Crop-based biofuels and the LCFS Standard

California Air Resources Board

March 26, 2009

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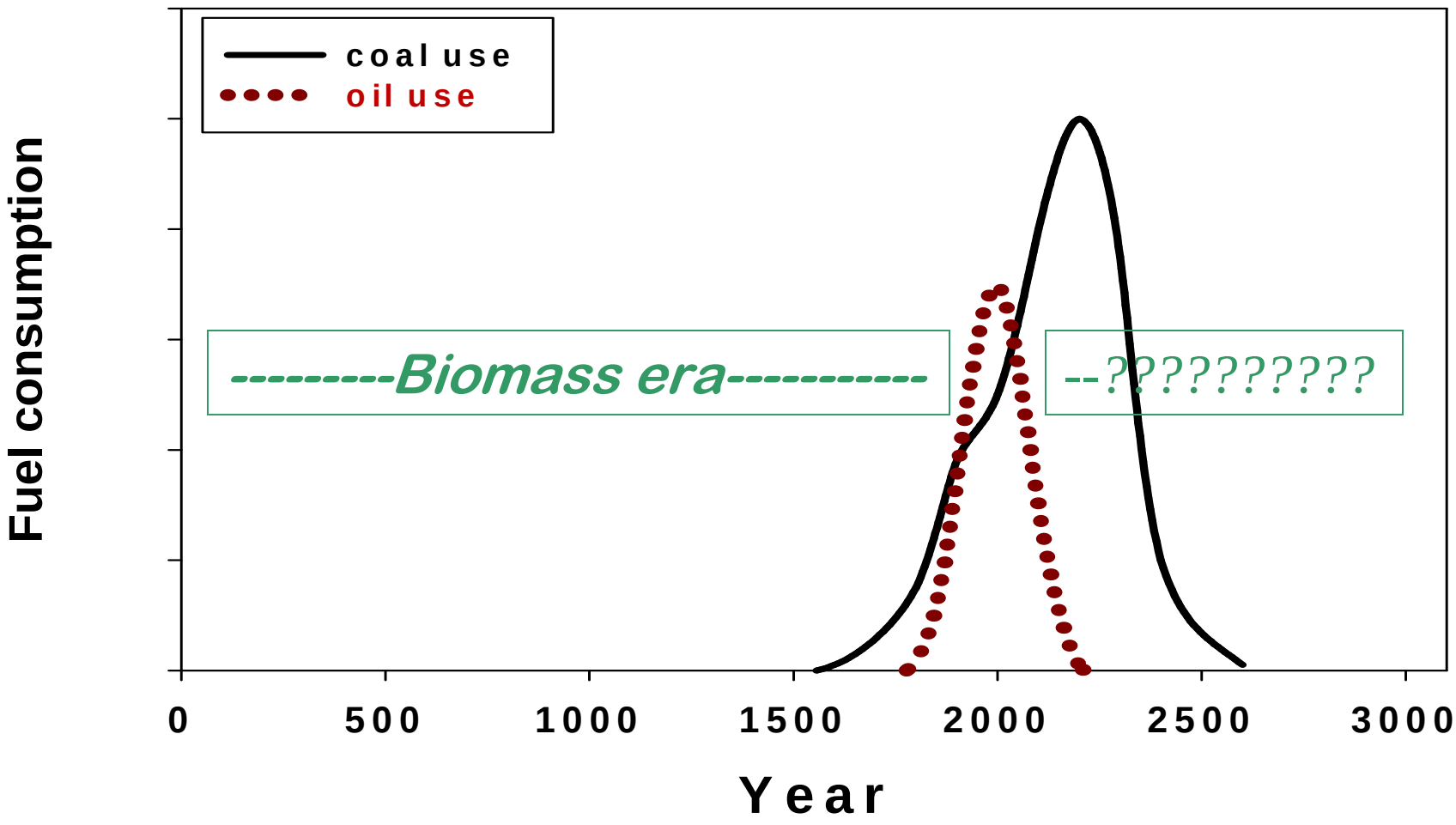
UC DAVIS PLANT SCIENCES

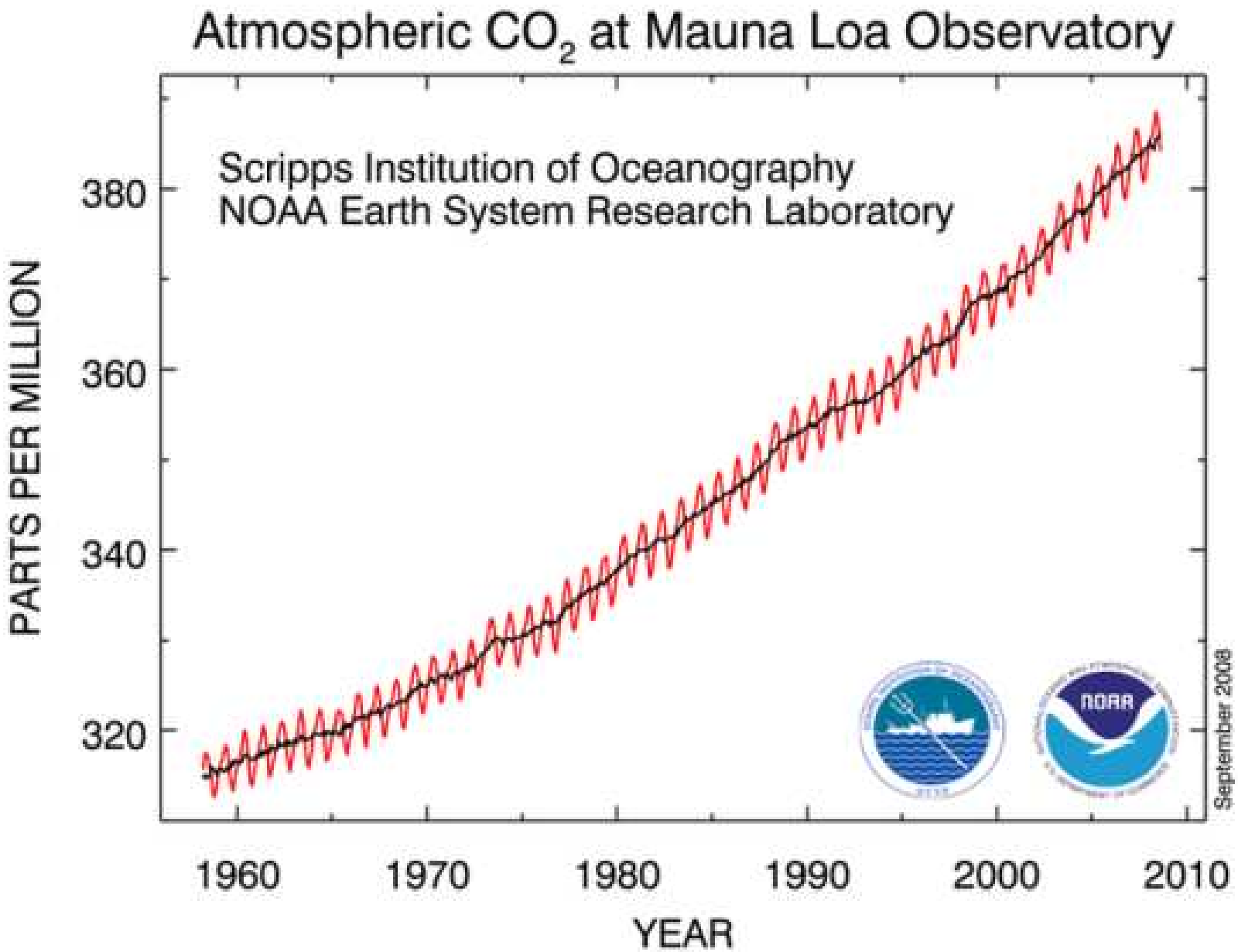
“I can see no escape from the dilemma (…resulting from the vastness of knowledge and the limits of a single mind), than that some of us should venture to embark on a synthesis of facts and theories, albeit with second-hand knowledge of some of them-and at the risk of makings fools of ourselves.”

E. Schrödinger (1944) - *What Is LIfe?*



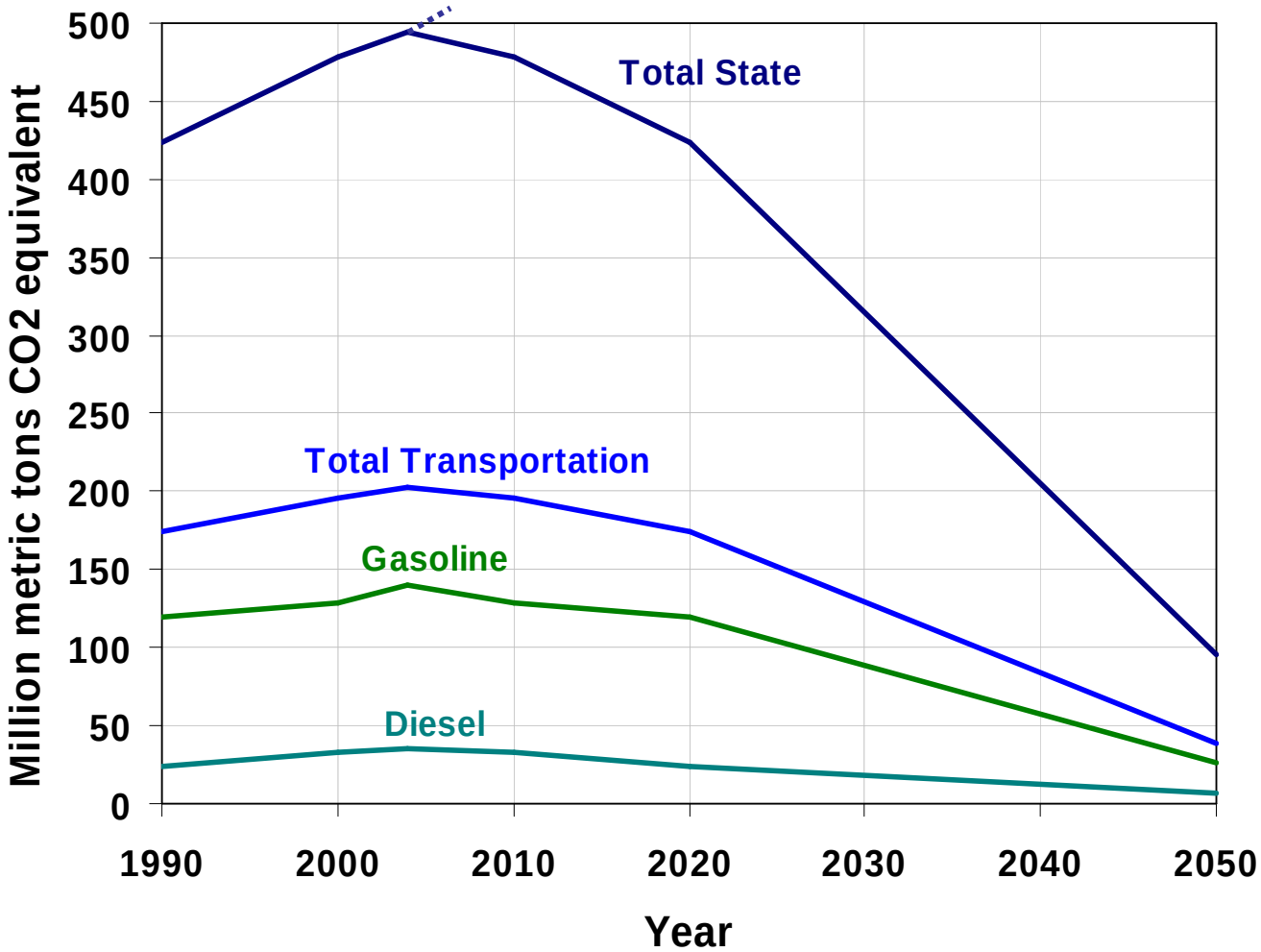
Expected duration of fossil fuels (0 to 3000 AD)

(redrawn from P.E. Hodgson, 1999)


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
NOAA
September 2008

California GHG reduction targets

(with uniform sectoral reductions)



- 2000 by 2010
- 1990 by 2020
- 80% below 1990 by 2050

Energy Return On Investment: the ratio of energy in a L of biofuel to the nonrenewable energy required to make it.

Source	EROI
Older US Oil	100:1
Current US Oil	15:1
Corn Ethanol	1.3:1 (1.6:1-2.2:1)
Brazilian sugar cane	6-9:1 (11-12:1)
Biodiesel (soy)	3:1
Cellulosic sources (2nd gen. mature technology)	5-12:1

Data: various sources

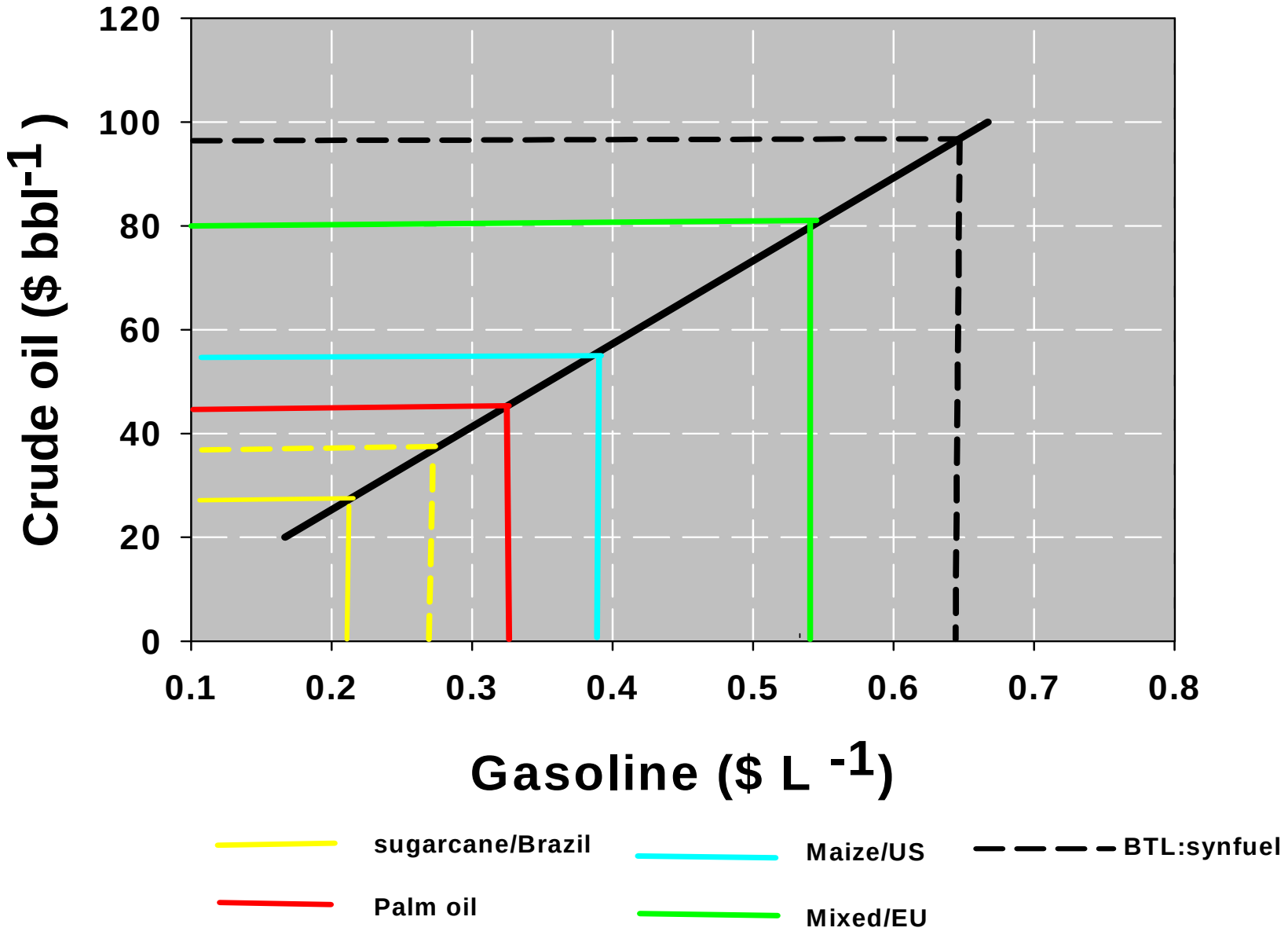
Multiple reasons for biofuels

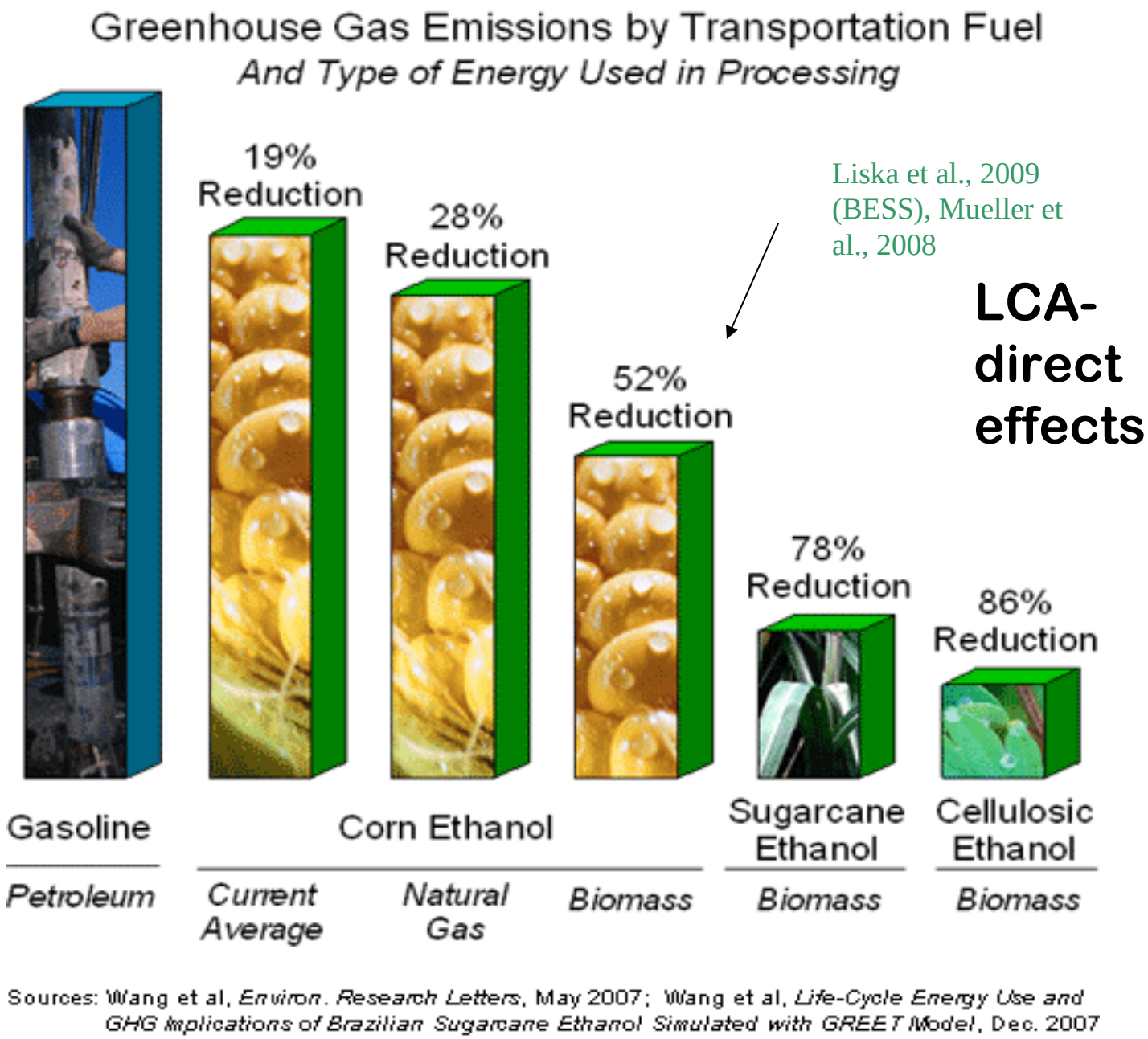
Alternative fuels from biomass will:

1. Diversify the supply of transportation fuels, provide more domestic sources and improve national security
2. Increase rural employment and wealth,
3. Reduce expensive crop surpluses
4. Distribute fuel refining
5. Benefit the environment by reducing petroleum use for transportation and GHG increases
6. Other benefits

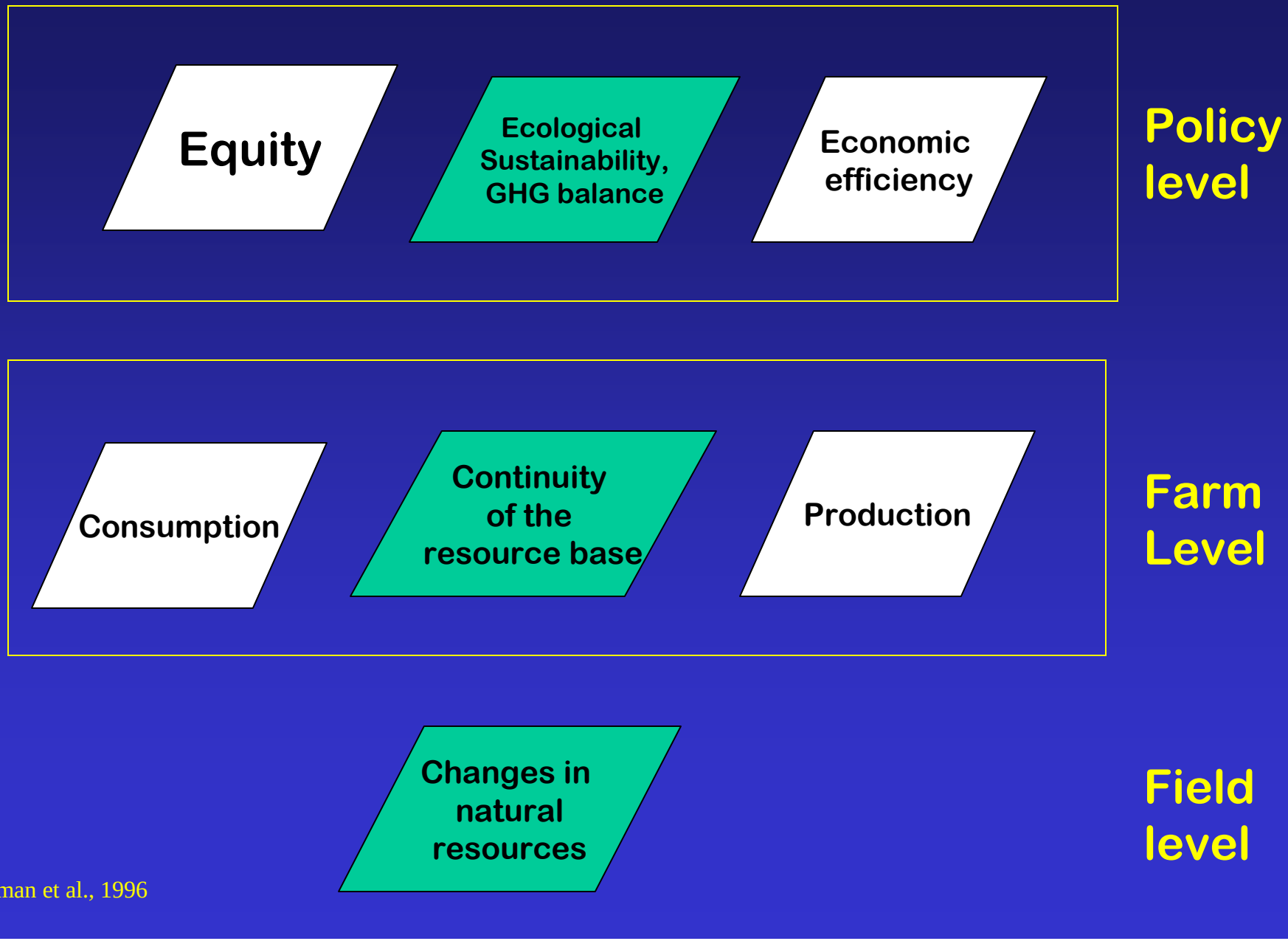
(DOE, USDA, other sources-2004)

Parity prices: Gasoline-crude oil-ethanol
(based on Schmidhuber and Mueller/FAO, 2007)



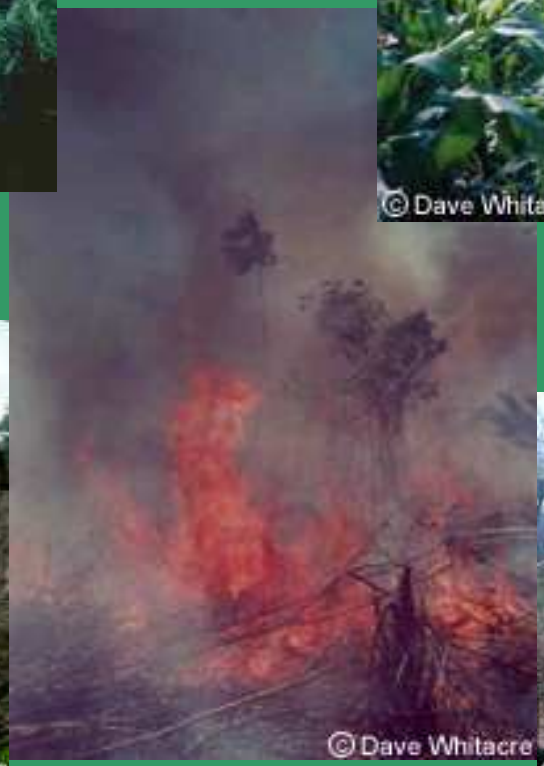

Greenhouse Gas Emissions by Transportation Fuel
And Type of Energy Used in Processing
19% Reduction
28% Reduction
52% Reduction
78% Reduction
86% Reduction
Liska et al., 2009 (BESS), Mueller et al., 2008
LCA-direct effects
Gasoline
Petroleum
Corn Ethanol
Current Average
Natural Gas
Biomass
Sugarcane Ethanol
Biomass
Cellulosic Ethanol
Biomass
Sources: Wang et al, Environ. Research Letters, May 2007; Wang et al, Life-Cycle Energy Use and GHG Implications of Brazilian Sugarcane Ethanol Simulated with GREET Model, Dec. 2007

What we call sustainable (including GHG balances) depends on the boundary conditions



Kruseman et al., 1996

Swidden agriculture in the tropics



By producing biofuels on cropland, the demand for diverted food crops must be met by producing it on land elsewhere.

This displaced food production could lead to significant green house gas emissions and other environmental effects from this land conversion.

These emissions are not compensated by carbon savings from biofuel use.

Searchinger et al. 2008, Kammen et al., 2007

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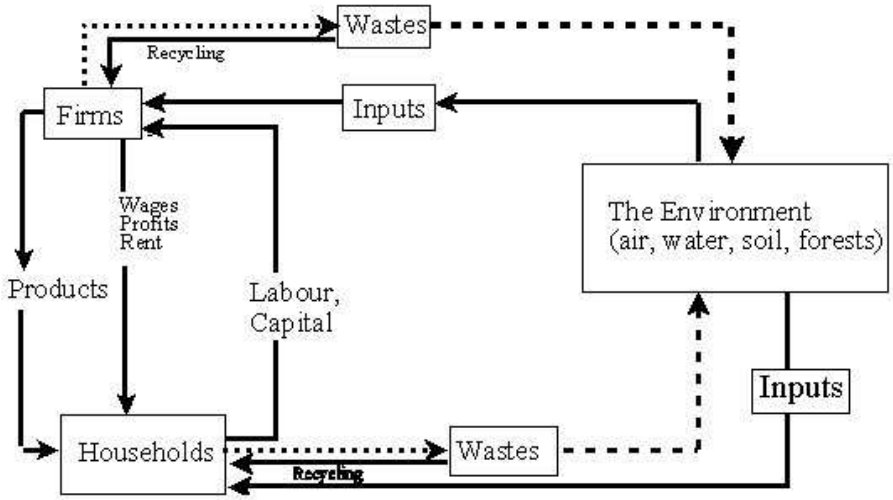
GTAP (Global Trade Analysis Project) is a global network of researchers … who conduct quantitative analysis of international economic policy issues, especially trade policy. They … produce a consistent global economic database, covering many sectors and all parts of the world. The database describes bilateral trade patterns, production, consumption and intermediate use of commodities and services. There are … databases for such things as greenhouse gas emissions and land use.

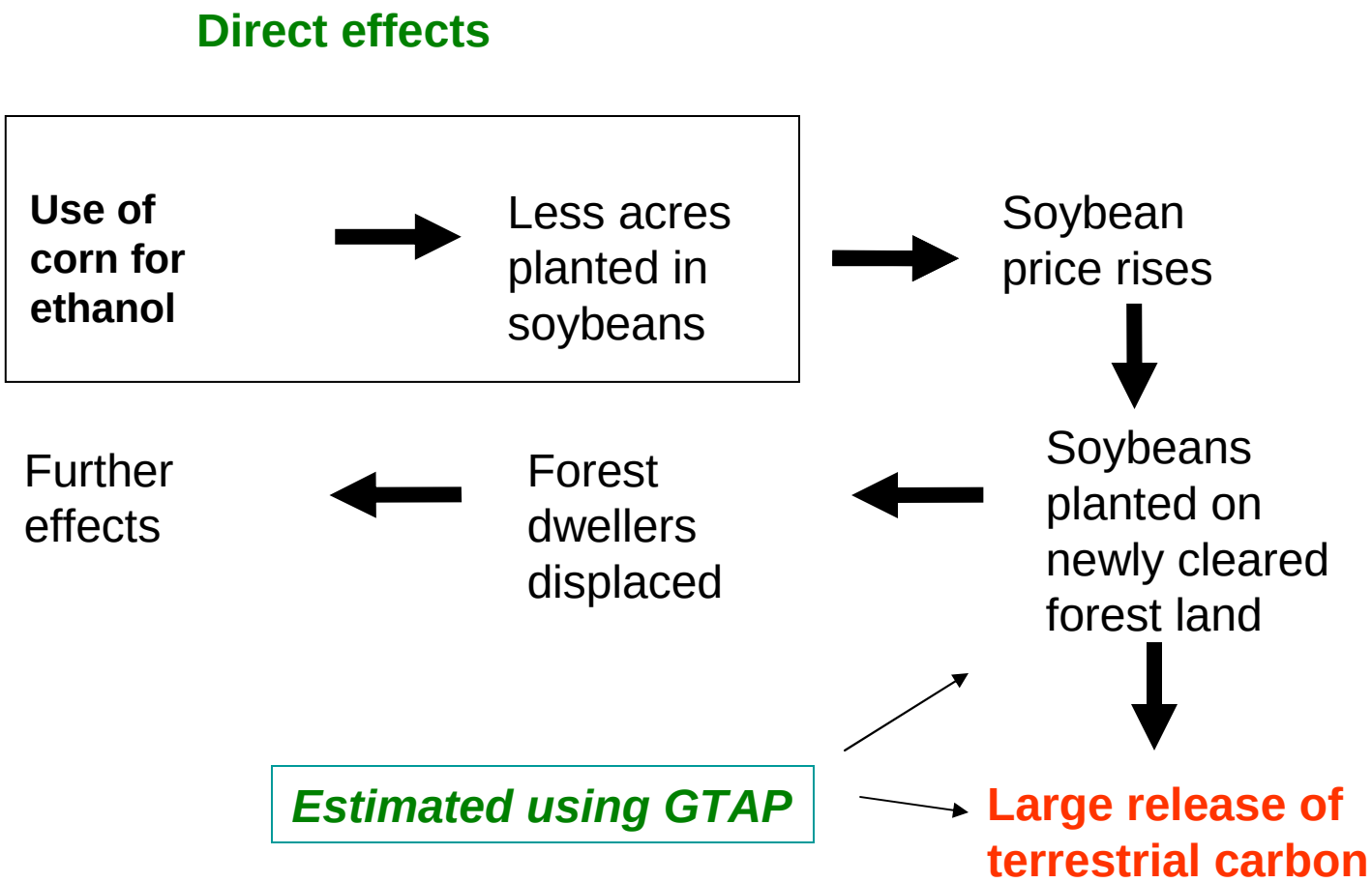
The network maintains a global computable general equilibrium (CGE) model, which uses the GTAP database. Besides the core model, there are many variants (including one focused on agricultural analysis), each focusing on a different issue in economic policy analysis.

CGE models characteristically consist of (a) equations integrating model variables and (b) a database (usually very detailed) consistent with the model equations. The equations tend to assume cost-minimizing behavior by producers, average-cost pricing, and household demands based on optimizing behavior.



Market Mediated Effects:

- **Market-mediated or Indirect Land Use Change (iLUC):**



Modified from Spatari, 2008

Modeling Indirect LUC

The logic of market mediated effects is clear. Indeed, calling them indirect effects is in one sense misleading.

However the importance and scale of such effects is far from clear.

The CGE models are uncertain in all important aspects:

(1) the effects of biofuels on world market prices,

(2) responsiveness of crop yields and consumption to price increases, and

(3) site-specific land conversion effects from price increases (also a data-base problem).

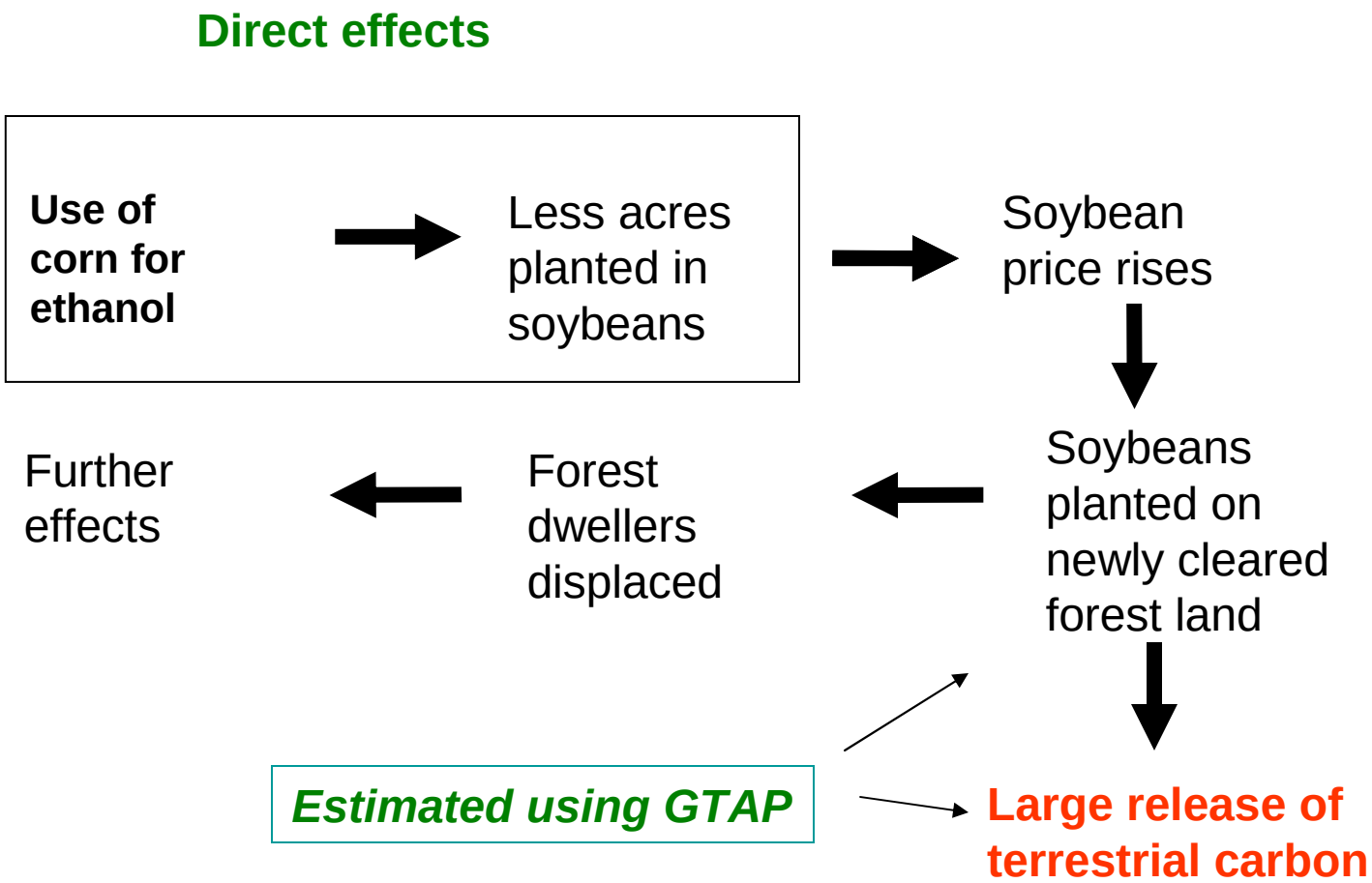
Liska and Perrin, submitted (Biofuels , Bioproducts and Refining)

Turner et al., 2007, PNAS: *The emergence of land change science for global environmental change and sustainability*.

- No facet of land change research has been more contested than that of cause.
- The distal factors that shape the proximate ones, such as urban poverty or national policies, tend to be difficult to connect empirically to land outcomes…
- For any locale, suites of factors tend to operate in … nested ways, and their specific configuration and interaction may lead to dissimilar outcomes…
- A sustainable land architecture for one place… need not render similar results …across different locales or expanded to large units of assessment, such as biomes or continents.

Market Mediated Effects:

- **Market-mediated or Indirect Land Use Change (iLUC):**



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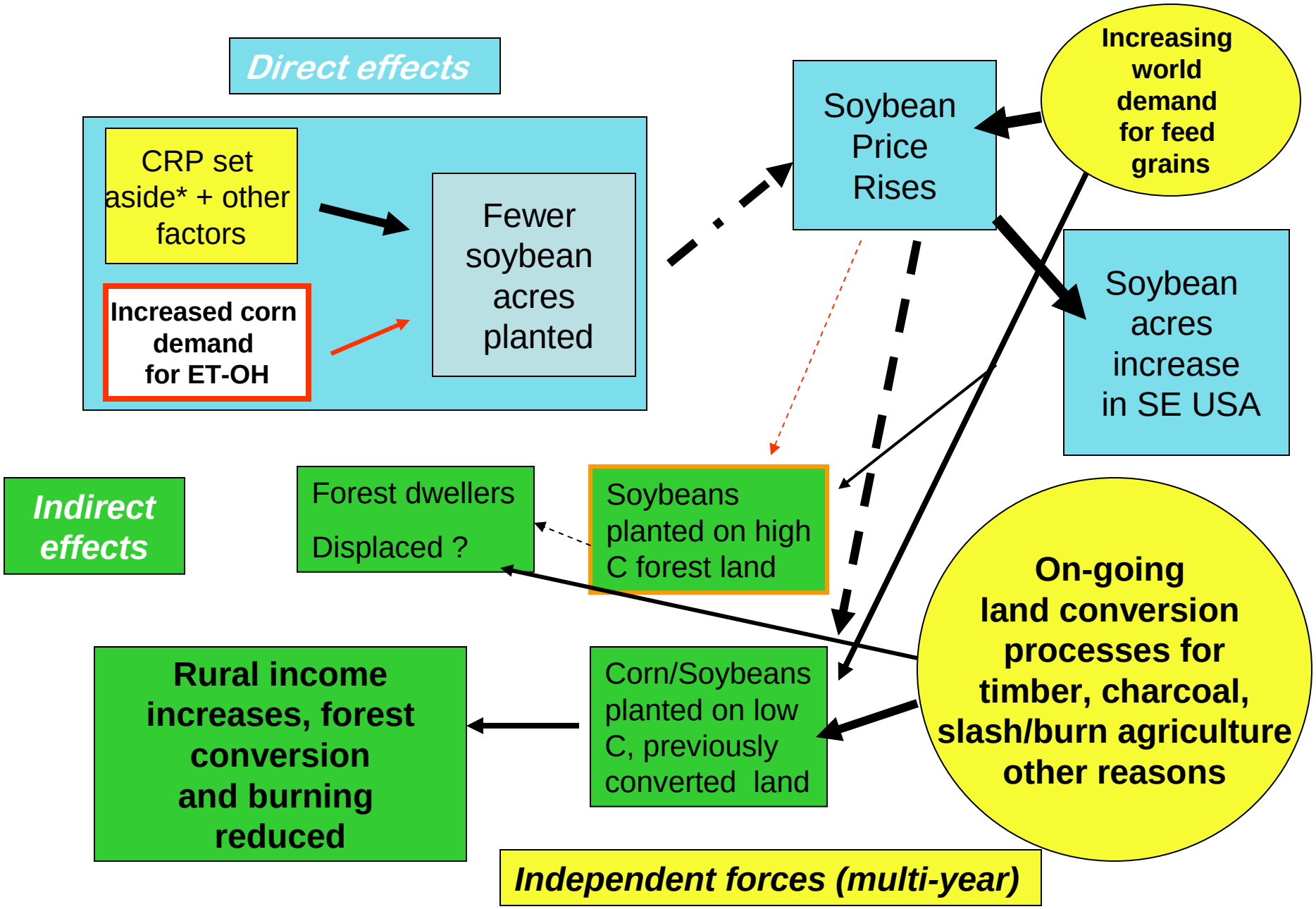
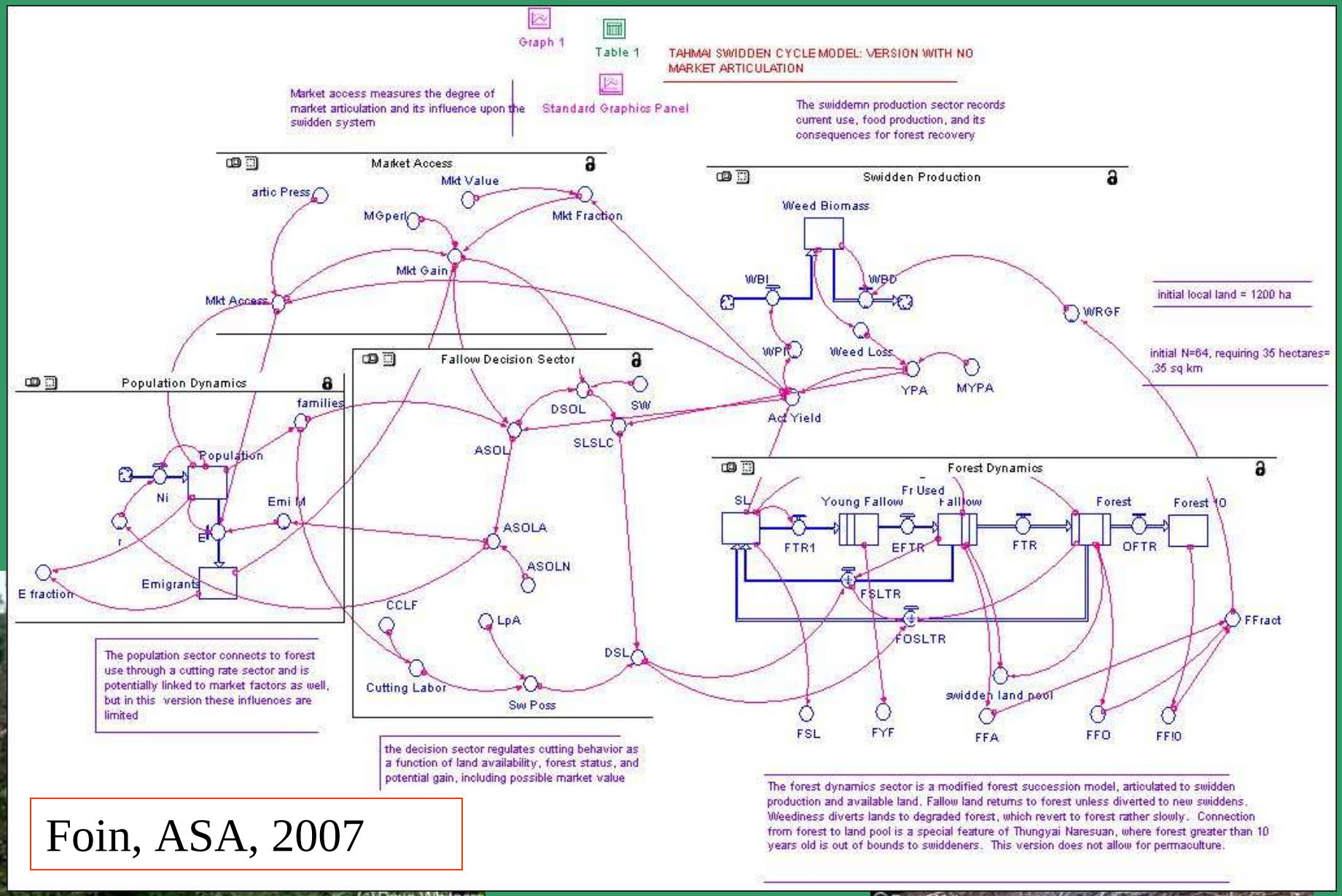
Market Mediated Effects of Corn Ethanol Use on Indirect Land Use Change



Tropical deforestation has been shown to be influenced by up to 16 direct causes including wood extraction, agriculture, and infrastructure development. The direct causes work in conjunction with at least 17 underlying causes related to demography, economics, technology, government policies and cultural attitudes.

(Lambin and Gaist, 2006)

Site-specific analysis of LUC, NE Thailand



Foin, ASA, 2007

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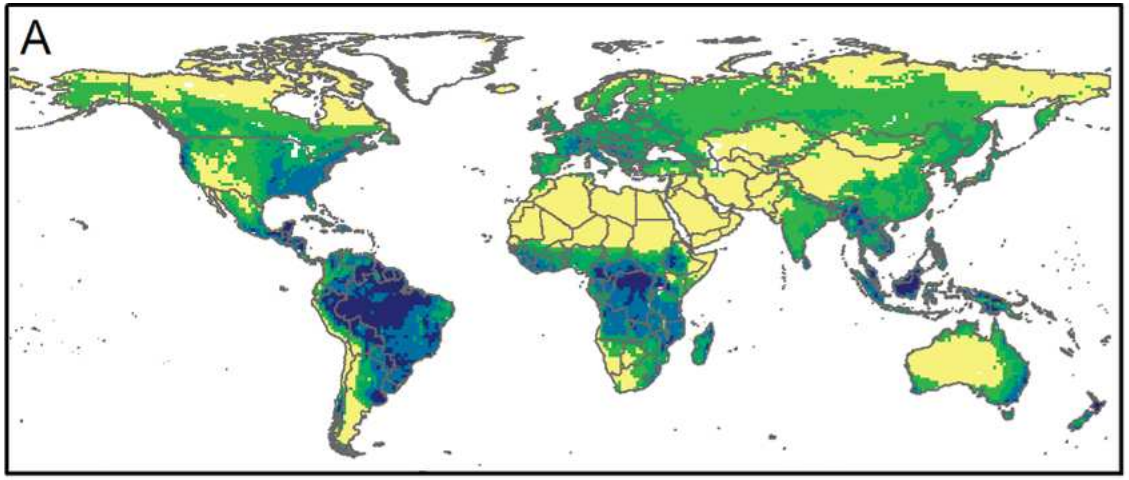
Land that is not included in GTAP databases may play an important role in bio-energy production in the tropics and sub-tropics and in affecting the global terrestrial C balance.

"While 38 million ha of primary rainforest are being cut down every year, there is an estimated 2.1 billion acres of potential replacement forest growing in the tropics."

FAO (2005)/ State of the World's Forests Report

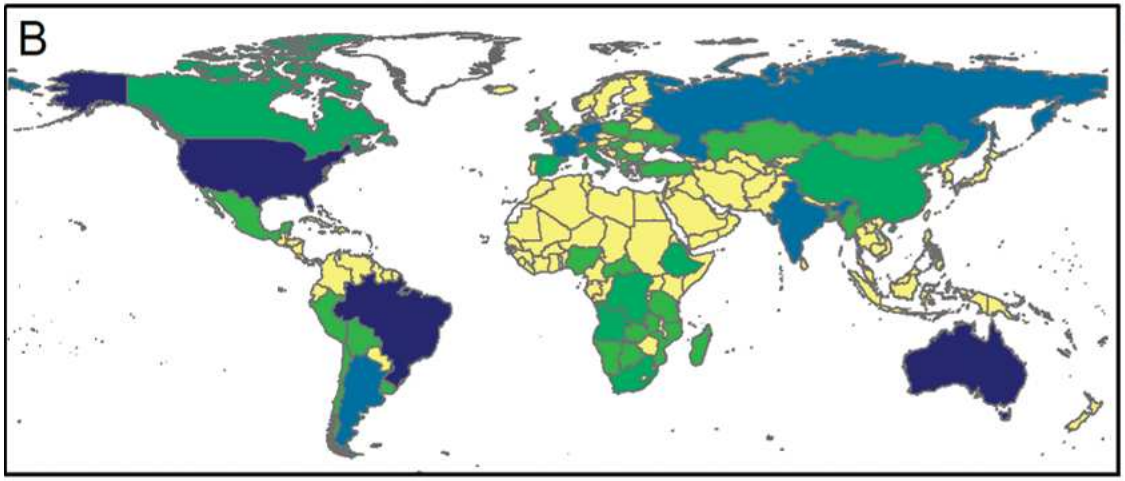
Cited by E. Rosenthal, NYT, 1-3-09



Natural Production (ton ha^{-1} y^{-1})

- 0 - 2
- 2 - 5
- 5 - 9
- 9 - 14
- 14 - 23

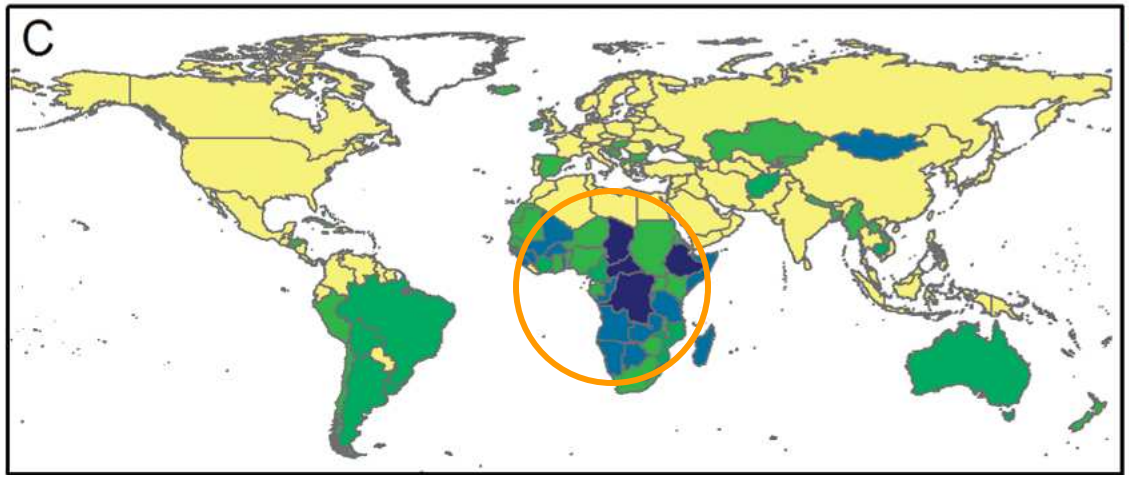
Biomass production potential on abandoned pastures. Campbell et al., ES&T, 2008.



Potential Production on Abandoned Agriculture (million ton y^{-1})

- 0 - 5
- 5 - 16
- 16 - 39
- 39 - 95
- 95 - 321

Land that was previously used for crop or pasture but has since been abandoned, and not converted to forest or urban use.

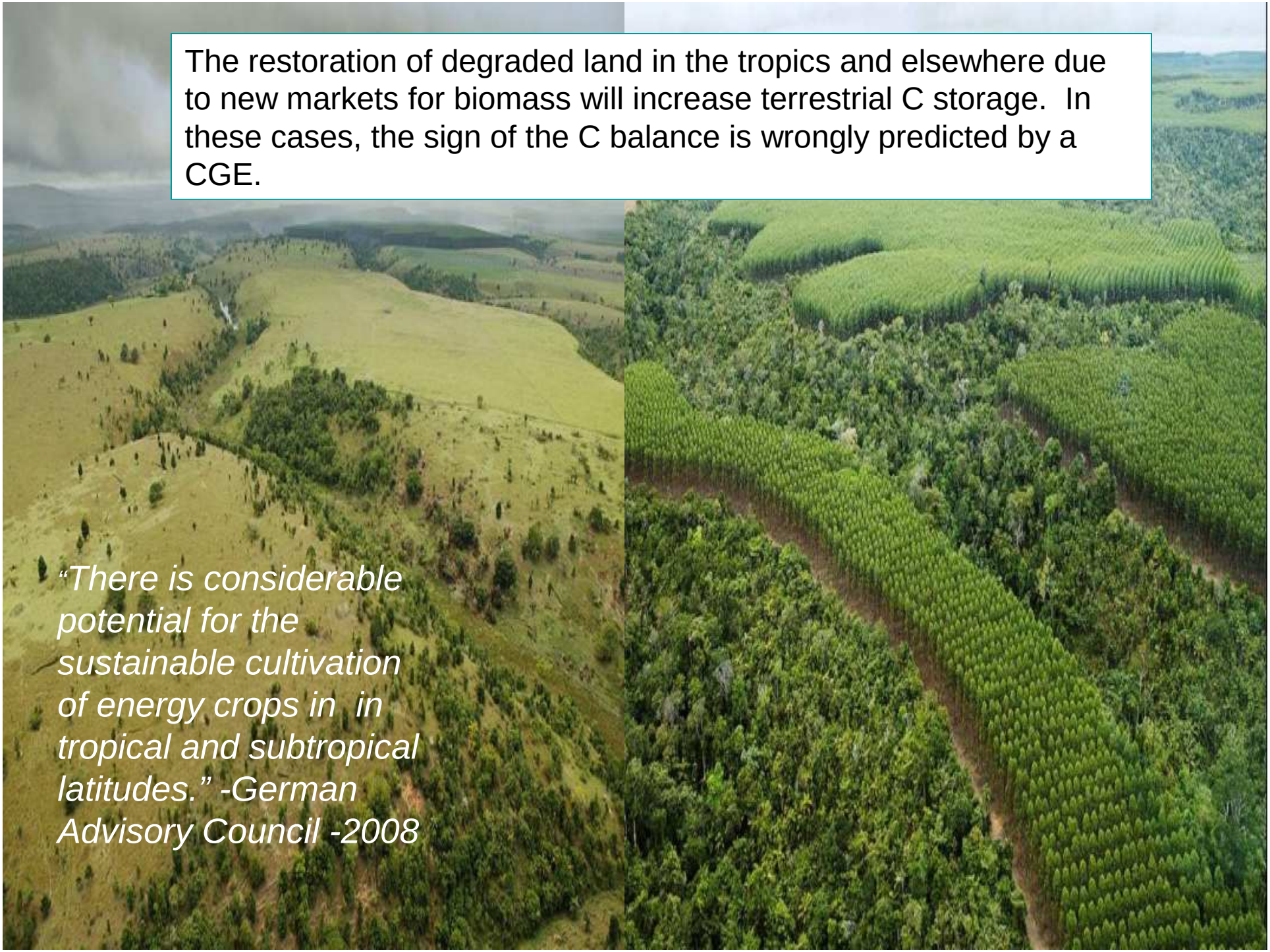


Bioenergy : Primary Demand (EJ y^{-1} : EJ y^{-1})

- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 5.0
- 5.0 - 38.0

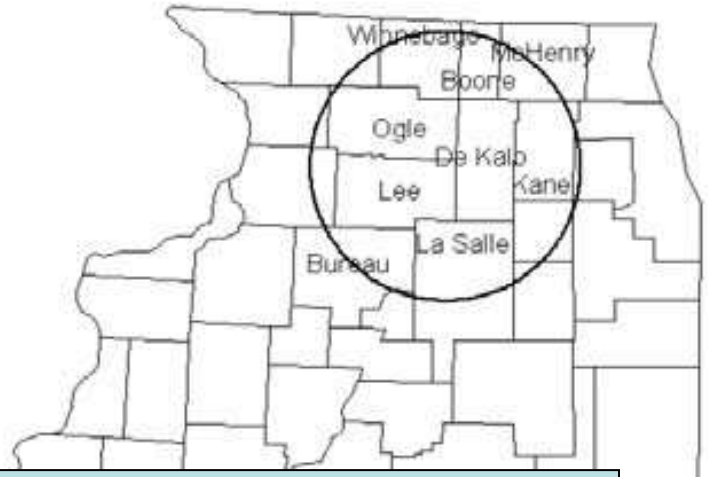
The energy potential for Africa from abandoned agricultural lands is many times the current energy need...

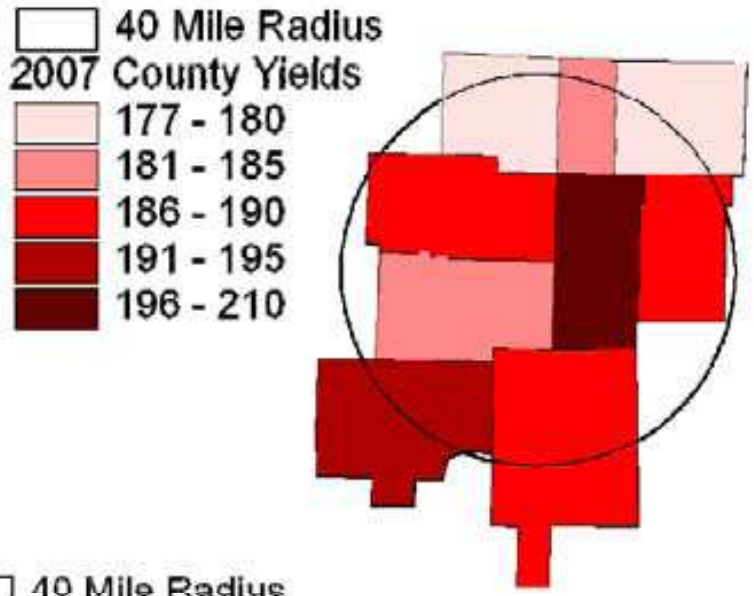
The restoration of degraded land in the tropics and elsewhere due to new markets for biomass will increase terrestrial C storage. In these cases, the sign of the C balance is wrongly predicted by a CGE.

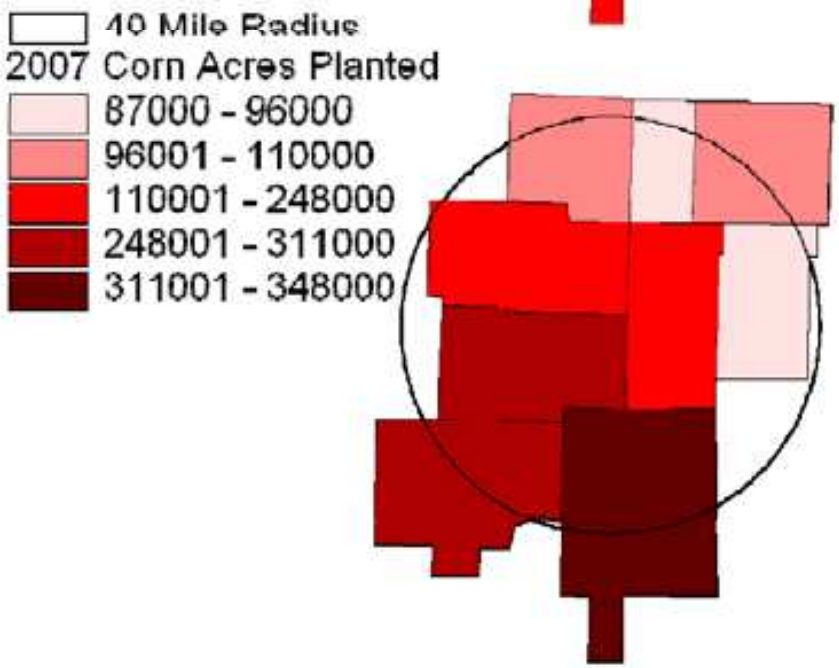


"There is considerable potential for the sustainable cultivation of energy crops in in tropical and subtropical latitudes." -German Advisory Council -2008

Counties in the 40-mile Radius and USDA NASS Data







Mueller et al., 2008, studied the effect on land conversion within the “corn-draw” area of a new ethanol plant in IL. They found that the new needs for grain for Et-OH were met via increases in yield, related to price response and favorable weather, and a small amount of land conversion from grasslands/woodlands (~4,000 ac) out of a total of 1,487,000 crop acres used (0.28%).

Modeling Indirect LUC

1. There is an uneasy relationship between methods and outputs. (T. Haniotis, 2009. Broadening the knowledge base for policies: experience with the Integrated Assessment of recent CAP reforms).
2. Models should be seen as learning tools, not truth machines. (J. Rotmans, 2009. Three decades of integrative assessment: the way forward).
3. There is no single policy that can control the response of complex systems. Attempting to do so will reduce sustainability. (several sources)

CGE models (like GTAP) model the reactions of the economy at one point in time. Results … are interpreted as showing the reaction of the economy in some future period to one or a few external shocks or policy changes. (Like crop withdrawal from food and feed markets for biofuels). This assumes the future behaves like the past, adjustment is instantaneous, and there is limited technological change occurring.

The results show the difference … between two alternative future states (with and without the policy shock). (e.g., how much new land was brought into production). Causality is assigned in the model.

Modeling Indirect LUC

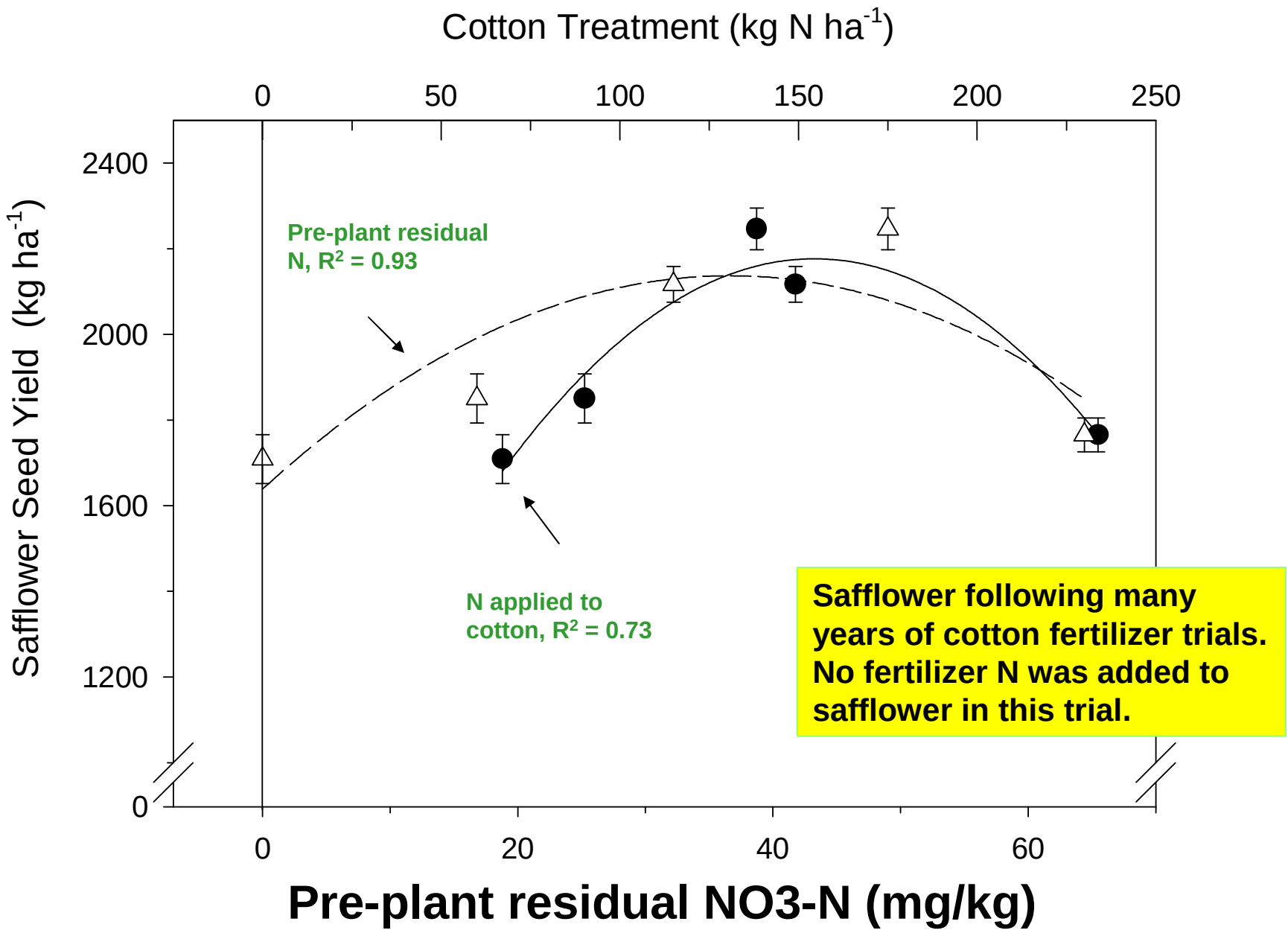
4. It is not food (or feed) vs fuels, but a question of how to create more sustainable agro-ecosystems (more diverse, more profitable). In many cases, crops grown for biomass may facilitate that process, not only in CA but also in many locations in the developing world were human need is great.

5. The distinction between first generation biofuels and second generation biofuels is partially arbitrary and misleading … If the entire crop plant were used (corn, sugarbeets), then energy yields could be similar to or even greater compared to so-called 2nd gen crops like switch grass. An integrated bio-refinery may change the production of energy to a by-product or waste management process rather than the primary activity.

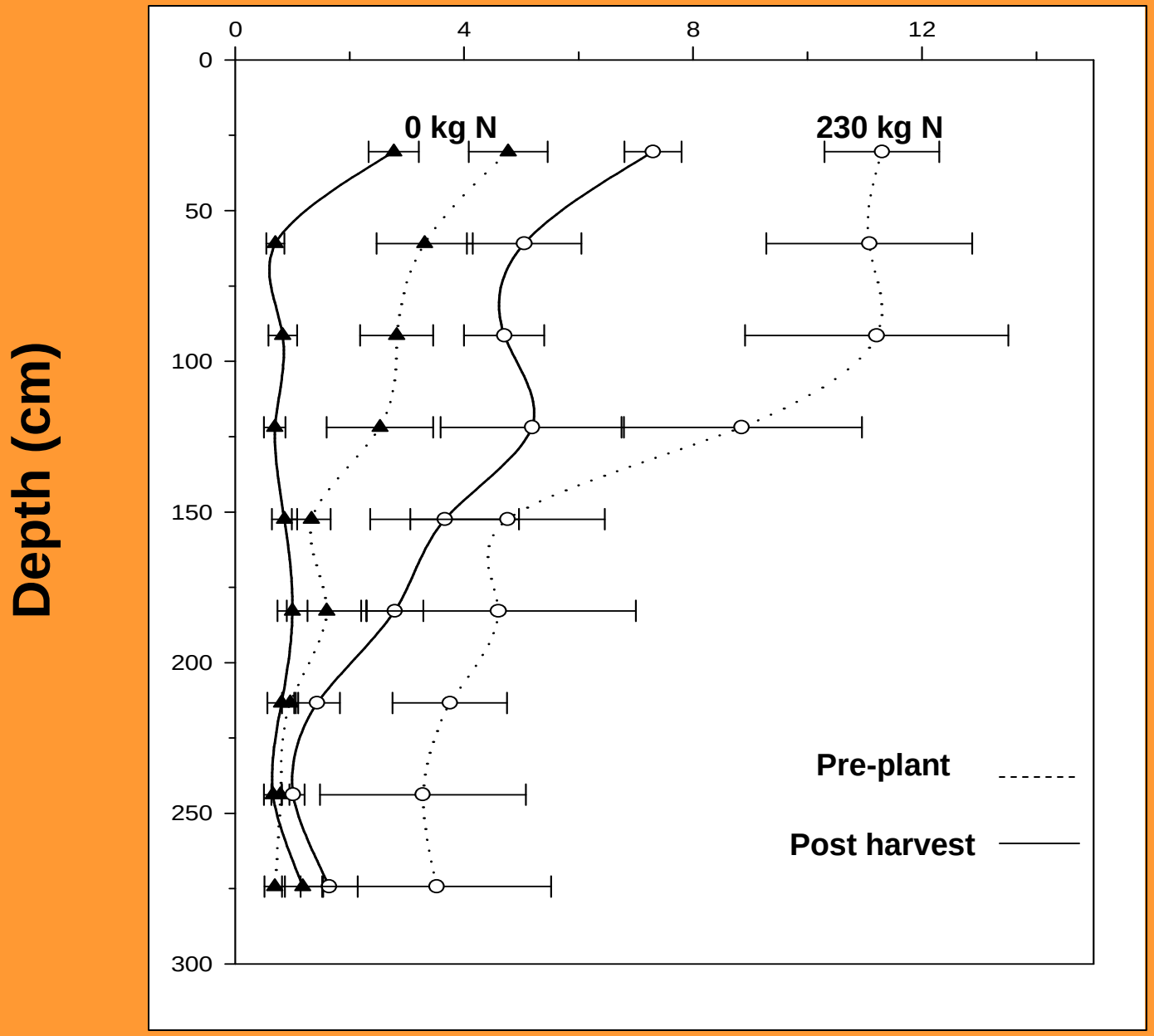
Safflower and Residual Nitrogen Management

Stephen Kaffka, Elias Bassil, Bob Hutmacher

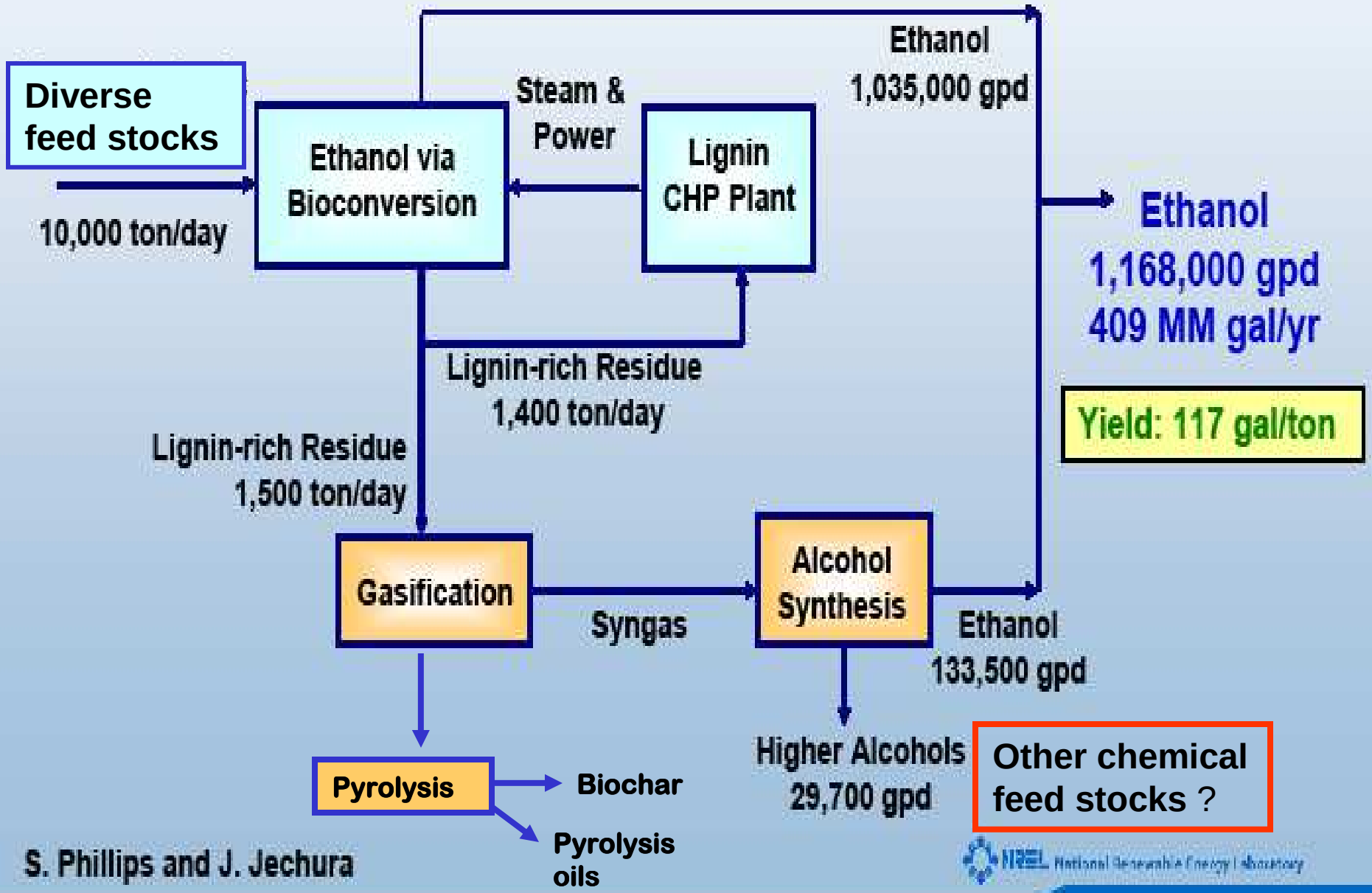
J. Agric Sci., Camb. 2002


Cotton Treatment (kg N ha-1)
0
50
100
150
200
250
2400
2000
1600
1200
0
Safflower Seed Yield (kg ha-1)
Pre-plant residual N, R2 = 0.93
N applied to cotton, R2 = 0.73
Safflower following many years of cotton fertilizer trials. No fertilizer N was added to safflower in this trial.
0
20
40
60
Pre-plant residual NO3-N (mg/kg)

Change in soil NO3-N during growth (mg/kg)



Potential future bio-refinery



S. Phillips and J. Jechura

NREL National Renewable Energy Laboratory

Sudzucker factory: Zeitz, Germany

Powered by lignite plus biomass

Feedstocks: sugarbeets, small grains, maize

Products: ethanol (350 M L/yr), biogas, electricity, animal feeds, nutrients

Pending: chemical feed stocks

Modeling Indirect LUC

6. The decision to impose an iLUC handicap on agricultural biofuels was premature and occurred without sufficient understanding of the nature of agricultural systems. This violates the principle of a performance standard by excluding potentially viable biofuel sources and methods.

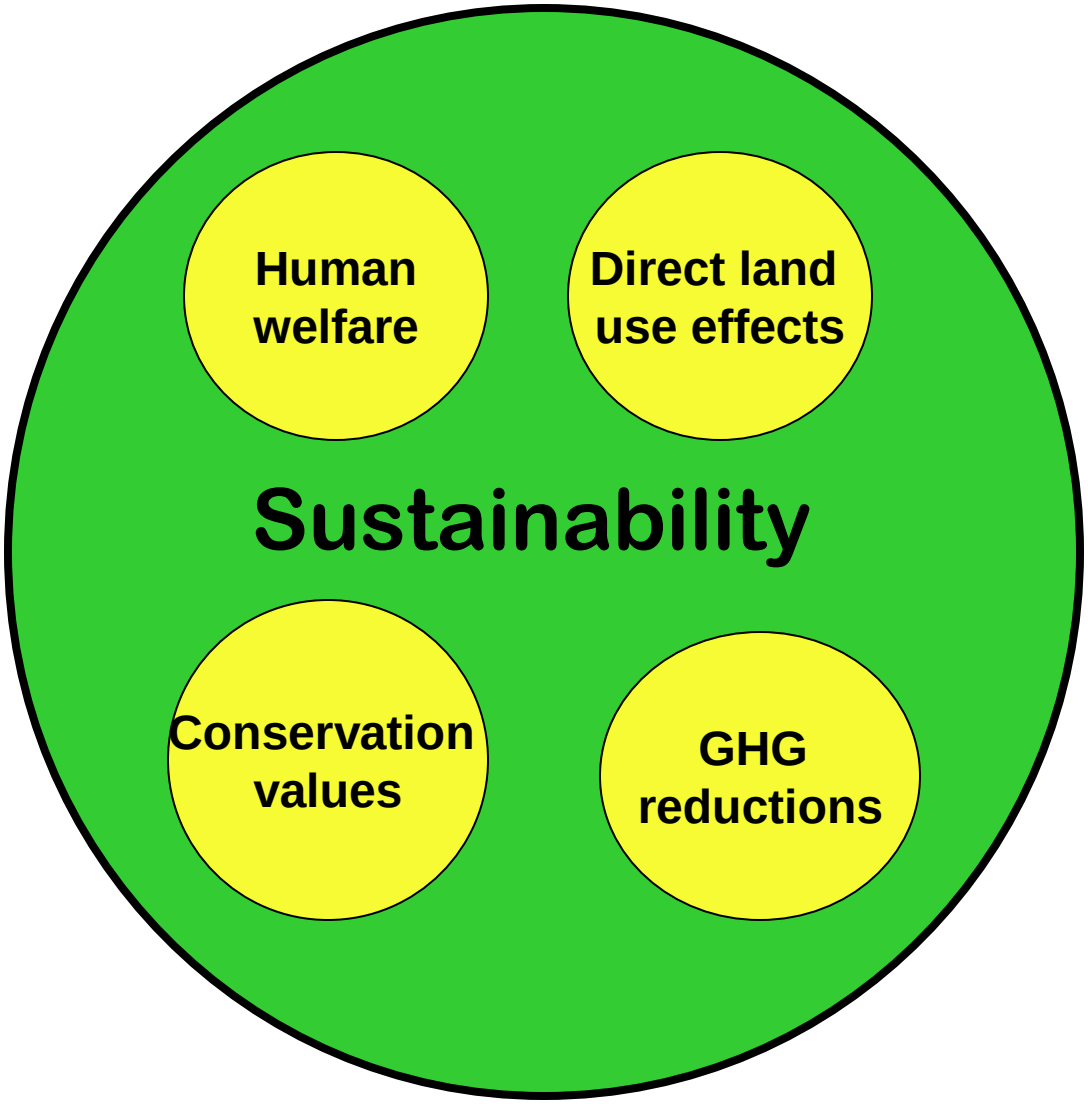
Modeling Indirect LUC

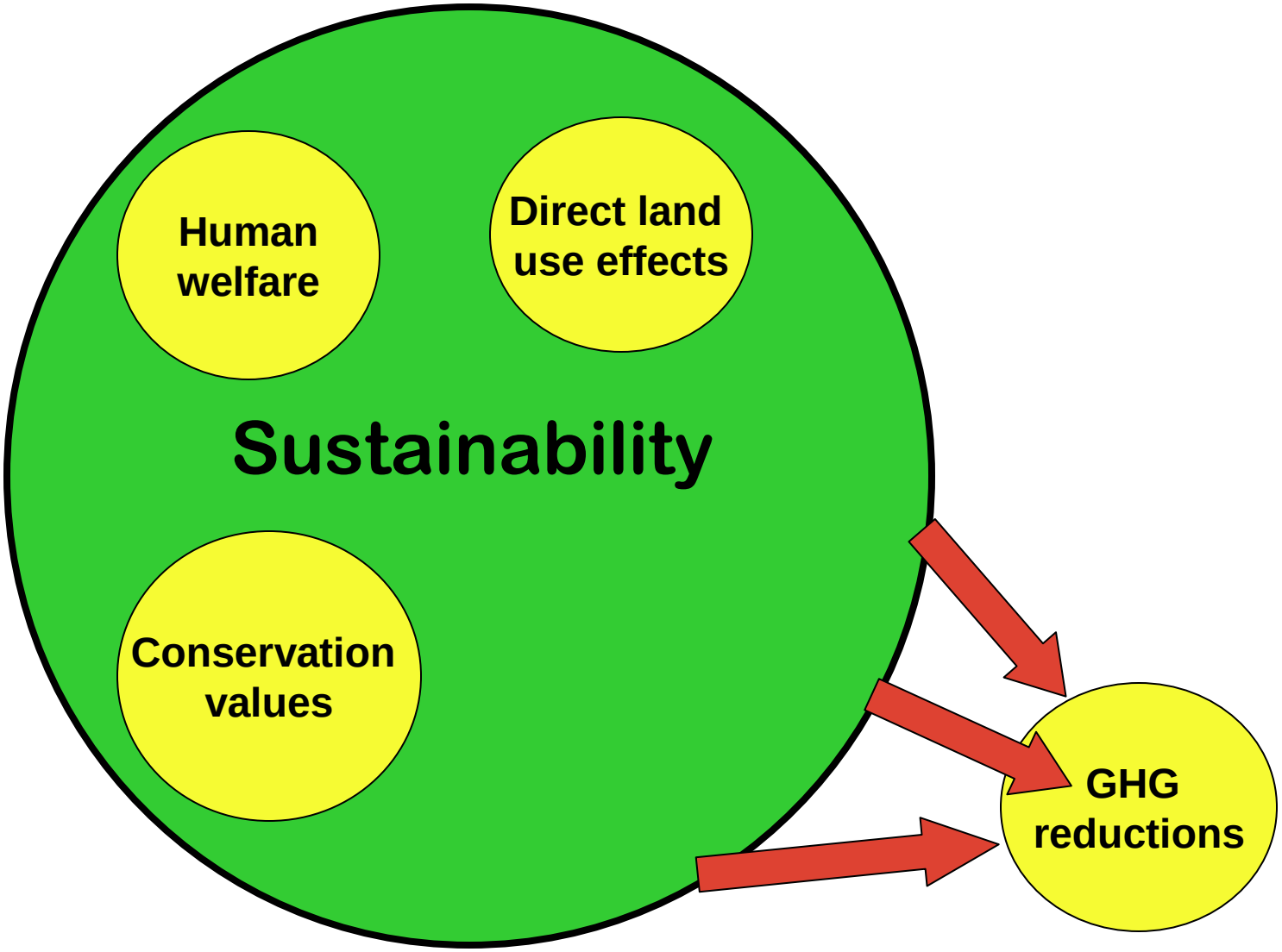
7. CA should encourage indigenous biofuel production to do its share to reduce GHG without exporting all the consequences of doing so to other locations. This is partly a matter of ethics, but it will also have the best estimates of GHG effects for local systems.

8. The key to a successful transition to a low carbon future will be entrepreneurial innovation. The state should err on the side of encouraging such innovation.

Modeling Indirect LUC

- The economic, social and ecological effects of regulation of the energy sector are so fundamental, far-reaching and complex, that prudence and time are needed to achieve the greatest net environmental and social benefits.


Human welfare
Direct land use effects
Sustainability
Conservation values
GHG reductions


Human welfare
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Multiple reasons for biofuels- AB 32 and the LCFS are not just GHG policies

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3. There is no single policy that can control the response of complex systems. Attempting to do so will reduce sustainability. (several sources)

How should we regulate?

Be humble, expect mistakes…

Go slowly…Gradually increase sustainability standards as knowledge and public consensus improves. Make sure the public agrees (legitimacy).

Use a light touch…Try not to constrain innovation, be willing to make prudent tradeoffs … The net long term public benefits from such innovation will outweigh short term losses of GHG benefits, if any, from overly restrictive policies.

Sustainability means flexibility, the ability to adjust to the unexpected.

How should we regulate?

iLUC should be estimated using several methods, with a preference for direct estimation. Reliance on a single method is unwise because no one model is currently able to deal with this complex issue adequately. Additional time is needed to create comparative iLUC approaches. **Rely only on the best direct GHG estimates.**

CA, the US, and EU should agree on the use several policy approaches to avoid undesirable LUC changes, including direct intervention to protect high value ecological areas in developing parts of the world, while allowing for the fulfillment of needed human development.

Oil production from tar sands in Alberta

An alternative to biomass use for energy