Reality is a special case

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See Ch.3 on indirect land-use change here: https://www.energy.gov/eere/bioenergy/articles/2016-billion-ton-report-volume-2-environmental-sustainability-effects

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Authors' work is dedicated to grandchildren & future generations.

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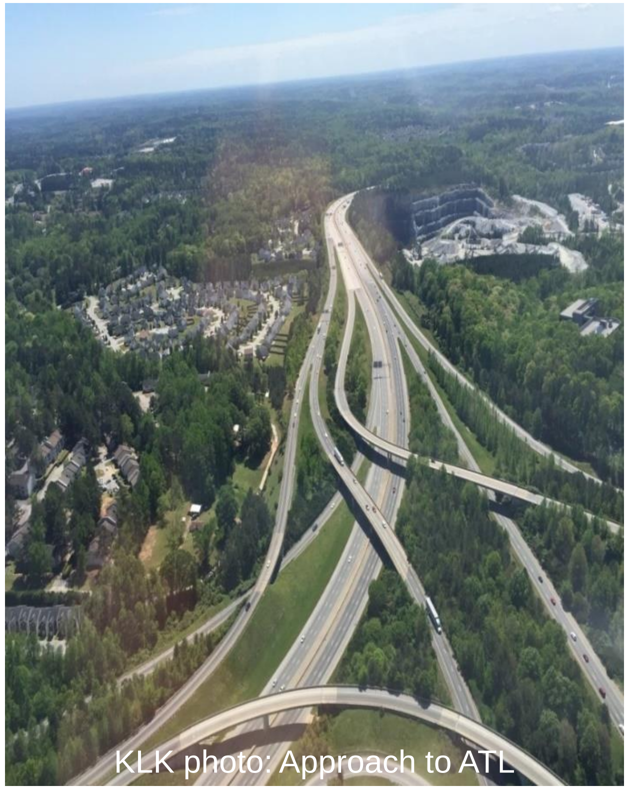
Outline

1. Defining LUC & ILUC
2. Why LUC calculations are difficult
3. Modeling vs reality
4. Guidelines for constructive progress
5. Q & A



Quick poll: Which of the following represent LUC?

(If you feel some are clearly LUC, or clearly not, feel free to explain in chat)

1. A 40-acre field enters a 10-year conservation set-aside program (CRP) contract; following cover crop establishment in year 1, tillage ceases for the next 9 years.
2. At the end of 10 years, the CRP contract is not renewed and the 40-acre field in example #1 is put back into pre-CRP crop rotations.
3. A hay field is harvested, cultivated & put into wheat-corn-soy rotation.
4. Two linear miles of fence row vegetation & access tracks are cleared to consolidate 8 small rain-fed parcels into one 160-acre field with pivot irrigation.
5. The harvest from a corn field begins to serve as feedstock for a local ethanol plant rather than prior unknown use (sold to local elevator).

Quick poll: Which of the following represent LUC?

Results (total % >100 due to the multiple choices available)

1. A 40-acre field enters a 10-year conservation set-aside program (CRP) contract; following cover crop establishment in year 1, tillage ceases for the next 9 years.

   31,34%

2. At the end of 10 years, the CRP contract is not renewed and the 40-acre field in example #1 is put back into pre-CRP crop rotations.

   34,33%

3. A hay field is harvested, cultivated & put into wheat-corn-soy rotation.

   34,33%

4. Two linear miles of fence row vegetation & access tracks are cleared to consolidate 8 small rain-fed parcels into one 160-acre field with pivot irrigation.

   40,30%

5. The harvest from a corn field begins to serve as feedstock for a local ethanol plant rather than prior unknown use (sold to local elevator).

   32,84%

6. None of the above

   19,40%

Is there consensus on what represents LUC?

1. A 40-acre field enters a 10-year CRP contract; following cover crop establishment in year 1, tillage ceases for the next 9 years.
2. At the end of 10 years, the CRP contract cannot be renewed. The 40-acre field in example #1 is put back into pre-CRP crop rotations.
3. A hay field is harvested, cultivated & put into wheat-corn-soy rotation.
4. 10-20 acre of 180-acre field is low-lying & left fallow for 4 consecutive years due to heavy spring rainfall; on 5th year it returns to use as part of the larger row crop field.
5. The harvest from a corn field begins to serve as feedstock for a local ethanol plant rather than prior sales to local elevator.

In the first five cases, land management changed, but the "agricultural land use" category did not. In case 6, there is no change in land use or land management.

Is there consensus on what represents LUC?

Understanding of what constitutes direct LUC is pre-requisite to estimating other (indirect) effects.

Prior to calculating direct LUC, a clear definition & system to classify "land use" is essential.

IPCC definition of land use

- "Land use" appears in the IPCC glossary of terms 54 times.
- IPCC defines land use as: "The total of *arrangements, activities & inputs applied* to a parcel of land. The term land use is also used in the sense of *the social & economic purposes* for which land is managed (e.g., grazing, timber extraction, conservation & city dwelling)."
- "Cropland," a major land use category, appears only twice in the glossary. Cropland & several other major use categories are not defined in the glossary.
- Source: IPCC AR6 Glossary (2021)

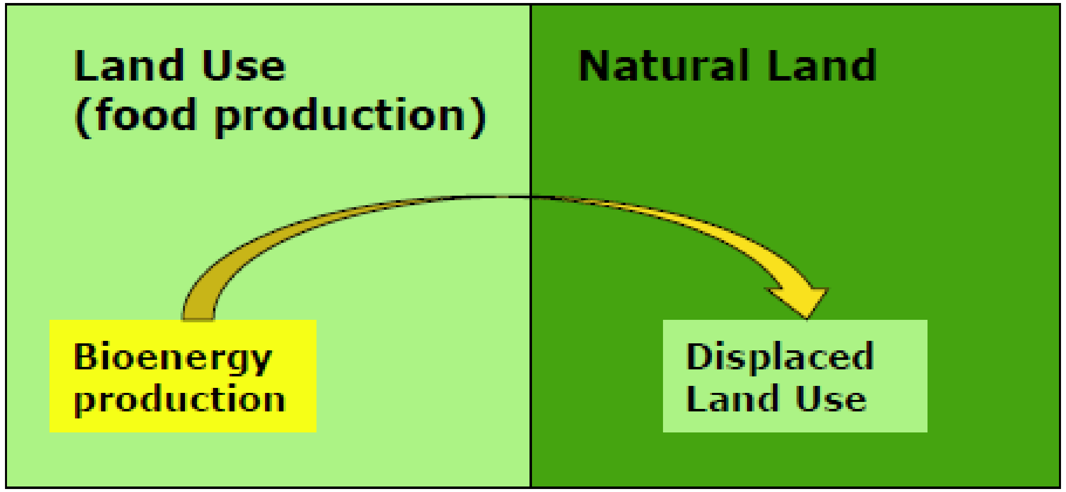
Definitions of LUC vary

- In scientific literature, land-use change (LUC) encompasses changes in **use categories *or*** changes in ***land management***.
- In common practice, LUC is a change from one land use category to another (ignores the fact that most productive lands involve complex mosaics of use).
- Basic IPCC land-use categories are forest land, cropland, grassland, wetlands, settlements, & other lands but no standards exist to assign land to each six basic category.

Defining Indirect Land-Use Change (ILUC)

ILUC: ***change*** in ***use*** in one place that ***causes*** a ***displacement*** in ***production*** of land-based products somewhere else…

- If a policy removes land from production or shifts products from one market to another (crops for bioenergy), it could lead to ILUC.
- Indirect LUC (ILUC) is a model construct (typically a subset of total LUC).
- ILUC estimates depend on input parameters, assumptions, & model specifications.
- ILUC estimated in models cannot be verified in practice (real world).



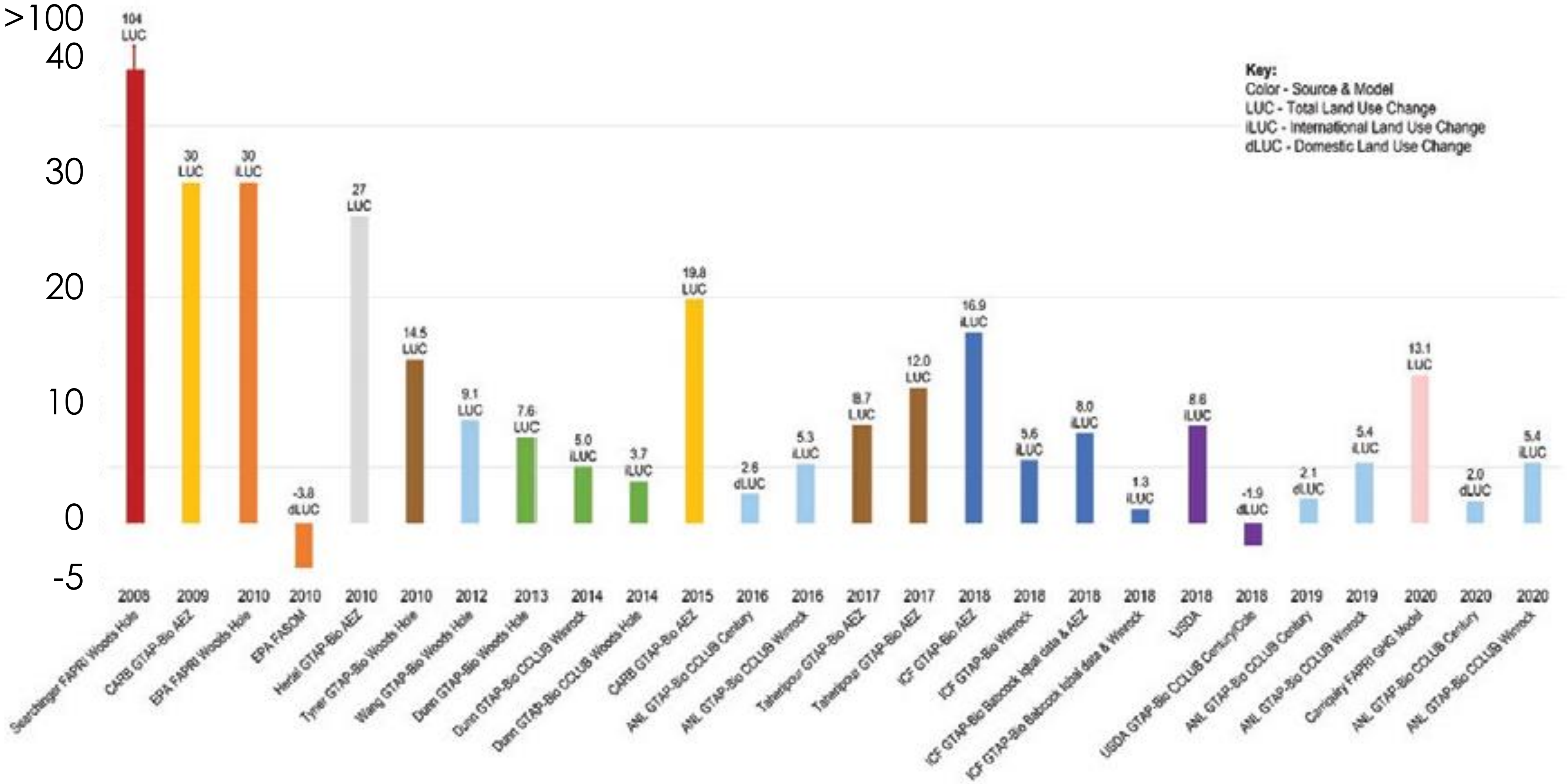
Source: PBL Netherlands Environmental Assessment Agency.

Note that reference to "***natural land***" further complicates definitions & analysis.

Source: PBL V. Daioglou 2022: Review of Land Use Change Emission Estimates, a summary presentation for EPA. Accessed from: https://www.epa.gov/system/files/documents/2022-03/biofuel-ghg-model-workshop-luc-emission-estiim-2022-03-01.pdf

ILUC is defined in different ways

In this figure of LUC gCO2eq/Mj dLUC = **domestic** LUC (in USA) &
iLUC = **international** LUC (in rest of world) (source: Scully et al. 2021, ERL16-043001).
In other papers, dLUC = direct LUC & iLUC = indirect LUC.



ILUC is challenging due to lack of consensus on methods & terminology

Change:

- *Compared to what?*
- *Compared to when?*
- Spatial & temporal characteristics, & representational value of data, vary.
- Assumed reference conditions vary widely.

Water resources example

- pH
- acidity
- alkalinity
- chlorine
- hardness
- dissolved oxygen
- biological oxygen demand
- Minimum base flow or storm flow (max) in streams…

Where is the WUC? "water use change?"

- temperature
- odor
- herbicide concentration
- ISEs (ammonia, nitrate…)
- turbidity
- suspended solids
- color
- taste
- electrical conductivity…

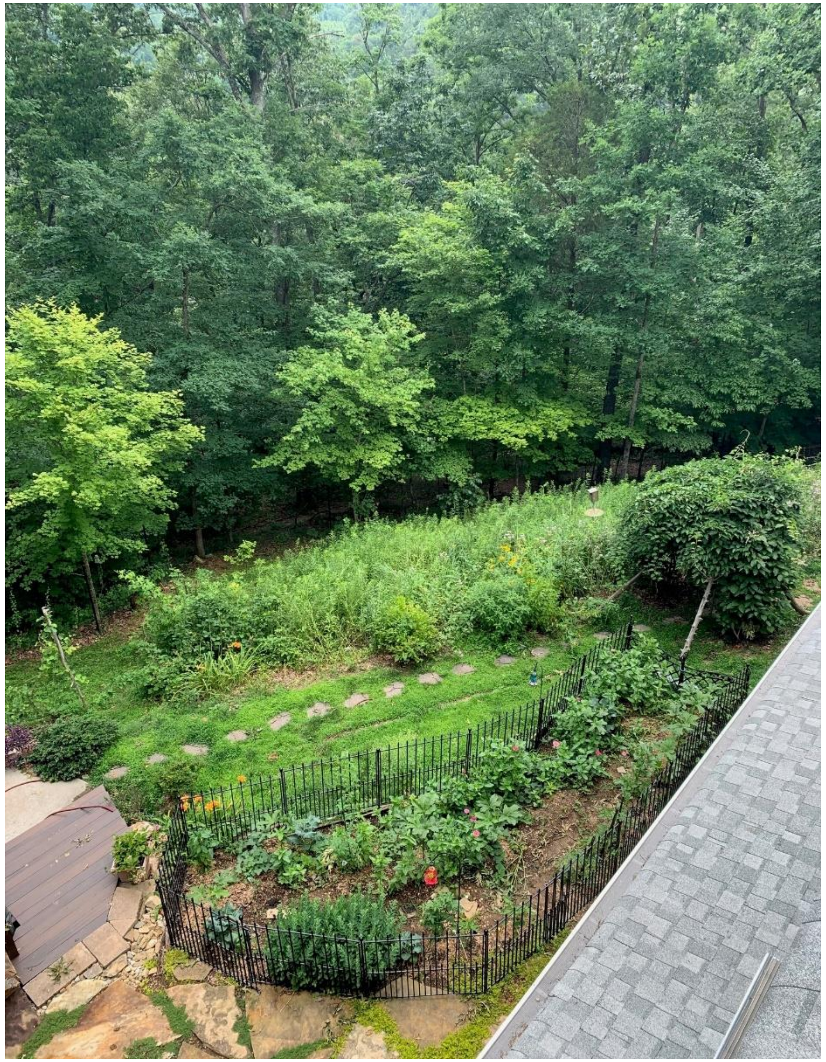
What is missing?

ILUC is challenging due to lack of consensus on methods & terminology

Land use:

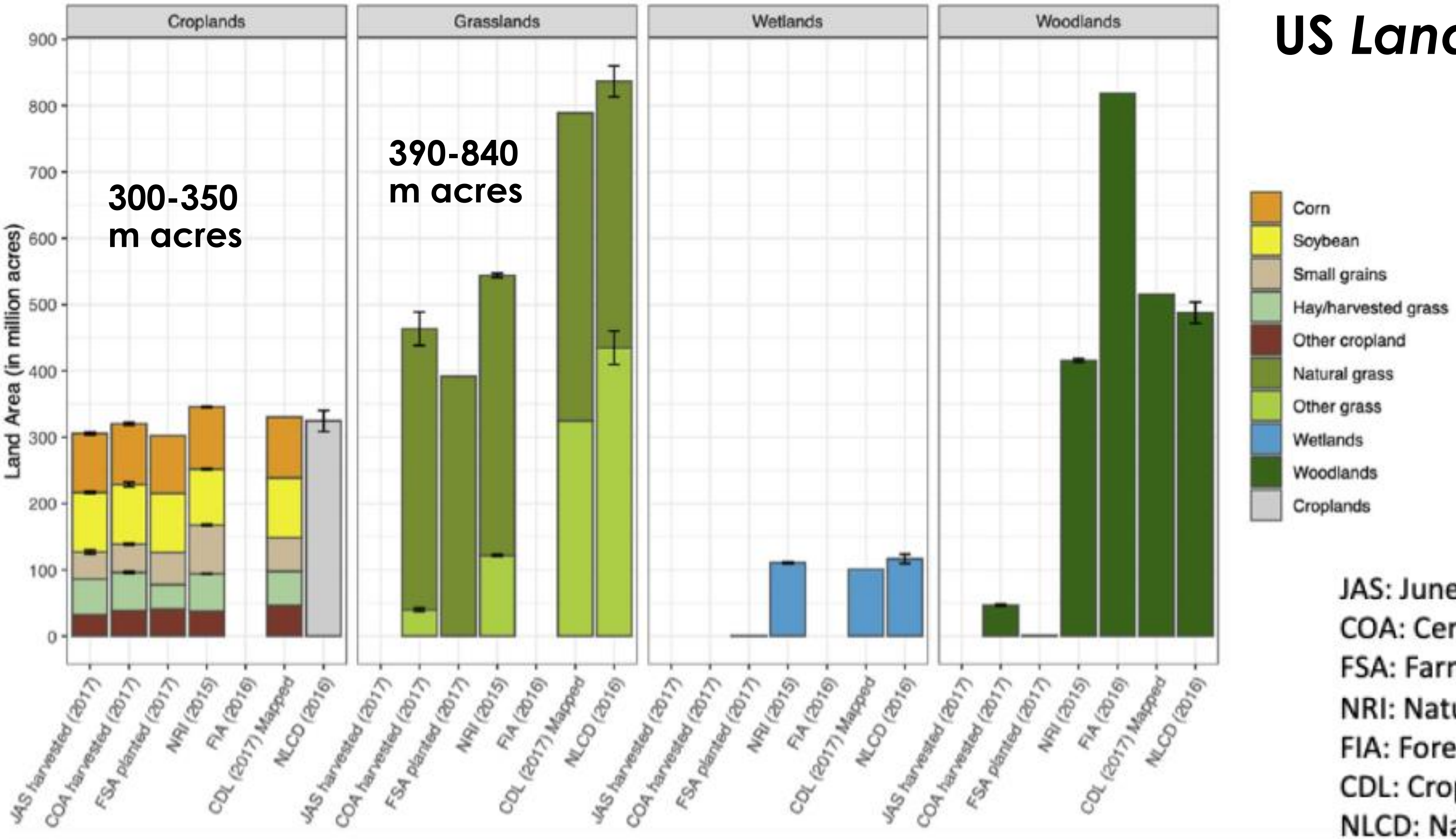
- *Land has multiple simultaneous uses*
- *Overlapping & integrated uses* are not easily segregated into distinct categories
- Use can change hourly, daily, seasonally, etc.

Land cover analysis is supported by standard classification systems but is still challenging to quantify, even with large investments in data collection…



The view from my window: less than one hectare with at least 12 simultaneous & constantly evolving uses

US *Land Cover* Data

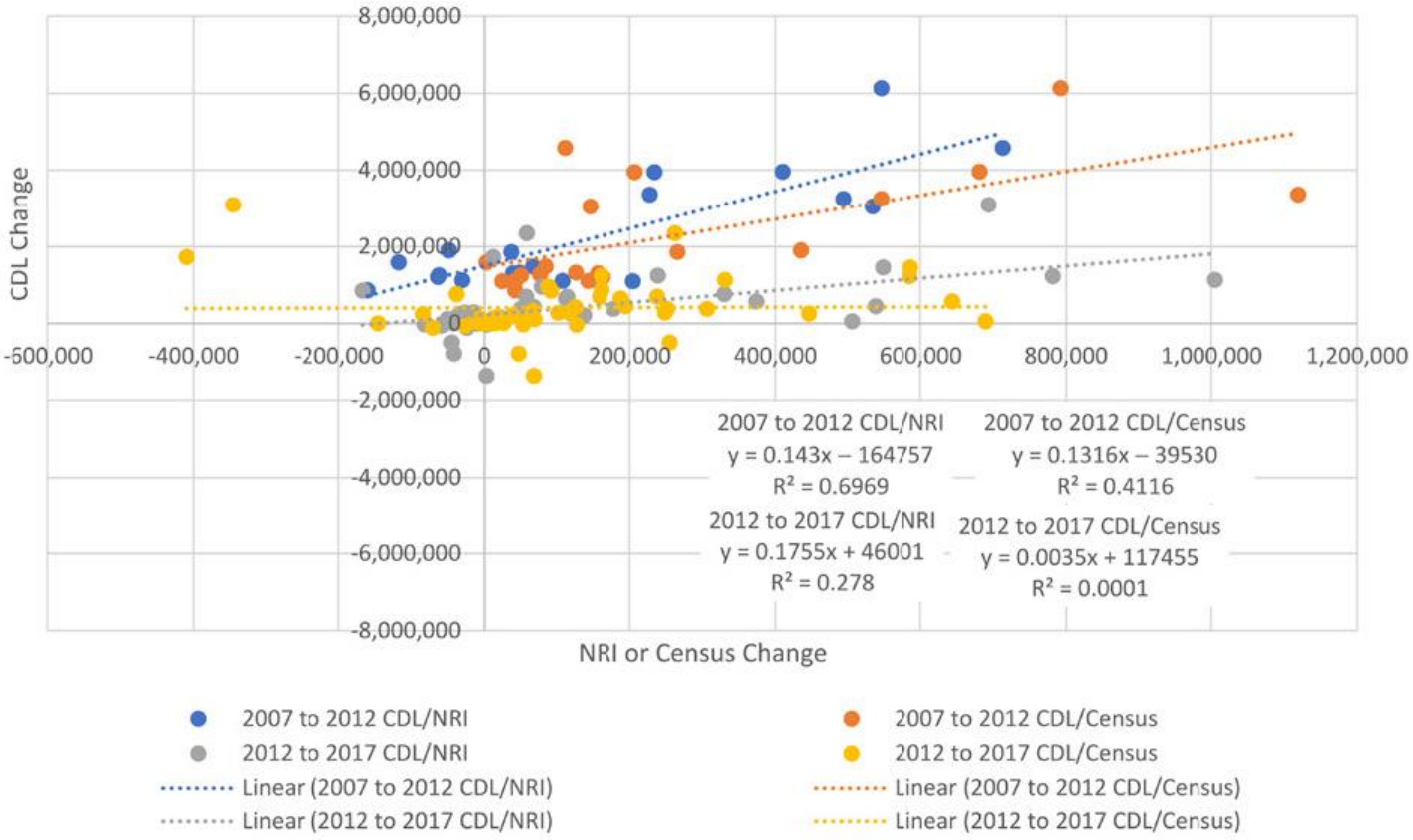


JAS: June Area Survey
COA: Census of Agriculture
FSA: Farm Service Agency
NRI: Natural Resources Inventory
FIA: Forest Inventory Analysis
CDL: Cropland Data Layer
NLCD: National Land Cover Data Set

Wang, Minzi; Wander, Michelle; Mueller, Steffen; Martin, Nico; Dunn, Jennifer. "Evaluation of survey and remote sensing data products used to estimate land use change in the United States: Evolving issues and emerging opportunities." *Environmental Science and Policy*, **2022**, 129: 68-78.

Even cropland cover data are challenging to compare & interpret.

Figure 2. Comparison of change in cropland between the CDL, the NRI and the Census for 2007–2012 and 2012–2017.



Source: Copenhaver, K.; Hamada, Y.; Mueller, S.; Dunn, J.B. 2021. Examining the Characteristics of the Cropland Data Layer in the Context of Estimating Land Cover Change. ISPRS Int. J. Geo-Inf. 10, 281. https://doi.org/10.3390/ijgi10050281

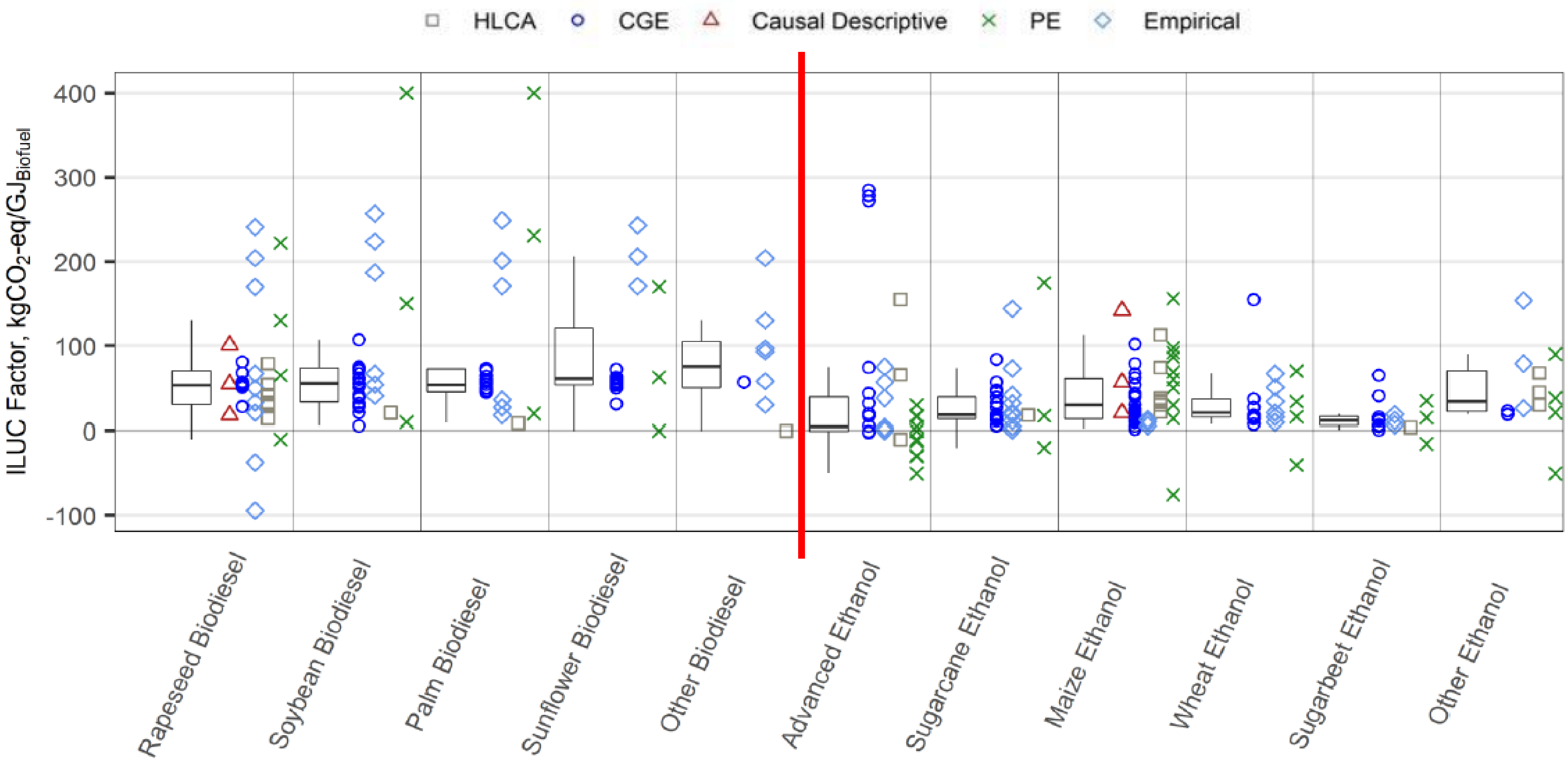
Causal analysis requires clear specification of effect & corresponding data

ILUC: a change in land use in one place that ***causes*** a displacement in production somewhere else. ***Cause cannot be established when effect is not adequately specified.***

- Causal relationship: If Action A occurs, then effect B will occur. It does not matter if an effect is called direct or indirect.
- The science of causal relationships is well developed (e.g., for epidemiology) but ***requires clear specification of the effect***, with sufficient data & analysis regarding conditions when & where the effect occurs & does not occur.
- Causal relationships can be tested with statistical tools (e.g., Granger Causal Analysis used by Oladosu et al. 2021), but tests require large amounts of data.

Source: Efroymson et al (2016) A causal analysis framework for land-use change & the potential role of bioenergy policy. Land Use Policy (59) 31 (Dec 2016) 516–527 http://dx.doi.org/10.1016/j.landusepol.2016.09.009

Many estimates for ILUC factors but none apply causal analysis



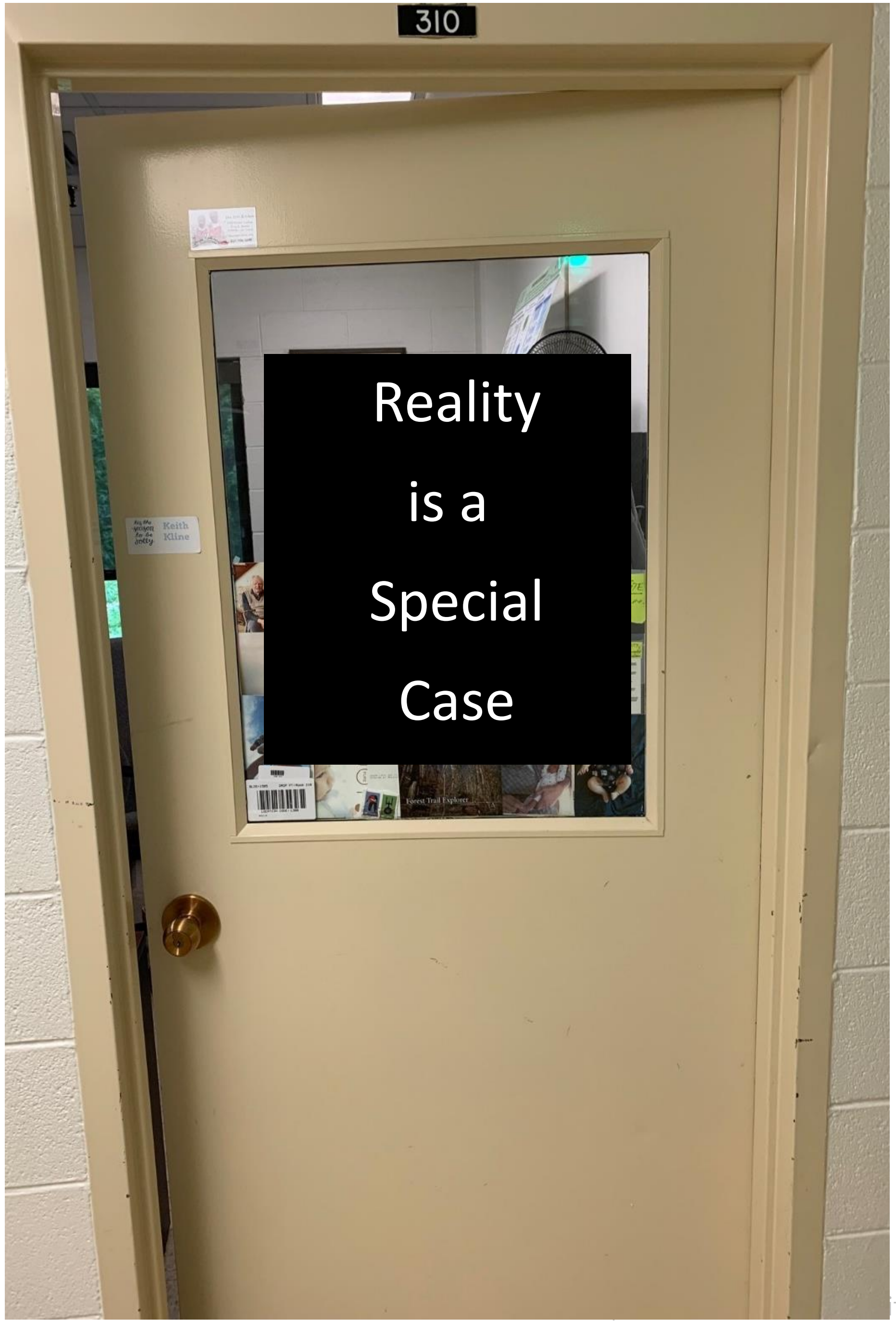
Source: PBL V. Daioglou 2022: Review of Land Use Change Emission Estimates, a summary presentation for EPA. Accessed from: https://www.epa.gov/system/files/documents/2022-03/biofuel-ghg-model-workshop-luc-emission-estiim-2022-03-01.pdf

Why is it so difficult to agree on what constitutes "direct LUC?" (non- exhaustive list)

- Lack of standard, verifiable
  - classification ontology for "land use"
  - site-specific, contextual data about prior land cover, management, rotations, etc.
- Inconsistent unit area measurements
- Lack of standards for temporal periods that define "change"
- High seasonal & inter-annual variability
- Confounding factors
  - long-term rotations,
  - shifting uses of grasslands,
  - extreme weather events
- Lack of documentation of error & uncertainty introduced by multiple interacting factors

Can modeling fill the knowledge gaps?

1. **Models help us explore relationships & "what if?" questions.**
2. **With sufficient data, models can help test theories & illustrate new understanding about complex systems**
3. **"All models are wrong; some are useful"**
4. **By design, models simplify. Context matters… and reality is always a 'special case'** (with acknowledgement to Dr. Robert H. Gardner, ORNL modeler)

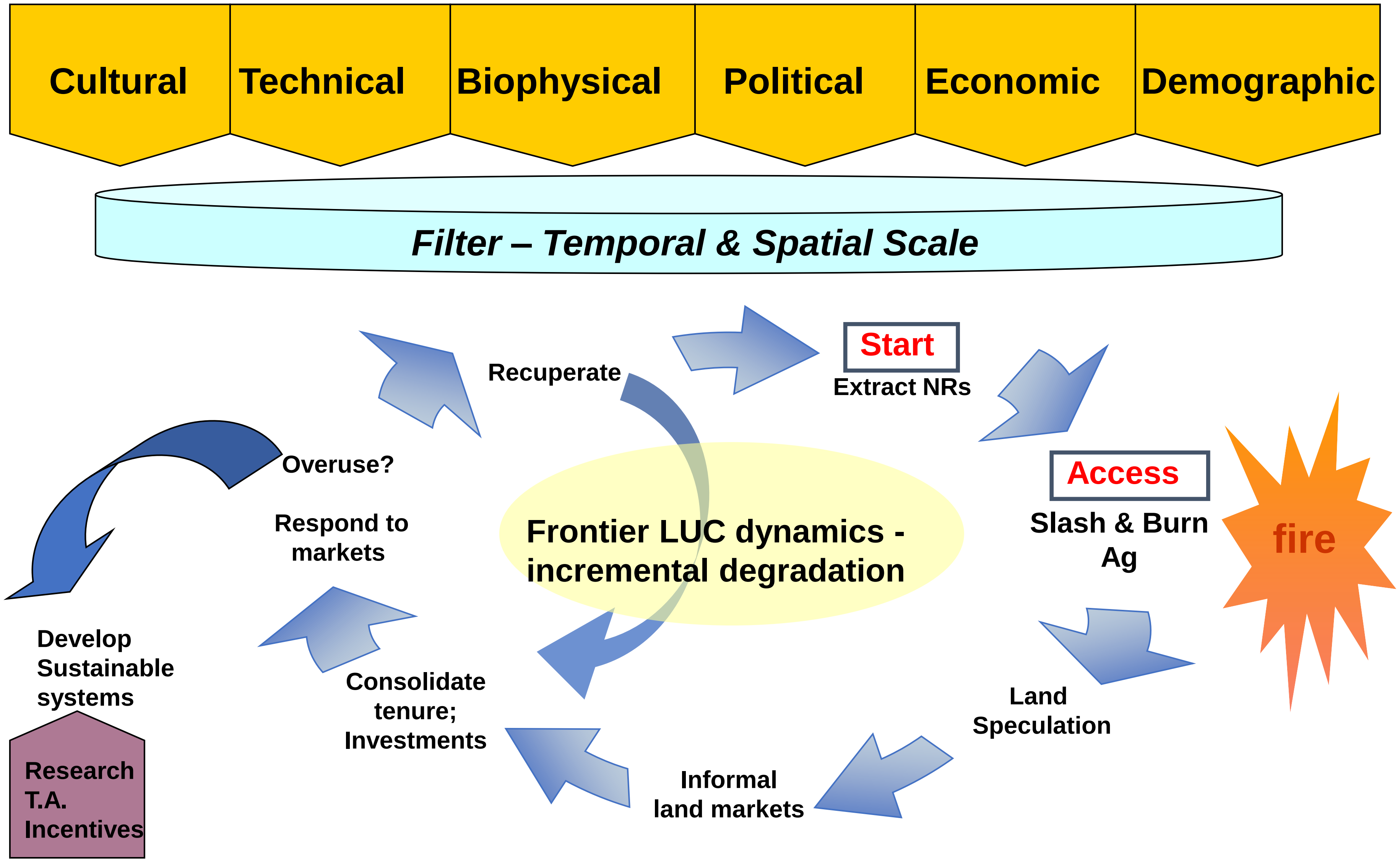


Examples of differences between LUC models & reality

1. Representation of policy or “change” in model specifications
2. Land ownership & rational economic decision-making assumptions
3. Assumed drivers of initial conversion
4. Land supply & management specifications
5. Choice of scenarios & baseline
6. Yield & other management trends
7. Issues of time, scale
8. Fire & other disturbances
9. Correlation versus causation
10. Baseline crop land area assumed fixed
11. Global data sets lack local context

Source: Kline KL, Oladosu GA, Dale VH, McBride AC (2011) Scientific analysis is essential to assess biofuel policy effects. Biomass & Bioenergy, 35, 4488-4491. & Kline et al 2011 “Top Ten Steps to Improve Quantification of Land-Use Change Effects of Bioenergy Systems”

Drivers of frontier land-use change are local



Dale & Kline, Chapter 8 (Fig 8.2, Initial LUC drivers) in: Land Use & the Carbon Cycle. 2013. D. Brown et al. eds. Cambridge Univ Press

Highly variable estimates -- ongoing LUC debates

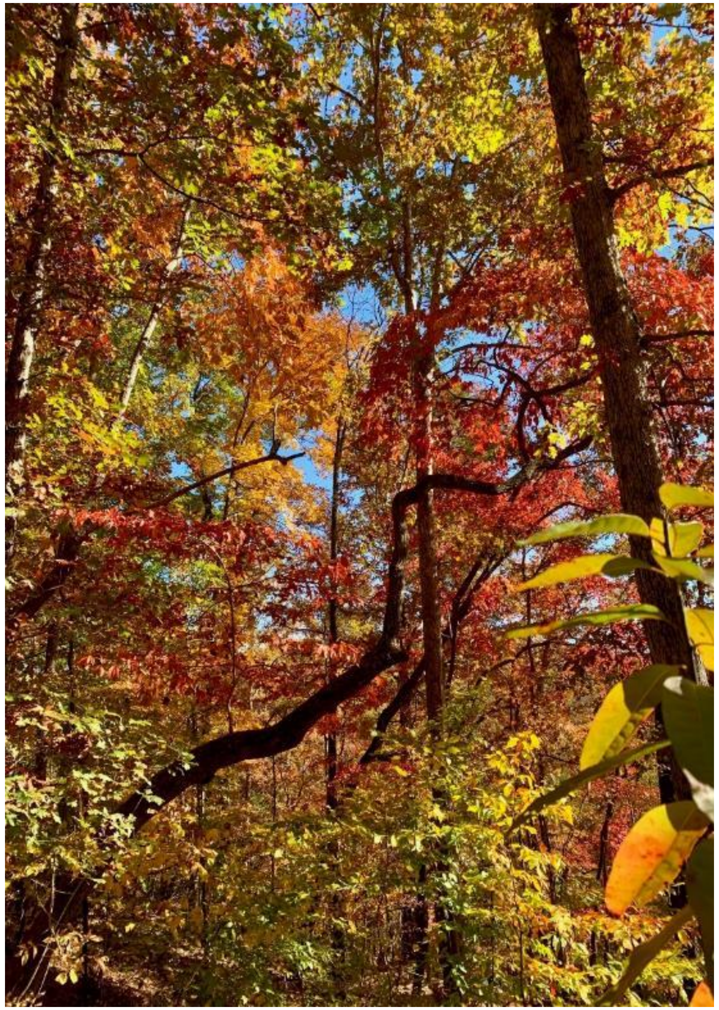
- **Recent exchange regarding US direct LUC estimates associated with Renewable Fuel Standard** *
  - **Over 100 pages of exchanges with clarifications, justifications, additional data citations…**
  - **No mutual agreement.**
- **Similar to the debates documented in 2009 international workshop on how to improve measurement of LUC** (see CBES 2010 LUC Workshop report https://cbes.ornl.gov)

Are we asking the right question?

* **Lark et al. https://www.pnas.org/doi/full/10.1073/pnas.2101084119 & response from DOE-sponsored researchers led by ANL GREET team: https://greet.es.anl.gov/files/comment_environ_outcomes_us_rfs2**

Asking better questions

- How can policy encourage land managers to adopt better practices?
- What data are required to improve quantification of cause-and-effect relationships?
- What are the most effective strategies & actions to identify & conserve high-conservation value land?
- What site-specific practices work best to increase productivity & environmental services such as carbon storage on managed land?



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Increasing awareness of ILUC limitations

- **Conclusions from recent analysis of ILUC by researchers at the Netherland Environmental Assessment Agency:**
  - **Efforts to improve ILUC modeling have not provided, & are not expected to provide, more 'definitive' or 'likely' ILUC factors.**
  - **ILUC does not help with the determination of GHG performance of biofuels**
  - **"A 'mean' ILUC value has little scientific underpinning"**
  - **Inherent & persistent uncertainties around potential market effects on agriculture & land limit the usefulness of specific ILUC factors.**

PBL Netherlands Environmental Assessment Agency

Source: PBL V. Daioglou 2022: Review of Land Use Change Emission Estimates, a summary presentation for EPA. Accessed from: https://www.epa.gov/system/files/documents/2022-03/biofuel-ghg-model-workshop-luc-emission-estiim-2022-03-01.pdf

Guidelines & solutions

- ✓ Comprehensive approach applied to all land-related products & services
- ✓ Risk-based assessments supported by remote sensing & verificatio protocols where risks are identified
- ✓ Use clear, descriptive terms & typologies with consistency
- ✓ Document data sources & assumptions
- ✓ Highlight long-term trends & any notable deviations from trends
- ✓ Avoid drawing conclusions based on:
  - Two-point comparisons
  - Comparisons involving data from mixed sources
  - Comparisons based on aggregate or average values
  - Data sets that are not statistically validated & ground-truthed
  - Comparisons that rely on data sets that do not account for total land surface area in a consistent manner over time (e.g., CDL)

Source: Kline et al. multi-agency presentation 12 Apr2016 & Draft Chapter guidelines for preparing BT16 Vol.2

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To end debate & controversy over LUC/ILUC we must shift the paradigm

1. Start with clear, consistent terms & definitions.
2. **Apply standard approach & classification system to:**
   - Monitor ***land cover, land qualities*** (e.g., carbon stocks, productivity) & ***land management*** (type, intensity, frequency…)
   - Work with stakeholders to verify what is most important (we cannot effectively monitor & communicate everything)
   - ***Share validated data documenting historical*** (baseline) trends in these variables
   - Establish a common data set for projected land cover, land qualities, & management under a "business as usual" scenario aligned with the climate modeling community's *shared socioeconomic pathways*
   - Develop & validate models based on verifiable data & testable hypotheses
3. Remember, its not "LUC" in models that matters but how land cover, land qualities, & management change on the ground.

To build public confidence

- Apply a place-based approach (context matters)
- Engage the public in the process
- Base analyses on evidence
- Be transparent: communicate distinctions among methods & confidence in data & findings
- Provide timely, & reliable information on effects that are of high priority to local stakeholders

We can build consensus on verifiable standards for assessing changes in land cover, land management, & important land qualities using scientific evidence.

This is not possible for "LUC"

See Kiskey et al. 2021, *Thinking Big & Thinking Small: A Conceptual Framework for Best Practices…Sustainability; &*
Kline 2021: Research & communications for building trust in sustainably-sourced biomass; presented to the Advanced Bioeconomy Leadership Conference, ABLC Digital 2021, World Stage Forum on Global Trends, https://biofuelsdigest.com/ablcd/

Thank You!

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Additional slides & References

For more information

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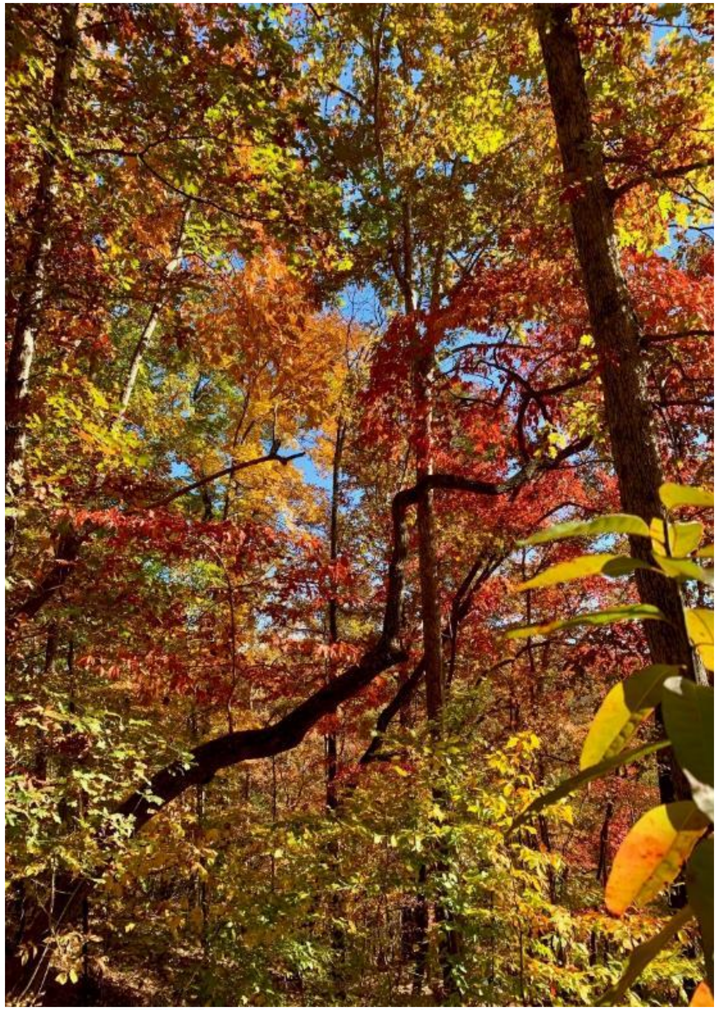
- ORNL https://www.ornl.gov/
- Clean Energy Ministerial https://www.cleanenergyministerial.org/
- CEM Bioenergy Initiative & Sustainability Workstream https://www.cleanenergyministerial.org/initiatives-campaigns/biofuture-platform/
- IEA Bioenergy https://www.ieabioenergy.com/
- IEA Renewables 2022 Report https://www.iea.org/reports/renewables-2022
- IEA Net Zero by 2050 Analysis https://www.iea.org/reports/net-zero-by-2050
- ISO TC323 Circular Economy https://www.iso.org/committee/7203984.html



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Metrics identified in literature & DOE Billion Ton (BT16) that perform better than "LUC"

Measures that can be verified include:

- carbon stocks
- types & timing of any soil disturbance
- productivity (above & below ground, both in terms of material harvested & in terms of total NPP [see McBride et al. 2011, Indicators])
- seasonal evolution (timing & duration) of specific characteristics of vegetative land cover including canopy closure, organic matter, exposed soil surface areas
- management practices (type, intensity, depth & frequency of tillage & any other activities that disturb or impact soil, water, & vegetation)
- application of herbicides, pesticides, fertilizers & any cultivation or other management practice (and their movement & impacts on surrounding environment)
- standard environmental indicators as discussed in US DOE BT16 volume 2 for air, water, biodiversity, soil carbon, soil compaction, GHG emissions, biodiversity, etc..

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Useful definition: Land management - IPCC

Land management

- Sum of land-use practices (e.g., sowing, fertilizing, weeding, harvesting, thinning, clear-cutting) that take place within broader land-use categories. (Pongratz et al. 2018)

- Source: IPCC AR6 Glossary (2021)

NOTE: Clear, concise definitions are inherently better when consistency, understanding, or measurement are required. A definition should be written such that the definition could be inserted in a sentence to replace the word that is being defined.

Land management *can impact most environmental indicators*

	Indicator
Soil quality	1. Total organic carbon (TOC)
	2. Total nitrogen (N)
	3. Extractable phosphorus (P)
	4. Bulk density
Water quality & quantity	5. Nitrate concentration in streams (and export)
	6. Total phosphorus (P) concentration in streams (and export)
	7. Suspended sediment concentration in streams (and export)
	8. Herbicide concentration in streams (and export)
	9. Storm flow
	10. Minimum base flow
	11. Consumptive water use

	Indicator
Greenhouse gases	12. CO_2 equivalent emissions (CO_2 & N_2O)
Biodiversity	13. Presence of taxa of special concern
	14. Habitat area of taxa of special concern
Air quality	15. Tropospheric ozone
	16. Carbon monoxide
	17. Total particulate matter less than 2.5µm diameter ($PM_{2.5}$)
	18. Total particulate matter less than 10µm diameter (PM_{10})
	Extra: VOCs, SO_x, NO_x
Productivity	19. Aboveground net primary productivity or Yield

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

Addressed in Vol. 2 BT16

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