BIOENERGY: THE NEED FOR ADDITIONAL CARBON

TIM SEARCHINGER, PRINCETON UNIVERSITY AND GERMAN MARSHALL FUND

PRESENTATION TO NATIONAL ASSOCIATION OF CLEAN AIR AGENCIES

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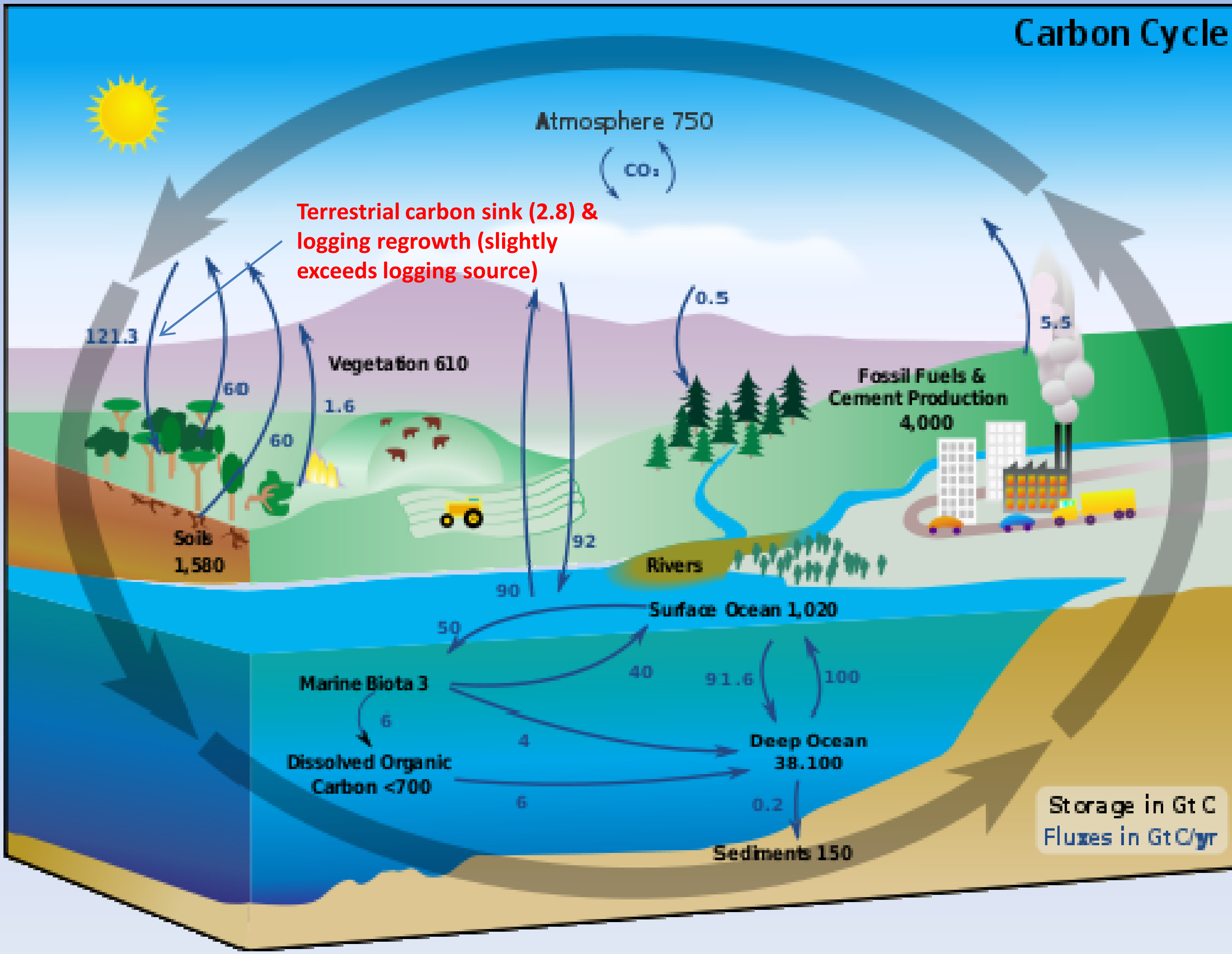
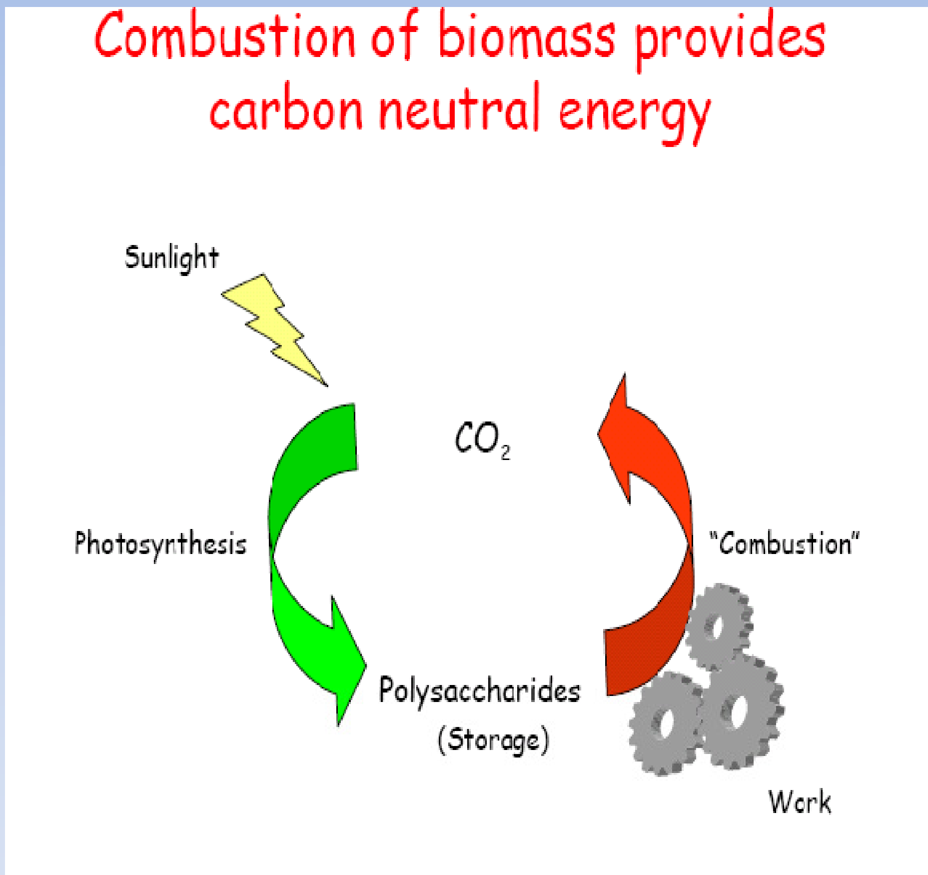
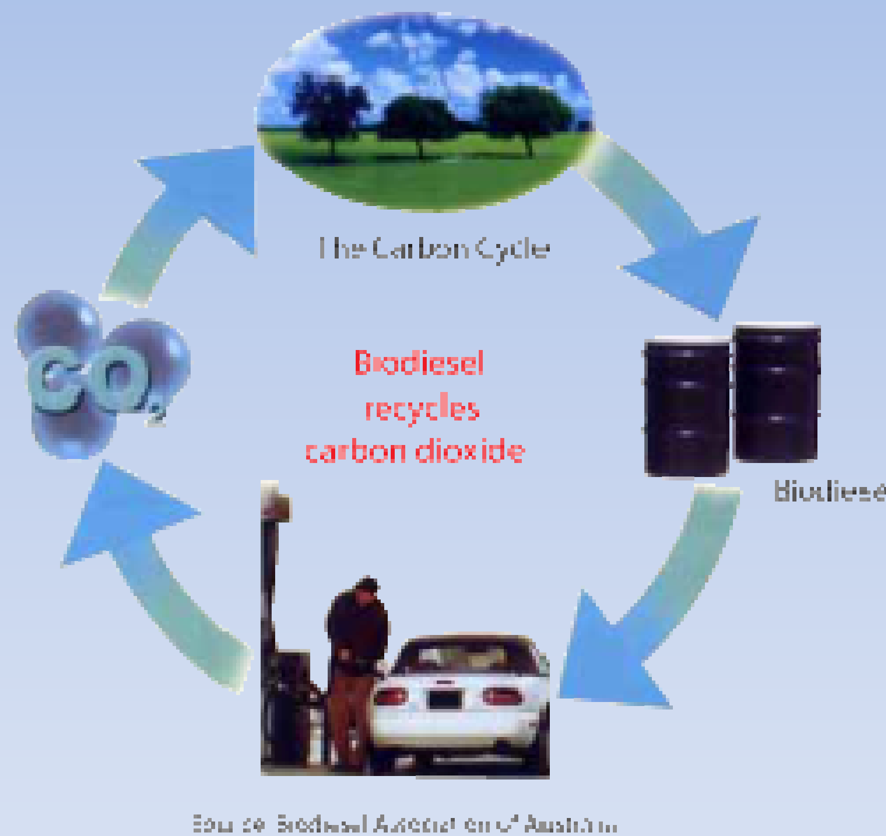

Carbon Cycle
Atmosphere 750
CO₂
Terrestrial carbon sink (2.8) & logging regrowth (slightly exceeds logging source)
121.3
60
60
1.6
Vegetation 610
0.5
5.5
Fossil Fuels & Cement Production 4,000
Soils 1,580
92
90
Rivers
Surface Ocean 1,020
50
40
Marine Biota 3
6
91.6
100
4
Deep Ocean 38,100
Dissolved Organic Carbon <700
6
0.2
Sediments 150
Storage in Gt C
Fluxes in Gt C/yr

BOTH FOSSIL & BIOENERGY COMBUSTION DIRECTLY EMIT CARBON DIOXIDE

Potential Savings Come from Plant Uptake



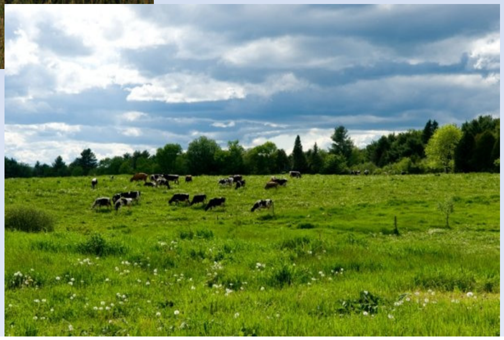


Bioenergy is a form of land-based carbon offset

Land grows plants whether for bioenergy or not:

* forest
* food

Only ADDITIONAL plant growth helps



90 Scientist Letter to Congress

"Bioenergy can reduce atmospheric carbon dioxide if land and plants are managed to take up additional carbon dioxide beyond what they would absorb without bioenergy. Alternatively, bioenergy can use some vegetative residues that would otherwise decompose and release carbon to the atmosphere rapidly. Whether land and plants sequester additional carbon to offset emissions from burning the biomass depends on changes both in the rates of plant growth and in the carbon storage in plants and soils."

W. Schlesinger, Donald Kennedy, Sallie Chilsolm, Norm Christensen, Gretchen Daily, Gene Likens, Dan Kammen, Tom Lovejoy, Michael Oppenheimer, Stuart Pimm, Phil Robertson, Stephen Schneider, Robert Socolow ,Dan Sperling, John Terborgh et al.

Some Estimated Potential Additional Biomass Potential

DOE –" Billion Ton Supply"	
Forest product residues	145
Logging residues	64
Urban wood residues	47
Agricultural residues	428
Process residues/manure	106
	790
Other Sources	
Municipal solid waste	100
Cover crops (summer/winter)	200
	300

- Algae
- Flue gases
- Fall harvests from CRP

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

2008 Studies With Similar Conclusions

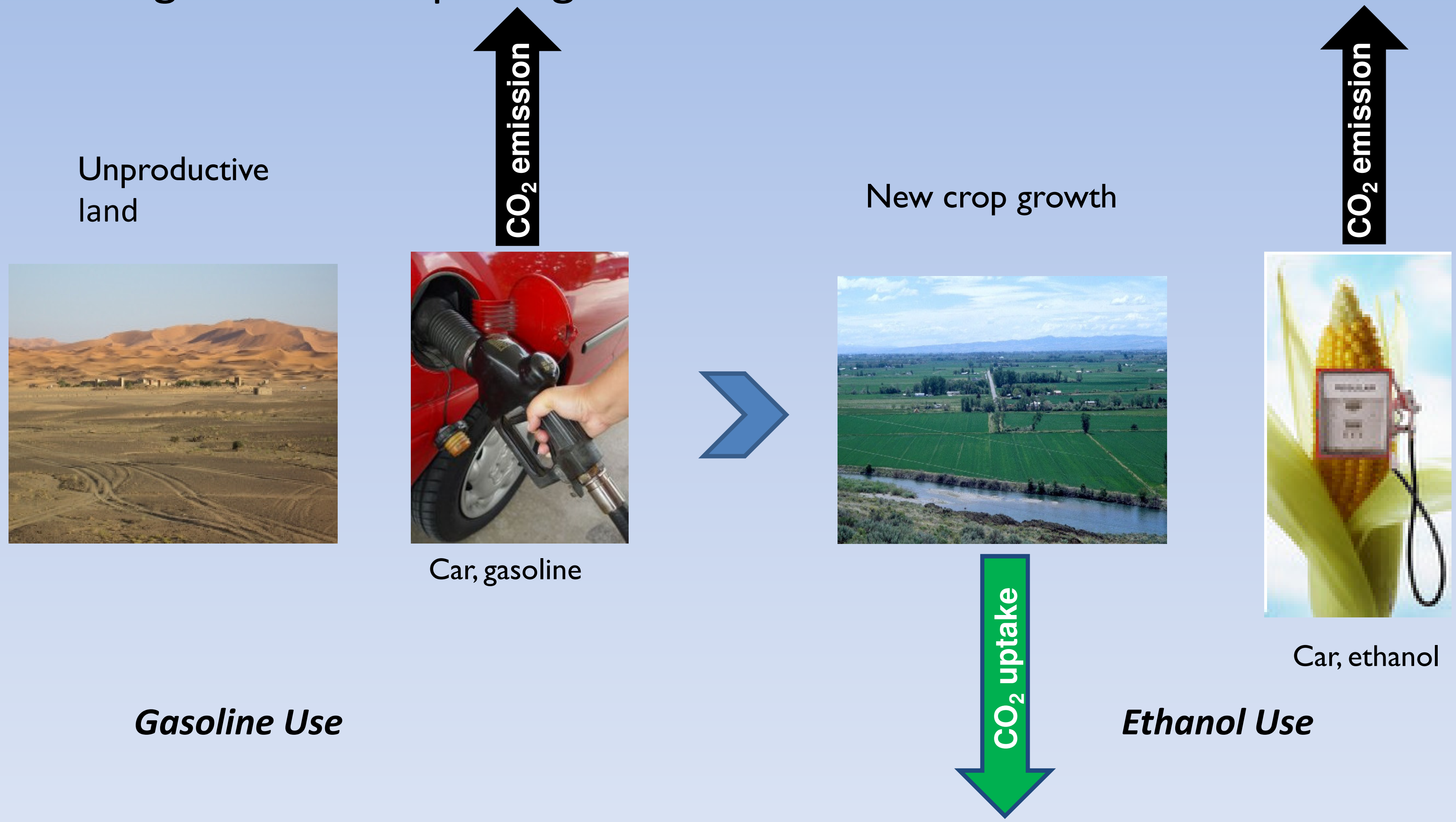
- UK Renewable Fuels Agency (Gallagher Review)
- EU Joint Research Center
- World Bank
- FAO
- Netherlands Environmental Assessment AGency
- OECD
- European Economic and Social Committee
- Scientific Committee on Problems of the Environment
- British Royal Society

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

Source of fuel*	Feedstock: Mining crude oil or growing crop and transporting to refiner	Refining & distributing fuel	Tailpipe Emissions	Total GHGs & % Increase for Biofuel *Without Plant Credit*	Credit for Plant Growth	Total GHGs & % Savings for Biofuel
Gasoline	**+4.5**	**+8**	**+73.3**	–	**0**	**85.8**
EU Ethanol	***+40***	***+21.2***	~~***+71.4***~~	***+132.6 (+54%)***	~~***-71.4***~~	***+61.2 (-29%)***
Diesel	**+4.6**	**+9.6**	**+73.2**	–	–	**87.4**
EU Biodiesel from Rape	***+35.5***	***11.1***	~~***+76.2***~~	***122.8 (+41%)***	~~***-76.2***~~	***+46.6 (-47%)***

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



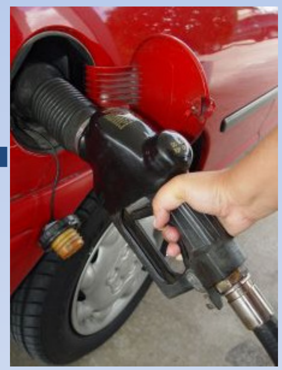
Using otherwise burned or decomposed crop residues for biofuels - Reduced emissions through reduced land sources

CO_2 emission

Burning or decomposing crop residues

+

CO_2 emission



Car, gasoline

→

Reduced emissions from Residues

+

CO_2 emission

C

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

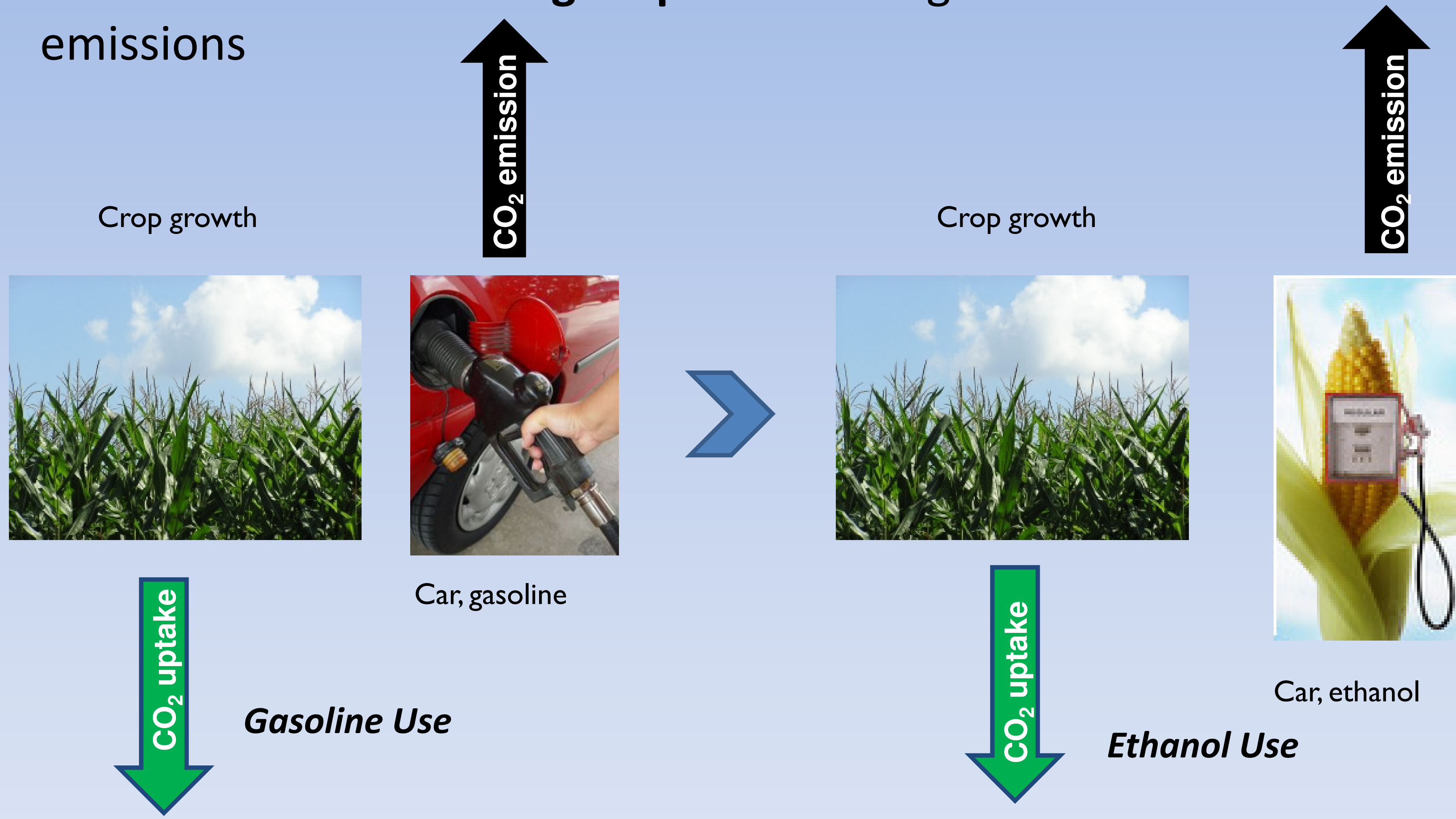
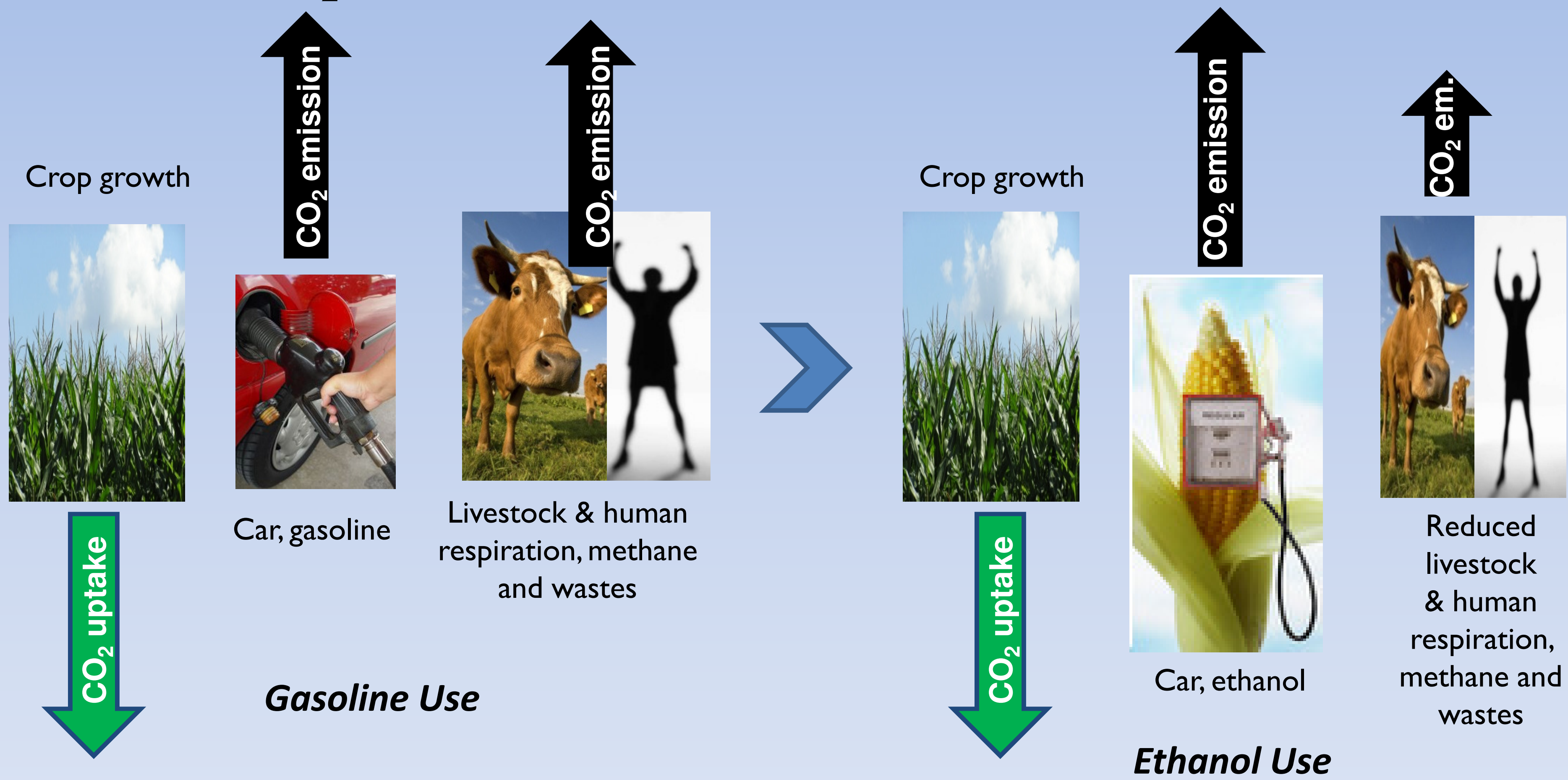


Figure 3 - Indirect effect 1 of adopting ethanol – Ethanol leads to less crop consumption for feed and food, which reduces CO_2



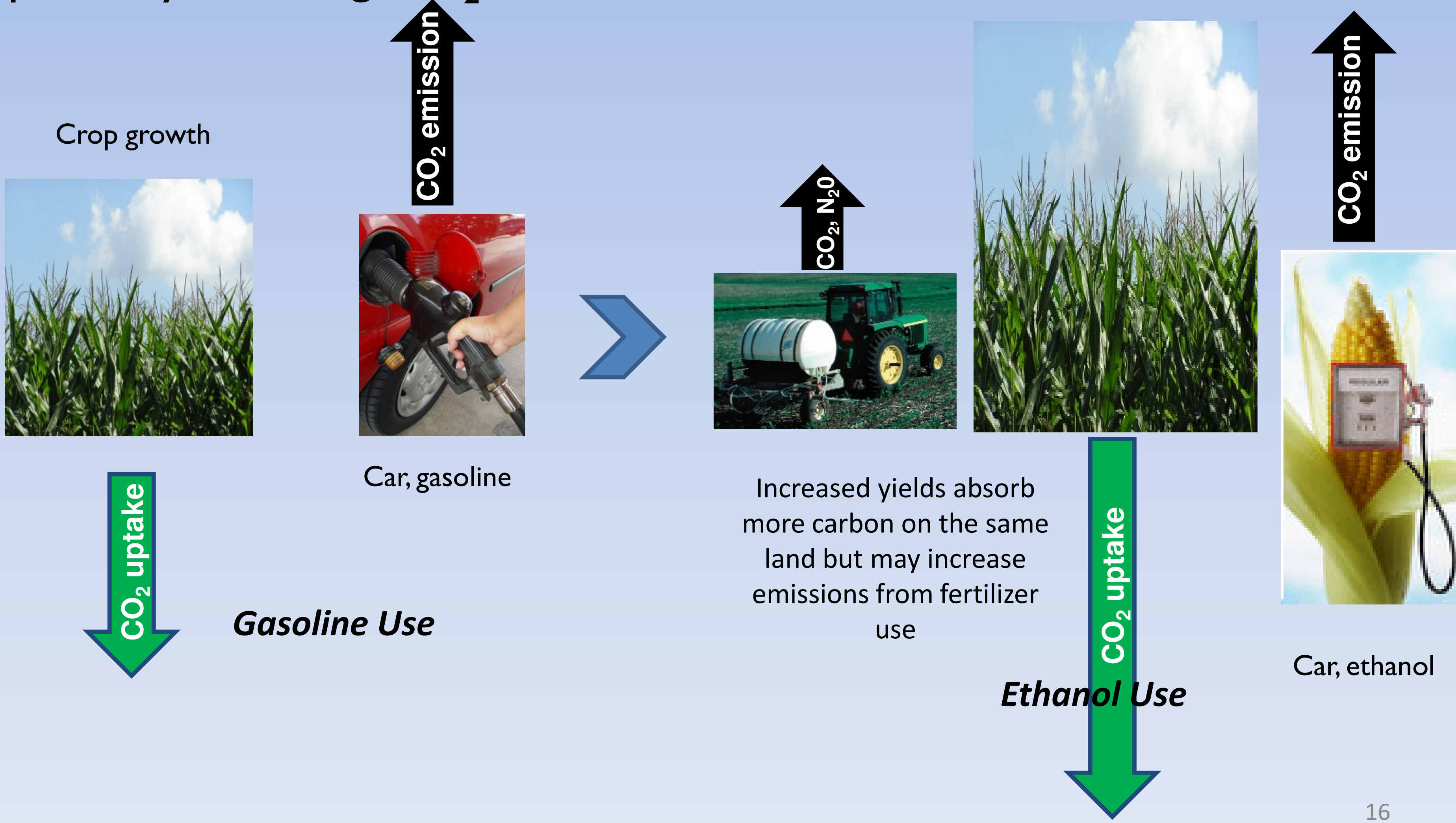
(vertical arrows indicate carbon uptake and emissions)

Importance of Food Consumption Reduction in LCAs for Biofuels

Model and Type of Ethanol	*Food Consumption Reduction (exclusive of by-products)*
GTAP US Maize	**52%**
Impact US Maize	**36%**
IMPACT EU Wheat	**47%**
FAPRI CARD EU Wheat	**34%**
GTAP EU Wheat	**46%**

from JRC 2010

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



Crop Yields Growth Needed 2006-2020 to Provide Food and 10.3% of World Transport Fuel Without Deforestation

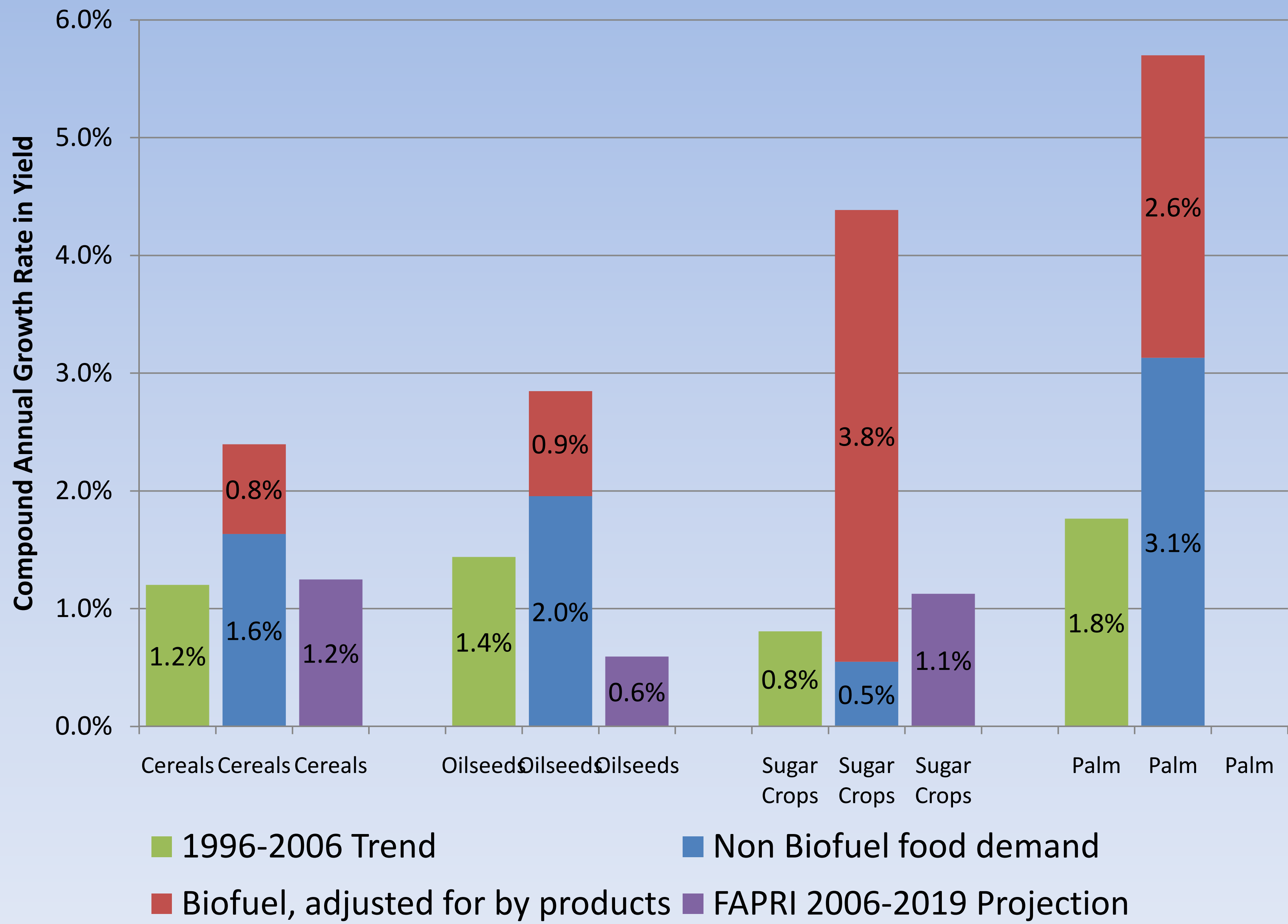
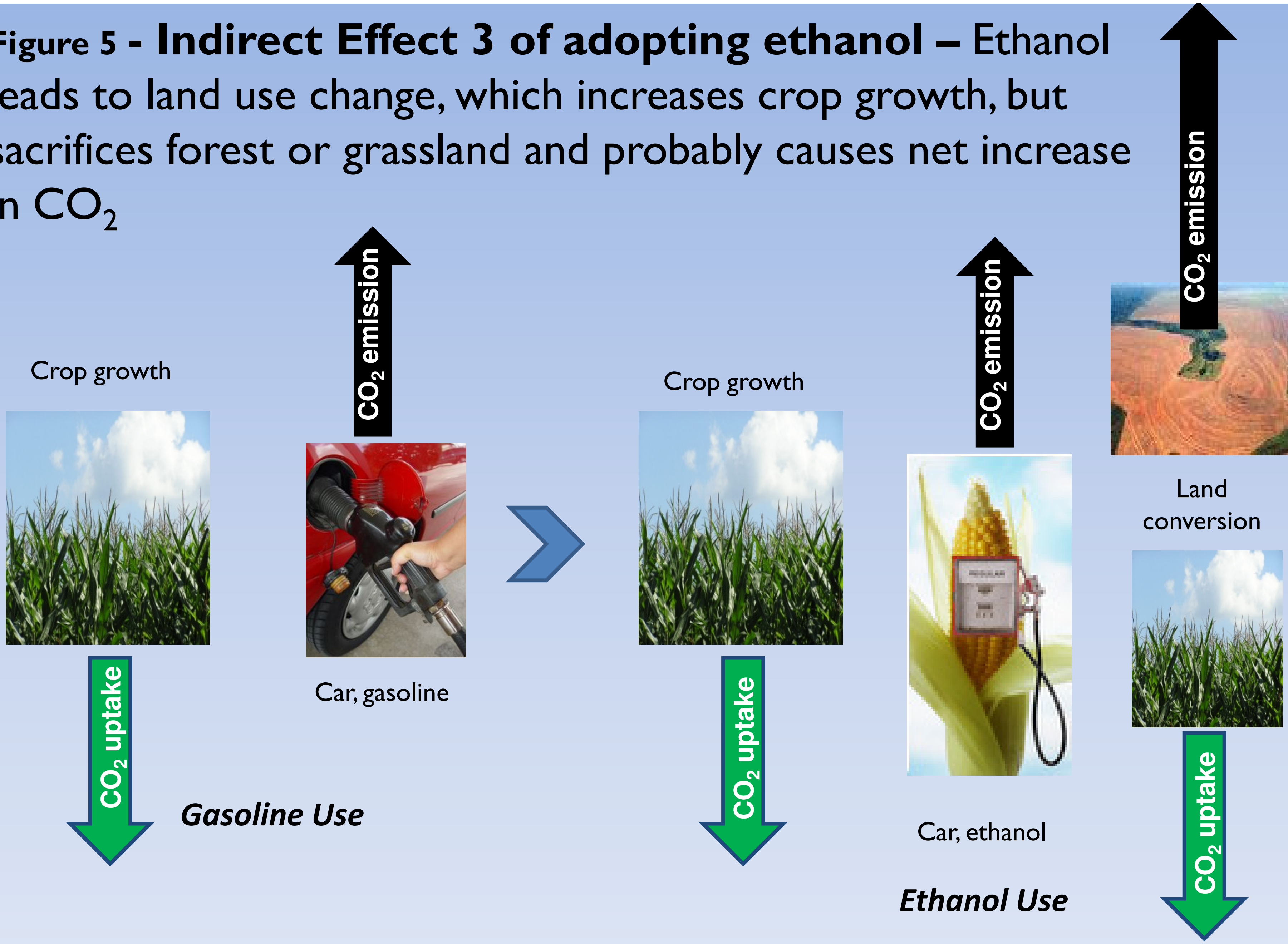


Figure 5 - Indirect Effect 3 of adopting ethanol – Ethanol leads to land use change, which increases crop growth, but sacrifices forest or grassland and probably causes net increase in CO_2



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

Key Points

- No direct GHG benefits from using existing crops for biofuels
- Indirect GHG "benefits" from
  - Reduced food consumption
  - Additional yield on existing cropland land
  - New crops on new cropland
    - BUT MUST ALSO COUNT LOST CARBON STORAGE AND ONGOING SEQUESTRATION ON THAT LAND
- If indirect effects too uncertain to calculate, then cannot assume any GHG reductions
- Cellulosic ethanol not necessarily better, depends on land use implications

EMISSIONS OF ELECTRICITY FROM NEW ENGLAND WHOLE TREES

Initial Committed Emissions:

- Emissions from unused cut wood (roots & residues)

  ~ 1/3 of total standing wood

- Smokestack emissions

  ~ 2.75 to 3 tons of CO_2 from wood for each 1 ton from natural gas or 1.5 tons compared to coal

  Upfront emissions are roughly 400% of gas per kwh

Subsequent 20 or 30 years

Growth if harvested minus growth if unharvested, e.g.,

Harvest mid-age forest- probably lowers total growth after 20 years & little change after 30 for many forests

Thin understory – probably decrease growth

Thin mature trees from above – net increase in growth but not enough to recover carbon debt

Bottom line: probable large increase in emissions

50 Year Old Interior Douglas Fir/Western Hemlock

(Emissions per hectare harvested for electricity)

(Forest carbon loss and re-growth figures from Stephen Mitchell, Nicholas School, Duke University)

Gross Emissions ~ 264

Smokestack emissions ~ **148** tonnes

*- Carbon stock of live trees pure hectare is **193** tonnes is above ground, assuming 10% coarse roots, leave 15% of aboveground (half of normal residues), yields **148** tonnes of carbon in wood fuel .*

Emissions from unharvested wood:

Root Loss ~ ***12*** tonnes *-65% of coarse roots decompose)*

Residues ~ **14** tonnes – leave ***26*** *tonnes on forest floor, 55% decomposes in first 20 years*

Foregone sequestration if existing forest not harvested and were to continue to grow **90** tonnes

Emissions Savings - 85 tonnes (replace natural gas) or 126 tonnes (replace coal)

Avoided fossil emissions - **54** tonnes (replace gas) or **99** tonnes (replace coal) (accounts for lifecycle emissions)

Carbon Sequestration from Regenerating Forest over 20 years *(including trees, dead branches, understory and coarse roots)* – **30** tonnes

***Net Effect Over 20 Years**: 3 times than gas (179 v. 54) ; two times higher than coal (264 v. 138)*

Sustainable harvest?

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

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

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 bioenregy emissions “to avoid doublecounting”

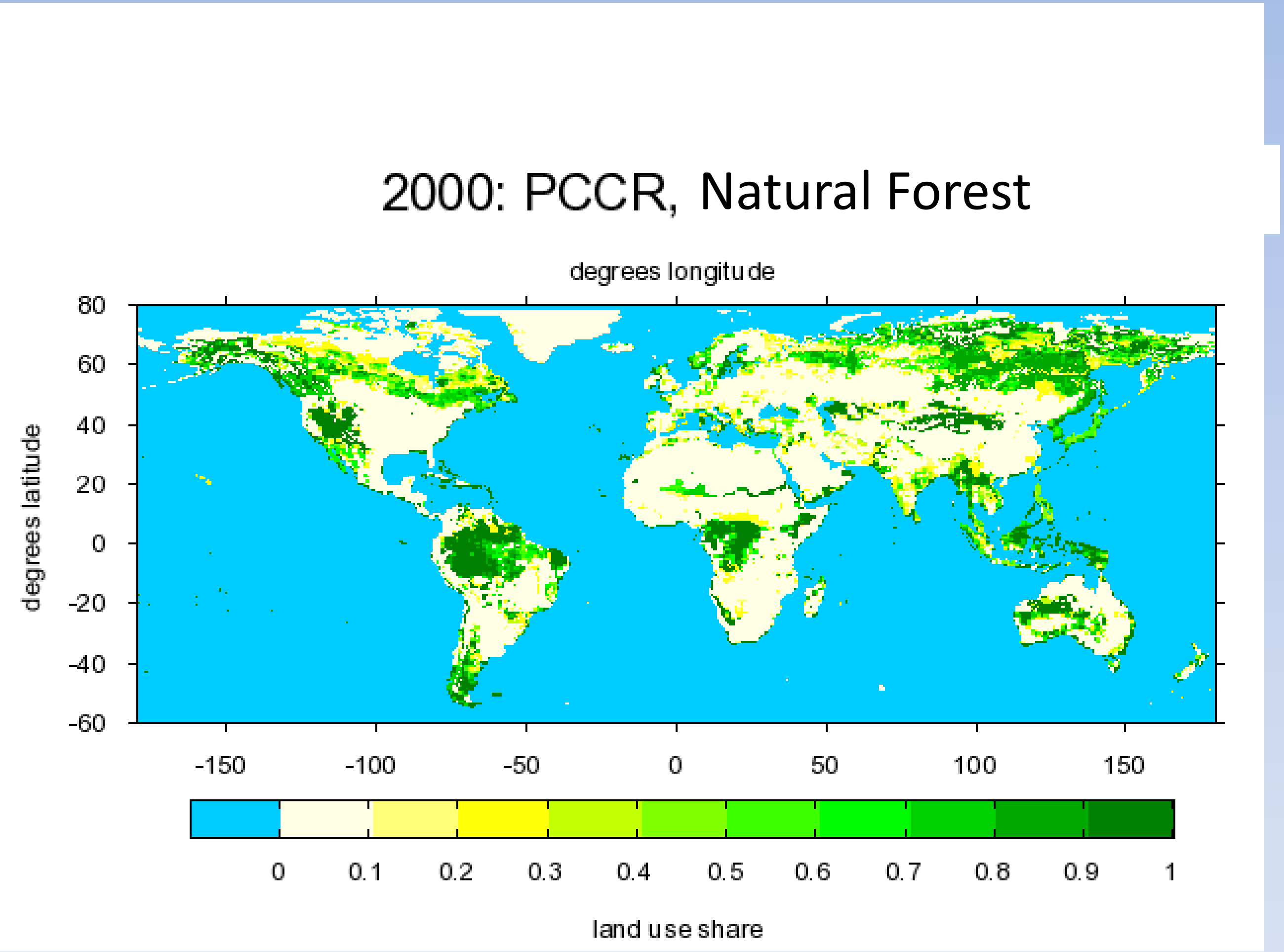
10% World Transport Fuel Target for Biofuels by 2020 Using Present Mix of Feedstocks

10% of Transport Fuel	2% of Total Energy Demand	18% Cereals (adjusted for by-products)	75% Sugar Crops	45% Vegetable Oil

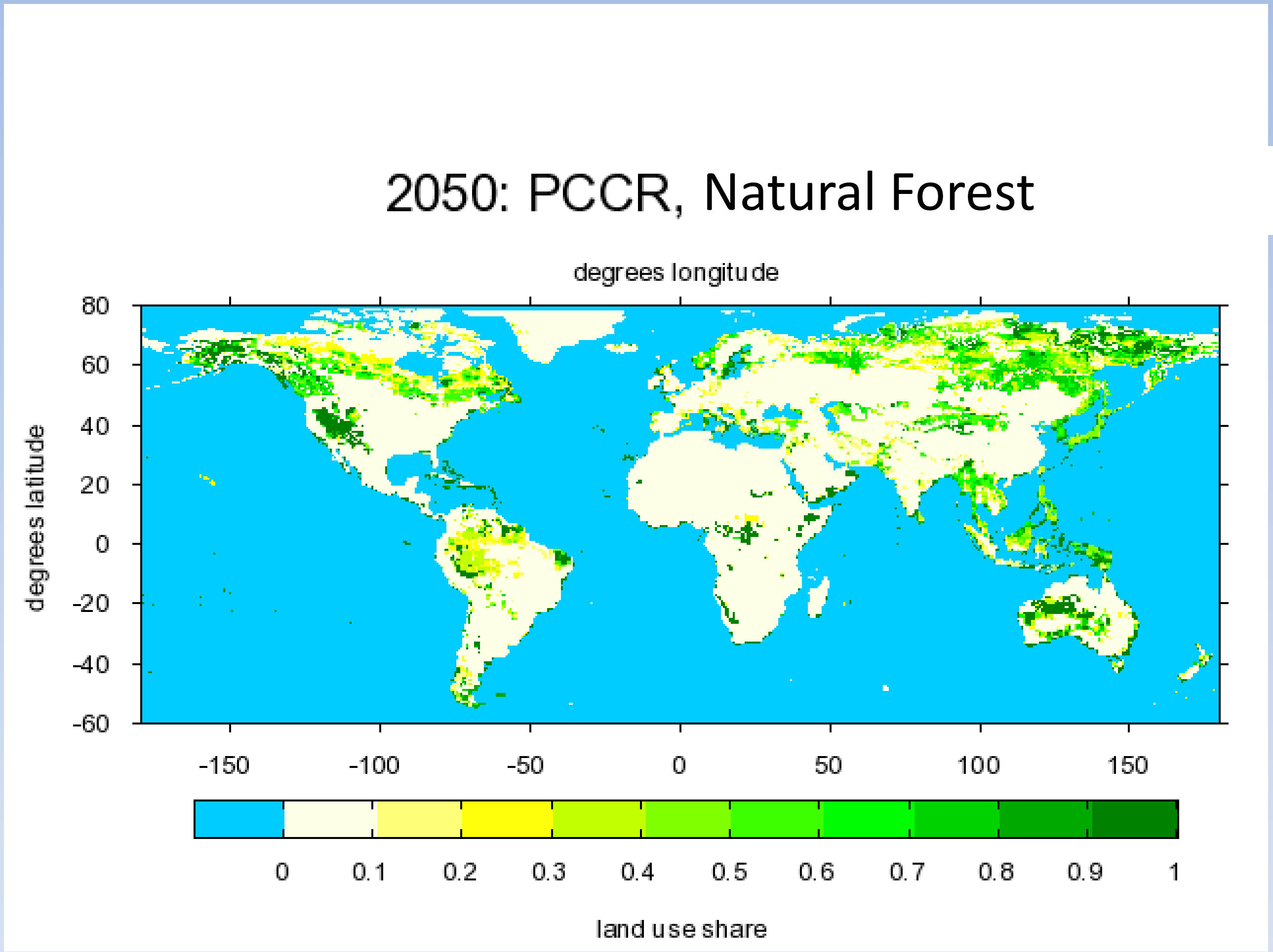
All annually harvested crops, forage, residues and wood paper products embody 185 Exajoules of Energy, Roughly 20% of 2050 World Energy Demand

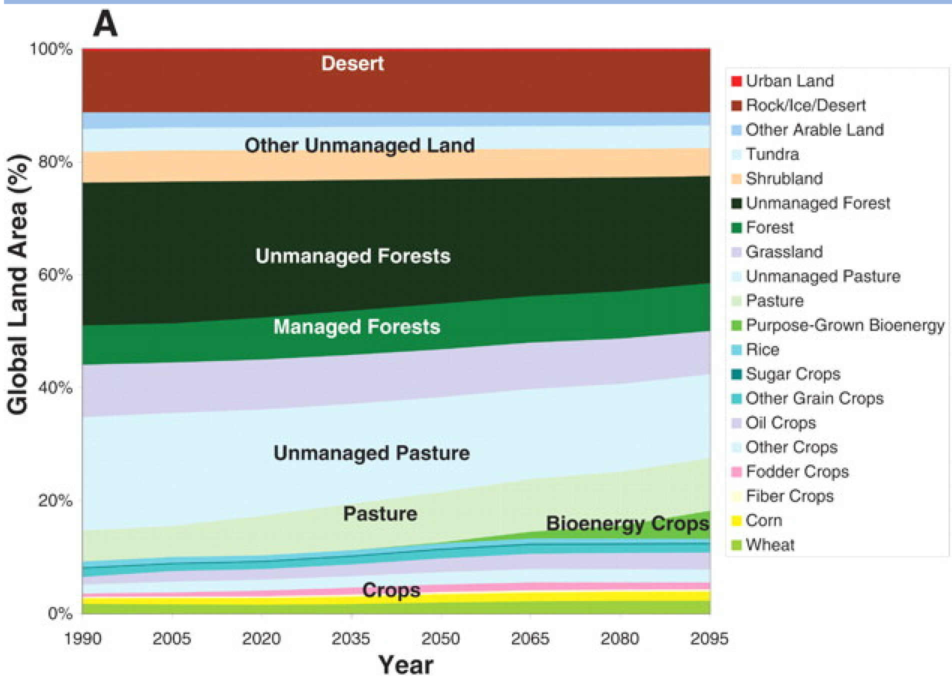
Process	Yearly energy flow [EJ/yr]
Terrestrial above-ground net primary production, potential	1 309
Human-induced reduction of productivity	68
Terrestrial above-ground net primary production, current	1 241
Terrestrial above-ground NPP excl. forests + wilderness	580
Human biomass harvest and destruction	337
Human biomass harvest used for economic purposes	225
- used for livestock (includes ‚recycled' biomass)	129
- used as food	28
- current bioenergy use (includes ‚recycled' biomass)	40
Bioenergy potential estimates 2050	60 – 1 200

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

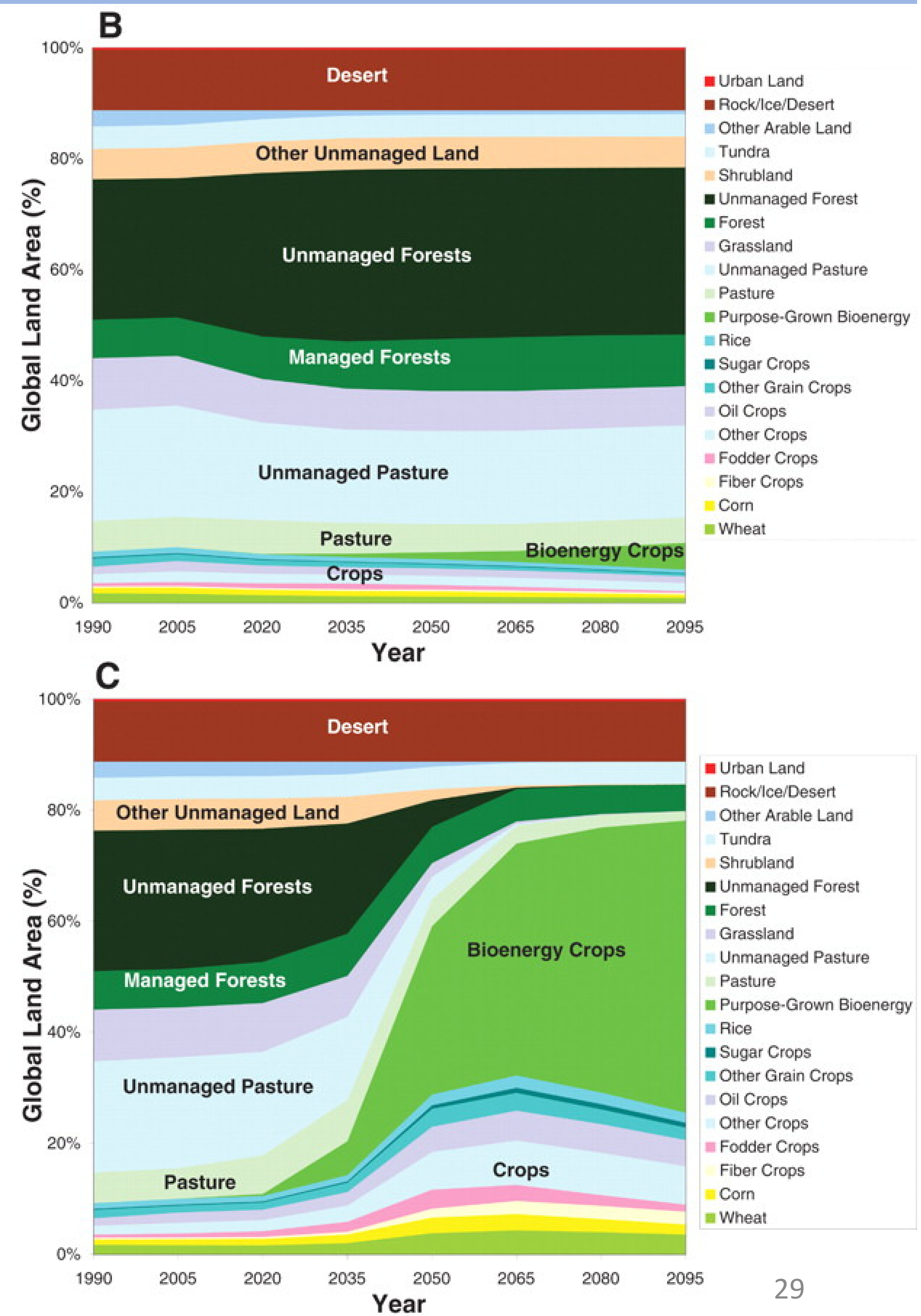


Natural Forest ("Deforestation" Scenario)





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



Massachusetts Approach
Do not Credit Already Used Carbon

LCA shall "credit carbon stored in biomass fuel only to the extent that the stored carbon is 'additional' and that the biomass would not otherwise be used (e.g., for food, animal feed or durable wood products) and its carbon content would not otherwise remain sequestered in trees, plants or soils."

Sec. Bowles Letter to Giudice (July 7, 2010)