

# Perspectives on Land-Use Change Analyses

Presented by Keith Kline  
for the  
**CRC WORKSHOP ON LIFE CYCLE ANALYSIS  
OF BIOFUELS**  
Argonne National Lab, Oct 18-19, 2011

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## CBES

Center for BioEnergy  
Sustainability



US Department of Energy



# What are effects of bioenergy policy on land?

1. Representation of policy in model specifications
2. Economic decision-making assumptions
3. Conceptual framework for drivers of initial conversion
4. Land supply & management specifications
5. Assumed land use by farmers (cellulosic, bioenergy choice)
6. Modeling yield change
7. Issues of time, scale
8. Fire & other disturbances
9. Correlation versus causation
10. Many, many data issues to resolve

**It depends**

– See IEA Joint Task 38-40-43 presentation on LUC –  
<http://ieabioenergy-task38.org/workshops/campinas2011/>

### Solutions for a cultivated planet

Jonathan A. Foley<sup>1</sup>, Navin Ramankutty<sup>2</sup>, Kate A. Brauman<sup>1</sup>, Emily S. Cassidy<sup>1</sup>, James S. Gerber<sup>1</sup>, Matt Johnston<sup>1</sup>, Nathaniel D. Mueller<sup>1</sup>, Christine O'Connell<sup>1</sup>, Deepak K. Ray<sup>1</sup>, Paul C. West<sup>1</sup>, Christian Balzer<sup>3</sup>, Elena M. Bennett<sup>4</sup>, Stephen R. Carpenter<sup>5</sup>, Jason Hill<sup>1,6</sup>, Chad Monfreda<sup>7</sup>, Stephen Polasky<sup>1,8</sup>, Johan Rockström<sup>9</sup>, John Sheehan<sup>1</sup>, Stefan Siebert<sup>10</sup>, David Tilman<sup>1,11</sup> & David P. M. Zaks<sup>12</sup>

- Close 'yield gaps' on underperforming lands
- Increase cropping efficiency
- Reduce waste
- Halt expansion into sensitive ecosystems, forests

*See CRC abstract: Despite uncertainty and strong disagreements on ILUC, there are many important measures on which diverse stakeholders CAN AGREE*

I would add: Diversify, reduce market volatility...

# Land-Use Change Analyses

- **LUC and ILUC – definitions?**  
**Change compared to what?**
  - **Model assumptions and scenarios versus**
    - **current reality ?**
    - **desired future ?**
- **What LUC is most important?**  
**Most concerns (and emissions) are associated with deforestation**
- **What really drives deforestation?**  
**Requires causal analysis**
- **Important to “get it right” to be effective**  
**Good intentions to avoid unintended consequences can lead to other unintended consequences**

# Threats to forests: local governance (policy, corruption, poverty, insecurity), fire and pests...

## Solutions:

- Rural livelihoods\*
- Land tenure
- Improve governance, local participation and capacity, enforcement
- Land-use plans, soil management, productive uses to reduce fire\*
- Inventory & protect key conservation areas\*



**\*Bioenergy policy could help**

Source: Kline, 2008 California Biomass Collaborative., based on USAID-FAA Sec. 118/119 Reports for 2000-2008.

FAO 2010c. See FAO forest management and conservation best practices: [http://www.fao.org/bestpractices/content/05/05\\_02\\_en.htm](http://www.fao.org/bestpractices/content/05/05_02_en.htm)

# Available Land & Estimated ILUC → Africa, Latin America, Asia

- Models assume land is privately owned & managed rationally for profit... but most forests are public property

➤ **Public land clearing is either (a) illegal or (b) policy-driven**

- Convergence toward reality (?) How to include:
  - Market failures
  - Public land issues
  - Variable effects of bioenergy policy depending on access to information, markets, tenure, security, and enforcement, among others

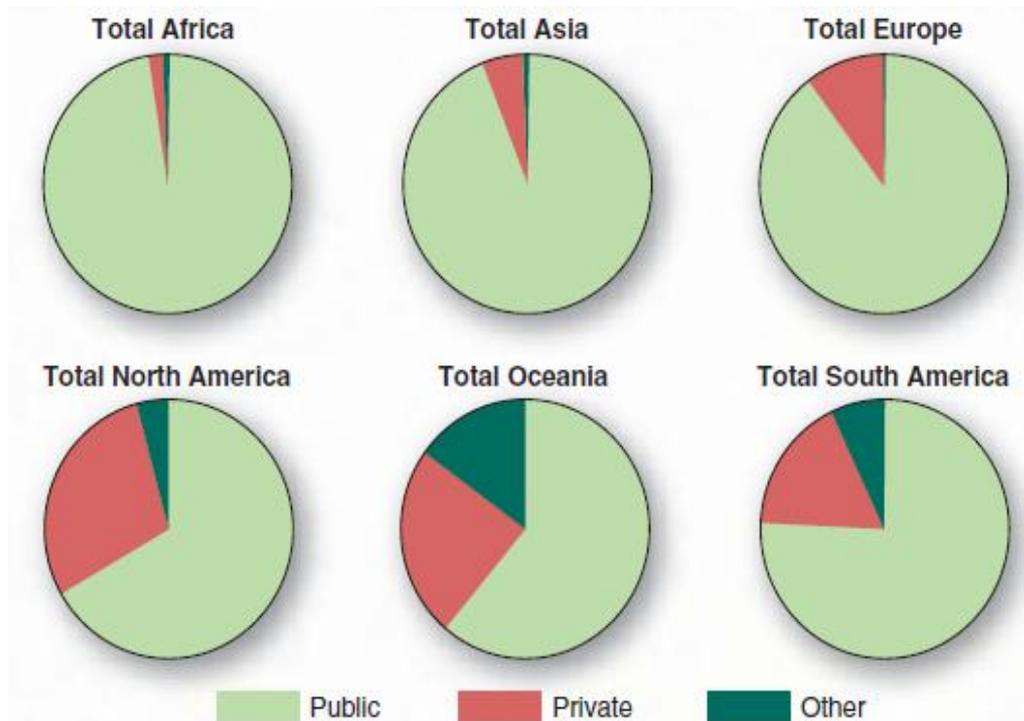
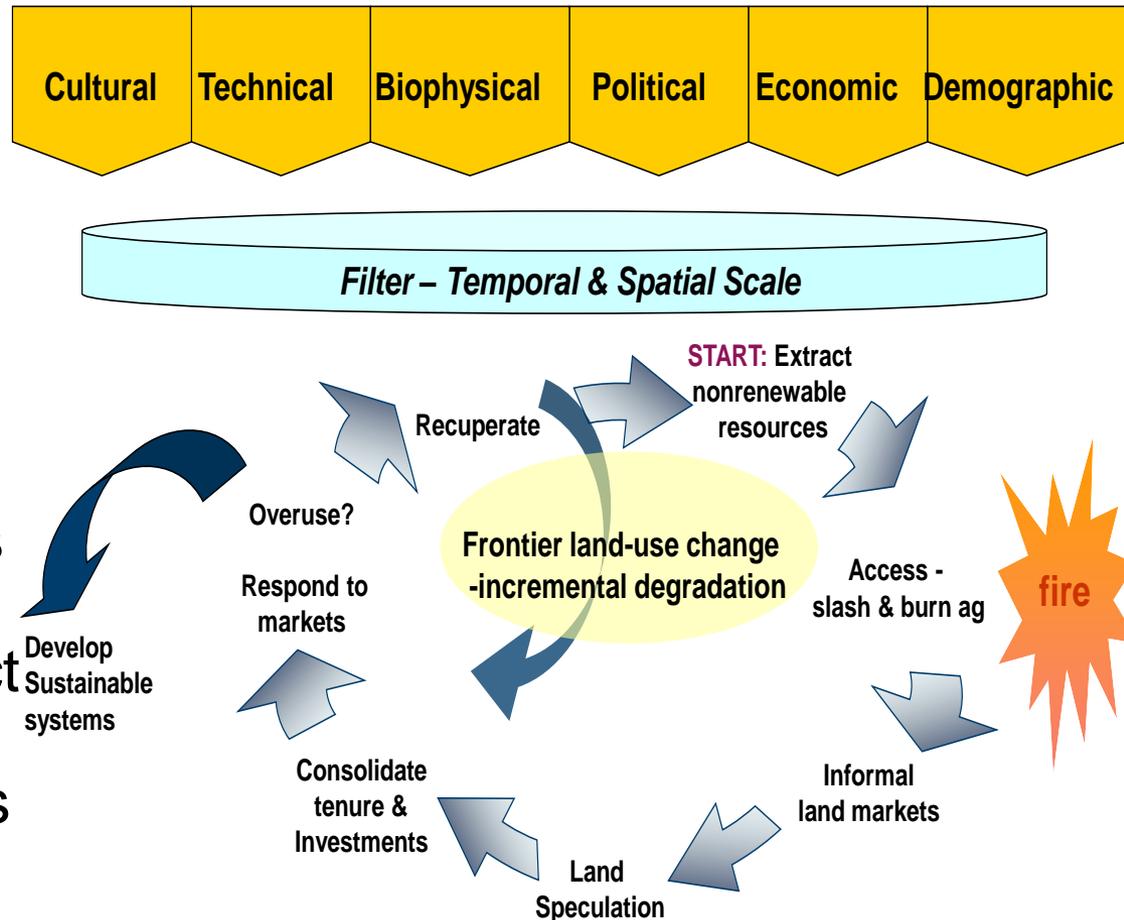


Figure: Agrawal et al., 2008, Science 320  
(based on FAO data)

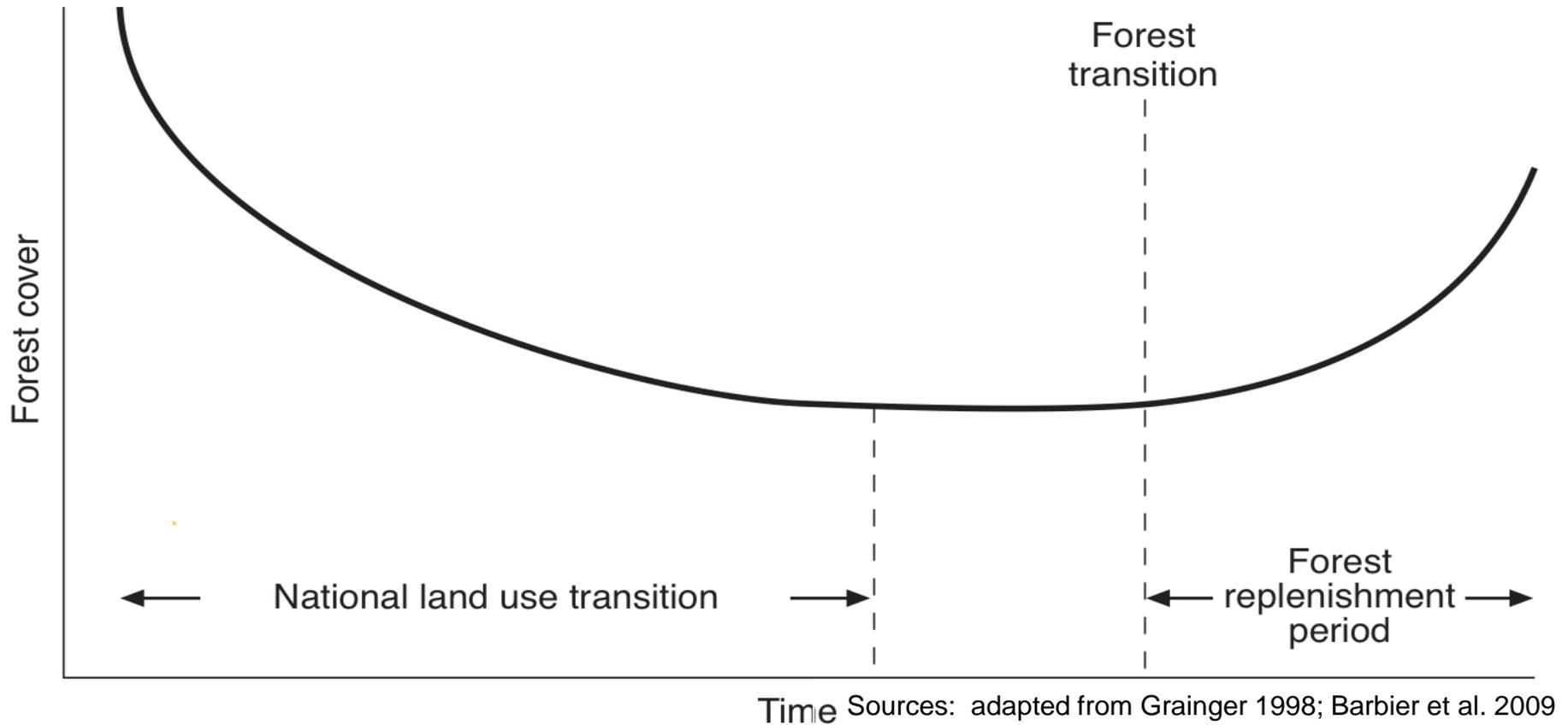
# Conceptual framework for drivers of initial conversion

- Key drivers: **local** social, biophysical, political, legal, demographic & economic forces
- Models use global price effects to estimate LUC – conversion
- To estimate LUC, models should reflect how bioenergy policies interact with drivers of first-time conversion at local scales



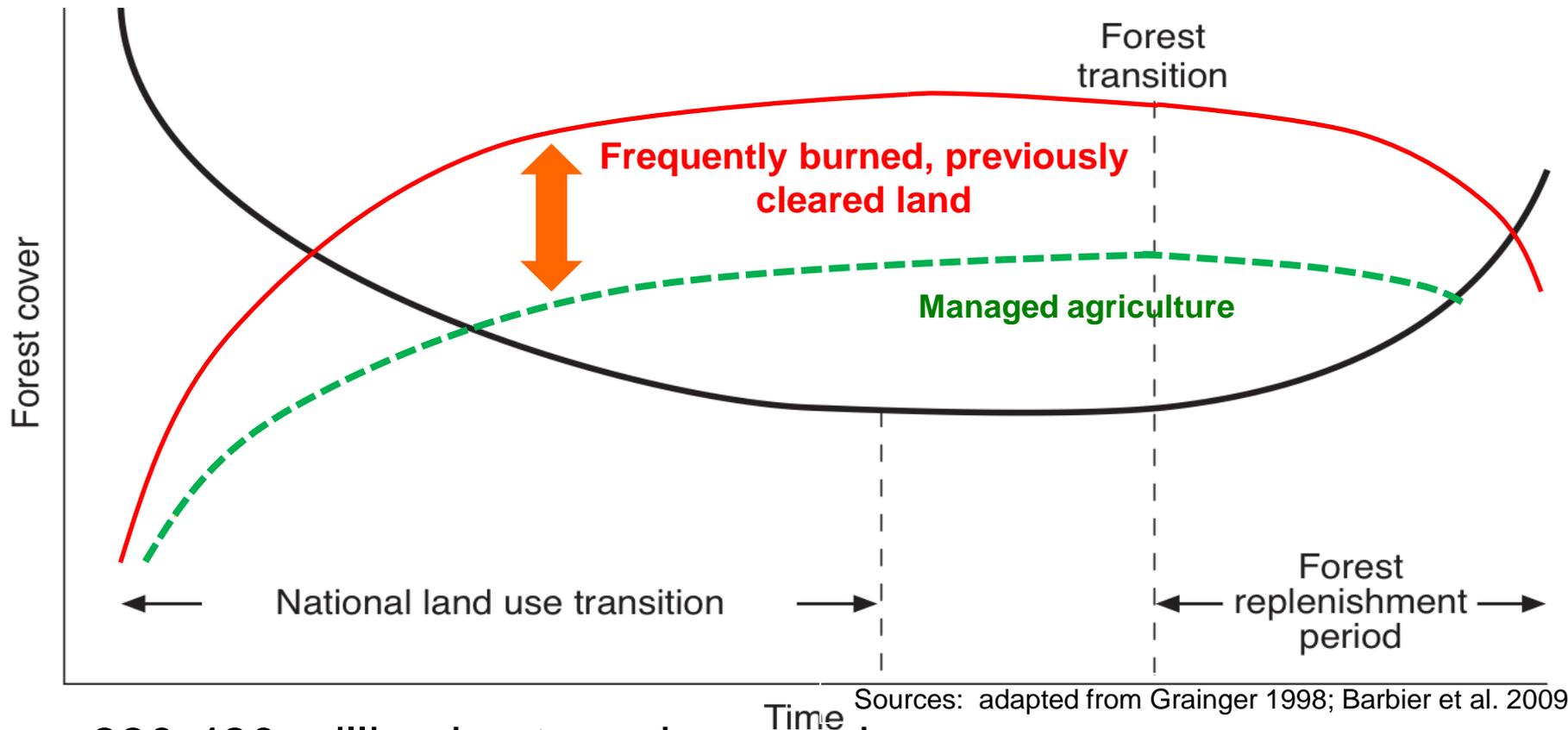
- No single model adequately explains global deforestation, but empirically-based models can explain LUC at regional & local scales

# Alternative perspectives: Forest Transition Model



- Downward slope driven by local context
- Recovery more influenced by external factors

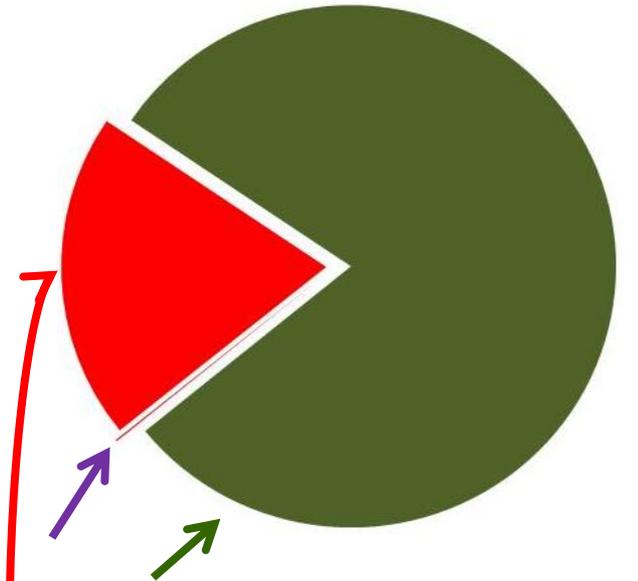
FIRE is a management tool for large areas of previously cleared, under-utilized land.



- 330-430 million hectares burn each year (Giglio et al. 2010)  
***Biofuel markets and other incentives for more productive management of previously cleared lands, can reduce fire and pressure on remaining forests. Policy effects may be opposite of those assumed in current models.***

# Putting global land factors into perspective

- Models define land assets by “rents”
- Models assume land is fully & optimally used
- Need to incorporate full land supply & potential productivity
- Need to consider multiple uses, urban food production, & double or triple cropping opportunities
- Need to simulate farm-management strategies that increase production without expansion
  - Shifts in rotations
  - More efficient use of field edges, idle land
  - Adjust planting densities
  - Shifts within crop categories



**Ag land available for expansion without deforestation: 1500 M ha illustrated here (up to 5000 M ha globally)**

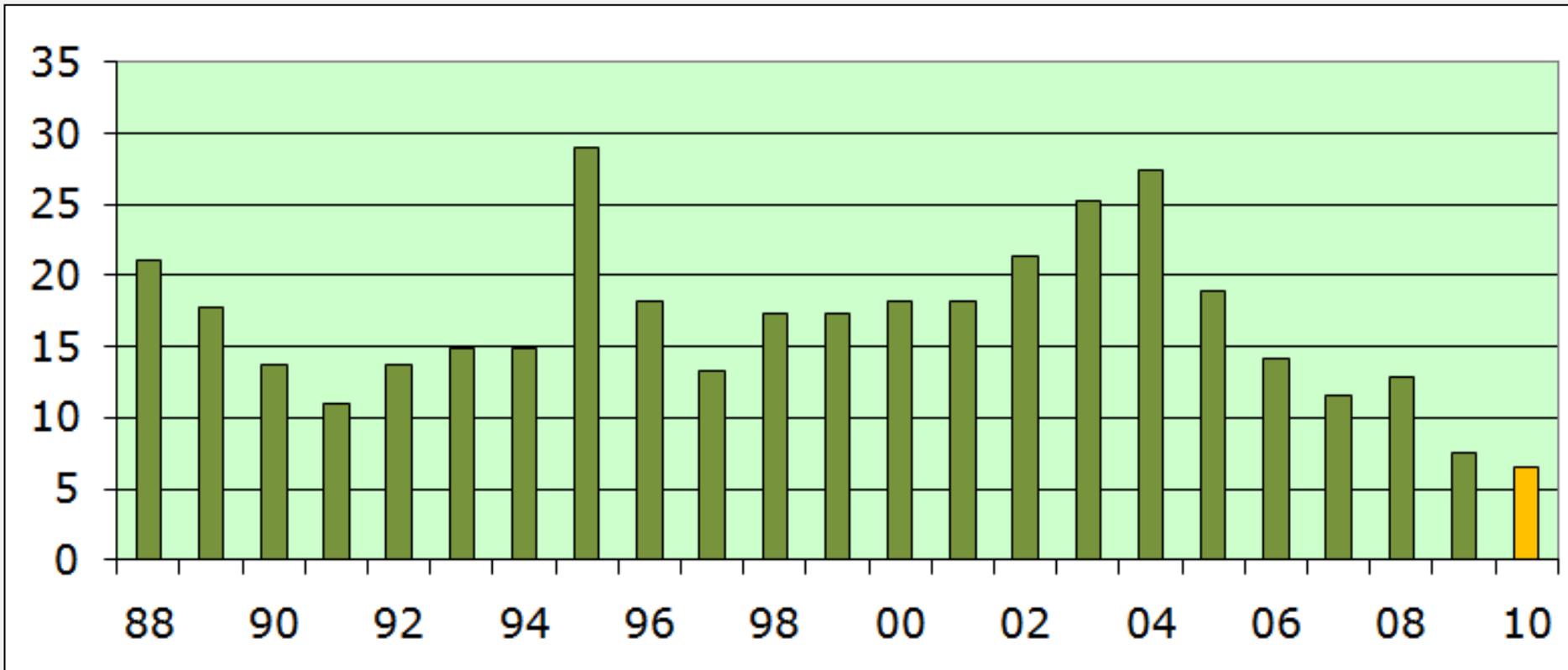
**Global area burned each year = 380 M ha**

Purple sliver: conversion to developed/urban use

Bioenergy use: too small to visualize at this scale

# Correlation versus causation

- **FAO, 2010: Global tropical deforestation rate (avg. annual loss) fell > 20% compared to prior decade, led by decline in Brazil (chart below)**

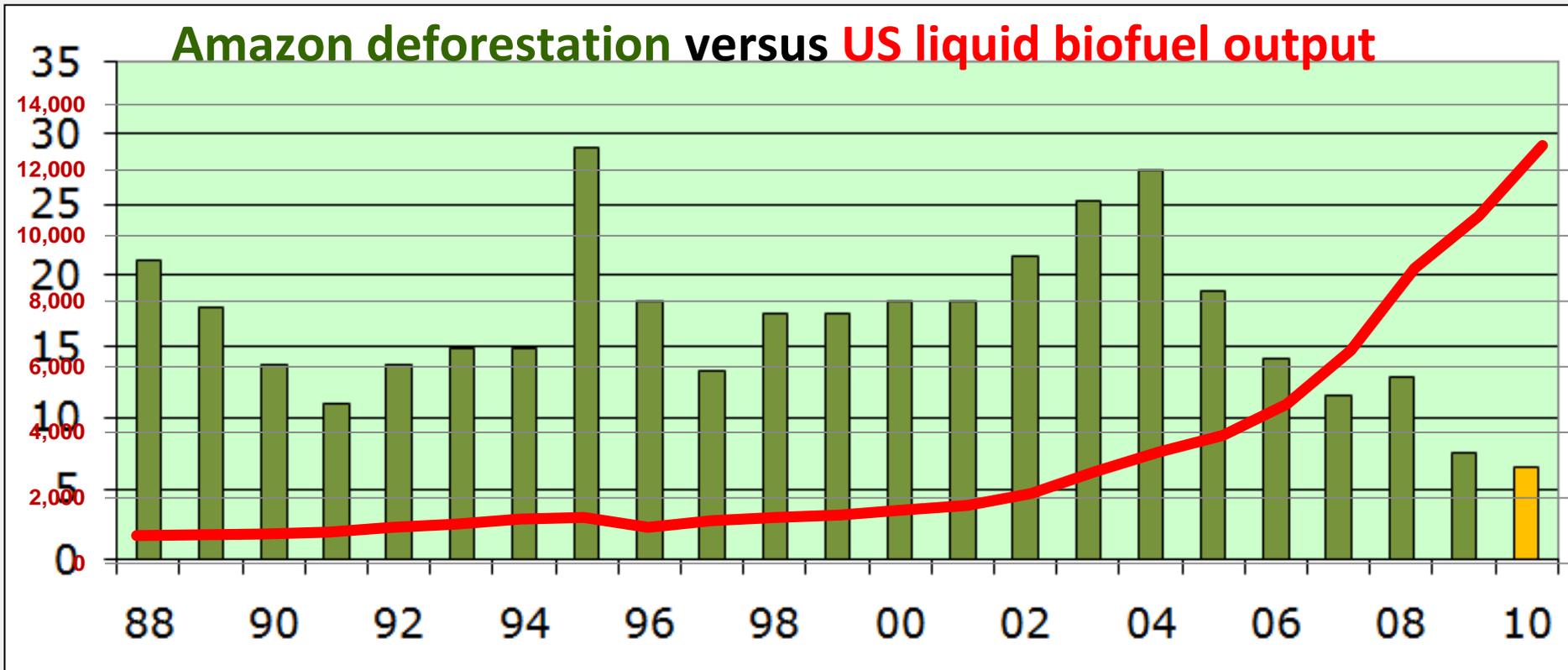


## Deforestation rate in Brazil's Amazon, thousands square km per year

Source: INPE-PRODES Brazil Space Agency: [http://www.dpi.inpe.br/gilberto/present/prodes\\_taxa2010.ppt](http://www.dpi.inpe.br/gilberto/present/prodes_taxa2010.ppt) Yellow bar for 2010 indicates preliminary result of analysis.

# Correlation versus causation

- Need causal analysis of models and input assumptions
- If, when, how, and in what ways, do changes in biofuel policy affect deforestation trends?



## Deforestation rate in Brazil's Amazon, thousands square km per year

Source: INPE-PRODES Brazil Space Agency: [http://www.dpi.inpe.br/gilberto/present/prodes\\_taxa2010.ppt](http://www.dpi.inpe.br/gilberto/present/prodes_taxa2010.ppt) Yellow bar for 2010 indicates preliminary result of analysis.

United States  
Department of  
Agriculture



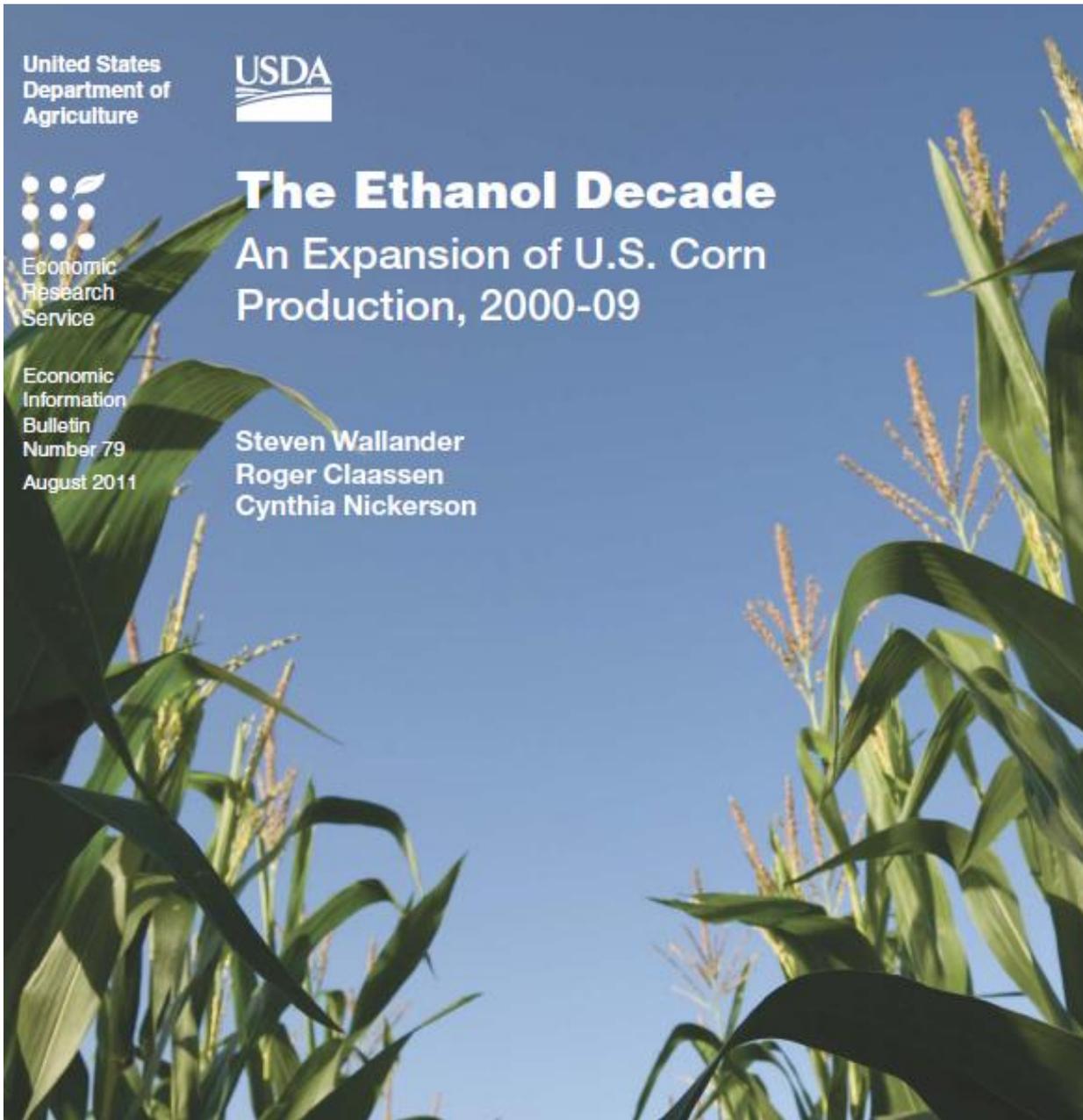
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Information  
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# The Ethanol Decade

## An Expansion of U.S. Corn Production, 2000-09

Steven Wallander  
Roger Claassen  
Cynthia Nickerson



Wallander et al. 2011. *The Ethanol Decade: An Expansion of U.S. Corn Production, 2000-09*. EIB-79. Economic Research Service/USDA, August, 2011.

# Modeled LUC: large decreases in forest, pasture and soybeans with large net ag expansion

TABLE 1  
Comparing simulation studies of corn ethanol expansion

Study	Searchinger et al.	Searchinger et al.	Malcolm et al.	EPA RFS2 RIA (FASOM)	EPA RFS2 RIA (FAPRI-CARD)
Year modeled	2016/17	2016/17	2015	2022	2022
<i>Billion gallons</i>					
Increase in ethanol	14.77 (from 14.75 to 29.52)	8.08 (from 14.75 to 22.84)	1.7 (from 13.30 to 15.00)	2.7 corn-based (from 12.3 to 15.00) plus 13.5 cellulosic	2.7 corn-based (from 12.3 to 15.00) plus small change in imported ethanol
<b>Predicted change in land-use/cropping selection</b>					
<i>Million acres</i>					
Predicted increase in corn acres	19.4	10.0	3.2	3.6	1.8
Predicted increase in cropland	5.5	2.9	4.9	8.1	0.7
Other major predicted increases			Soybeans (1.9)	Switchgrass (12.5)	
Major predicted decreases	Soybeans (-9.6) Wheat (-4.8)	Soybeans (-4.1) Wheat (-3.3)	Rice and sorghum (each -0.1)	Wheat (-2.9) Soybeans (-1.4) Barley (-1.2) Rice and hay (each -0.8) Oats and cotton (each -0.2)	Soybeans (-0.7)

EPA=U.S. Environmental Protection Agency.  
RFS2=Renewable Fuel Standard Program.  
RIA=Regulatory Impact Analysis.

FASOM=Forest and Agricultural Sector Optimization Model.

FAPRI-CARD=Food and Agricultural Policy Research Institute-Center for Agricultural and Rural Development.

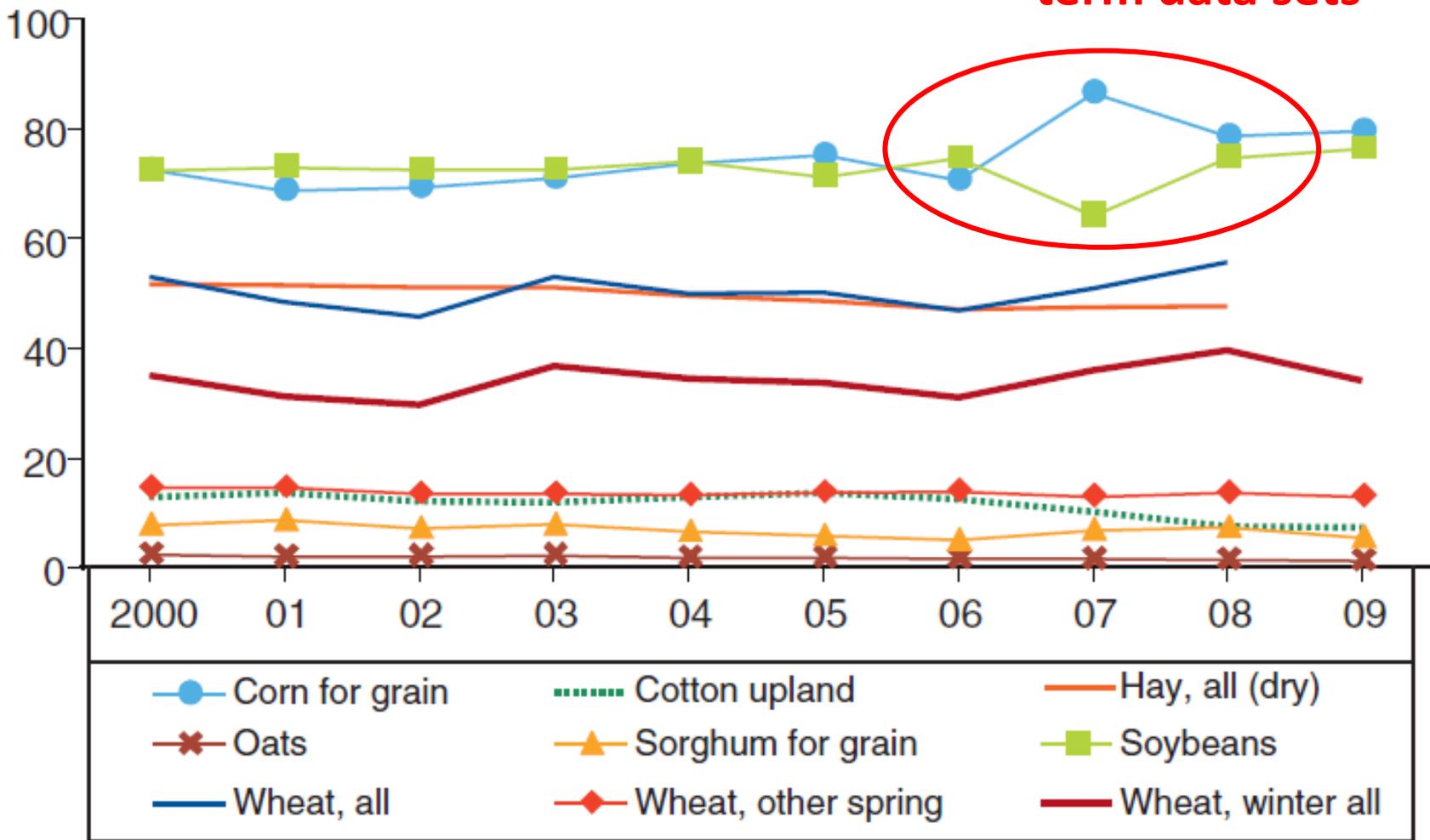
Source: Searchinger et al., 2008; Malcolm et al., 2009; U.S. Environmental Protection Agency, 2010.

From: Wallander et al. 2011. *The Ethanol Decade: An Expansion of U.S. Corn Production, 2000-09*. EIB-79. Economic Research Service/USDA, August, 2011.

Figure 2

# Harvested acreage for major U.S. crops

Millions of acres



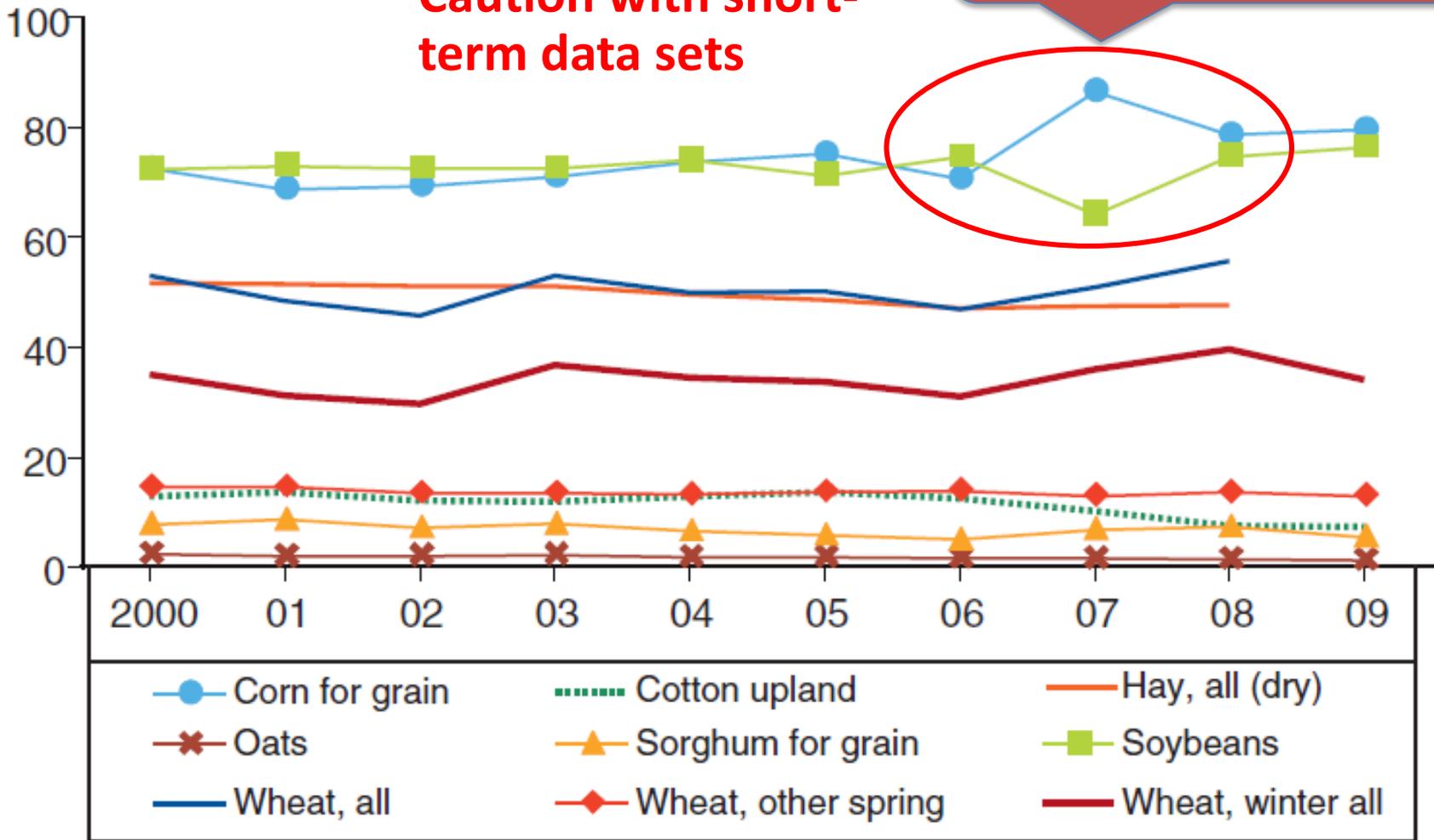
Source: USDA, National Agricultural Statistics Service Crop Production Summaries.

Wallander et al. 2011. *The Ethanol Decade: An Expansion of U.S. Corn Production, 2000-09*. EIB-79. Economic Research Service/USDA, August, 2011.

Figure 2

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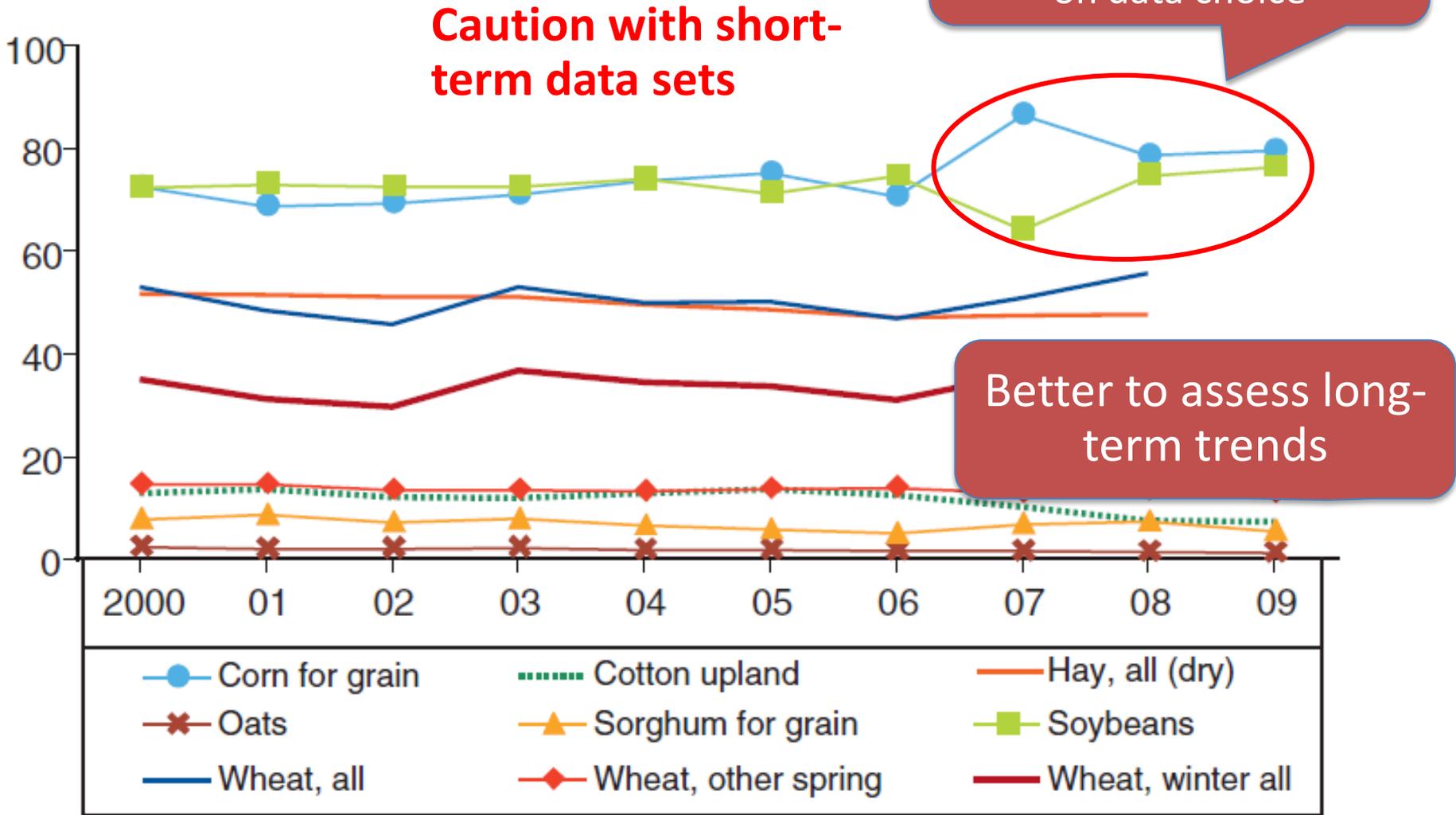
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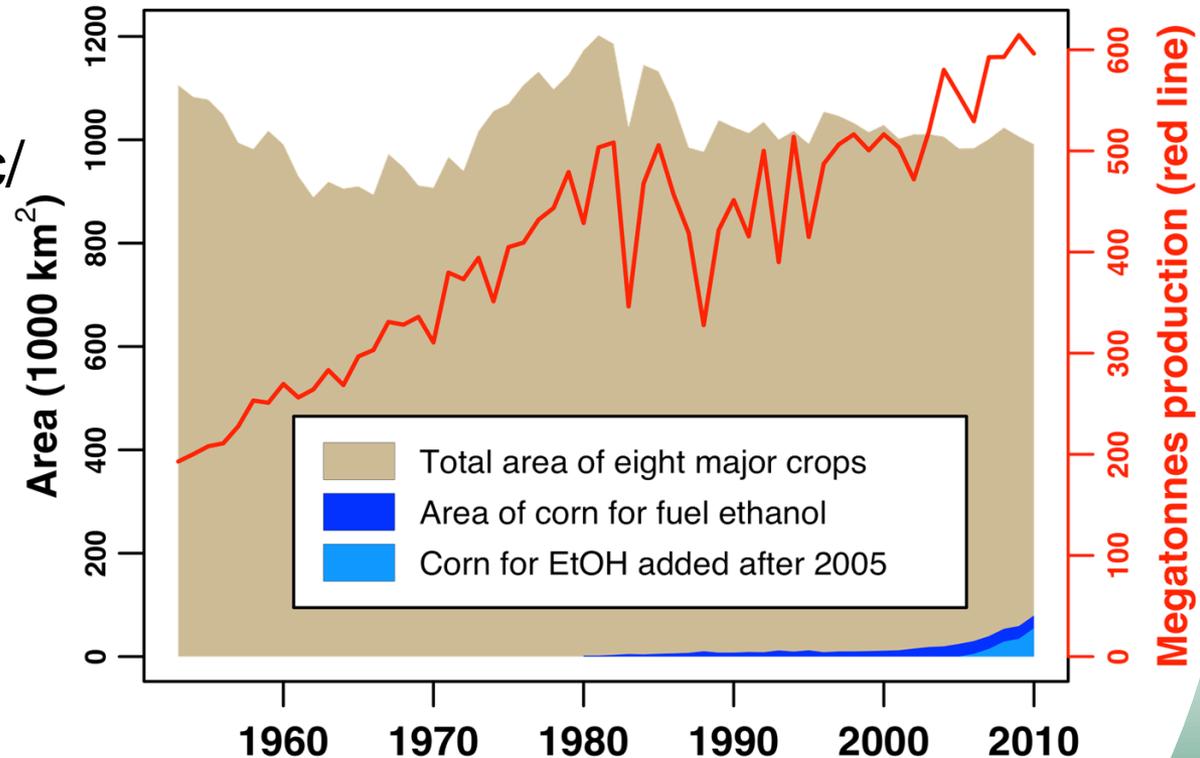
Source: USDA, National Agricultural Statistics Service Crop Production Summaries.

Wallander et al. 2011. *The Ethanol Decade: An Expansion of U.S. Corn Production, 2000-09*. EIB-79. Economic Research Service/USDA, August, 2011.

# Representation of policy in model specifications

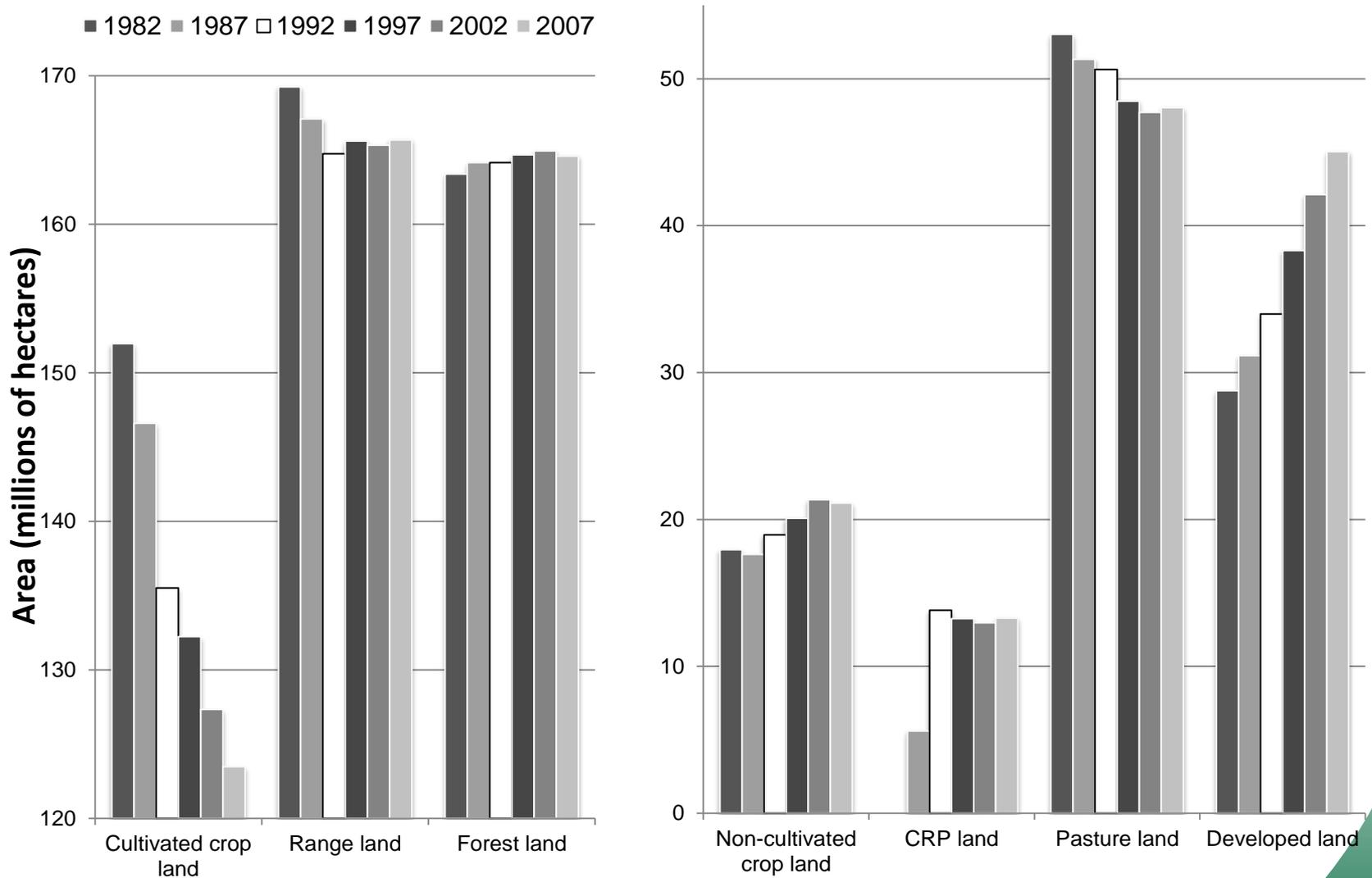
- Shock in demand?
- Different biofuel policies have distinct land-use & economic/welfare implications
- Different ways to specify policies in a model may have greater effects than policy per se
- Policy specifications (assumptions & scenarios) must be calibrated & validated to reflect actual policies

US total planted area and production of barley, corn, cotton, oats, rice, sorghum, soybeans & wheat



ORNL Chart based on USDA data (A.McBride)

# What are Implications of *actual* (not modeled) LUC trends?



Graphic based on data from the USDA 2009-NRI. Dale et al. 2011.

# Stable/static land conditions\* assumed for baseline

- Need to simulate effects relative to moving targets of gross & net change trends in land-cover & land-use\*
- Dynamics should capture changing rates, directions & types of land-cover & land-use\* at local scales
- Models need to capture historic range of variability in key land\* variables

\* ***Better land metrics and data are required***

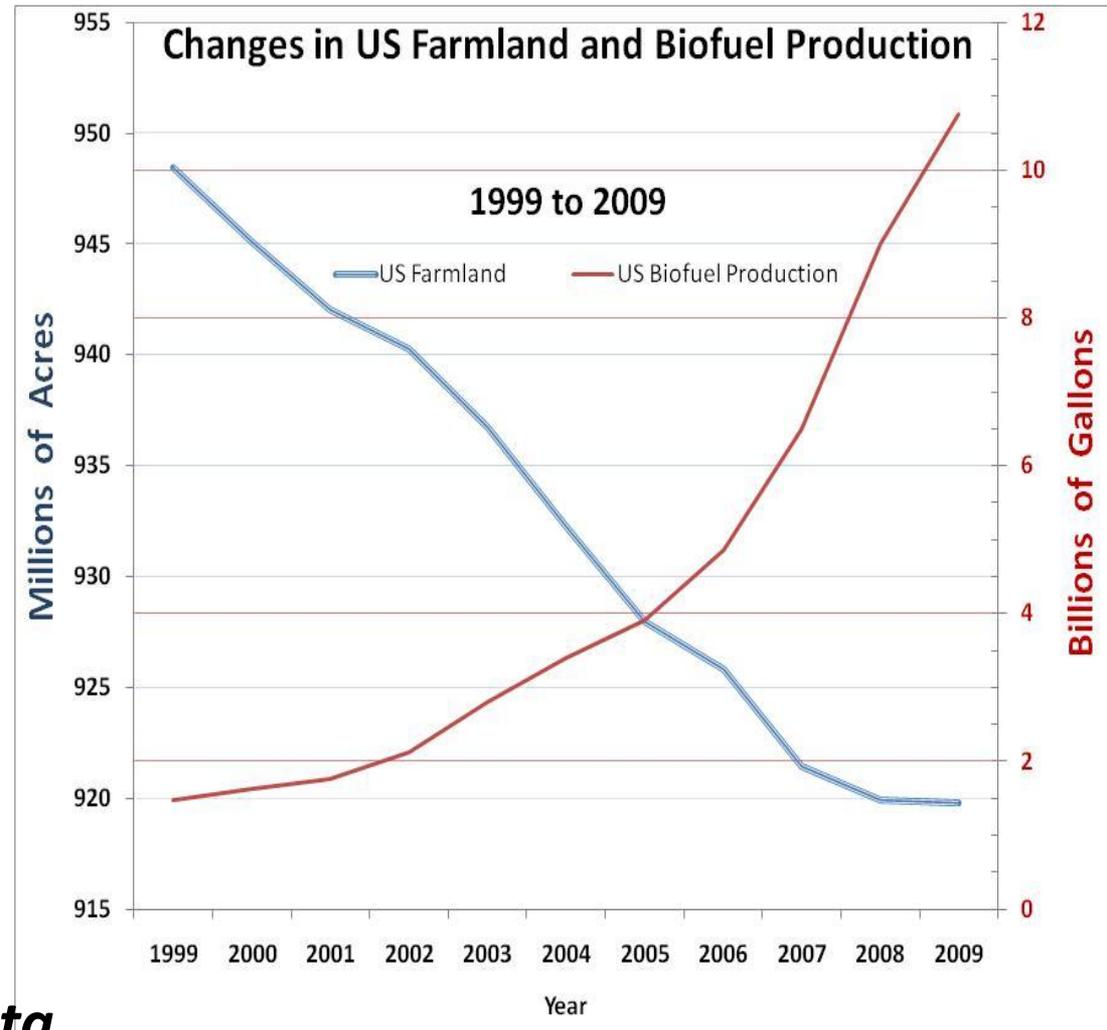
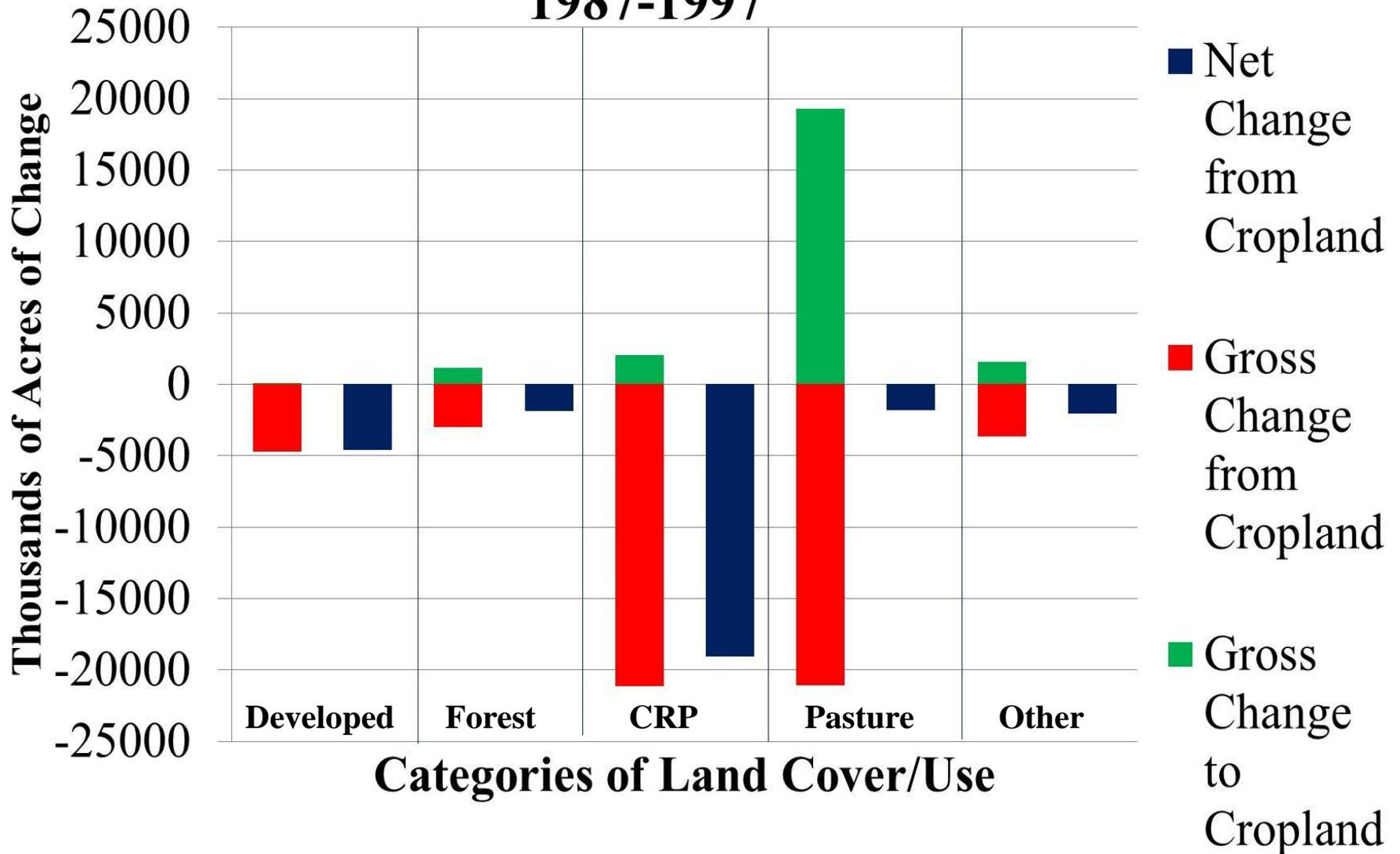


Chart by author using farmland data from USDA NASS 2010 and ethanol production data from the RFA statistics Aug 2011.

# Stable/static land conditions? Comparing Net and Gross Changes in Cropland 1987-1997

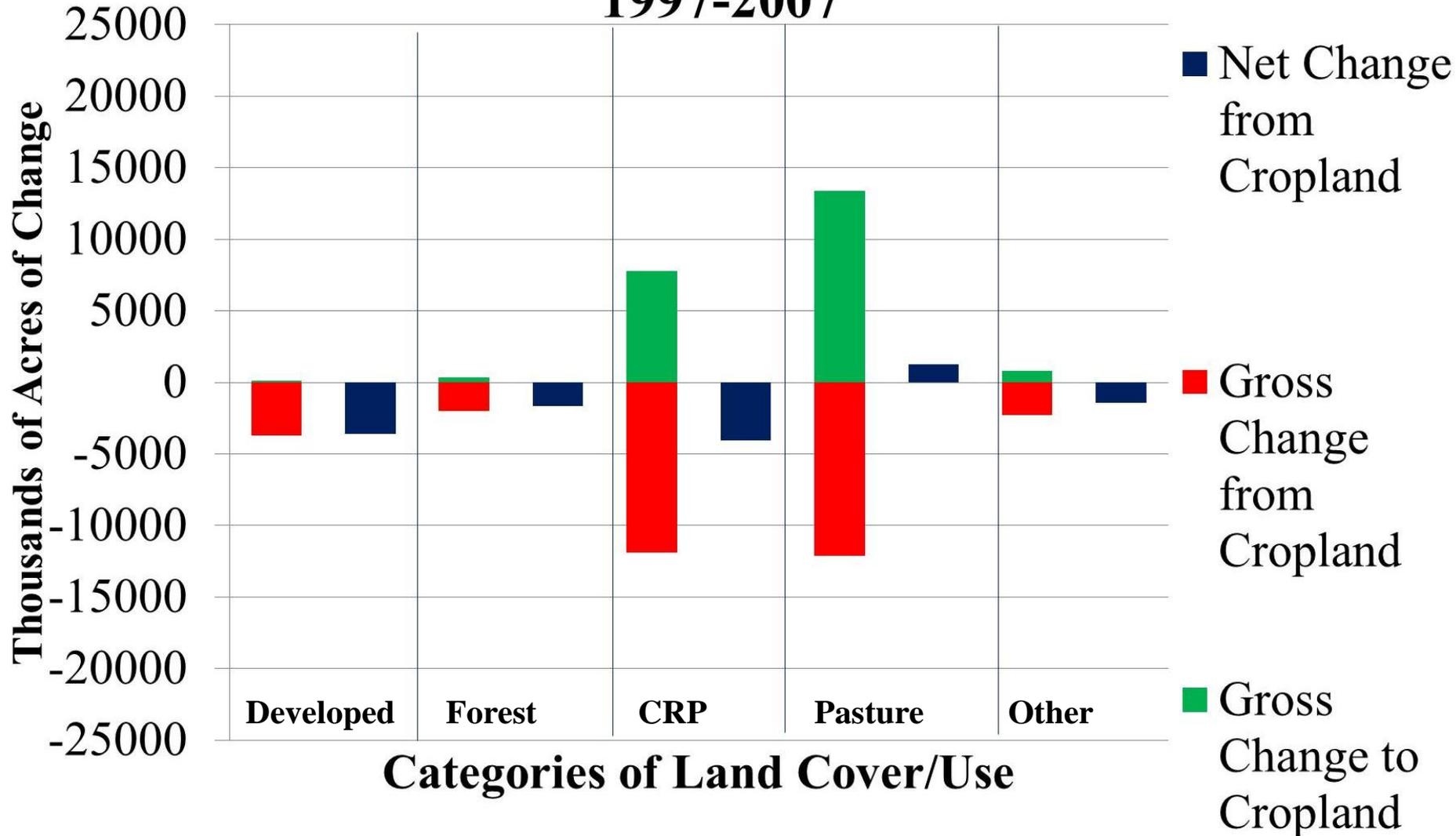


ORNL graphic based on data from the USDA 2009-NRI

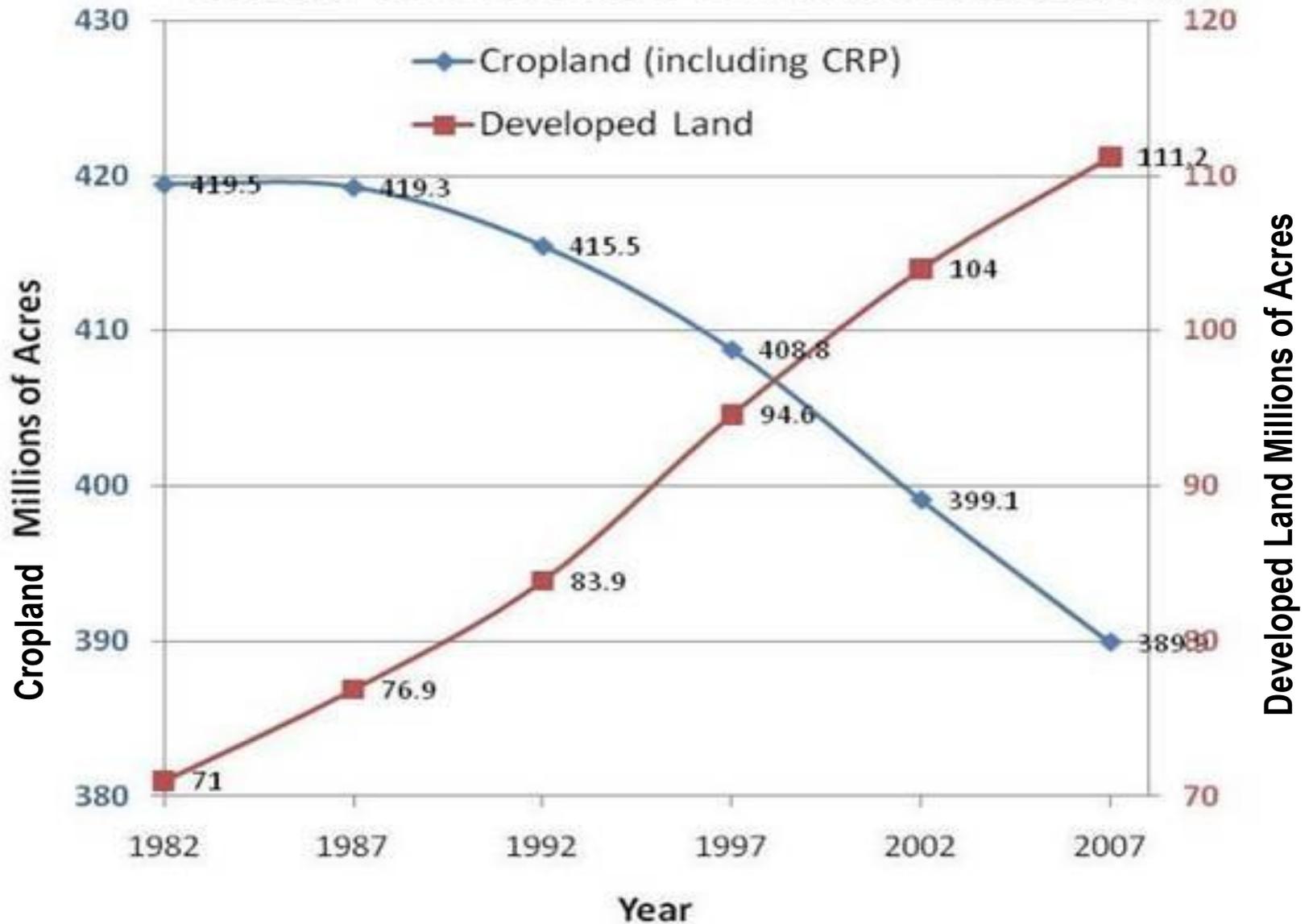
# Stable/static land conditions?

## Comparing Net and Gross Changes in Cropland

1997-2007



# What are Implications of *Real* (not modeled) Change in U.S. Land Use (Source: USDA 2009, NRI)



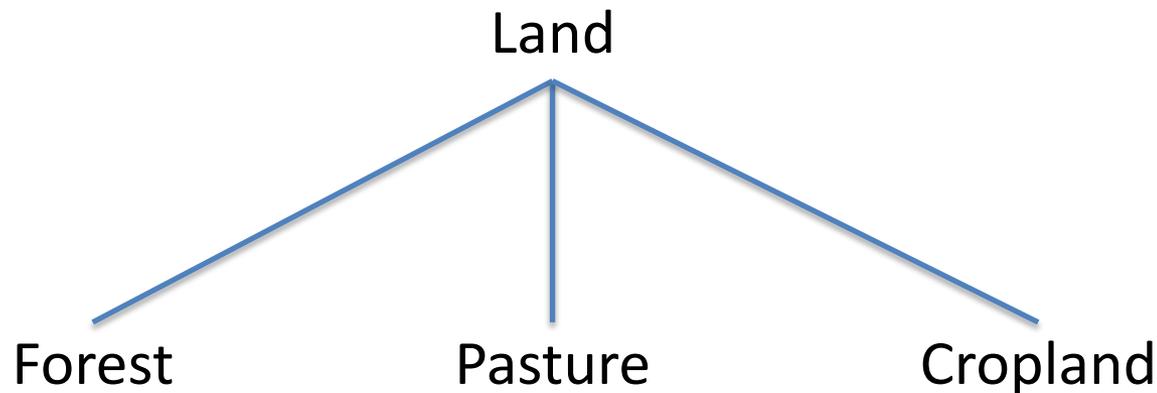
ORNL graphic based on data from the USDA 2009-NRI

# Example: GTAP Model (Tyner et al. 2010)

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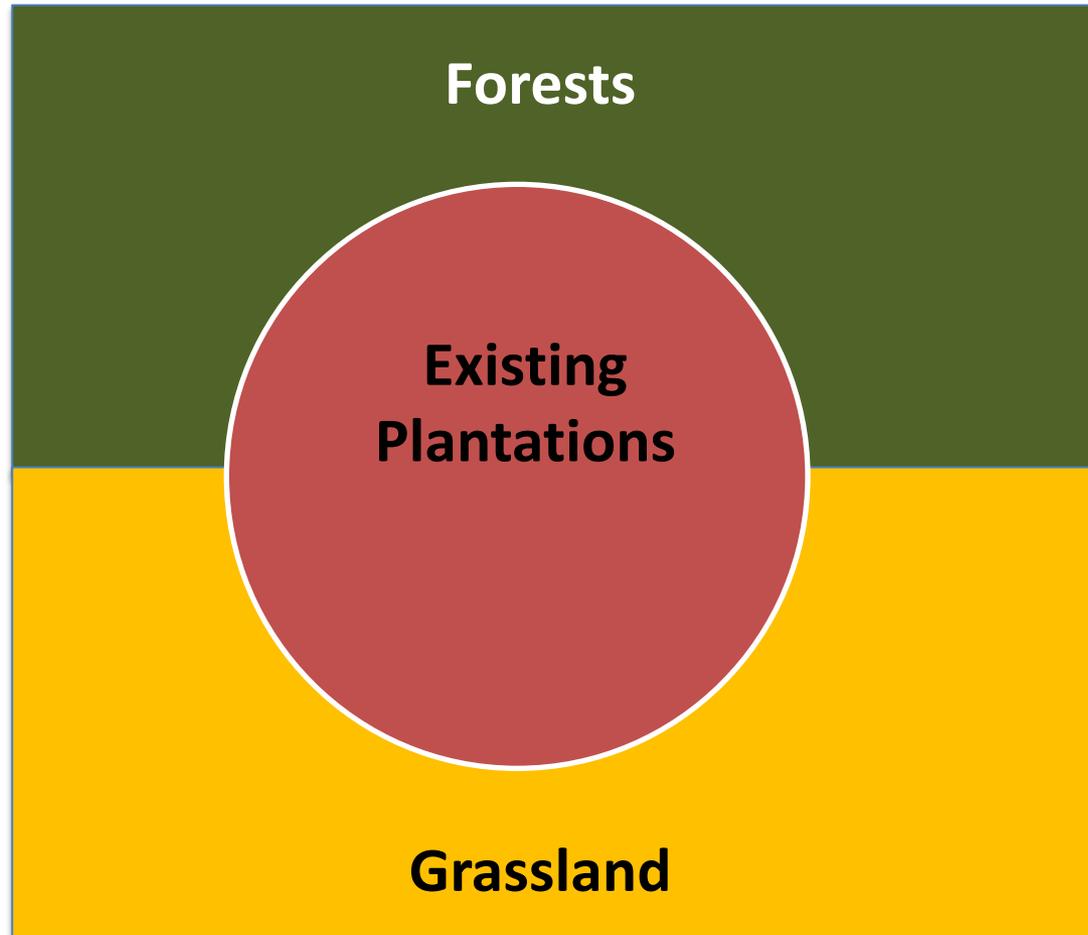
Models are, by definition, simplifications

- Static land-use in baseline – optimal uses assumed
- Shock (change in demand)
- Price-driven responses re-establish ‘equilibrium’



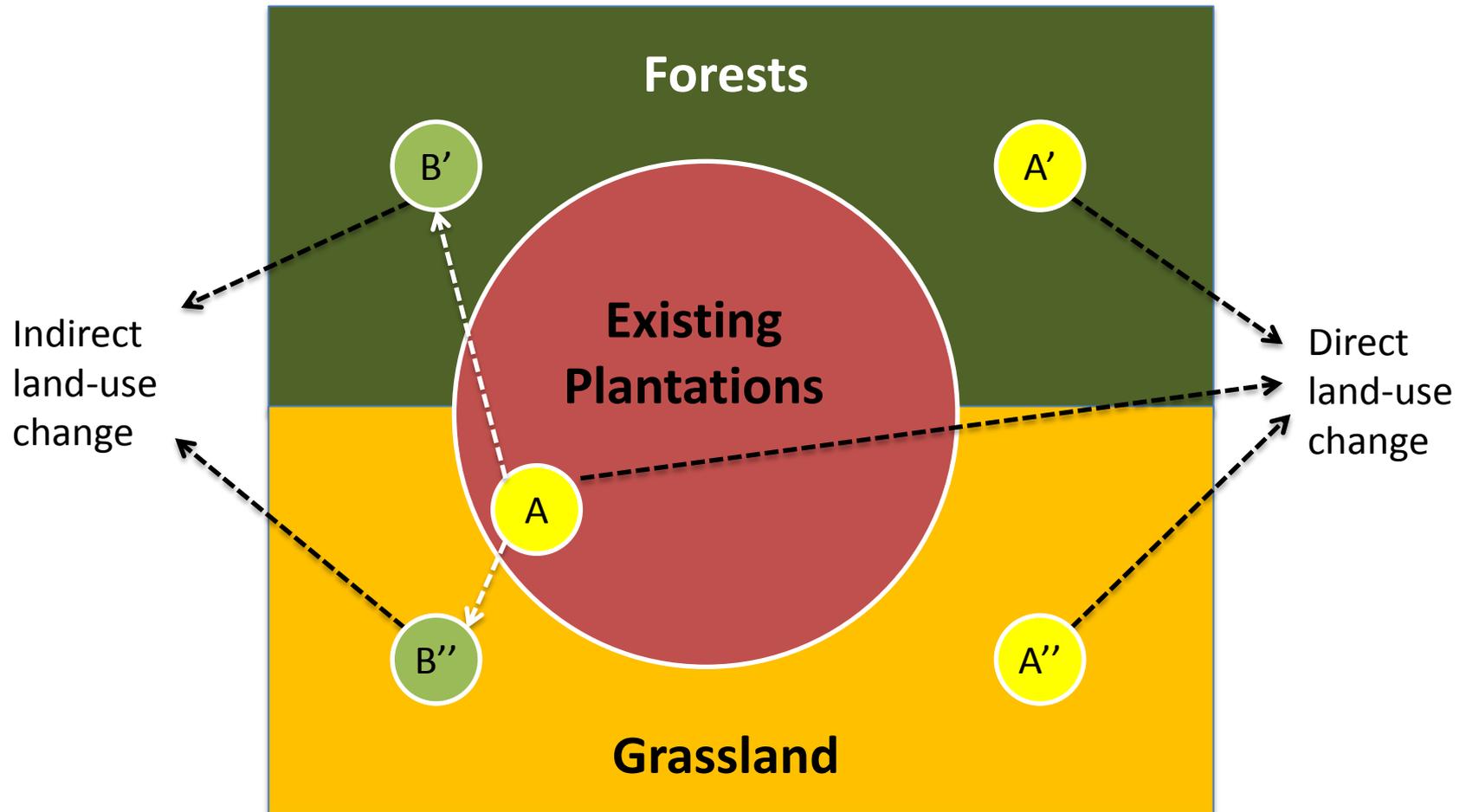
Adapted from Tyner et al., 2010: Figure 1.  
An overview of the GTAP model

Models for land-use change begin with simplified representations of land cover



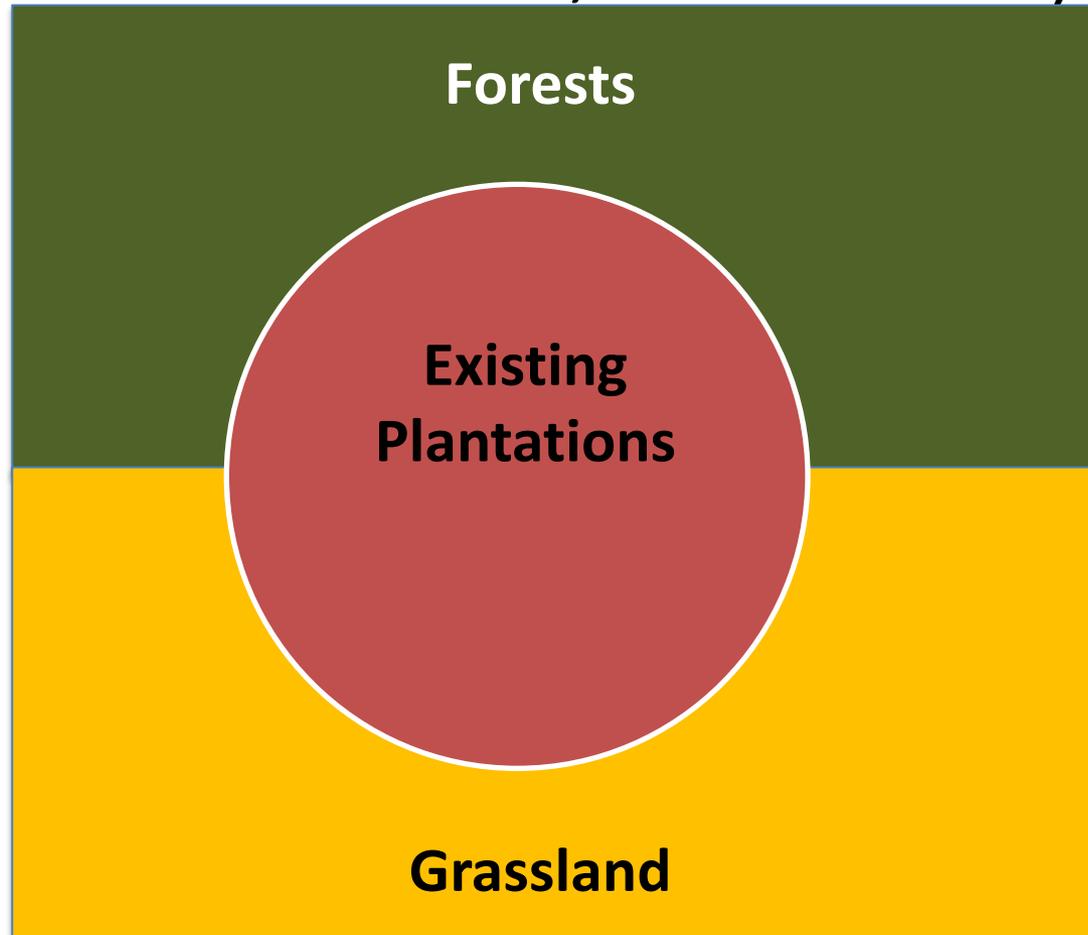
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament),  
Ecofys 2010 (Dehue), Ecofys 2011, OEKO 2010 and others

# Current LUC models: assumptions define direct (A) & potential indirect effects (B)



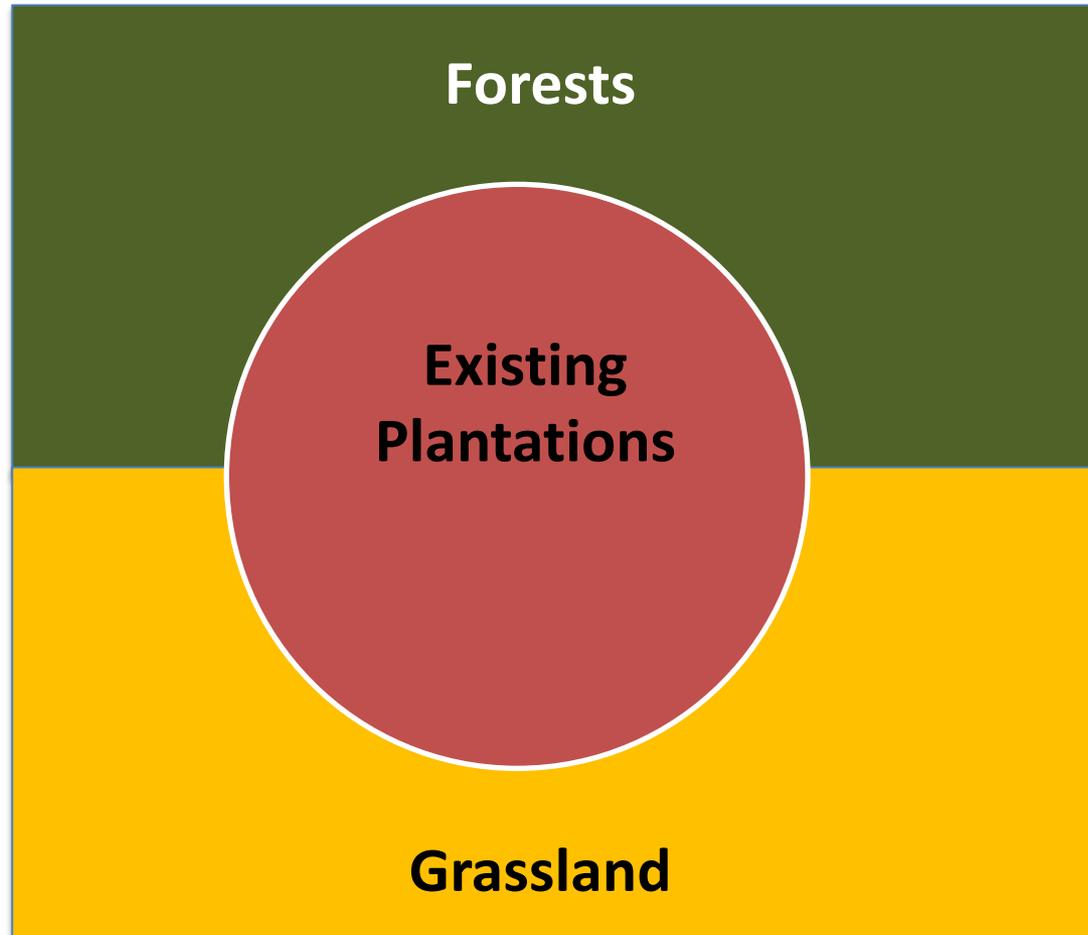
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament),  
Ecofys 2010, Ecofys 2011, OEKO 2010 and others

Models that start with this representation  
presume displacement  
(not “if” but rather, “how much”)



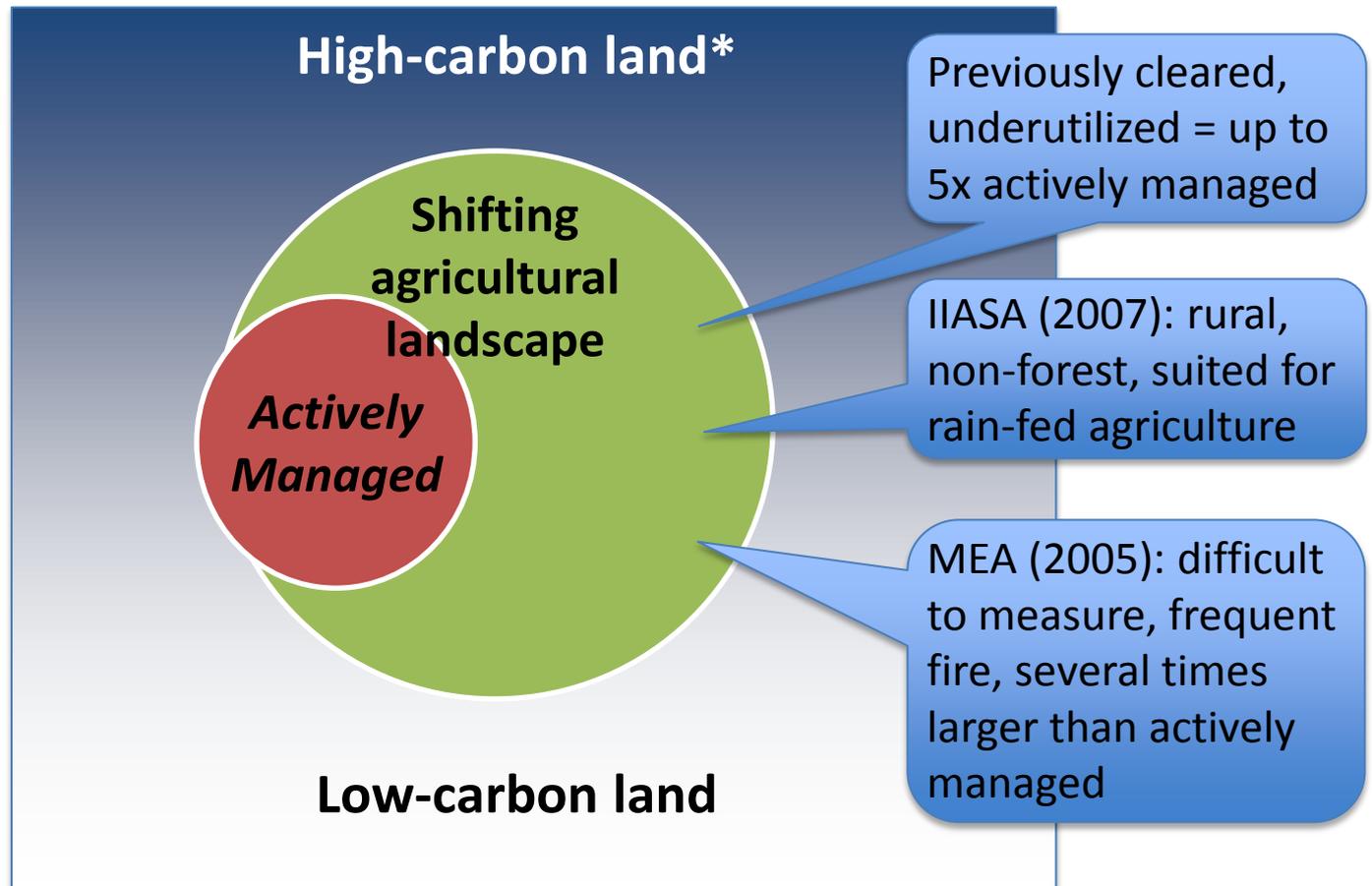
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament),  
Ecofys 2010, Ecofys 2011, OEKO 2010 and others

# What are the alternatives?



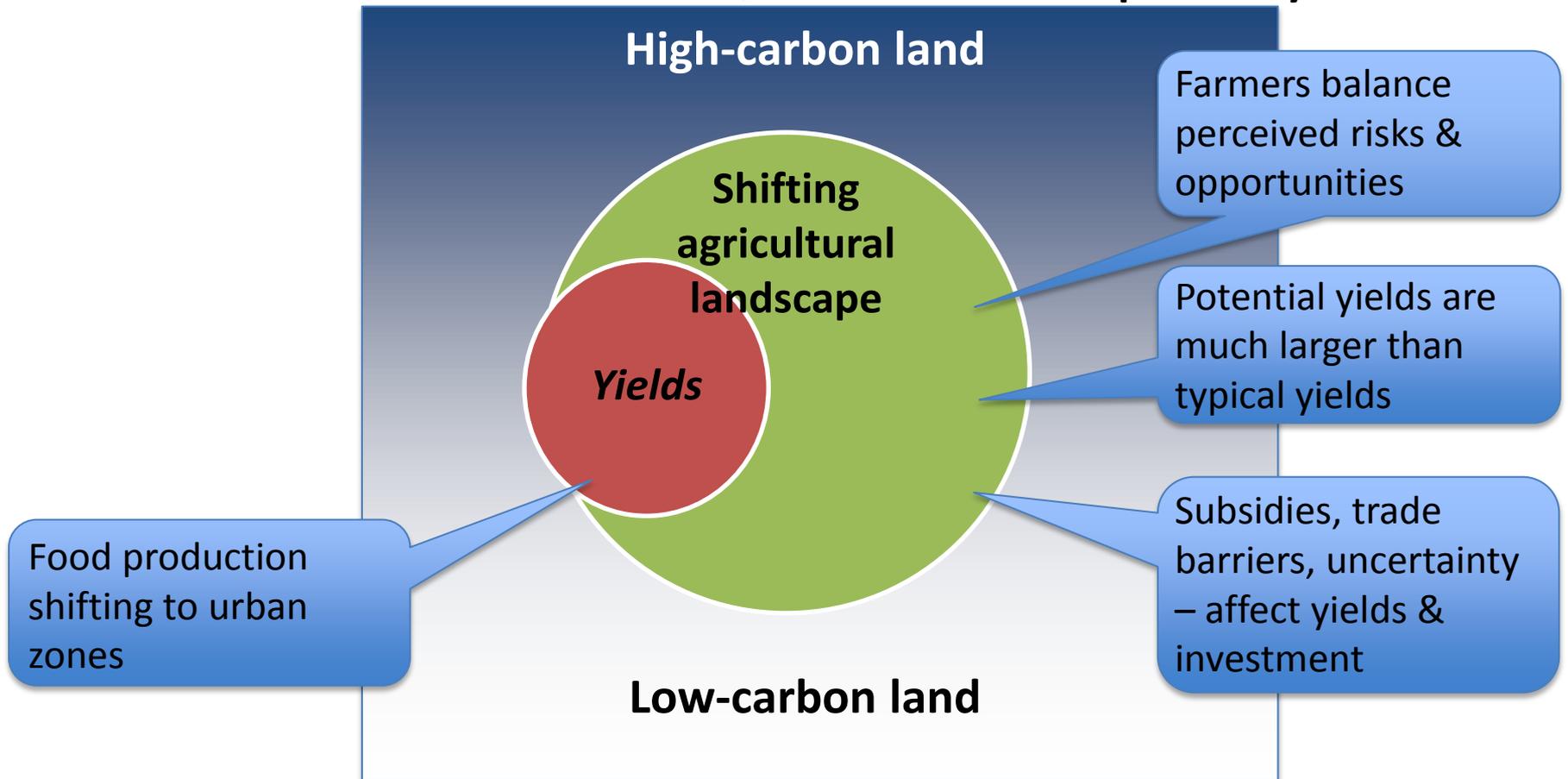
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament),  
Ecofys 2010, Ecofys 2011, OEKO 2010 and others

# Difficult to represent complex dynamics of observed land cover & land use changes

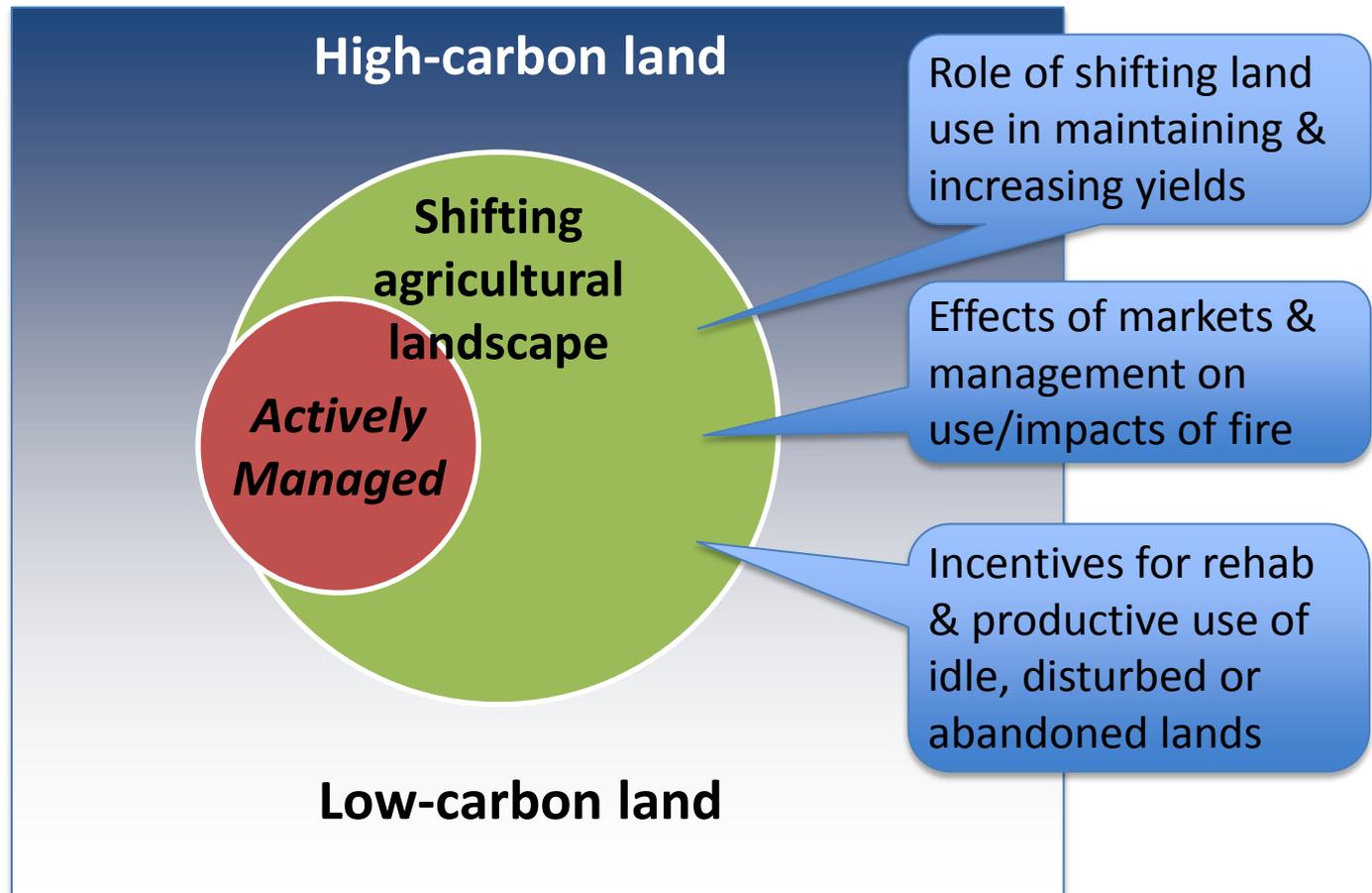


\*Data on nutrient cycling, productivity, environmental services – stocks, flows & potential capacity – all important - it's NOT just about carbon

# Definitions of “land use,” changing yields, urbanization trends, add to complexity



Many data needs (spatial, temporal) for more accurate representation of historic trends



Let's focus on the shifting agricultural landscape...

# Interactions among new markets & product diversification are complex



As observed in U.S\* .:

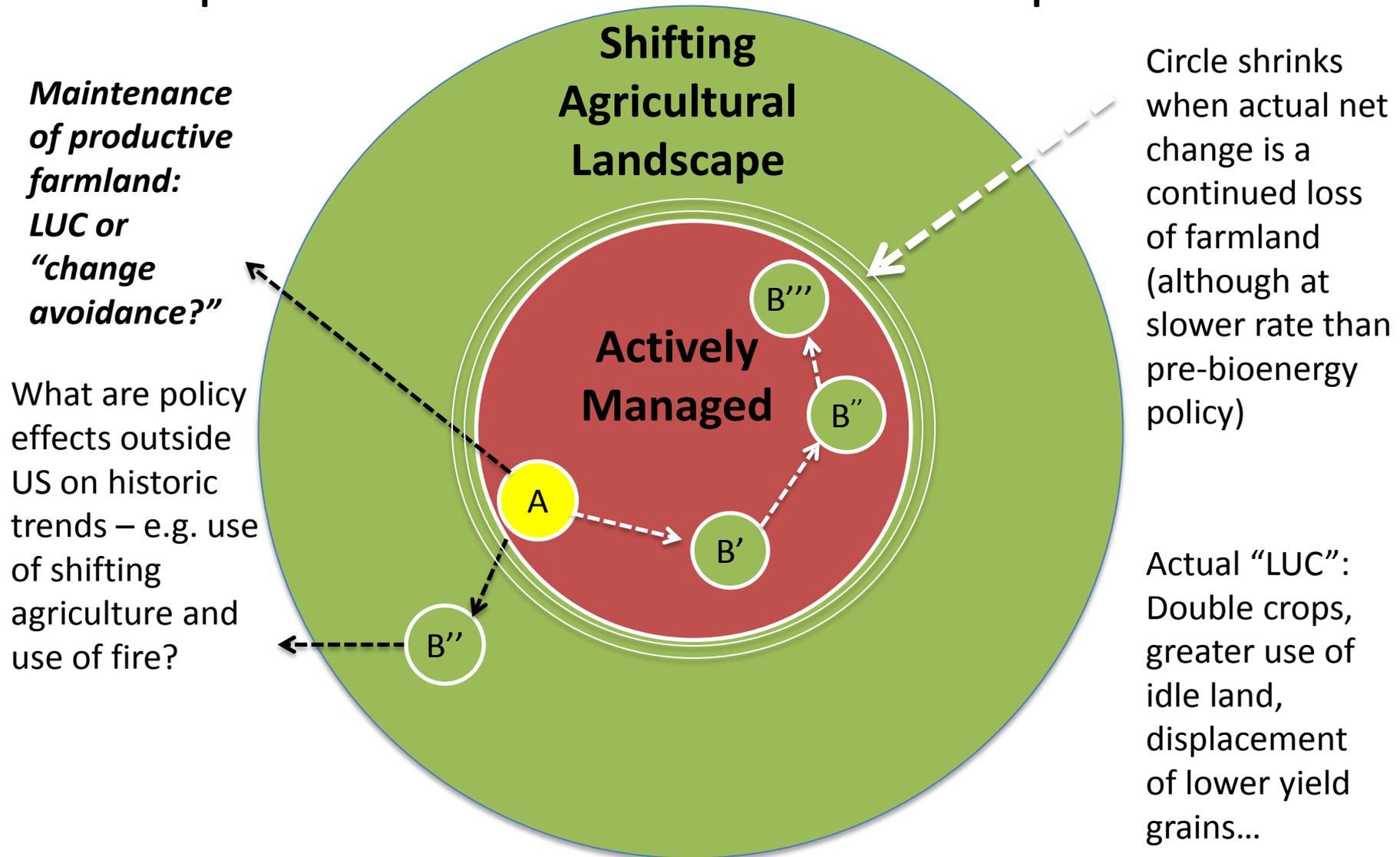
Net changes:  
reduced cotton,  
sorghum  
pasture;  
reduced rate of  
farmland loss

More double-  
crops; higher  
yields

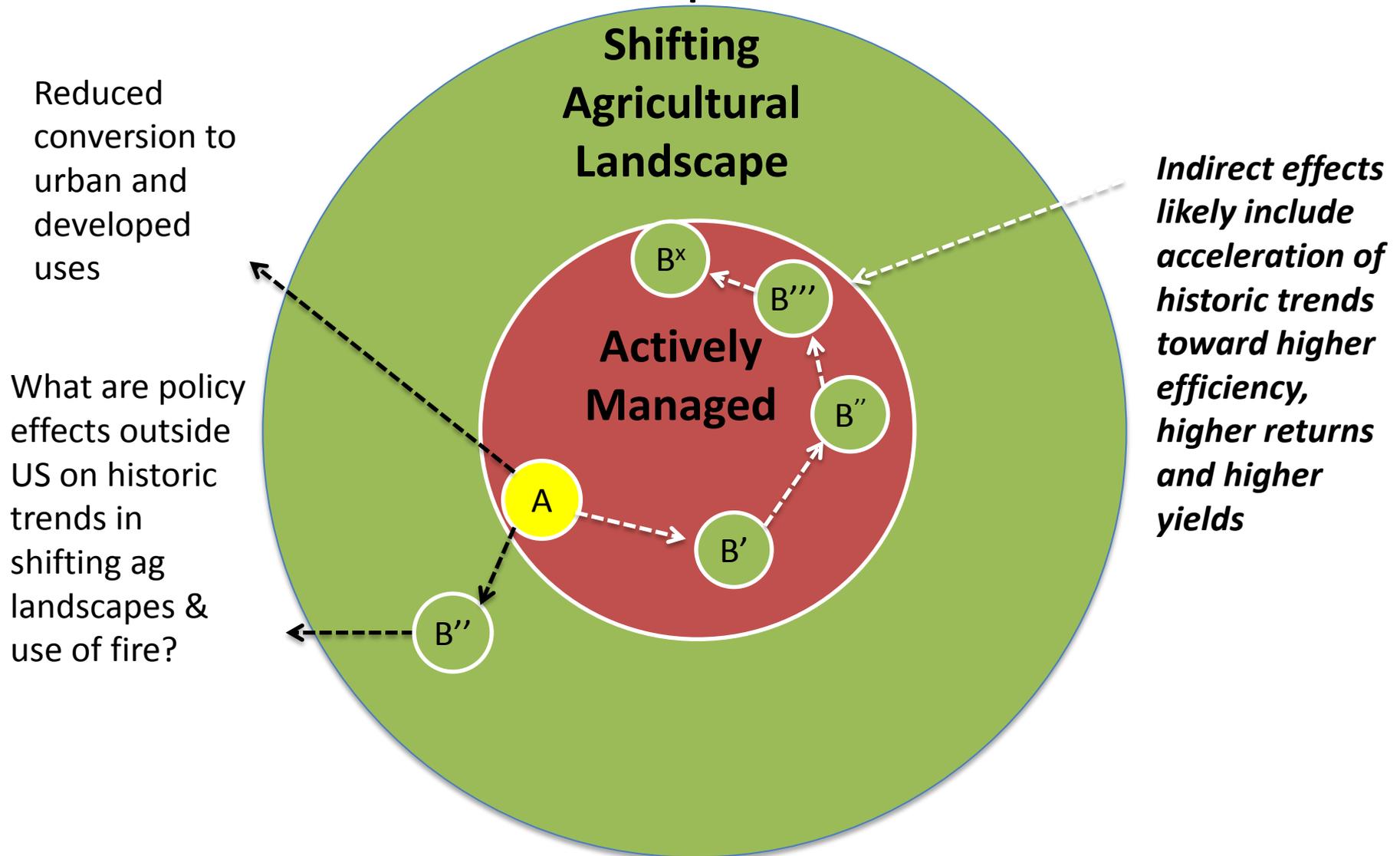
Displacement  
of idle land &  
lower yield  
grains –  
increased  
feed/DDGs  
exports

\* USDA NASS data; Wallander et al. 2011

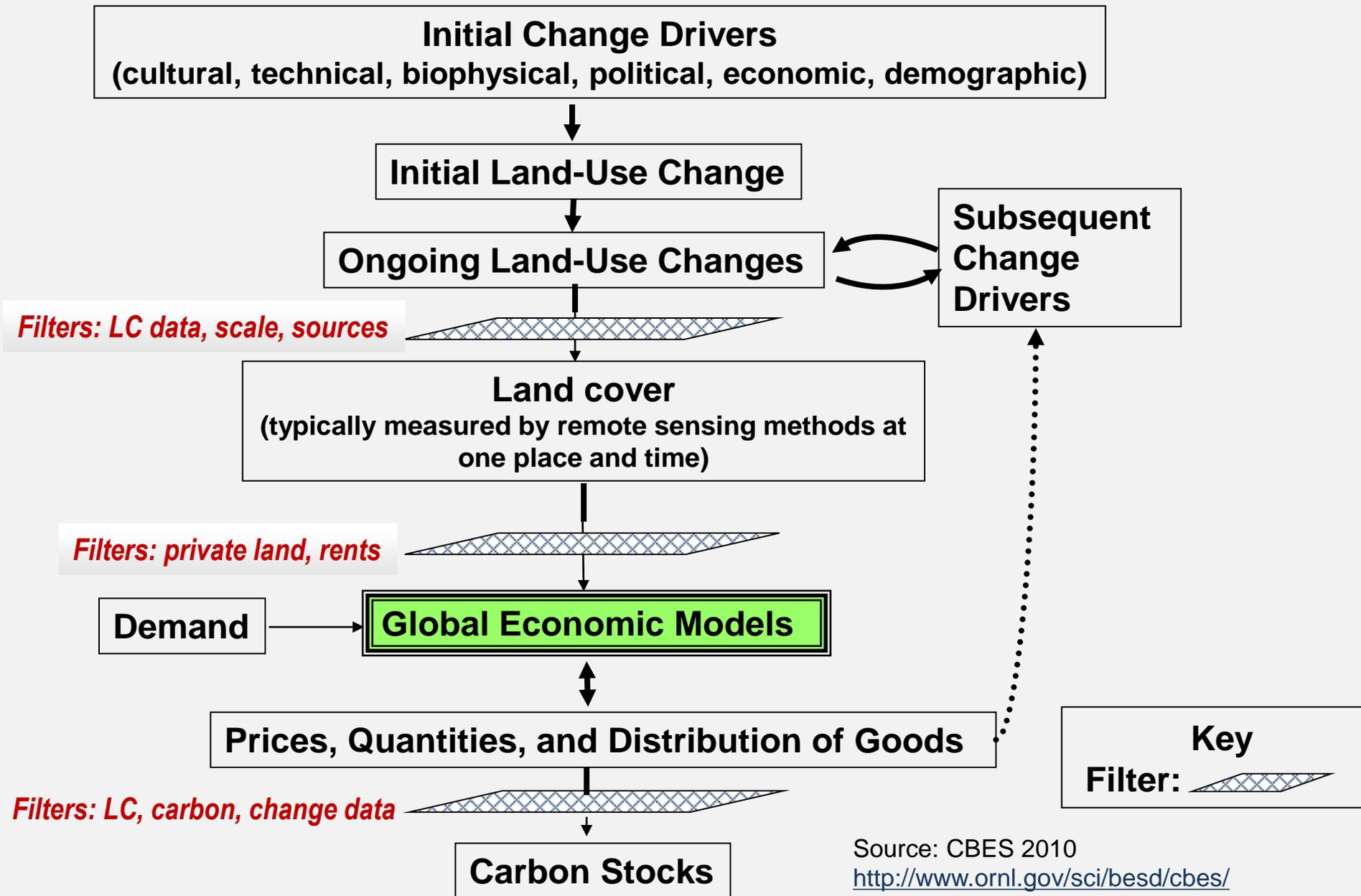
# Interactions among new markets & product diversification are complex



# Interactions among new markets & product diversification are complex



# Land use models - constrained by data, filters



# Decomposition Analysis of Empirical Data

## Findings: minimal land-use change from corn use for ethanol over the last decade

Empirical decomposition analysis showed that recent corn use for ethanol production were largely due to:

- Reallocation of domestic corn consumption in favor of ethanol
- Increases in domestic production of corn – two-thirds from increases in corn yield

**Implication:** The domestic market for corn adjusted flexibly to ethanol production with minimal land-use change and little export market impacts

\*Oladosu G., K. Kline, R. Uria-Martinez and L. Eaton “Sources of corn for ethanol production in the United States: a decomposition analysis of the empirical data”; Biofuels, Bioprod. Bioref. (2011); DOI: 10.1002/bbb.305

# Review of Land Use and Yield Change

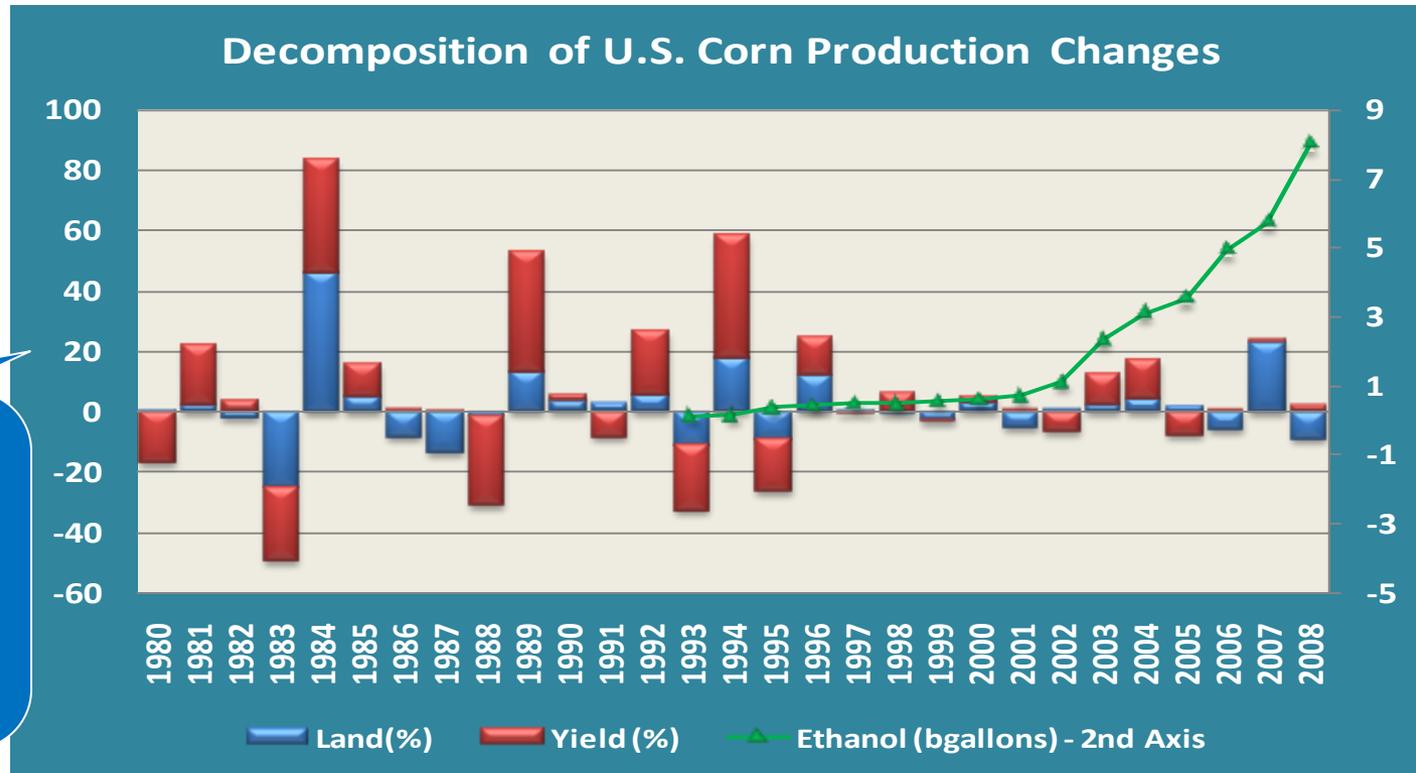
Production equation:

$$Q = Y.L$$

Decomposition:

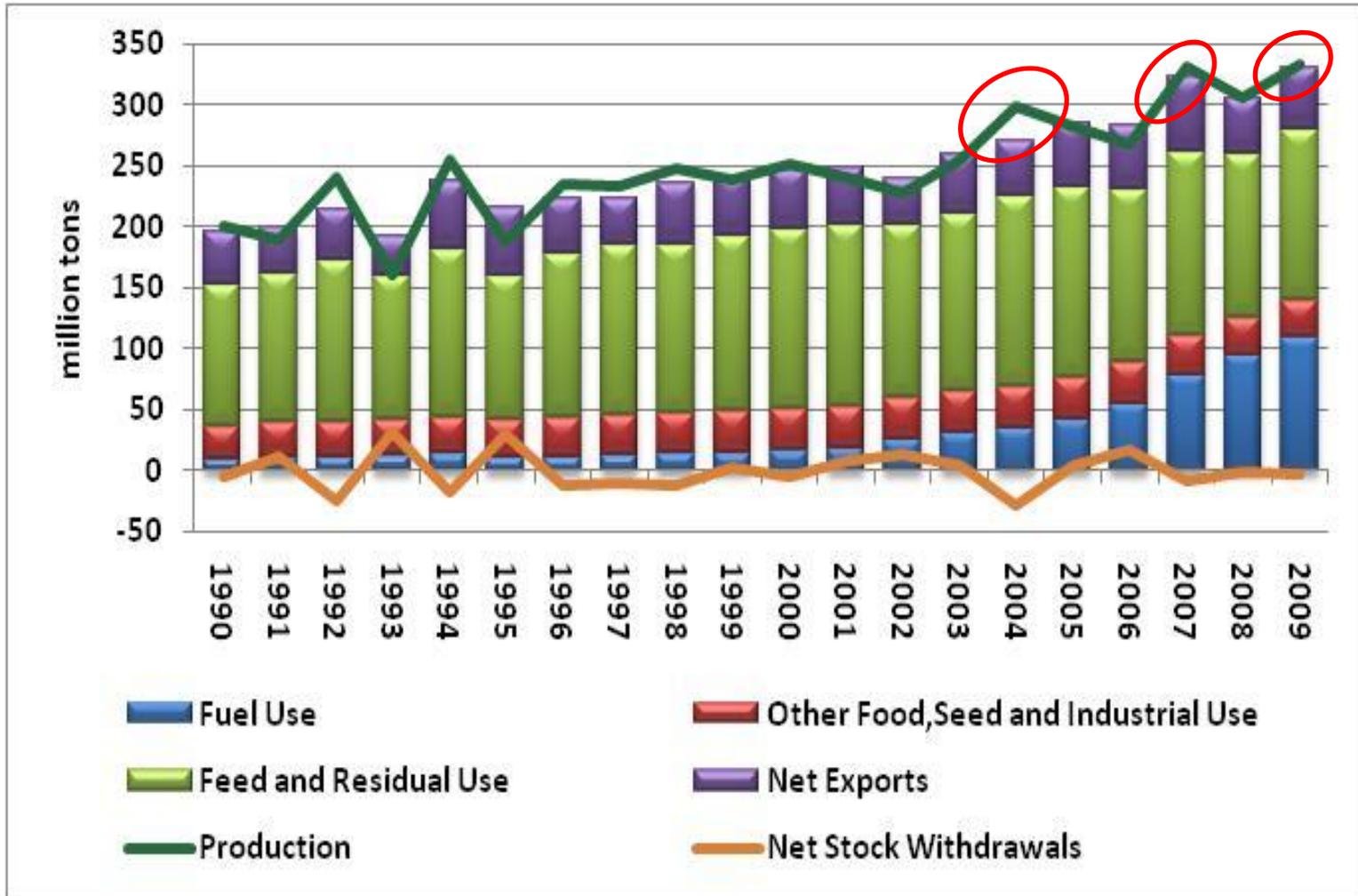
$$\frac{\Delta Q}{Q} = \frac{\Delta Y}{Y} + \frac{\Delta L}{L}$$

Note changes in volatility over time. Also, land and yield contribution tend to change in the same direction



- Yield contribution to growth in production is substantial
- Since 2001, land share exceeds yield share in only 3 years\*
  - 2002 & 2005 were both years of net negative output growth
  - 2007 positive output growth dominated by land increase

# Review of the Empirical Corn Data: Exports Up 50% from 2002 -07, as Use for Ethanol Quintupled



➤ **Corn production increased in 2003, 2004, 2007 & 2009**

Source: Oladosu et al. 2011

# Science and Models

Science follows a *systematic methodology based on evidence*\*

Models are simplified views of the world, not true representations of complexity

Models explore specific relationships

- E.g. “shock” prescribed system to estimate biofuel effects on land
- Results reflect assumptions, baseline, input data, conceptual view
- **Science (data + resources + time) needed to assess and verify assumptions**

There is no scientific consensus on methods or estimates of indirect land use change from bioenergy\*\*  
Don't forget to look outside.



\*Source: Science Council of Britain <http://www.sciencecouncil.org/>

\*\* CARB 2011, final reports from Expert Work Group on LUC. CBES 2010. EC 2010.

# Policy Opportunities to Move Forward

Improve soil  
& water  
management

- Precision management
- Tillage intensity
- Crop mix, rotations, cover crops
- Land restoration
- Technology (plants, microbes, biochar)

Increase  
Efficiency

- Reduce inputs/increase **yields**
- Open, transparent markets
- Minimize transaction costs
- Prioritize, incentivize, measure

Diversify

- Uses & markets
- Substitution options
- Bases of production

Adopt  
Systems  
Perspective

- Multi-scale
- Long term & adaptive
- Integrated land-use plans

# Win–Win options

Good policy & governance are key

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Improve  
livelihoods,  
resilience

Build capacity

Reduce market  
volatility

Provide incentives  
(for things we can  
measure)

Start with what is  
most important

Cooperate  
(plenty we *can*  
agree on)

**Increase system efficiency & capacity to  
provide multiple services over long term**

“With the benefit of hindsight, we may discover that indirect LUC penalties not only lack scientific basis, but also undermine their intended purpose by creating market uncertainty for cleaner alternatives to fossil fuels and by displacing direct performance incentives to improve land management with a complex and costly regulatory framework based on “double guessing” that cannot be verified, measured or managed.”

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Available at [www.sciencedirect.com](http://www.sciencedirect.com)



<http://www.elsevier.com/locate/biombioe>



**Scientific analysis is essential to assess biofuel policy effects:  
In response to the paper by Kim and Dale on “Indirect land-  
use change for biofuels: Testing predictions and improving  
analytical methodologies”**

*Keith L. Kline\*, Gbadebo A. Oladosu, Virginia H. Dale, Allen C. McBride*

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# Thank you!

<http://www.ornl.gov/sci/besd/cbes>

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Related references  
and  
extra slides

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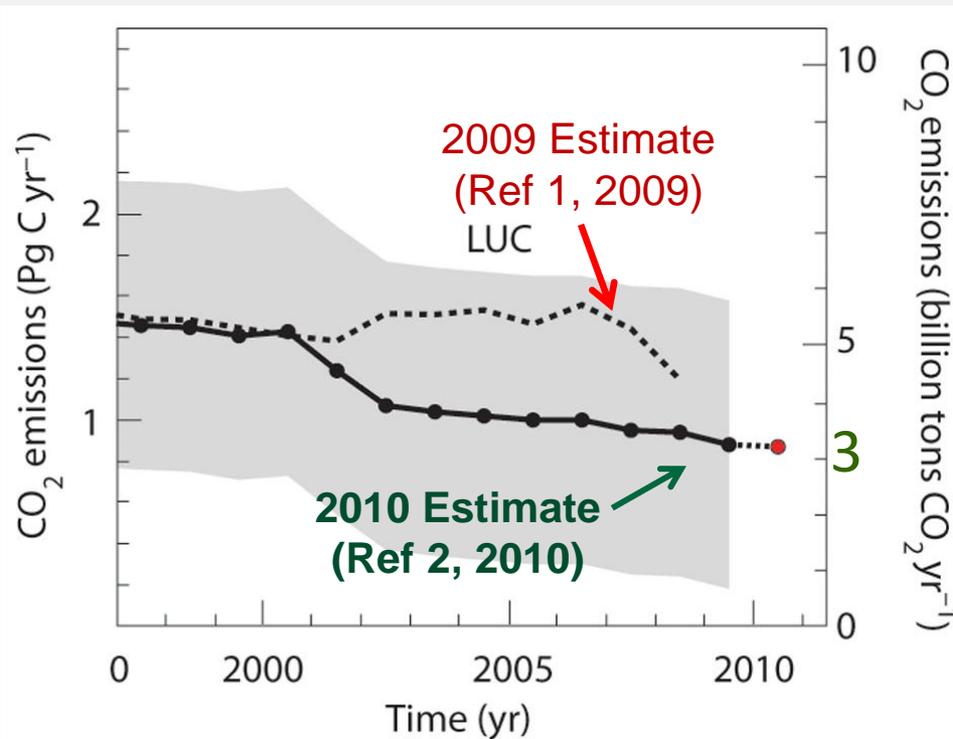
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# Summary: Top Ten Improvements

1. Representation of policy in model specifications
2. Economic decision-making assumptions
3. Conceptual framework for drivers of initial conversion
4. Land supply & management specifications
5. Assumed land use dynamics (scenarios, baseline choice)
6. Modeling yield change
7. Issues of time, scale
8. Fire & other disturbances
9. Correlation versus causation
10. Many, many data issues to resolve

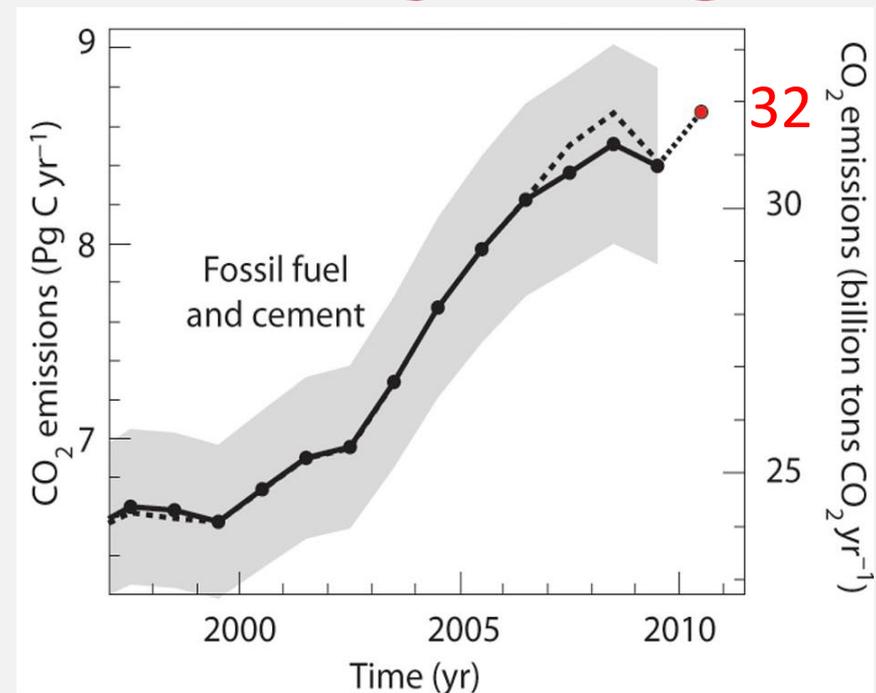


# LUC emissions down; still “guesstimates”



Shaded areas around lines represent estimated range of uncertainty

# Fossil emissions rapidly rising

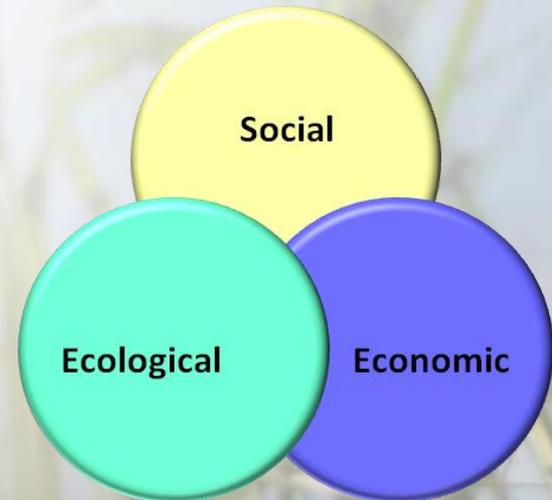


>90% of current CO<sub>2</sub> emissions are from fossil fuel; fossil share rapidly and more certainly rising

Sources: (1) Le Quéré, C. et al. Nature Geosci.v2, 831–836 (2009).  
(2) Friedlingstein et al. Nature Geosci.v3, 811–812, (Nov. 2010).

# Sustainability

- Contextual, relative (more/less) & process based (a trajectory not a “state”)
- Scales matter
- Systems approaches can optimize socio-economic & ecologic benefits of bioenergy
- Sustainability implications of biofuel choices are complex
- Definitions and assessment involves stakeholder participation and a suite of measures
- You can only manage what you can measure



# Related Publications (ORNL)

- Kline KL, et al. 2011 (in press; on-line Sept. 10). Scientific analysis is essential to assess biofuel policy effects: In response to the paper by Kim and Dale on “Indirect land use change for biofuels: Testing predictions and improving analytical methodologies.” *Biomass and Bioenergy*; doi:10.1016/j.biombioe.2011.08.011
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