Biomass for Energy?

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2017
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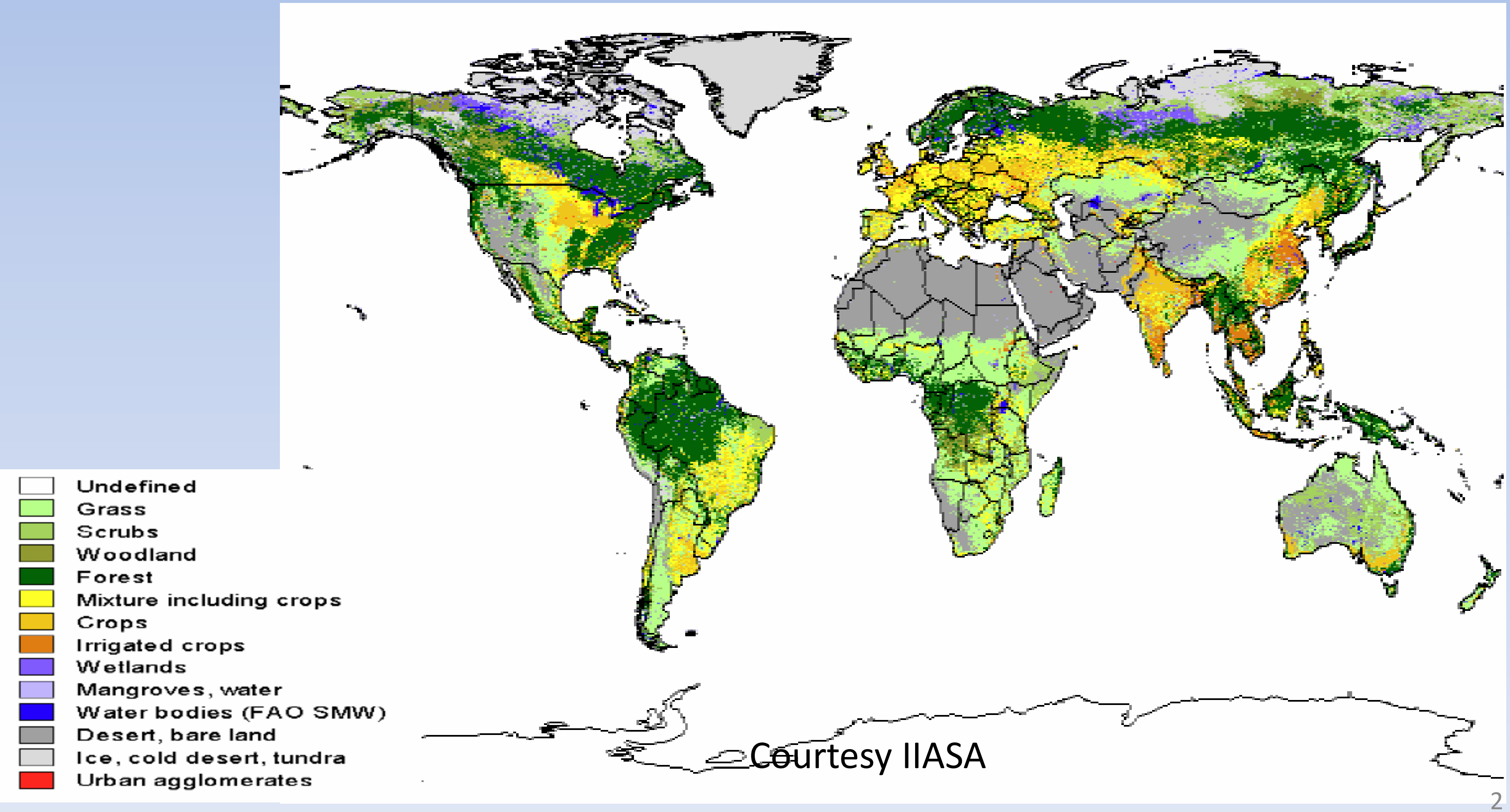
Existing Global Plant Harvests Have Transformed or Substantially Manipulated ~ 75% of all Vegetated Lands

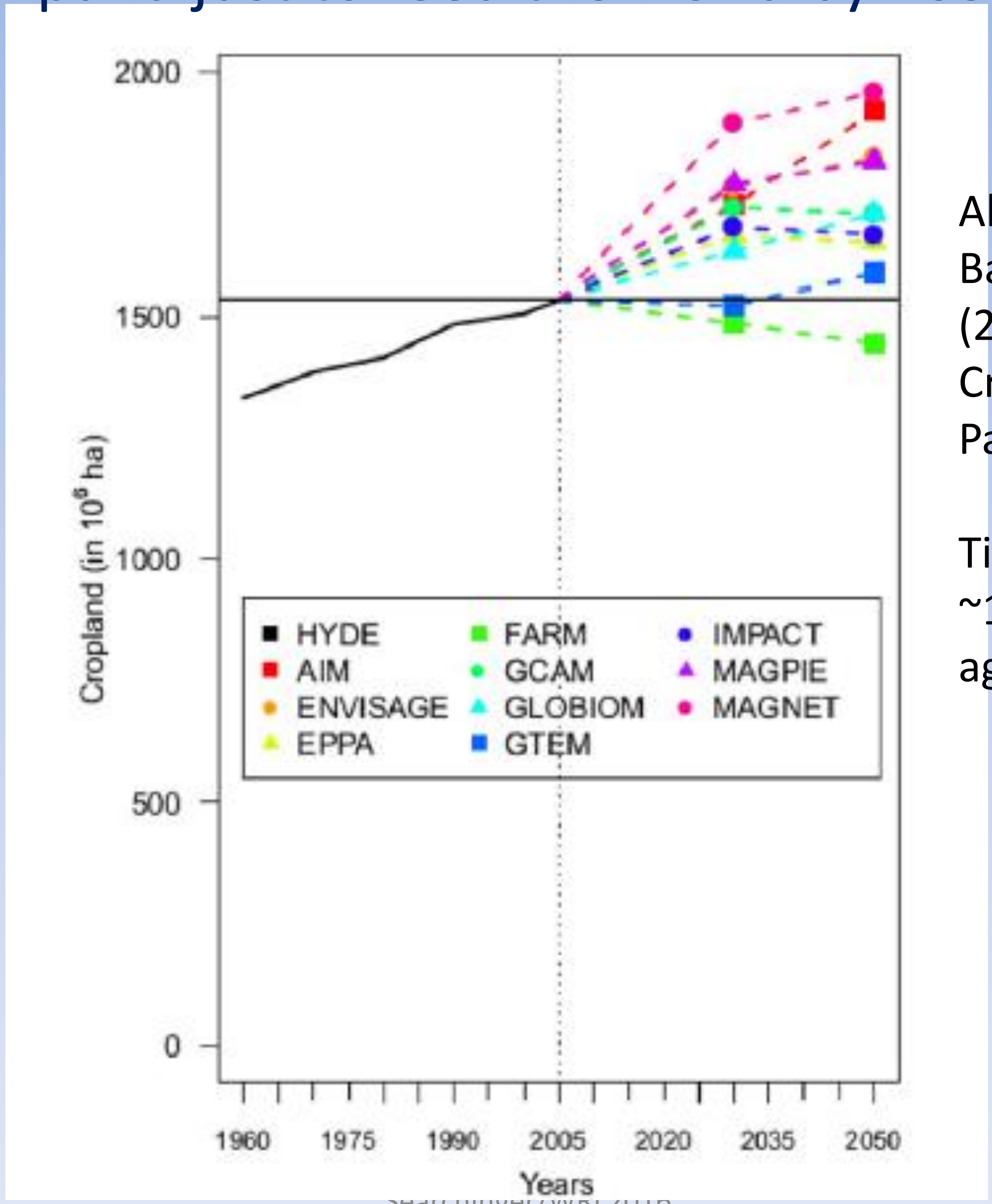


Courtesy IIASA

Nearly all studies project that cropland will need to expand just to feed the world by 2050.

Chart shows Future Cropland Projections from Different Models

C. Schmitz et al. Agricultural Economics 45 (2014) 69–84



Also:

Bajzelj et. al., Nature CC (2014)

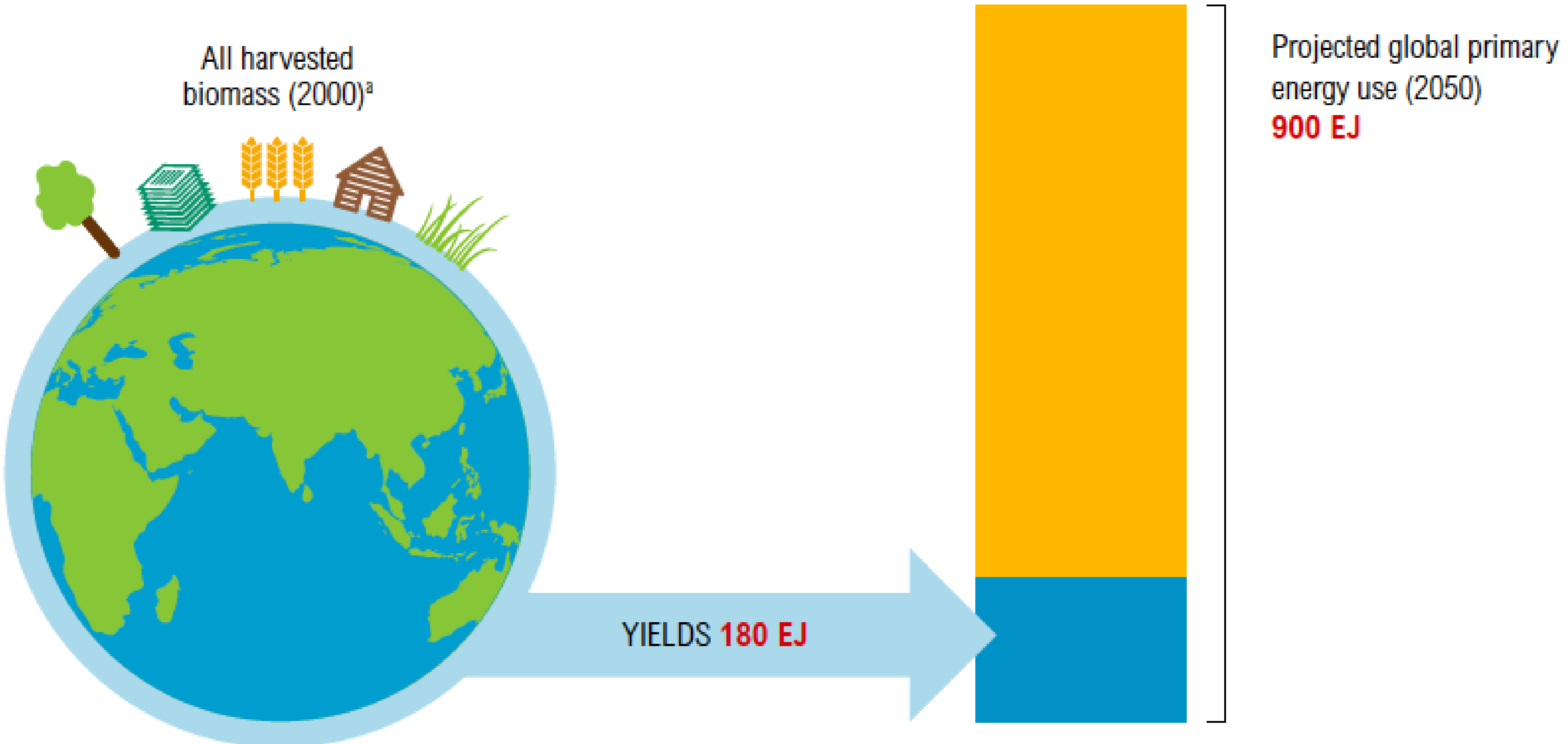
Cropland + 660

Pasture + 430

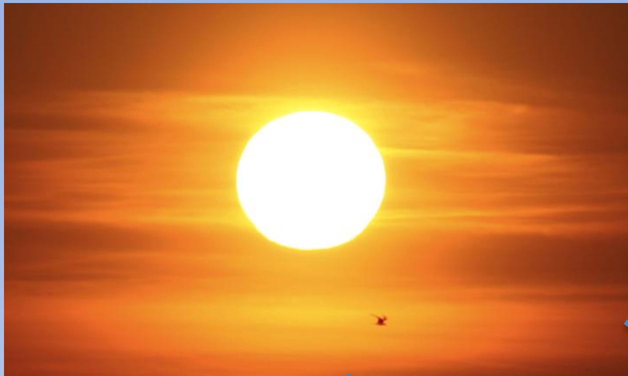
Tilman et al. (2011)

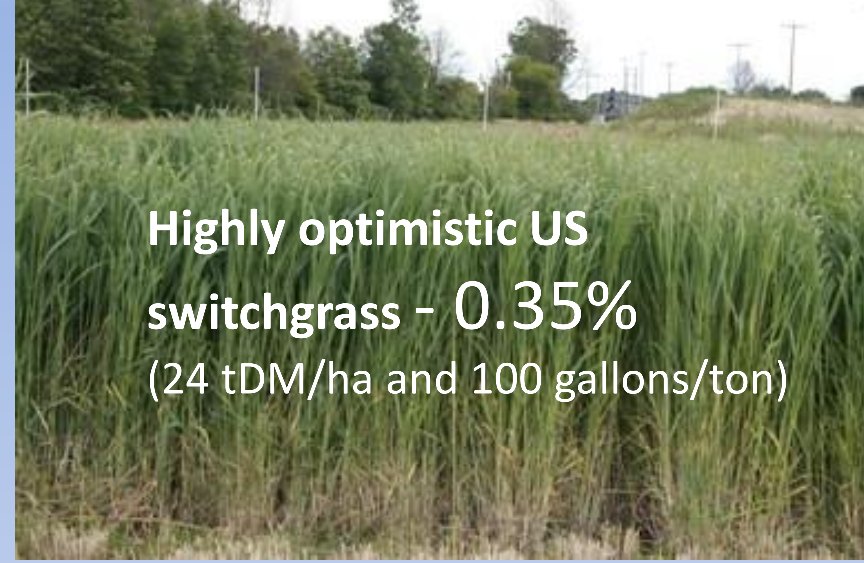
~1 billion total additional agricultural land

Figure 4 | **Using All of the World's Harvested Biomass for Energy Would Provide Just 20 Percent of the World's Energy Needs in 2050** (Exajoules per year)

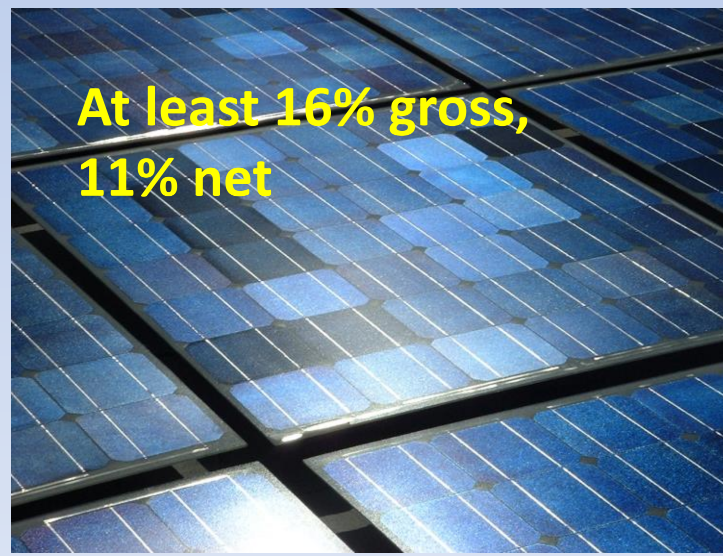


Source: Authors' calculations based on Haberl et al. (2007), IEA (2008), and JRC (2011).
Note: a. Total amount of crops, harvested residues, grass eaten by livestock, and harvested wood contained 225 EJ, but would replace only 180 EJ of fossil fuels because of conversion efficiencies from biomass to useable energy.




Highly optimistic US
switchgrass - 0.35%
(24 tDM/ha and 100 gallons/ton)


Brazilian sugarcane – 0.2%


At least 16% gross,
11% net

Large Bioenergy Potential Studies Double Count Biomass and Carbon

- Most potential arable land –IPCC 2001 chapter 8 - 1.4 billion hectares, SCOPE (2015), and/or
- All forest growth in excess of harvest (Smeets 2008, Bauen et al. 2009)and/or
- All "abandoned" cropland (Hoodwijk (2004) and/or
- Hundreds of millions of hectares of "grazing" land
- Hundreds of millions of hectares of "other" land – woody savanna (Fischer 2001; Smith 2007, Cai 2011, Van Vuuren)
- Diversion of timber product demand elsewhere

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

FORESTS IN SOUTHEASTERN U.S.

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Enviva Wood Pellet Mill
(Sampson County, North Carolina, February 2017)

Truck with hardwood logs entering Enviva wood pellet mill
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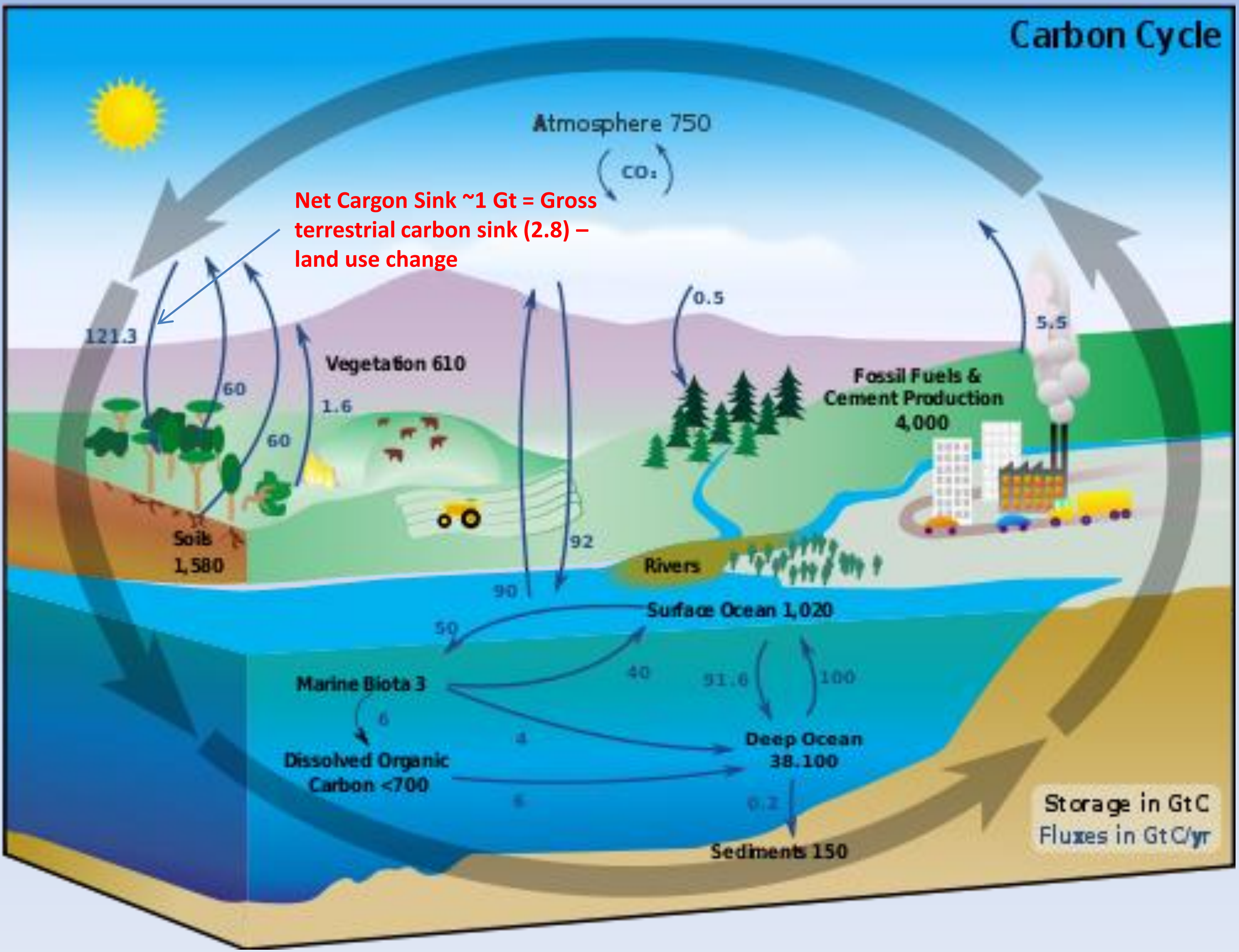
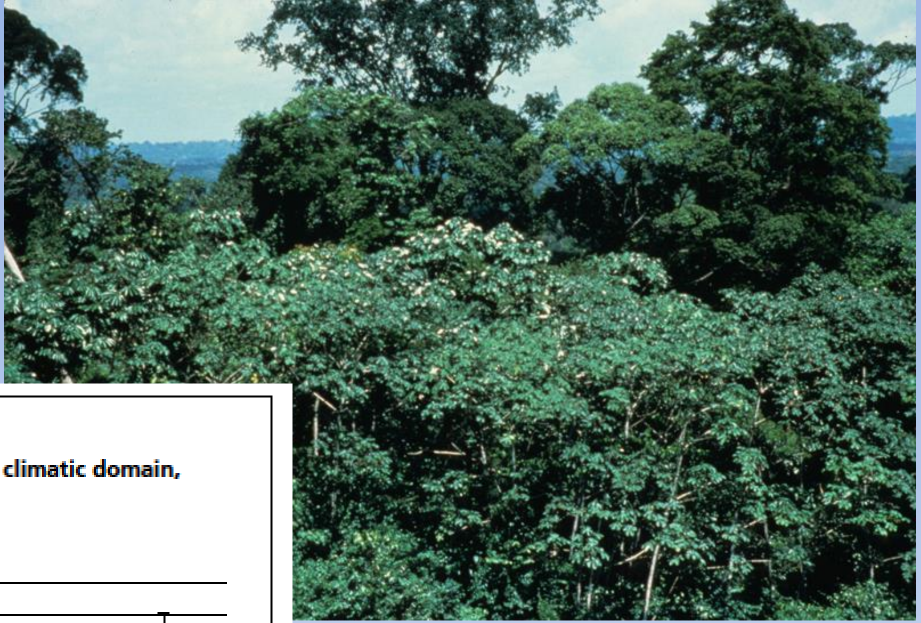
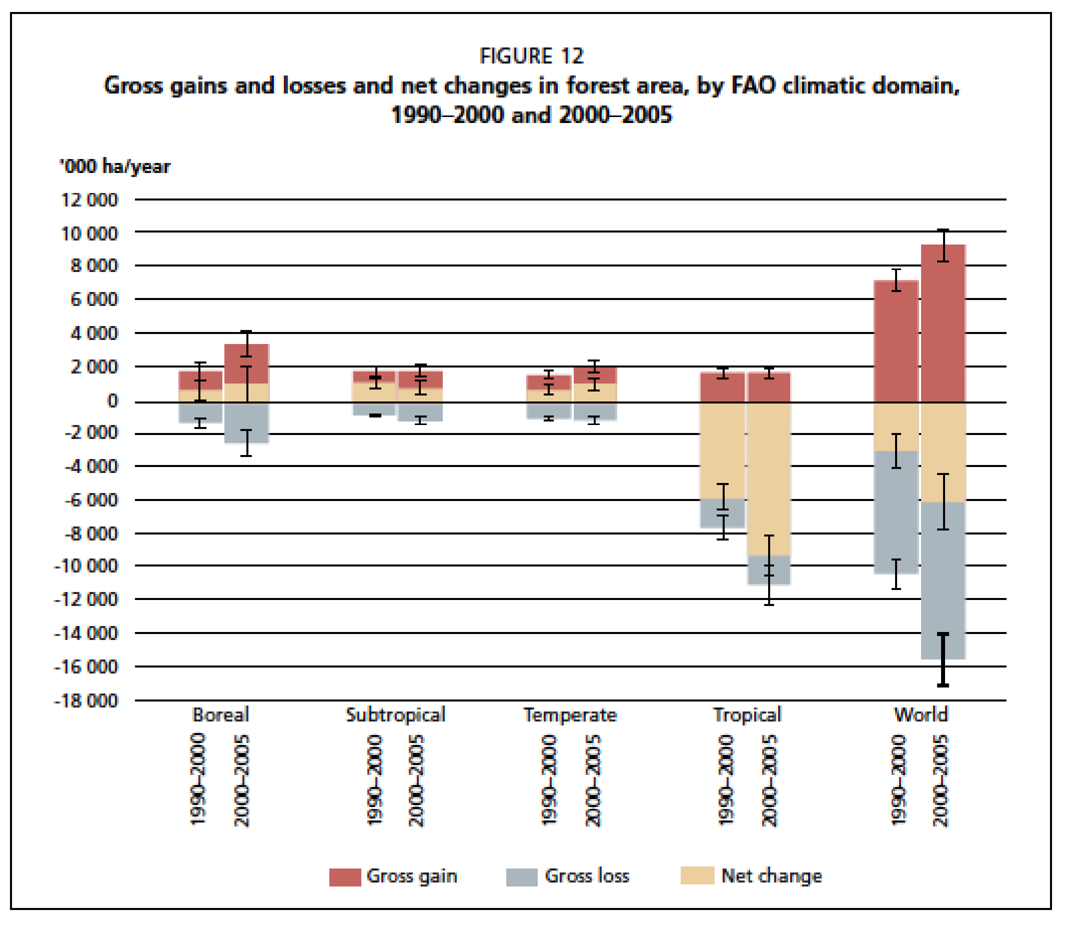

Carbon Cycle
Atmosphere 750
CO2
Net Cargon Sink ~1 Gt = Gross terrestrial carbon sink (2.8) – land use change
121.3
60
60
1.6
Vegetation 610
Soils 1,580
90
92
0.5
5.5
Fossil Fuels & Cement Production 4,000
Rivers
Surface Ocean 1,020
50
40
Marine Biota 3
91.6
100
6
4
Deep Ocean 38,100
Dissolved Organic Carbon <700
6
0.2
Sediments 150
Storage in GtC
Fluxes in GtC/yr





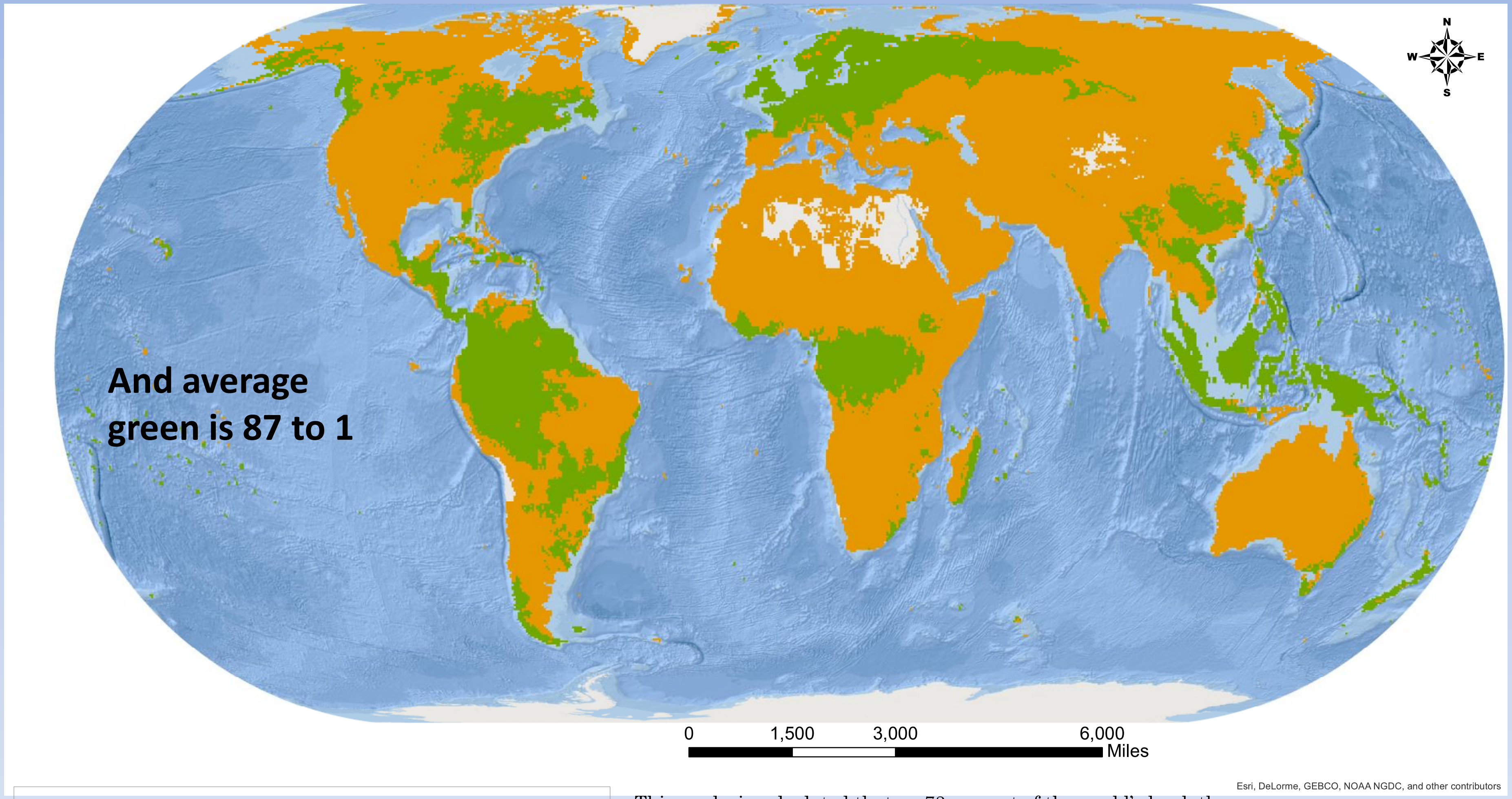
Forest Regrowth on Abandoned Land is Critical to Lower **Net** Loss of Forests & Carbon

FAO, Global forest land use change 1990-2005 (2012)

Benefit v. Cost of Using "Surplus" Land

	Savings from Displacing Petrol With No Land Use Change & No Production & Refining emissions	Savings from Displacing Petrol with Production & Refining Emissions Equal to 50% of Petrol, e.g. optimistic view of maize ethanol from Iowa	Carbon Cost of Just Not Allowing Any "Surplus" Land to Regrow Forest
Ethanol at High Yields 1040 liters/hectare (1040 liters/hectare: E.g. US Corn Ethanol (after deducting by-products) or Cellulosic ethanol at 17 dry tons/ha/y and 379 liters per	**~3 tons of carbon per hectare**	**1.5 tons of carbon per hectare**	**~3 – 4.5 tons of carbon per hectare**

Where is Solar Energy 100 Times More Efficient Than Bioenergy?



Relative Comparison of Bioenergy to Photovoltaics

Relative Production Efficiency

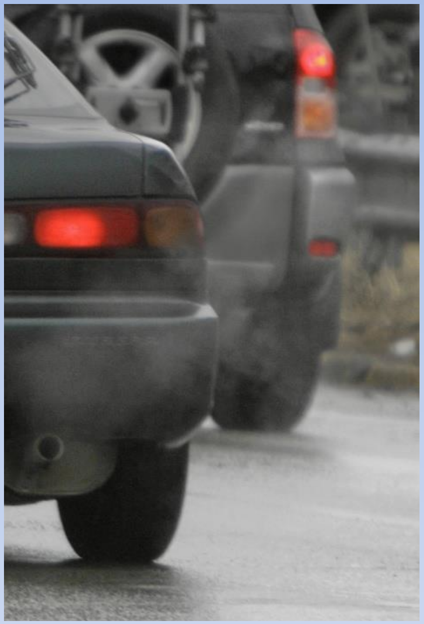
- Solar Energy Produces Less Than 100x Bioenergy
- Solar Energy Produces More Than 100x Bioenergy

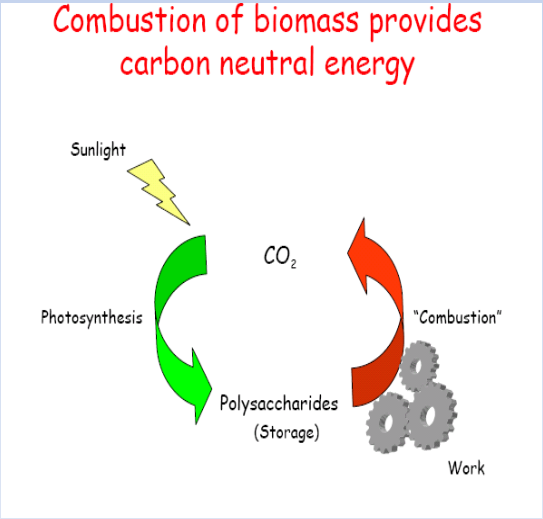
This analysis calculated that on 73 percent of the world's land, the useable energy output of PV would exceed that of bioenergy by a ratio of more than 100 to 1. Even on the 27 percent of land with a ratio less than 100 to 1, the average ratio would be 87 to 1.

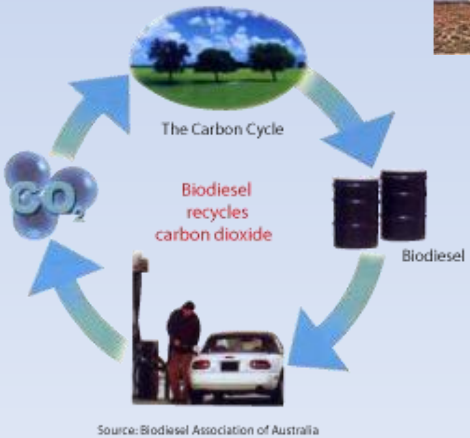
The GIS analysis was completed by Asa Strong and Susan Minnemeyer of WRI.

WORLD RESOURCES INSTITUTE

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







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	Ferment-ation 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 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

Bioenergy is a form of land-based carbon offset

Land grows plants whether for bioenergy or not:

* forest
* food

Only ADDITIONAL plant growth helps

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

CO_2 emission

Unproductive land

Car, gasoline

New crop growth

CO_2 uptake

CO_2 emission

Car, ethanol

Gasoline Use

Ethanol Use

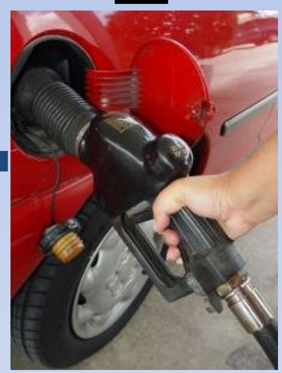
Using otherwise burned or decomposed crop residues for biofuels - Reduced emissions through reduced land sources

CO_2 emission

Burning or decomposing crop residues

\+

CO_2 emission

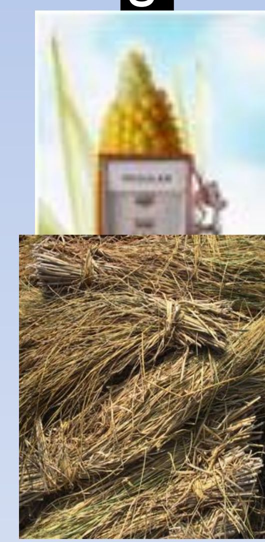


Car, gasoline

Reduced emissions from Residues

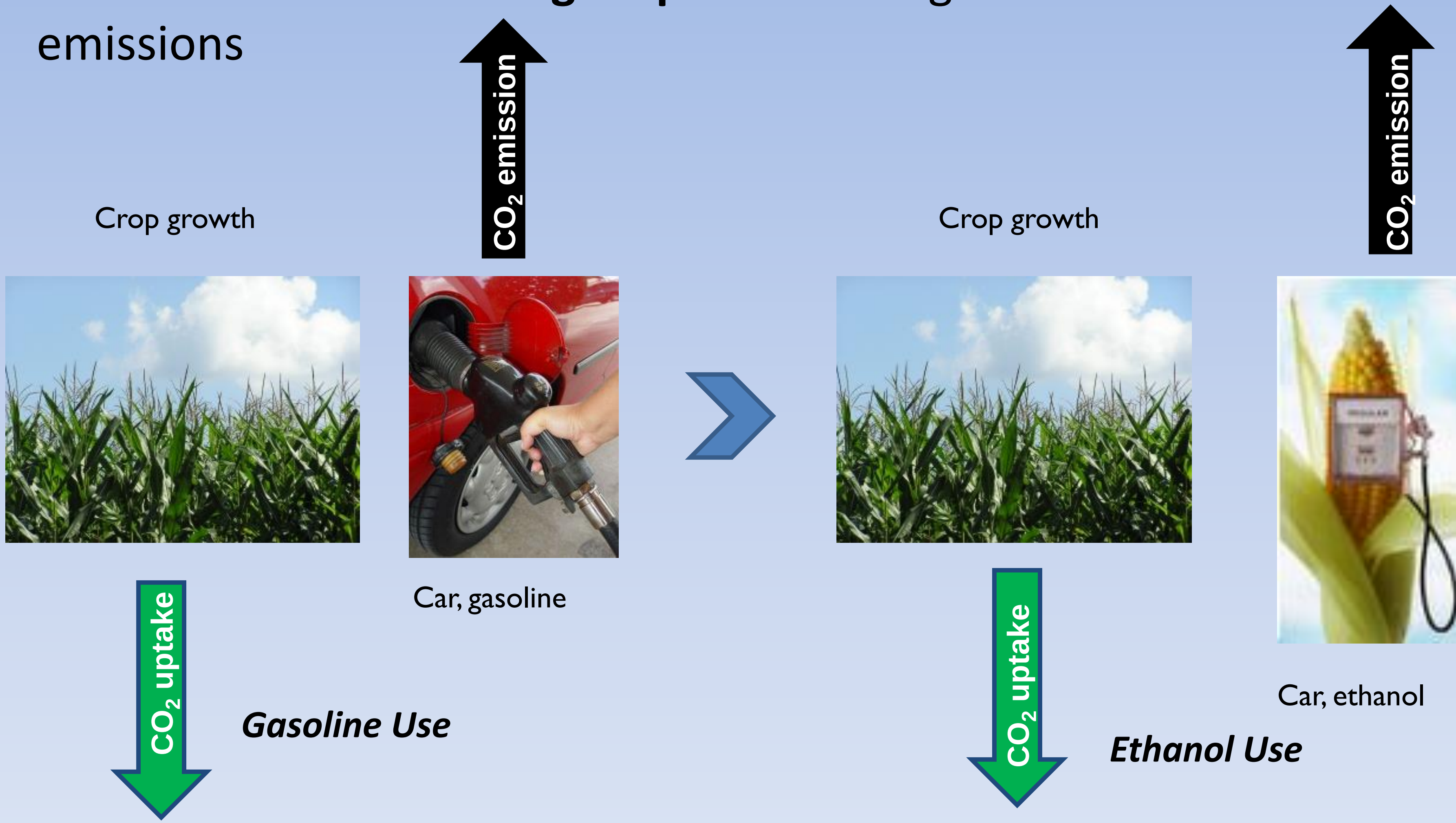
\+

CO_2 emission



Car, ethanol

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



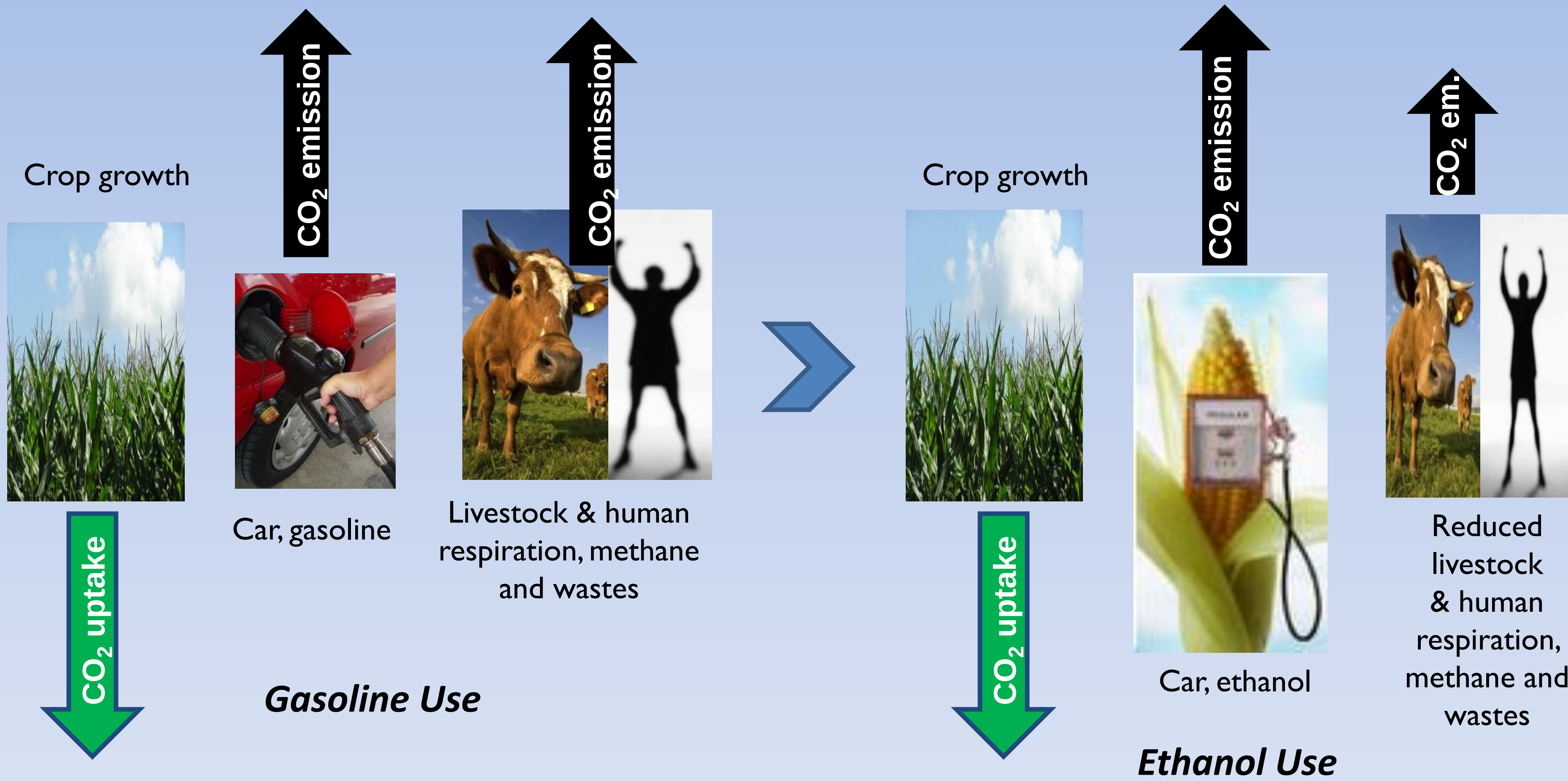
The IPCC does not treat bioenergy as carbon neutral

"The IPCC approach of not including bioenergy emissions in the Energy Sector total should not be interpreted as a conclusion about the sustainability or carbon neutrality of bioenergy." (http://www.ipcc-nggip.iges.or.jp/faq/faq.html)

"If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through *increased net carbon uptake of biota and soils".*

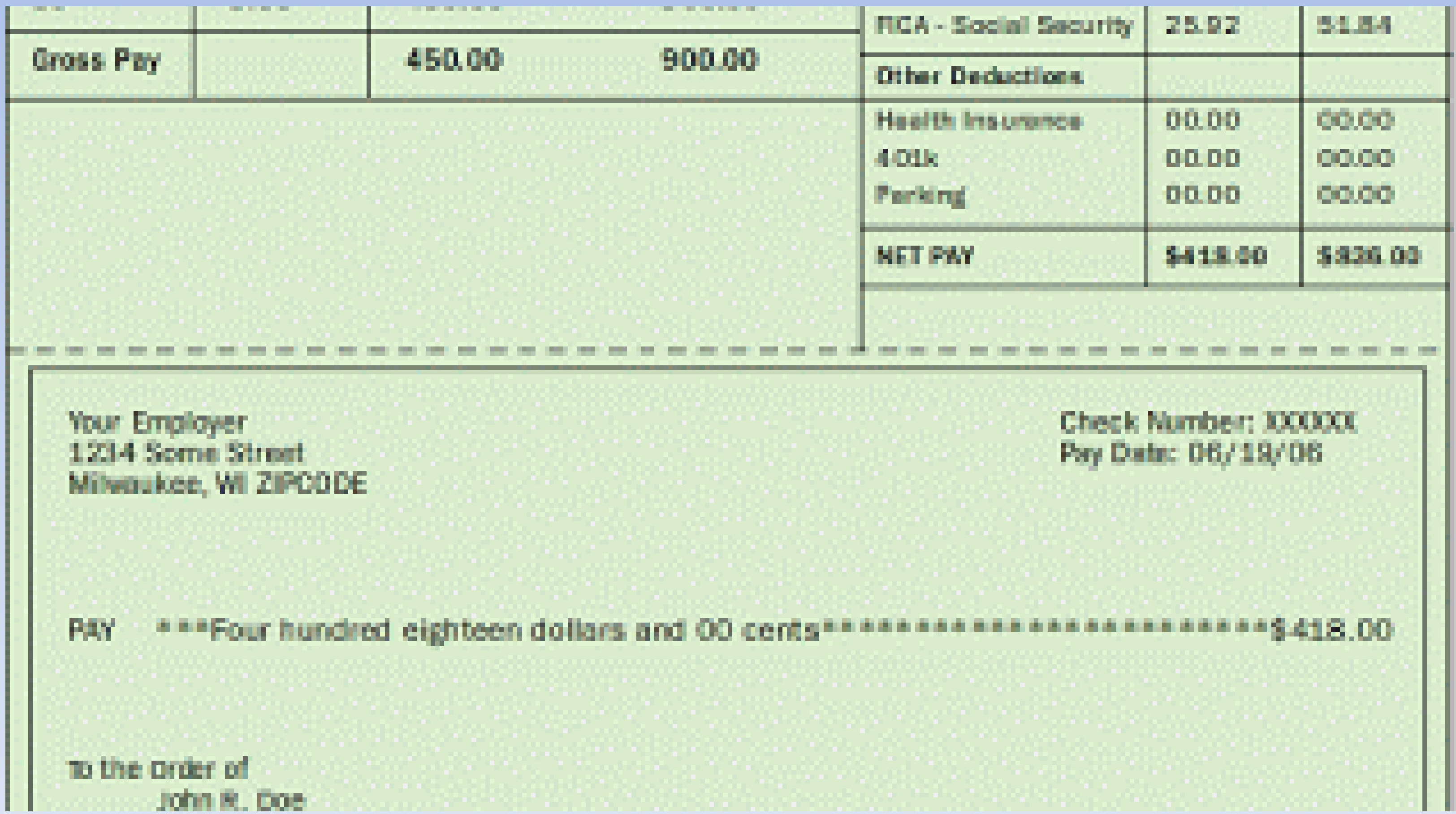
IPCC AR5 WG III 11.13.4 GHG emission estimates of bioenergy production systems, 2014

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)

Renewable Does Not Equal Carbon Free



Gross Pay		450.00	900.00

FICA - Social Security	25.92	51.84
Other Deductions		
Health Insurance	00.00	00.00
401k	00.00	00.00
Parking	00.00	00.00
NET PAY	$418.00	$836.00

Your Employer
1234 Some Street
Milwaukee, WI ZIPCODE

Check Number: XXXXX
Pay Date: 06/19/06

PAY ***Four hundred eighteen dollars and 00 cents***************************$418.00

To the Order of
John R. Doe

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.”

FORESTS IN SOUTHEASTERN U.S.

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Enviva Wood Pellet Mill
(Sampson County, North Carolina, February 2017)

Truck with hardwood logs entering Enviva wood pellet mill
(Sampson County, North Carolina, February 2017)

Sources of Wood Pellets in US

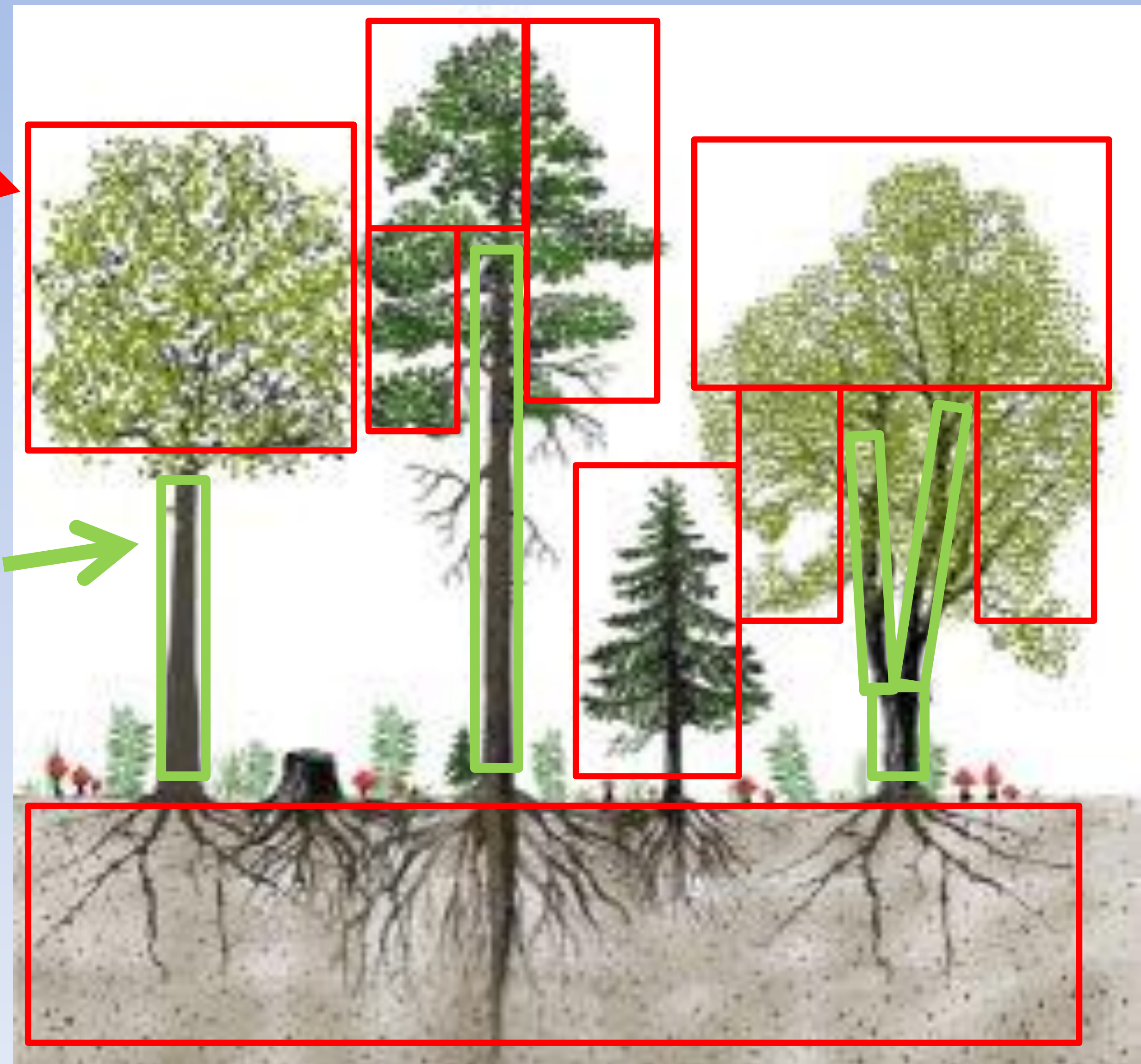
RISI Analysis for American Forest & Paper Association - 2015

76% pulpwood + 12% clean sawnmill residuals otherwise used

A tonne of wood pellets represents ~2.85 tonnes of green wood lost or burned during harvesting and processing – all representing CO2 emissions (~1:1)

Biomass that is harvested and burned for process heat, or left onsite to decompose

Large-diameter roundwood suitable for pellet manufacture (but not bark)



What Are the Consequences of Harvesting Trees for Electricity
Typical Examples

Initial Committed Emissions:

- Emissions from unused cut wood (roots & residues)

  ~1/4 to 1/3 of total standing wood

- Smokestack emissions

  ~ Because wood is less efficient electricity source than coal or natural gas, burning wood produces 2.75 to 3 x CO_2 per KwH than burning coal and 1.5 x than natural gas *Subsequent 20 or 30 years*

Carbon effects are based on regrowth of trees if harvested for bioenergy minus growth if unharvested,

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

Harvest of mature trees speeds growth rate but larger up-front losses

Bottom line: probable large increase in emissions using wood than fossil fuels from well more than 30 years

Growing plants is climate positive. Buring/Using plants is climate negative.

"Bio" does not mean better

Some materials

- European Environmental Agency Science Committee Bioenergy Opinion (2011) www.eea.europa.eu/ds_resolveuid/FT87KIBQX1
- ~50 scientist letter to EU (2013)
- WRI, Avoiding Bioenergy Competition for Food Crops and Land (2014)
- Searchinger, Schlesinger, Oppenheimer, Robertson, Tilman et al., Fixing a Critical Climate Accounting Error (Science 2009)

Possible Carbon Costs of Land

Alternative Use of Land	Carbon opportunity cost of using land for bioenergy instead of alternative	Implicit ILUC Cost for Bioenergy at High Yields
Tropical seasonal forest (75% of Gibbs et al. 2008)	~5.5 tons/hectare/year	~163 gCO2/MJ
Humid tropical savanna (75% of Gibbs et al. 2008)	~3 tons C/hectare/year	~87 gCO2/MJ
Existing temperate forests (conservative)	~6-~8 tons/hectare	174-232 gCO2/MJ
Increased yields replace half of all diverted crops & all new land is otherwise abandoned land that would reforest	~1.5 tons/hectare	43 gCO2/MJ

Searchinger, Edwards et al., Do Biofuel Policies Seek to Cut Emissions by Cutting Food, Science (2015)

Government Biofuel Models That Find GHG Reductions Do So Because They Estimate that 25% to 50% of Calories Diverted to Grain Ethanol are Not Replaced

Role of reduced food consumption in life-cycle greenhouse gas emissions

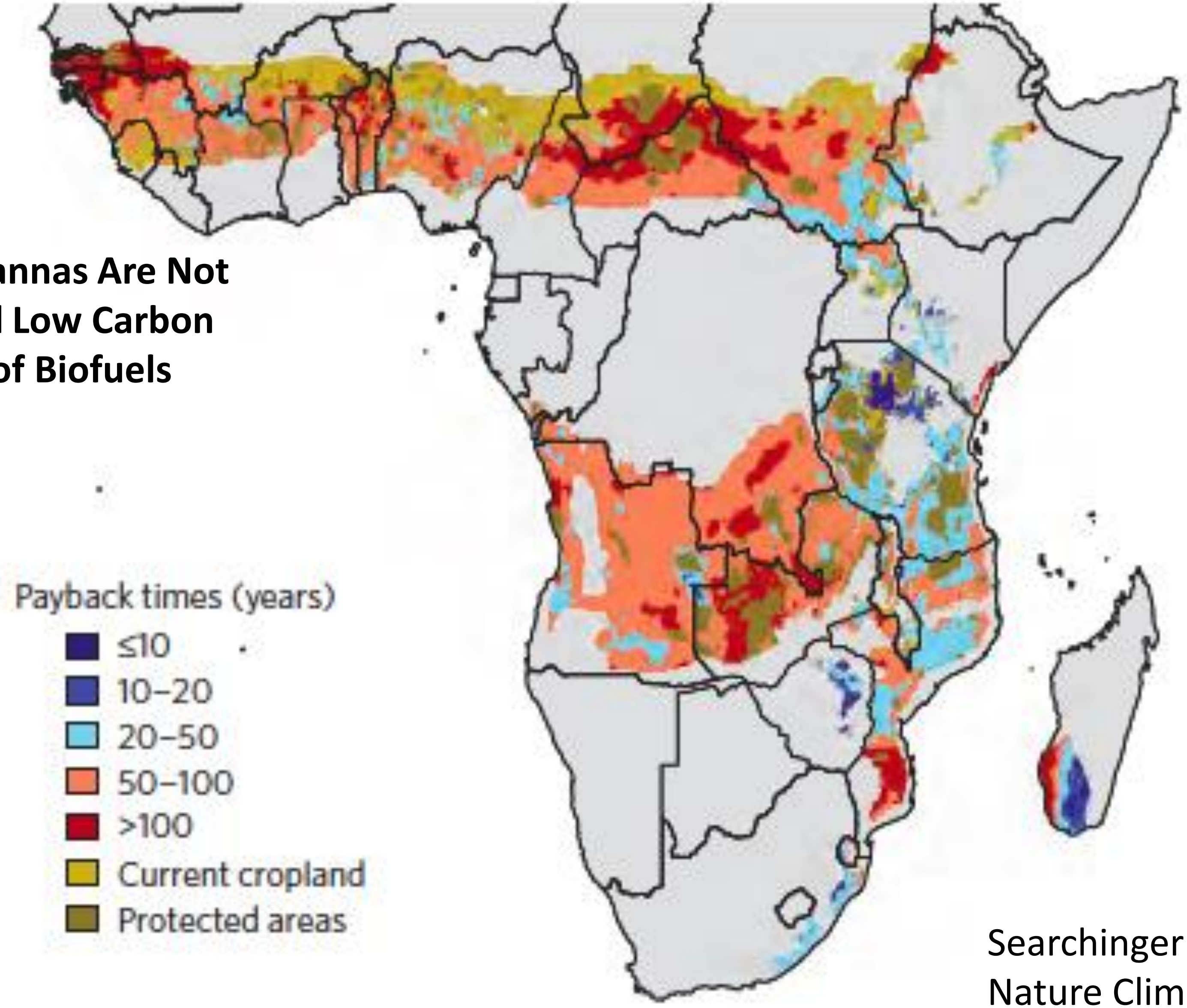
SOURCE OF FUEL	DIRECT PRODUCTION AND USE EMISSIONS (CO_2EQ/MJ): A Production and refining emissions from fossil fuels and trace gases	EMISSIONS AND OFFSETS OF CROP CARBON: B Fermentation of grain	C Vehicle exhaust	NET OFFSETS (CO_2EQ/MJ): D Additional crop production from both yield gains and new cropland (offset)	E Reduced respiration and waste due to reduced crop consumption (offset)	F LUC (emission from new cropland)	TOTALS AND % CHANGE FROM GASOLINE (CO_2EQ/MJ): G Total including reduced food consumption (A+B+C+D+E+F)	H Total excluding reduced food consumption (A+B+C+D+F)
CALIFORNIA AIR RESOURCES BOARD							**GASOLINE = 99**	
GTAP US CORN (2009)	69	36	71	−54	−53	42	111 (12%)	164 (65%)
GTAP NEW US CORN (HIGHER YIELD ELASTICITY	69	36	71	−75	−32	13	82 (-17%)	114 (15%)
GTAP NEW US CORN (LOWER YIELD ELASTICITY	69	36	71	−63	−44	25	94 (−5%)	138 (40%)
GTAP EU WHEAT (ORIGINAL)	67	36	71	−63	−44	155	223 (125%)	267 (169%)
U.S. ENVIRONMENTAL PROTECTION AGENCY							**GASOLINE = 93**	
FAPRI US CORN (2022 ESTIMATE)	49	36	71	−86	−25	34	79 (−15%)	104 (12%)
EUROPEAN UNION							**GASOLINE = 87**	
IFPRI-MIRAGE WHEAT	67	36	71	−73	−34	17	84 (−4%)	118 (36%)
IFPRI-MIRAGE EC CORN	69	36	71	−84	−23	11	80 (−8%)	103 (19%)

One lesson: Bioenergy is the Hummer of Global Land Use

Converted Miombo
Woodland Zambia

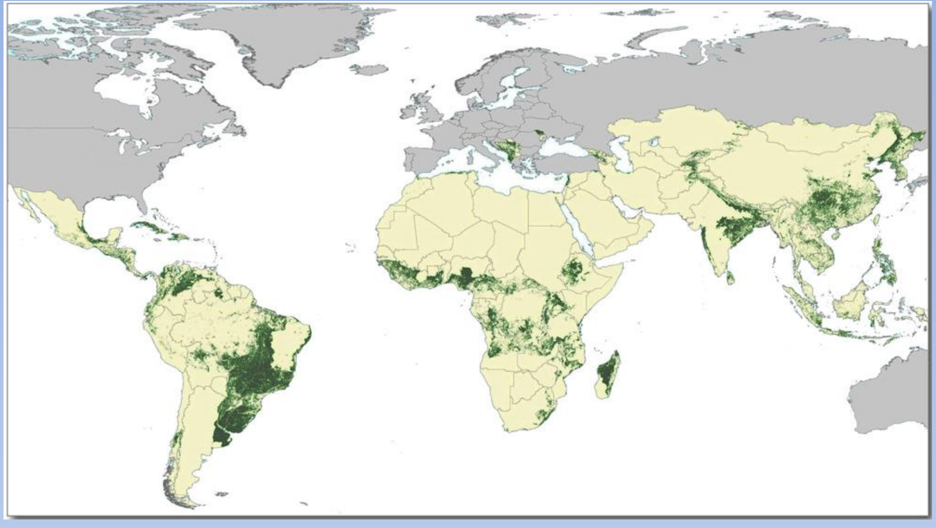
Kob Migration
Sudan

Wet Savannas Are Not Potential Low Carbon Sources of Biofuels

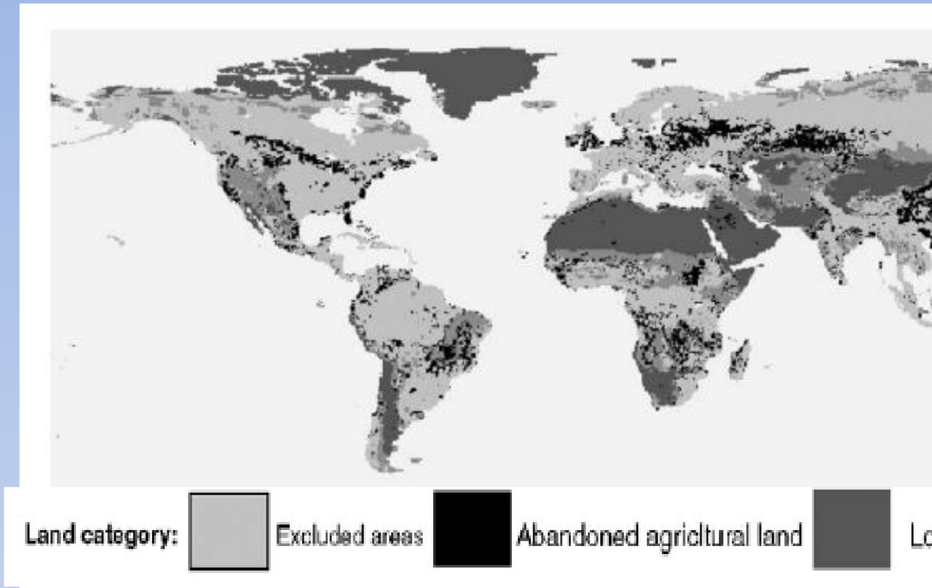


Searchinger et al., Nature Climate Change (2015)

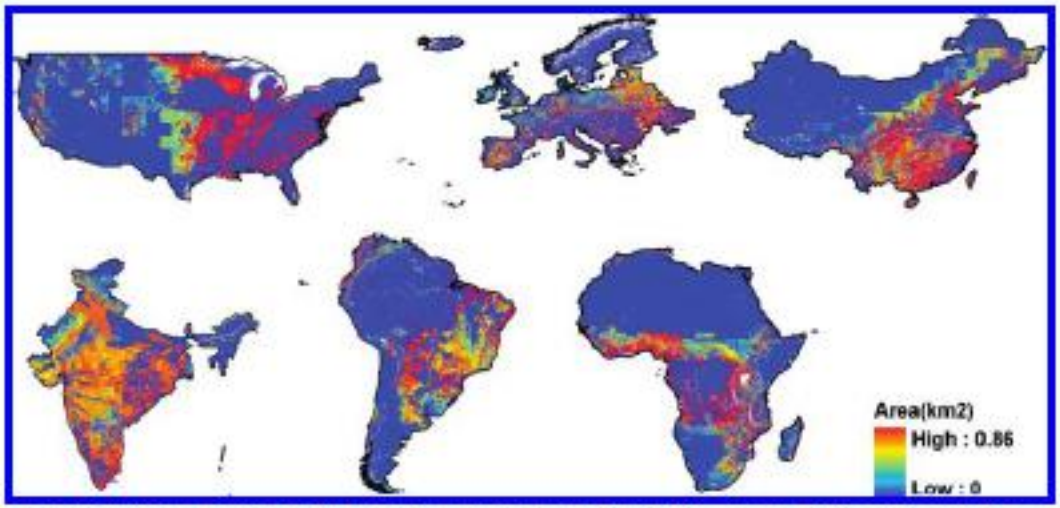
Figure 3 | Carbon payback times for use of dedicated perennial grasses for ethanol.



Zomer et al. Ag Ecosystems (2008): Fig. 2. Global map of CDM-AR suitable land (dark green) within Non-Annex I countries (light yellow), as delineated by the land suitability analysis. A 30% crown cover density threshold was used to define forest, and protected areas are not included.



Hoodgwijk et al. (2005)

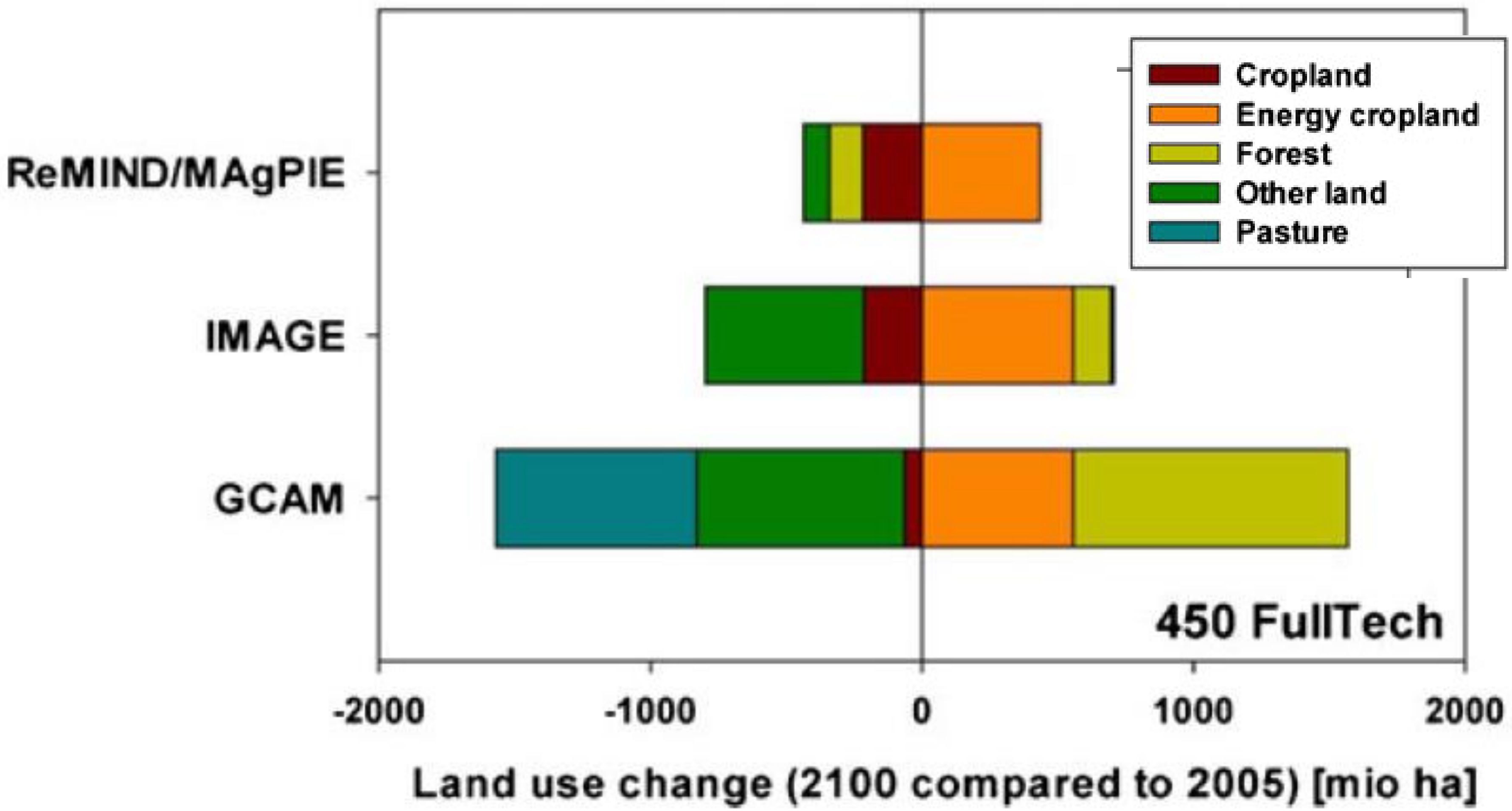


GURE 2. Maps of land available for bioenergy production under scenario 4 in U.S., Europe, China, India, South America, and Africa.

Cai et al., Figure 2

The pasture challenge

IAMS THAT PREDICT LARGE QUANTITIES OF BECCS ARE THOUGHT EXPERIMENTS BASED ON ULTRA-LAND-EFFICIENT WORLD SUCH AS LIMITED BEEF



Popp et al. Climatic Change (2014)

Sum Up

- Bioenergy is inefficient
- Land is not available because of rising food/timber & carbon storage demands
- Land always has high carbon opportunity cost, which Commission proposal largely ignores
- All large analyses of bioenergy potential and GHG reductions double count biomass & carbon
- Solar + reforestation more than 100 times better use of surplus land