Tim Searchinger
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(tsearchi@princeton.edu)
(202) 465-2074

LCFS Questions - Why Focus on Fuel GHG Efficiency

What about?

- Total GHG/mile
- VMT reduction
- Drivetrain efficiency

  Gasoline 96 gCO2/MJ *versus*

  Electricity 105 g/MJ (renewables & natural gas), but

  35 gCO2/MJ adjusted for drivetrain efficiency

  (source CARB)

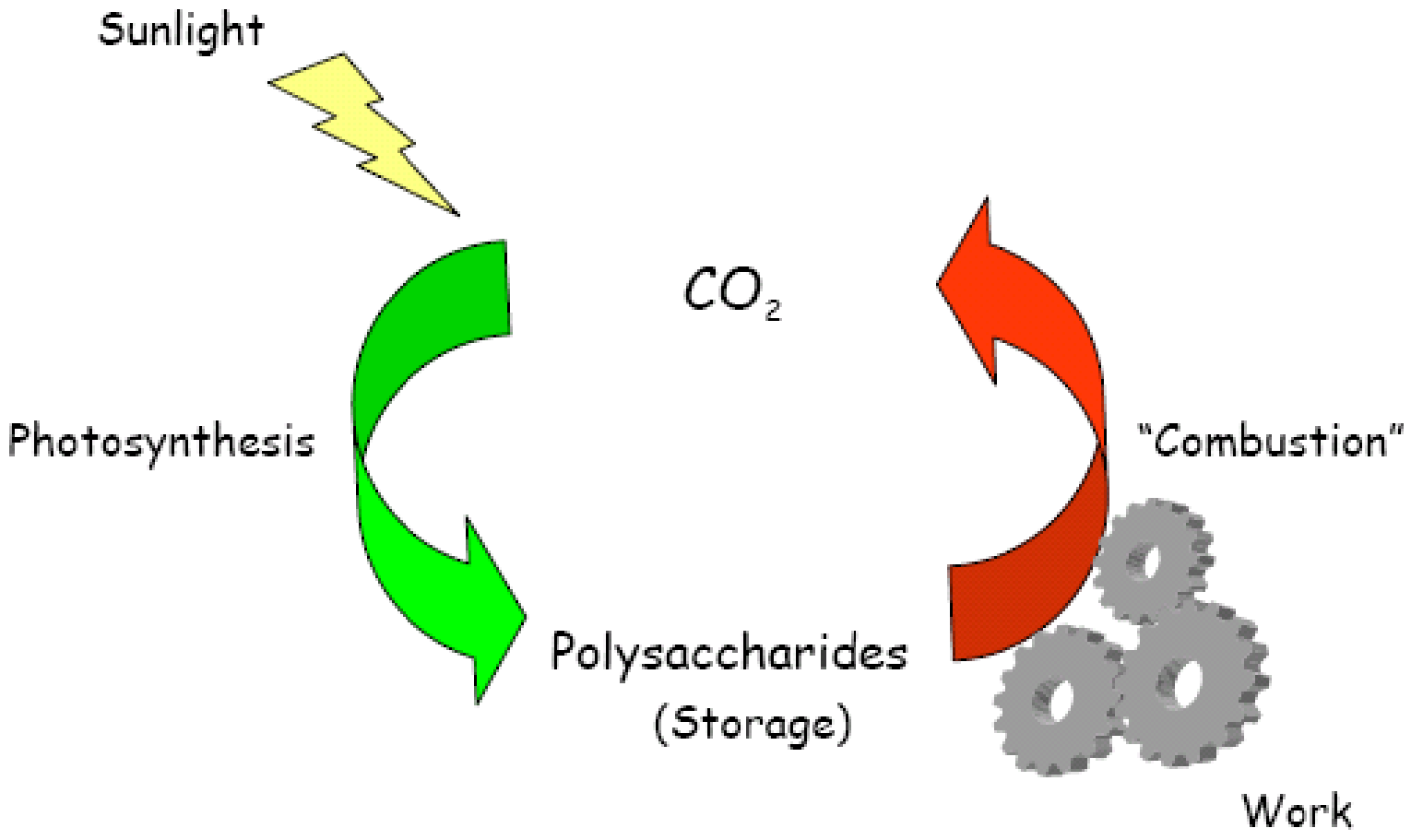
Short-term performance standard versus Technology transformation

- Cheapest incremental reductions do not equal biggest, long-term changes

Single Criterion Approach?

- Biodiversity
- Water
- Air pollution
- Hunger
- Financial cost
- Land opportunity cost
- Threshold GHG benefit

Combustion of biomass provides carbon neutral energy



Feedstock Credit is Critical to Findings of Greenhouse Gas Benefits

Source of Fuel*	Making Feed-stock	Refining Fuel	Vehicle Operation (Burning Fuel)	Net Land Use Effects		Total GHGs	% Change in Net GHGs vs. Gasoline
				Plant Uptake from Atmosphere (GREET)	Land Use Change		
Gasoline	**+4**	**+15**	**+72**	**0**	–	**+92**	–
Corn Ethanol (GREET)	**+24**	**+40**	**+71**	**-62**	–	**+74** **(+135** without feedstock credit)	**-20%** **(+47%** without feedstock credit)
Cellulosic Ethanol (GREET)	**+10**	**+9**	**+71**	**-62**		**+27** (+**90** w/o feedstock credit	**-70%** (-2% w/o feedstock credit

Greenhouse gasses (CO_2) per mega joule of fuel

Why a land/plant credit?

- Land already exists
- Forests and Grassland conversion
- Cropland produces carbon benefit in form of protein, carbohydrates, fats.

Potential Sources of Bioenergy Offset

- Plants take up additional carbon
- Cause reduction in demand for food/timber carbon
- Bioenergy uses waste carbon that would otherwise decompose anyway

National Academy of Sciences (May 2009)

- "If food crops or lands used for food production are diverted to produce biofuels rather than food, additional land will probably be cleared elsewhere in the world and drawn into food production. The greenhouse gas emissions caused by such clearing of land, especially forests, will decrease or even negate the greenhouse-gas benefits of the resulting biofuels." p. 79

- "Producers need to grow biofuel feedstocks on degraded agricultural land to avoid direct and indirect competition with the food supply and also need to minimize land-use practices that result in substantial net greenhouse-gas emissions." p. 79

Potential Biomass
No Land Use Change

DOE –" Billion Ton Supply" (in millions)

Forest product residues	145
Logging residues	64
Urban wood residues	47
Agricultural residues	428
Process residues/manure	106
	790

IEA – 2008

100 EJ from crop and forest residues worldwide

NAS – 2009

500 billion dry tons available in U.S.
~ 40 billion gallons

Tilman, Lynd, Somerville, Searchinger et al, Science (2009), also look at cover crops, CRP, degraded, abandoned cropland, double/mixed crops, municipal/industrial waste

Other 2008/09 Studies – Similar Conclusions

- UK Renewable Fuels Agency (Gallagher Review)
- EU Joint Research Center
- World Bank
- FAO
- Netherlands Environmental Assessment Agency
- OECD
- European Economic and Social Committee
- Scientific Committee on Problems of the Environment
- British Royal Society

If you have to have an LCFS

- Avoid biofuels that cause land use change
- Large, minimum CO2 reduction
- Don't count hunger as a benefit
- Don't count biofuels grown with irrigation

Direct Effects of Diverting Crops to Biofuels –
No Change in Emissions

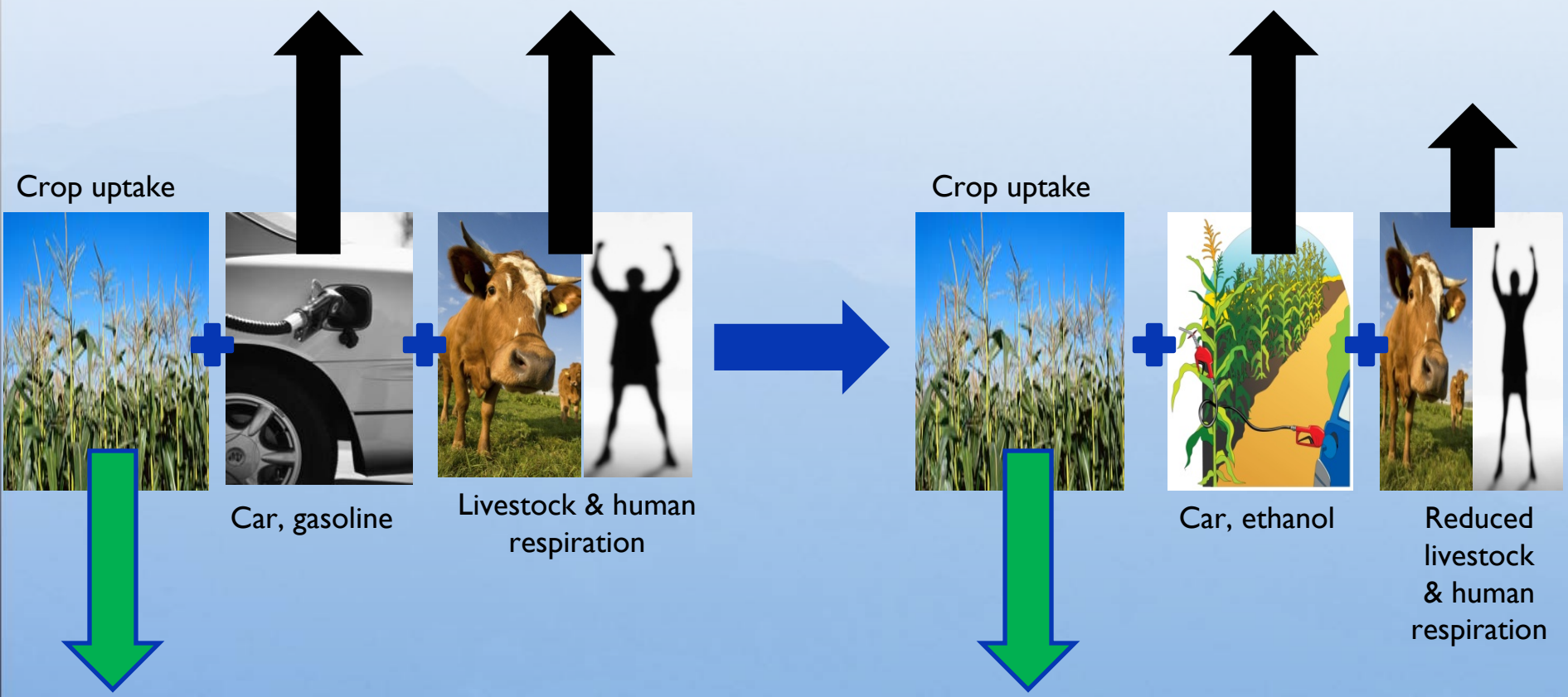
Corn uptake

Car, gasoline

Corn uptake

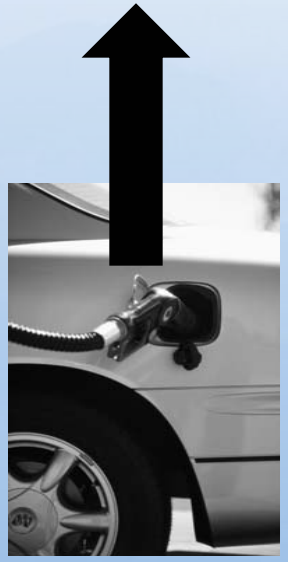
Car, ethanol

Indirect Scenario 1 – Ethanol Leads to Less Crop Consumption for Food, which Reduces CO2

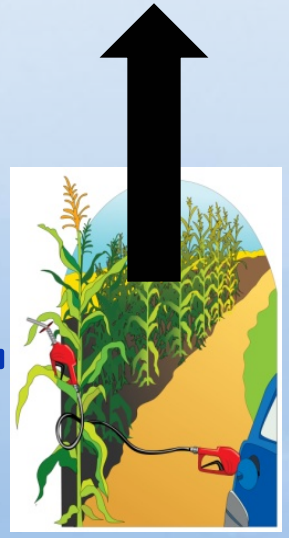


Indirect Scenario 2 – Ethanol Leads to Yield Growth on Existing Farmland to Replace Diverted Crops, which Absorb More Atmospheric Carbon and Reduces CO2

Crop uptake



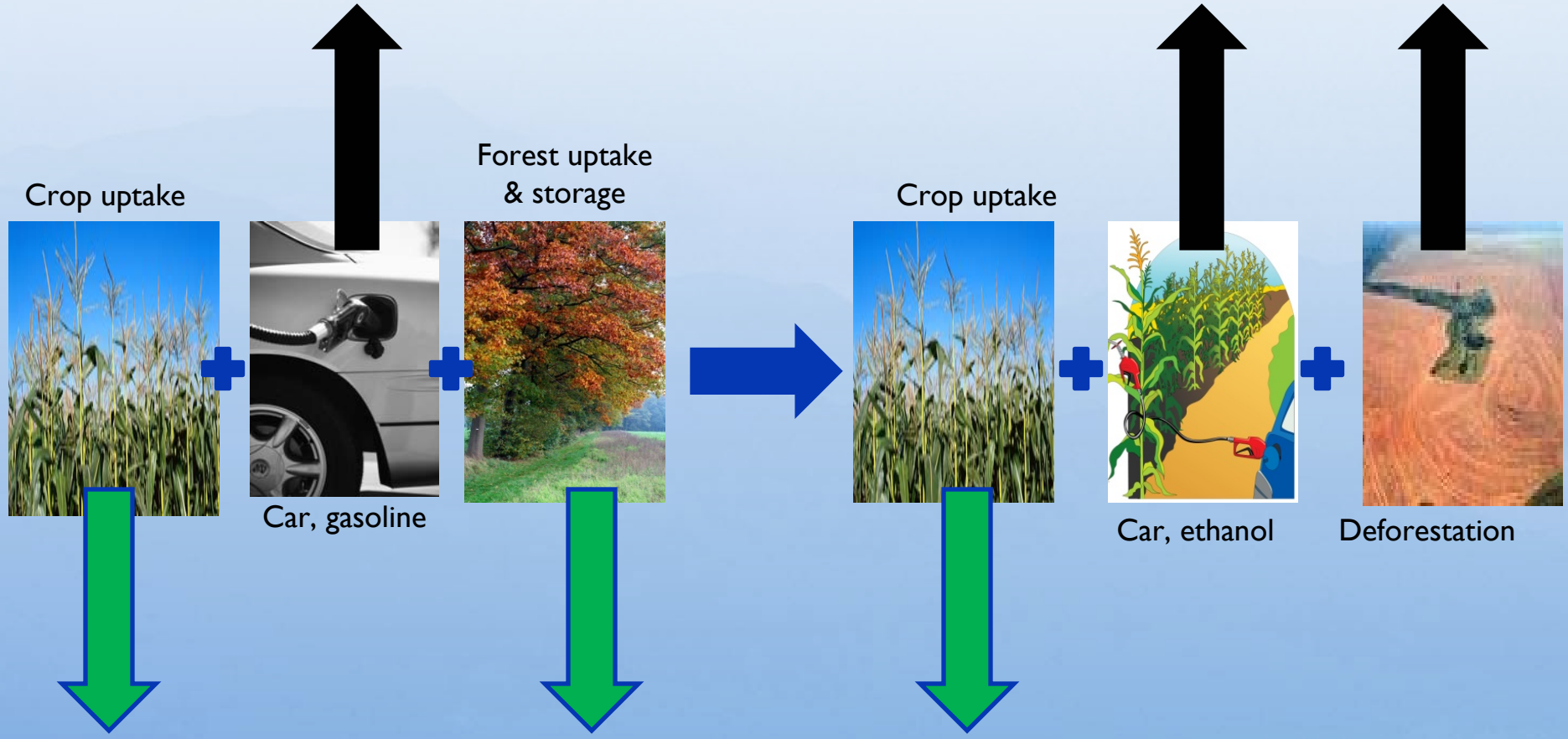
Car, gasoline



Car, ethanol

Increased yields, which absorb more carbon on the same land but may involve increased emissions from inputs, such as nitrous oxide

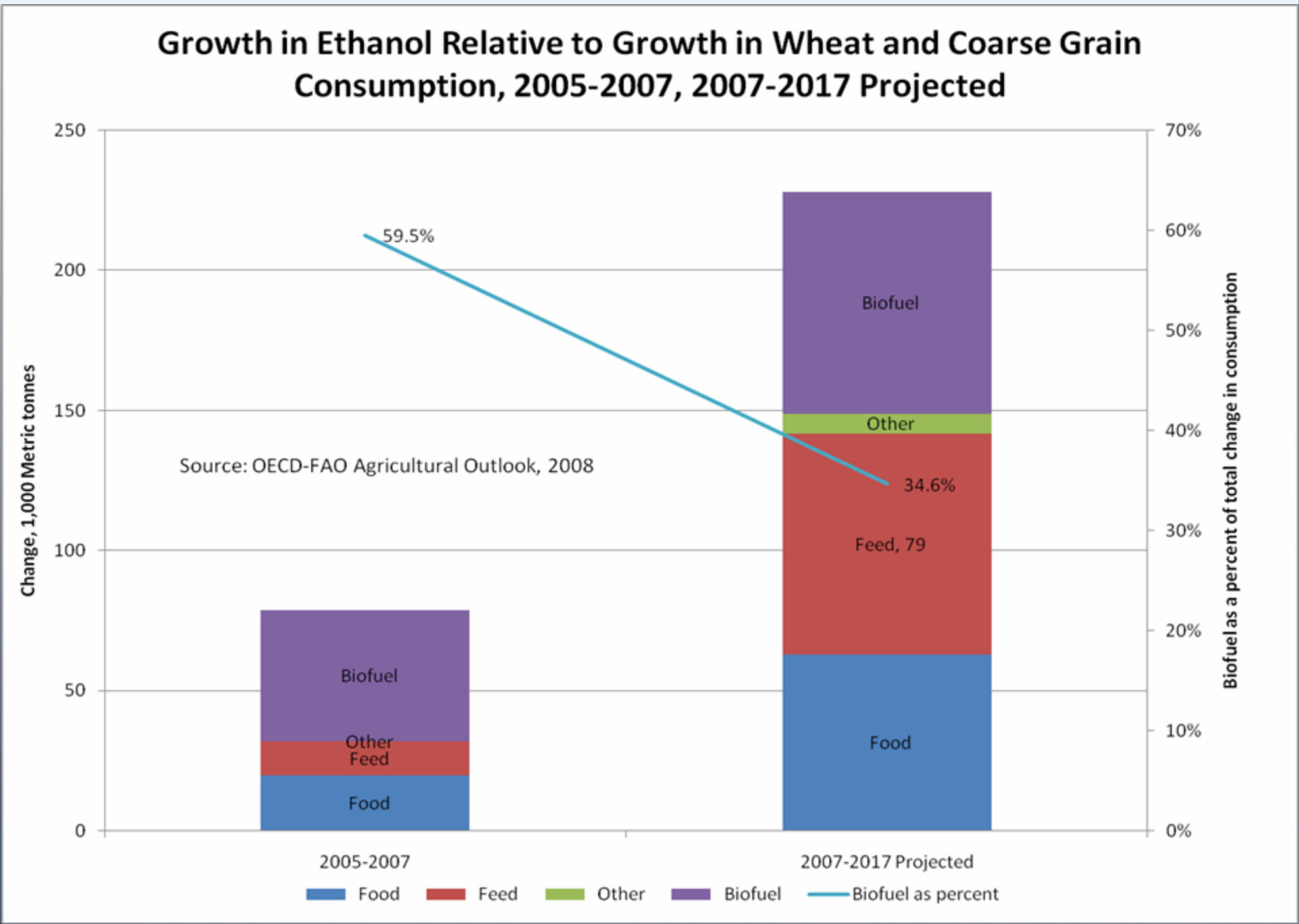
Indirect Scenario 3 – Diverted crops replaced by agricultural Land Expansion, which Increases CO2

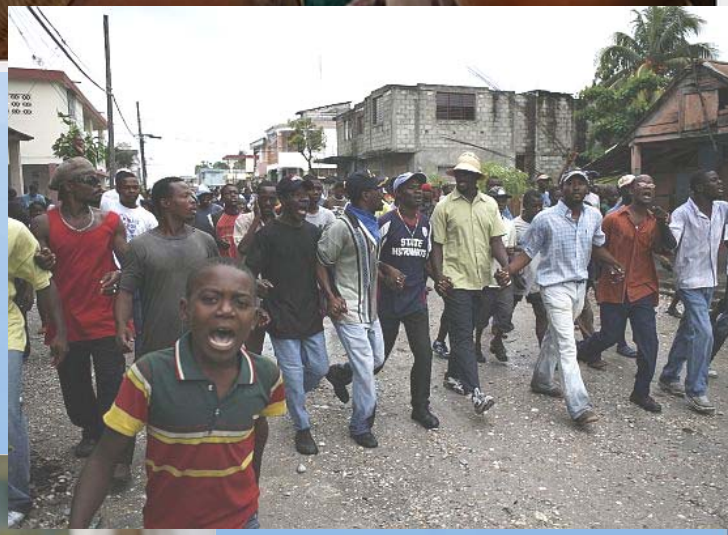


Indirect Effects Follow Markets – Businessmen Are Not Dumb

The new situation: Surge in prices

Source: Data from FAO 2008 and IMF 2008.

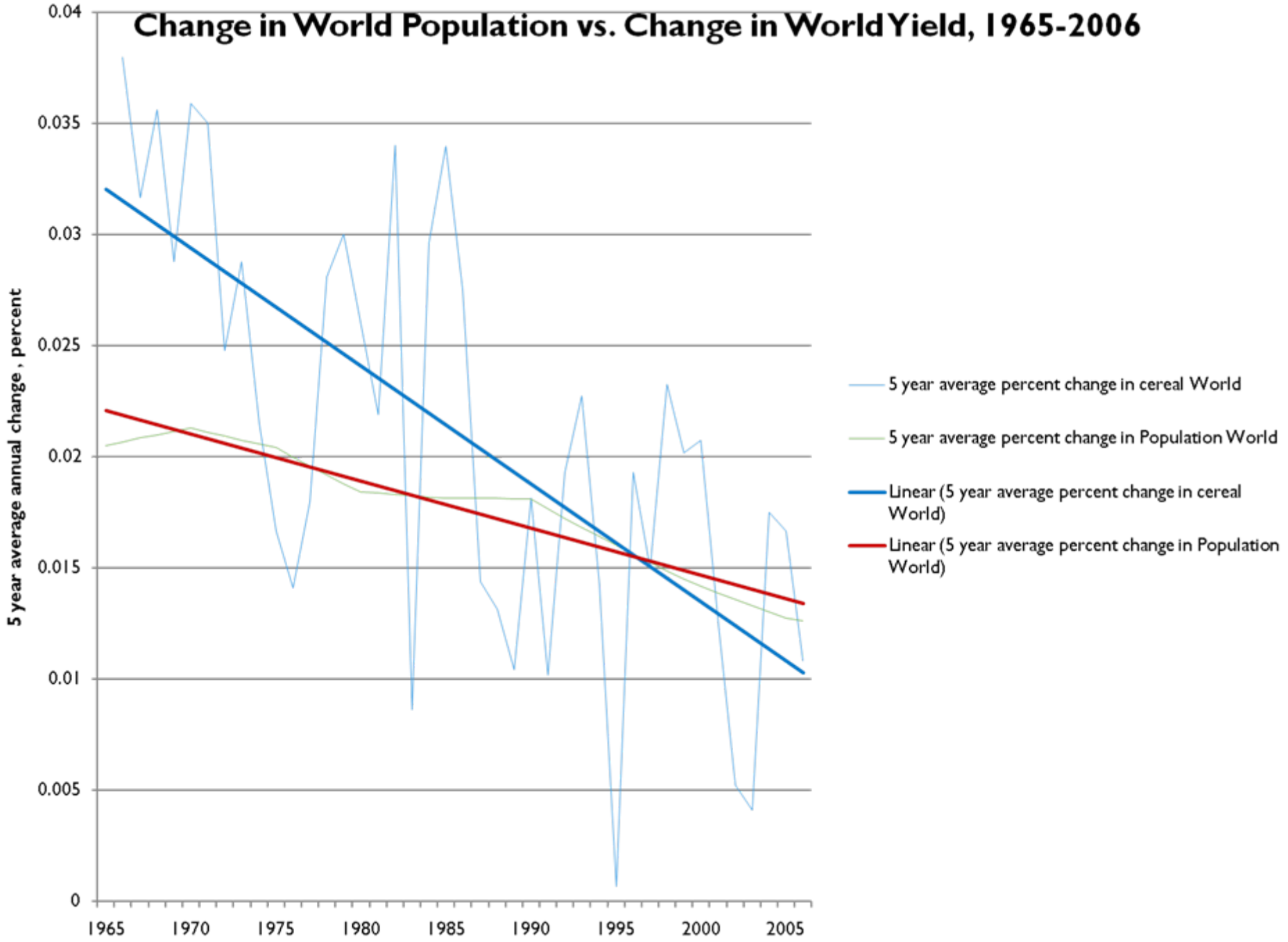

Growth in Ethanol Relative to Growth in Wheat and Coarse Grain Consumption, 2005-2007, 2007-2017 Projected
Change, 1,000 Metric tonnes
Biofuel as a percent of total change in consumption
250
200
150
100
50
0
70%
60%
50%
40%
30%
20%
10%
0%
59.5%
34.6%
Source: OECD-FAO Agricultural Outlook, 2008
Biofuel
Other
Feed
Food
Biofuel
Other
Feed, 79
Food
2005-2007
2007-2017 Projected
Food
Feed
Other
Biofuel
Biofuel as percent



- 16% of world malnourished
- 1/3 of children in developing world stunted
- 30 million babies born impaired due to lack of natal nutrition
- 5 million children die annually from causes related to lack of nutrition

Implied Yield Growth by 2020 Scenario 10.2% Transport Fuel(Etech 4)

Crop	Biofuels, adjusted for by products	Non Biofuel food demand	Biofuel and Non Biofuel	1996-2006 Trend
Cereals (corn,wheat	0.8%	1.8%	2.6%	1.3%
Oilseeds (soy, rape)	0.9%	2.2%	3.2%	1.5%
Sugar (cane)	5.0%	0.6%	5.5%	0.8%
Palm	3.0%	3.9%	6.9%	1.9%


Change in World Population vs. Change in World Yield, 1965-2006
5 year average annual change , percent
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
5 year average percent change in cereal World
5 year average percent change in Population World
Linear (5 year average percent change in cereal World)
Linear (5 year average percent change in Population World)

Land Use Context

- Deforestation ~20% of CO2 Emissions
- Mitigation calls for 200 million hectares of afforestation
- Need to reduce agricultural production emissions
- Using land to produce biofuels hinders these goals

Land Opportunity Cost

Carbon Benefit of Using Land for Biofuel

- 3 t/ha/yr – corn ethanol – GREET
- 8.6 t/ha/yr – cellulosic ethanol – GREET (swtichgrass at 18 t/ha/yr, 359 l/t)

Carbon Cost of Using Land for Biofuel

- Fallow land - forest regeneration, temperate forest 7.5 - 12 t/ha/yr
- Existing forest (lose 600-1000 tons) = 15-35 t/ha/yr (over 30 years) plus lost forest growth
- Existing grassland/savannah (lose 75-300 tons), 2.5-10 t/ha/yr (over 30 years) plus lost forage

Why CARB/Purdue Estimate Smaller Than Searchinger et al.

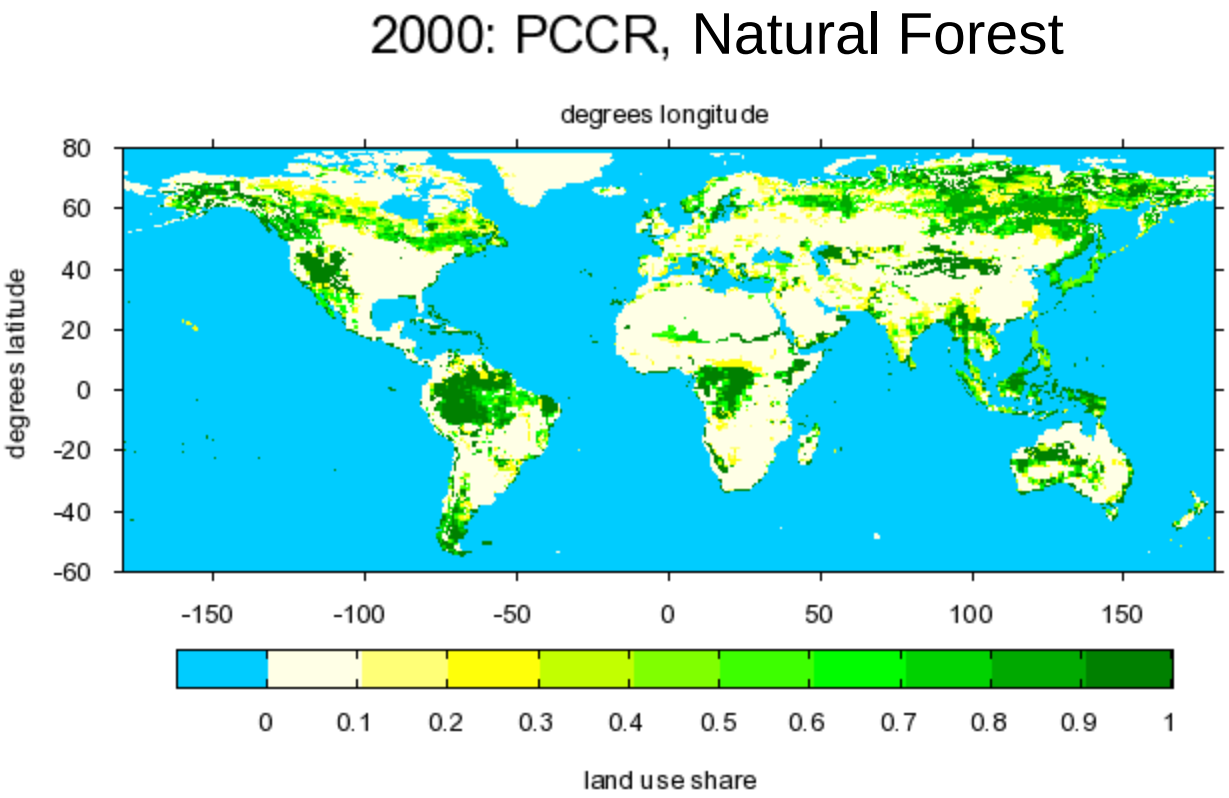
- Very little forest conversion – could not model conversion of natural forest
- More than half of diverted acres not replaced because of reduced food or other product demands – 100% of corn benefits due to reduced food consumption

The Big Issue

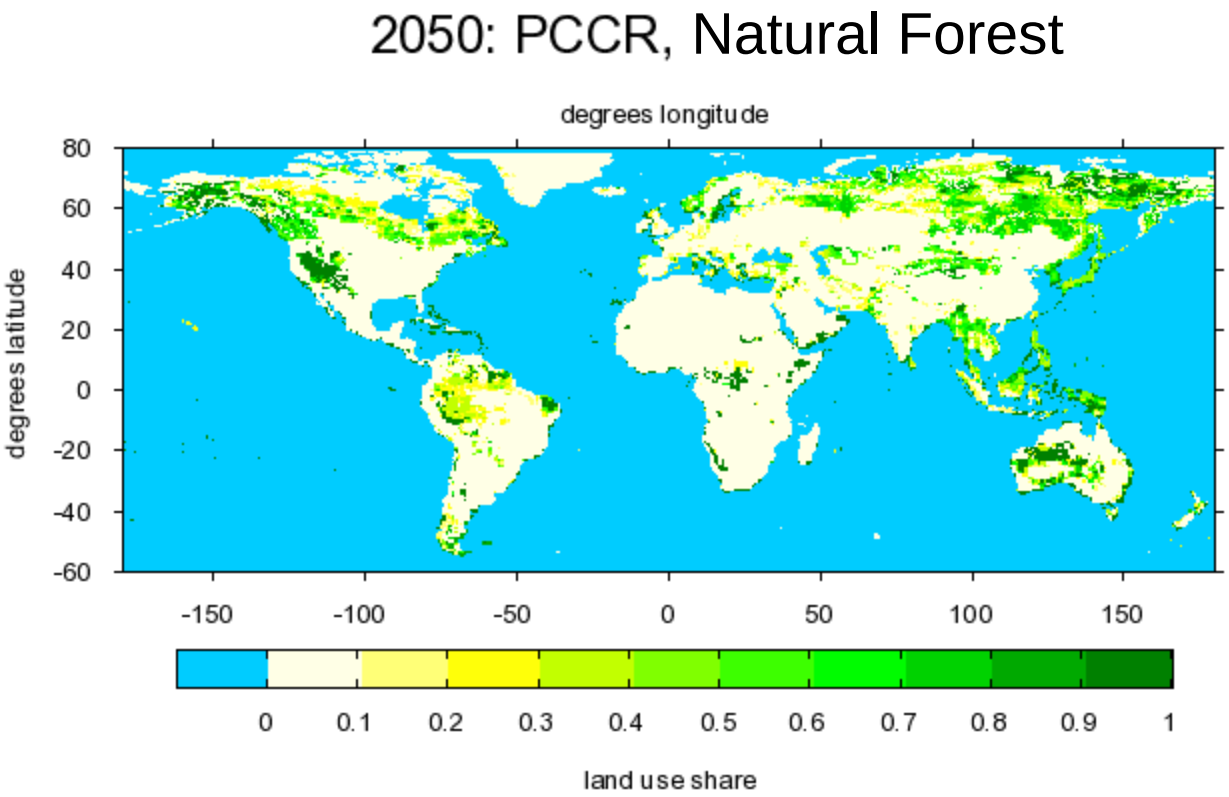
Exemption for Bioenergy Under a Cap & Trade System

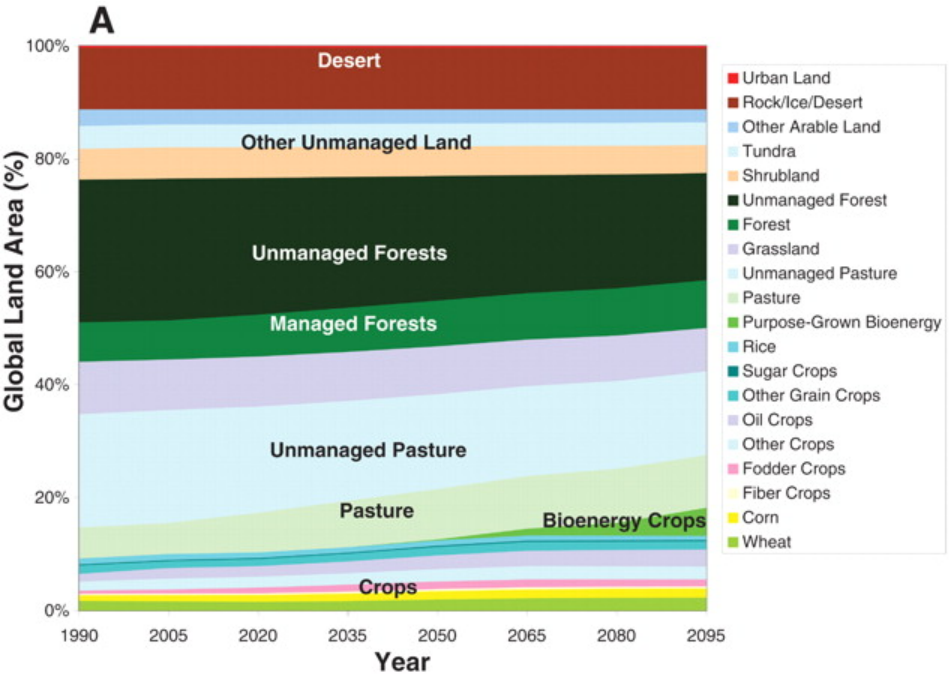
- IPCC 2000 Land Use Report (p. 355): Because "fossil fuel substitution is already 'rewarded'" by excluding emissions from the combustion of bioenergy, "to avoid underreporting . . . any changes in biomass stocks on lands . . . resulting from the production of biofuels would need to be included in the accounts."

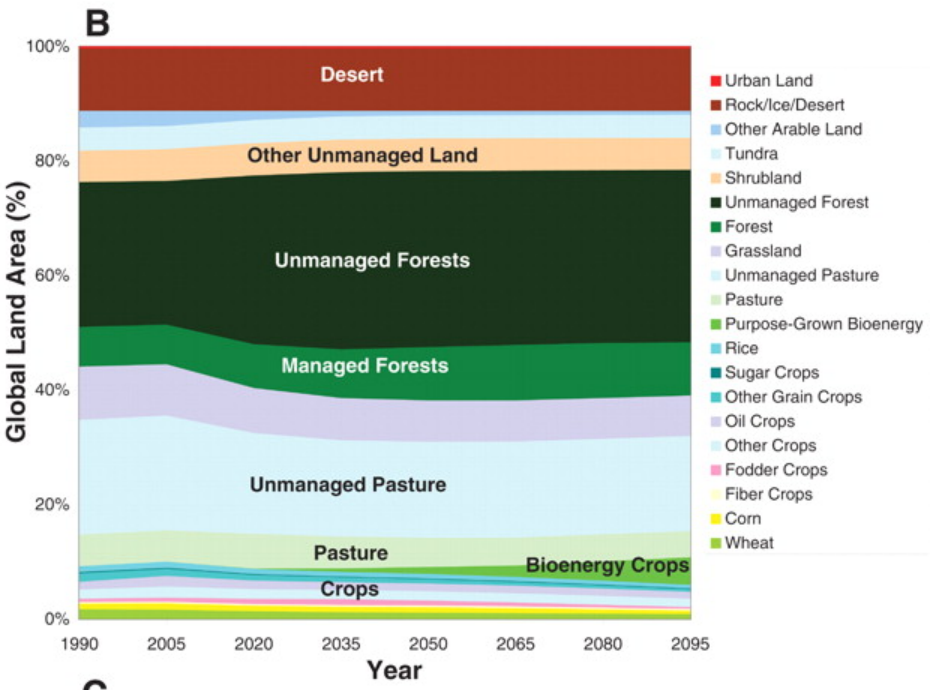
Natural Forest (Melillo, Gurgel, et al. 2009)

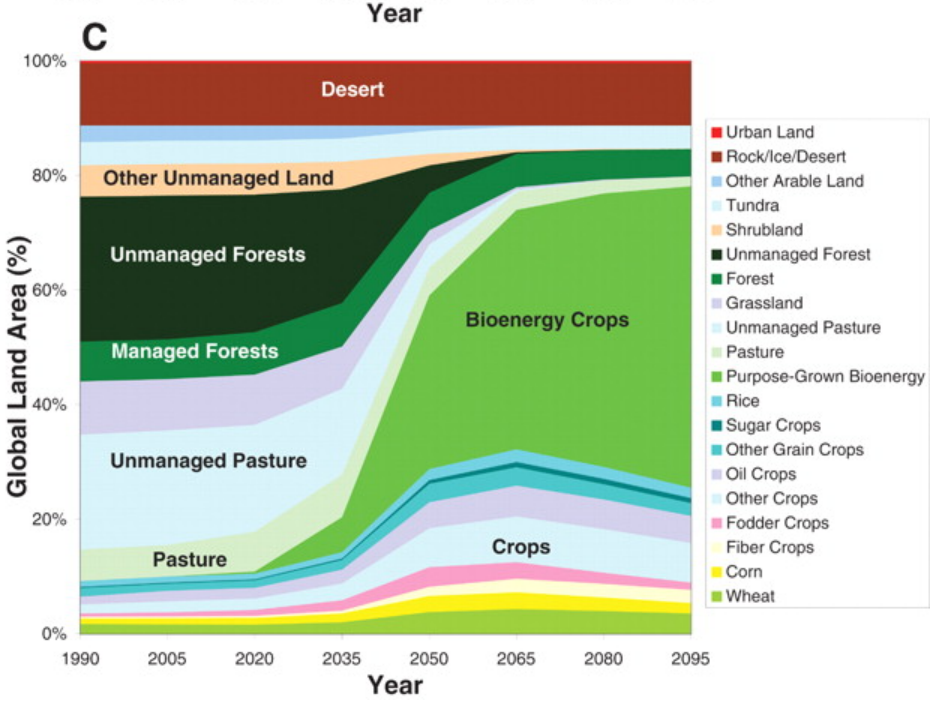


Natural Forest ("Deforestation" Scenario)









Wise et al., *Science* 324:1183 (2009)