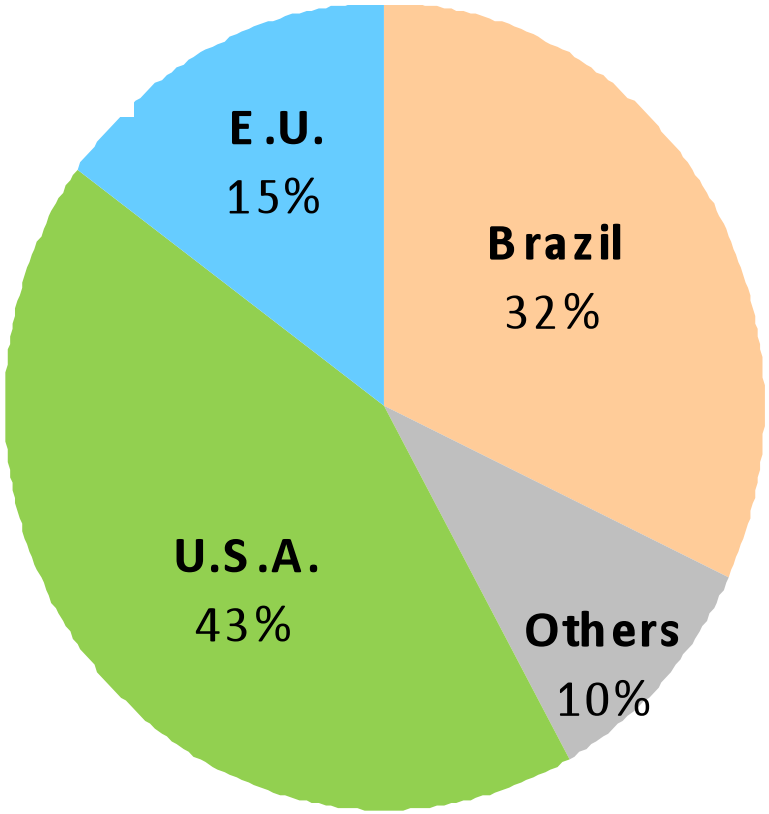
2007:

United States -- 26% of corn to produce ethanol for 1.3% of total liquid fuel use.

**(1.8% of transportation liquid fuel use;
0.5% of total energy use)**

Brazil -- 60% of sugar cane harvest to produce ethanol for 15% of liquid fuel use.

All liquid biofuels (ethanol, biodiesel)



Biodiesel dominated by rapeseed in both EU and elsewhere.



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Some national goals:

USA :

- **-- 26 billion liters ethanol by 2012**
- **-- 54 billion liters ethanol from corn by 2022**
- **-- 70 billion liters "advanced biofuels" by 2022**

European Union:

- **-- 5.75% of total transportation fuel by 2010**
- **-- 10% by 2020 (but must meet greenhouse gas emission and biodiversity standards)**

China – 100% E10 (10% ethanol in gasoline) by 2012

India – 20% of all diesel use to be biodiesel by 2020

Many countries have ambitious liquid biofuel goals -- 10% or more of transportation fuels by 2020 or so.

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

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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

-- hydrocarbon fuels such as "biomass to liquid fuels," or BtL



Included in our analysis, but unproven and developing technologies, so much greater uncertainty.

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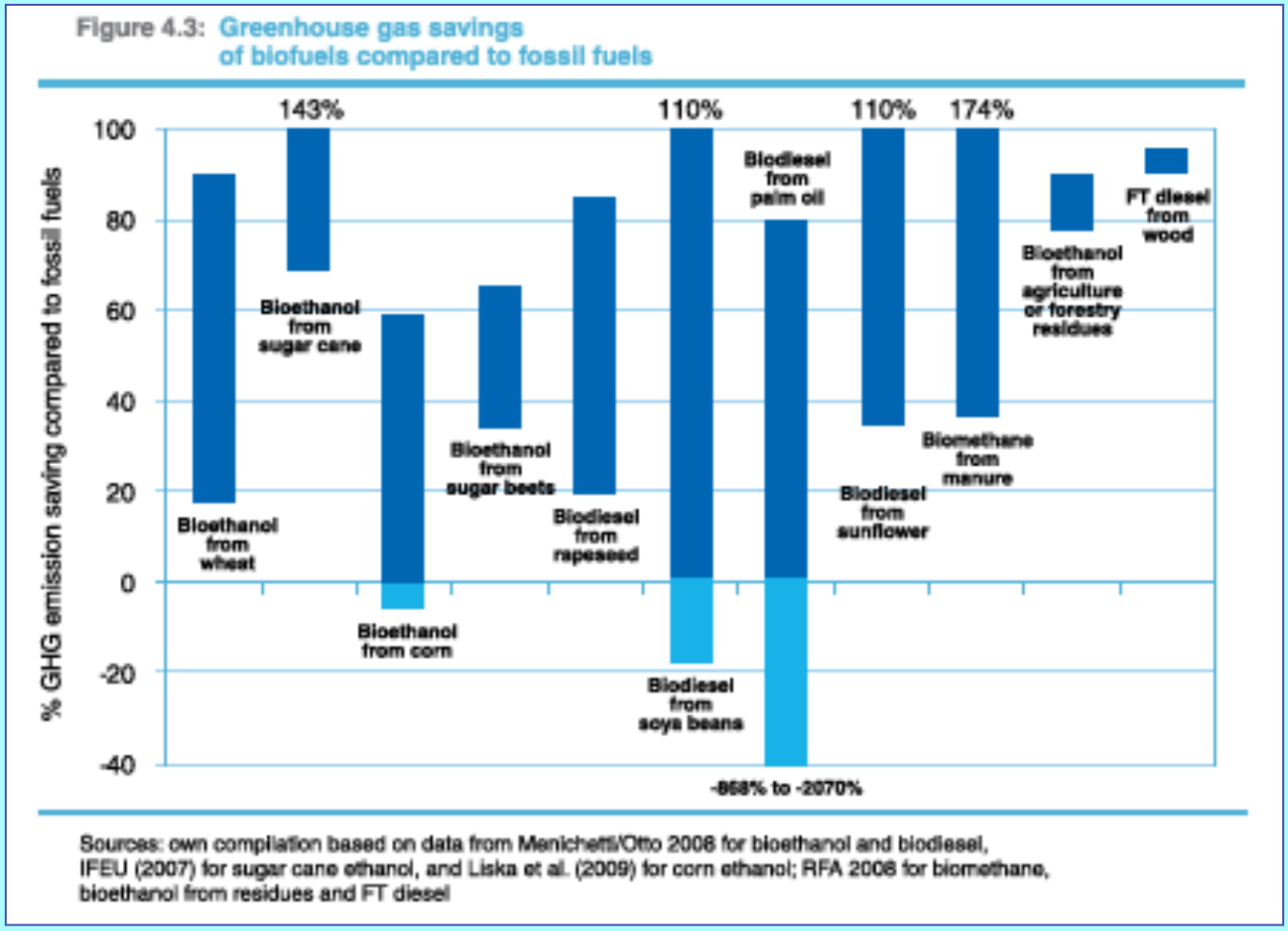
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Environmental effects (including greenhouse gas emissions) vary, depending upon issues such as:

- **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**

good

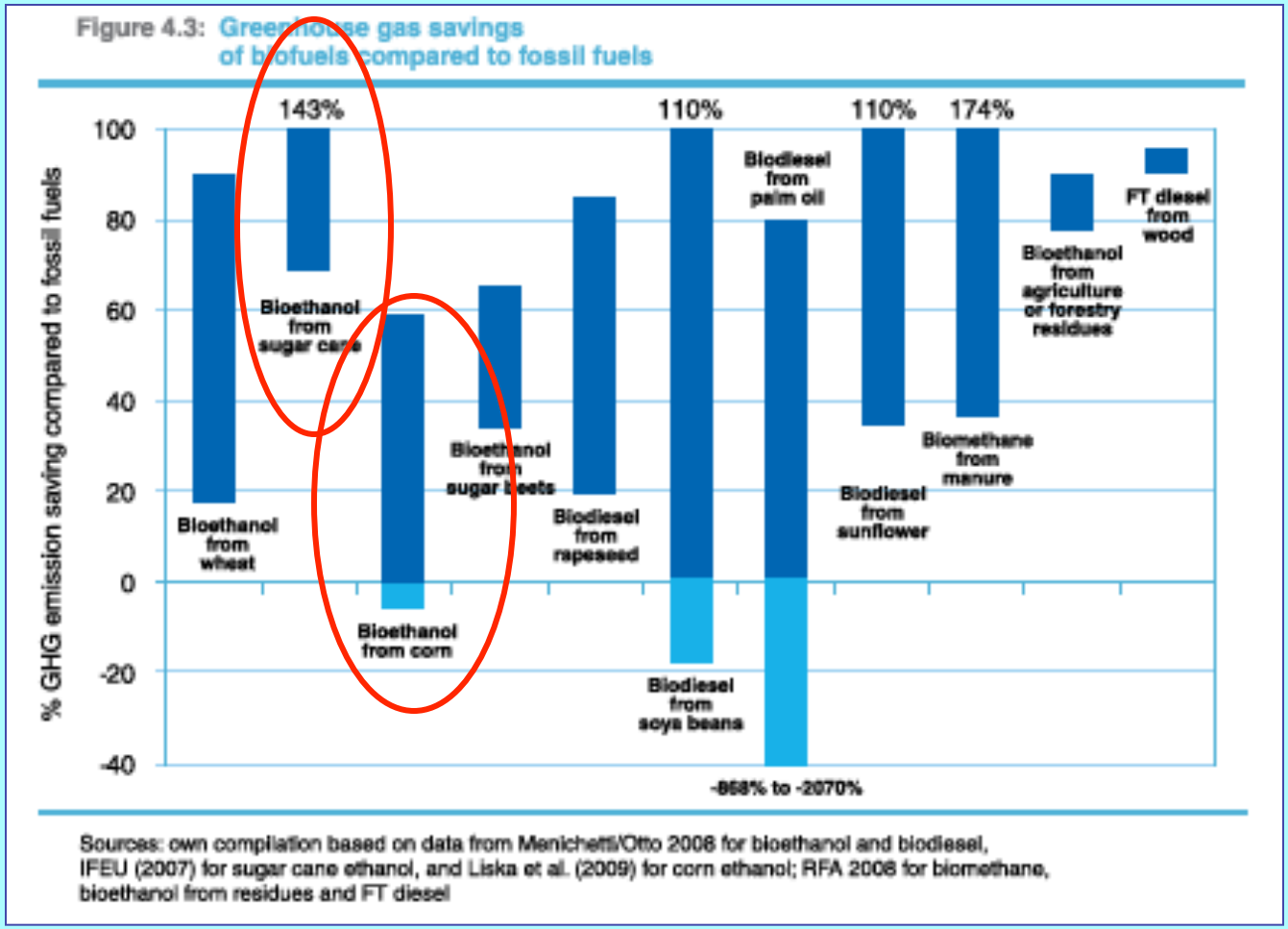
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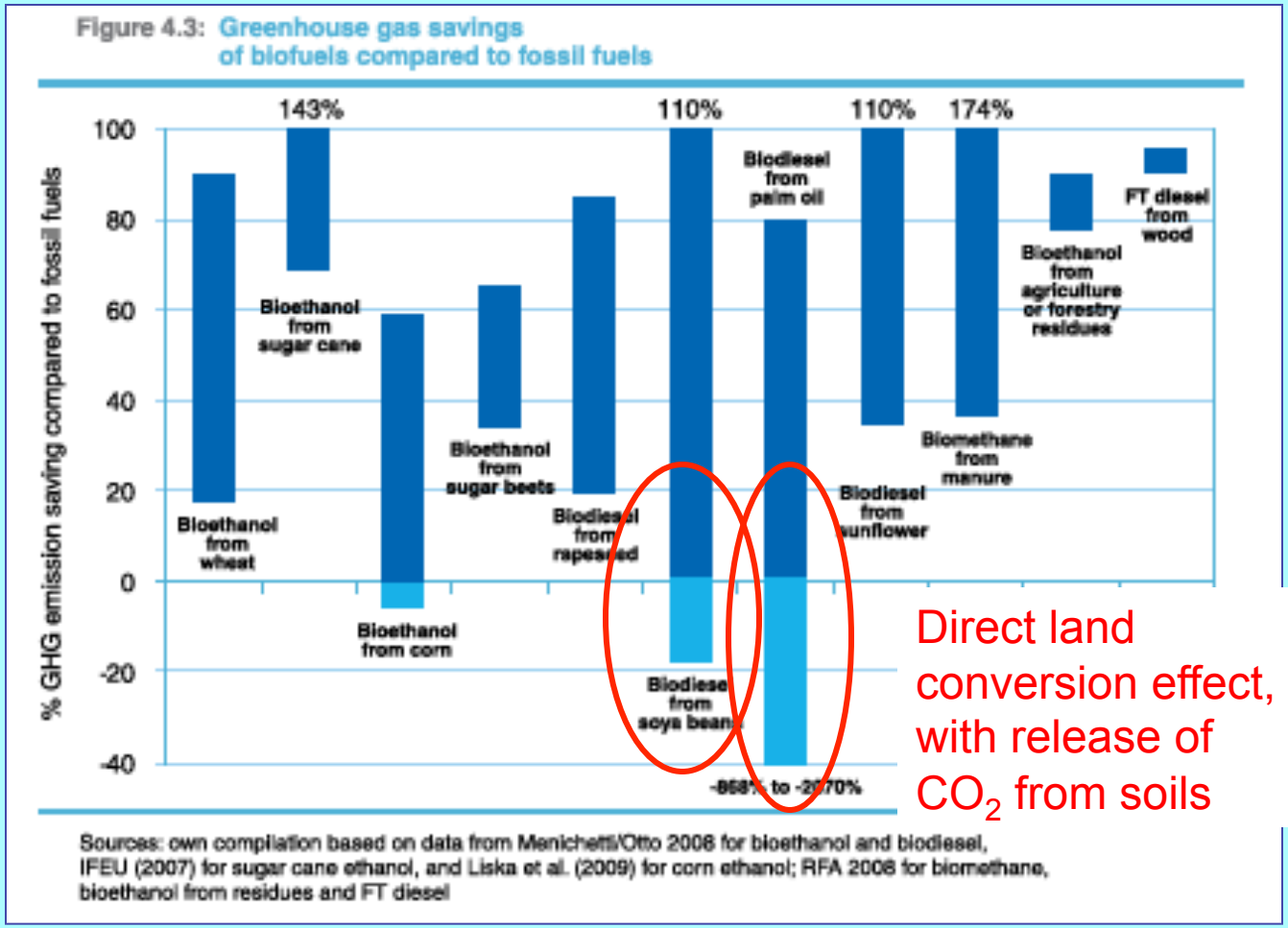
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Indonesia plans to expand palm oil plantations 4X by 2030 (to 26 million hectares).

Virgin rain forest will be cut for most of this (67%).

A loss of 30% of all Indonesian rain forests.

Half of the rain forest land lost would be peat bogs…

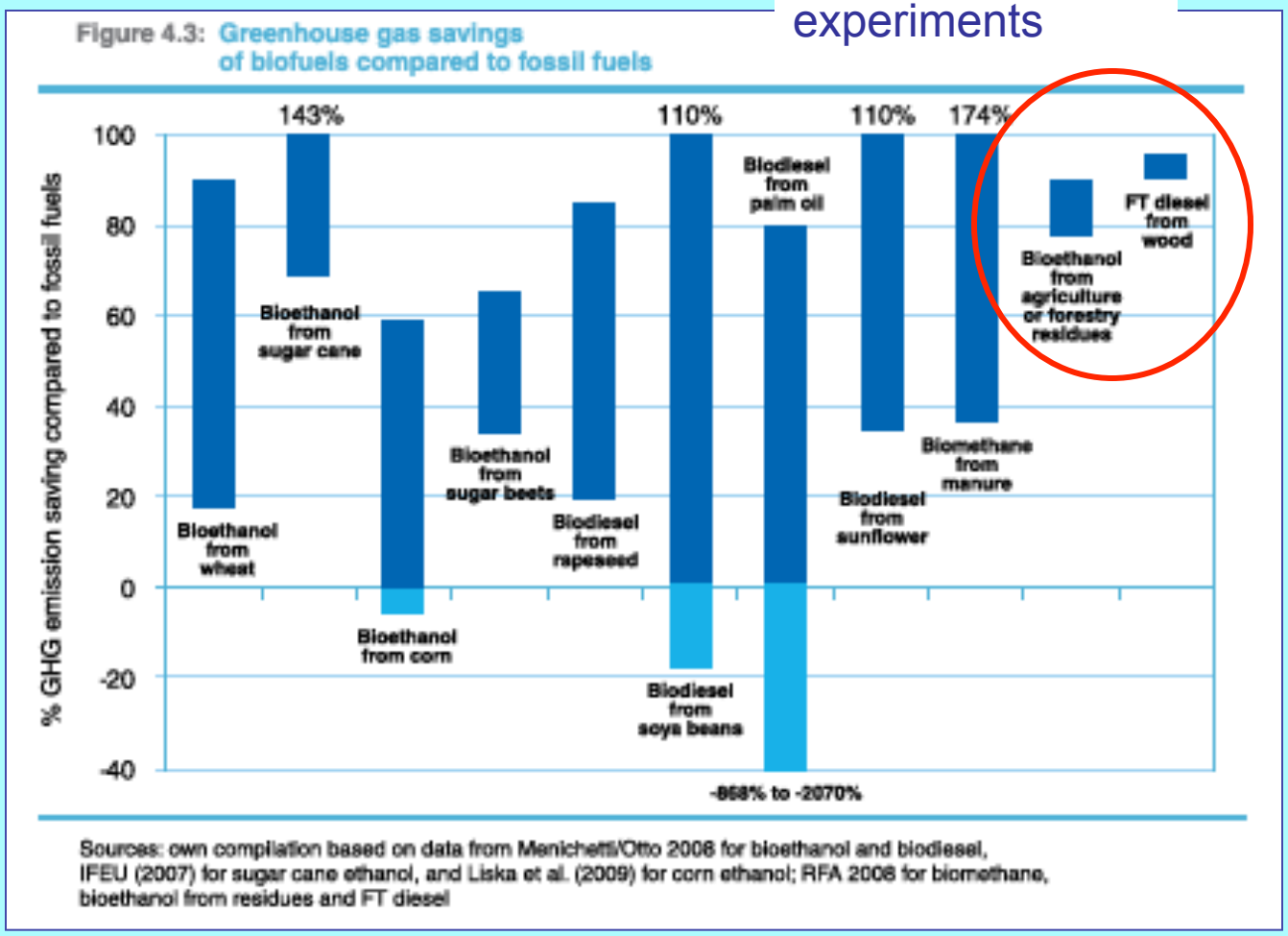
Estimated increase of 1.4 gigatons CO_2 per year (4% of current global CO_2 flux)

(Bringezu et al. 2008)

Based on small-scale pilot experiments

good

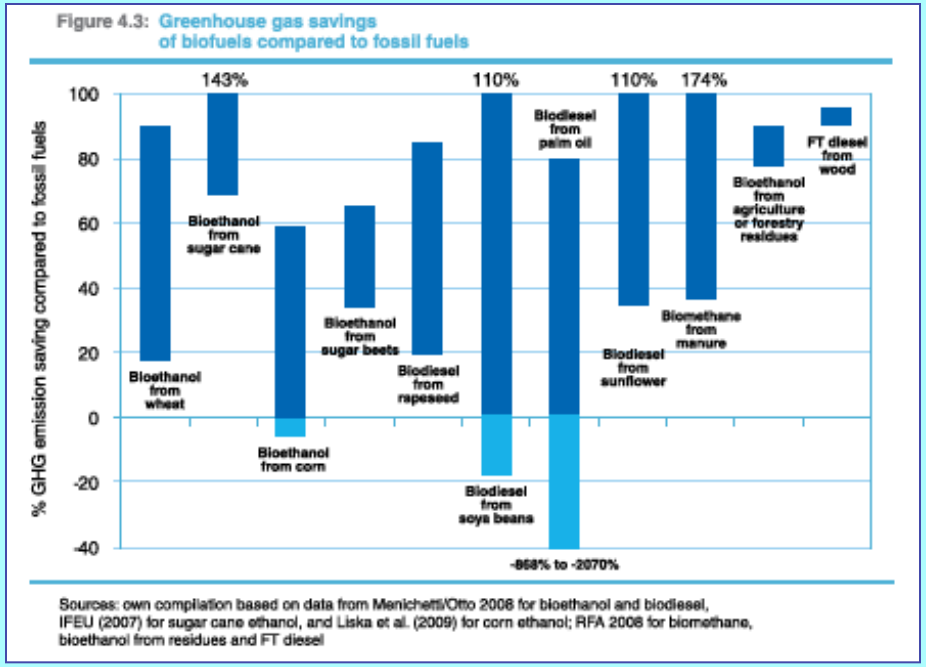
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This life-cycle analysis (LCA) approach underestimates greenhouse gas emissions for at least 3 reasons:

- Methane release from using natural gas as a process fuel not included (makes upper end of corn-ethanol far less favorable).
- Nitrous oxide emissions from agricultural use of nitrogen underestimated by 3- to 4-fold (makes almost all biofuels less favorable, by a lot for both corn-ethanol and ethanol from sugar cane).
- Indirect land use effects not included (makes far more unfavorable any biofuel that is expanding on land previously used for food agriculture).



Industrial Designation or Common Name	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon			
				SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4x10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7x10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03x10^{-3}	310	289	298	153

Intergovernmental Panel on Climate Change (2007)

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Indirect land use effect

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 …."**

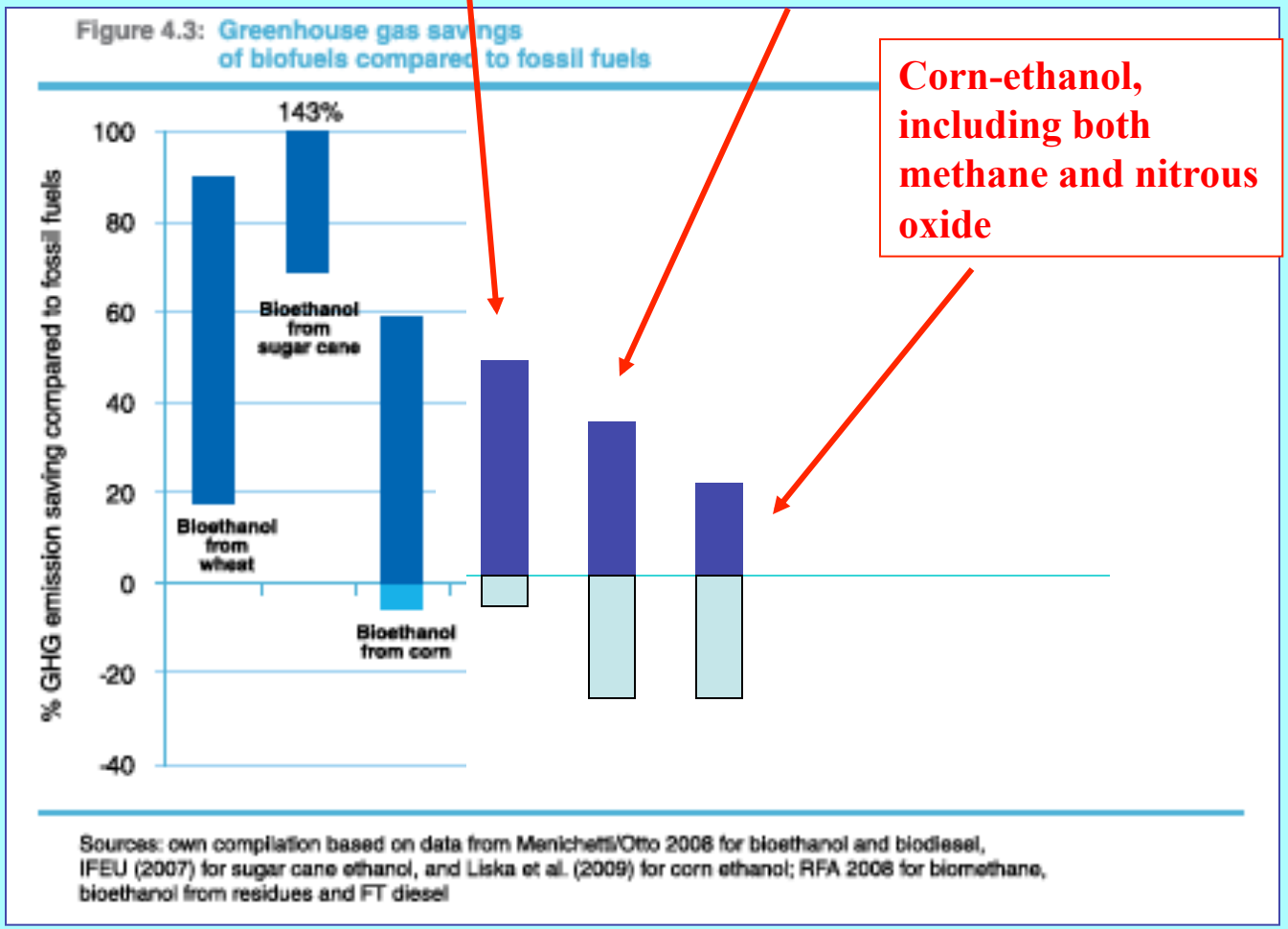
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Corn-ethanol, including methane from natural gas use

Corn-ethanol, including nitrous oxide

Corn-ethanol, including both methane and nitrous oxide



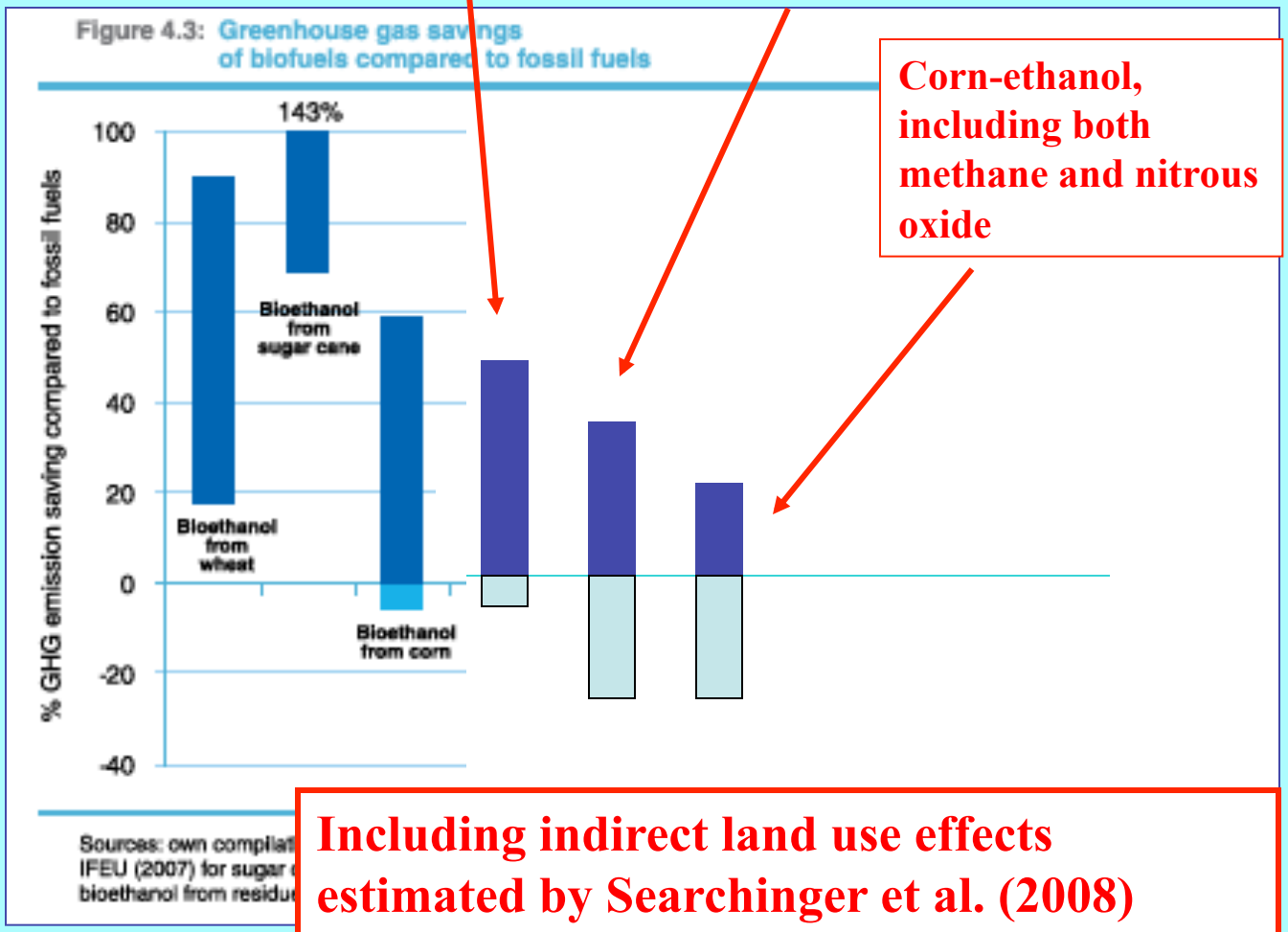
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Corn-ethanol, including methane from natural gas use

Corn-ethanol, including nitrous oxide

Corn-ethanol, including both methane and nitrous oxide



Including indirect land use effects estimated by Searchinger et al. (2008) moves the mean off-scale down to -200%!

Conclusions on greenhouse gases:



- **Biofuels grown on cleared forests or grasslands -- release of greenhouse gases from clearing usually exceeds decades worth of fossil fuel offsets.**

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

.



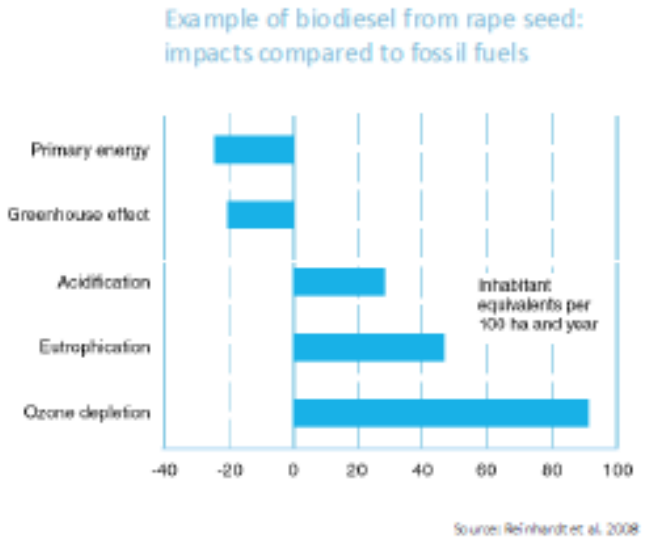
- **Diverting land previously used for food crops to biofuels can result indirectly in clearing of forests or grasslands, as farmers clear other lands for food production.**

- **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.**

Other environmental impacts of biofuels are so far insufficiently covered by life cycle assessments

- Biofuels tend to have **impacts on** eutrophication, acidification, and ozone depletion.
- Impacts such as water consumption and effects on biodiversity are hardly considered by LCA. **A harmonized set of impact indicators is lacking.**
- **LCA is a useful tool, but has methodological constraints that should be taken into account when analysing and comparing results:** varying assumptions. For instance, results of life-cycle GHG balances depend on the way land conversion related impacts are attributed.
- LCA, as a product-oriented approach, needs to be **complemented by analytical approaches that capture larger spatial and socio-economic contexts** in order to account for effects such as indirect land use change.



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SCOPE Project conclusions on other environmental effects:

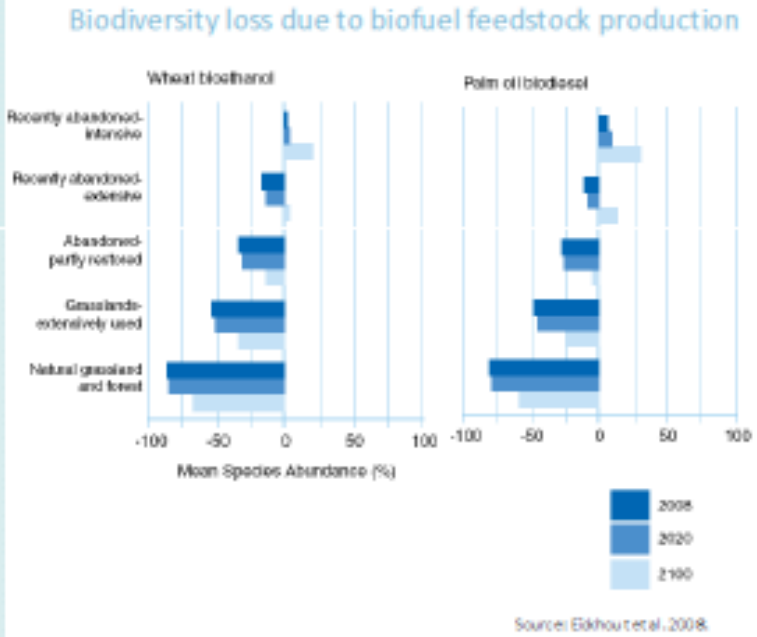


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Biofuel production and consumption have a variety of effects on the local and regional environment. Growing crops is essentially the same for biofuels as for other agricultural purposes. However, the environmental impacts of agriculture often increase as more land is used, land is farmed more intensively, and marginal lands are placed into agriculture.

Land conversion for biofuel crops can lead to significant loss of biodiversity

- **In particular habitat loss through land use change might have a large impact on biological diversity.**
- **Invasive species** as feedstocks, and nutrient pollution through intensive agriculture may further impact on biological diversity.
- **Benefits from mitigated climate change** can not compensate losses by habitat conversion for decades.
- However, utilizing **recently abandoned and degraded land** could lead to beneficial effects for biodiversity.



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

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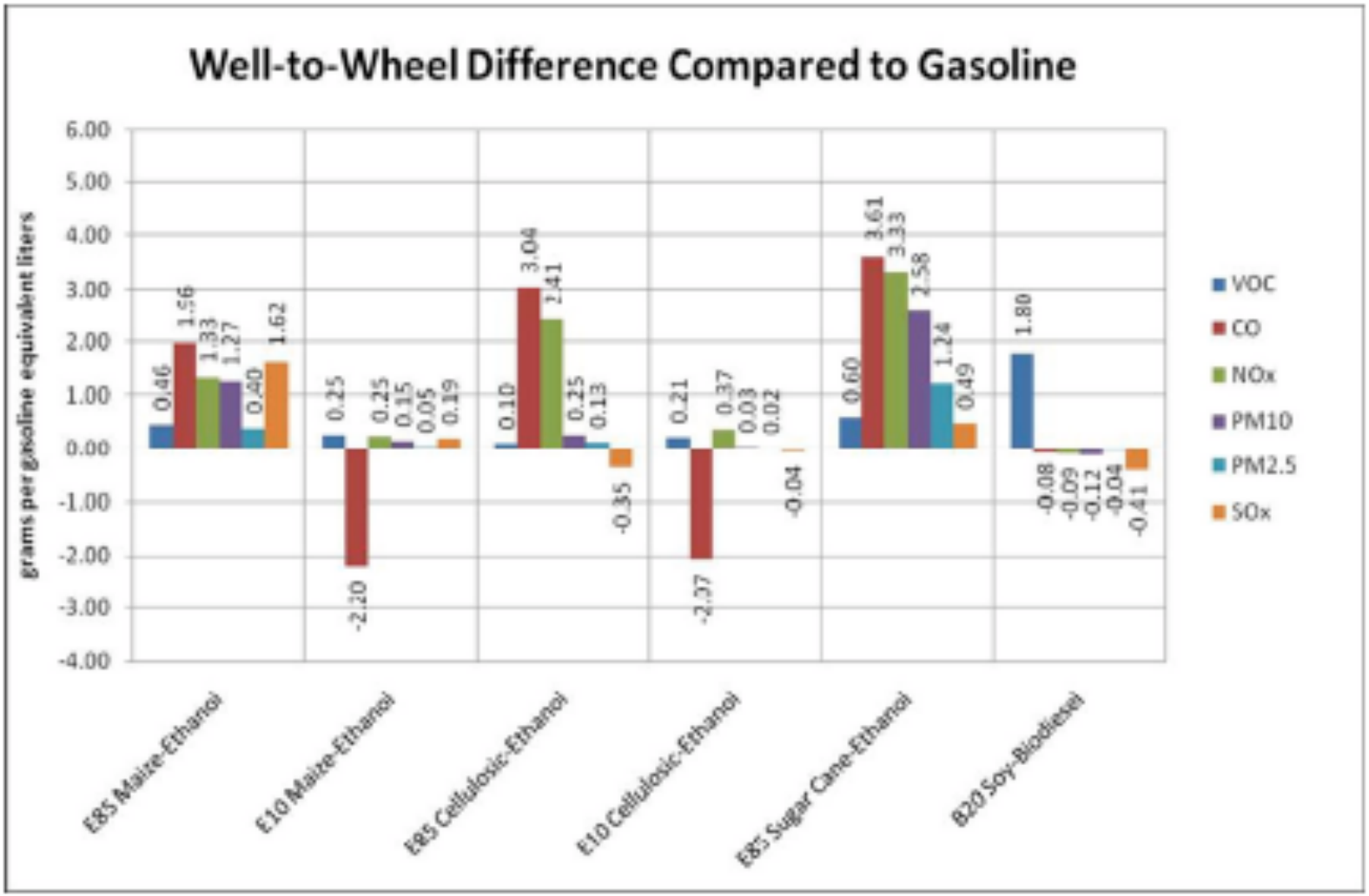
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(Luiz Martinelli)

Bad

Good



(Hess et al. 2009)

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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.

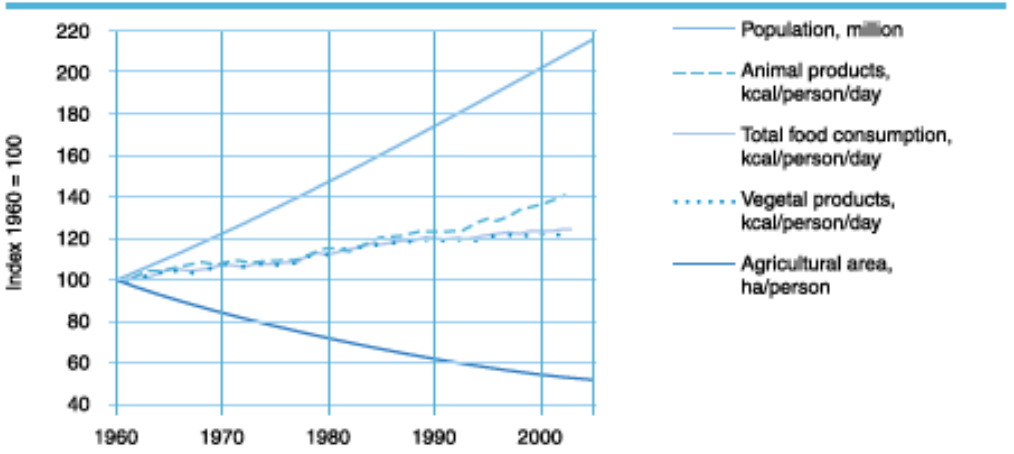
Bioenergy potential has to be assessed in light of global trends: population growth, nutrition, yields

- **Global population** is expected to grow by 36% between 2000 and 2030 (medium projection of UN/FAO).
- **Average crop yields** are expected to increase at about the same rate. However, relative yield increases have in general weakend (estimates for global yields in the next decade predict 1-1.1% p.a. growth for cereals).
- **Meat consumption** is expected to increase by 22% per capita between 2000-2030, which requires more cropland for feed.
- **Effects of climate change** will put further pressure on yield improvements and availability of arable land.
- **Feeding the world population will require the expansion of global cropland. Additional demand for non-food biomass will add on top of this.**

Development of global population, agriculture land and consumption per person in the past (1960-2005)



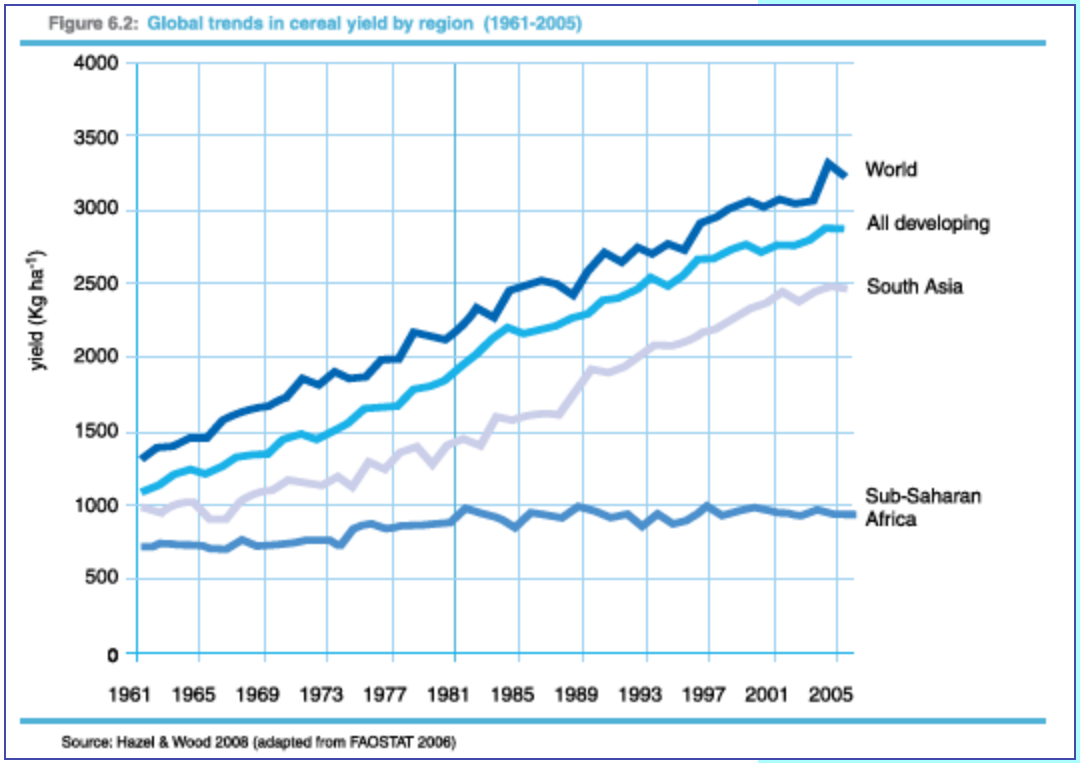
Figure 3.9: **Development of global population, agriculture land and consumption per person in the past (1960 - 2005)**



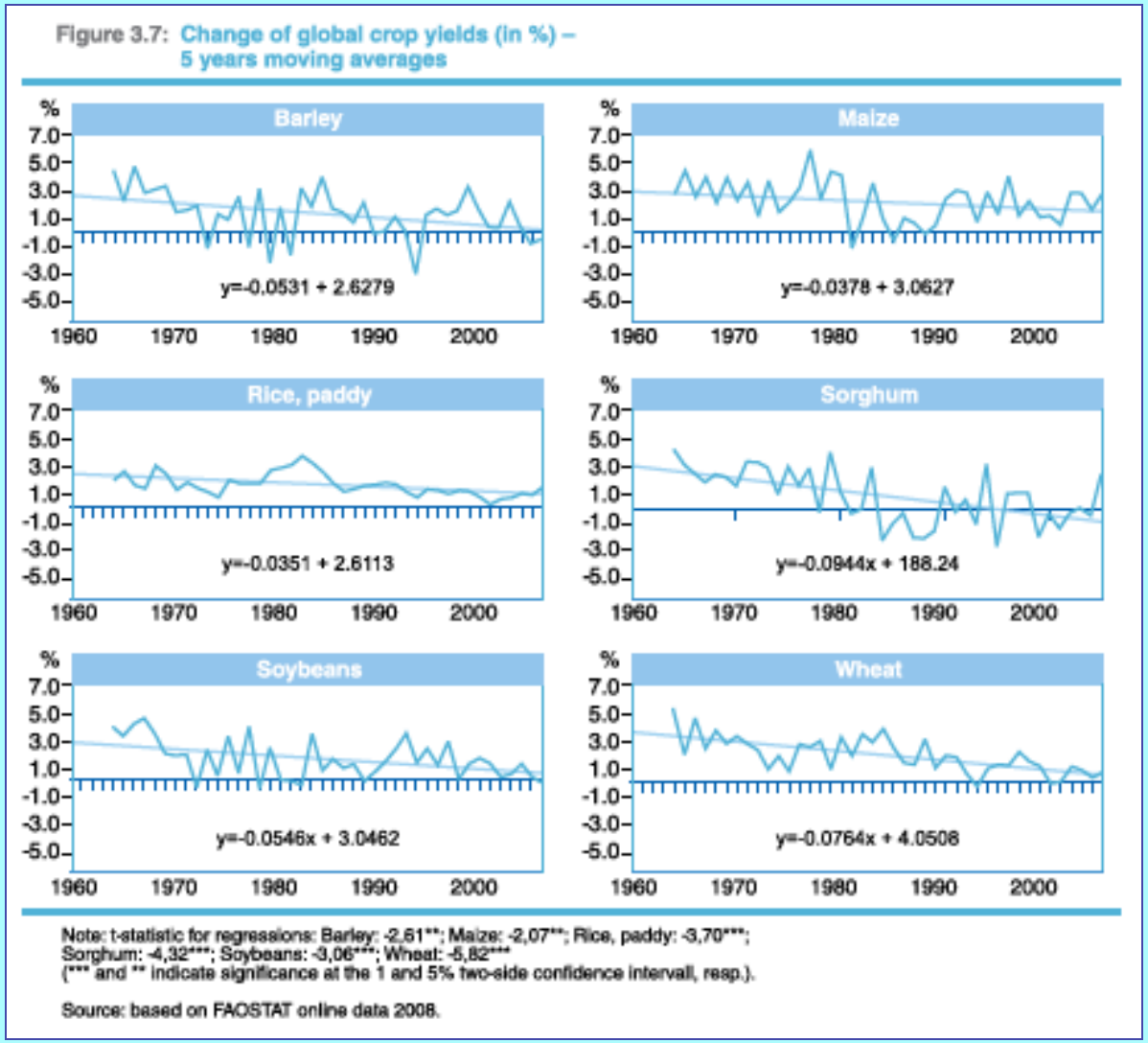
Sources: UN population statistics online; FAOSTAT online

Options
Increasing yields and optimizing agricultural production

- The past trends and the potential to increase yields differs among regions.
- Unused potential for yield increase seem to exist in regions such as Sub-Saharan Africa.

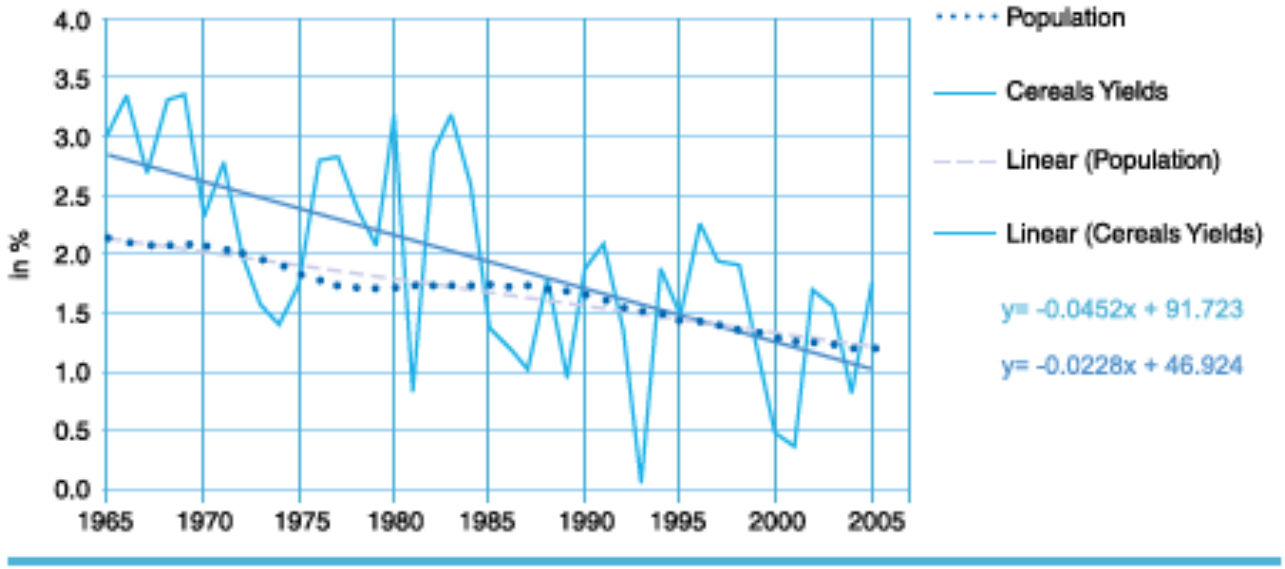


(UNEP 2009)


Figure 3.7: Change of global crop yields (in %) – 5 years moving averages
Barley
y=-0.0531 + 2.6279
Maize
y=-0.0378 + 3.0627
Rice, paddy
y=-0.0351 + 2.6113
Sorghum
y=-0.0944x + 188.24
Soybeans
y=-0.0546x + 3.0462
Wheat
y=-0.0764x + 4.0508
%
7.0
5.0
3.0
1.0
-1.0
-3.0
-5.0
1960
1970
1980
1990
2000
Note: t-statistic for regressions: Barley: -2,61**; Maize: -2,07**; Rice, paddy: -3,70***; Sorghum: -4,32***; Soybeans: -3,06***; Wheat: -5,82***
(*** and ** indicate significance at the 1 and 5% two-side confidence intervall, resp.).
Source: based on FAOSTAT online data 2008.

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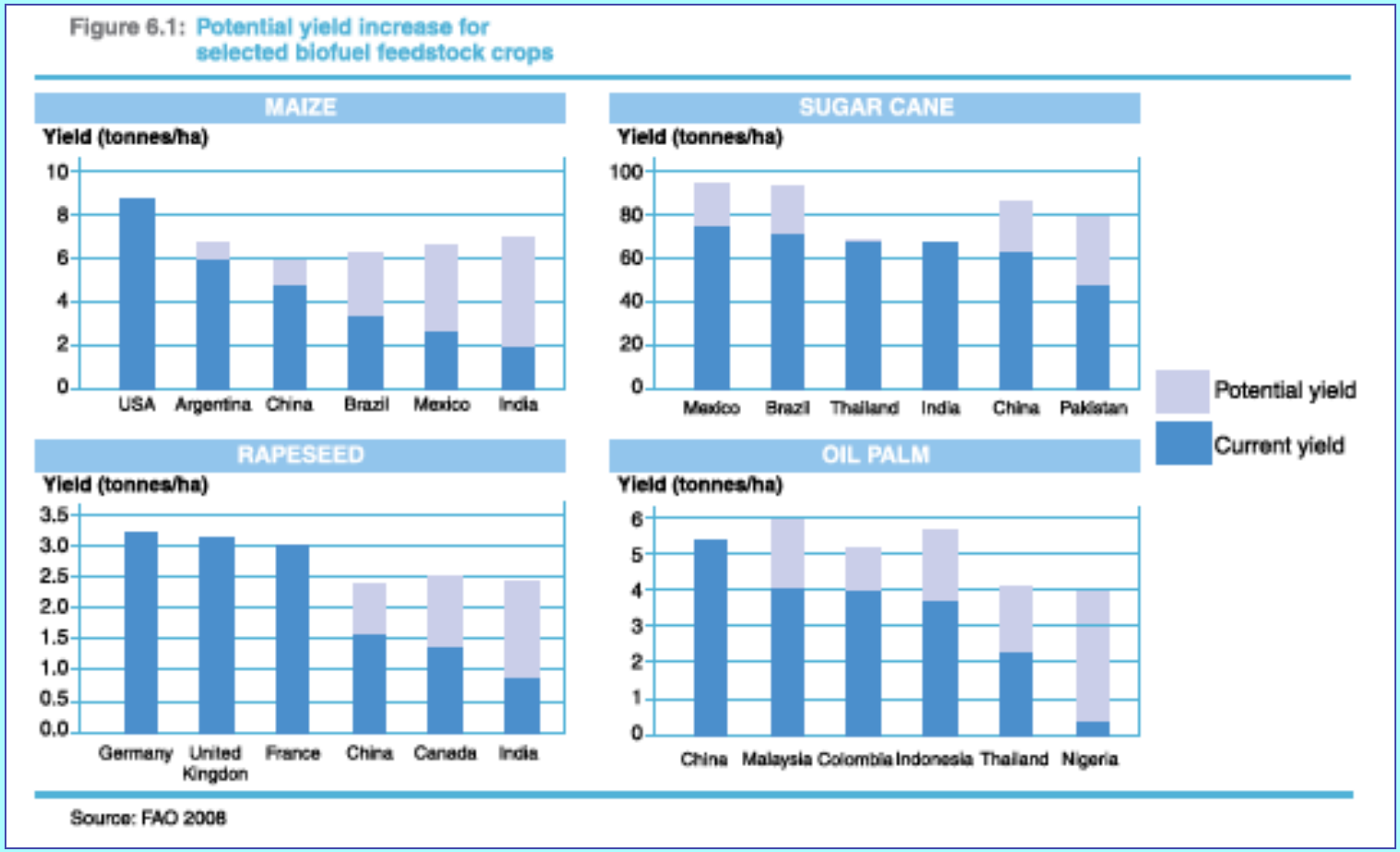
Figure 3.8: World population vs. cereal yields: growth rates as moving average over 5 year periods, 1961 to 2006



Note: t-statistic for regressions: Population: -28,55***; Cereals Yields: -5,12*** (*** indicates significance at the 1% two-side confidence level).

Sources: U.S. Census Bureau, International Data Base; FAOSTAT online for cereals yields.

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Figure 6.1: Potential yield increase for selected biofuel feedstock crops
MAIZE
Yield (tonnes/ha)
10
8
6
4
2
0
USA
Argentina
China
Brazil
Mexico
India
SUGAR CANE
Yield (tonnes/ha)
100
80
60
40
20
0
Mexico
Brazil
Thailand
India
China
Pakistan
Potential yield
Current yield
RAPESEED
Yield (tonnes/ha)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Germany
United Kingdon
France
China
Canada
India
OIL PALM
Yield (tonnes/ha)
6
5
4
3
2
1
0
China
Malaysia
Colombia
Indonesia
Thailand
Nigeria
Source: FAO 2008

(UNEP 2009)

Land is a limiting factor for biofuels development

- **Conservative estimates of projected land use for biofuel crops vary between 35-166 Mha for 2020.**
- Estimates of long-term potential land requirements for biofuels vary widely and depend on the basic assumptions made - mainly type of feedstock, geographical location and level of input and yield increase.
- Ravindranath et al (2009) estimated that 118-508 Mha would be required in 2030 to provide 10% of transport fuel demand with 1st gen biofuels. For comparison, total cropland is about 1,500 ha.
- **Land use change has a range of potential implications, including on GHG balance and biodiversity.**





The drive to meet the demand for palm oil is resulting in conversion of forested areas into palm oil plantations.

These satellite images reveal how a combination of transmigration, logging interests, and palm oil plantation development have transformed an area that was previously tropical lowland rain and swamp forest..

Source:
UNEP Atlas One Planet - Many People

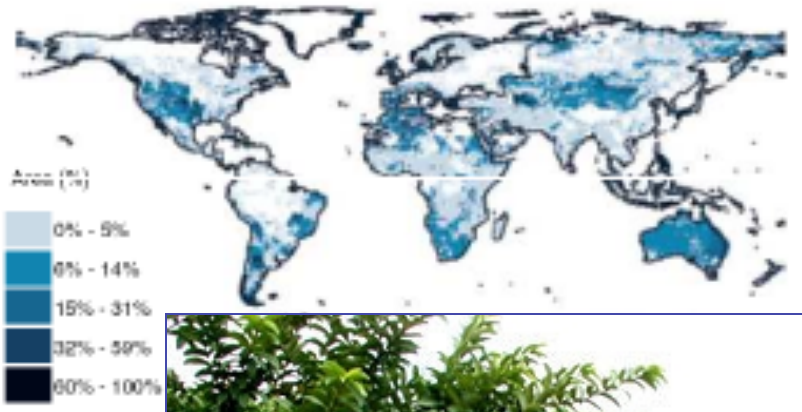
To meet 10% liquid fuel use by biofuels will require an area of between 8% and 34% of current global cropland.

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Options
Restoring formerly degraded land

- Abandoned, marginal and degraded land may be used for biofuel production.
- Certain crops can restore productivity of degraded land.
- However, use of abandoned, marginal and degraded land may :
  - compete with nature restoration
  - require higher inputs
  - save less GHG than forest regrowing naturally on abandoned land

Worldwide potential of abandoned land



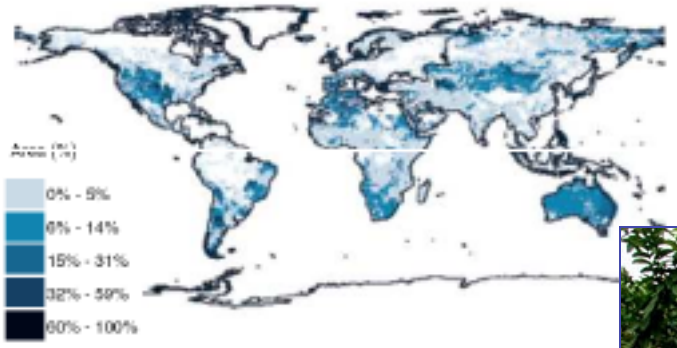


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  - require higher inputs
  - save less GHG than forest regrowing naturally on abandoned land

Worldwide potential of abandoned land



Source: Campbell et al.



Jatropha? Grows anywhere in tropics, but requires water to produce fuel!

Massive failed experiment in India…..





- **Using wastes and agricultural and forest residues for biofuels is likely to produce greenhouse gas benefits.**

- **Care must be taken to assure that enough residuals are left behind to protect soil health and carbon levels.**



• **Using wastes and agricultural and forest residues for biofuels is likely to produce greenhouse gas benefits.**

IEA estimates of potential:

Ag residues = 15-70 (EJ/year)
Forest residues = 30-150
Dung = 5-55

Current global use of biomass energy = 40 EJ/year
(1.2 EJ/year from liquid biofuels)



“Cellulosic ethanol” = ethanol fermented from cellulose (wood, grasses)

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- corrosive (difficult and expensive to transport and store)
- must be distilled to remove water (energetically costly)
- high in oxygen, leading to greater nitrogen emissions

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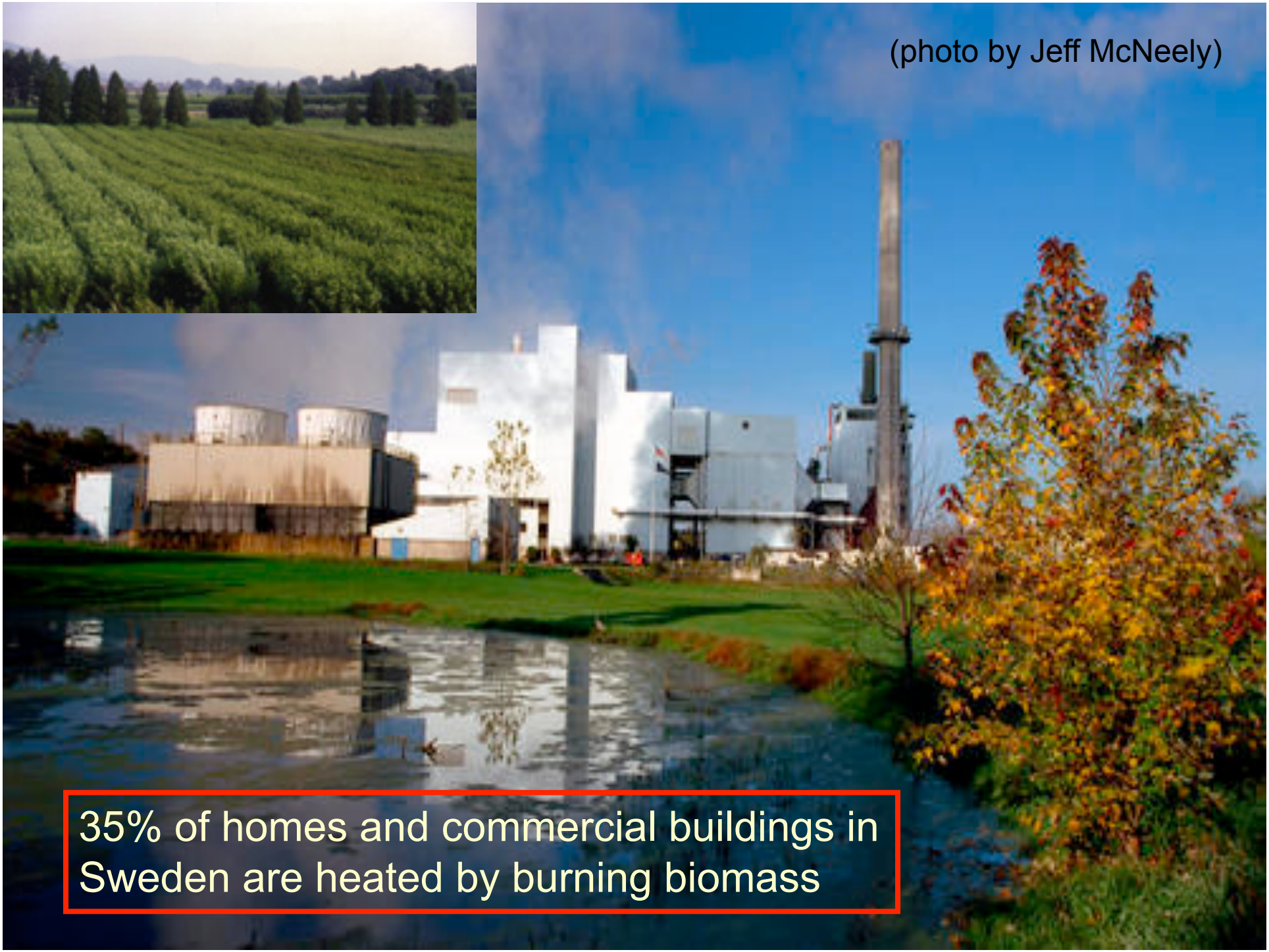
Liquid hydrocarbons or methane gas from cellulose probably far better fuels.

Better yet, burn cellulosic biomass instead to co-generate heat and electricity. Greater efficiency, so less land needed, less environmental problems.

Per area of land:

- **1 unit of energy for ethanol from corn**
- **3.5 units for ethanol from switchgrass**
- **9 units from burning switchgrass**

Direct combustion of solid biofuels reduces fossil fuel oil, since 40% of global use of oil is for stationary, non-transportation uses (29% in the US).


(photo by Jeff McNeely)
35% of homes and commercial buildings in Sweden are heated by burning biomass

Key messages

- Mobilize agricultural potentials in regions that have lagged – increase yields in an environmentally & socially benign manner
- Limit expansion of cropland and direct new development to degraded land, considering potential environmental and social impacts
- Explore low input cultivation of perennials to limit eutrophication
- Promote energy from residues/waste rather than energy crops
- Foster cascading use of biomass
- Promote use of bioenergy for stationary application rather than for transport
- Limit overall biomass & energy demand (efficiency in fuel consumption, etc.)

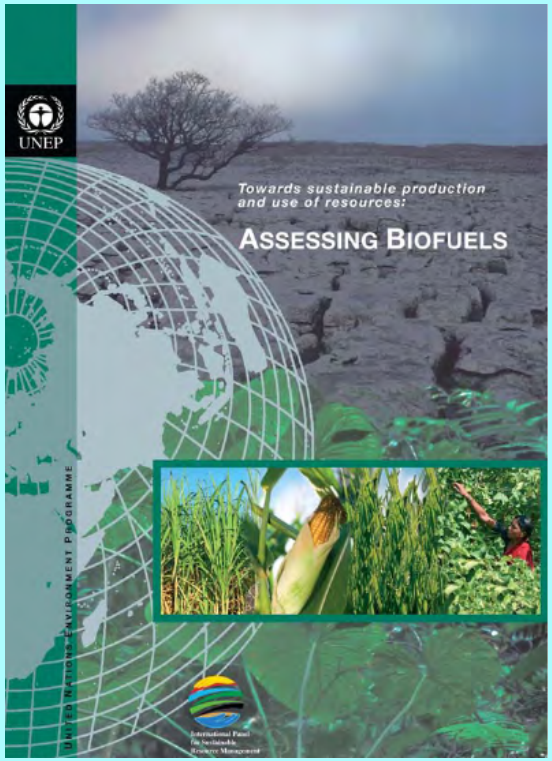


Key authors:
S. Bringezu, H. Schütz, M. O´Brien,
L. Kauppi, R.W. Howarth, J. McNeely

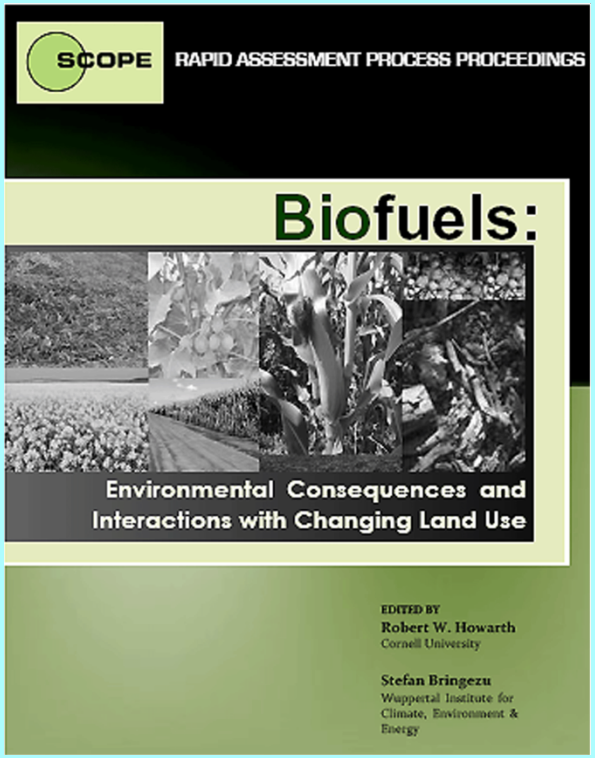
The full report, including references can be accessed at the following website:
www.unep.fr

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For more information, please contact:
Martina Otto, UNEP
martina.otto@unep.org



http://www.unep.org/PDF/Assessing_Biofuels.pdf



http://cip.cornell.edu/biofuels