LUC dynamics and improving sustainability assessments: models, science and causal analysis

Presentation for the 97th annual meeting of the Ecological Society of America (ESA)
Life on Earth: Preserving, Utilizing and Sustaining our Ecosystems
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Outline

- Key points, Jerry's advice
- Definitions –
  - sustainability
  - indicators
  - models, science, causal analysis
- Assumptions and knowledge gaps
- Costs/benefits of certification
  – ISO initiative
- A path forward
  (win-win opportunities)

Presentation points:

> LUC models and premises need strong foundations in observation, empirical evidence and causal analysis

> Scale matters (spatial and temporal)

> Incentives to improve services from managed landscapes is key

> Goals must be clear and measurable; progress monitored

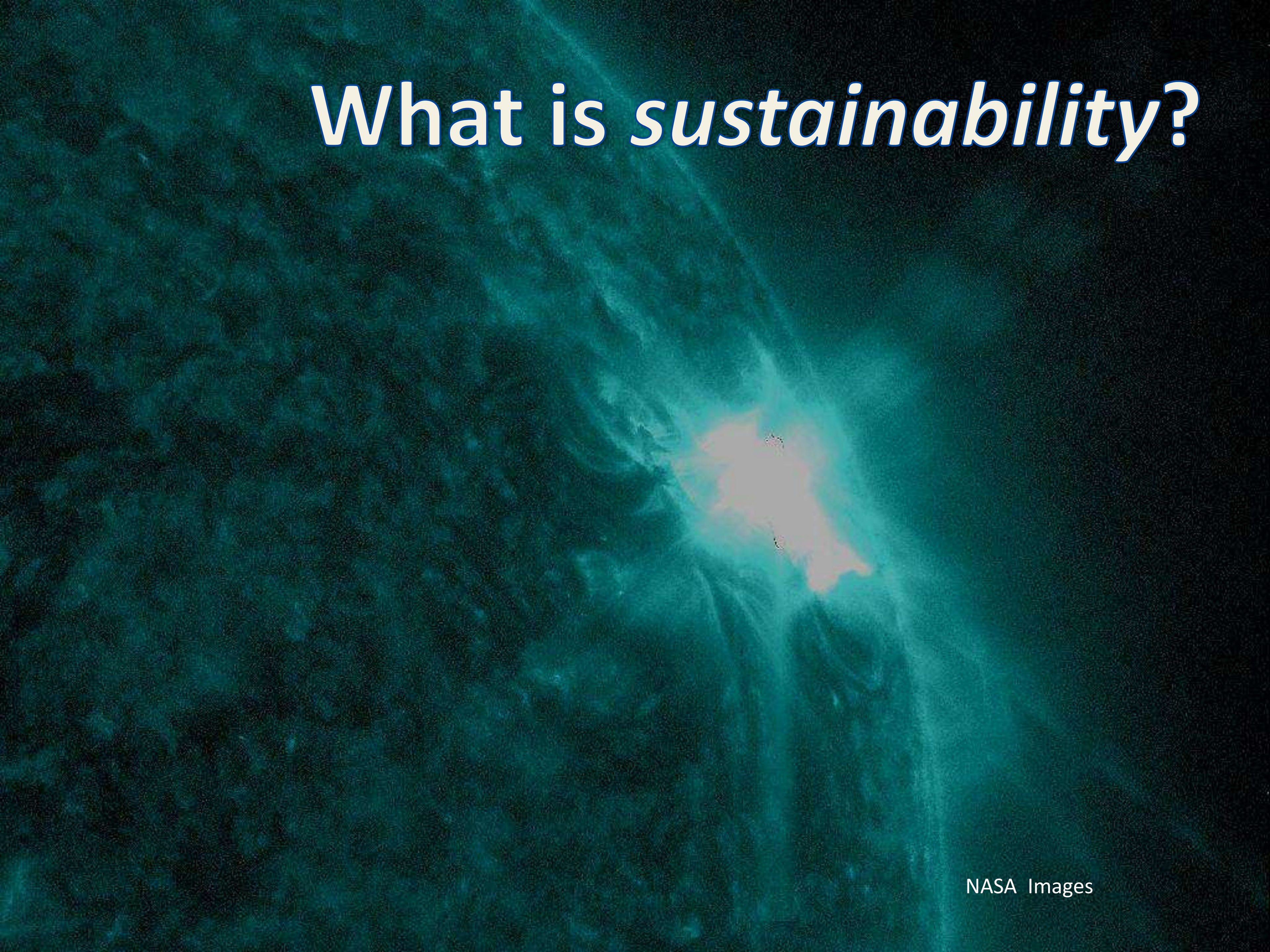
> Assessment is context specific

> Best to focus on win-win opportunities (socio-econ-political)

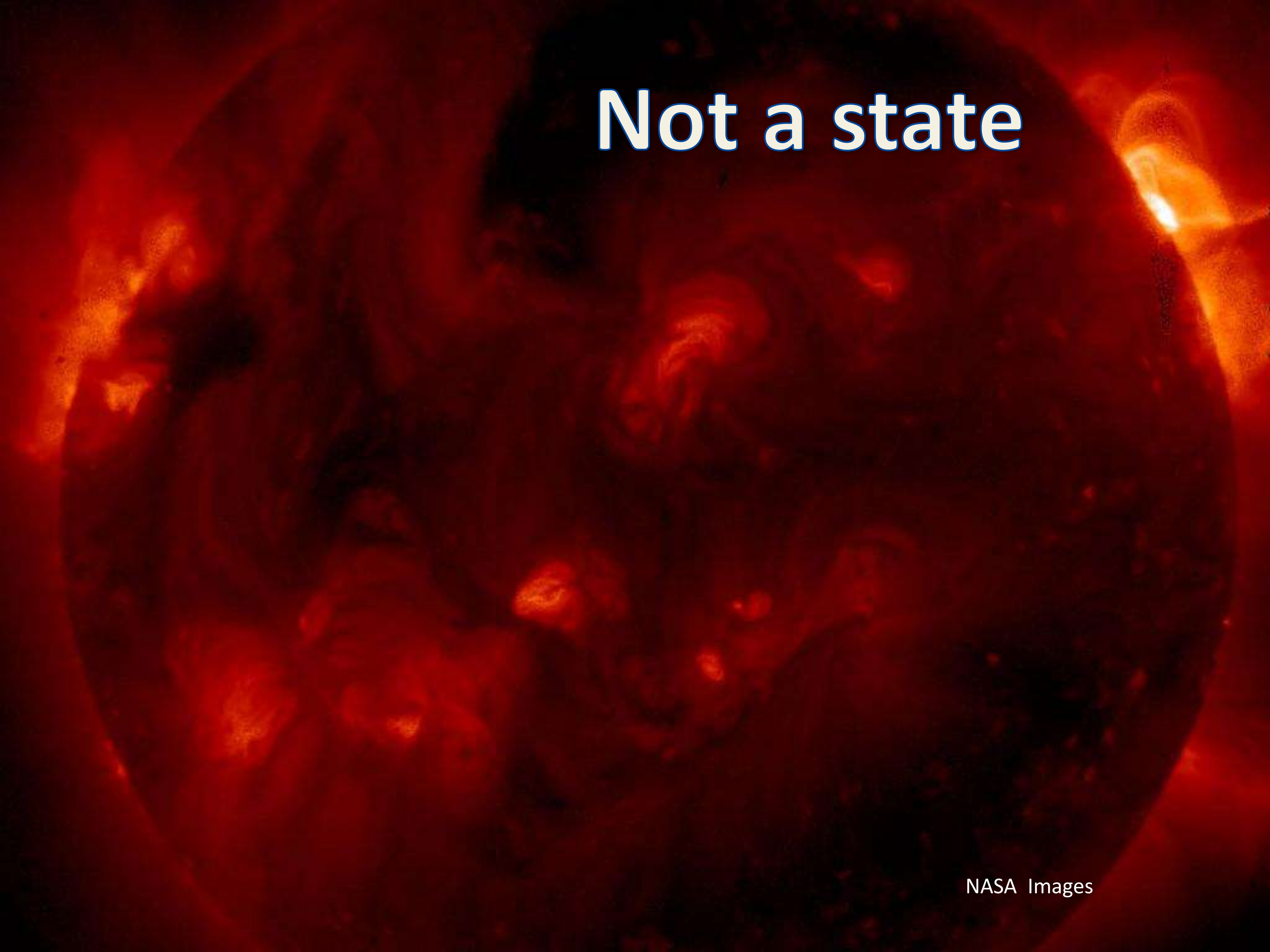
Jerry Franklin (ESA plenary, Portland, Aug. 6th 2012)

* Examine the premise of everything. Always.
* Landscape approach essential for land management issues.
* Stewardship is imperative.
* Its not black and white, but shades of green.
* Policies, no matter how good, must be socially acceptable to be sustainable.

What is *sustainability*?



NASA Images


Not a state
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A trajectory…
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Relative to other possible trajectories

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Scale matters

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Perspective matters
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How we define and measured is fundamental to understanding

Measurement is challenging…

"Not everything that can be counted counts, and not everything that counts can be counted."

-William Bruce Cameron

NASA Images

The performance paradox:
You can’t manage
what you can’t (or don’t) measure.

NASA Images

“Sustainability” An overused term

- The capacity of an activity to continue while maintaining options for future generations
- Integrating environmental, social and economic dimensions
- Compared to what?

Sustainability Indicators

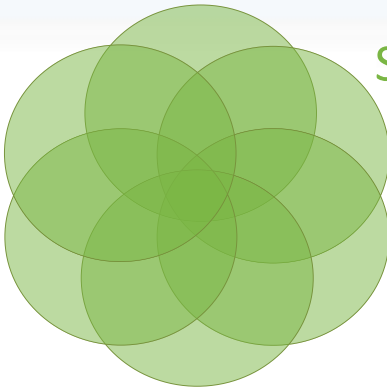
A measurement that provides information about the effects of human activities on the environment, society or economy.

Indicators should be

- Useful
  - Policymakers
  - Producers
- Technically effective
  - Sensitive to stresses on system
  - Anticipatory: signify impending change
  - Have known variability in response
- Practical
  - Easily measured
  - Consider context of measure
  - Broadly applicable
  - Predict changes that can be averted by management actions

Dale and Beyeler. 2001. Challenges in the development and use of ecological indicators. *Ecological Indicators* 1: 3-10.

Categories for indicators of environmental and socioeconomic sustainability



McBride et al. (2011) *Ecological Indicators* 11:1277-1289

Dale et al. (In review) *Ecological Indicators*

Recognize that measures and interpretations are <u>context</u> specific

[Efroymson et al. 2012, *Environmental Management*]

Examples of environmental sustainability indicators

Environment	Indicator	Units
Soil quality	1. Total organic carbon (TOC)	Mg/ha
	2. Total nitrogen (N)	Mg/ha
	3. Extractable phosphorus (P)	Mg/ha
	4. Bulk density	g/cm^3
Water quality and quantity	5. Nitrate concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	6. Total phosphorus (P) concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	7. Suspended sediment concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	8. Herbicide concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	9. storm flow	L/s
	10. Minimum base flow	L/s
	11. Consumptive water use (incorporates base flow)	feedstock production: m^3/ha/day; biorefinery: m^3/day

Environment	Indicator	Units
Greenhouse gases	12. CO_2 equivalent emissions (CO_2 and N_2O)	kgC_{eq}/GJ
Biodiversity	13. Presence of taxa of special concern	Presence
	14. Habitat area of taxa of special concern	ha
Air quality	15. Tropospheric ozone	ppb
	16. Carbon monoxide	ppm
	17. Total particulate matter less than 2.5μm diameter ($PM_{2.5}$)	$\mu g/m^3$
	18. Total particulate matter less than 10μm diameter (PM_{10})	$\mu g/m^3$
Productivity	19. Aboveground net primary productivity (ANPP) / Yield	gC/m^2/year

McBride et al. (2011)
Ecological Indicators
11:1277-1289

Science and Models

- Models
  - Are simplified views of the world, not true representations of complexity
  - Generate estimates that reflect assumptions, baseline, input data, and conceptual views
  - Are tools designed to explore specific relationships
    - E.g., “market shock” effects on simplified global economy
- Science
  - Follows a systematic methodology based on evidence
  - Requires data + resources + time to assess and verify assumptions
  - Is a tedious process of testing/disproving hypotheses

There is no scientific consensus on methods to estimate land-use change (LUC) associated with energy policies, much less sustainability

Sources: Science Council of Britain http://www.sciencecouncil.org/
Kline et al. 2011; CARB 2011 final reports from Expert Work Group on LUC; CBES 2010; EC 2010.

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One aspect of sustainability: What are effects of bioenergy policy on LUC?

Ways to improve estimates of LUC:

1. Representation of policy in model specifications
2. Economic decision-making assumptions
3. Conceptual framework for drivers of initial conversion
4. Land supply & management specification
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

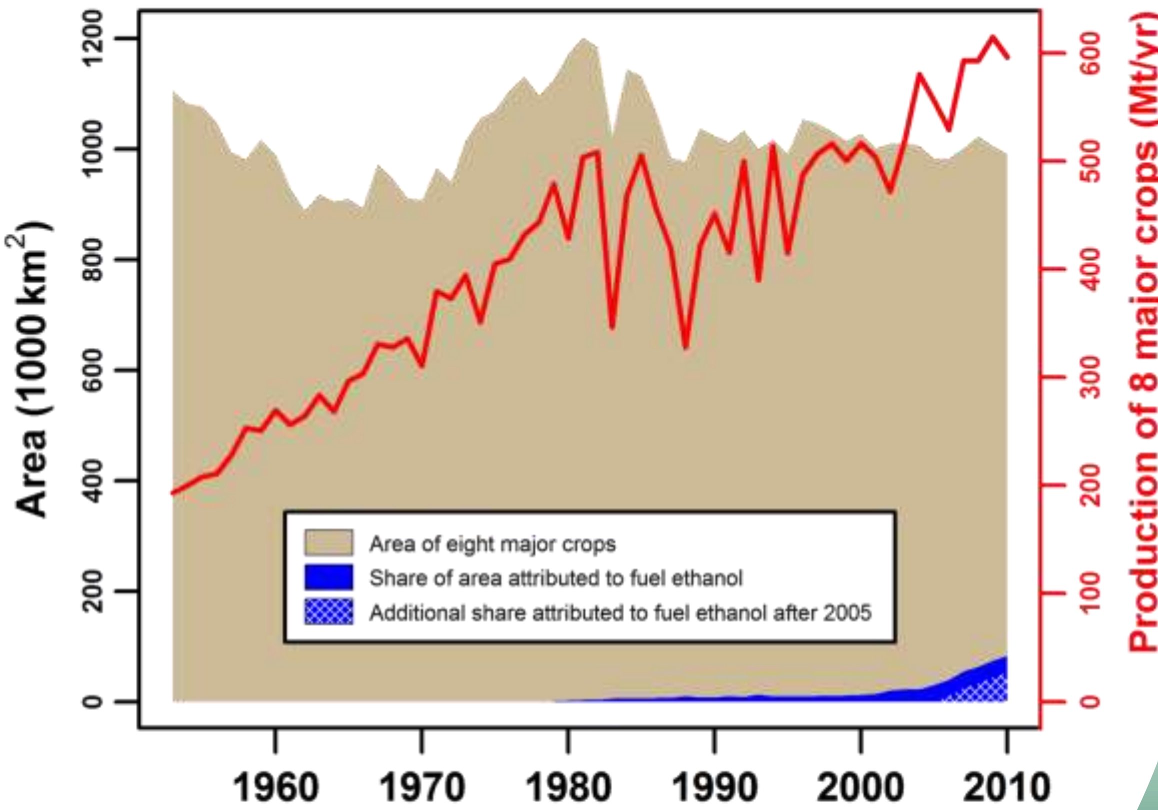
It depends

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

Example: Issues in modeling bioenergy policy to estimate effects

- Different policies (e.g. mandate, tax, etc.) have distinct environmental and socioeconomic implications.
- Modeling policy is challenging
  - Policy often modeled as a "shock" in demand. What if there is no shock (fig.)?
  - Effects of policy specifications, assumptions, and scenarios in models should be tested
  - Do model simulations reflect actual policies? Effects?

US total planted area (shaded) and production (red line) of major crops



ORNL Fig based on USDA data (A.McBride)

USDA eight major crops are: barley, corn, cotton, oats, rice, sorghum, soybeans and wheat.

See: Oladosu and Kline, 2010.
Oladosu et al. 2011.

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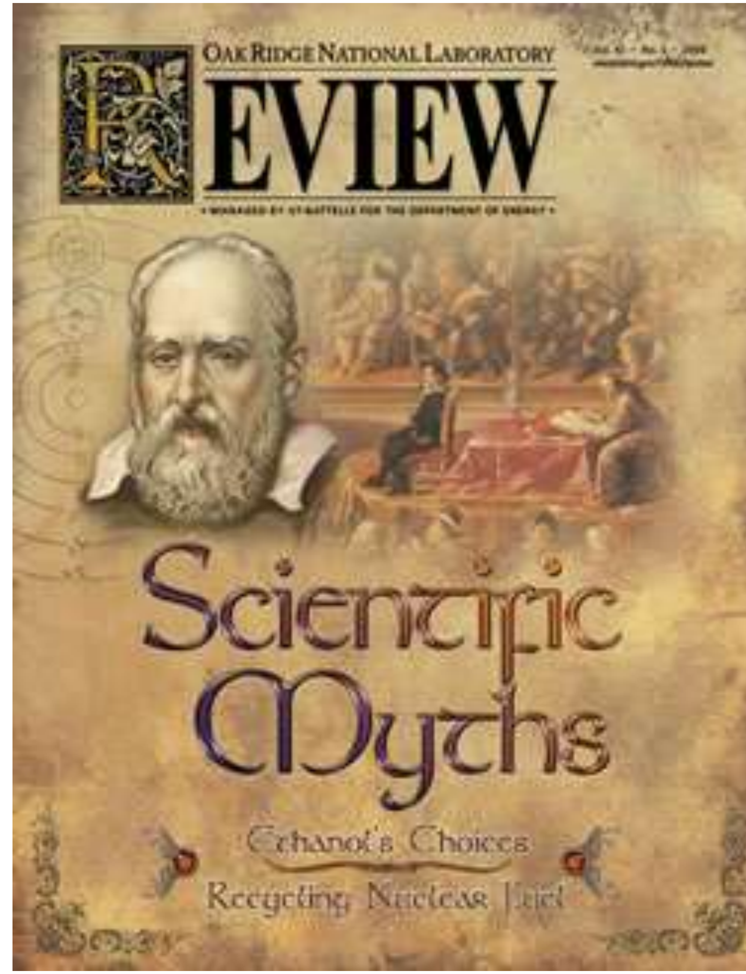
Example: data inputs for global land available for expansion without affecting forest habitat*

- Small portion of global land suited for agriculture is harvested each year
- Uncertainty about current land uses is surprisingly large
- Approximately 1.4 billion hectares (give or take 0.3 billion) are harvested each year out of the total of 3 to 5 billion hectares "available" (previously cleared)
  - Remainder: mostly 'pasture,' large areas that burn frequently
  - "Available" = non-reserve, non-forest lands with climate and soils suited for rainfed agriculture



* Kline and Dale 2008. Science 321:199-200.
* Kline et al. 2009. Issues in Science and Technology 25,3:75-84.
* Kline et al. 2011. Biomass and Bioenergy 35:4488-4491.
Giglio et al. 2010 (global burned area)

Premise: land cover change can explain cause

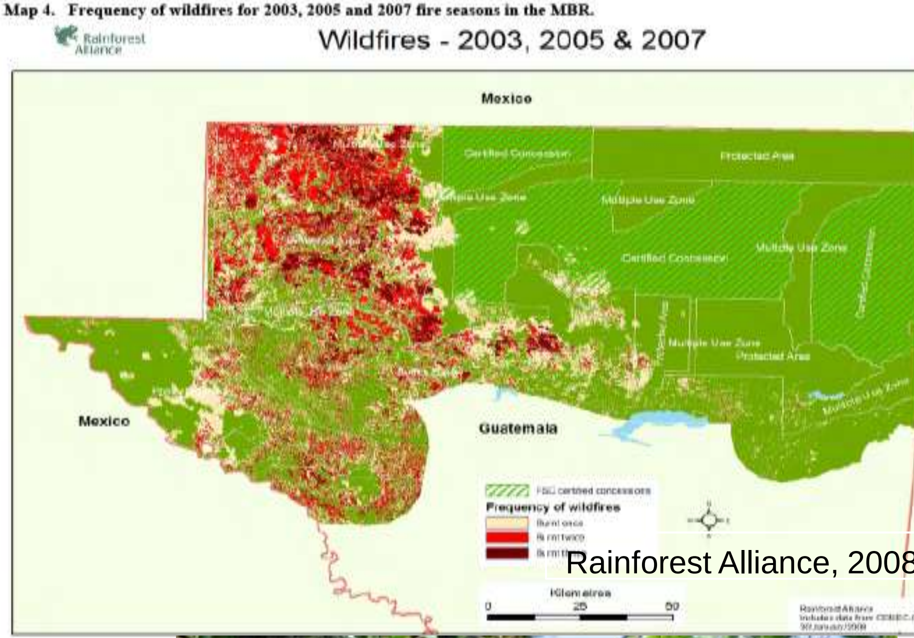
Global land cover change is estimated from limited data and simple classes (forest, grassland/pasture, cropland).

Models –

- Assume land cover class reflects "use"
- Assume change from forest (to grassland or crops) is caused by "agriculture"
- Assume land is privately held and
    - managed to maximize profit
    - based on perfect market information
- Assume expansion of agriculture is driven by market prices
- Conclude that changes in agricultural prices cause deforestation
- Does scientific analysis support ANY of these assumptions?

Map reflects burning and land conversions in a National Park area of Guatemala (Maya Biosphere Reserve) where habitat loss, fires, and water and soil contamination and human settlement are legacies of oil

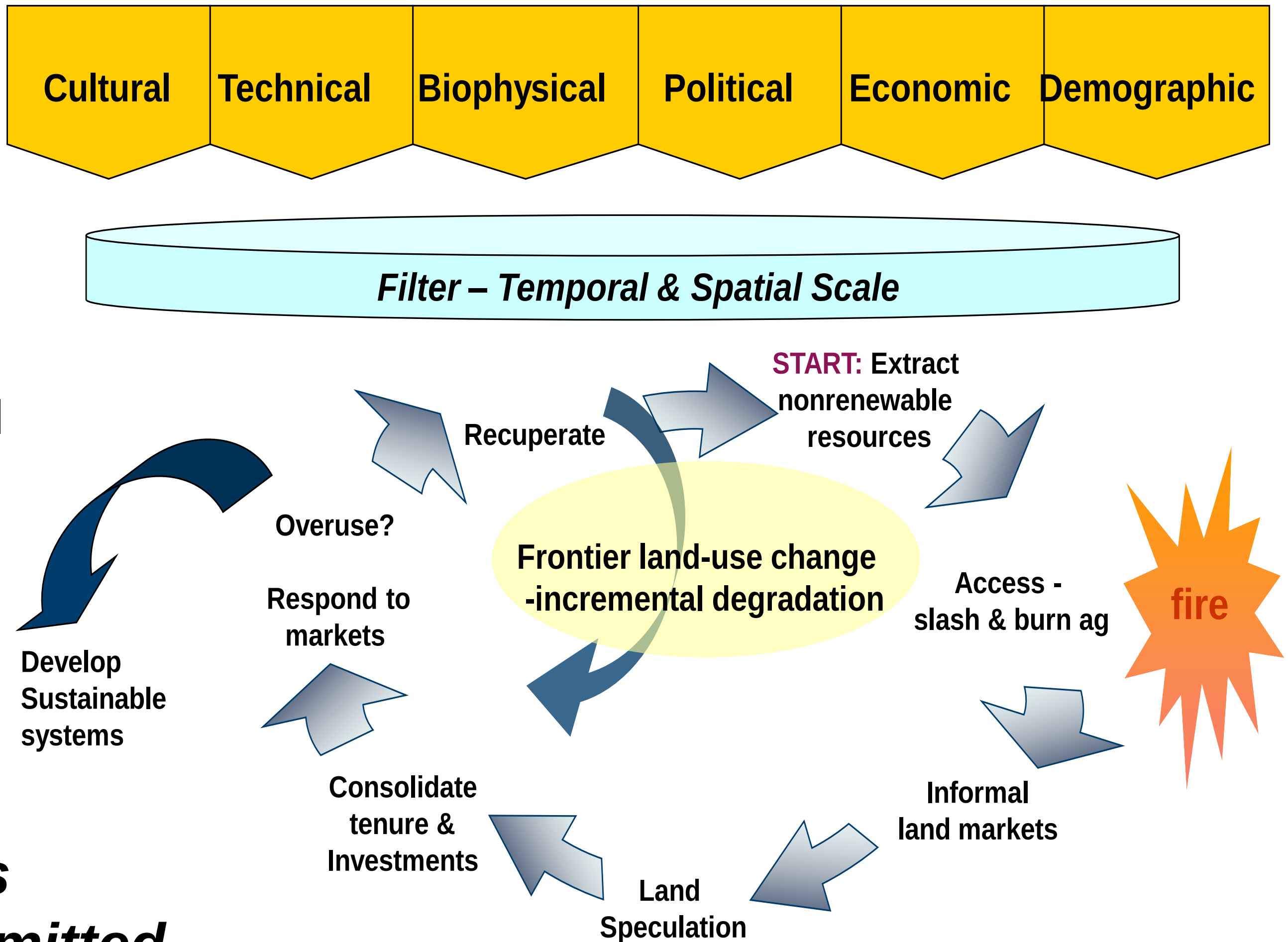
Map 4. Frequency of wildfires for 2003, 2005 and 2007 fire seasons in the MBR.



Rainforest Alliance, 2008

Causation? LUC is complex, dynamic process

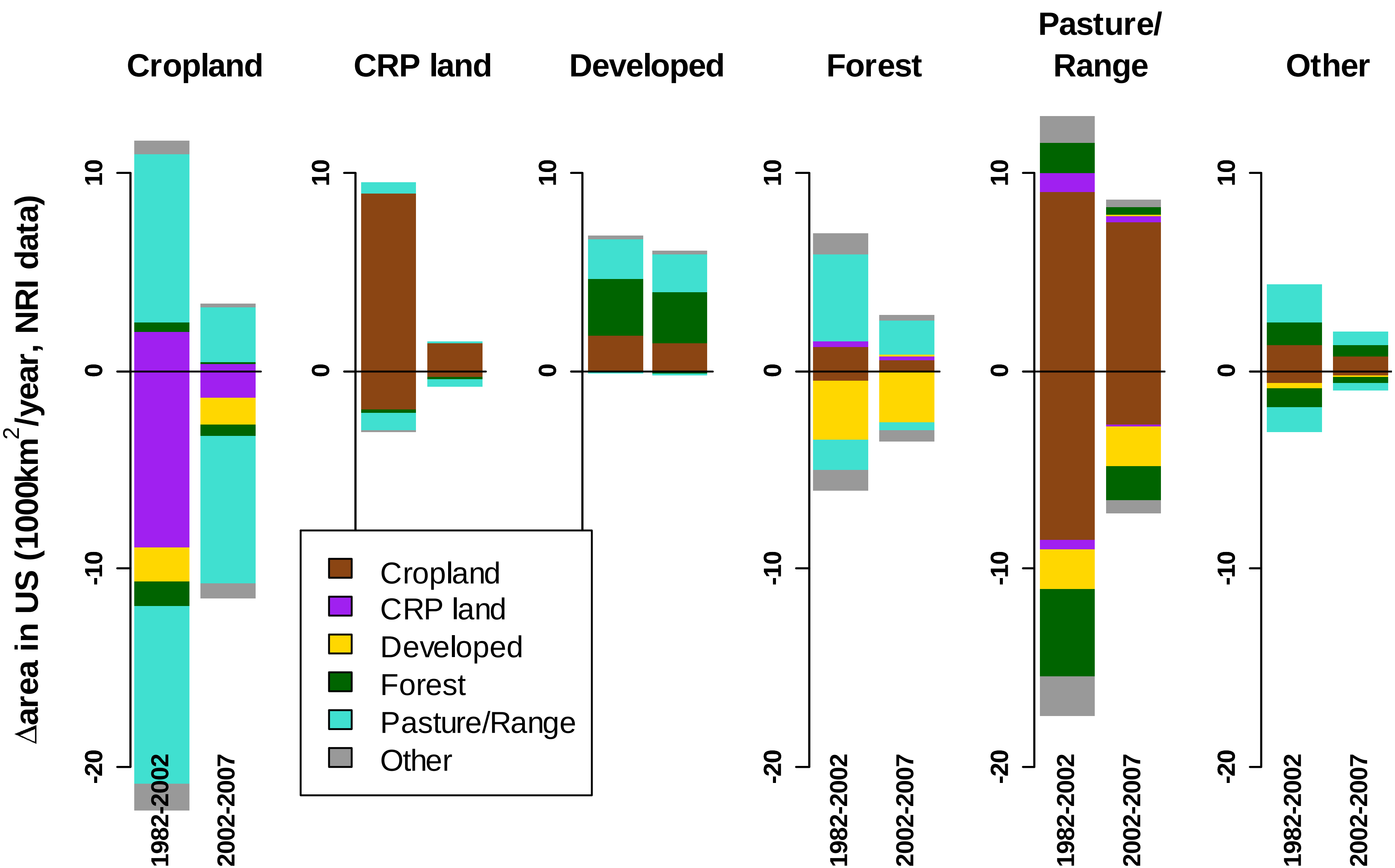
- ***Driving first-time conversion:***
  - Limited capacity for governance, policies
  - Extractive (incl. oil/gas) industries
  - Access, biophysical conditions
  - Making/holding land claims
  - Poverty - this is the safety net



- ***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.

Gross changes in US to (above) and from (below) each of six land classes, based on NRI data.

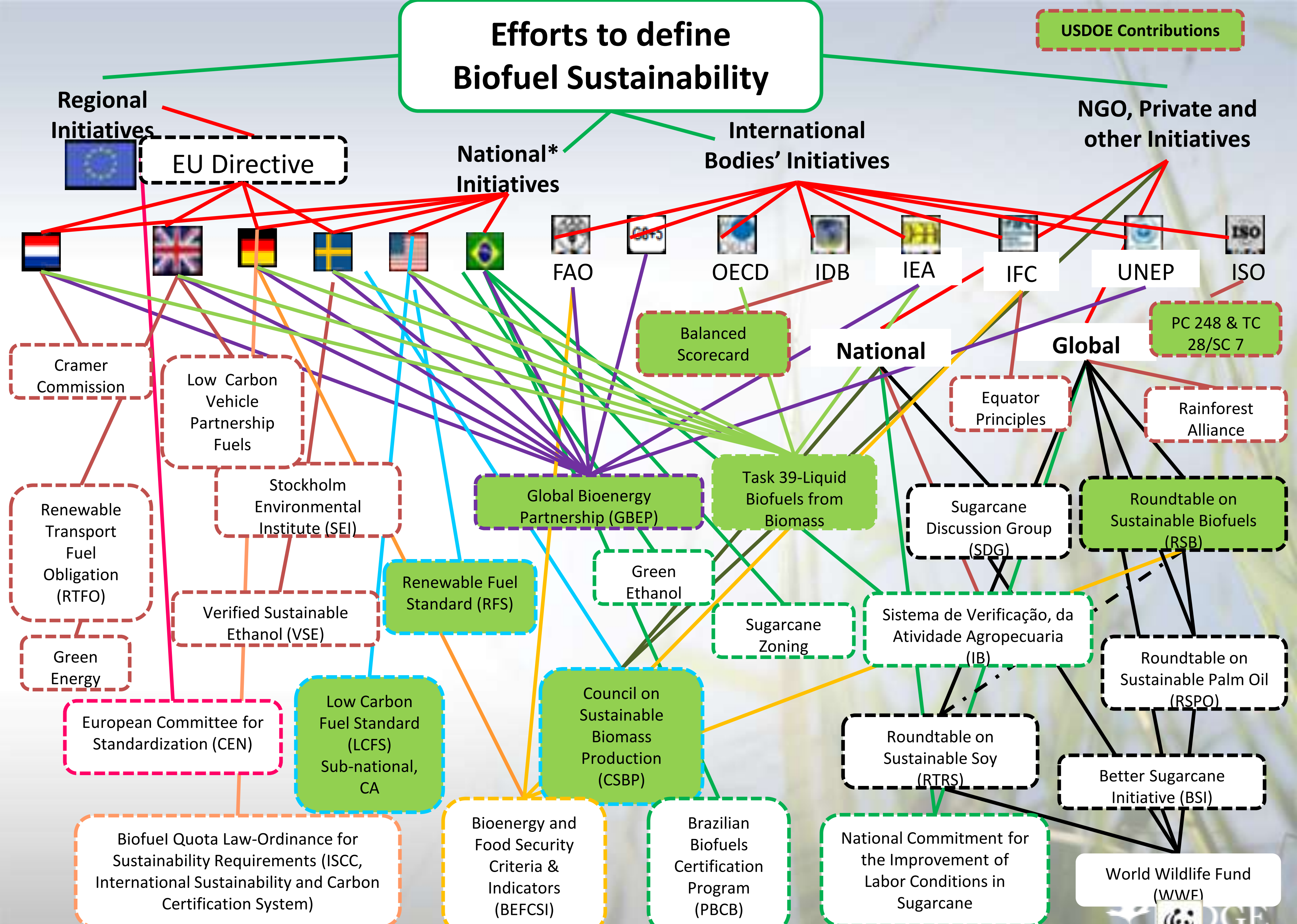


Many initiatives are exploring indicators for sustainability – e.g. for bioenergy…

- ISO (International Organization for Standardization)
- GBEP (Global Bioenergy Partnership)
- CSBP (Council on Sustainable Biomass Production)
- RSB (Roundtable on Sustainable Biofuels)
- Many more

BUT

- Some indicators focus on management practices although knowledge is limited about which practices are "sustainable"
- Implementation is limited by indicators being too
  - ✓ Numerous
  - ✓ Broad
  - ✓ Costly
  - ✓ Difficult to measure



* Australia Subnational, NSW

Source: NREL (Chum, Warner), UNICA

Science to support bioenergy sustainability

Published research and active involvement are *CRITICAL* (ISO, IPCC…)

- Transparency, open dialogue
- Process involving users, stakeholders
- To be "science-based" must define, monitor, and measure each aspect

Recommendations

- Improve consistency of definitions, indicators, protocols for measurement
- Assess *actual* effects of *policy* (avoid over-reliance on unverified models)
- Minimize costs relative to value added
- Select, test and apply practical and useful indicators
- Identify opportunities to streamline

IEA Bioenergy Joint Task Meeting (2011): “Can certification ensure sustainability?”

“No” because –

1. Nothing can **ensure** sustainability.
2. There are too many opportunities for substitution in markets
3. Transaction costs for certification, monitoring and verification are too high relative to the value of the product (biomass)
4. *There* is no evidence of sustained political will and sufficient “market premiums”
5. Even well-designed schemes can be too easily “gamed” and it only takes a few well-publicized cases to undermine credibility.

IEA Joint Bioenergy Tasks Question (modified): "Can certification facilitate sustainability?"

"Yes" ***if*** **it –**

1. Is developed with and adopted by users to meet their needs
2. Provides science-based tools and guidelines that move production toward more sustainable and profitable paths (from users' perspectives)
3. Is adaptable to changing contexts and priorities
4. Can be implemented on a "level playing field" (new entries need political will, financial incentives)

Win-Win Opportunities to Move Forward

Improve soil & water management

- Precision management and nutrient recycling
- 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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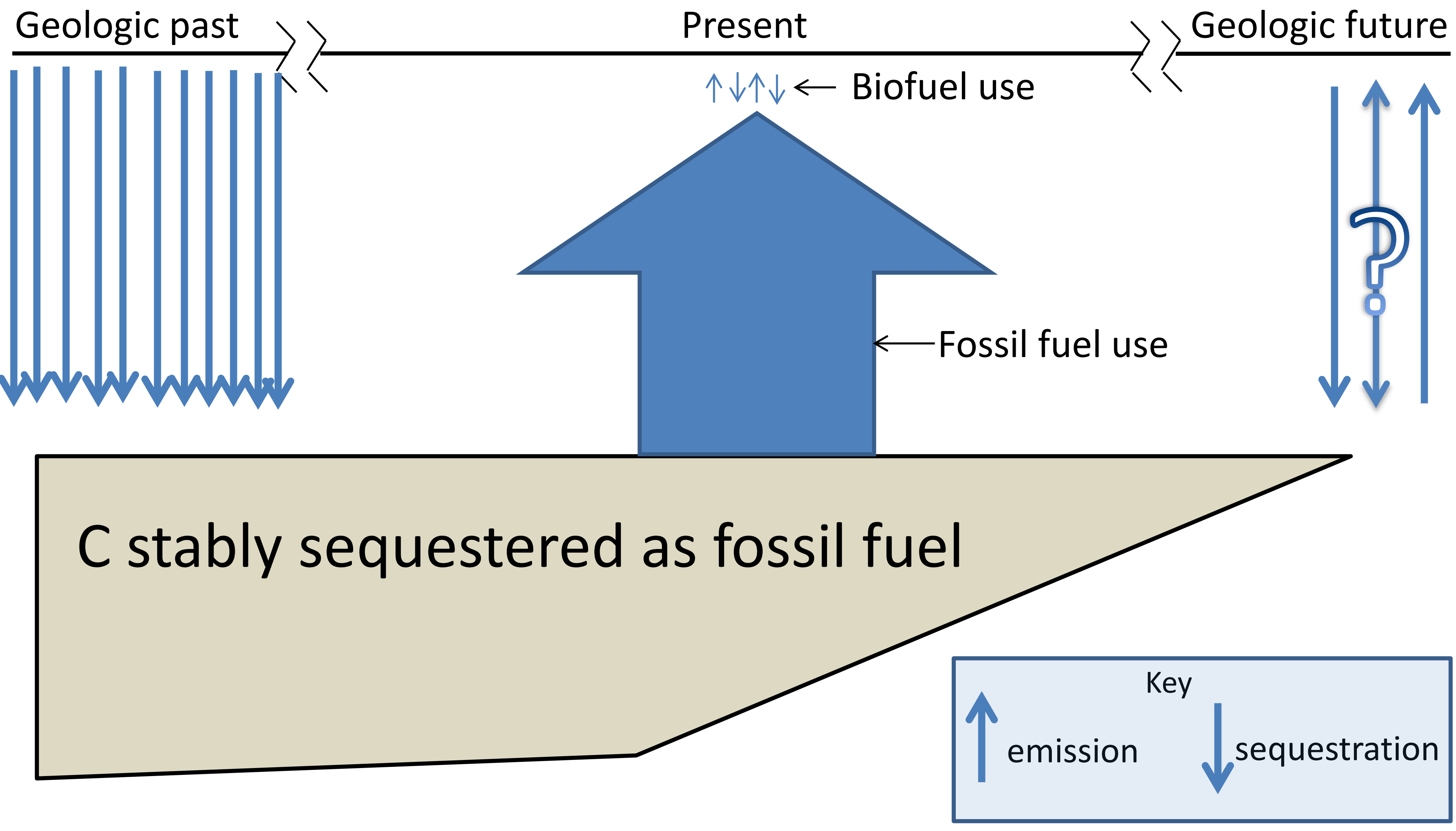
Intrinsic scale differences challenge comparison



Conceptual chart developed by K.L. Kline and A. McBride, ORNL.

Thank you

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Related ORNL Publications (see CBES web site)

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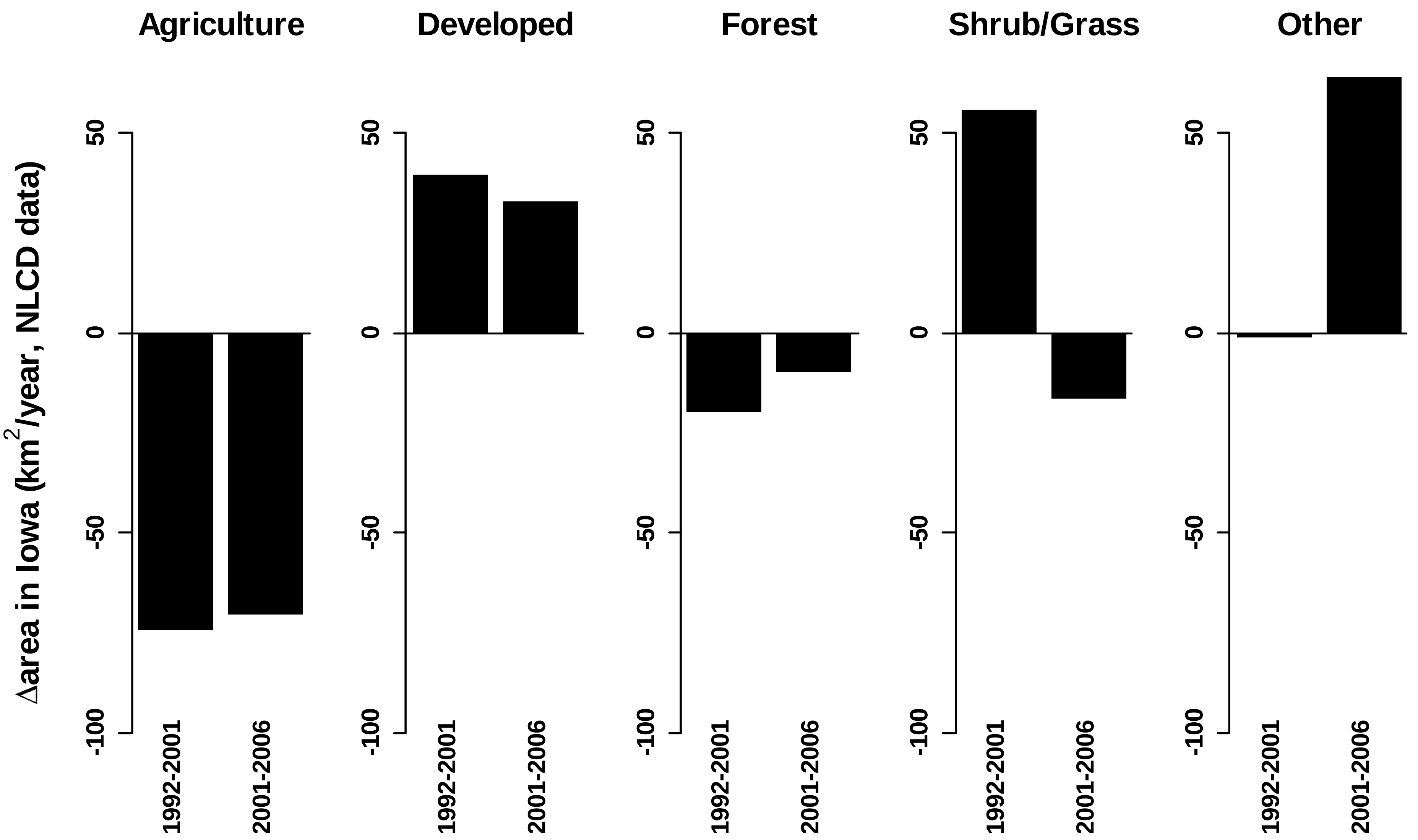

Net changes in Iowa to (above) and from (below) each of five land classes, based on NLCD data.

Summary – modeling project issues/goals

Reliable land information: cover, uses, productivity, soil qualities, C stocks, fluxes (C, nutrients), environmental services…, is essential

Misalignment between models and available data is a major hurdle for effective land use change assessment

- Evaluation of effects of averaging and data aggregation at different scales
- Characterize land resources with consistent measures (stocks, productivity)
- Design theoretical and computational frameworks for changes in land resources
- Develop operational linkages for models that operate at different scales

Improved modeling requires better data and new community approach

- Improve temporal resolution of LC/UL data
- Community benchmarks for LU/LC data sets
- Data to support causality analysis
- Verifiable values for stocks, flows, and services (temporally and geospatially referenced)

Thank you

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