# Land and resource assessment challenges and opportunities

Global Sustainable Bioenergy (GSB) Workshop - Future Research Directions for Sustainable Bioenergy

**Held at ORNL with participants supported by FAPESP**
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Presented by Keith L Kline

Environmental Science Division
Center for BioEnergy Sustainability
Oak Ridge National Laboratory
Oak Ridge, Tennessee
[http://www.ornl.gov/sci/ees/cbes/](http://www.ornl.gov/sci/ees/cbes/)


U.S. DEPARTMENT OF ENERGY

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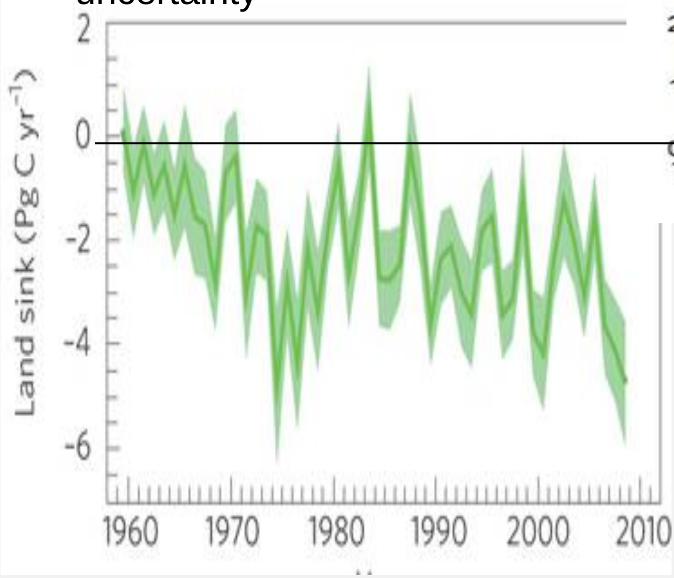
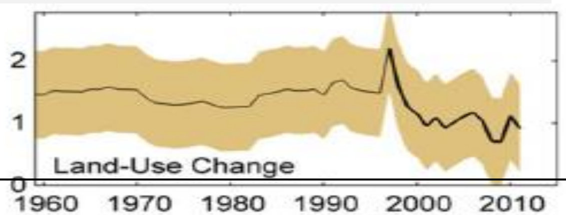
# Putting global "Land Use" emissions into perspective 1960-2012

- **Land management, after deducting uncertain LUC, grows in importance as a sink**
- **Global Carbon Project (based on ORNL CDIAC data) reports: "Over 90% of current CO2 emissions from fossil fuels"**

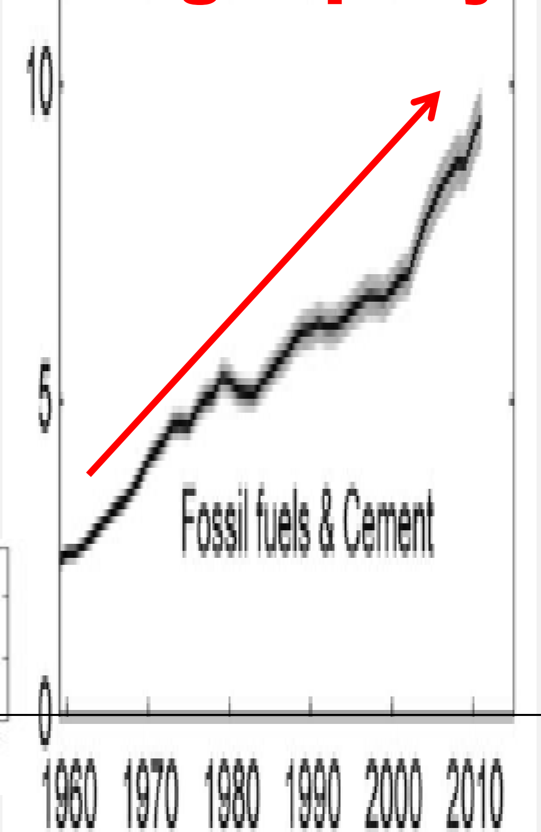
## Fossil emissions rising rapidly

Shaded areas around lines represent estimated range of uncertainty



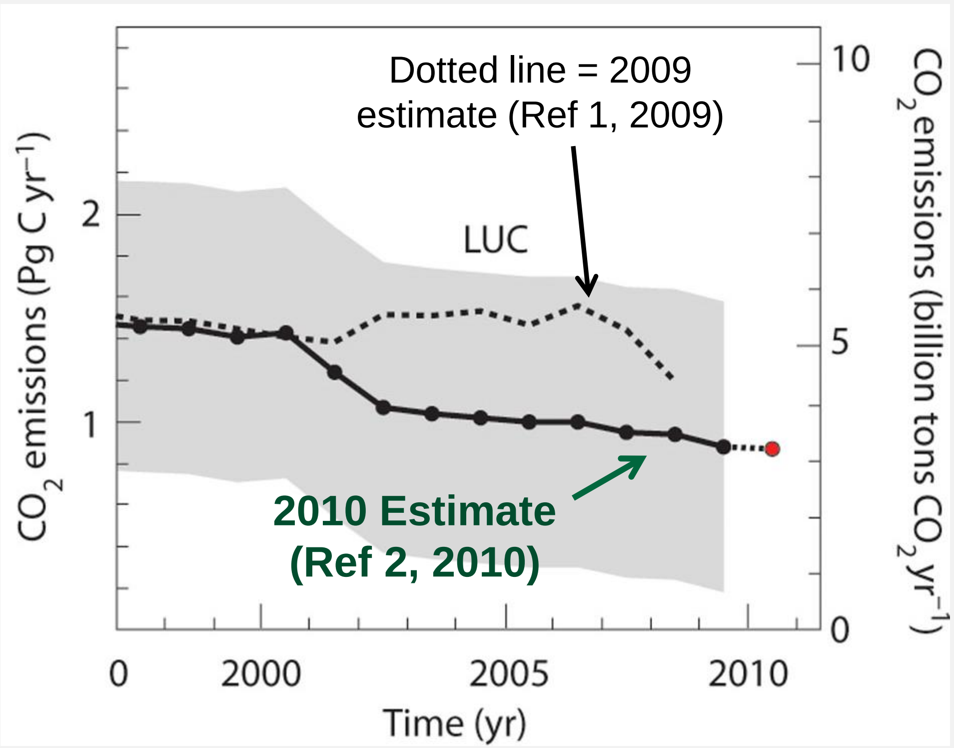

GCP "Land-Use Change" estimate based on emission factors associated with global reported deforestation and fires

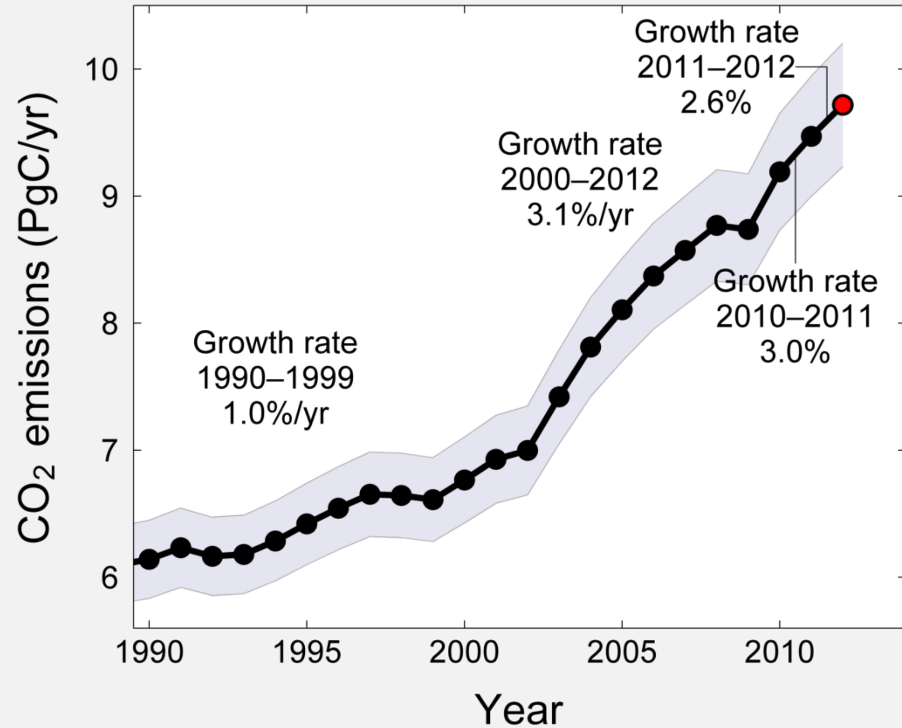



Source: Le Quéré, C. et al. Nature Geosci.v2, 831–836 (2009) for sink; Global Carbon Project (2013) for LUC and fossil.

# How are "LUC emissions" estimated? Why so much uncertainty? What makes them unique?

# Fossil emissions persistently rise

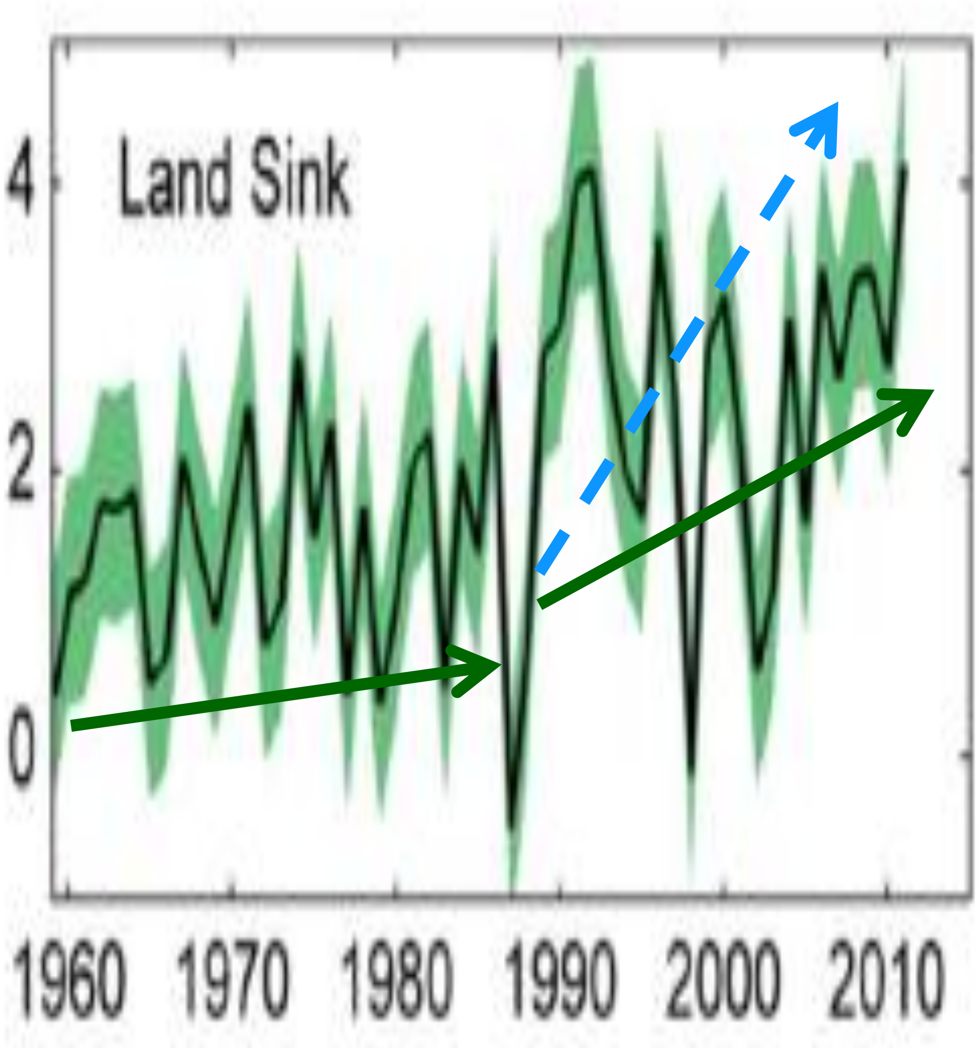



- Fossil share rapidly rising
- Very little uncertainty

**Shaded areas around lines represent estimated range of uncertainty**


Sources: (1) Le Quéré, C. et al. Nature Geosci.v2, 831–836 (2009).
(2) Friedlingstein et al. Nature Geosci.v3, 811–812, (Nov. 2010). See Global Carbon Project 2013




**NET emission from land can be a significant SINK.**

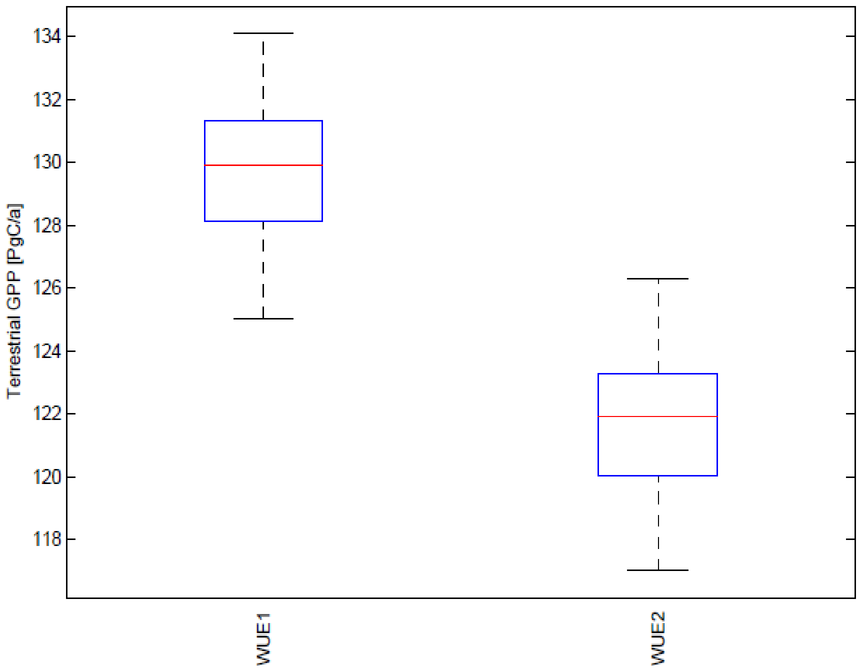
**Expanding this sink (dotted line) depends on management to increase storage capacity as well as NPP.**

Source: Global Carbon Project 2013

# Global data uncertainty –

Fig 9 (box plots to right): Note significant difference in results depending on whether MODIS or SPOT is used. WUE1: MODIS based land cover and LAI; long-term average ; WUE2: SPOT VGT based land cover and LAI; long-term average

"Fig. 9 shows two box plots with the GPP distributions that stem from a) model parameter distributions and the two different precipitation datasets. These results show that the uncertainty of land cover and maximum LAI on the global GPP number is as high as the uncertainty of model parameters and precipitation." (Beer et al. 2010)




GPP: differences in the median values is in the range of 7-10 PgC/a - *or about nine times the current estimates of total annual C emissions from global land use change*
(per Friedlingstein et al. Nature Geosci.v3, Nov. 2010)

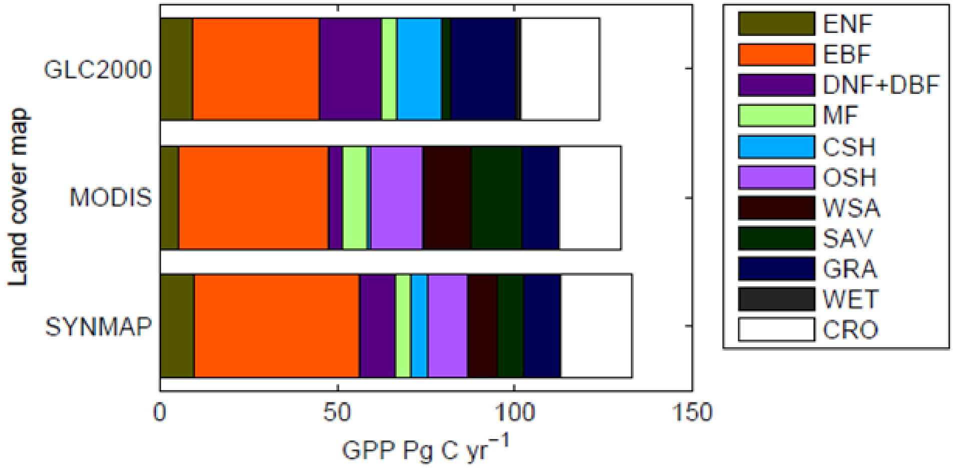
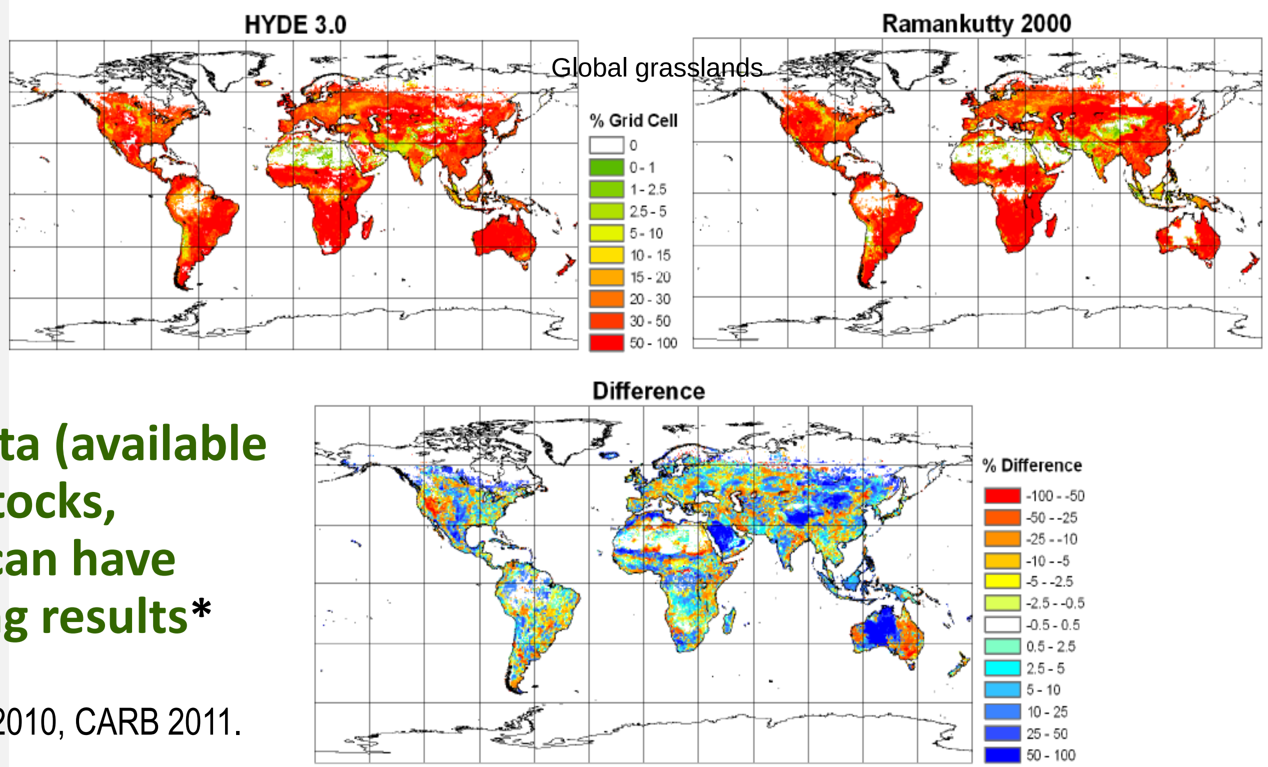



Figure 11: Distribution of global GPP estimates per land cover class

# Land cover uncertainty. Land use?

- **Constantly changing**
  - Cropland shifting → fallow → grassland → “secondary forest” → partial return to crops…
  - Lines between classes blur, overlap
  - Land use versus cover: distinct, different values
- **Difficult to measure**
  - Data aggregated and homogenized
  - Scale matters: temporal and spatial differ greatly
  - Need better standard descriptors: carbon and nutrient stocks and flows)
- **Small adjustments in data (available land; assumed carbon stocks, classification systems) can have huge effects on modeling results***




* For examples see: CBES 2010, EC 2010, CARB 2011.

**Charts: Preliminary results, Johannes Feddema, Geography Department, University of Kansas**

# What does “grassland” mean?

photo credits: USDA,
Natural Resources Conservation Service

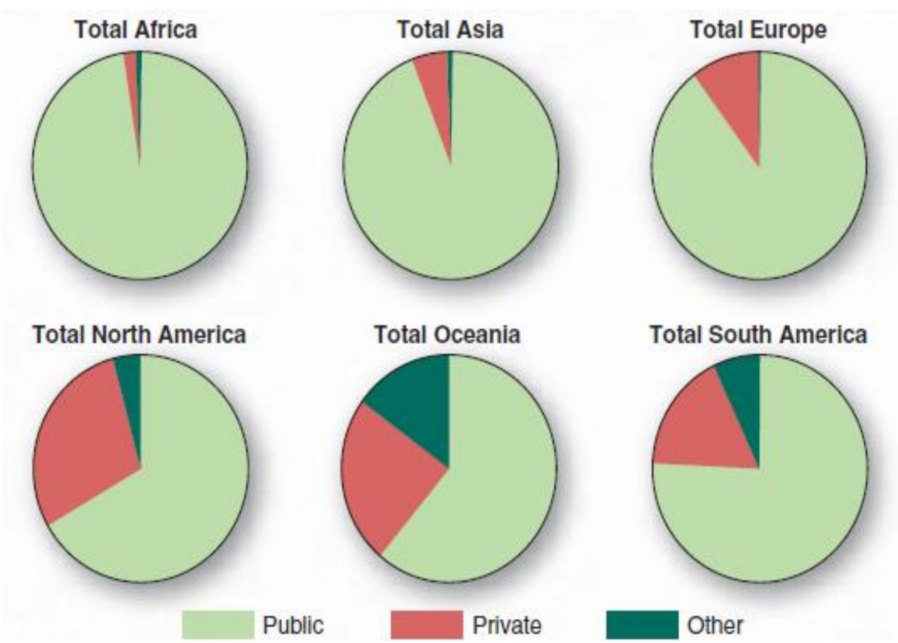
# Estimates of available land: FAO-IIASA 2007 (and others)

**FAO2007: Study of rural land suited for rainfed agriculture – mapping process with multi-layered constraints and zero deforestation from 2000 baseline (Km2)**

| | Med-hi suitabi | low-medium | total |
|---|---|---|---|
| LAC | 8,376,000 | 10,347,000 | 18,723,000 |
| Sub-Sahara Africa | 5,585,000 | 6,139,000 | 11,724,000 |
| Developed nations | 8,292,000 | 10,664,000 | 18,956,000 |
| Developing | 14,642,000 | 25,233,000 | 39,875,000 |
| Total suitable | 22,934,000 | 35,897,000 | 58,831,000 |
| not suitable | | | 42,199,000 |
| Forest etc assumed not available | | | 25,344,000 |
| total rural area studied | | | 126,374,000 |
| Urban/built-up ecosystem area | | | 284,202 |
| Areas not included (irrigated lands, polar regions) | | | 22,281,798 |
| Earth's land area | | | 148,940,000 |

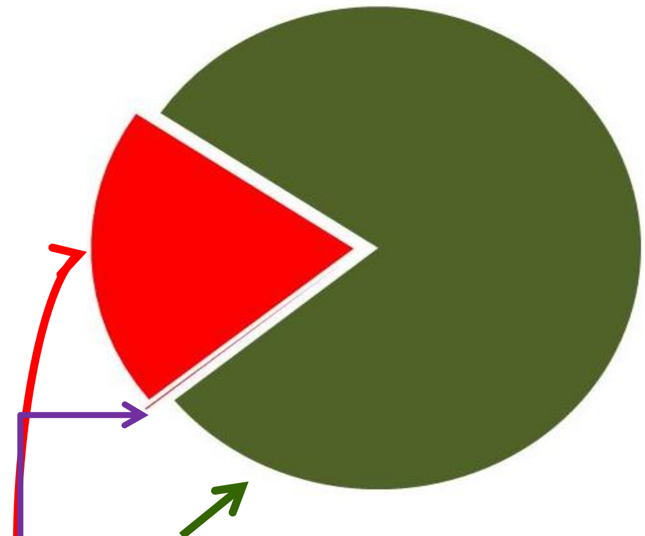
# Putting global land factors into perspective

- Many models
  - Define land assets by “rents”
  - Assume land is fully & optimally used
  - Assume causal links between policy, production and land use
  - Incorporate biofuel policy as a ”shock”
  - Assume private ownership…




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

Based on FAO 2007



Ag land available = previously cleared and underused = 1500 m ha (could be much more)

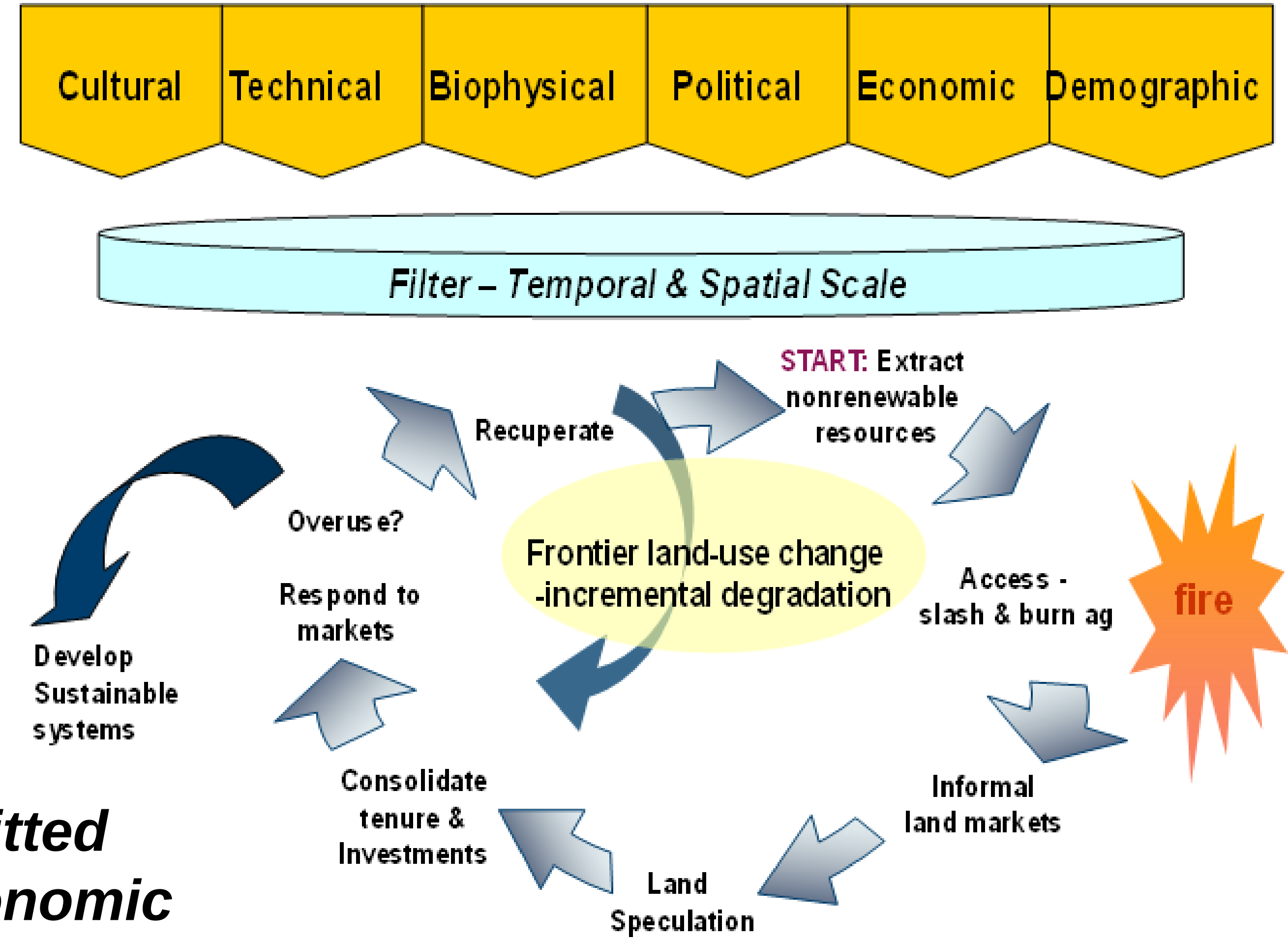
Global area burned each year = 380 M ha (Giglio et al. 2010) (+35%?)

Area converted to developed/urban use

Bioenergy LUC: too small to visualize here

# Causation? LUC is complex, dynamic process

- ***Many forces drive first-time conversion:***
  - Limited capacity for governance, ***policies***
  - Extractive (incl. oil/gas) industries
  - Access, biophysical conditions
  - Making/holding land claims
  - Poverty - land is the safety net




- ***Major land assets and drivers are omitted from the global economic models used to estimate LUC***

Source: Kline and Dale 2008. Science 321:199-200.

# Research options to address challenges of attribution

## Causal Analysis Framework

- Clear statement of problem
- Characterization of historic trends in land qualities
- Hypotheses for cause(s) of specified change(s)
- Easy eliminations and attributions
- Potential causal pathway diagrams
- Data sufficiency determination
- Strength of evidence
- Allocation of proportional causation
- Relationship with biofuel policy

Essential to clearly define effect. E.g., what is meant by "land-use change"?

- land management
- land cover
- carbon stocks
- nutrient cycling

Defined in measurable terms

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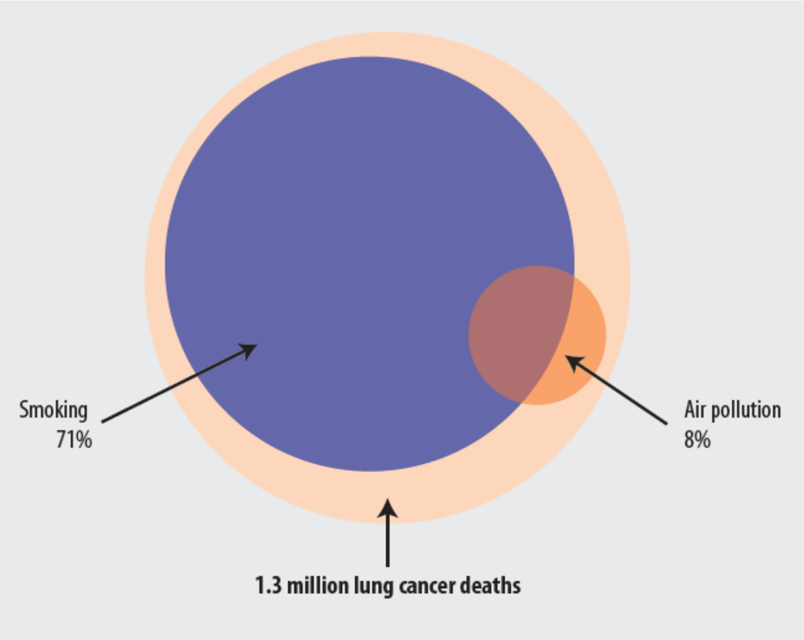
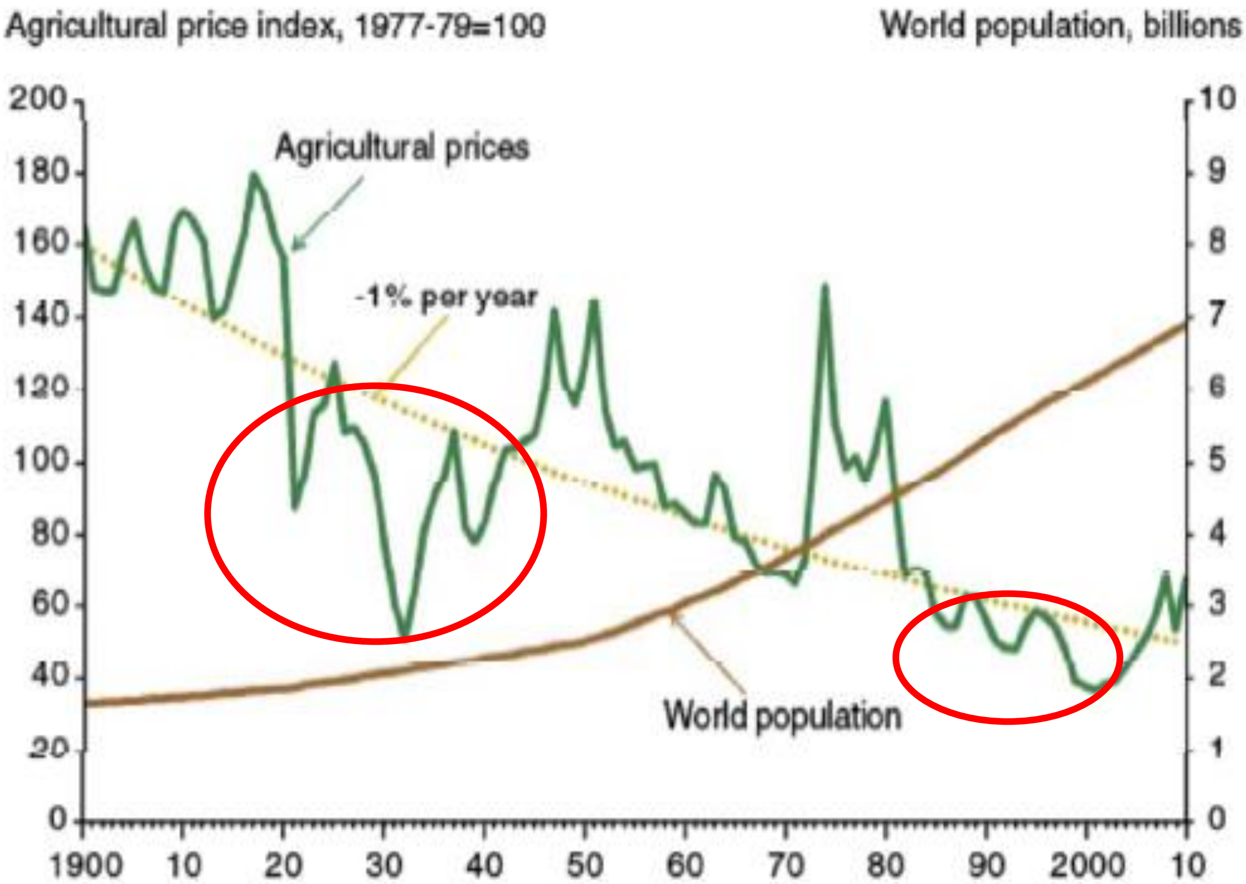
## Evidence

- Plausible cause and pathway
- Spatial co-occurrence
- Time order
- Analogous drivers
- Simulation model results
- Driver-response relationships

World Health Organization 2009 example of allocation



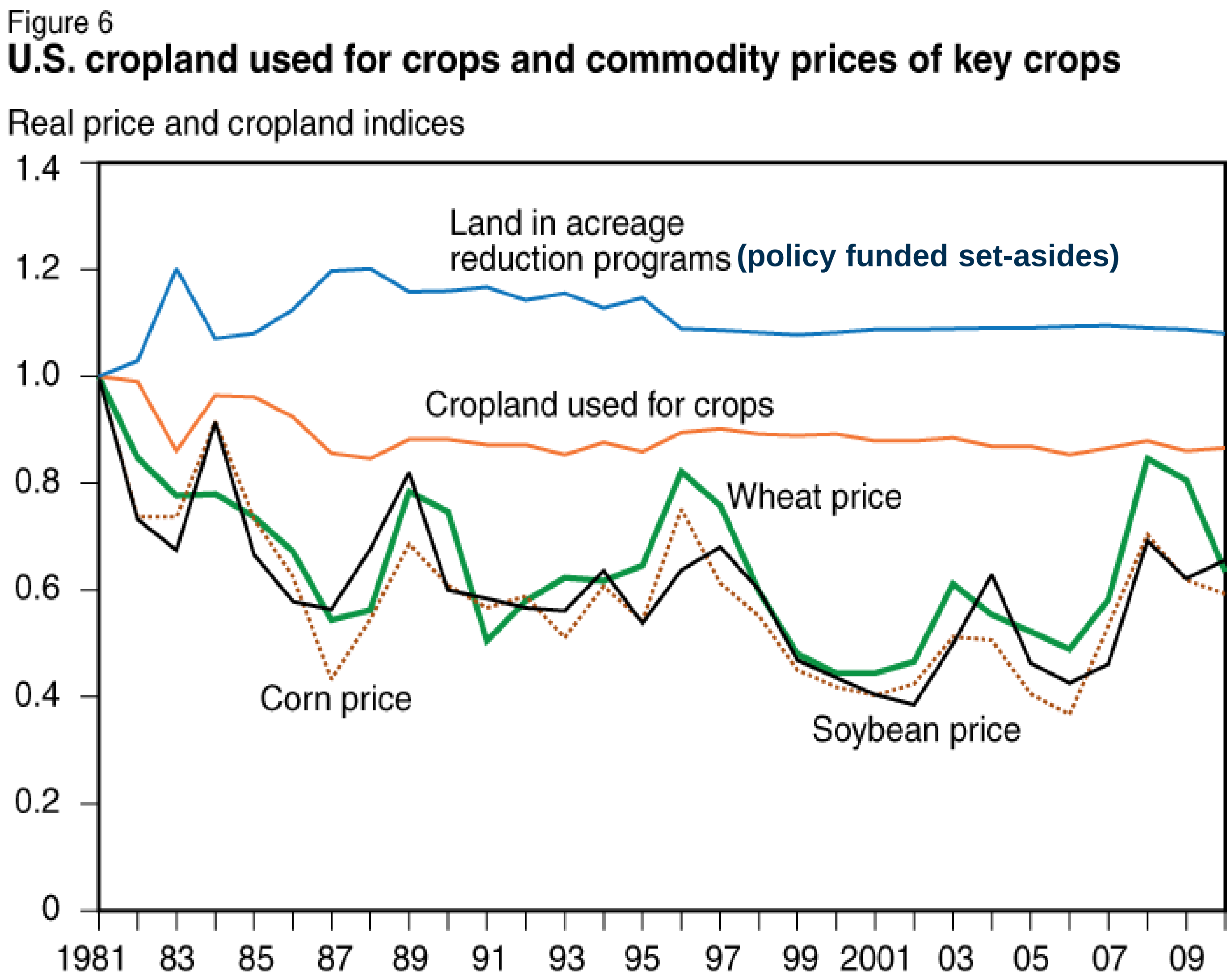
**Real agricultural prices have fallen since 1900, even as world population growth accelerated**




Source: USDA, Economic Research Service using Fuglie, Wang, and Ball (2012). Depicted in the chart is the Grilli-Yang agricultural price index adjusted for inflation by the U.S. Gross Domestic Product implicit price index. The Grilli-Yang price index is a composite of 18 crop and livestock prices, each weighted by its share of global agricultural trade (Pfaffenzeller et al., 2007). World population estimates are from the United Nations.

**Consider historic trends… crop prices**

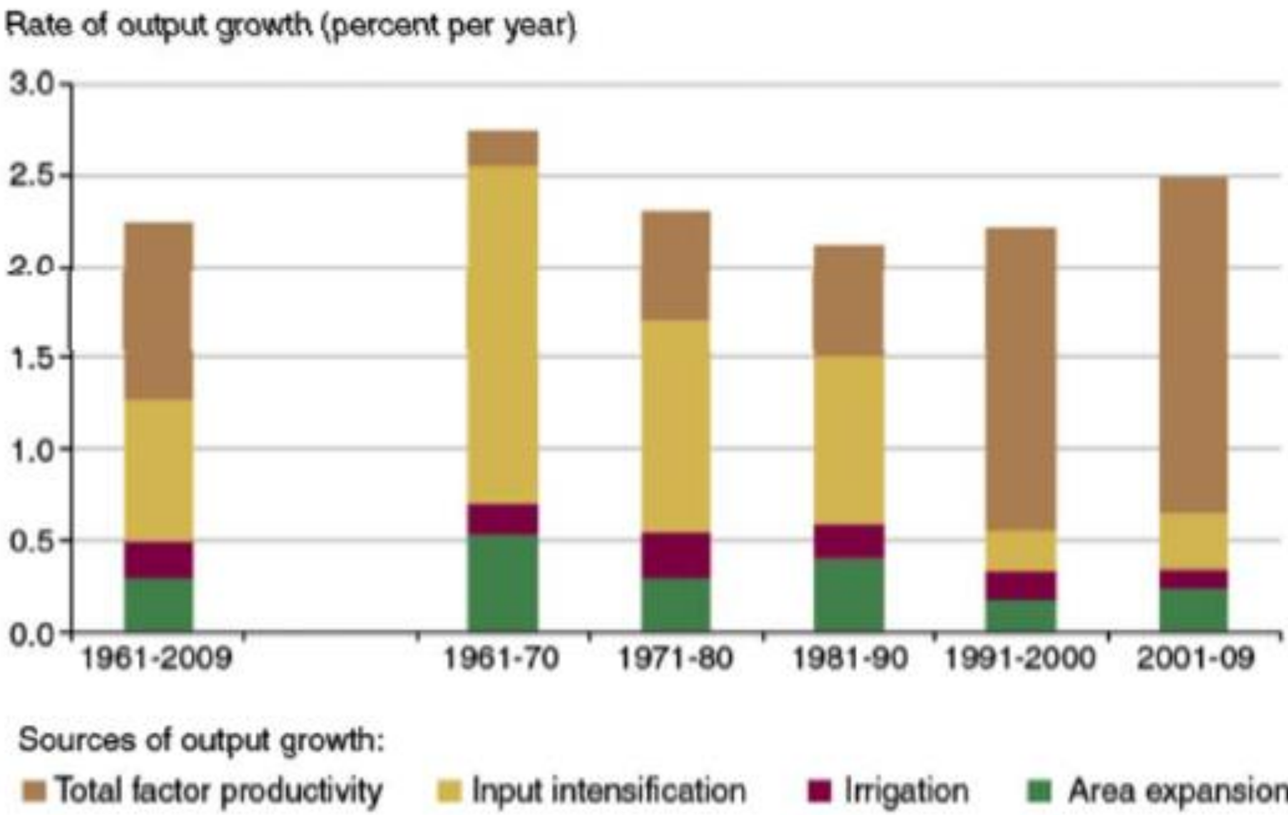
# Economic modeling assumptions




Contrary to some modeling assumptions, expectations of commodity prices and risk affect choices of ***what*** to grow on previously defined agricultural landscapes, rather than determining ***how much*** **total area** is dedicated to agricultural use

Source: USDA ERS 2011. http://www.ers.usda.gov/publications/eib89/

# Total factor productivity replaced resource expansion and input intensification as primary source of growth in agricultural output.




The height of the bar is the average annual growth rate in gross agricultural output over the period. The color components decompose the source of the growth into parts due to (i) agricultural land expansions; (ii) extension of irrigation to cropland; (iii) greater use of fertilizer, machinery, labor, and other inputs per acre of cropland; and (iv) total factor productivity.
Source: Fuglie, Wang and Ball (2012).

**How can "LUC" models incorporate the growing role of "total factor productivity?"**

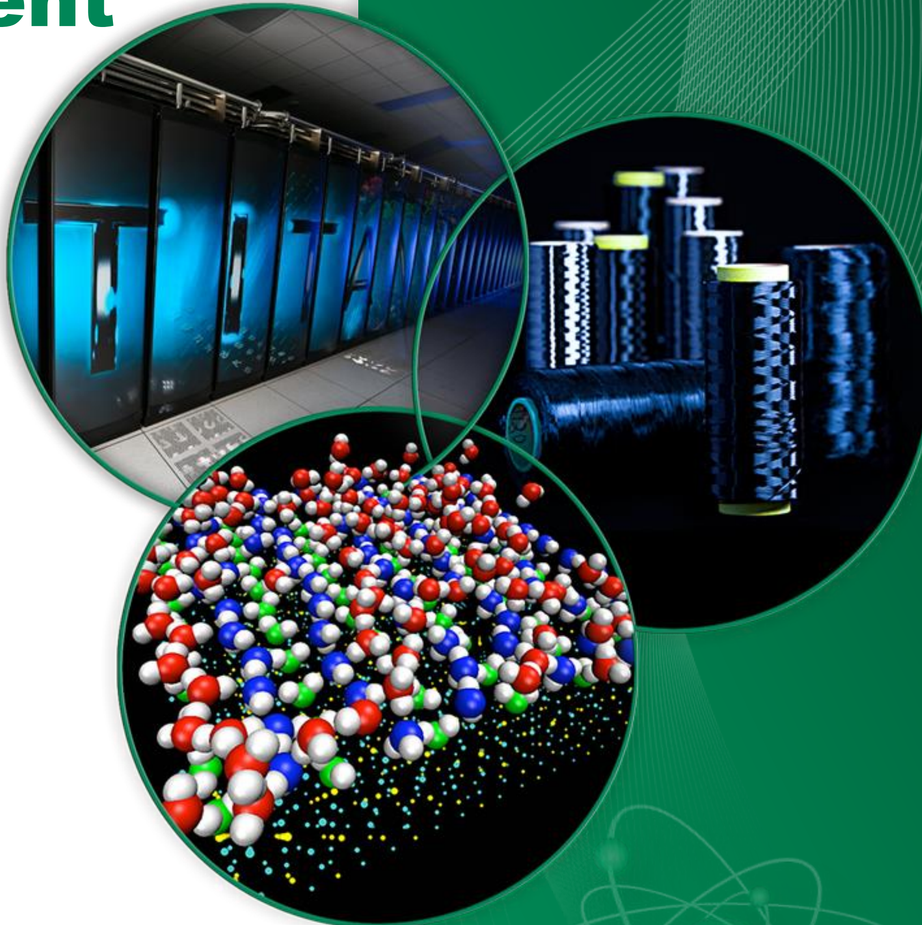
# Research Opportunities and Needs – Update since IEA meeting in Brazil:

1. Definitions: beginning with the **L**, **U** and ***C*** of LUC
2. Representation of <u>policy</u> in model specifications
3. Conceptual framework for:
   a) Drivers of initial conversion
   b) Constraints, limiting factors (land, labor, market demand)
4. Land supply, productivity and management specifications
5. Economic decision-making assumptions
6. Assumed and modeled change dynamics
   a) Baseline choice
   b) Reference scenario(s)
   c) Fire and other major disturbance regimes (anthropogenic, natural)
7. Modeling yield, efficiency, and technology changes in response to…
8. Issues of time, scale (analytical boundaries)
9. Discerning correlation, contribution (rate change), causation
10. Many, many **<u>data</u>** issues

Conclusion: take care in discussing land use, land cover, and change.

Oak Ridge National Laboratory

# ORNL Feedstock Resource Assessment and Analysis



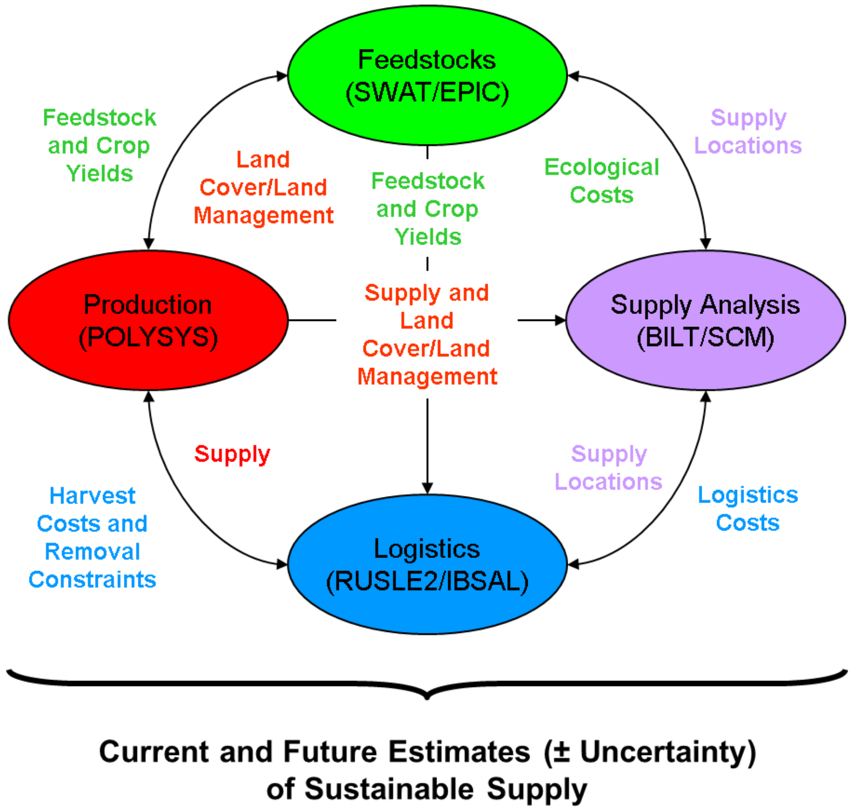
Laurence Eaton, Matthew Langholtz, Anthony Turhollow

Date: June 12th, 2013

GSB Project Meeting
Oak Ridge, Tennessee

# Integrated Resource Assessment

- Current and relevant feedstock price and supply projections.
- Incorporation of additional feedstocks (e.g., algae, MSW).
- Move toward Integrated Land Management.
- Spatially-explicit realizations
  - Stranded resources
  - Farmgate to Rx throat
  - Integrated modeling of externalities
  - Testing of policy scenarios



# U.S. Billion Ton Update (2011)


- Forecasts of potential additional biomass
  - Multi-institutional effort
  - 20-year projections of economic availability of biomass (price, location, scenario)

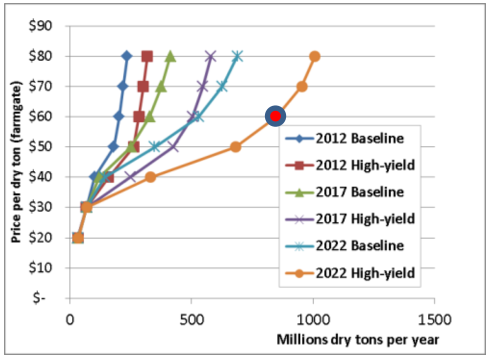
- Forest resources
  - Logging residues
  - Forest thinnings (fuel treatments)
  - Conventional wood
  - Fuelwood
  - Primary mill residues
  - Secondary mill residues
  - Pulping liquors
  - Urban wood residues

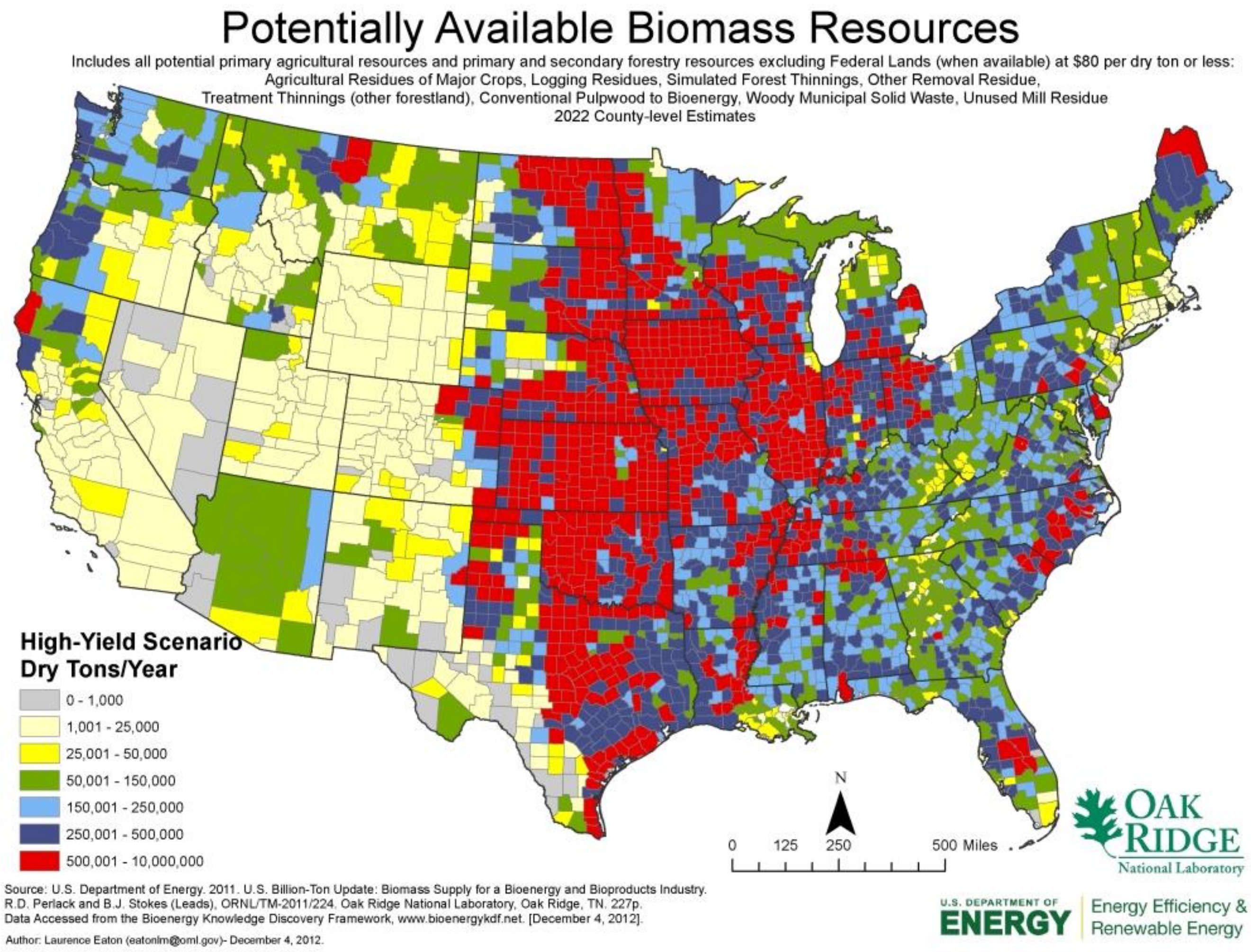
- Agricultural resources
  - Crop residues
  - Grains to biofuels
  - Perennial grasses
  - Perennial woody crops
  - Animal manures
  - Food/feed processing residues
  - MSW and landfill gases
  - Annual energy crop (added for 2011)

# Supply Curve Results

- **2022**
- **High-yield scenario**
- **$60 dry ton$^{-1}$**

**848 x $10^6$ dt**

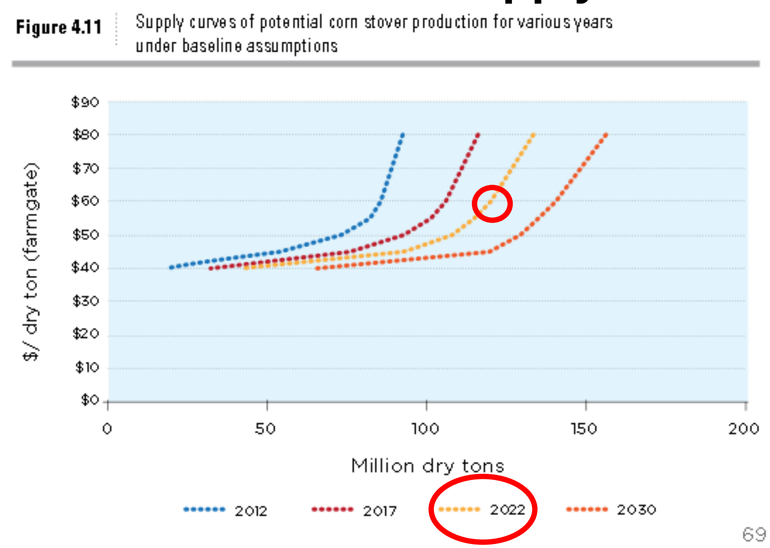


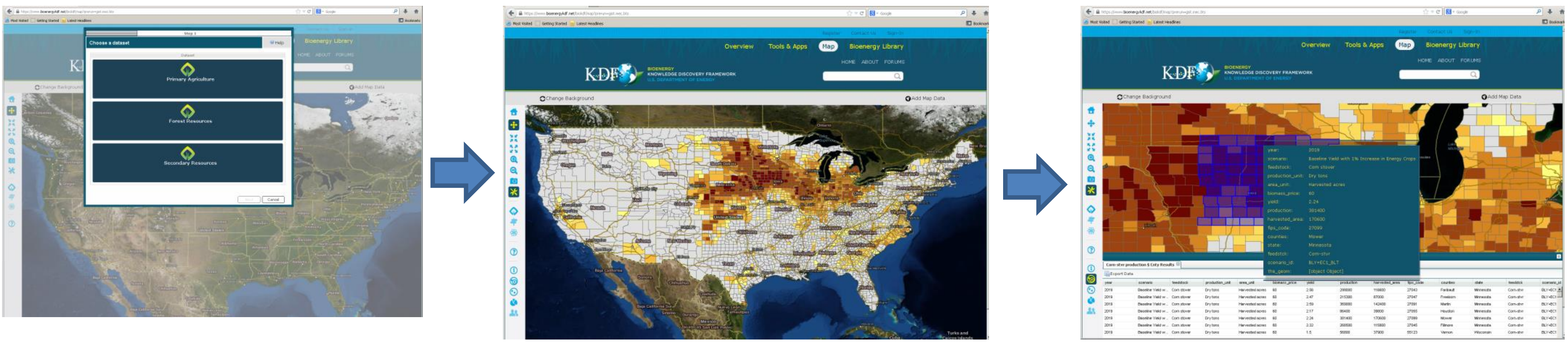
# Bioenergy KDF Resources

- Billion Ton Data Explorer
  - Visualize custom supplies from the BT2 findings
  - Available for all potential resources identified as new biomass sources

## Corn Stover Supply




## Online Tool Workflow



https://bioenergykdf.net/

# Thank you!

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The views in this presentation are those of the authors who are responsible for any errors or omissions.

**Collaborators include**
LM Baskaran, M Davis, B Davison, ME Downing, LM Eaton, RA Efroymson, C Farley, NA Griffiths, M Hilliard, H Jager, S Kang, PN Leiby, M Langholtz, LR Lynd, G Marland, A McBride, S Surendran Nair, GA Oladosu, ES Parish, RD Perlack,, T Wilbanks, SB Wright, LL Wright…

**DOE OBP staff –**
Z Haq, K Johnson, A Lindauer, P Grabowski, A Goss-Eng.

**Other labs and organizations** –
H Chum (NREL), M Wang (ANL), C Corr and ISO committee colleagues (ISO PC248)…