Proper Accounting of Bioenergy: The Need for Additional Carbon

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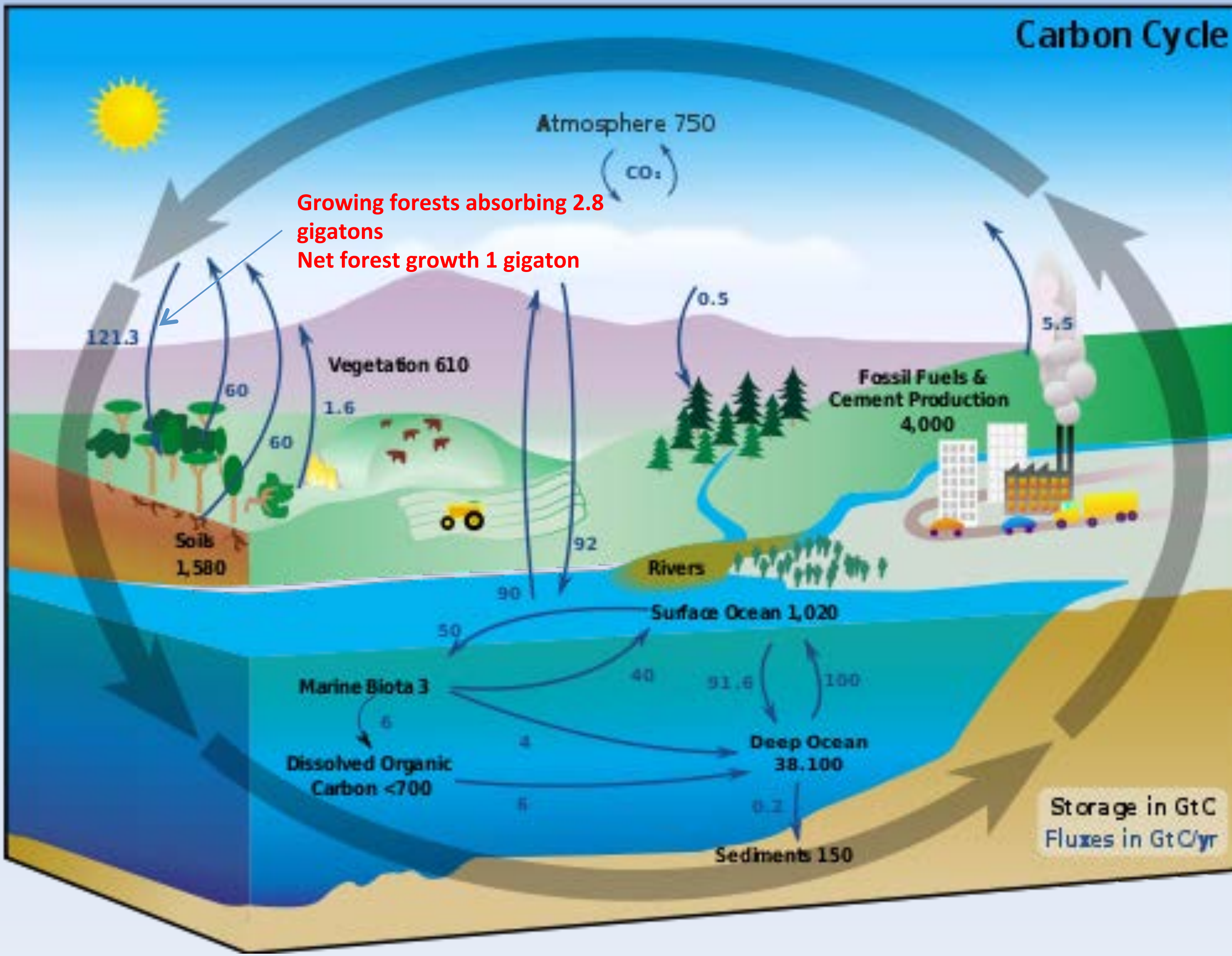
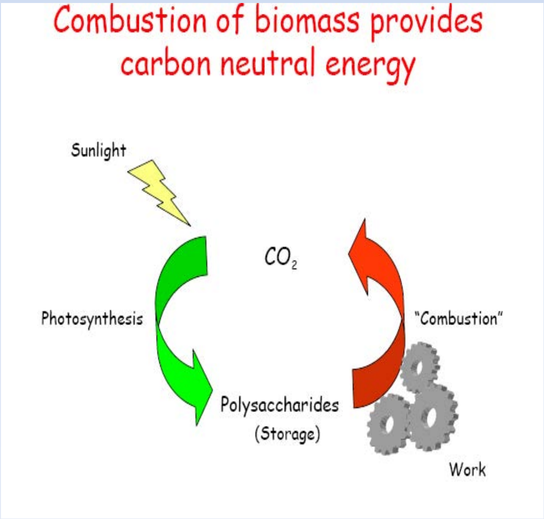
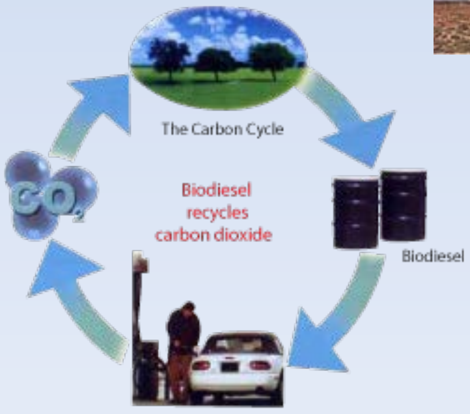
December, 2012


Carbon Cycle
Atmosphere 750
CO₂
Growing forests absorbing 2.8 gigatons
Net forest growth 1 gigaton
121.3
60
60
1.6
Vegetation 610
90
92
0.5
5.5
Fossil Fuels & Cement Production 4,000
Soils 1,580
Rivers
Surface Ocean 1,020
50
40
Marine Biota 3
91.6
100
6
4
Dissolved Organic Carbon <700
Deep Ocean 38,100
6
0.2
Sediments 150
Storage in GtC
Fluxes in GtC/yr

Both biomass and fossil fuel combustion emit carbon dioxide, Potential Savings Come from Plant Uptake





Source: Biodiesel Association of Australia

BIOENERGY IS A FORM OF LAND-BASED CARBON OFFSET

Land grows plants whether for bioenergy or not:

* forest
* food

Only ADDITIONAL plant growth helps

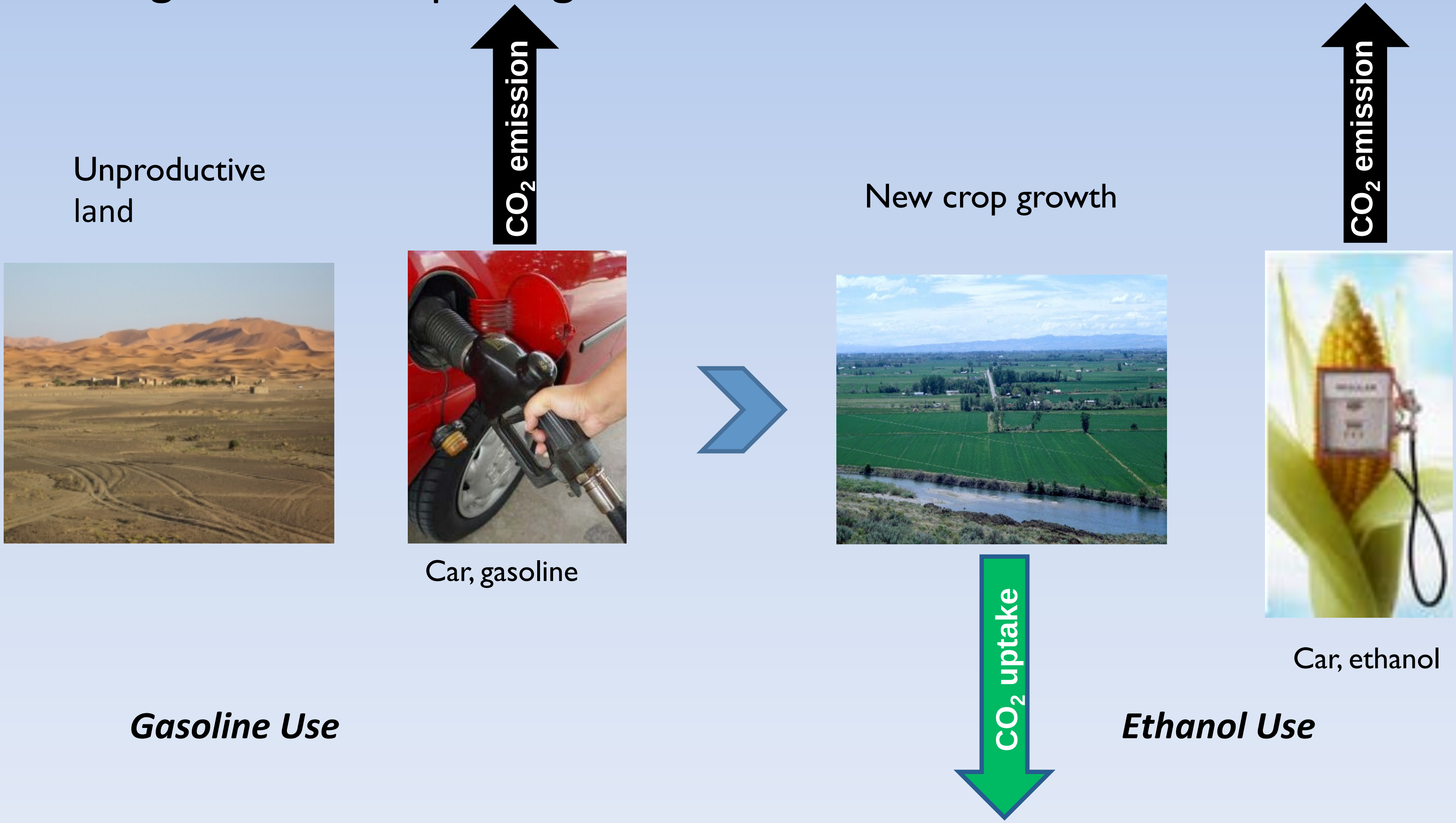
Put another way, biofuel benefits come not from changing what goes up, but adding to what comes down or stays down

Credit for Plant Growth Explains Findings of Greenhouse Gas Benefits in LCAs – EU JRC

Source of fuel*	Producing Feedstock (crude oil or crop)	Refining	Tailpipe Emis-sions	Fermen-tation emissions	Total GHGs & % Increase for Biofuel *__Without Plant Credit__*	Credit for Plant Growth	Total GHGs & % Savings for Biofuel
Gasoline	**+4.5**	**+8**	**+73.3**	**-**	**85.8**	**-**	**85.8**
EU wheat ethanol	***+40***	***+21.2***	***~~+71.4~~***	***~~+35.7~~***	***168.3 (+96%)***	***~~107.1~~***	***+61.2 (-29%)***

Greenhouse gas emissions and sinks (CO_2 eqv.) per mega joule of fuel

Figure 1 – Effect of switching from gasoline to biofuels grown on otherwise unproductive land – Reduced atmospheric CO_2 through increased plant growth



Imperata Grasslands

Using otherwise burned or decomposed crop residues for biofuels - Reduced emissions through reduced land sources

CO_2 emission

Burning or decomposing crop residues

CO_2 emission

Car, gasoline

Reduced emissions from Residues

CO_2 emission

Figure 2 - **Direct effect of switching from gasoline to biofuels that use existing crops –** No change in emissions

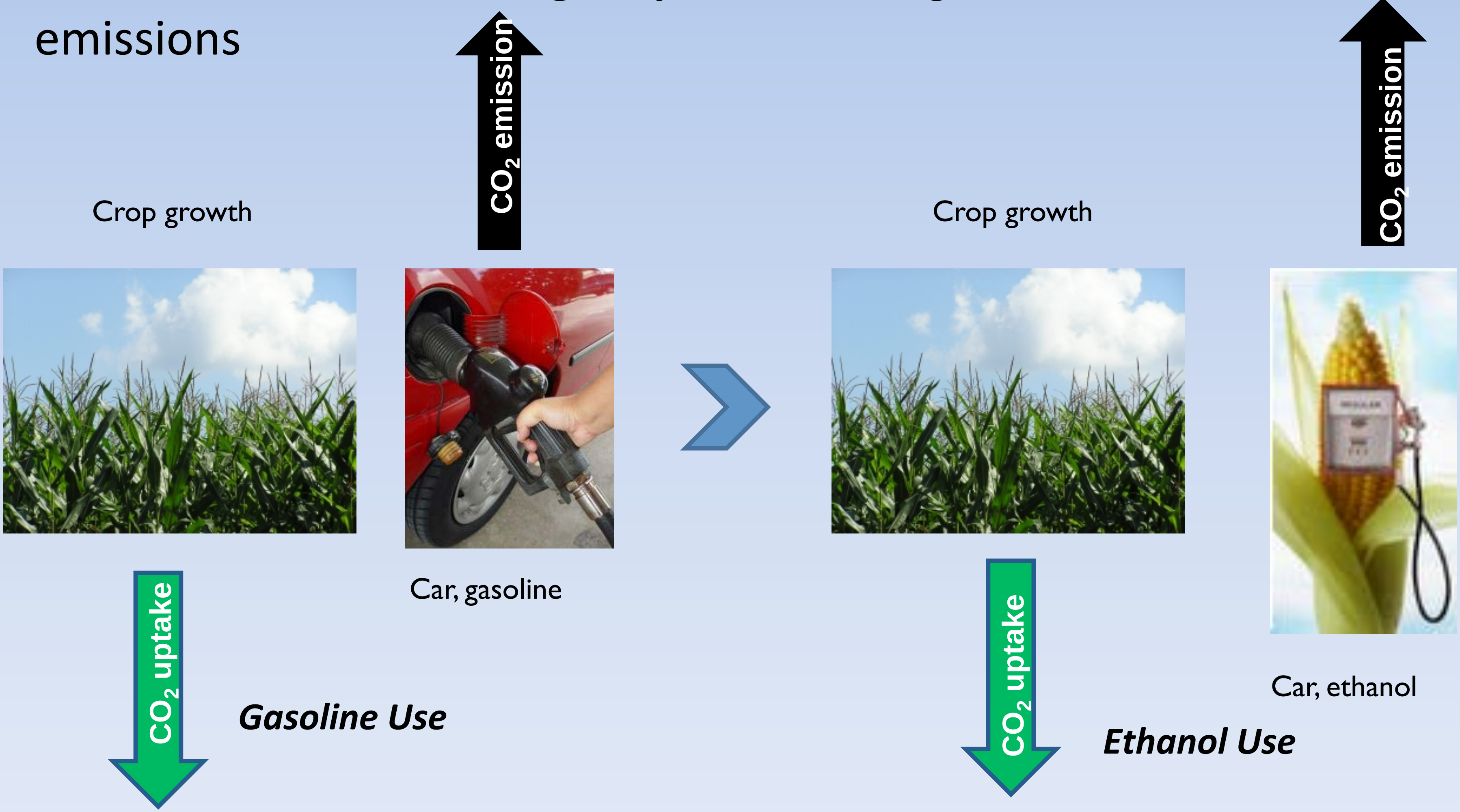
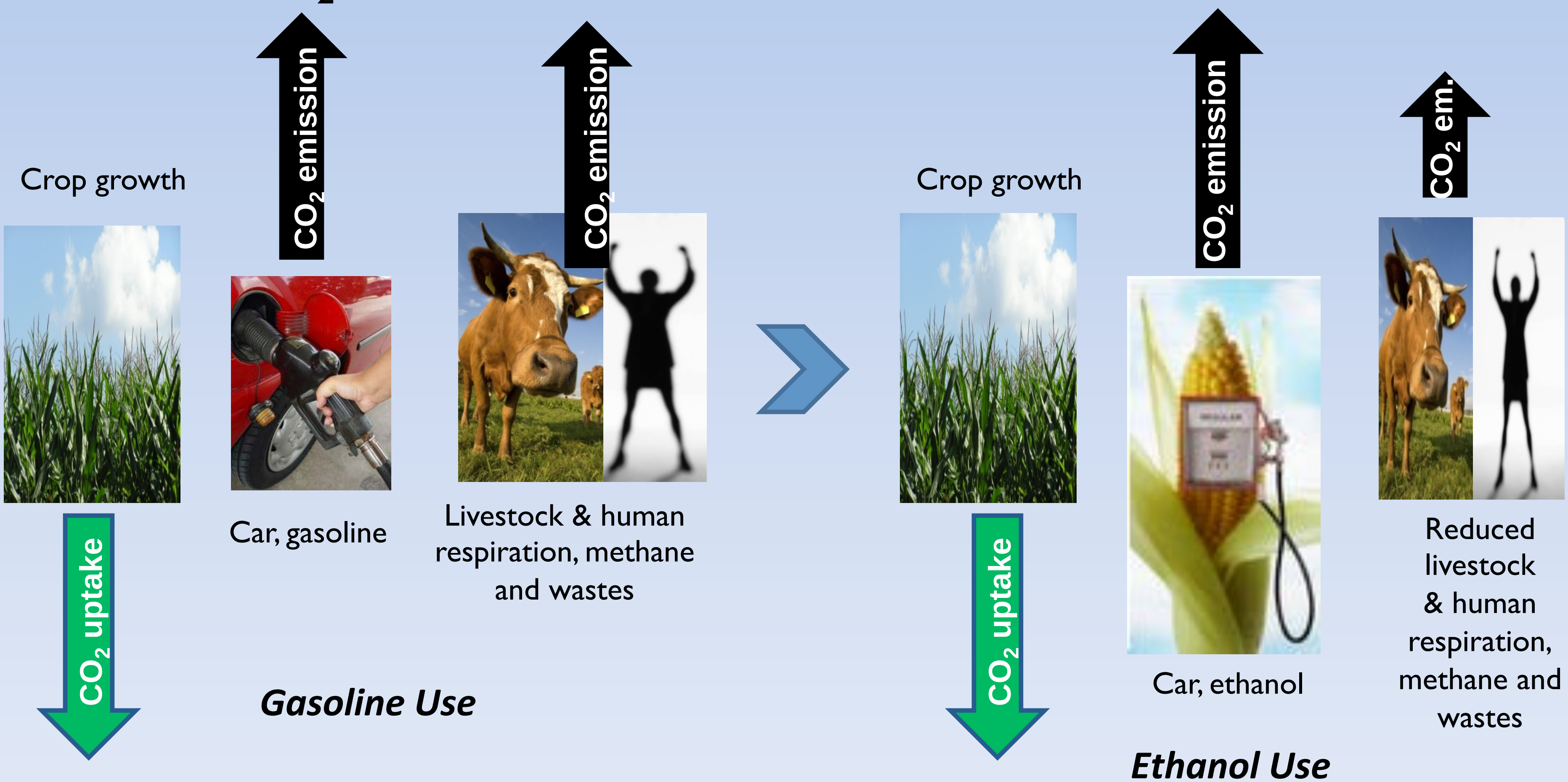


Figure 3 - Indirect effect I of adopting ethanol – Ethanol leads to less crop consumption for feed and food, which reduces CO_2



(vertical arrows indicate carbon uptake and emissions)

Figure 4 - Indirect effect 2 of adopting ethanol – Ethanol leads to yield growth on existing farmland to replace diverted crops, absorbing more carbon and probably reducing CO_2

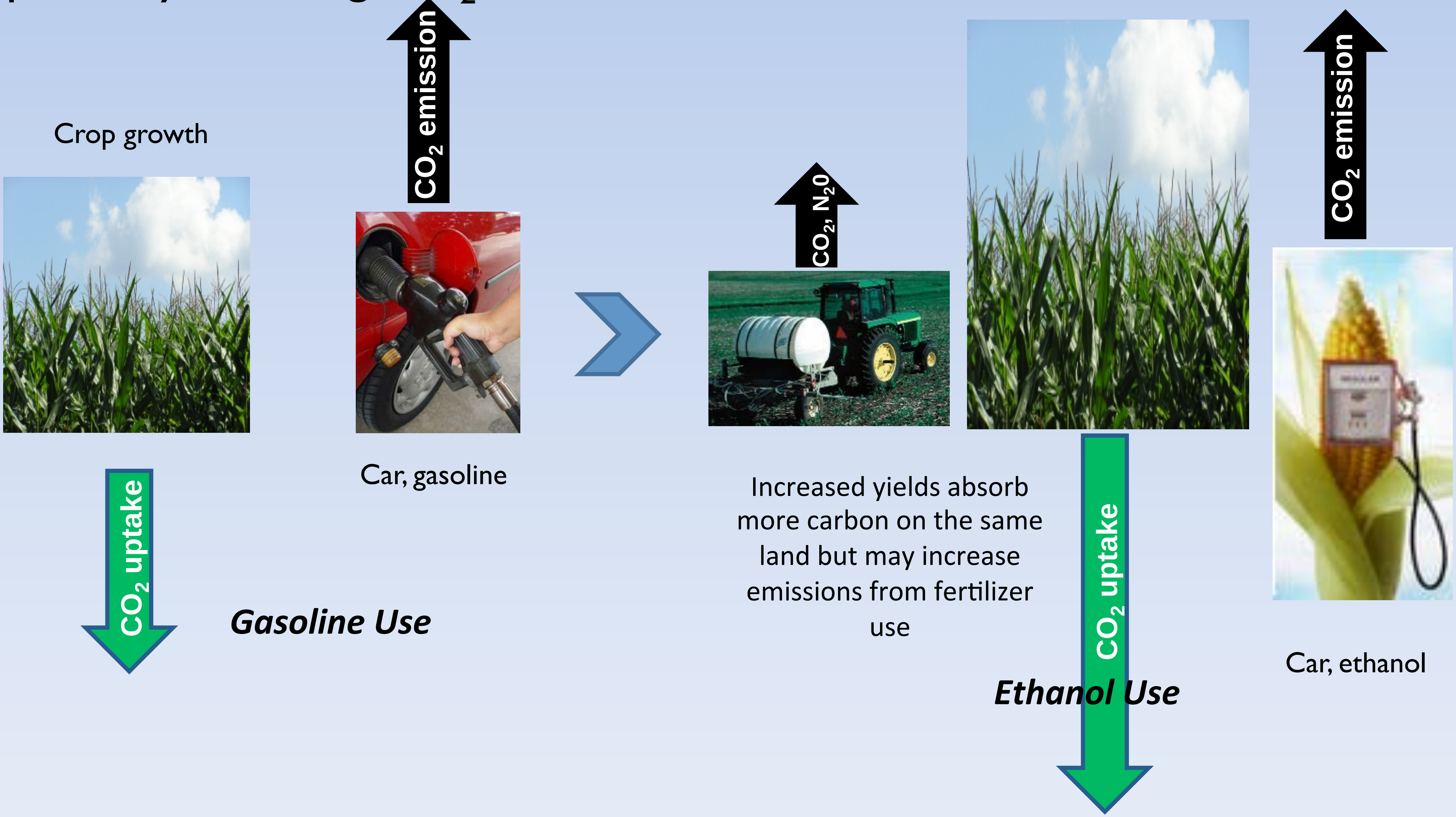
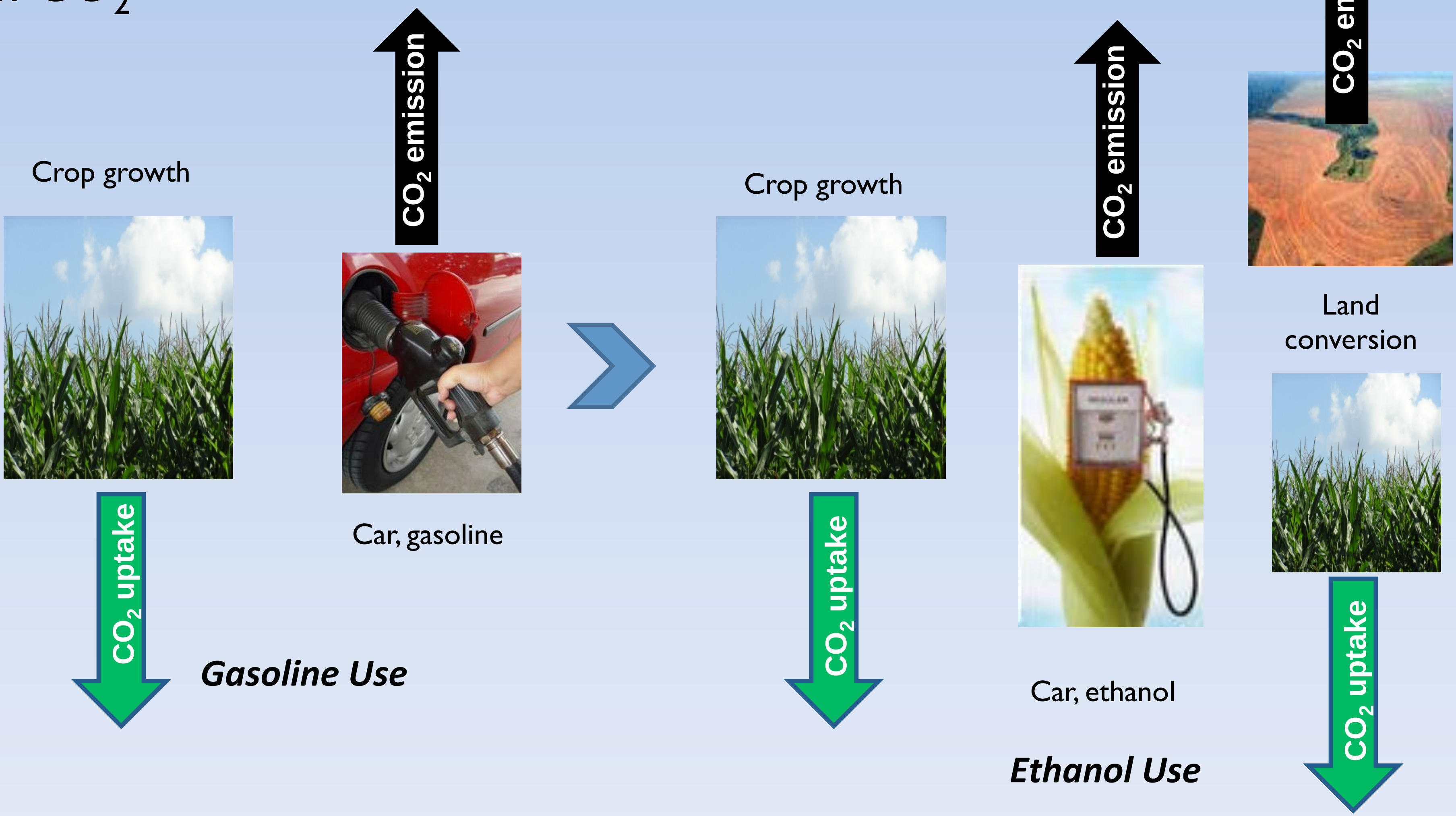
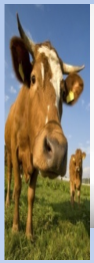


Figure 5 - Indirect Effect 3 of adopting ethanol – Ethanol leads to land use change, which increases crop growth, but sacrifices forest or grassland and probably causes net increase in CO_2



Reduced food consumption

+




Yield gains due to biofuels


+

-

Land use change


=

107 MJ

Typical Understanding of Indirect Land Use Change Misunderstand What It Really Means

CO_2 emisson

But
oh,
oh

Yeah!

Land Carbon Cost

Benefit of Using Land for Biofuel

- 3 t/ha/yr – maize ethanol – GREET
- 8.6 t/ha/yr – cellulosic ethanol –

GREET (switchgrass 18 t/ha/yr, 359 l/t)

Cost of Using Land for Biofuel

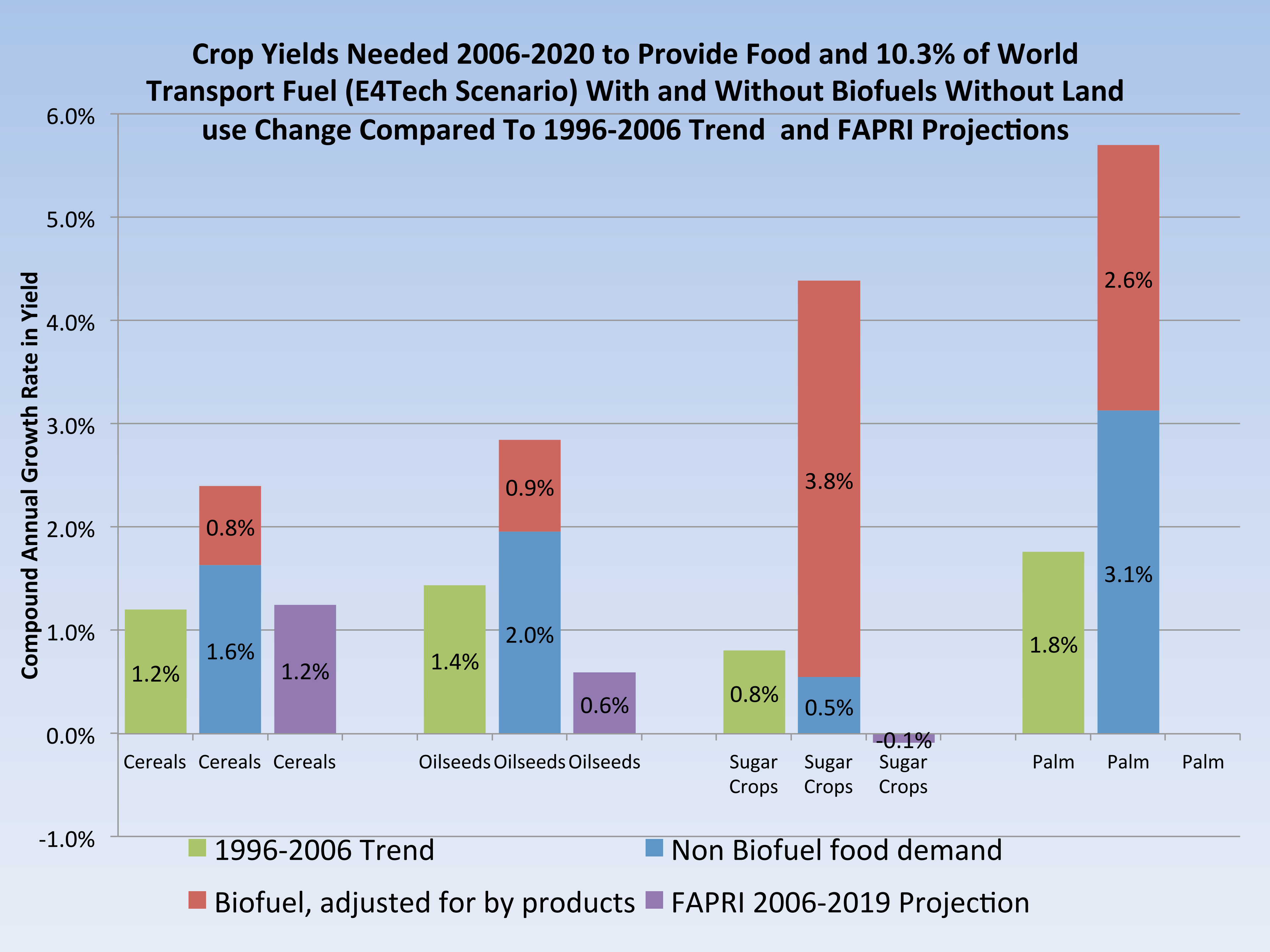
- Fallow land - forest regeneration,

  7.5 - 12 t/ha/yr
- Existing forest = 12-35 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 for grazing animals

Importance of Food Consumption Reduction in LCAs for Biofuels

Model and Type of Ethanol	*Food Consumption Reduction (exclusive of by-products) and CO_2 savings from reduced respiration*
GTAP US Maize	**51% - 55g/MJ**
IFPRI Maize	**24% - 21 g/MJ**
IFPRI Wheat	**26% - 17g/MJ**
GTAP EU Wheat	**44% - 53 g/MJ**
FAPRI (EPA)	**27% - 29 g/MJ**

from JRC 2010


Crop Yields Needed 2006-2020 to Provide Food and 10.3% of World Transport Fuel (E4Tech Scenario) With and Without Biofuels Without Land use Change Compared To 1996-2006 Trend and FAPRI Projections
Compound Annual Growth Rate in Yield
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
-1.0%
1.2%
1.6%
0.8%
1.2%
1.4%
2.0%
0.9%
0.6%
0.8%
0.5%
3.8%
-0.1%
1.8%
3.1%
2.6%
Cereals
Cereals
Cereals
Oilseeds
Oilseeds
Oilseeds
Sugar Crops
Sugar Crops
Sugar Crops
Palm
Palm
Palm
1996-2006 Trend
Non Biofuel food demand
Biofuel, adjusted for by products
FAPRI 2006-2019 Projection

25% of World Crops Today Required to Produce 10% of World Transport Fuel by 2020 – Roughly 2% of World Net Energy Supply

IPCC Guidelines

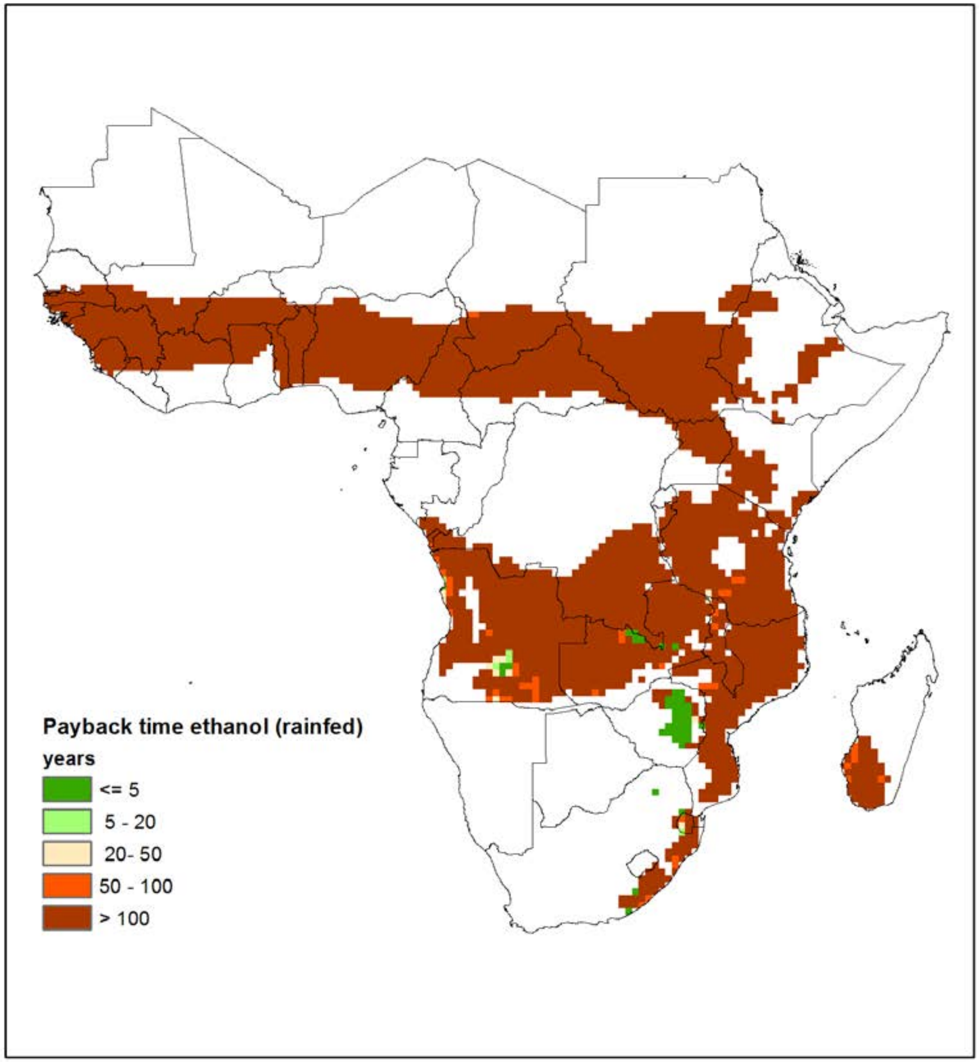
- IPCC 2000 Land Use Report (p. 355): Because "fossil fuel substitution is already 'rewarded'" by excluding emissions from the combustion of bioenergy, "to avoid underreporting . . . any changes in biomass stocks on lands . . . resulting from the production of biofuels would need to be included in the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

Large Bioenergy Potential Studies

- Most potential arable land – IPCC 2007 chapter 8 - 1.3billion hectares and/or
- All forest growth in excess of harvest (Smeets 2008)and/or
- All “abandoned” cropland (Hoodwijk (2004) and/or
- Hundreds of millions of hectares of “grazing” or “other” land – savannah (Fischer 2001; Smith 2007)
- Residues – do not exclude used residues or account for soil carbon

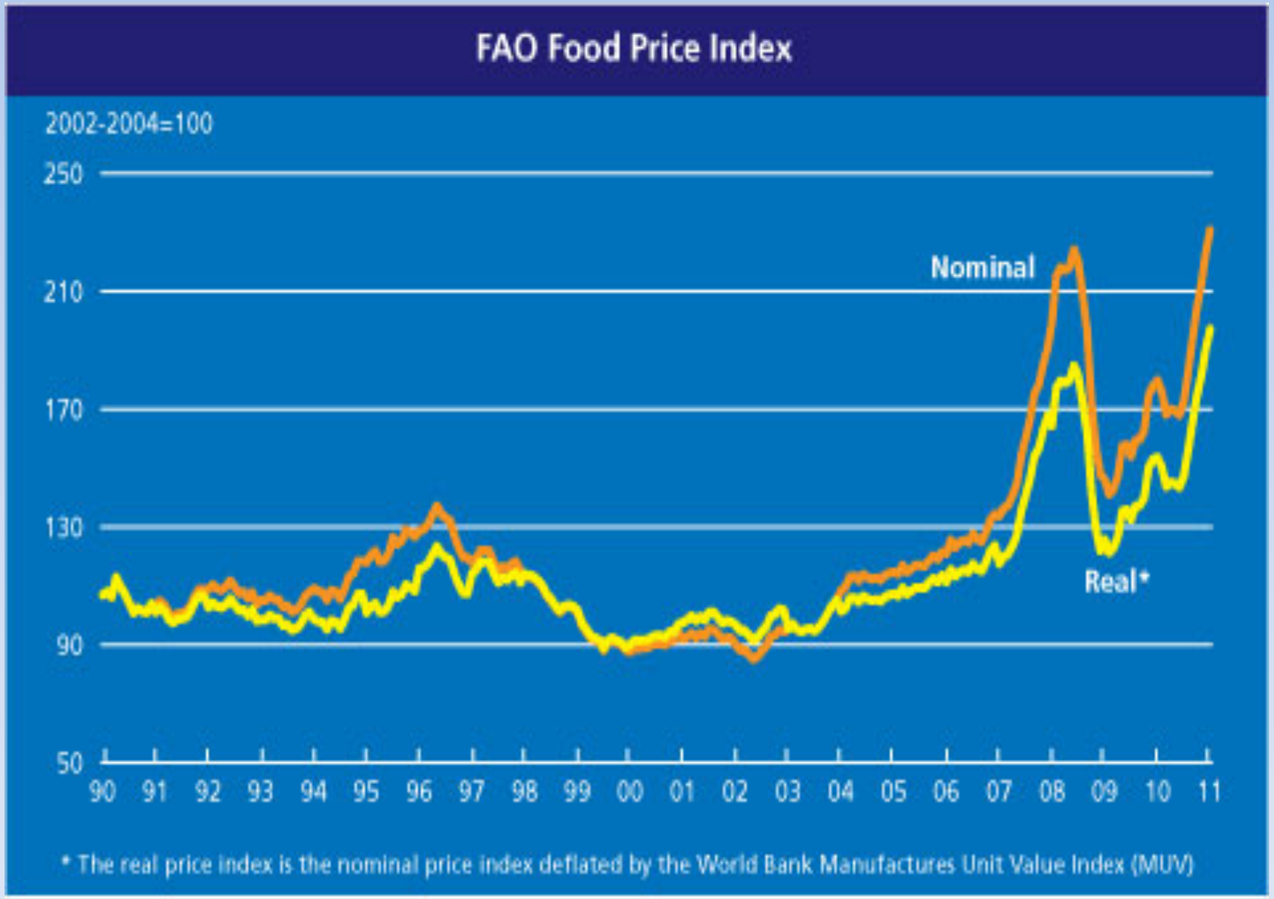
Recounts existing forest, forest re-growth, net terrestrial carbon sink, land counted for grazing

Carbon Payback Times – Ethanol from Cellulose – Wetter Savannas of Africa

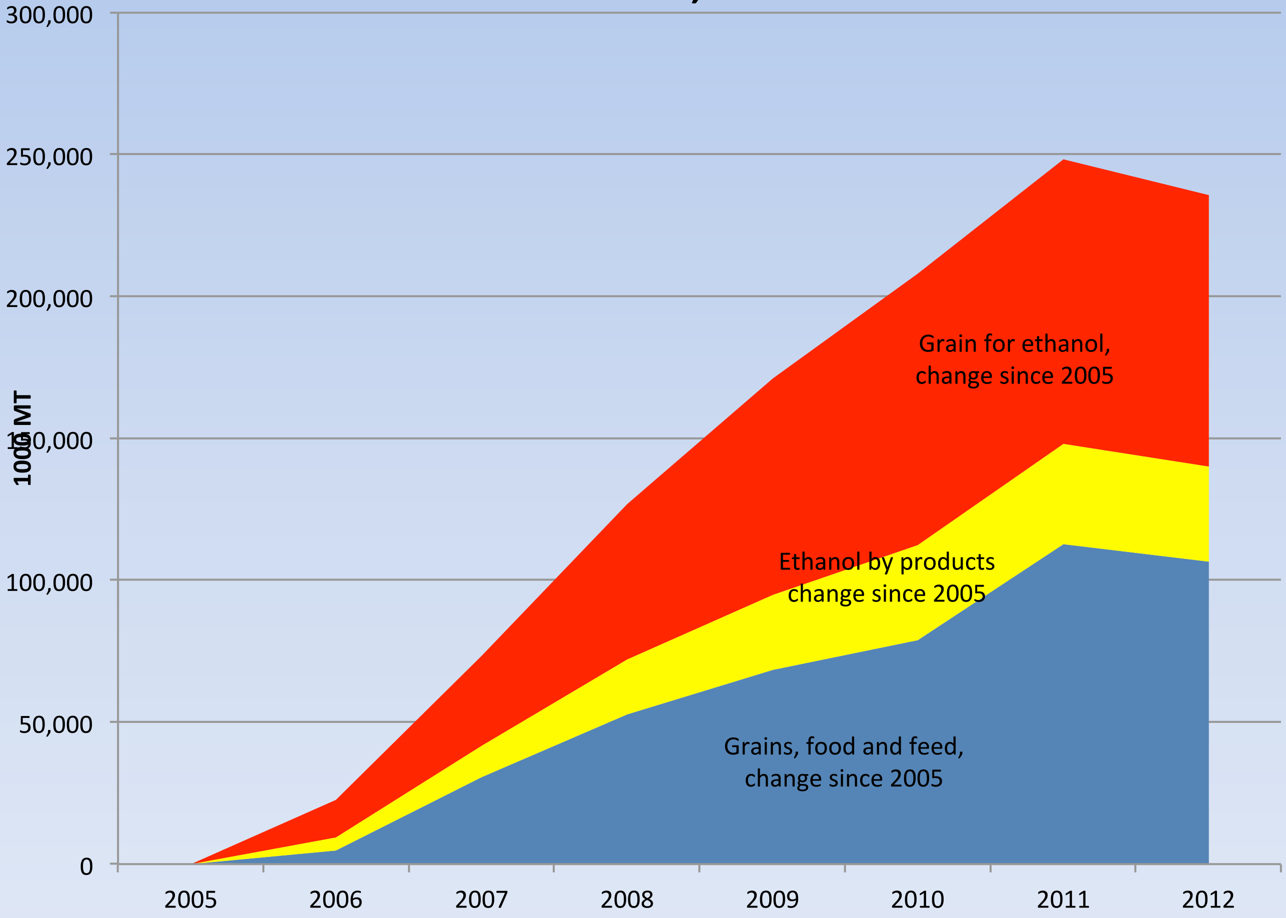


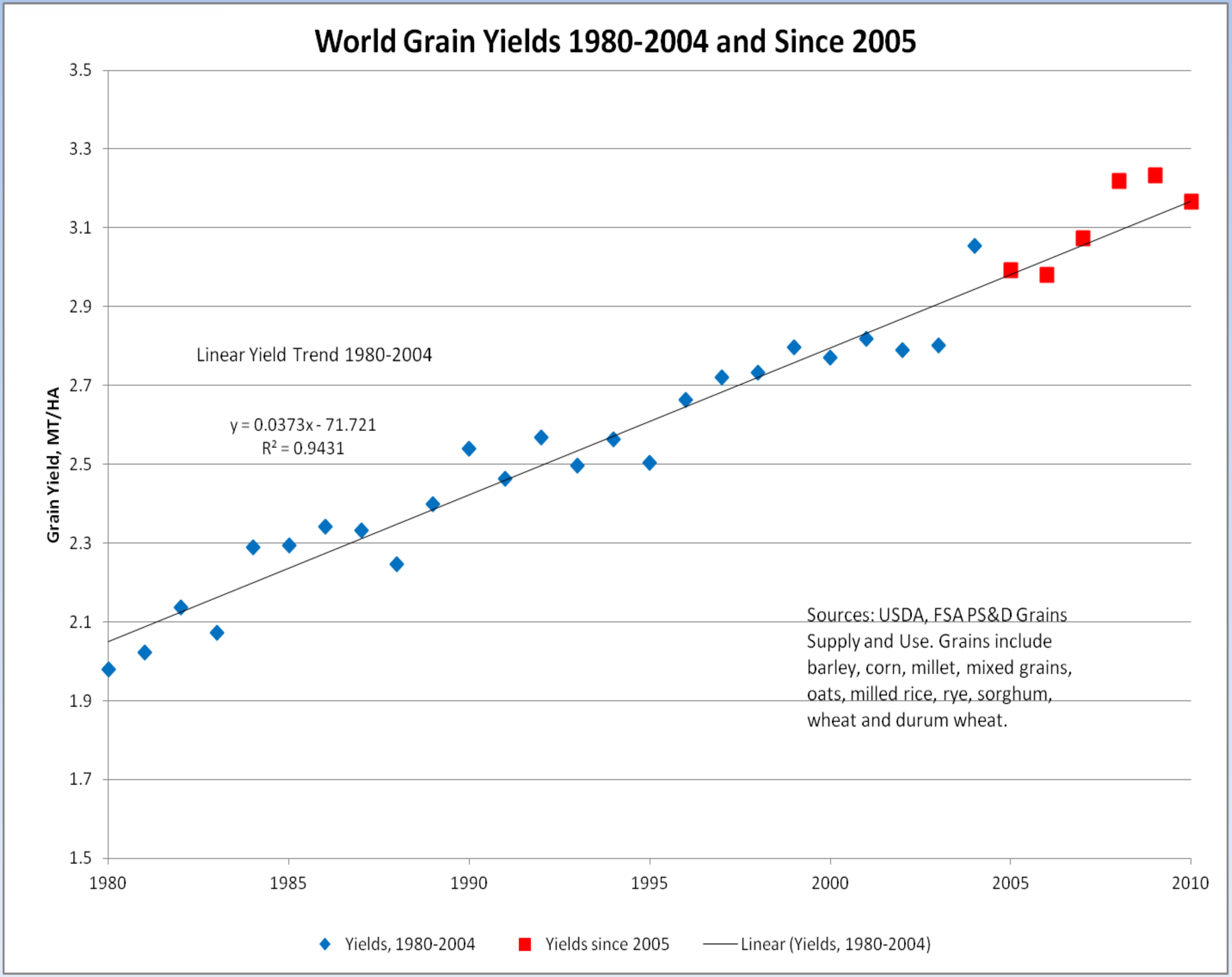
Southern Sudan

Coastal Kenya forest

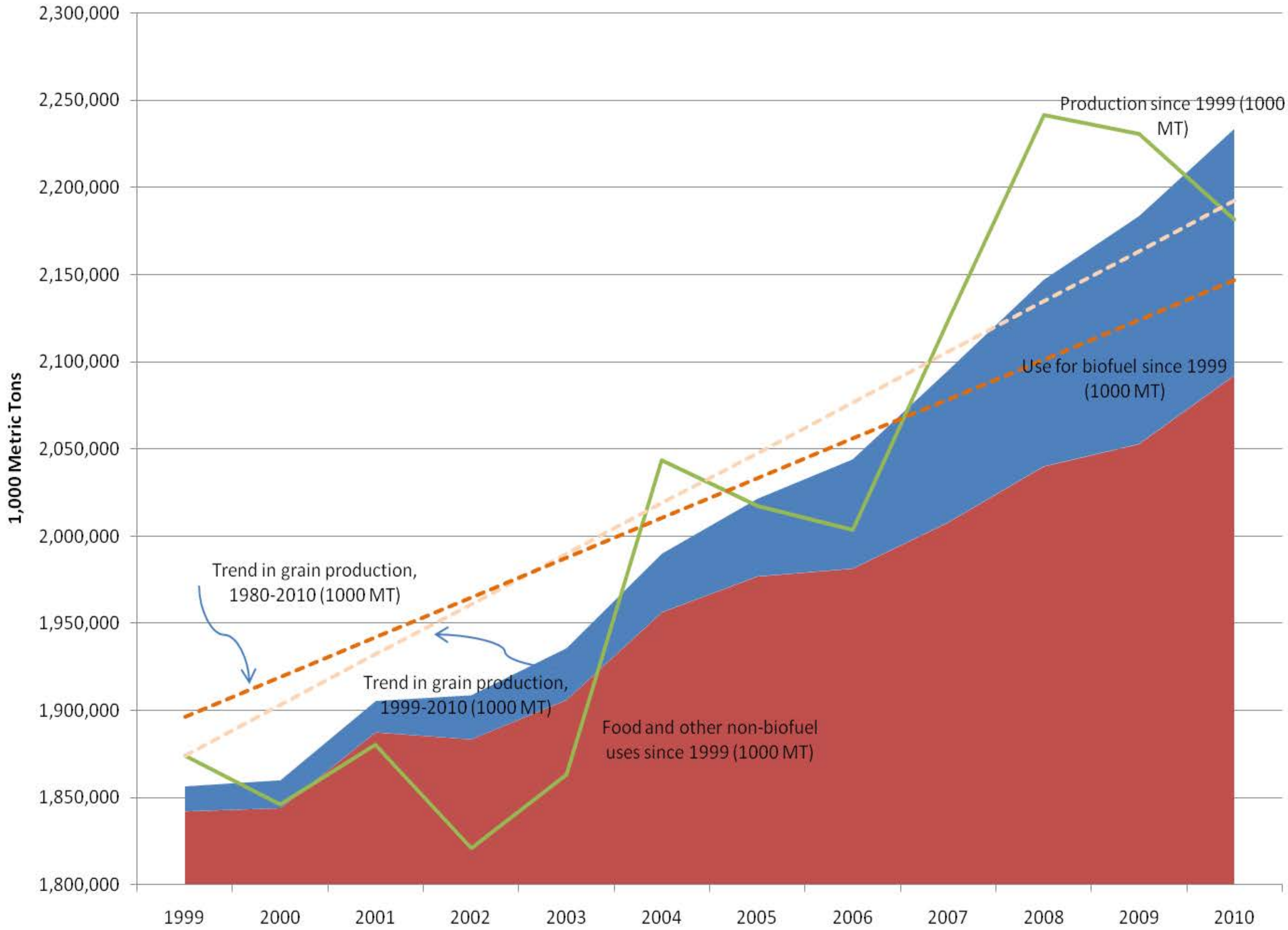

FAO Food Price Index
2002-2004=100
250
210
170
130
90
50
Nominal
Real*
90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11
* The real price index is the nominal price index deflated by the World Bank Manufactures Unit Value Index (MUV)

Change in Use for Food and Feed Versus Use for Biofuel, Grains




World Grain Yields 1980-2004 and Since 2005
Grain Yield, MT/HA
3.5
3.3
3.1
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5
1980
1985
1990
1995
2000
2005
2010
Linear Yield Trend 1980-2004
y = 0.0373x - 71.721
R² = 0.9431
Sources: USDA, FSA PS&D Grains Supply and Use. Grains include barley, corn, millet, mixed grains, oats, milled rice, rye, sorghum, wheat and durum wheat.
Yields, 1980-2004
Yields since 2005
Linear (Yields, 1980-2004)

World Grain Consumption and Production, 1999-2010



In Price of Farmland, Echoes of Another Boom

Jeff P. Freking, a farmer, in one of the fields near Le Mars, Iowa, that he purchased for $10,000 a acre at a land auction.

By WILLIAM NEUMAN

Published: New York Times - March 3, 2011

Simple Understanding of Using Wood for Electricity

- Wood starts by emitting ~ 3-4 times C02 as natural gas and ~ 1.5 - 2 times as much as coal
- Over 20 or 30 years, if mid-age forest harvested, there will often be further debt because unharvested forest would grow faster than regrowing forest
- If mature forest harvested, land must regrow ~75% of vegetated carbon within that period to repay debt and equal natural gas electricity - unlikely
- Net effect: greater than 2-fold increase in CO2

Sustainable harvest?

"Renewable" fuel and "sustainable" harvest do not equal carbon neutral.

Like using your bank interest, using annual carbon uptake for one purpose has cost of not using it for another.

Even "sustainable" harvest for energy still burns up terrestrial carbon sink

Key Points

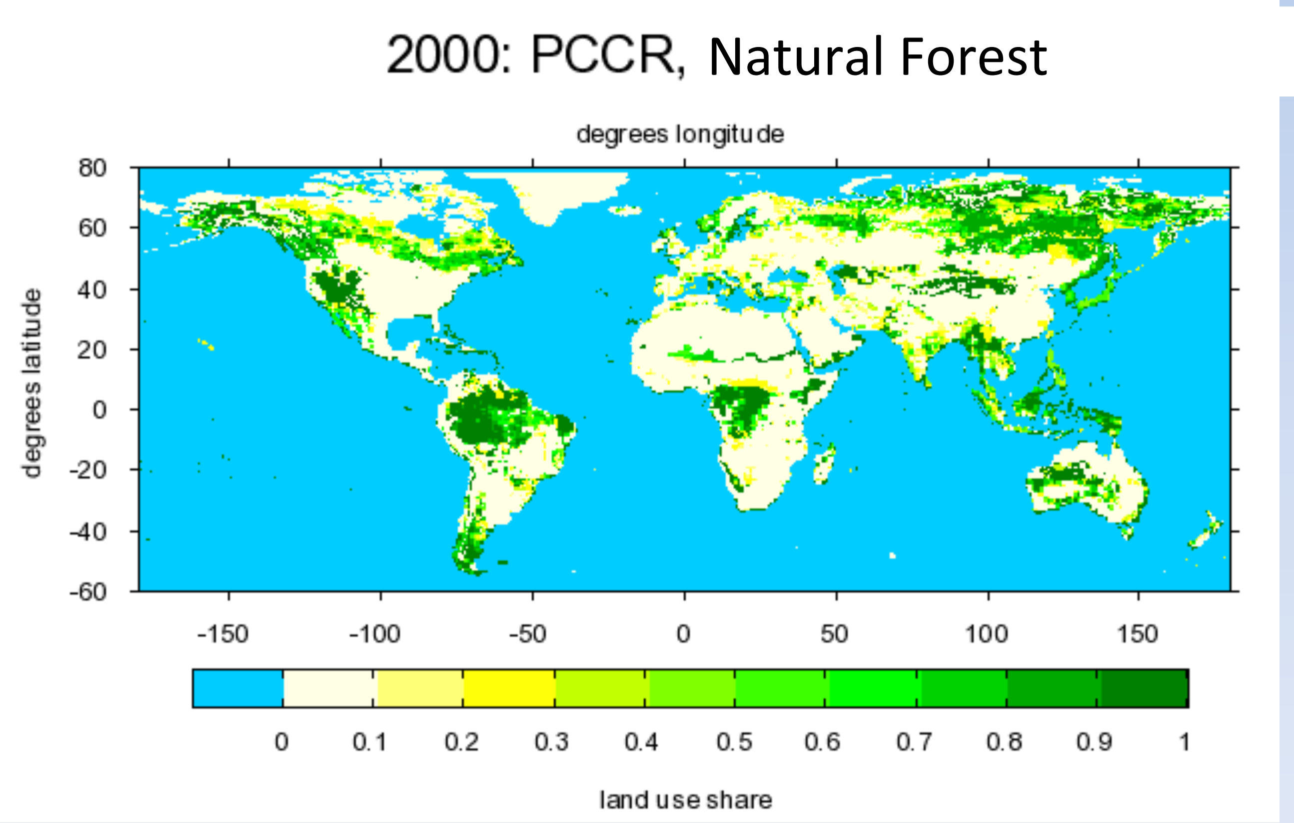
- There can be no GHG benefits from using existing crops for biofuels except through indirect effects
- If indirect effects are too uncertain to calculate, then one cannot assume any GHG reductions
- Cellulosic ethanol not necessarily better, depends on land use implications

To produce 20% of world energy demand by 2050 (IEA target), would require a doubling of world harvest of plant material (assuming biomass is used at 3/4 efficiency of fossil fuels!).

World Plant Harvest Today – from Haberl, European Environmental Agency Presentation (October, 2010) (below) (energy content of biomass converted from biomass use quantities in Haberl et al., PNAS (2007))

Above-ground biomass uptake (net primary production)	Exajoules/year
Natural vegetation	1,309
Human-induced reduction	68
Current total	1,241
Human harvest	225-*237*
Primary crops	64
Harvested crop residues	54
Biomass grazed	71
Wood removals (FAO)	36
Possible additional fuel wood not counted by FAO	*12*

Natural Forest
(Melillo, Gurgel, et al. 2008)



Natural Forest ("Deforestation" Scenario)