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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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 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

It depends

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

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nature

ANALYSIS

doi:10.1038/nature10452

Solutions for a cultivated planet

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

- 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

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

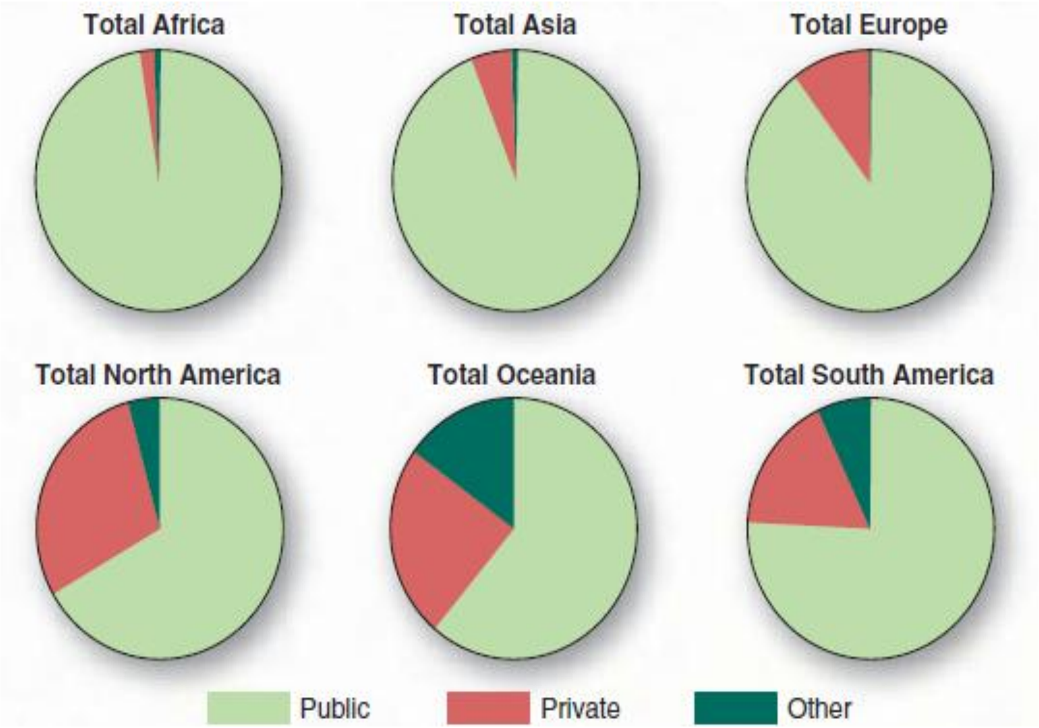
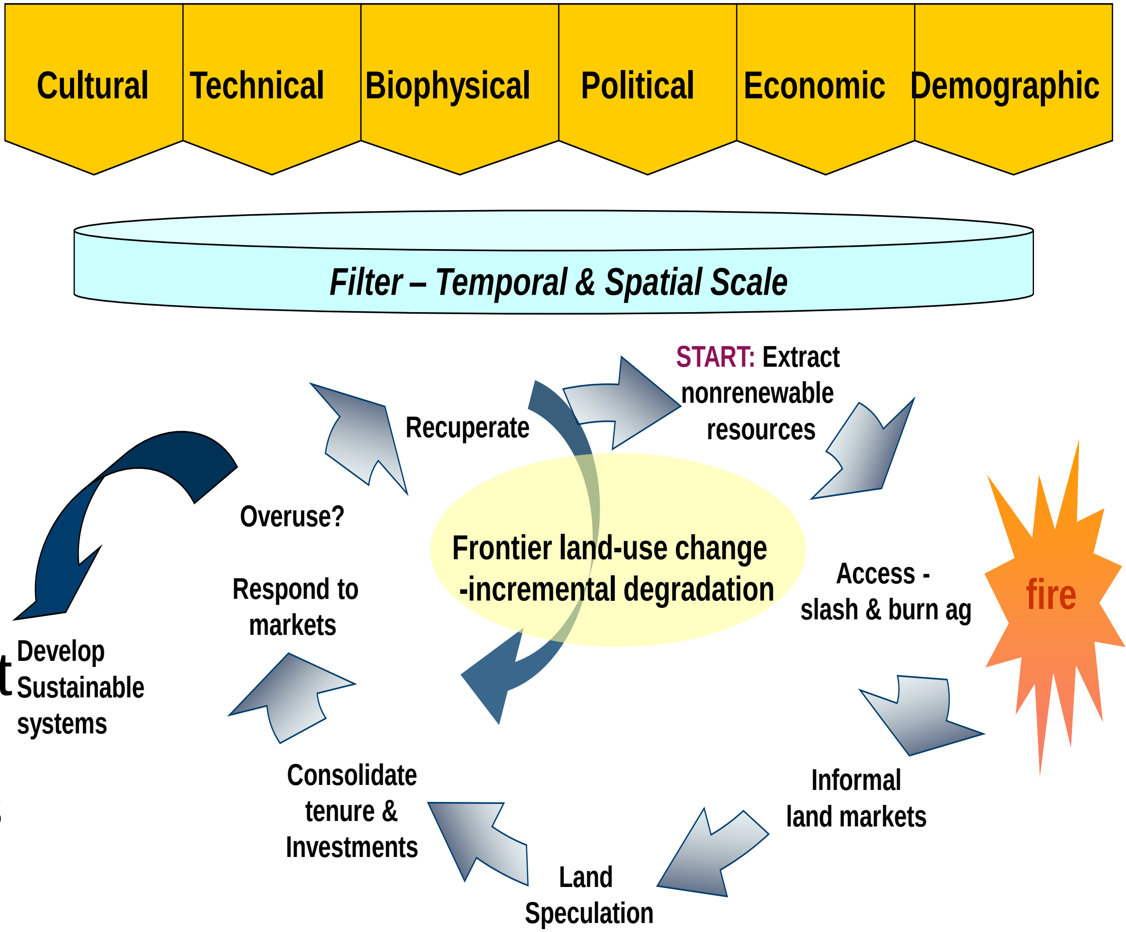


Figure: Agrawal et al., 2008, Science 320 (based on FAO data)

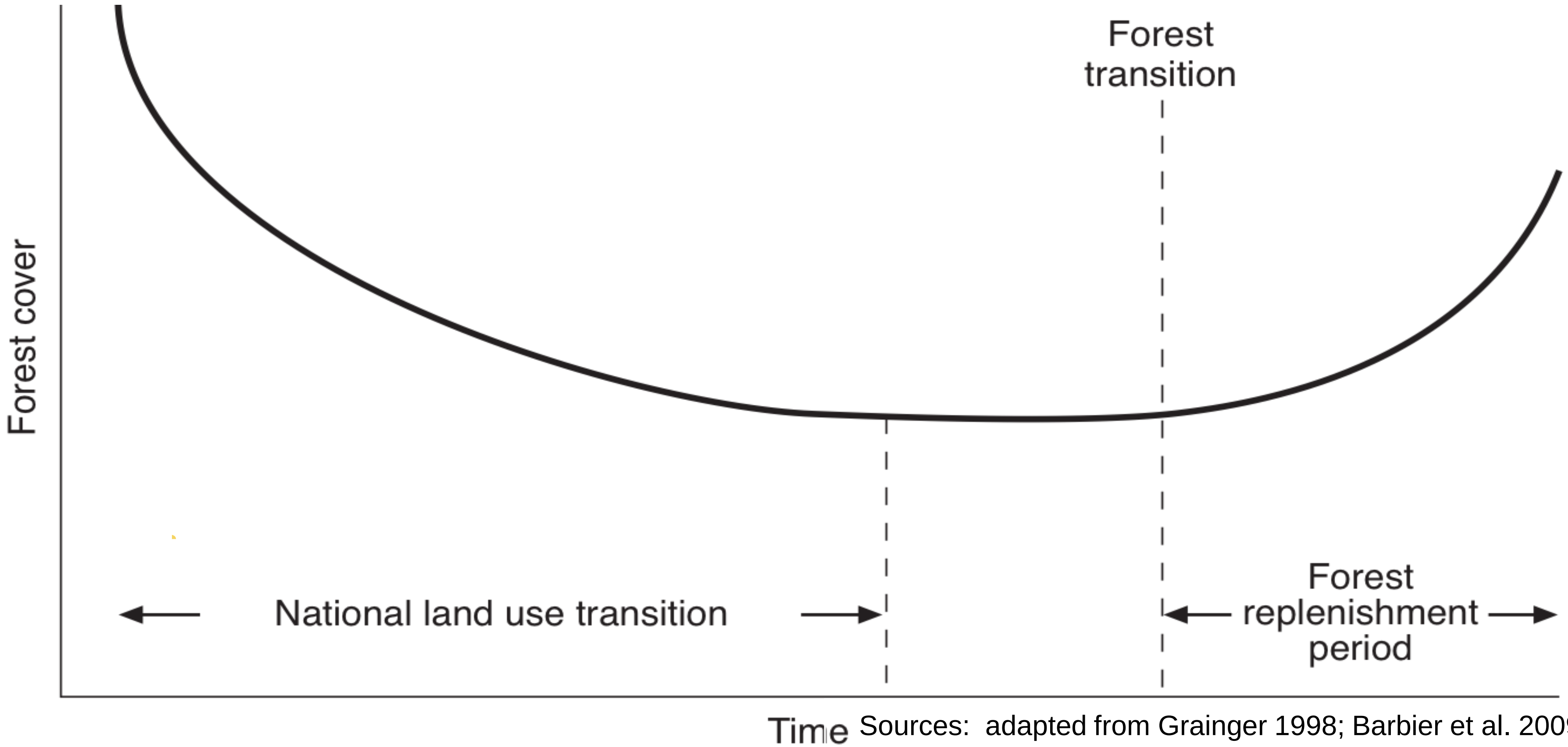
Conceptual framework for drivers of initial conversion

- 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

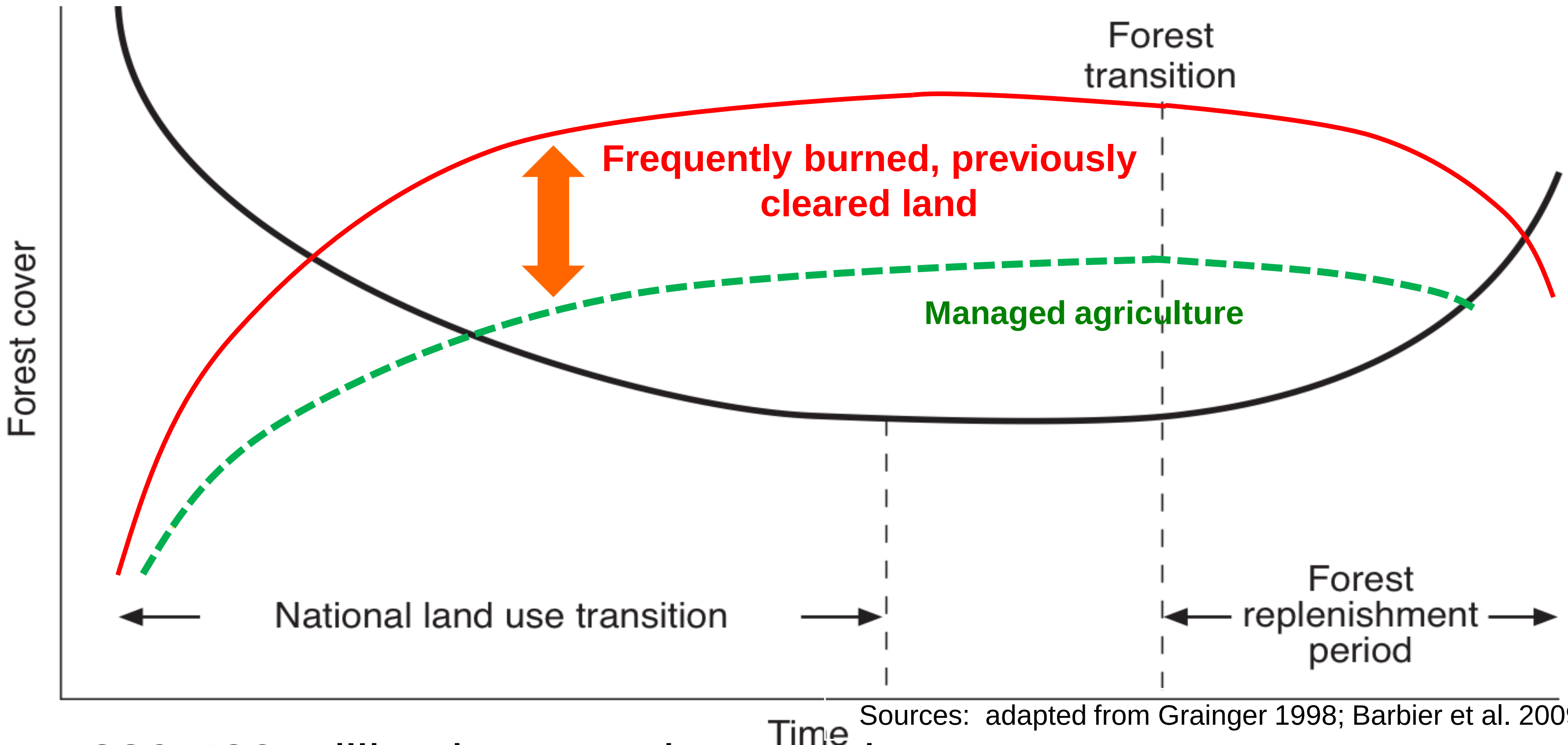
Alternative perspectives: Forest Transition Model



Sources: adapted from Grainger 1998; Barbier et al. 2009

- 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.



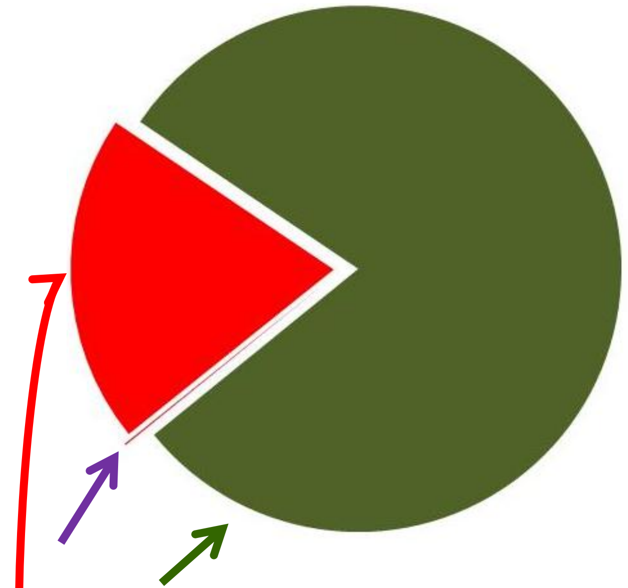
Sources: adapted from Grainger 1998; Barbier et al. 2009

- 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)

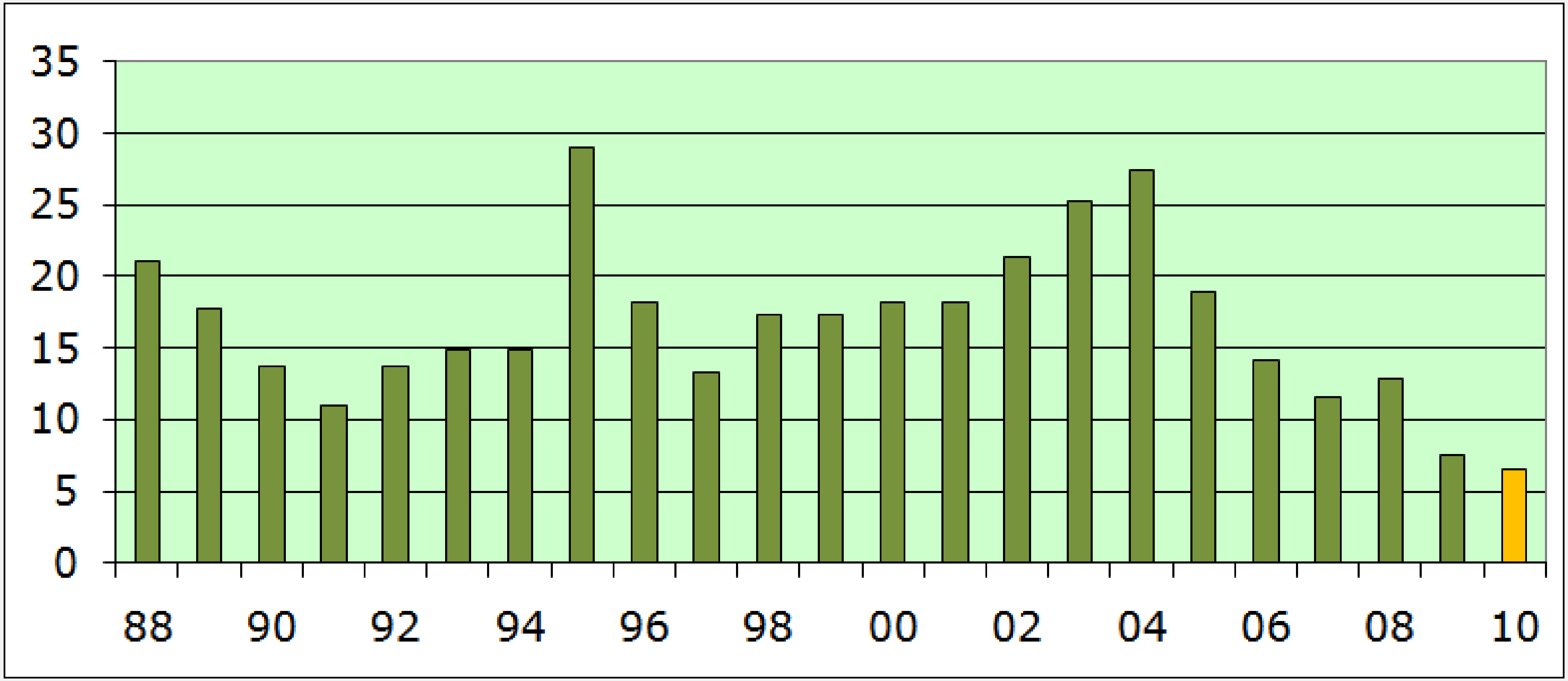
Global area burned each year = 380 M ha

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)**

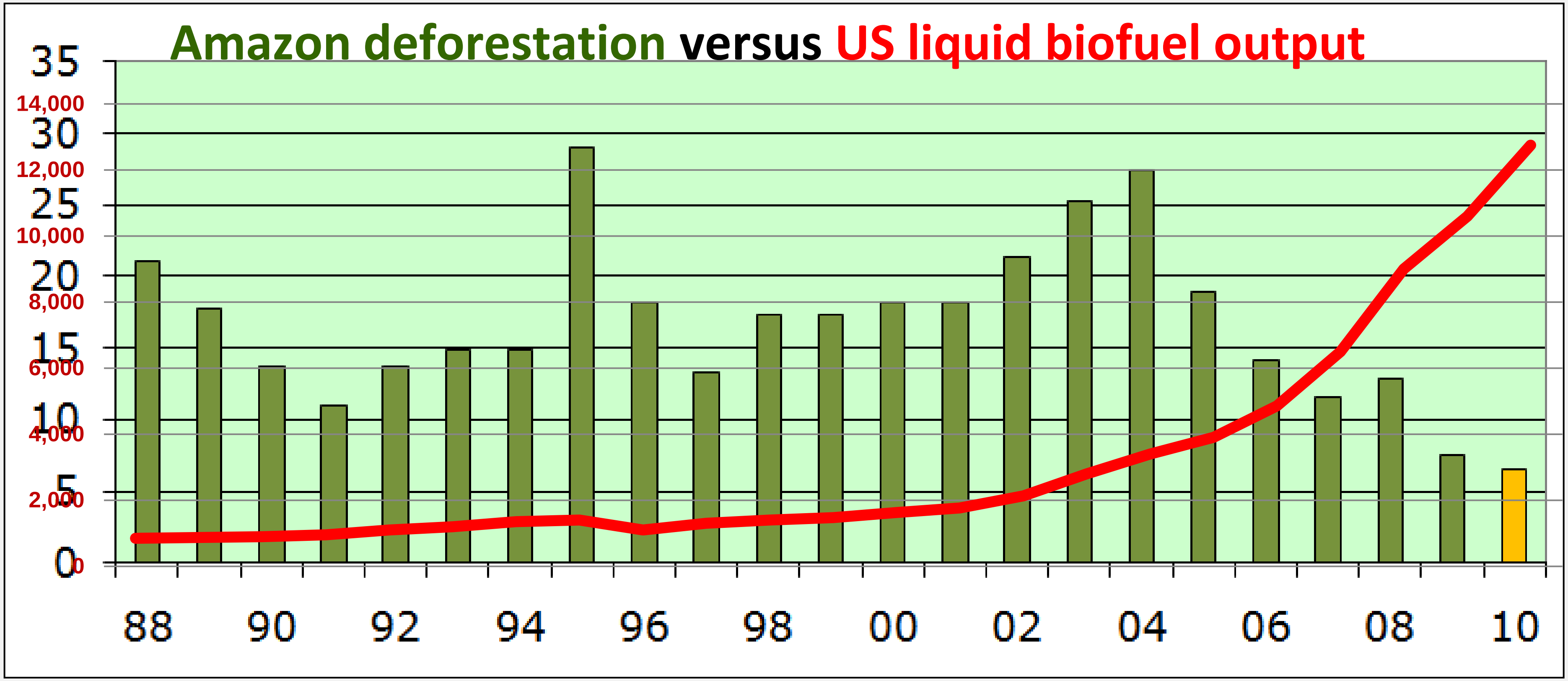


Deforestation rate in Brazil's Amazon, thousands square km per year

Source: INPE-PRODES Brazil Space Agency: http://www.dpi.inpe.br/gilberto/present/prodes_taxa2010.ppt 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?



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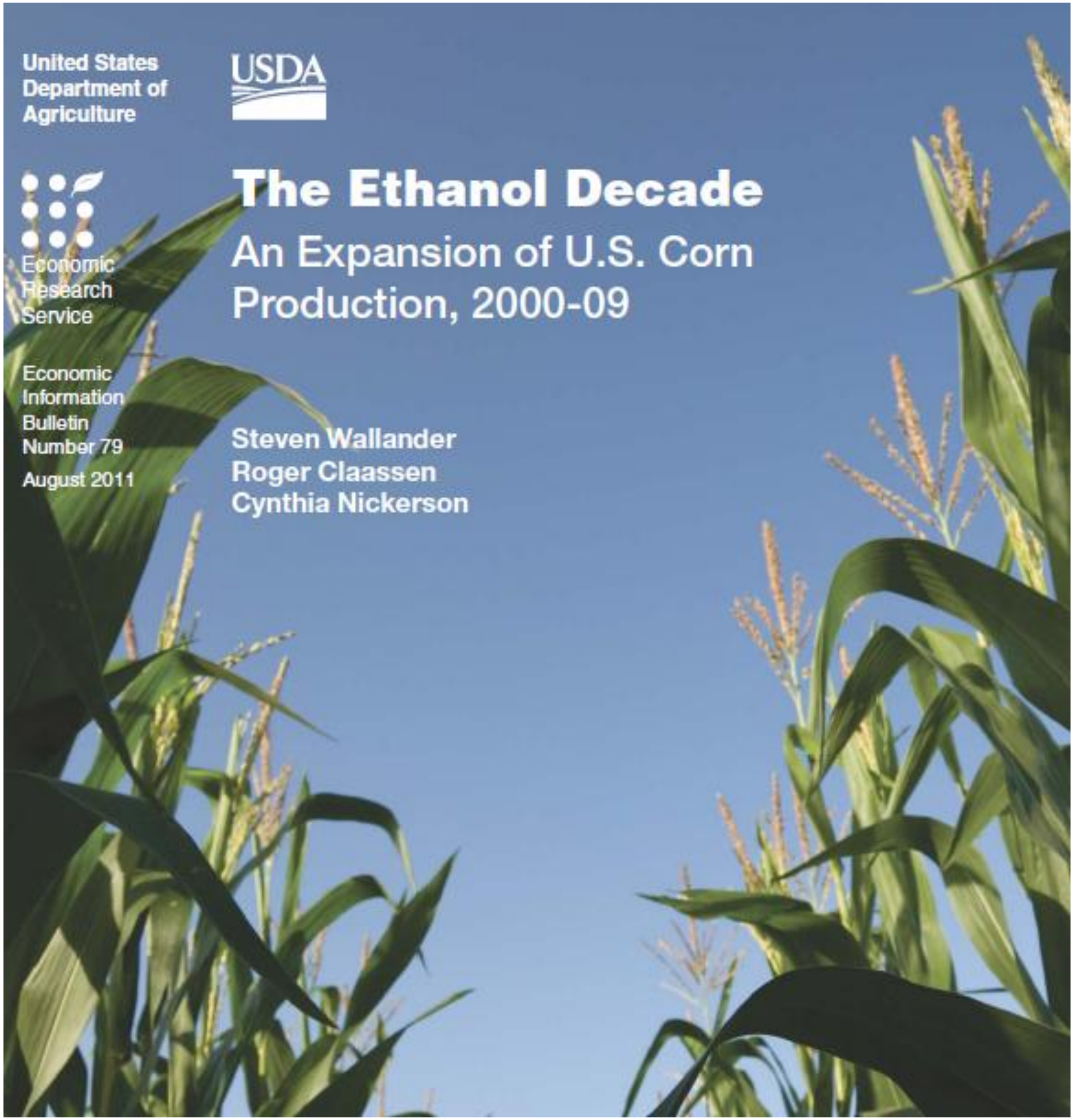


Wallander et al. 2011. *The Ethanol Decade: An Expansion of U.S. Corn Production, 2000-09.* EIB-79. Economic Research Service/USDA, August, 2011.

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
			Billion gallons		
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
			Predicted change in land-use/cropping selection		
			Million acres		
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)

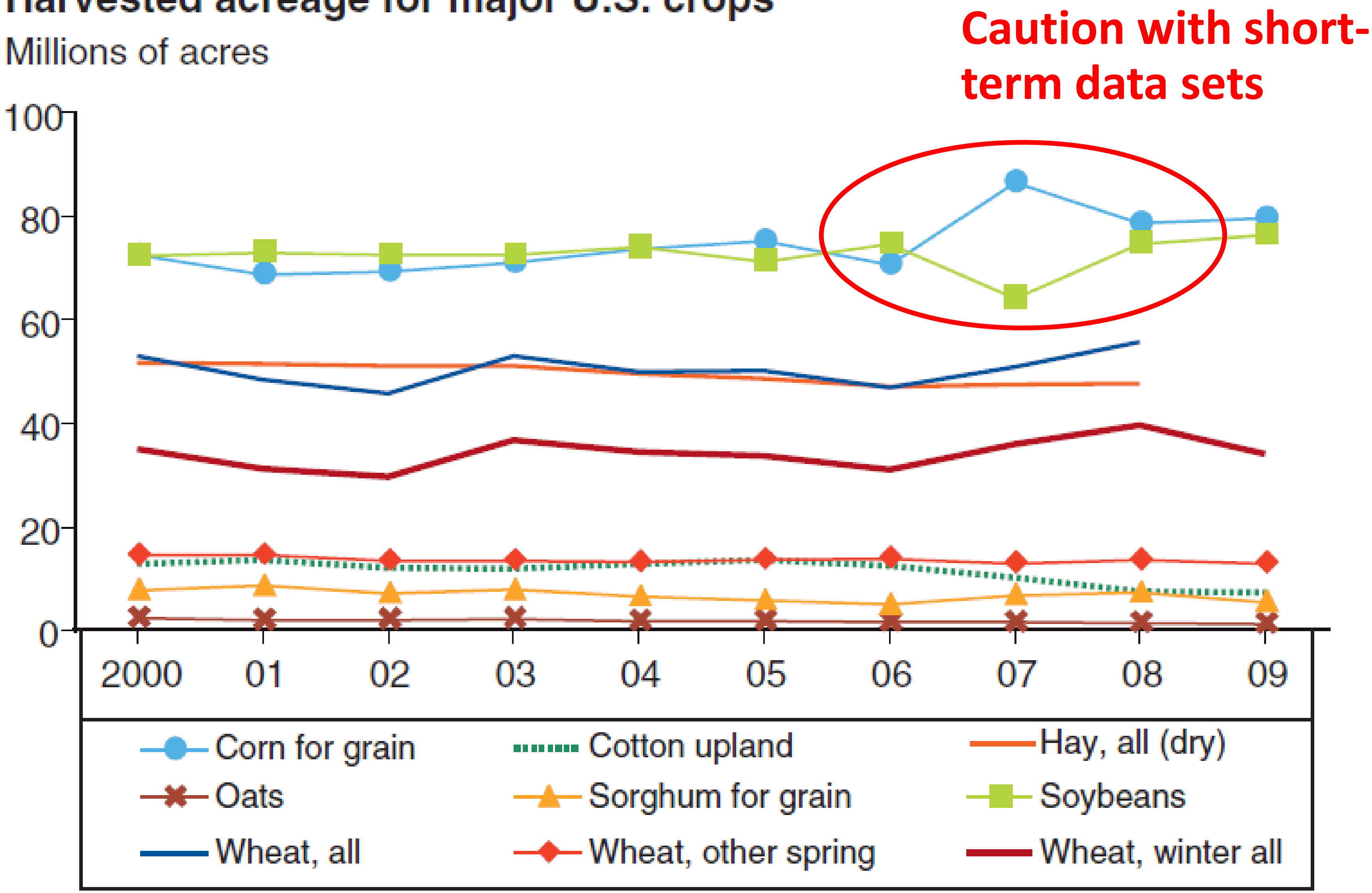
EPA–U.S. Environmental Protection Agency.
RFS2–Renewable Fuel Standard Program.
RIA–Regulatory Impact Analysis.
FASOM–Forest and Agricultural Sector Optimization Model.
FAPRI-CARD–Food and Agricultural Policy Research Institute-Center for Agricultural and Rural Development.
Source: Searchinger et al., 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.

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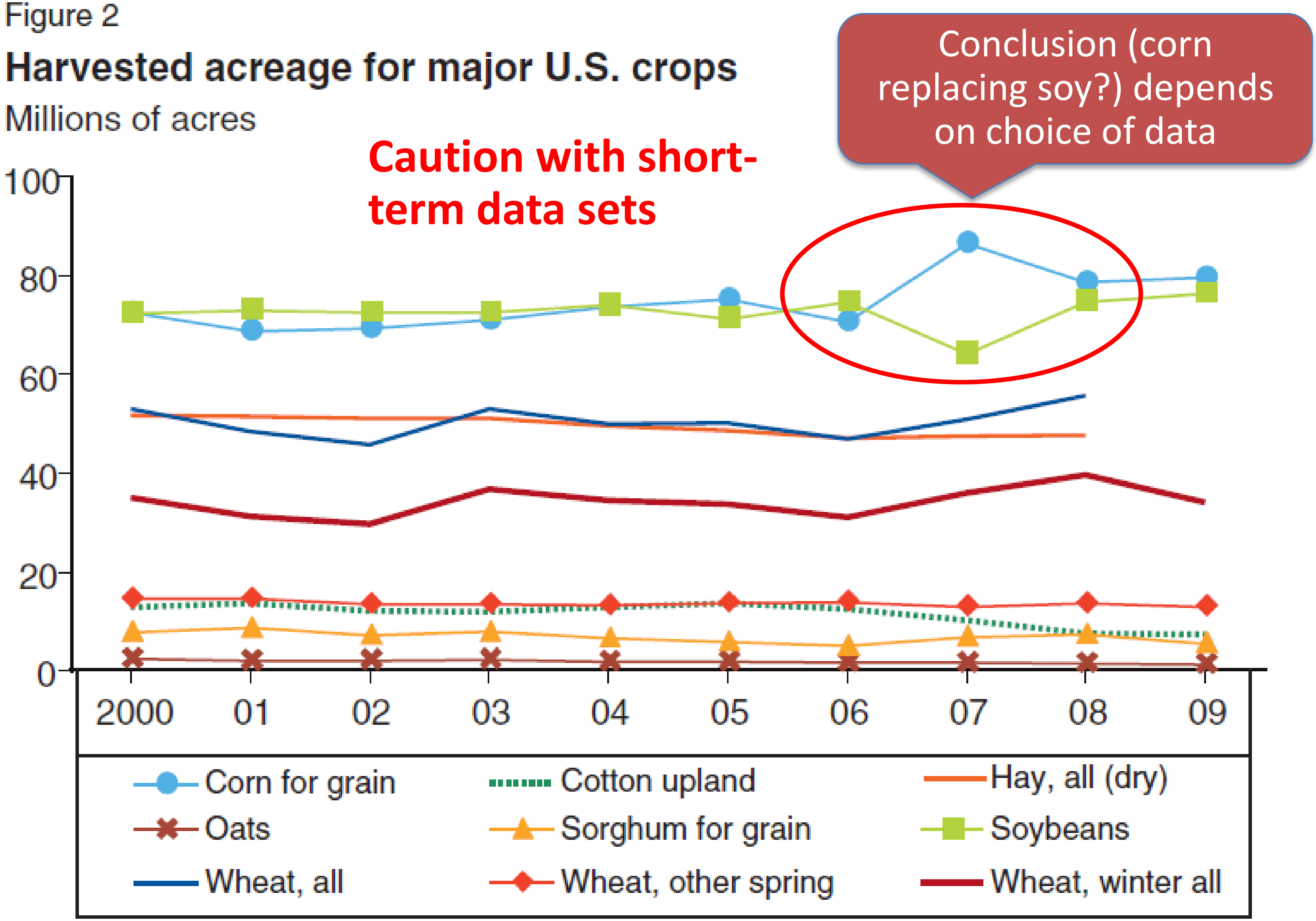

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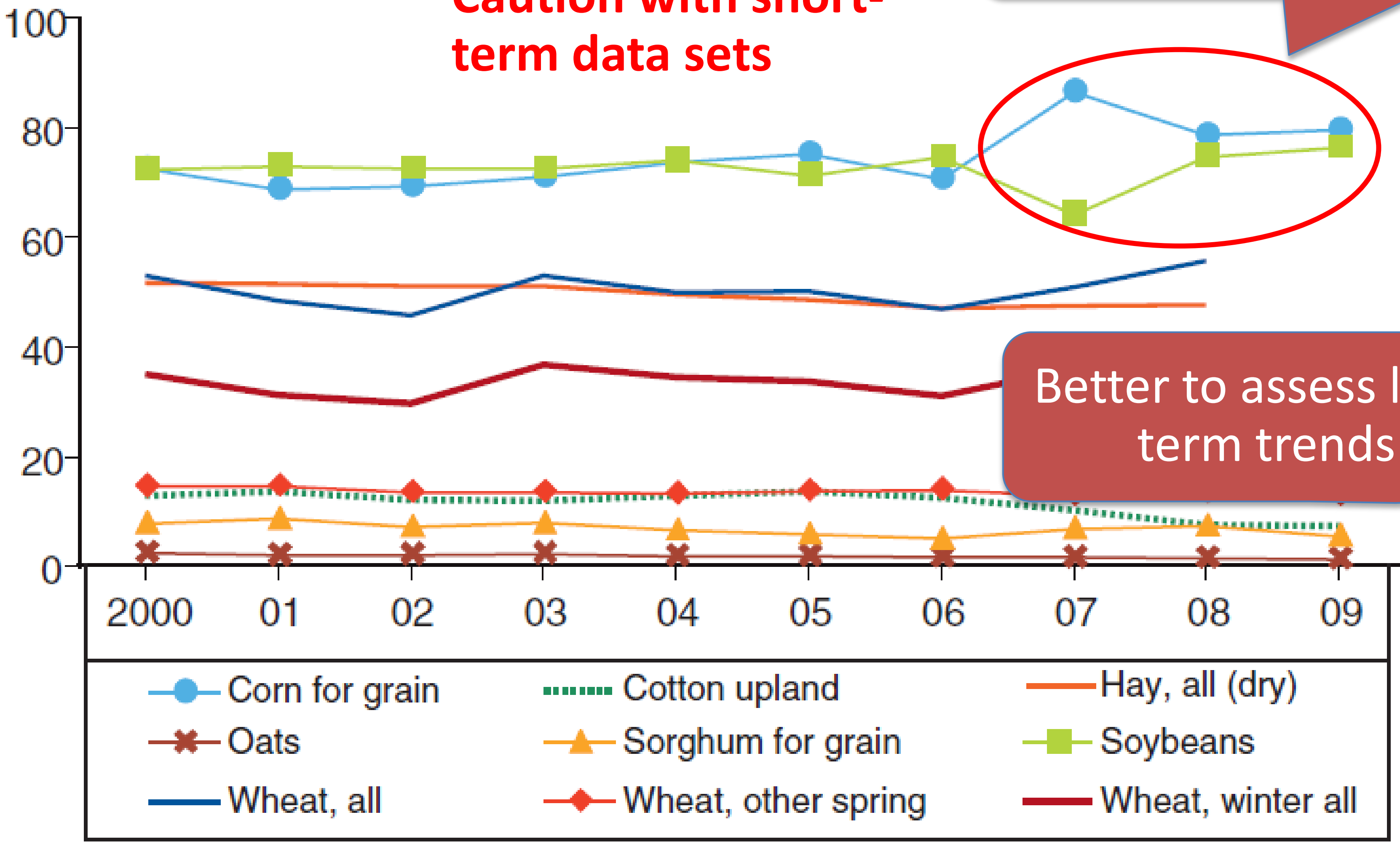
Harvested acreage for major U.S. crops

Millions of acres

Caution with short-term data sets

Opposite conclusion (soy replacing corn) depends on data choice



Better to assess long-term trends

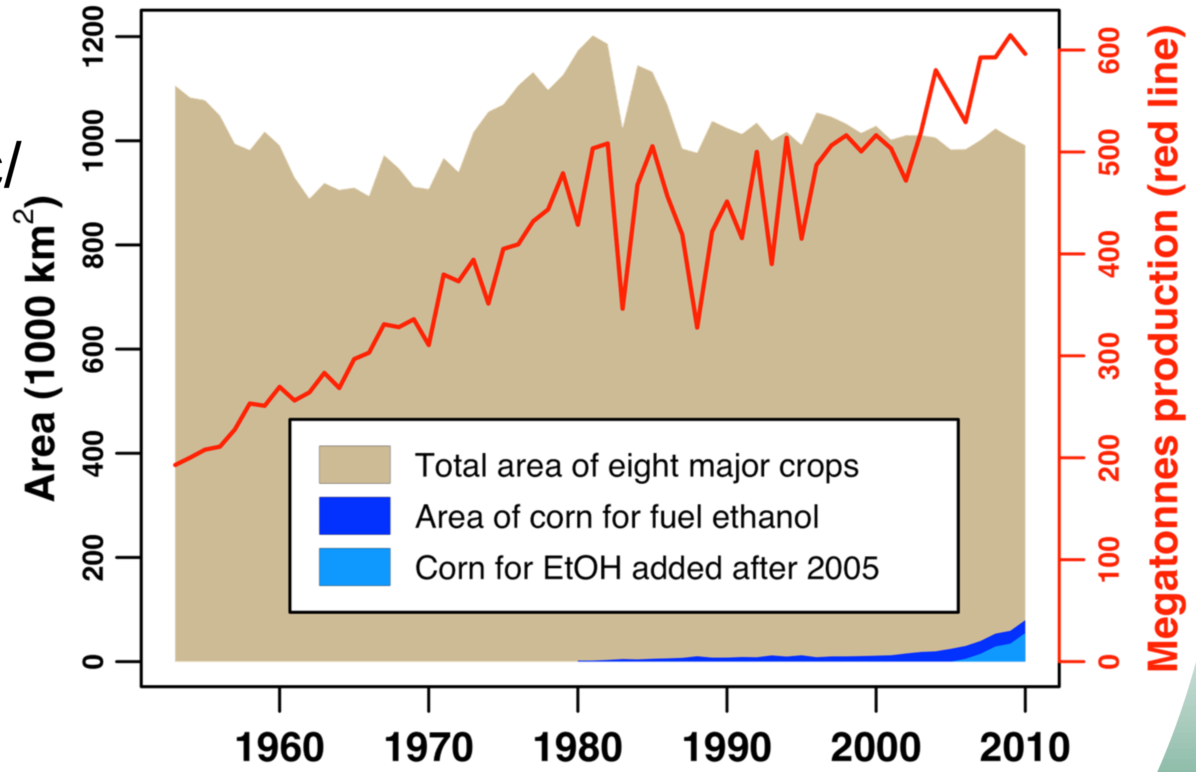
Source: USDA, National Agricultural Statistics Service Crop Production Summaries.

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

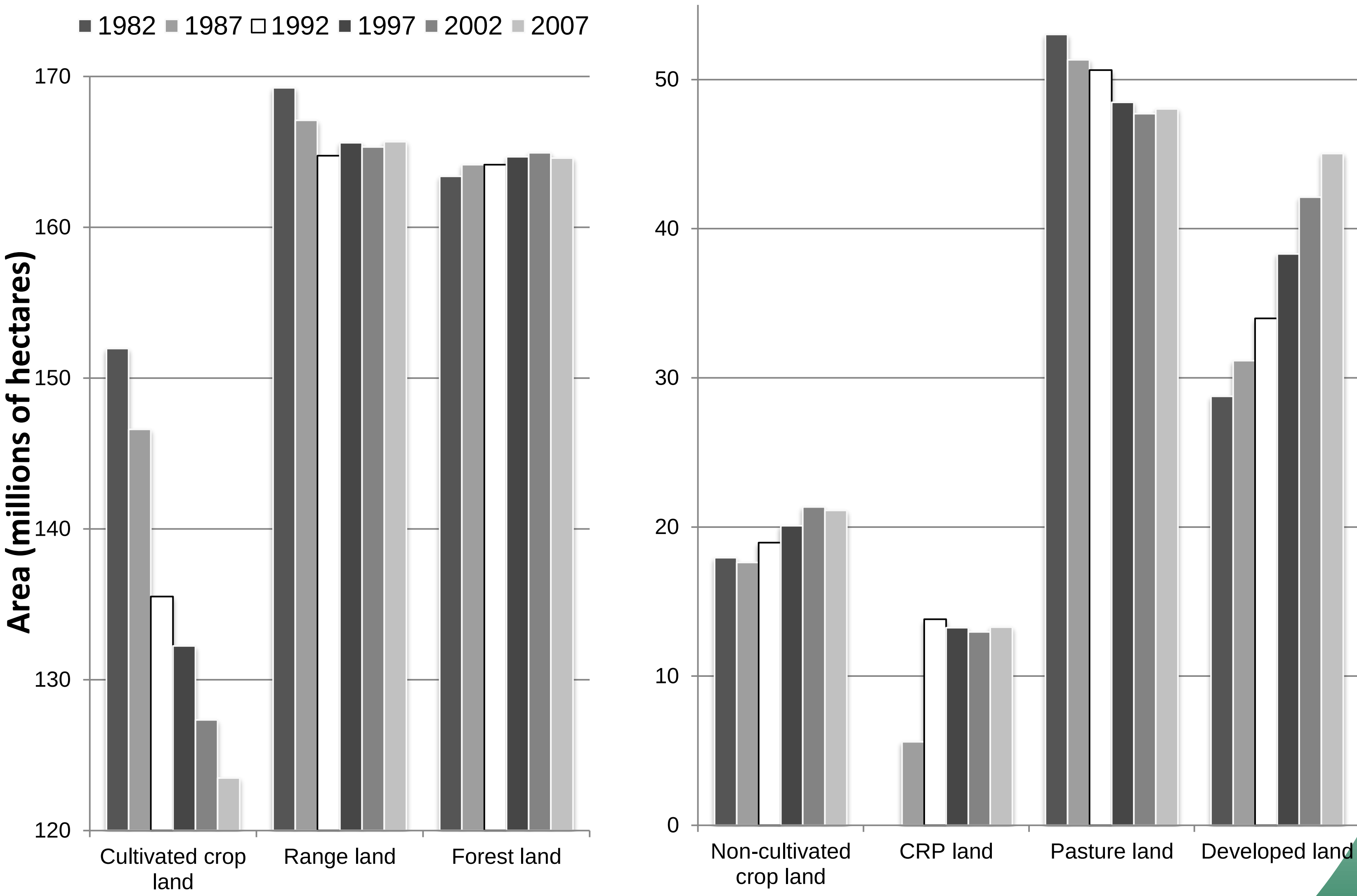
- Shock in demand?
- Different biofuel policies have distinct land-use & economic/ welfare implications
- Different ways to specify policies in a model may have greater effects than policy per se
- Policy specifications (assumptions & scenarios) must be calibrated & validated to reflect actual policies

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

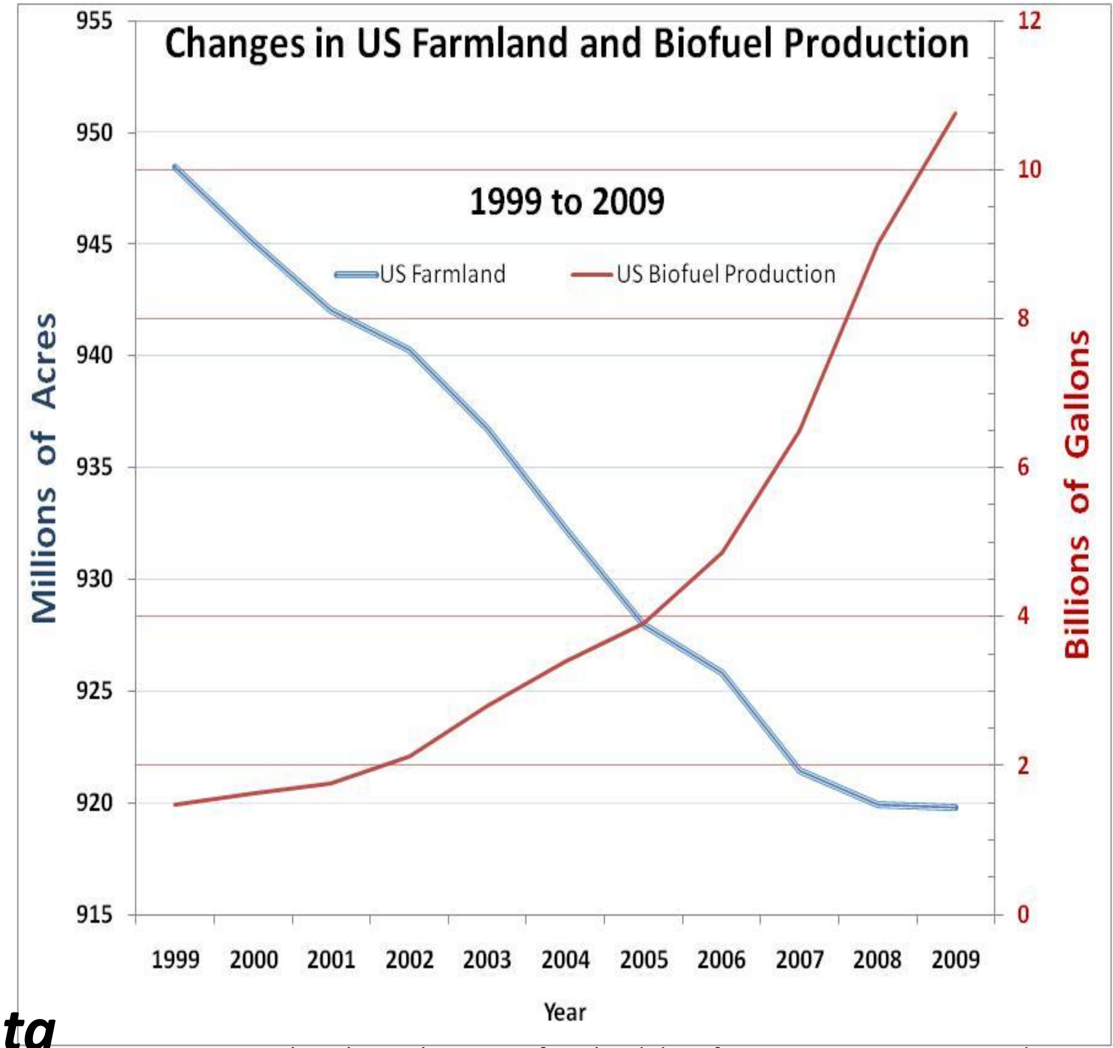
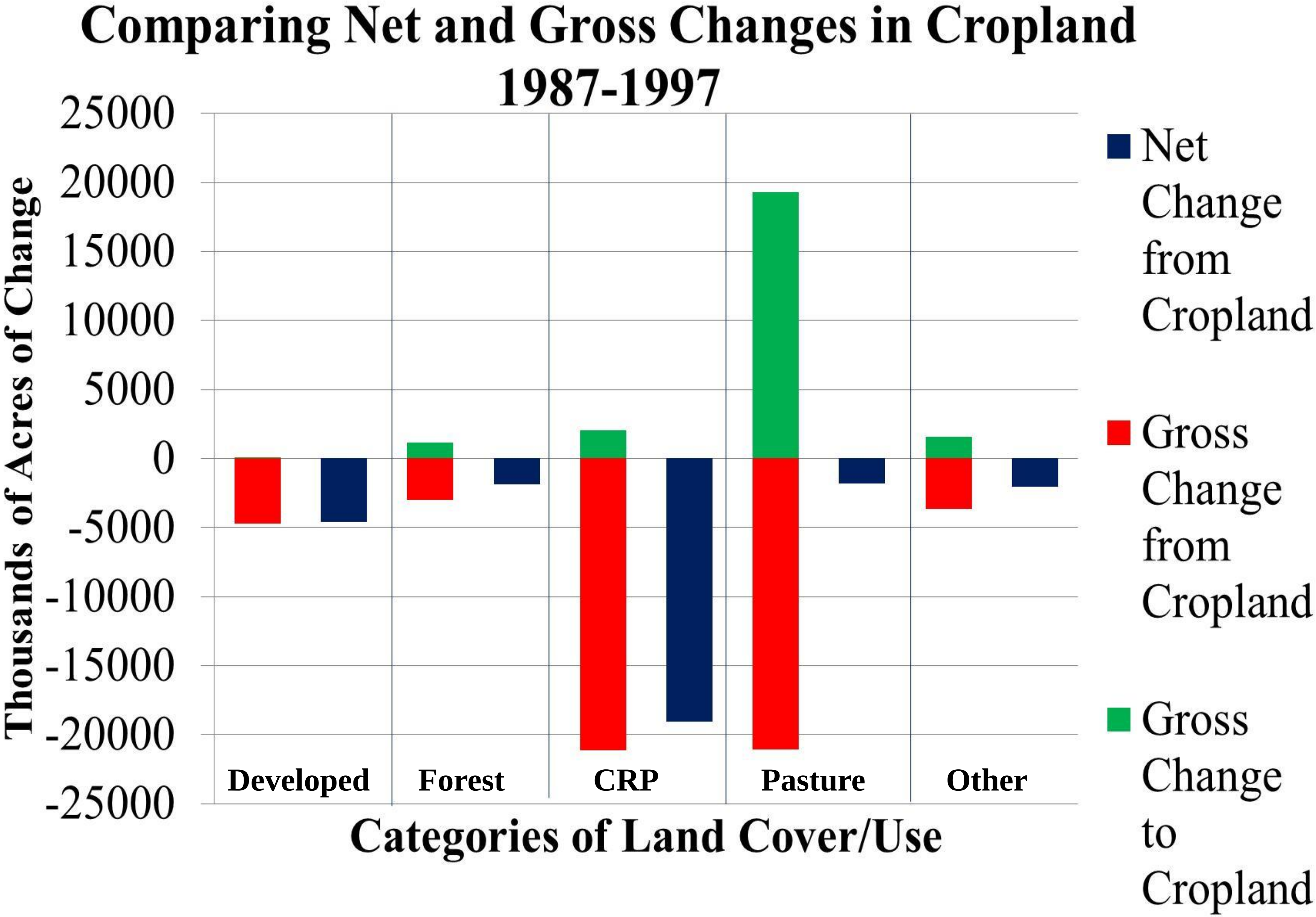


Chart by author using farmland data from USDA NASS 2010 and ethanol production data from the RFA statistics Aug 2011.

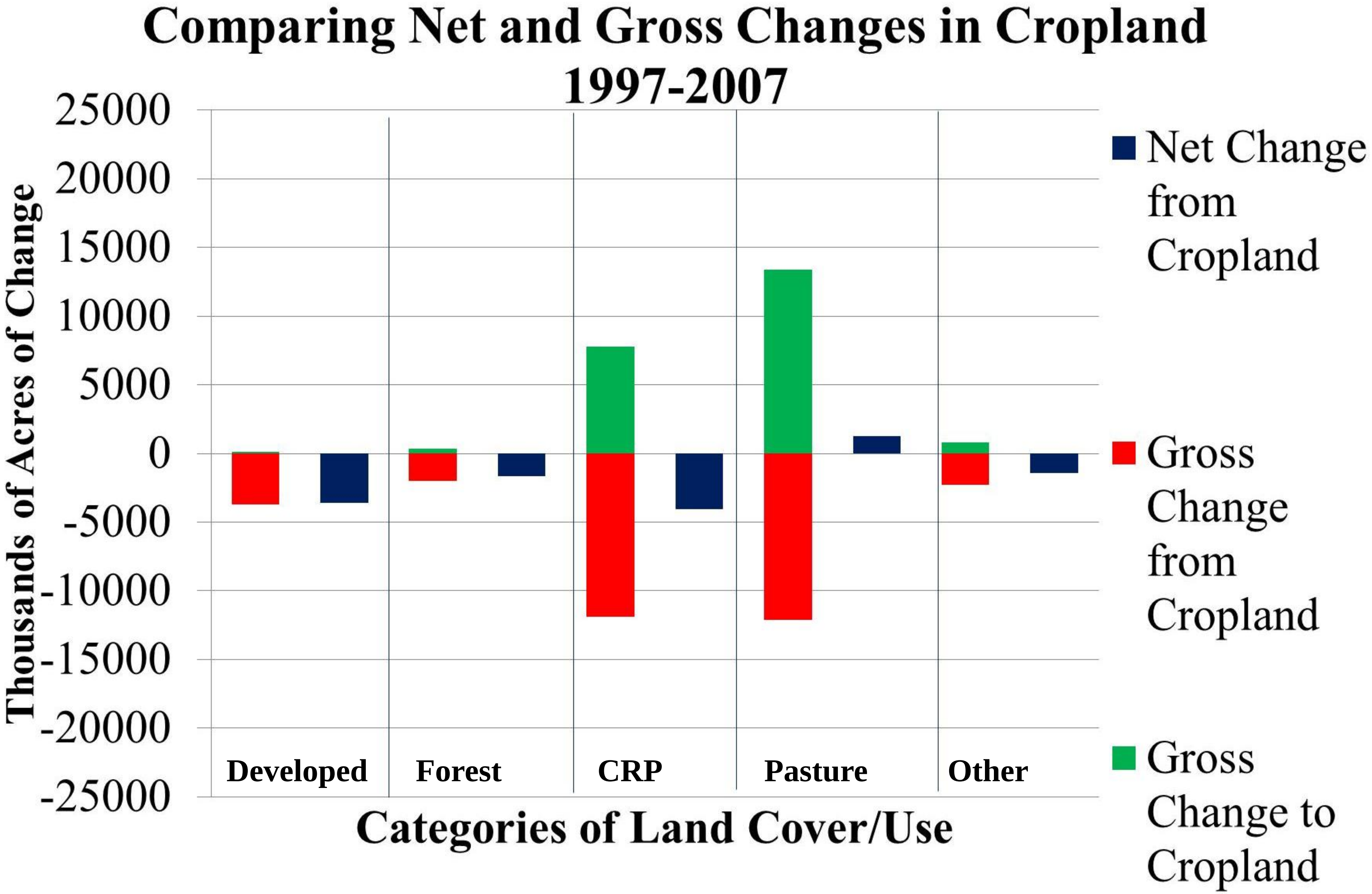
** Better land metrics and data are required*

Stable/static land conditions?



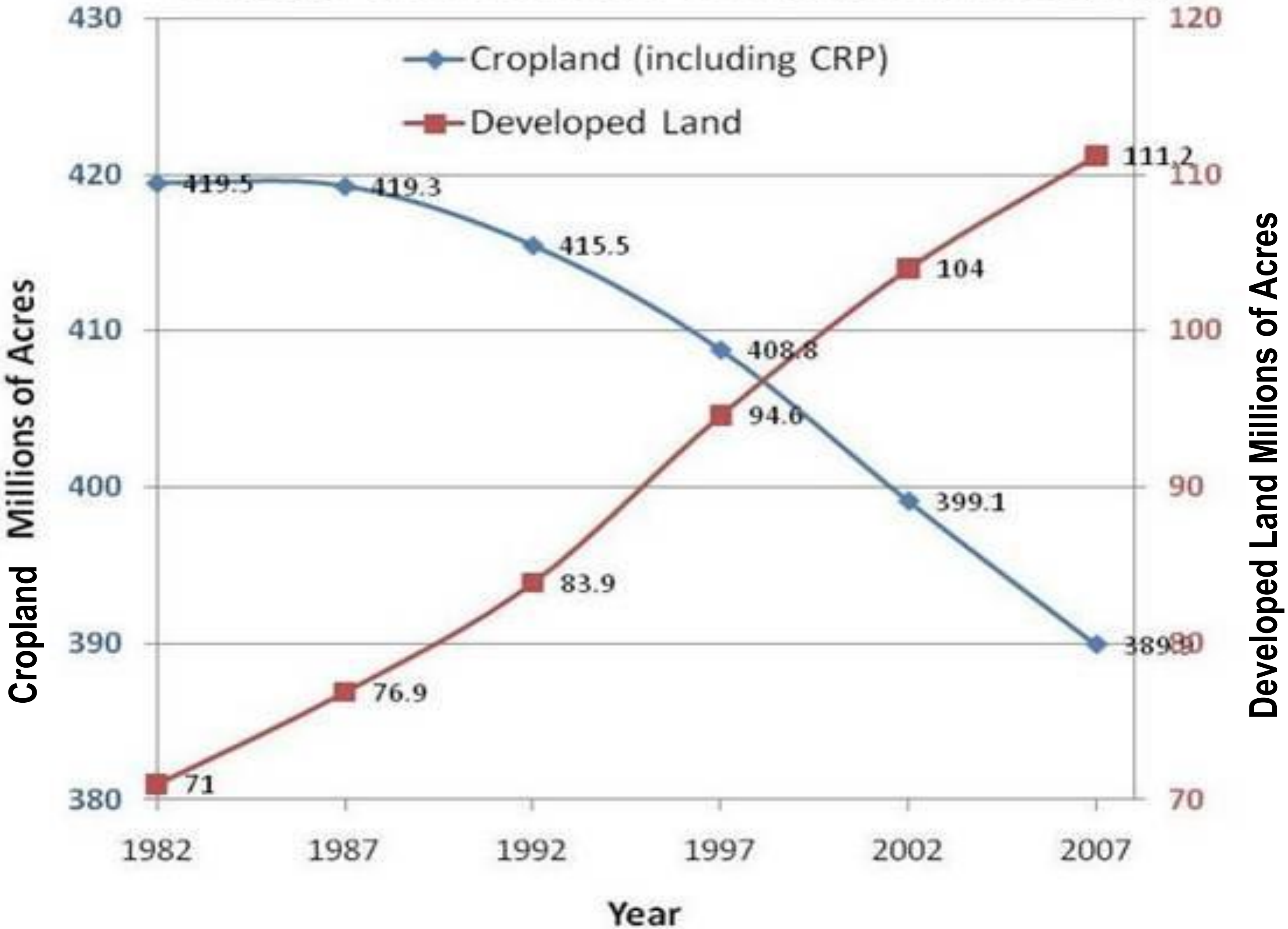
ORNL graphic based on data from the USDA 2009-NRI

Stable/static land conditions?



ORNL graphic based on data from the USDA 2009-NRI

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

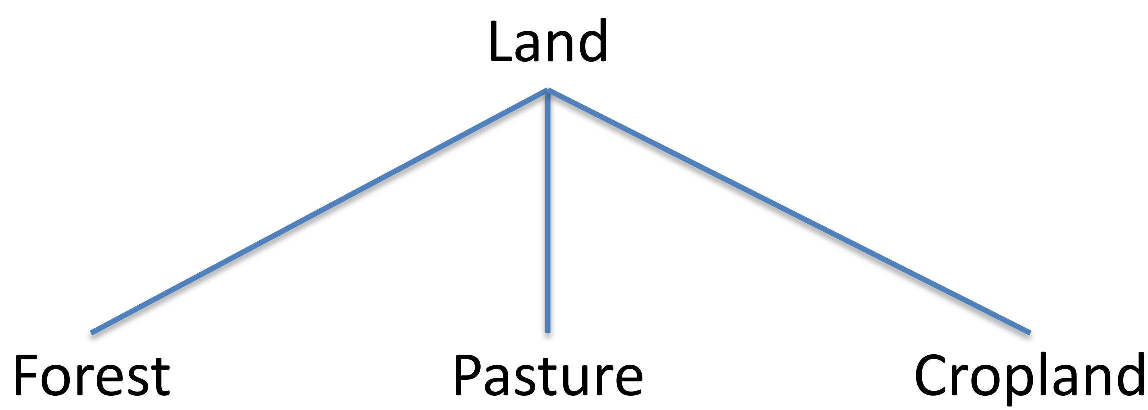


ORNL graphic based on data from the USDA 2009-NRI

Example: GTAP Model (Tyner et al. 2010)

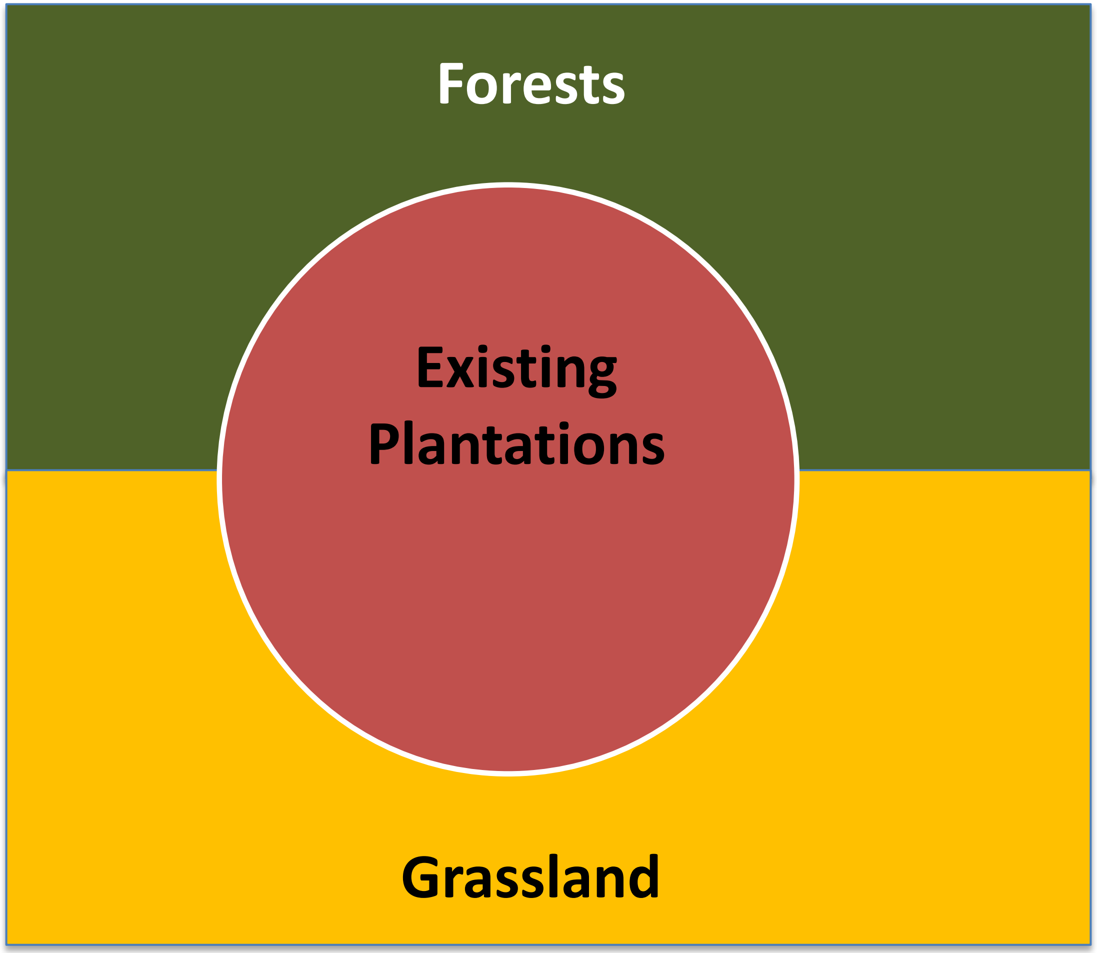
Models are, by definition, simplifications

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



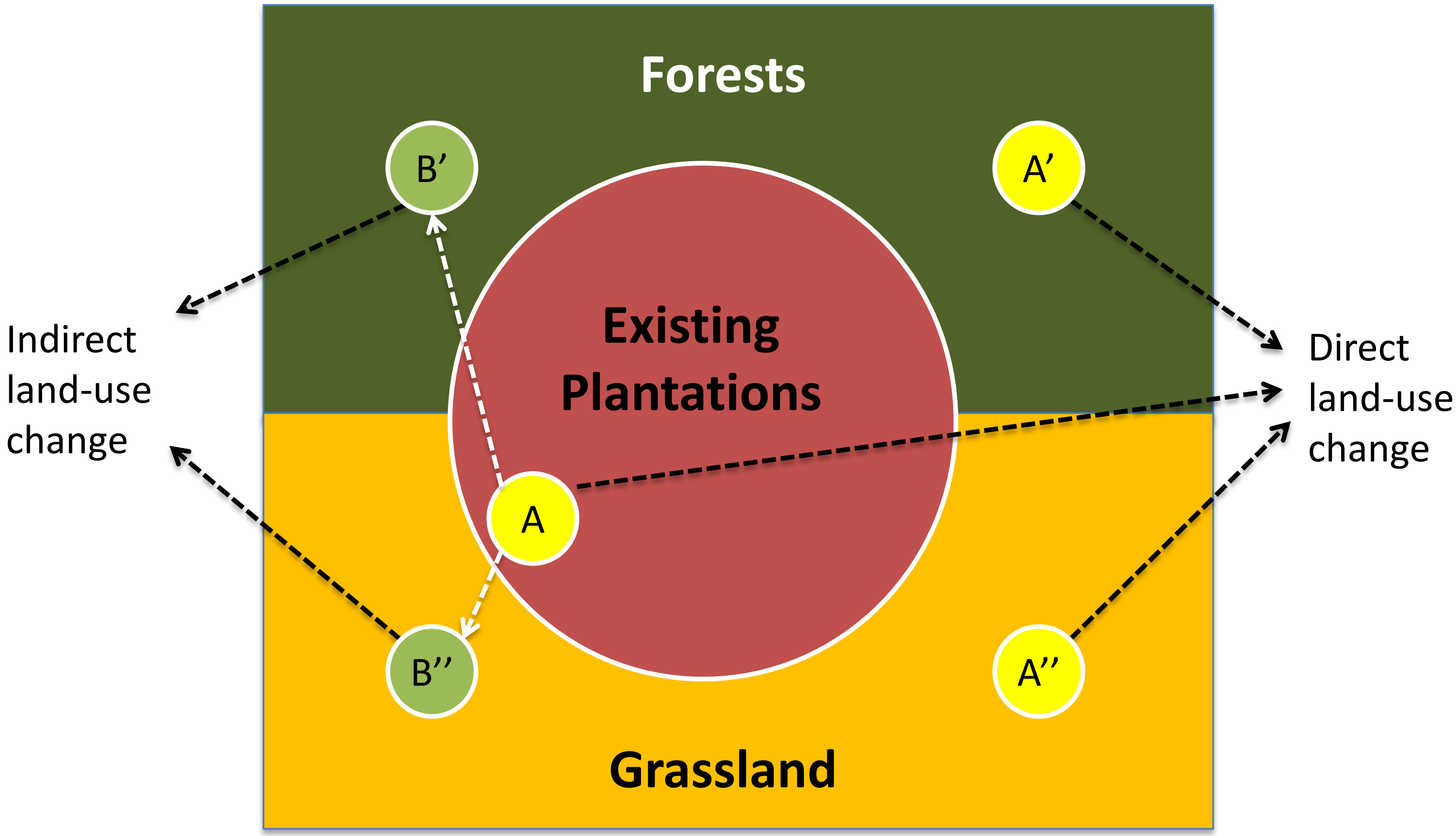
Adapted from Tyner et al., 2010: Figure 1. An overview of the GTAP model

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



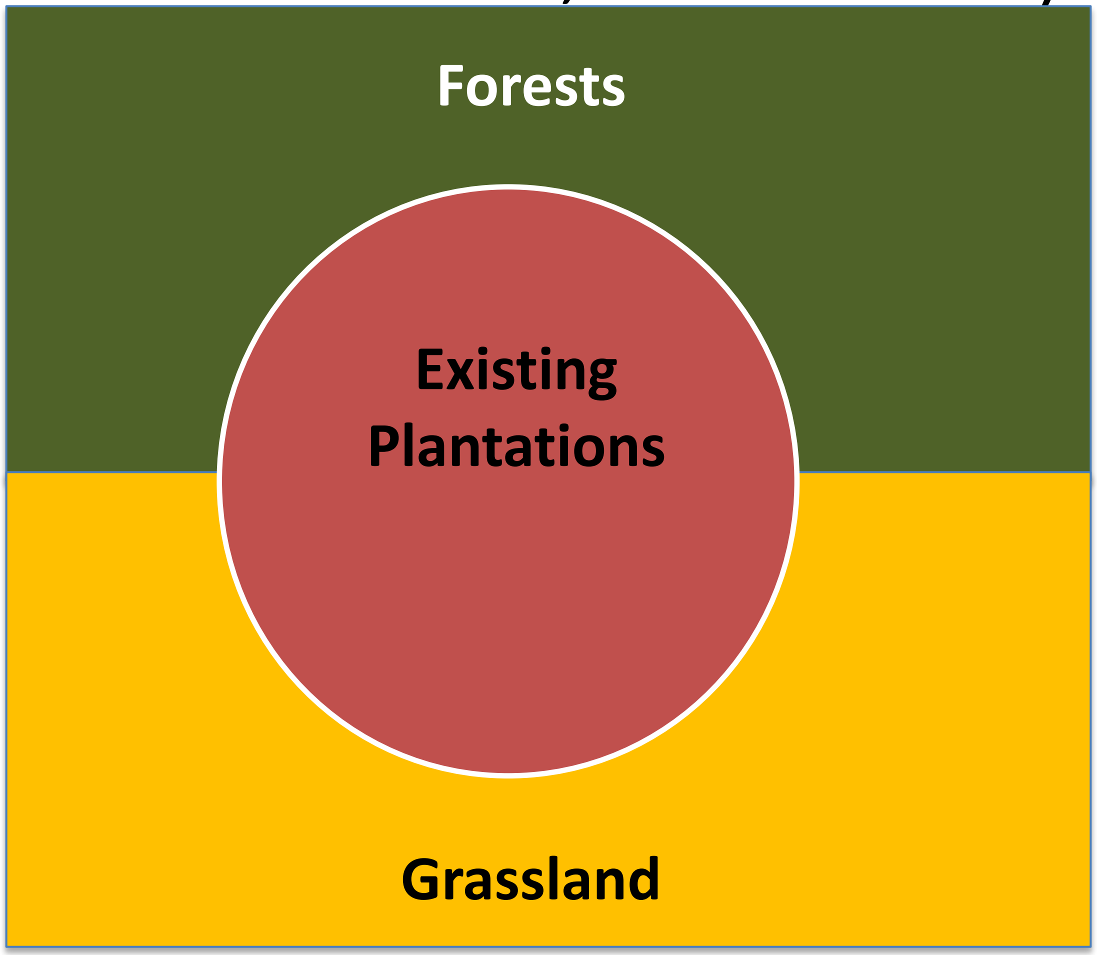
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament), Ecofys 2010 (Dehue), Ecofys 2011, OEKO 2010 and others

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



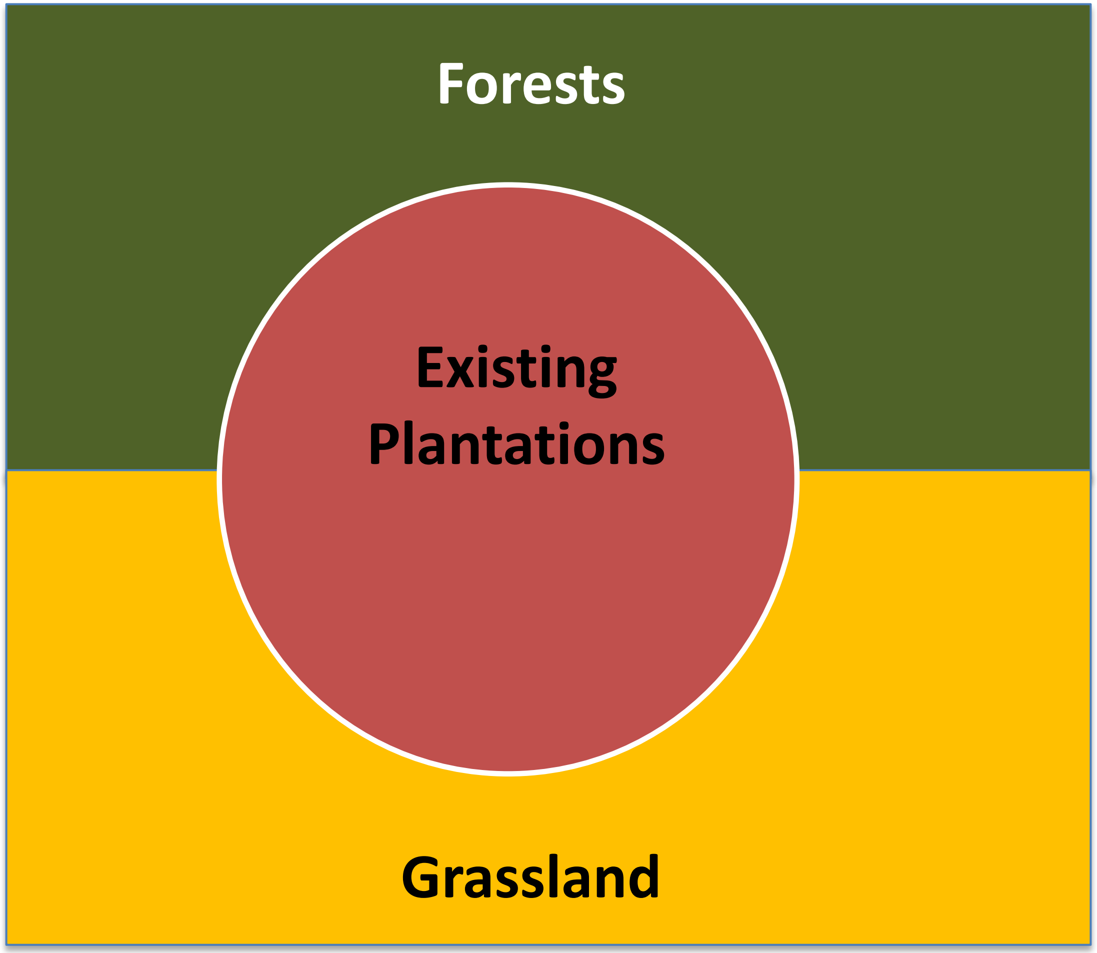
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament), Ecofys 2010, Ecofys 2011, OEKO 2010 and others

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



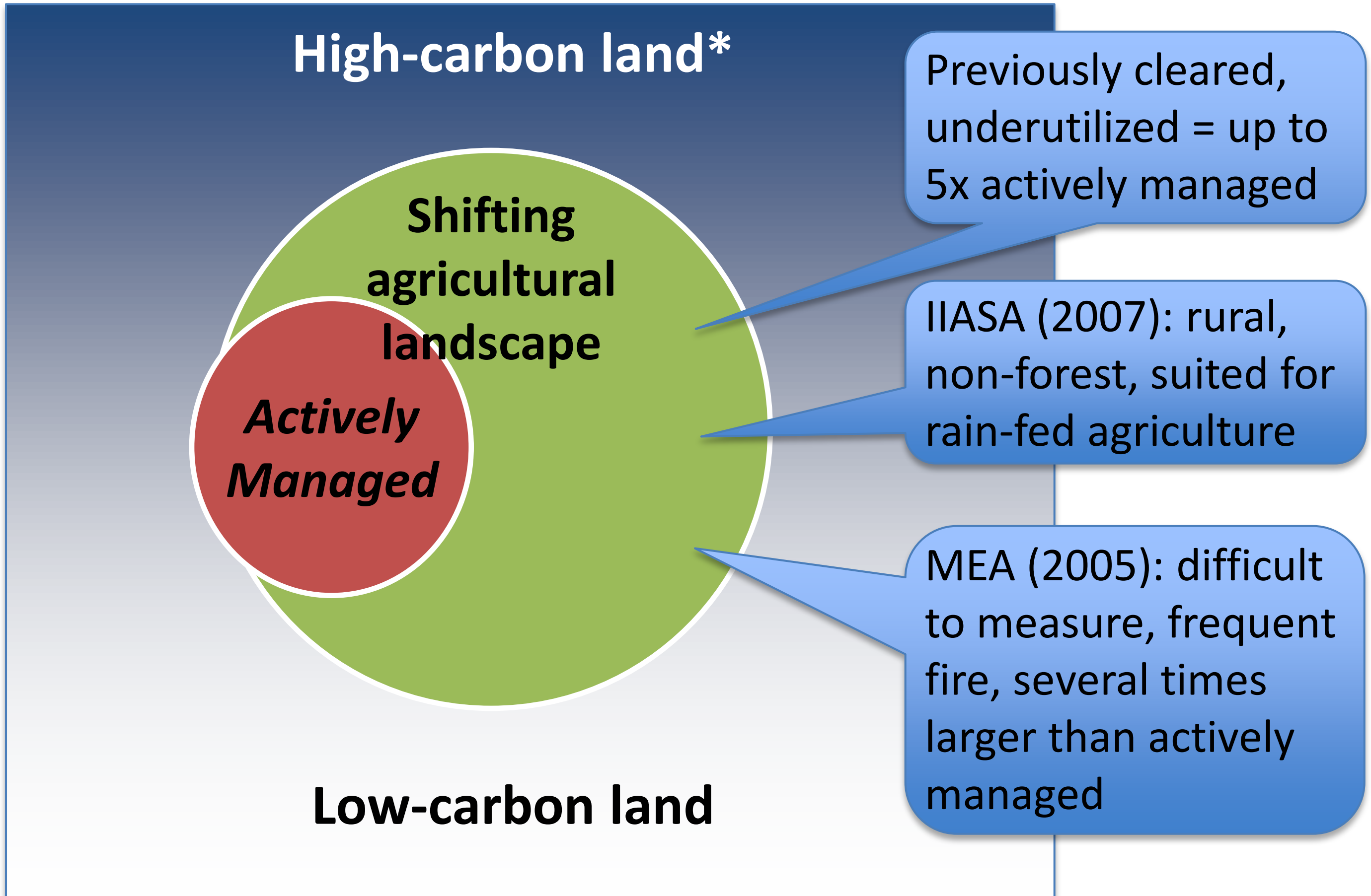
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament), Ecofys 2010, Ecofys 2011, OEKO 2010 and others

What are the alternatives?



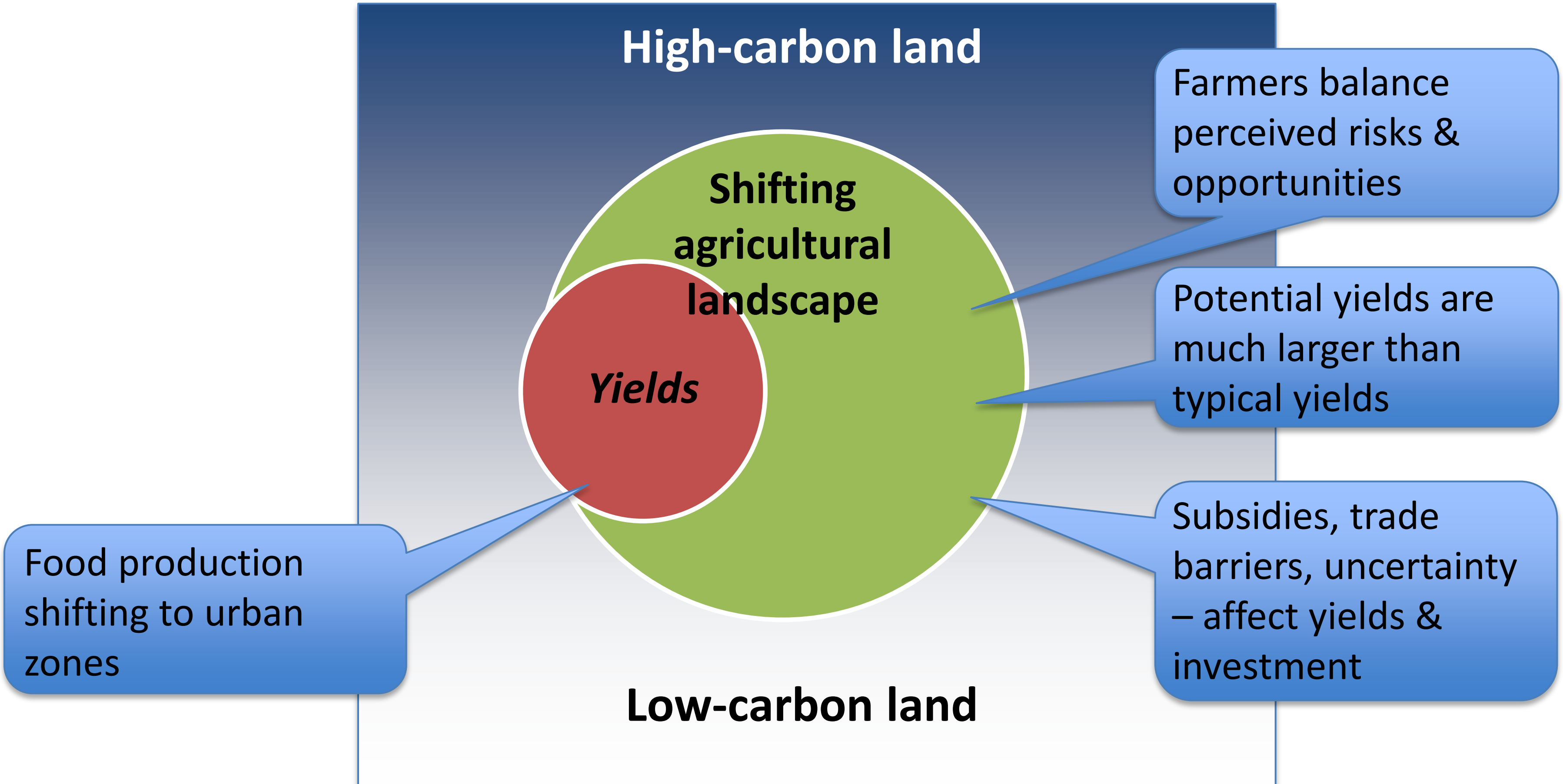
Adapted from Fritsche et al. 2011 (ILUC Study for European Parliament), Ecofys 2010, Ecofys 2011, OEKO 2010 and others

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

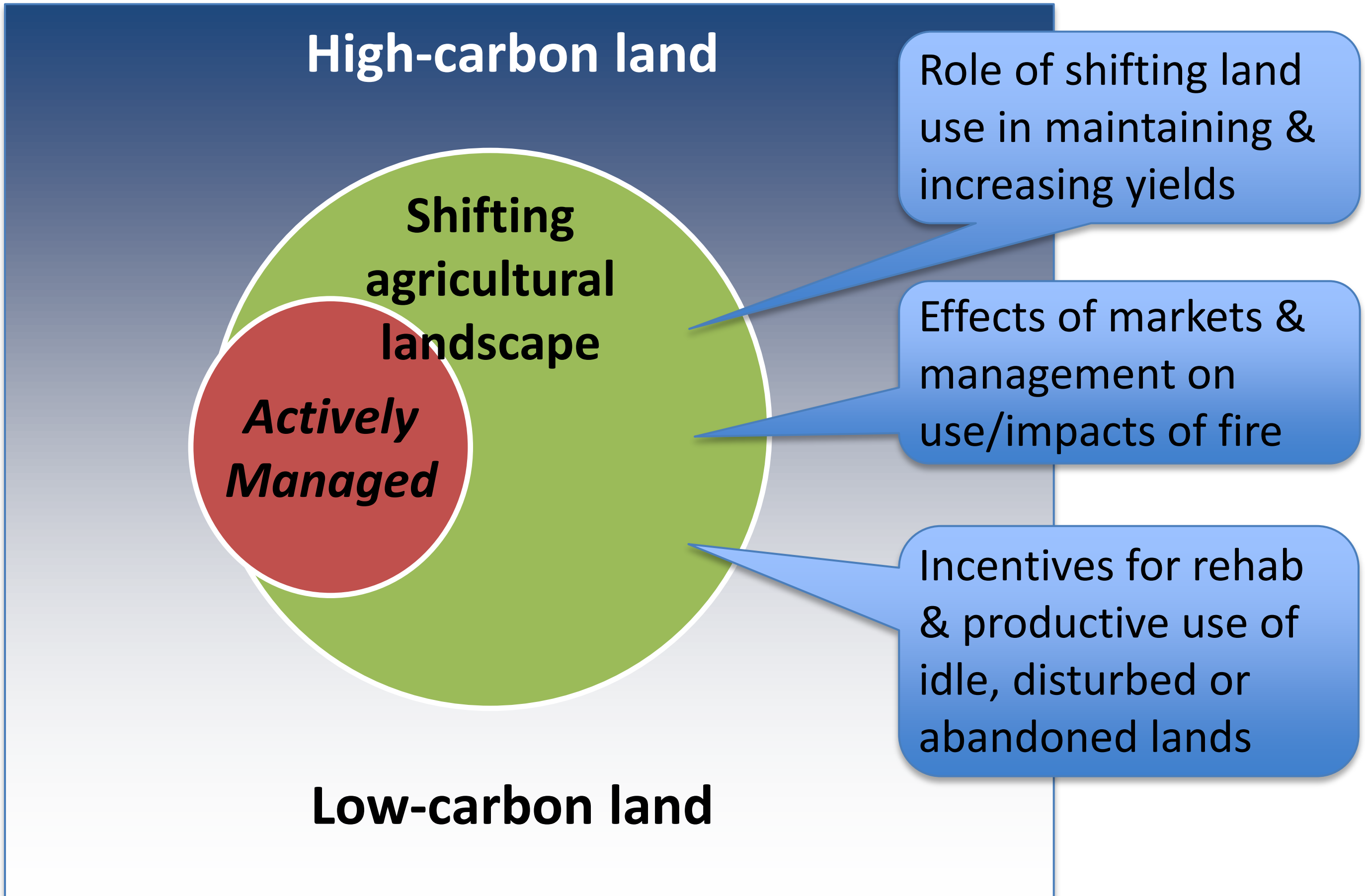


*Data on nutrient cycling, productivity, environmental services – stocks, flows & potential capacity – all important - it's NOT just about carbon

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

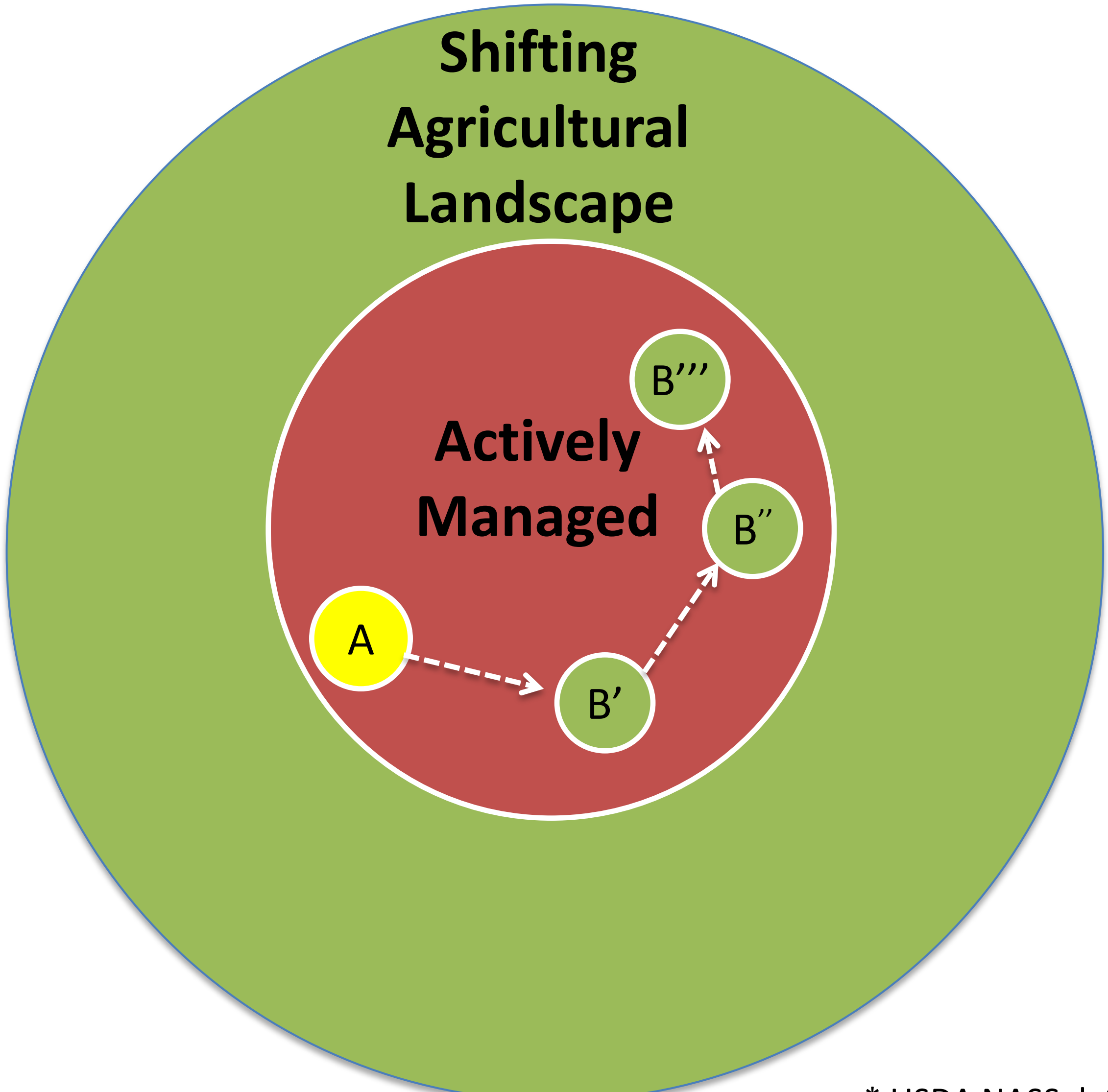


Many data needs (spatial, temporal) for more accurate representation of historic trends



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

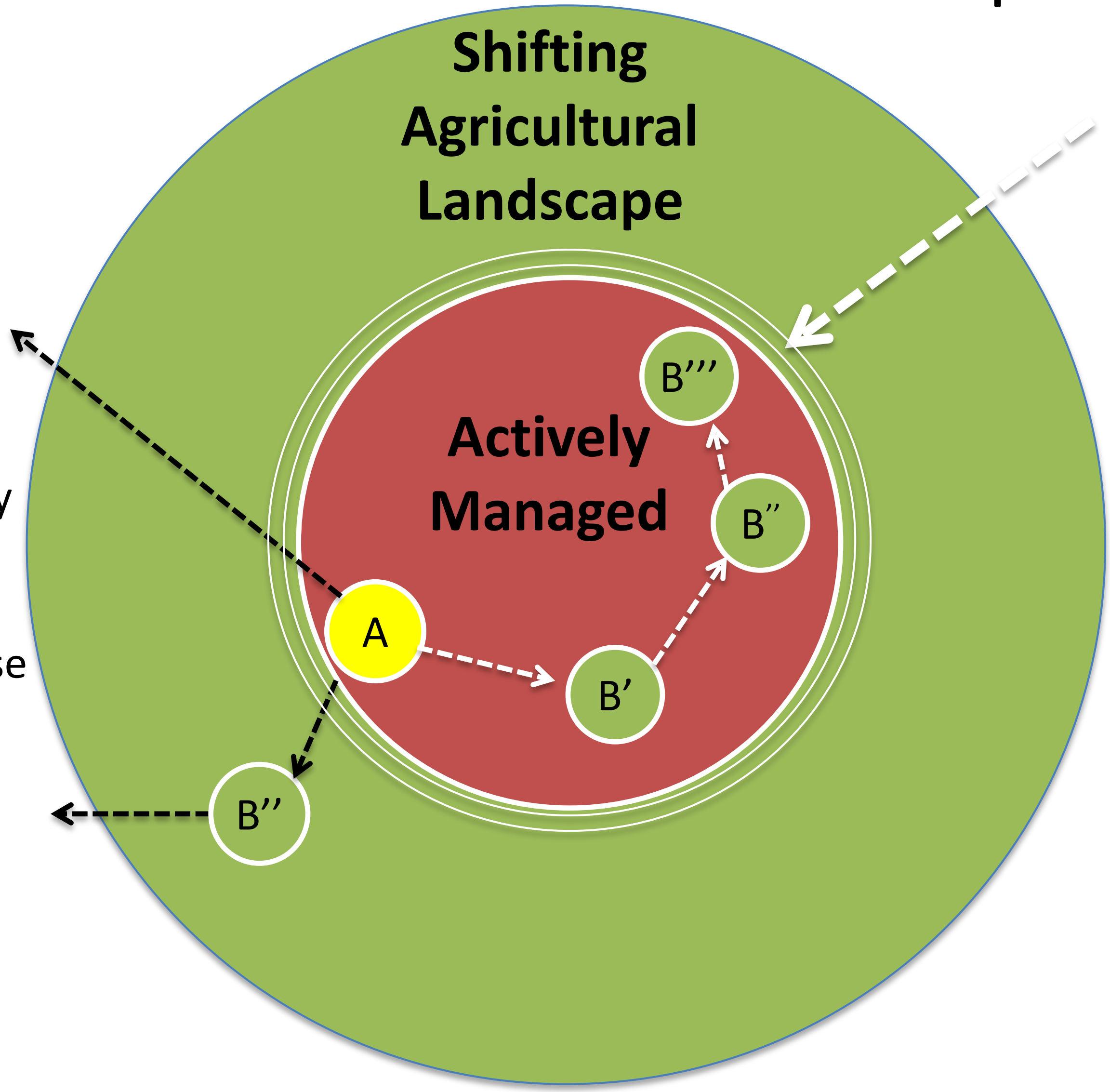
Displacement of idle land & lower yield grains – increased feed/DDGs exports

* USDA NASS data; Wallander et al. 2011

Interactions among new markets & product diversification are complex

Maintenance of productive farmland: LUC or "change avoidance?"

What are policy effects outside US on historic trends – e.g. use of shifting agriculture and use of fire?



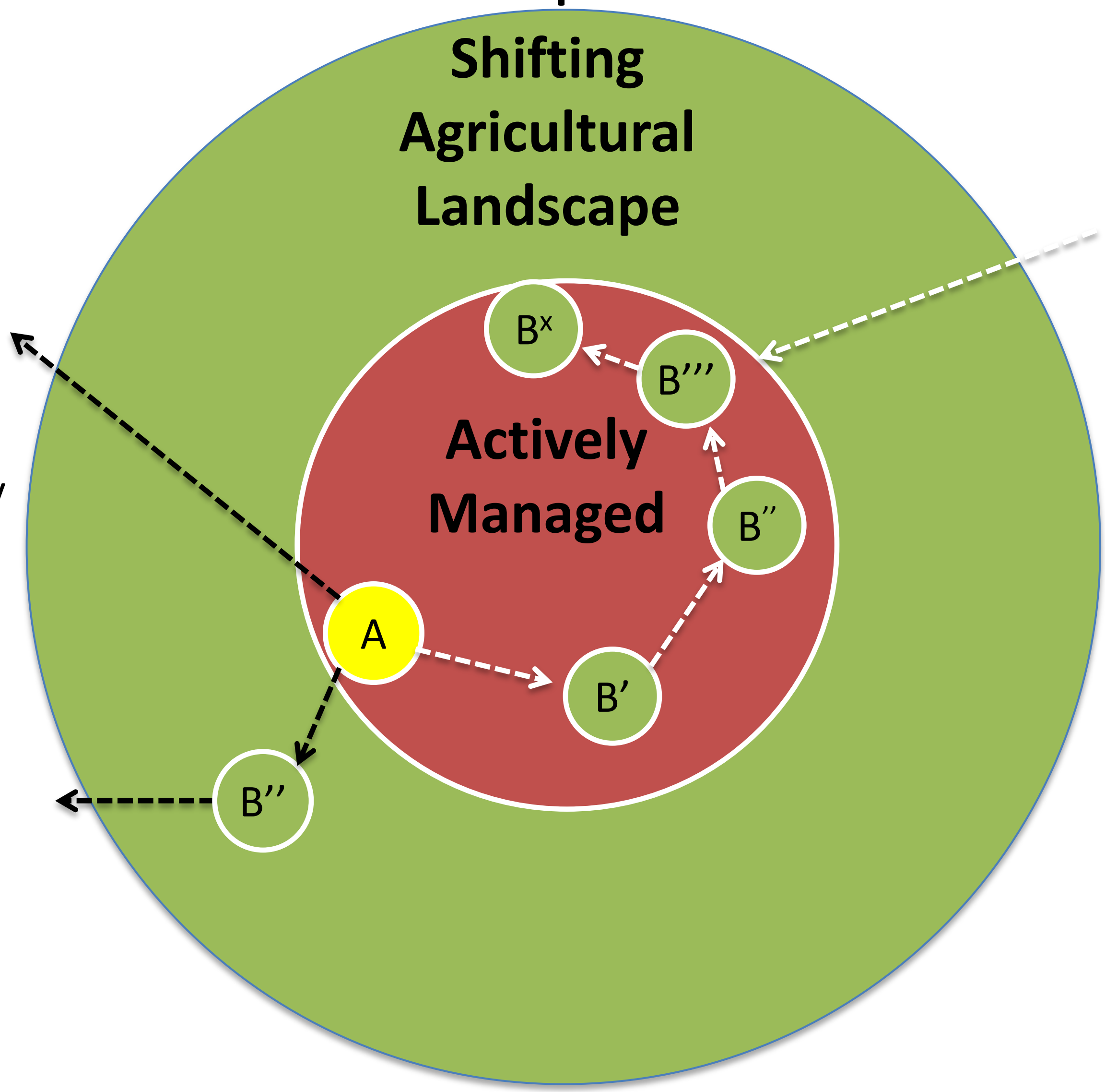
Circle shrinks when actual net change is a continued loss of farmland (although at slower rate than pre-bioenergy policy)

Actual "LUC": Double crops, greater use of idle land, displacement of lower yield grains…

Interactions among new markets & product diversification are complex

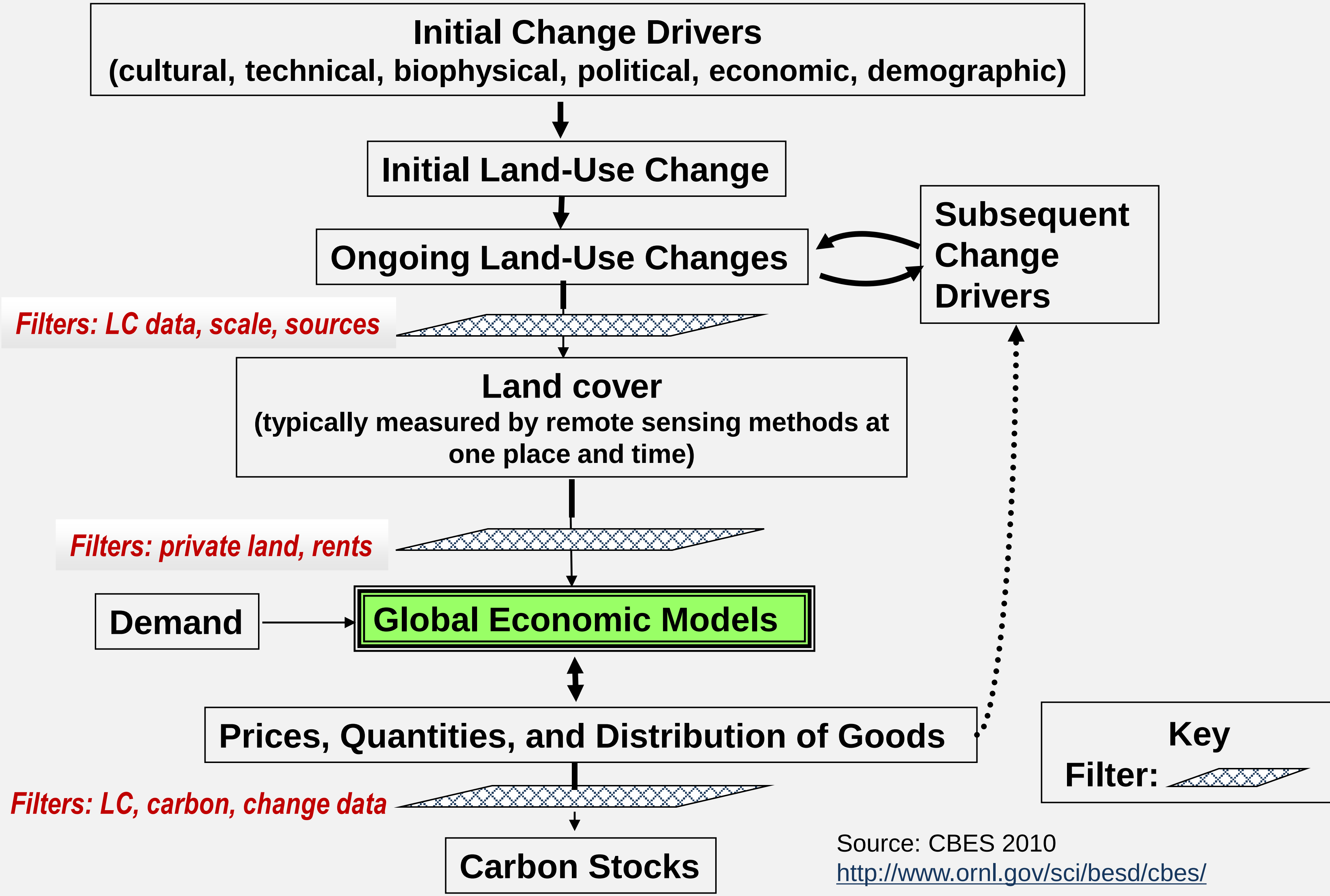
Reduced conversion to urban and developed uses

What are policy effects outside US on historic trends in shifting ag landscapes & use of fire?



Indirect effects likely include acceleration of historic trends toward higher efficiency, higher returns and higher yields

Land use models - constrained by data, filters



Source: CBES 2010
http://www.ornl.gov/sci/besd/cbes/

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

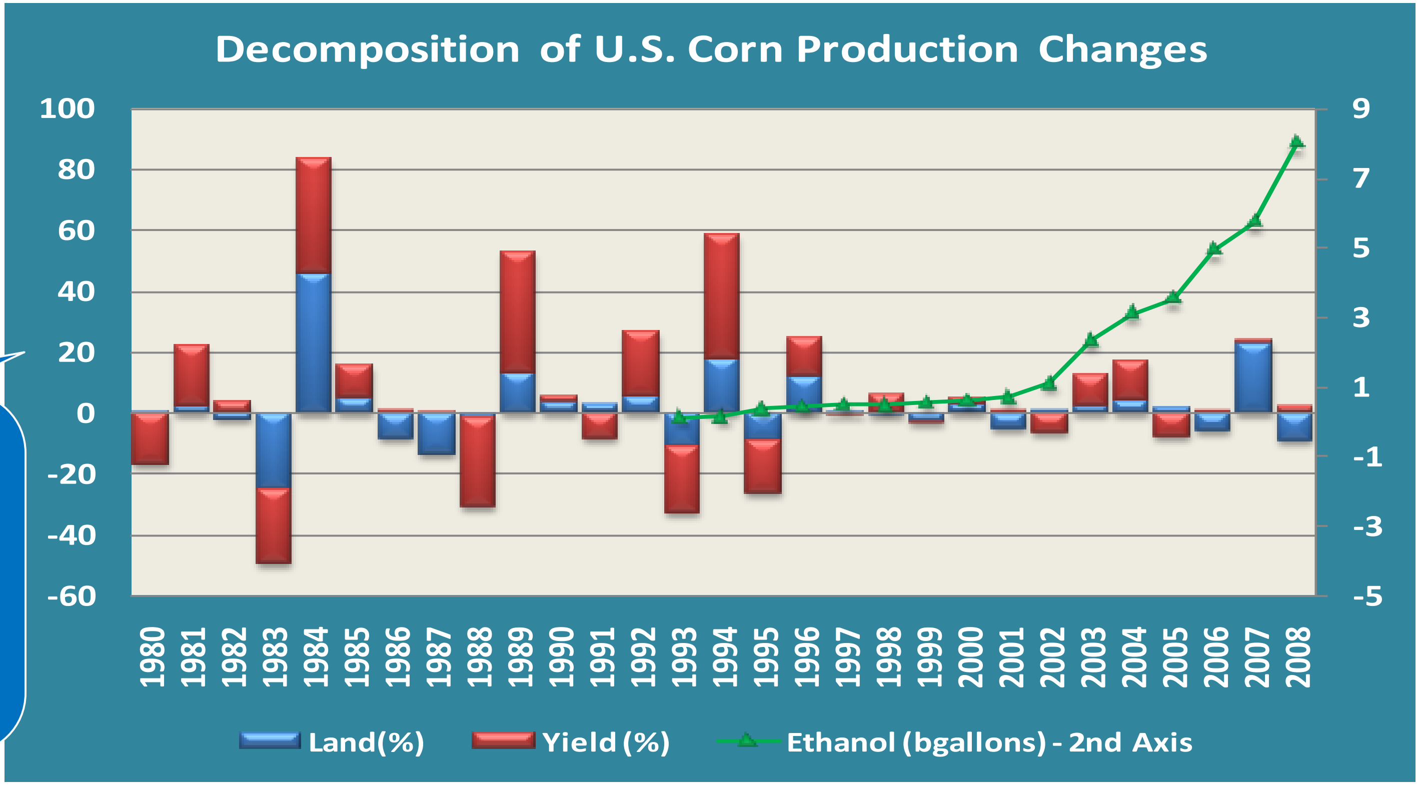
Production equation:

$$Q = Y.L$$

Decomposition:

$$\Delta Q/Q = \Delta Y/Y + \Delta L/L$$

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

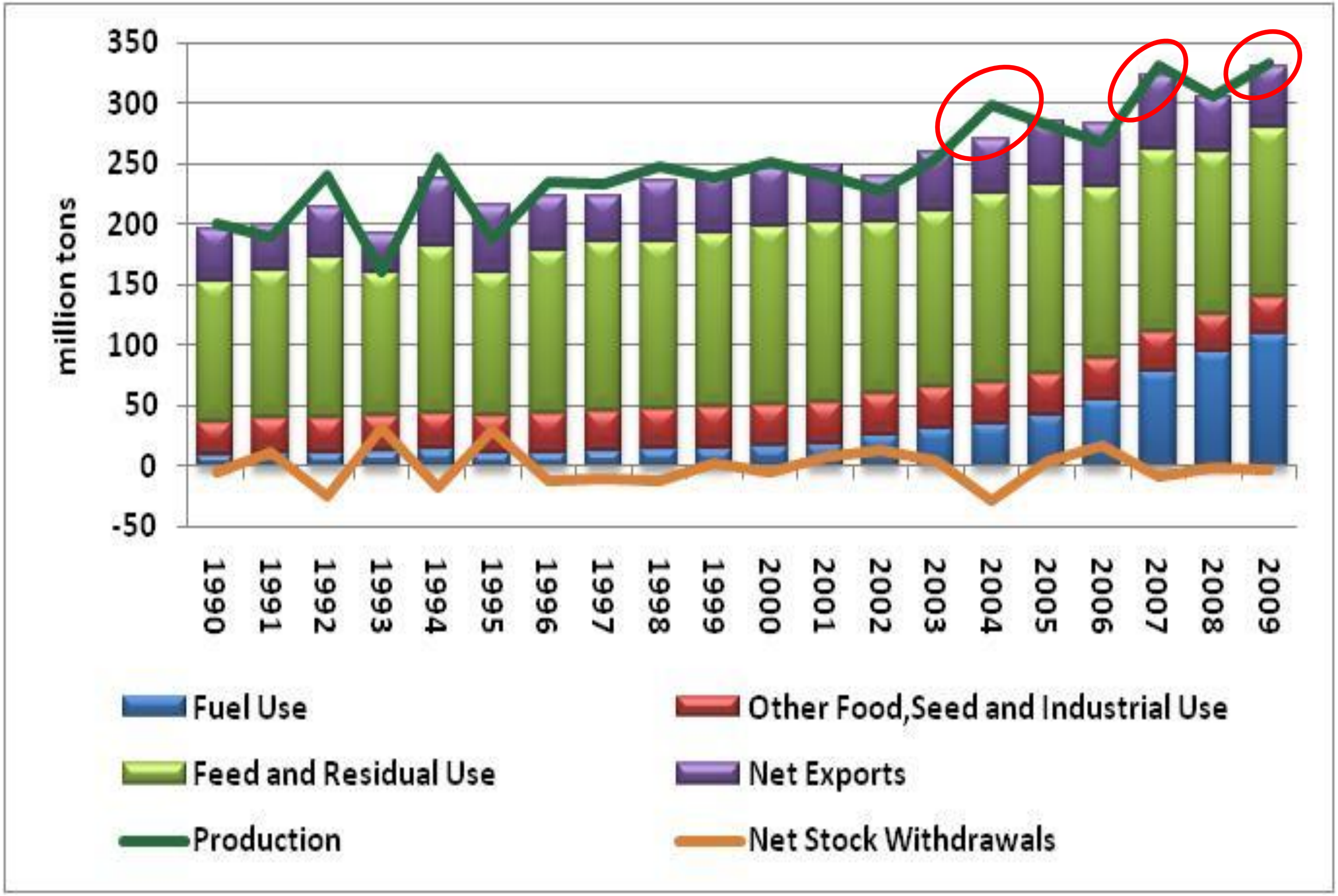


- **Yield contribution to growth in production is substantial**
- **Since 2001, land share exceeds yield share in only 3 years***
  - 2002 & 2005 were both years of net negative output growth
  - 2007 positive output growth dominated by land increase

*** Yield data are not normalized for weather**

Source: Oladosu et al. 2011

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 <u>evidence*</u>

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

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Win–Win options

Good policy & governance are key

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

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“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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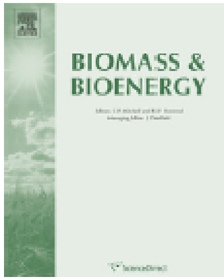

Scientific analysis is essential to assess biofuel policy effects: In response to the paper by Kim and Dale on “Indirect land-use change for biofuels: Testing predictions and improving analytical methodologies”

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

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Thank you!

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Related references
and
extra slides

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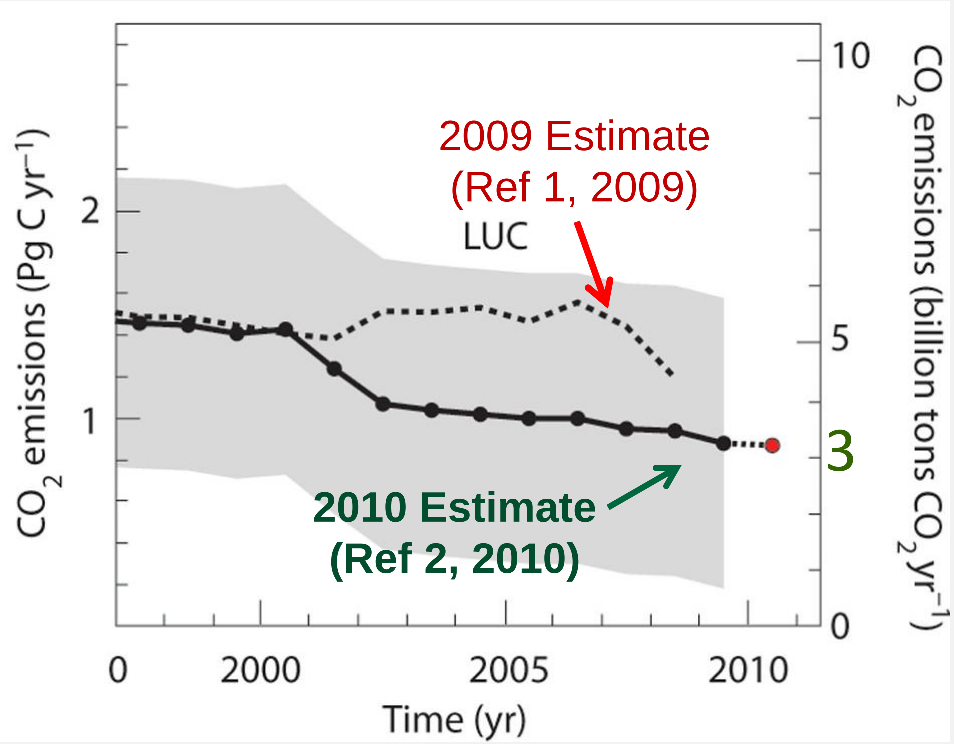
Summary: Top Ten Improvements

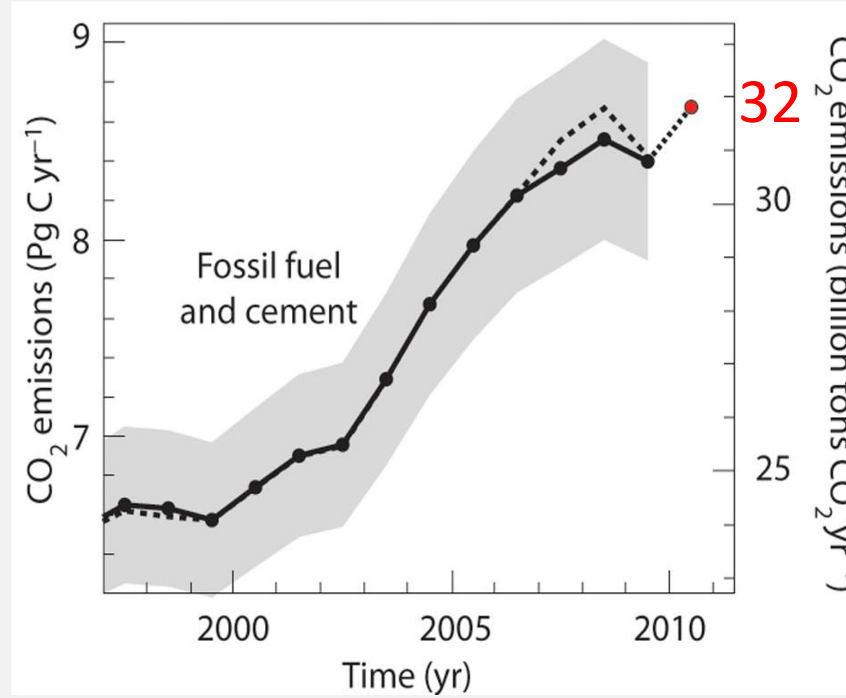
1. Representation of policy in model specifications
2. Economic decision-making assumptions
3. Conceptual framework for drivers of initial conversion
4. Land supply & management specifications
5. Assumed land use dynamics (scenarios, baseline choice)
6. Modeling yield change
7. Issues of time, scale
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

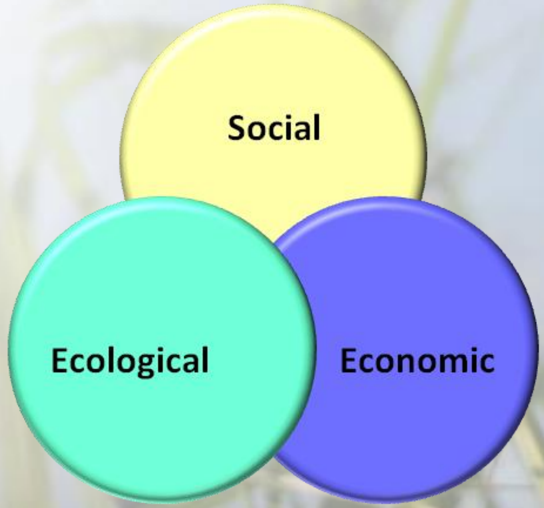


>90% of current CO2 emissions are from fossil fuel; fossil share rapidly and more certainly rising

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



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