

State of knowledge of land use impacts on
biogeochemical fluxes:

Land use change carbon
(15" → selective overview!)

(Ben: TRENDY, Peter: N₂O)

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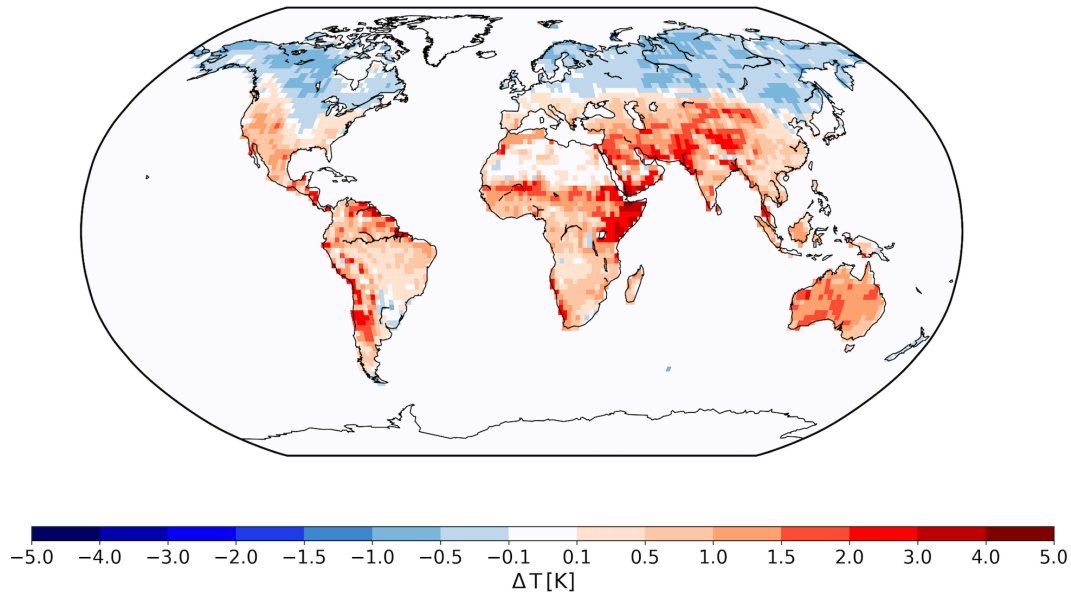
Emmy
Noether-
Programm

Deutsche
Forschungsgemeinschaft
DFG

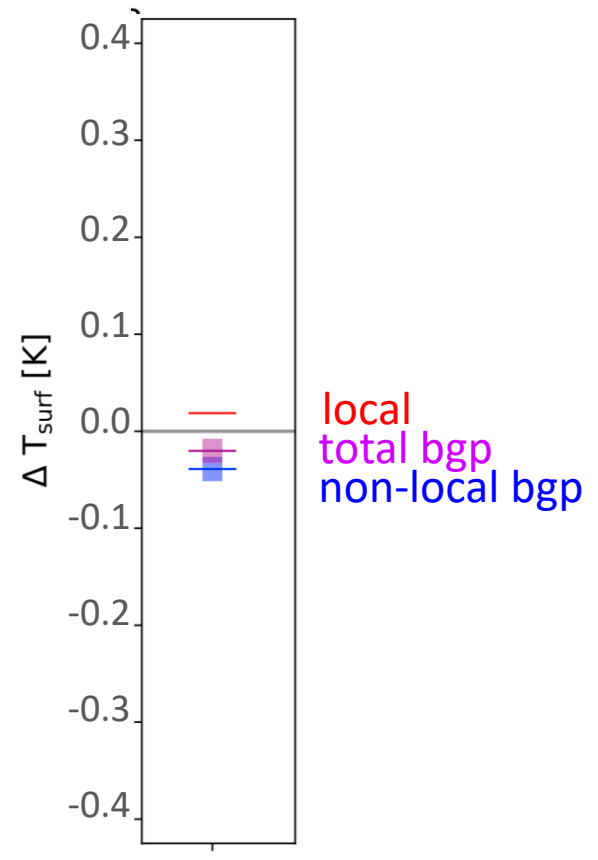


Biogeophysical vs carbon cycle effects of LUC

Surface temperature change for global deforestation

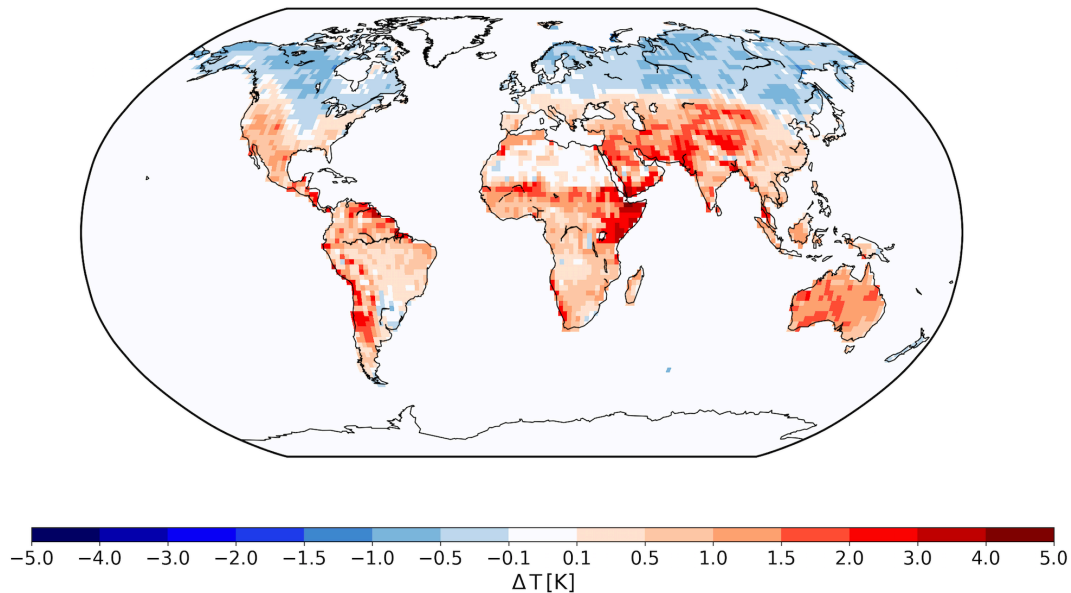


Temperature consequences of historical deforestation

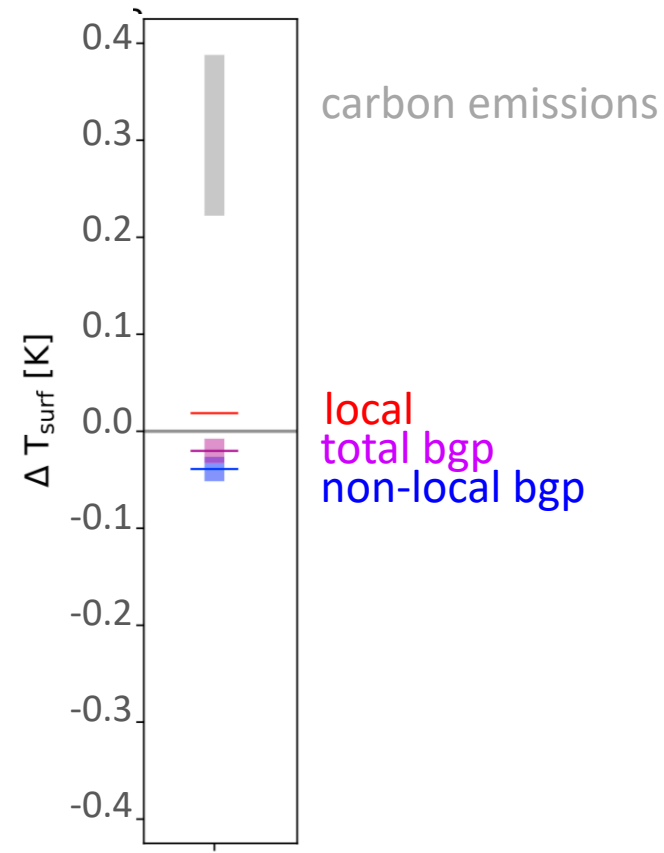


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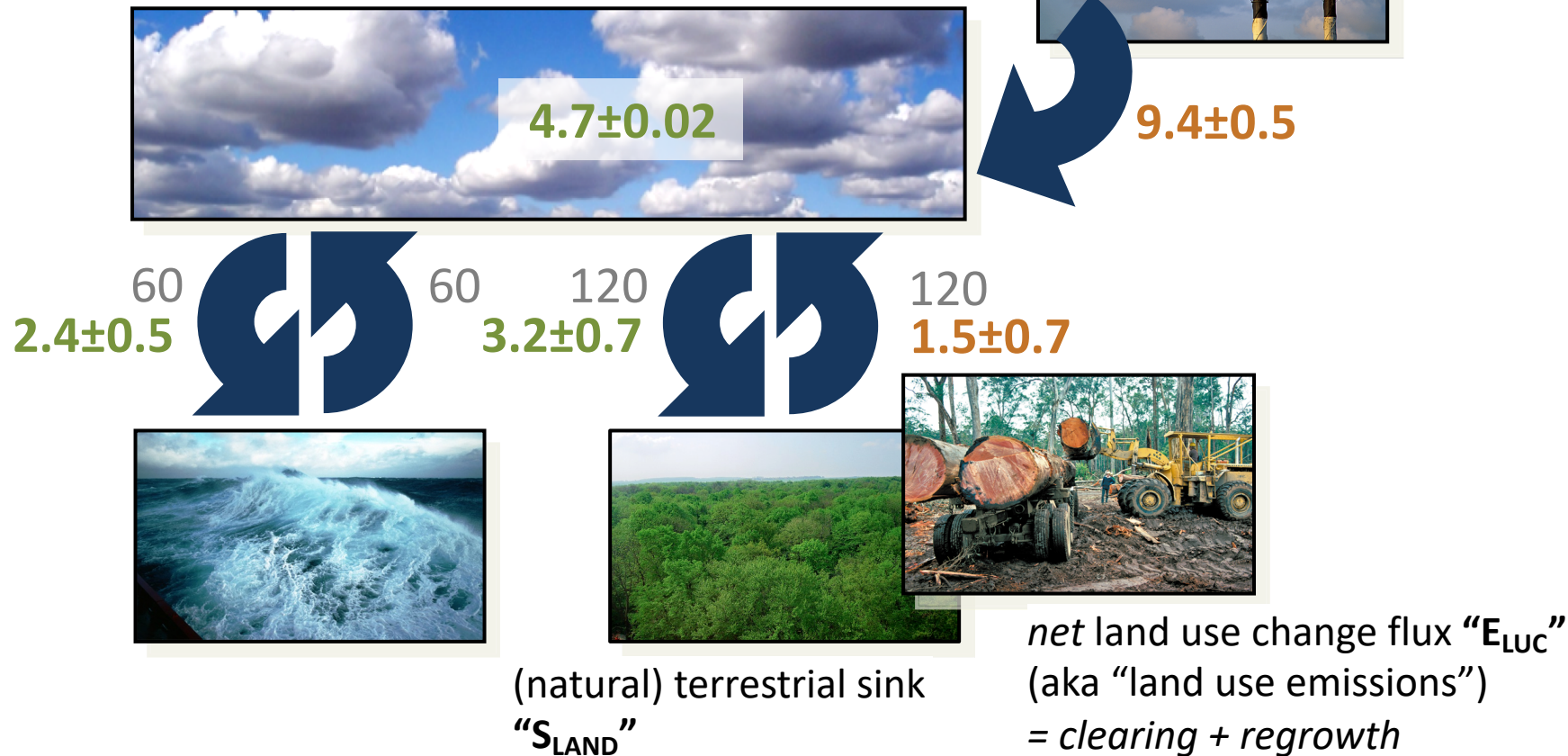


The Global Carbon Project's carbon budget

Present-day global carbon cycle

Approx. natural C fluxes in PgC/year

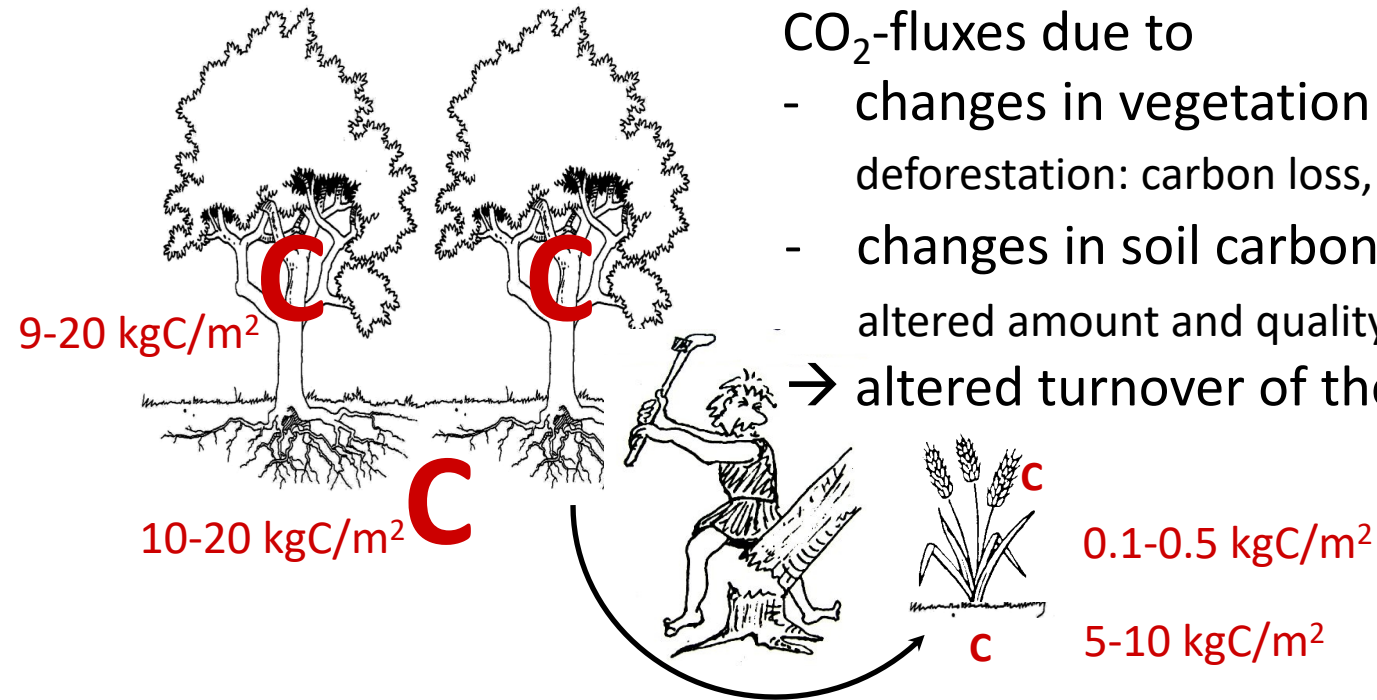
Human-induced **sources** and **sinks** (average 2008-2017)



Different timescales of CO₂-fluxes due to LUC

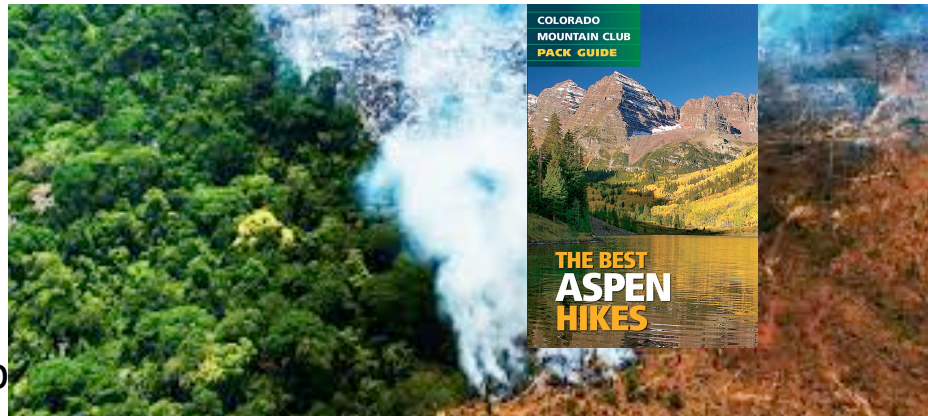
CO₂-fluxes due to

- changes in vegetation
deforestation: carbon loss, reforestation: carbon gain
- changes in soil carbon
altered amount and quality of litter material; erosion
→ altered turnover of the land



CO₂-fluxes
from
products

sub

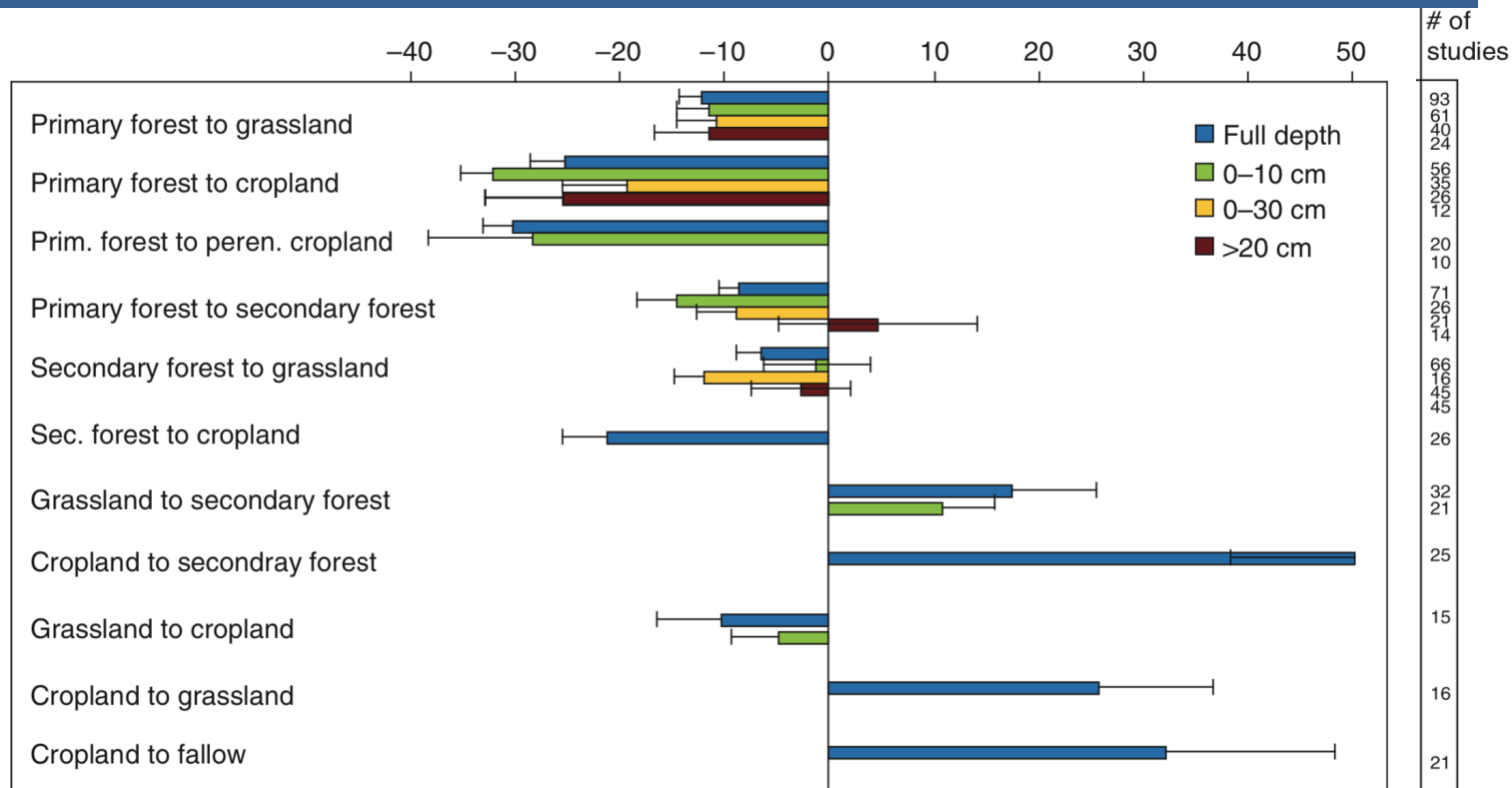


stitution of energy-
intensive material!

What do observations tell us about
land use and carbon fluxes?

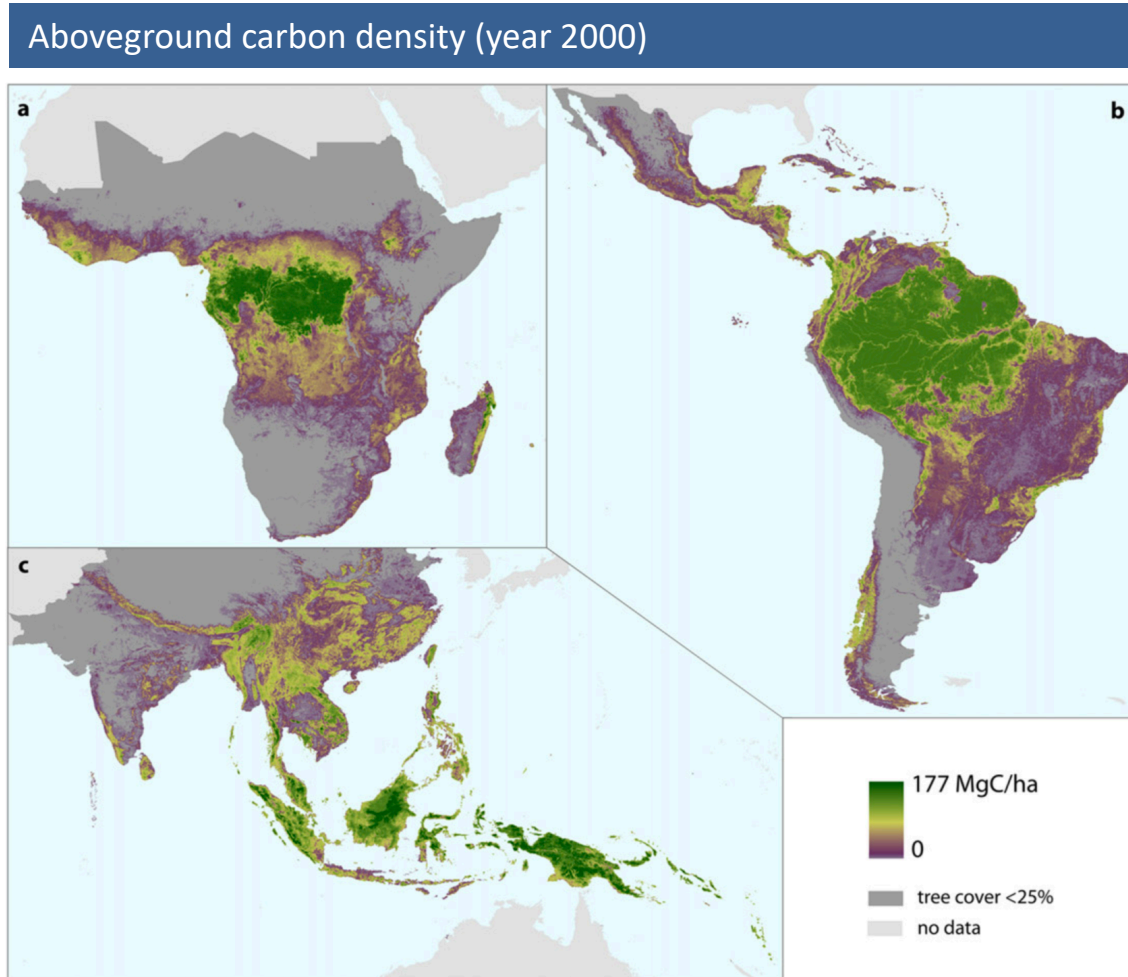
Effects on soil carbon

Meta-analysis of relative soil organic carbon stock changes due to different LUC transitions (%)



- Paired plots, soil chronosequences → brought to model scale by wealth of individual studies
- Chronosequences: comparison to models at site-level possible

Effects on biomass

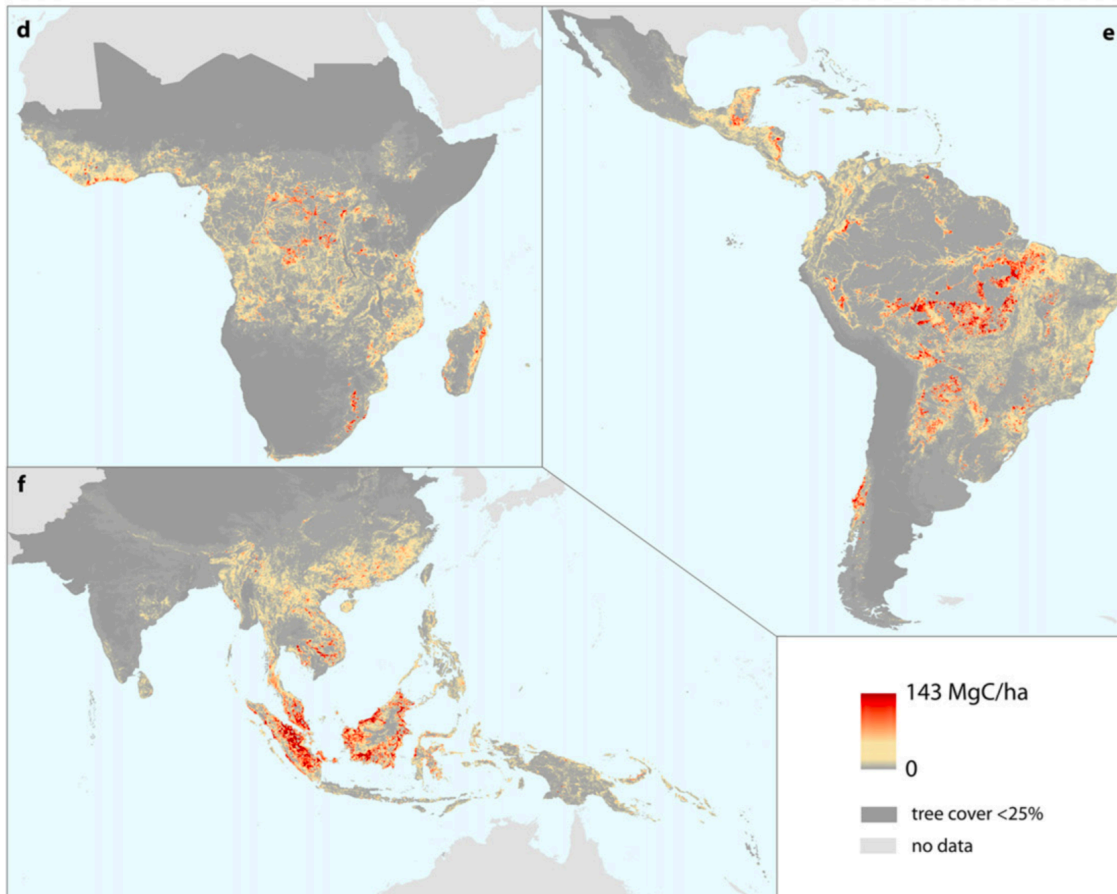


Several recent biomass products (L-VOD, Lidar-based, inventory-based)

e.g.,
Avitabile et al., 2016;
Brandt et al., 2018;
Carvalhais et al., 2014;
Liu et al., 2015;
Pan et al., 2011;
Saatchi et al., 2011;
Santoro et al., 2015;
Thurner et al., 2014;
Tyukavina et al., 2015

Effects on biomass

Aboveground carbon density losses 2000-2012



Hansen forest cover loss
∩ mean C density

Note:

- deforestation only (no regrowth)
- above-ground only

committed

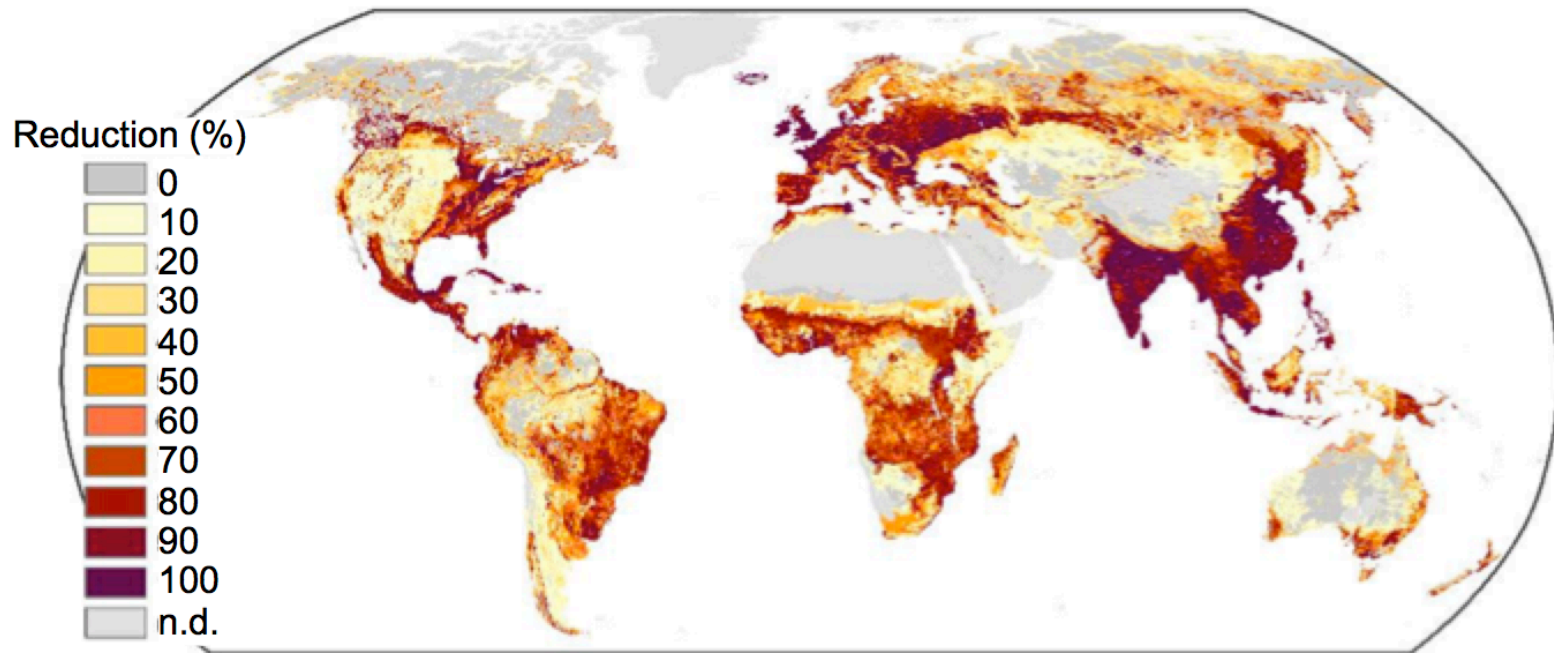
Other recent approaches:

- Baccini et al., 2012: RS-C density ∩ Houghton model
- Baccini et al., 2017: changes directly from C stock timeseries (→ includes degradation)

includes sink

Effects on biomass

Reduction in biomass inferred from combination of several datasets for actual (remote sensing, inventories) and potential biomass

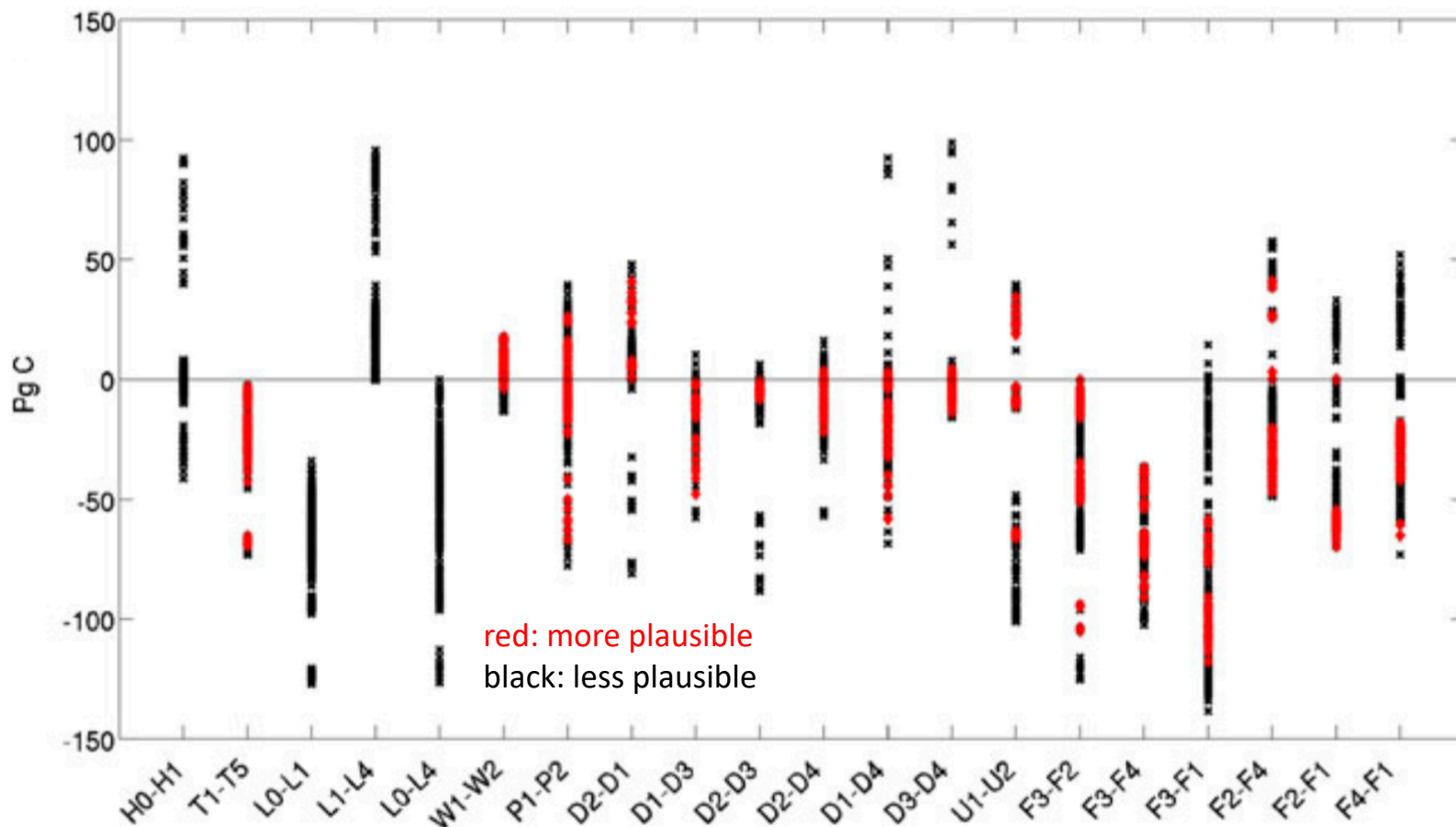


Half of the terrestrial biomass has been removed by land use change

What had we known about the
global net land use change flux
around the time of CMIP5?

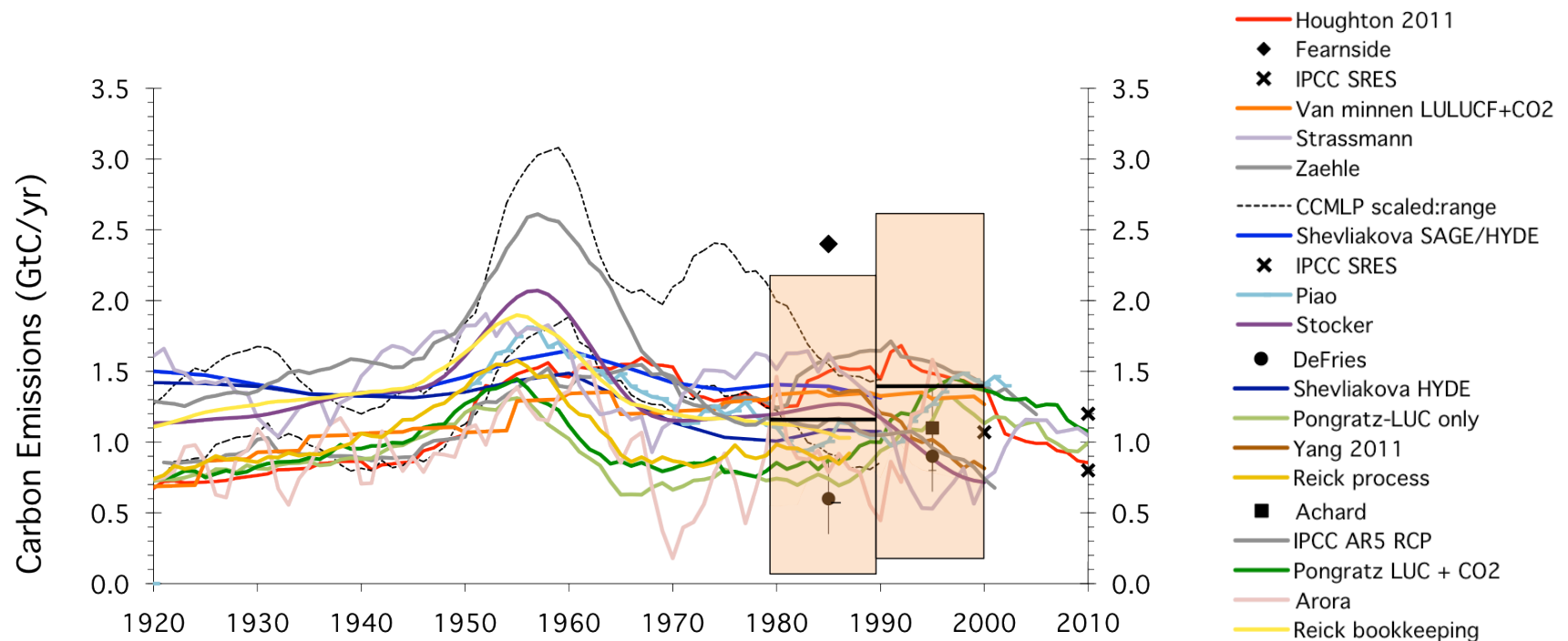
Large sensitivity towards LUC uncertainties

Model sensitivity of cumulative 1500-2100 above-ground biomass change due to LUC to large variety of model assumptions



Large spread for individual models (with different LUC datasets)

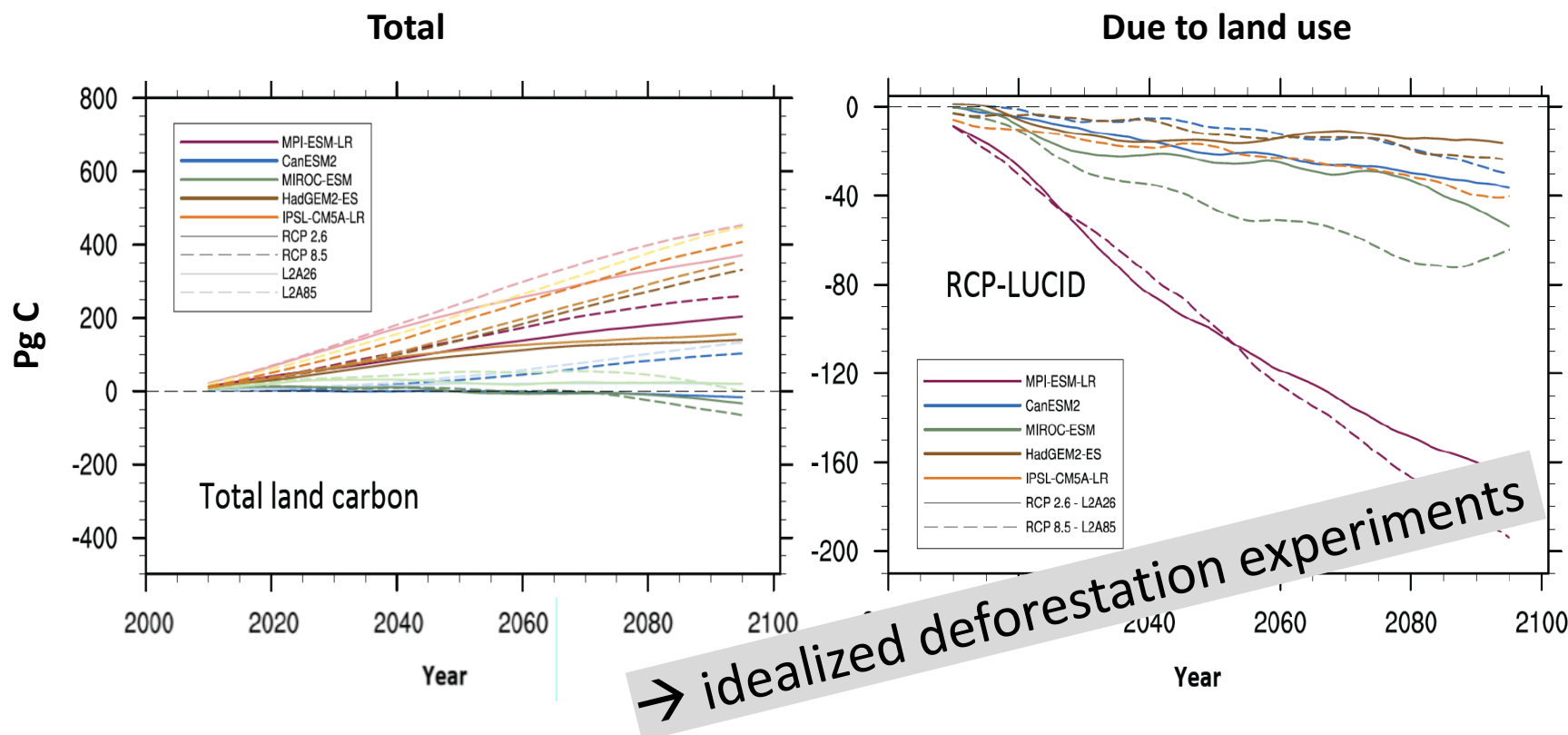
Compilation from around 2011 of studies of global (and pantropical) land use emissions



Large spread even for same setup and LUC data

LUCID-CMIP5

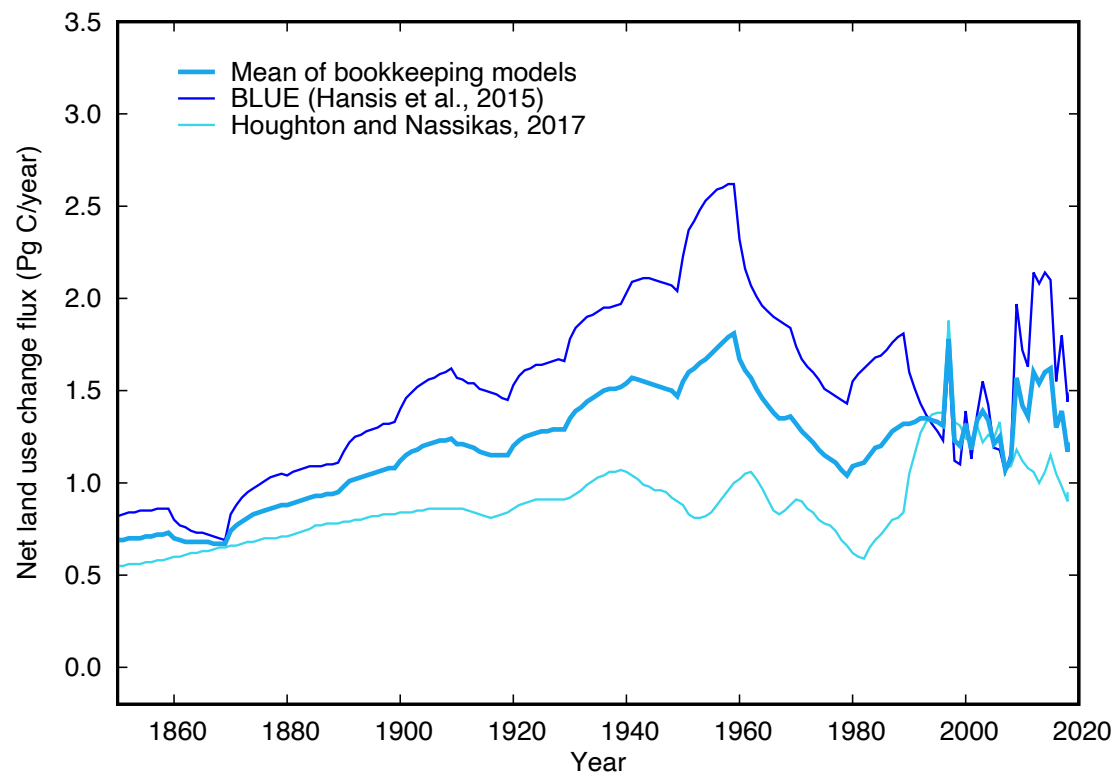
Changes in land carbon storage for RCP 8.5 and 2.6 from LUCID-CMIP5



The Global Carbon Project (GCP)'s
annual global carbon budget

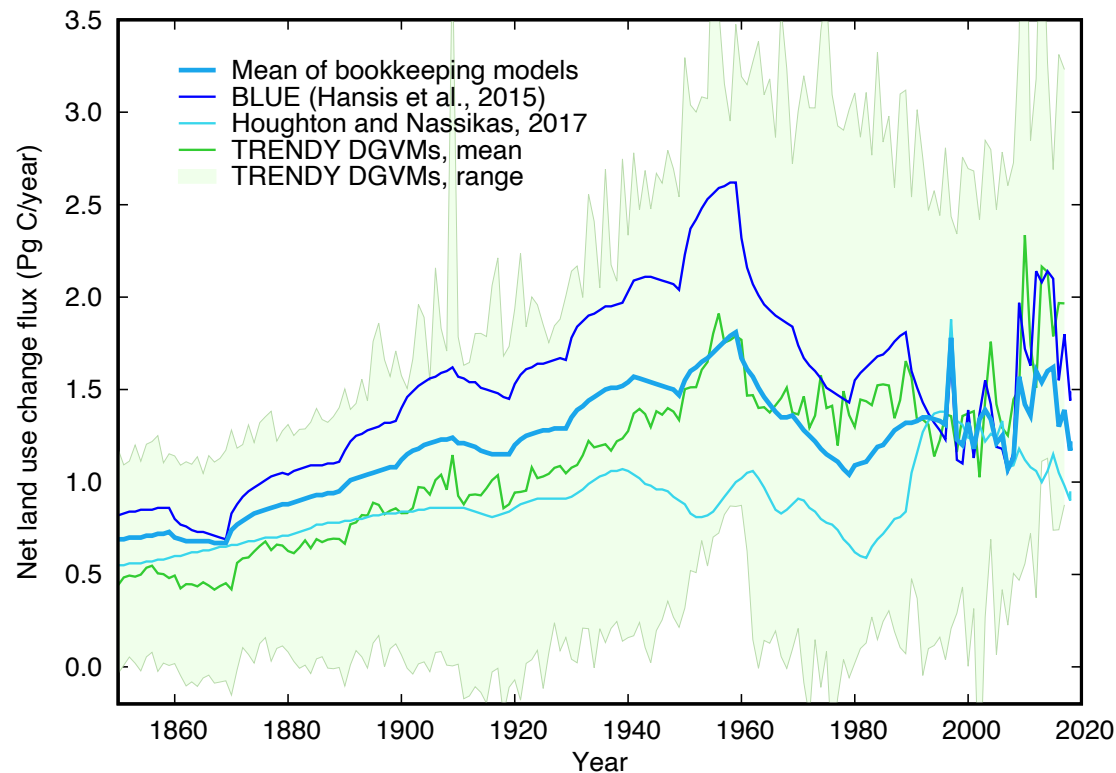
E_{LUC} in GCP's annual global carbon budget

- 2 bookkeeping models (update to 2 introduced 2017) (combine LUC with observed C densities and fixed response curves)
 - Houghton & Nassikas: country-level, uses FAO/FRA LUC data
 - BLUE (Hansis et al): 0.25 degrees, uses LUH2 LUC data

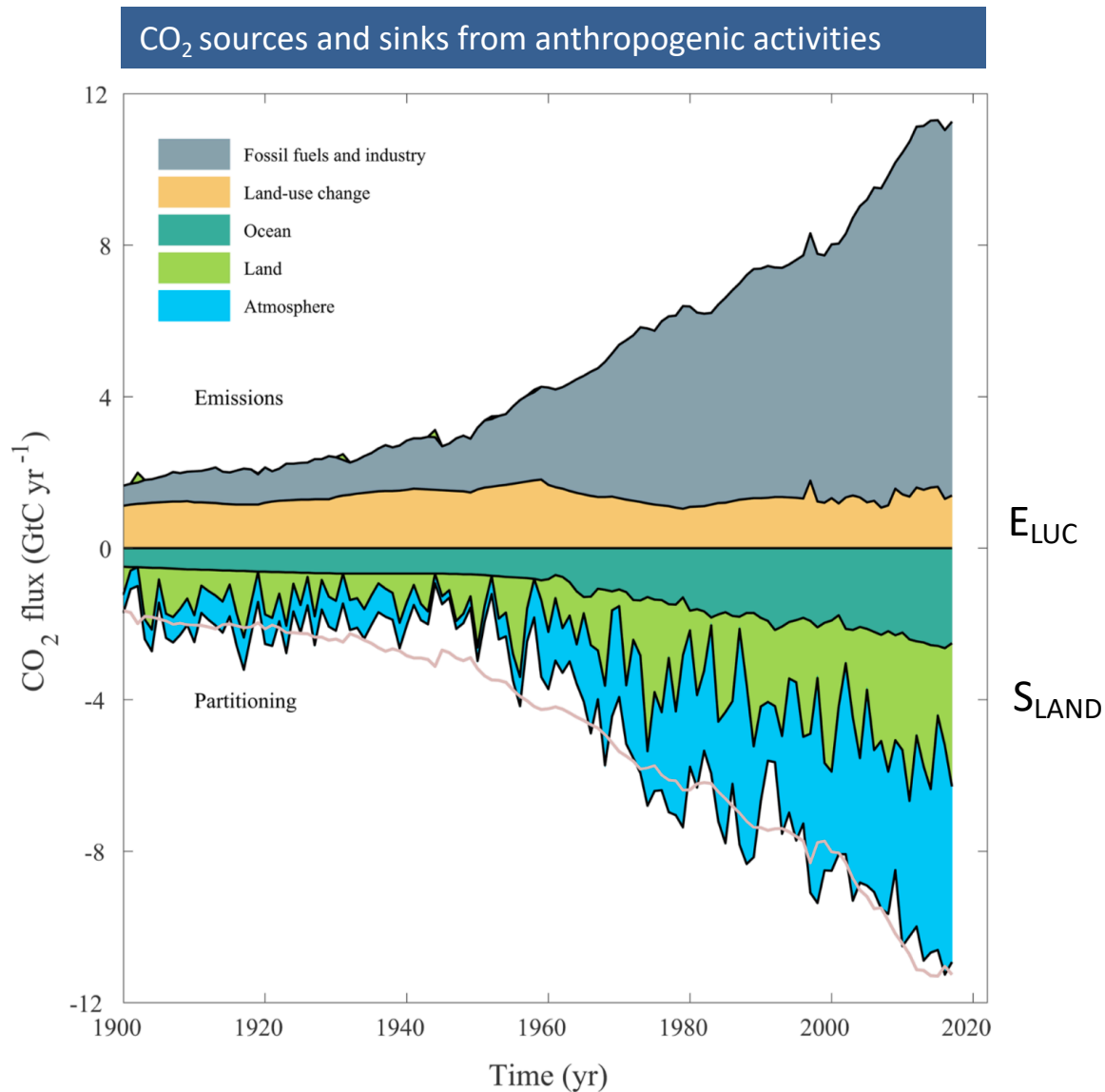


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- Uncertainty range from TRENDY DGVMs



GCP's annual global carbon budget



Cumulative 1850-2014:

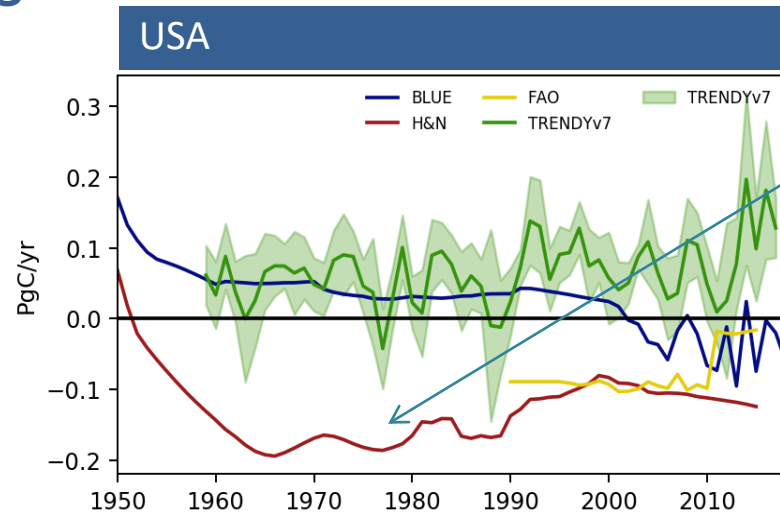
E_{FF} : 400 ± 20 PgC

E_{LUC} : 195 ± 75 PgC

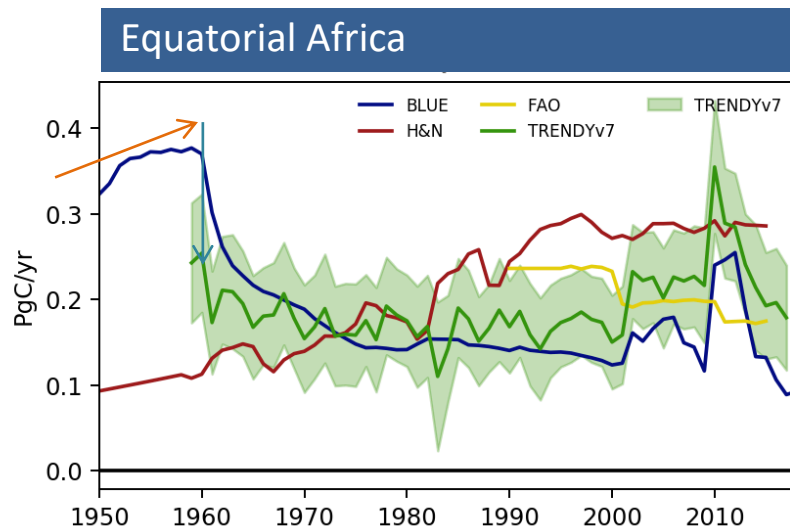
Some regional results

GCP's RECCAP-2 (REgional Carbon Cycle Assessment and Processes) has started!

→ some regions may provide better data soon



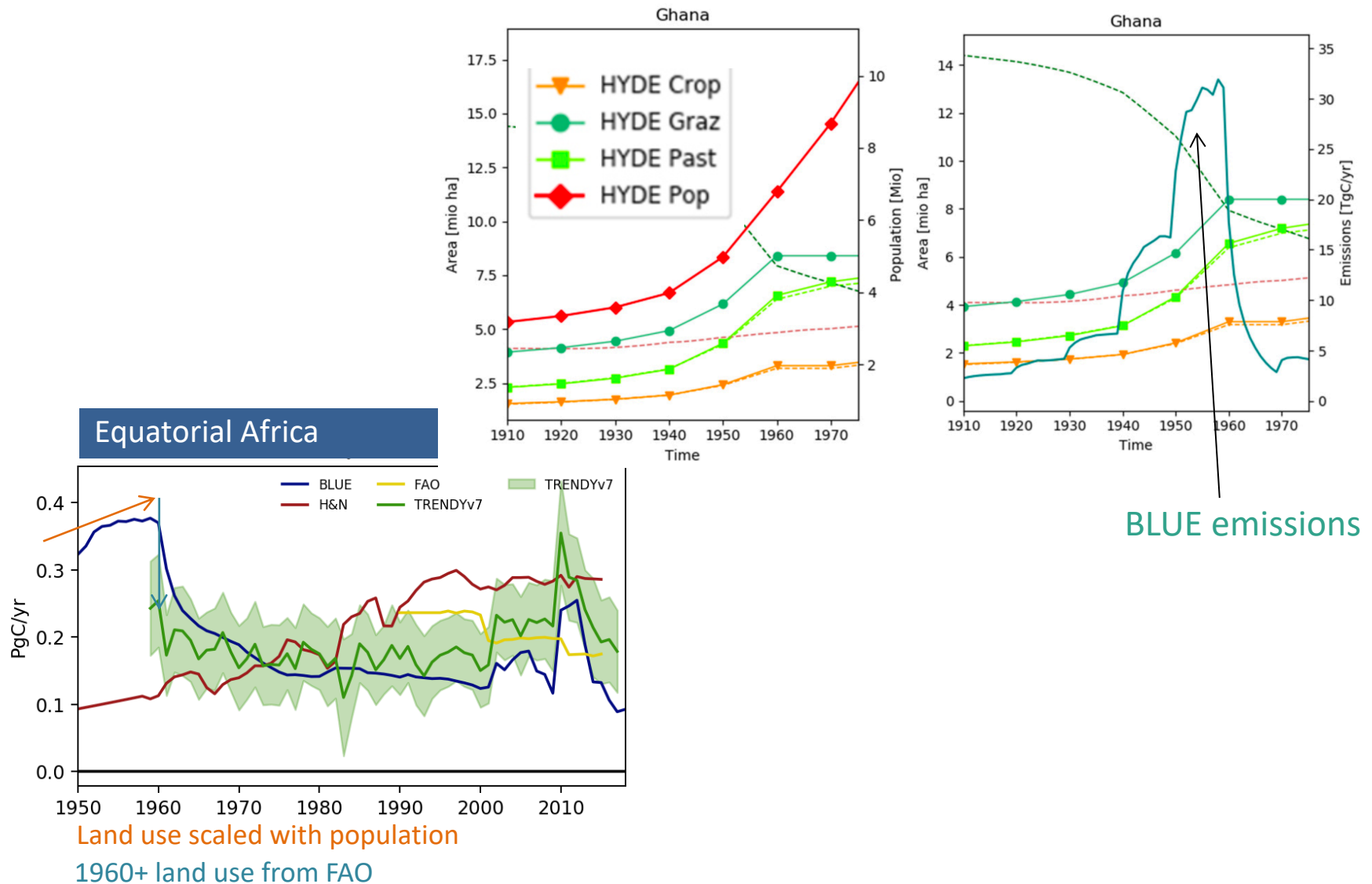
Fire suppression
(only) in U.S.



Land use scaled with population

1960+ land use from FAO

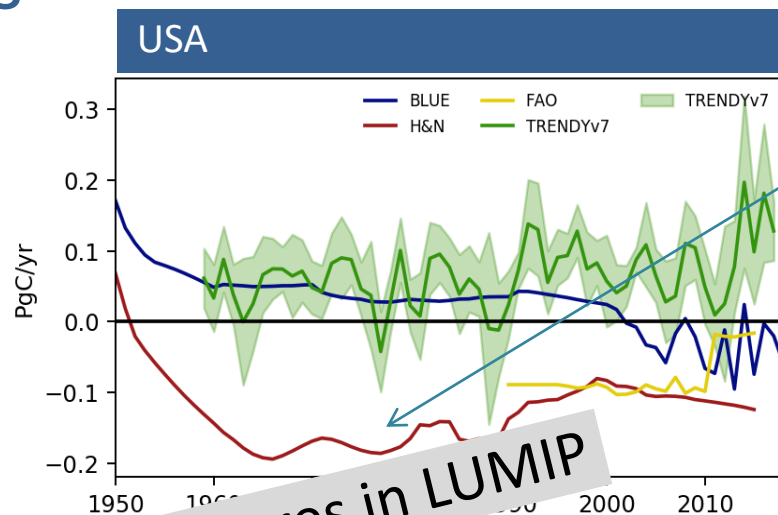
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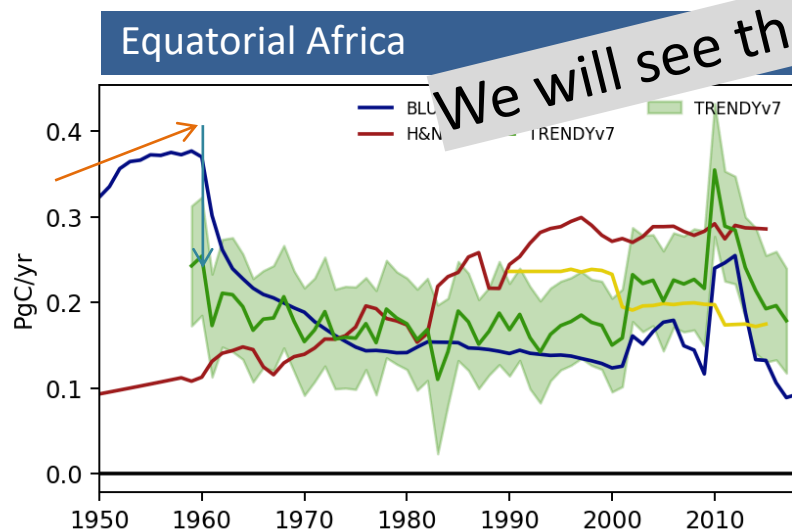
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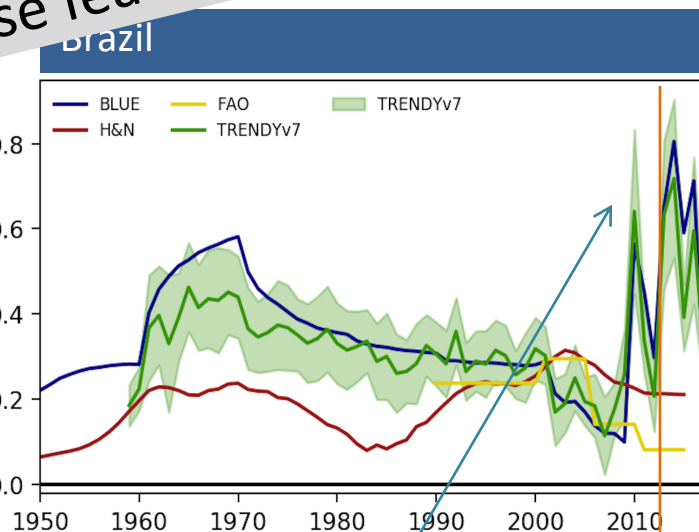


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Land use scaled with population

1960+ land use from FAO



2009/10: LUH2 not updated after HYDE bug

2013+ HYDE adding variability

Why few E_{LUC} estimates can be compared:
Terminological differences

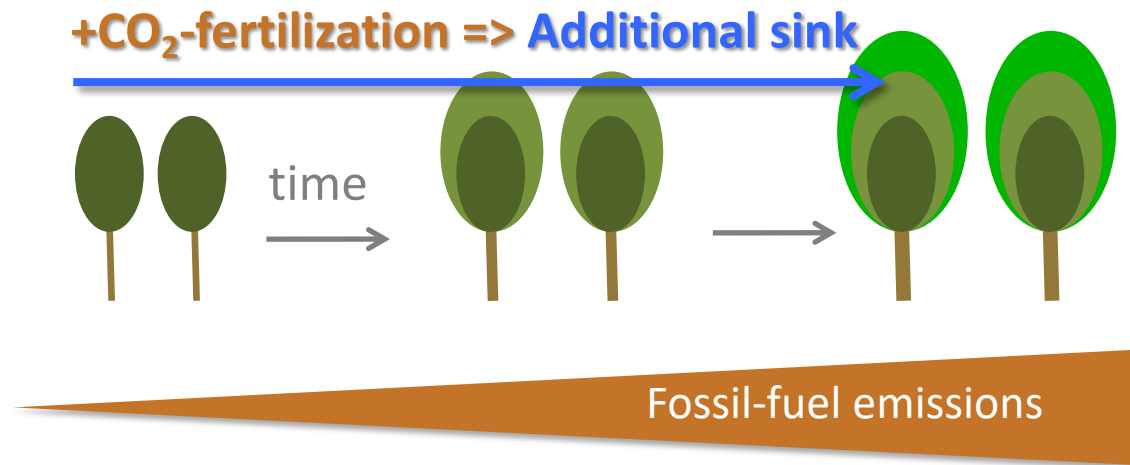
$$F_{\text{net land use flux}} = \Phi_{\text{land use}} - \Phi_{\text{no land use}}$$

Φ : Simulated net land-atmosphere flux

Coupled vs offline simulations

Coupled setup (ESMs)

“**Without** land use” simulation:

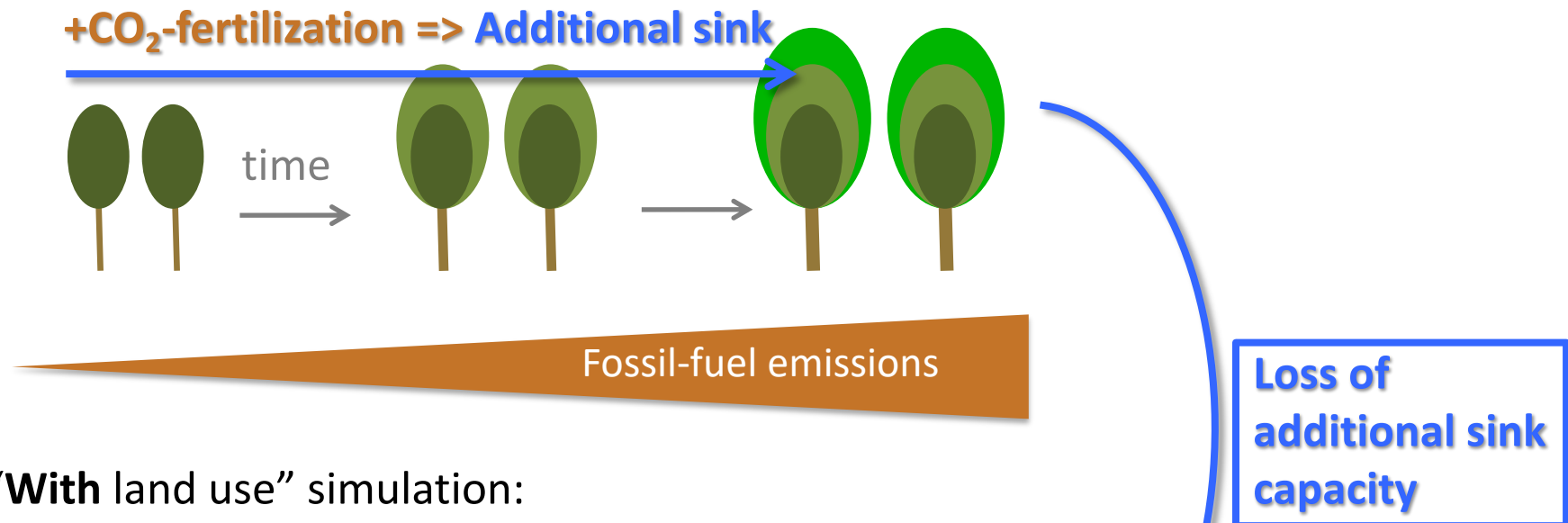


“**With** land use” simulation:

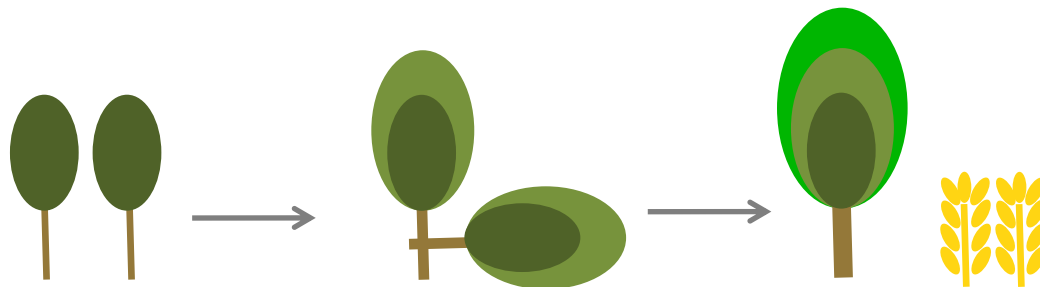
Coupled vs offline simulations

Coupled setup (ESMs)

“Without land use” simulation:



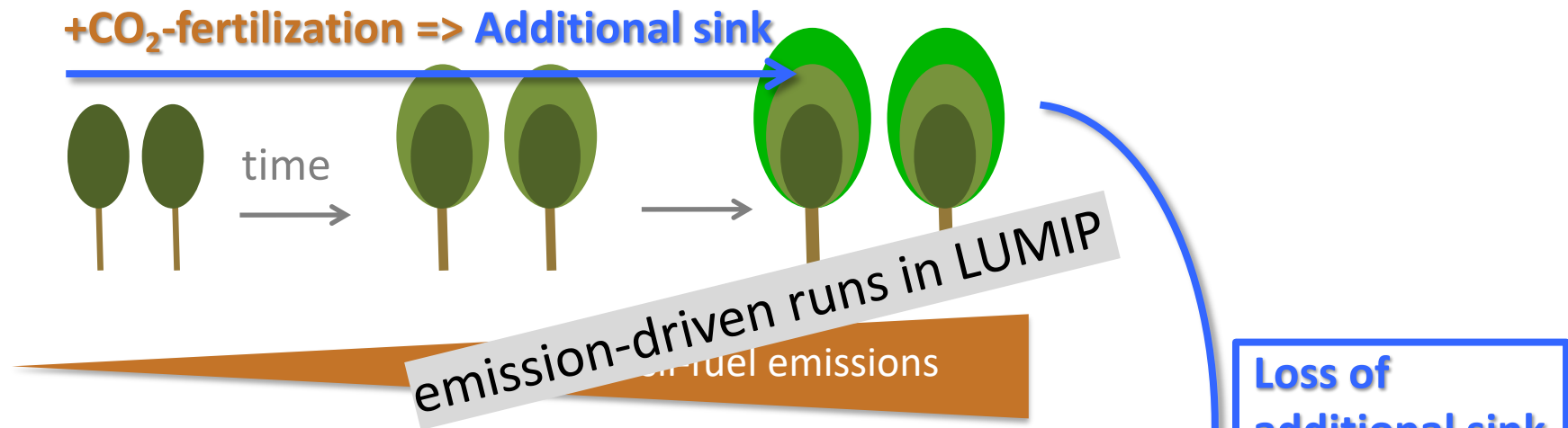
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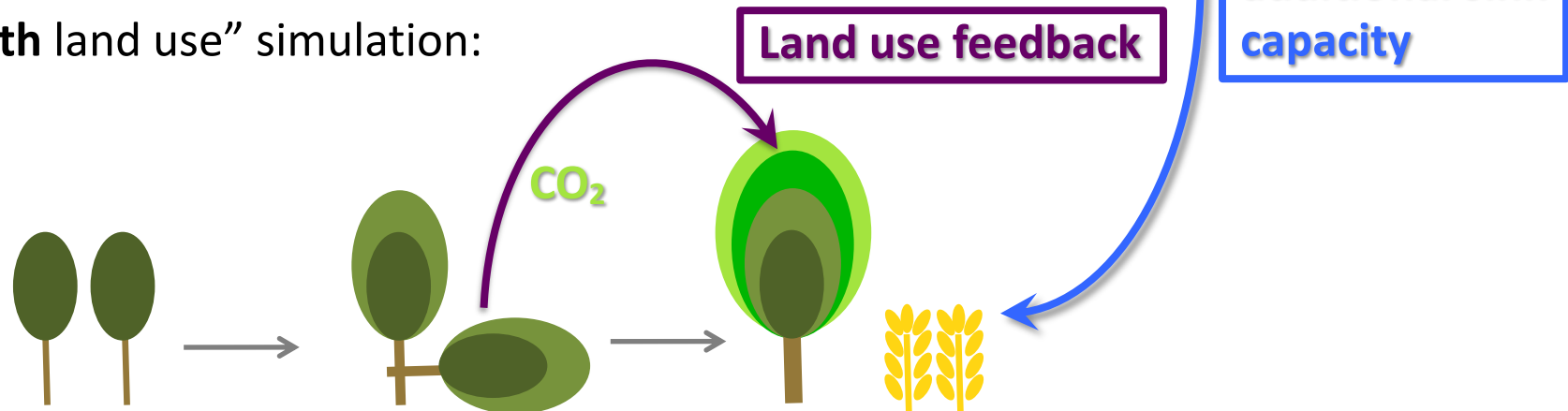
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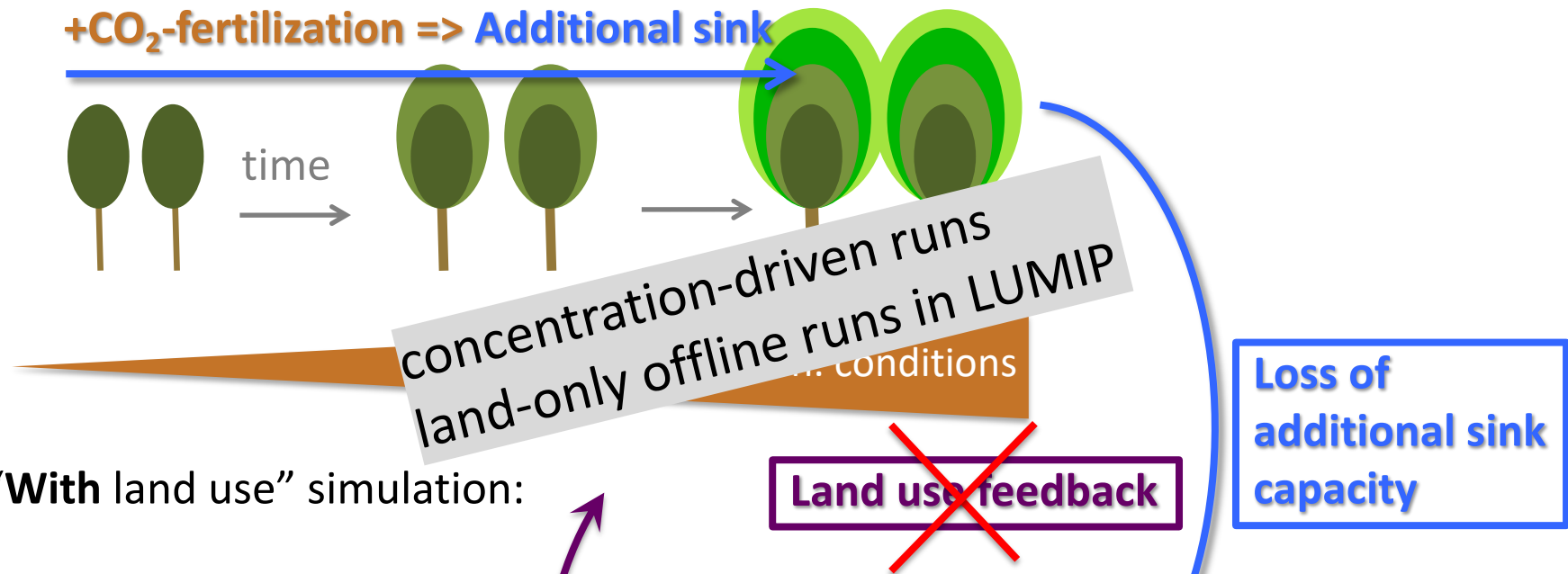
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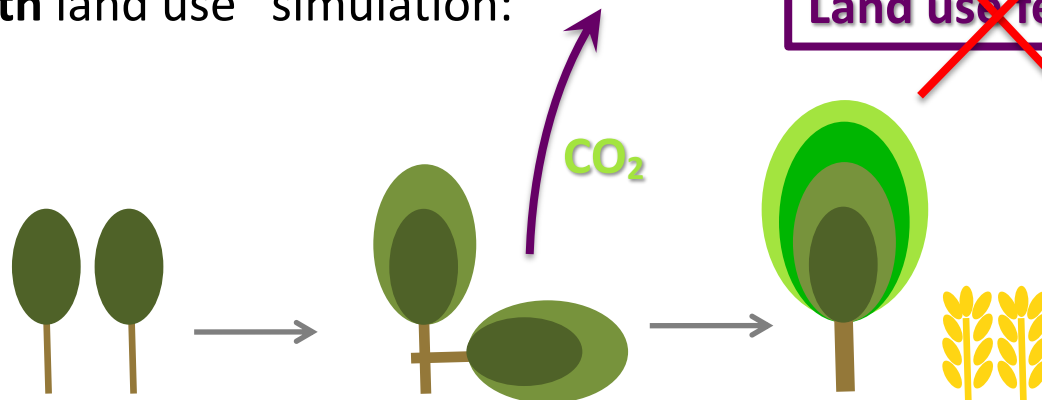
Coupled vs offline simulations

Offline setup (DGVMs)

“Without land use” simulation:



“With land use” simulation:

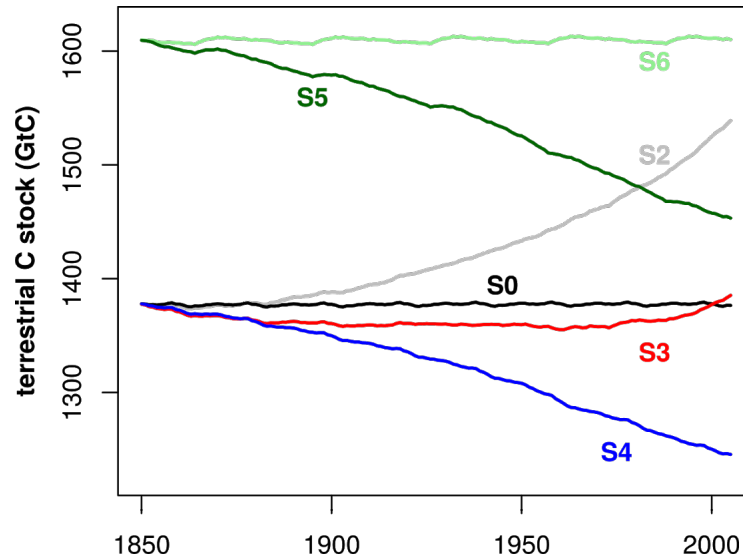


Key differences to bookkeeping

	Historically	Future
Land use feedback (feedback of E_{LUC} on S_{LAND} via atmos. CO_2 in emission-driven runs)	–25% to –50%	
Loss of additional sink (whenever LUC and noLUC runs are subtracted and climate/ CO_2 is changing the noLUC-forest implies an additional sink that is lost upon subtracting; e.g. TRENDY S2-S3)	+100%	+100% (SRES A2)
Exclusion of regrowth and delayed emissions (i.e. diagnose instantaneous emissions directly)	small	+300% to +600% (RCP 8.5)
Report $E_{LUC} + S_{LAND}$ on all managed land (UNFCCC, FAO)	–80%	

GCP: bring it all down to bookkeeping definition(?)

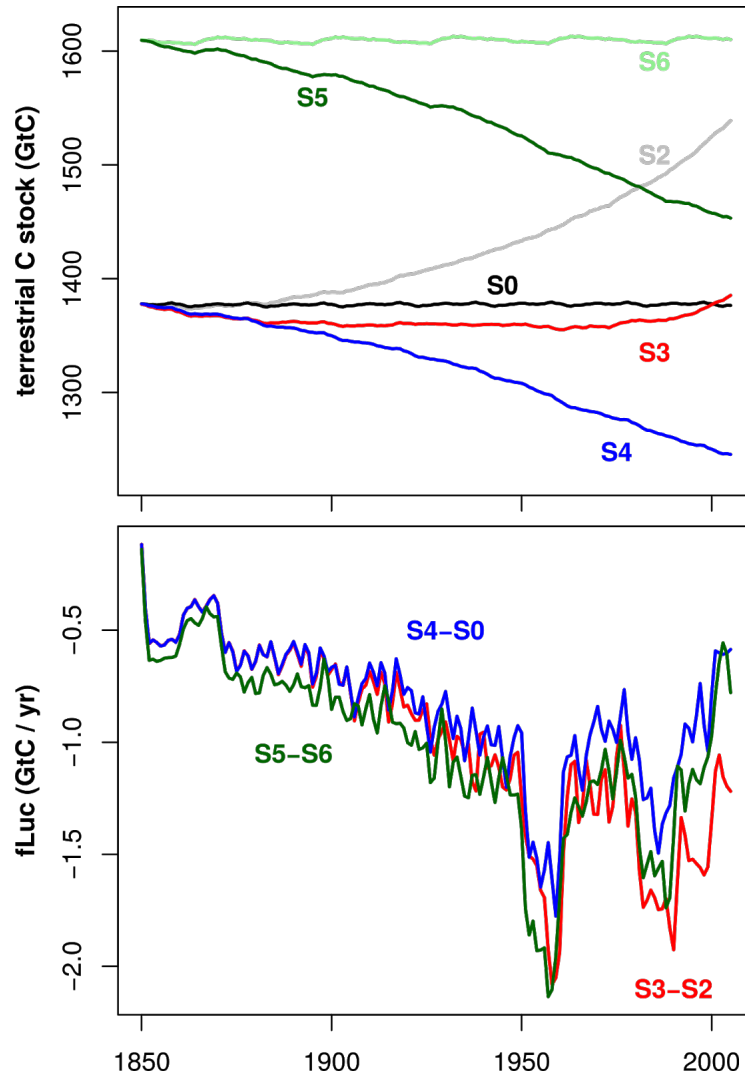
6(!) TRENDY runs in 2019 budget requested



Simulation		LUC	climate	CO ₂
S0	ctrl to S1-4	none	pre-ind	pre-ind.
S1		none	pre-ind	hist
S2		none	hist	hist
S3		LUC	hist	hist
S4		LUC	pre-ind	pre-ind
S5		LUC	pres.	pres.
S6	ctrl to S5	none	pres.	pres.

GCP: bring it all down to bookkeeping definition(?)

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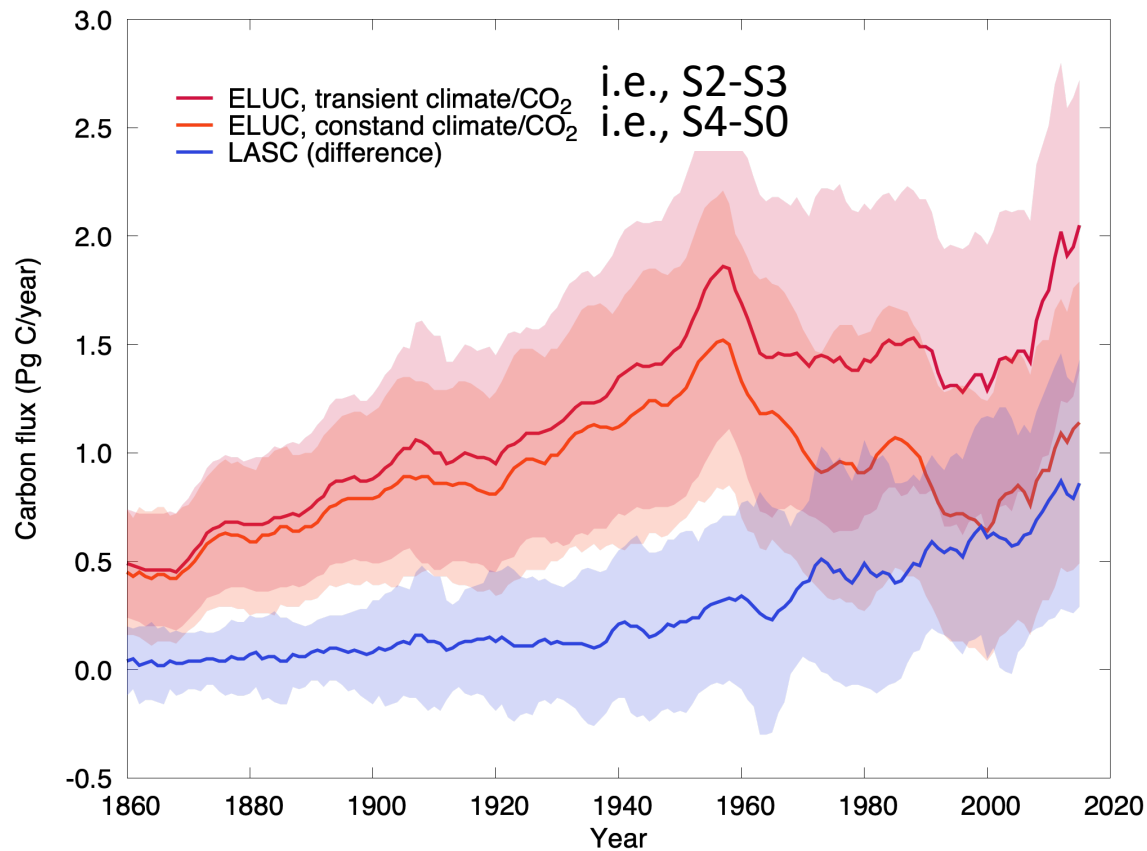


Simulation		LUC	climate	CO ₂
S0	ctrl to S1-4	none	pre-ind	pre-ind.
S1		none	pre-ind	hist
S2		none	hist	hist
S3		LUC	hist	hist
S4		LUC	pre-ind	pre-ind
S5		LUC	pres.	pres.
S6	ctrl to S5	none	pres.	pres.

- E_{LUC} as S4-S0 or as S6-S5 is closest to bookkeeping
- (Complicated consequences for S_{LAND})
- Estimate of loss of additional sink capacity as S4-S0 vs S2-S3

Key differences to bookkeeping

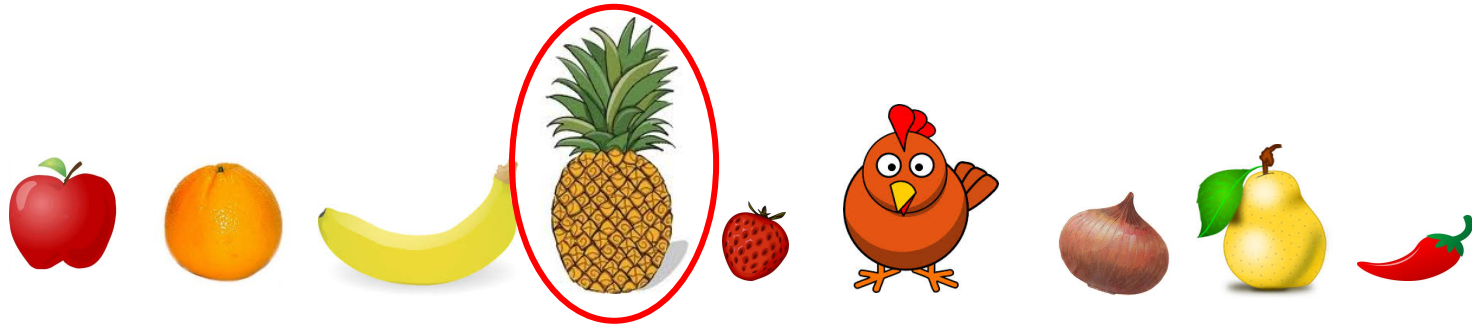
Loss of additional sink capacity in TRENDY



LASC doubles
 E_{LUC} size in
recent decades!

Conclusions on terminology

- 9 different definitions used in publications



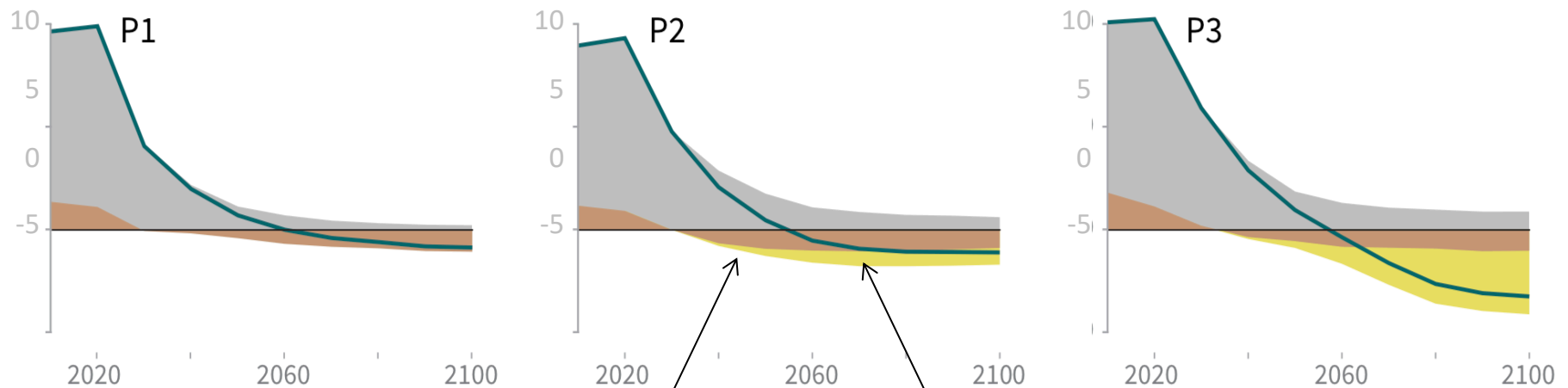
- Factor 2 (historically) to 6 (future) in spread of estimates
- for LUMIP:
 - comparison against publications requires care
 - don't mix up the 2.5 definitions used in the 3 LUMIP setups (offline, concentration-driven, emissions-driven)

Future land use change

Scenarios compatible with 1.5°C target

“Archetypes” of emission scenarios

CO₂-Emissions (PgC/year)



re/afforestation

BECCS (BioEnergy
with Carbon
Capture and
Storage)

→ land use change as negative emission technology (range)

→ $|E_{LUC}| \gg |E_{FF}|$!

Summary

Observations:

- near real-time tracking of biomass loss combining remote sensing and bookkeeping modeling?

CMIP5, Global Carbon Project (GCP)'s budget, 1.5 degree:

- Trends and patterns
 - Until 50s $E_{LUC} > E_{FF}$ – and again in the future!
 - RECCAP-2 ongoing
- Uncertainties
 - uncertain land use history
 - resolve large spread across models (→ talks by Ben, Victor)
 - terminological differences (factor 2-6), in particular land use feedback and loss of additional sink capacity