Current, Past, and Future Representations of Land Use and Land Cover in CESM

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NCAR

CESM Tutorial – August 10 2022

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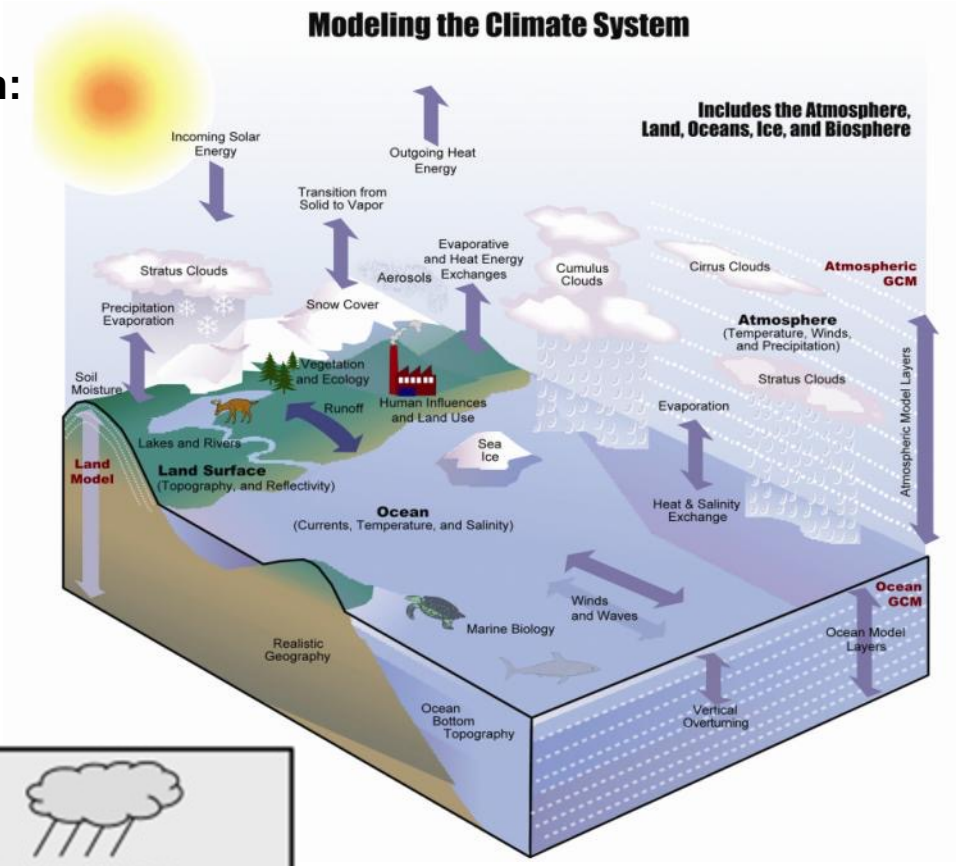
Understanding the role of Land in the Climate System: Investigations with an Earth System Model (NCAR CESM)

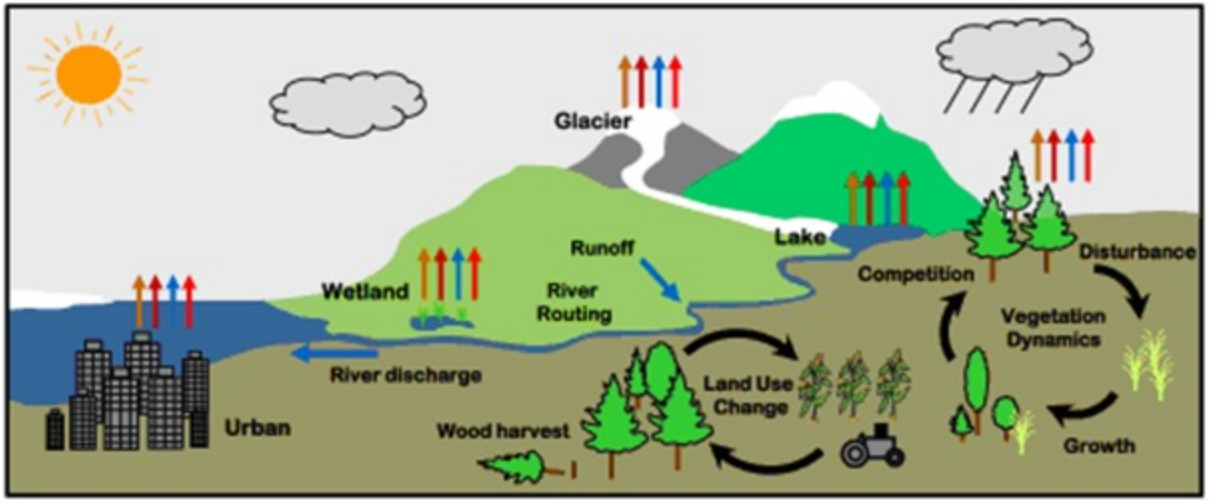
The land is a critical interface through which:

1. We study climate and climate change impacts on humans and ecosystems

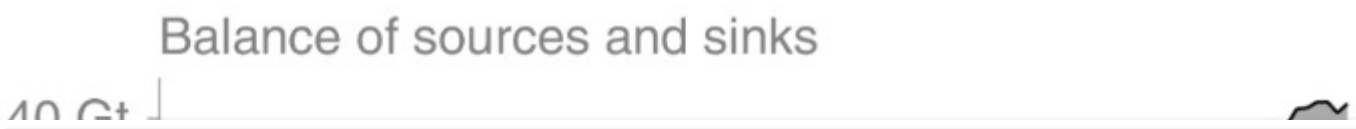
and

2. The impact that humans and ecosystems can force on the environment and climate





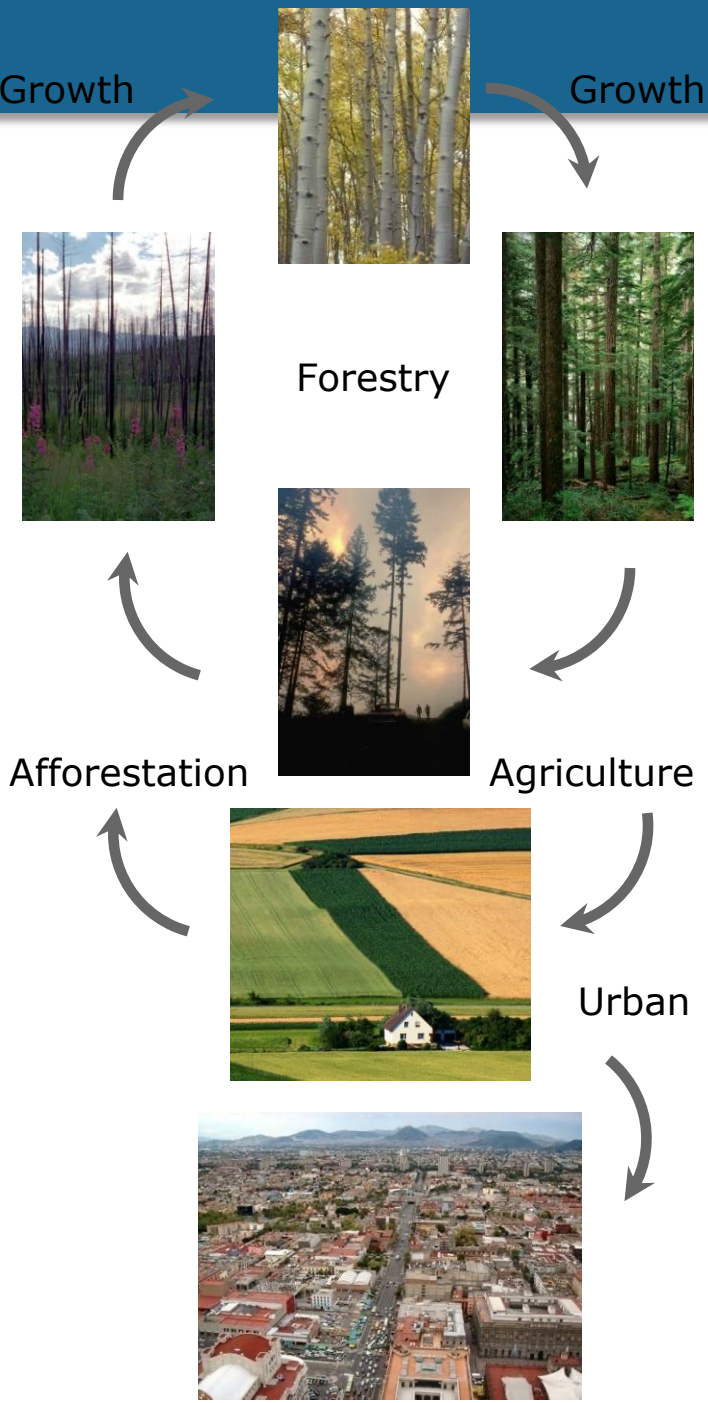
Land Cover Change Contribution to Carbon Emissions



Units of GtC	1850–2018
Emissions	
Fossil CO_2 emissions (E_{FF})	440 ± 20
Land use change CO_2 emissions (E_{LUC})	205 ± 60^{c}
Total emissions	645 ± 65
Partitioning	
Growth rate in atmospheric CO_2 concentration (G_{ATM})	255 ± 5
Ocean sink (S_{OCEAN})^{e}	160 ± 20
Terrestrial sink (S_{LAND})	195 ± 40

Global Carbon Project • Data: CDIAC/GCP/NOAA-ESRL/UNFCCC/BP/USGS

Land Cover Change Biogeophysics

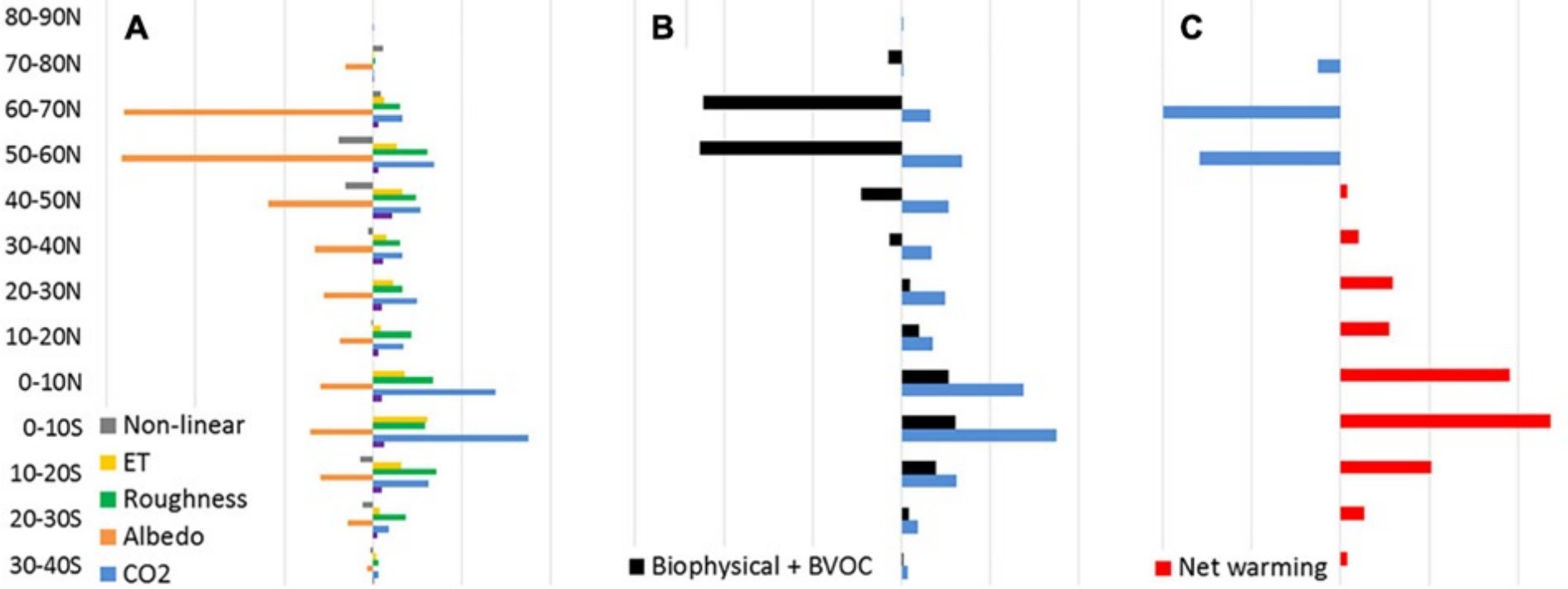


Land Cover Change Deforestation Impacts

Growth

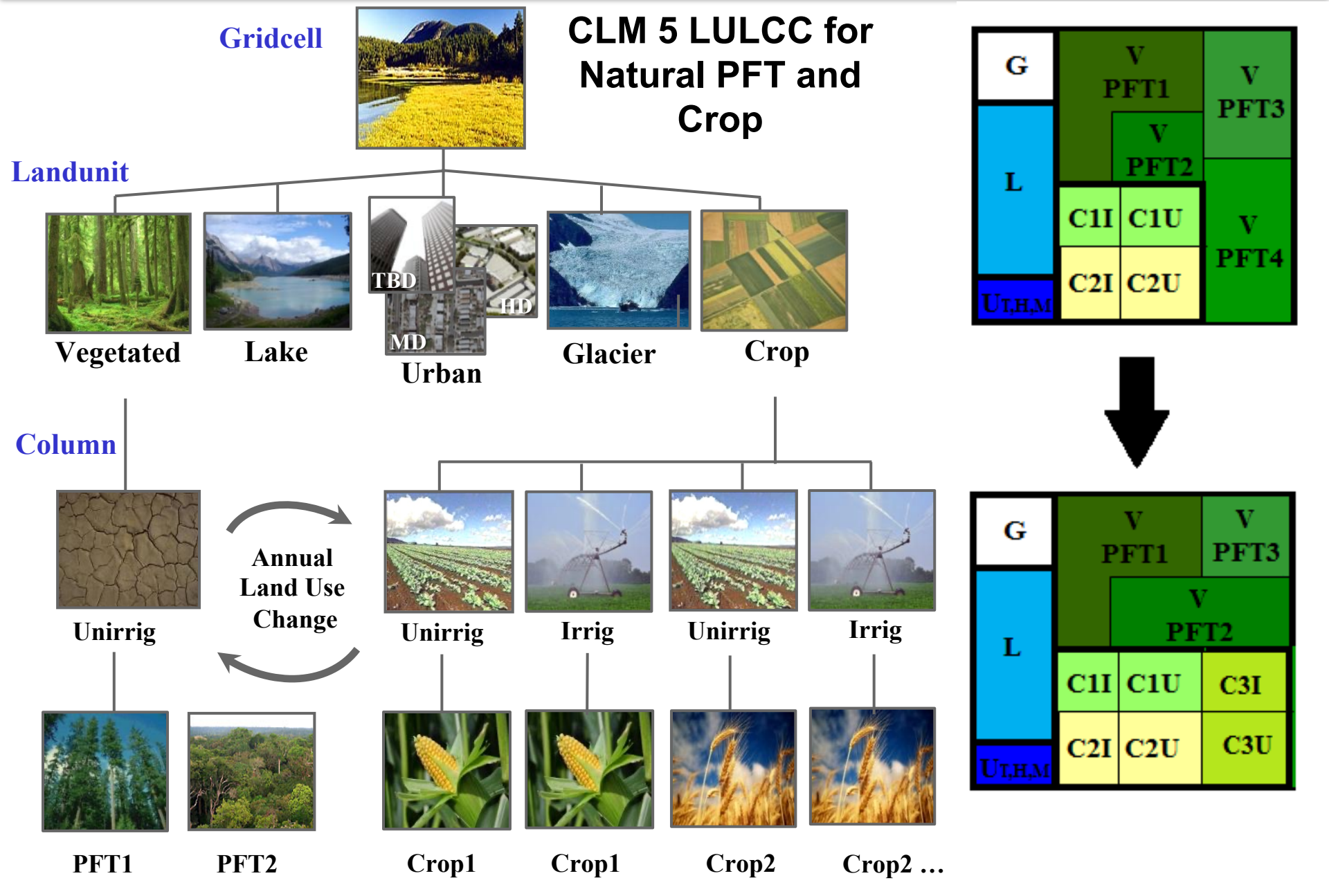
Growth

Forestry

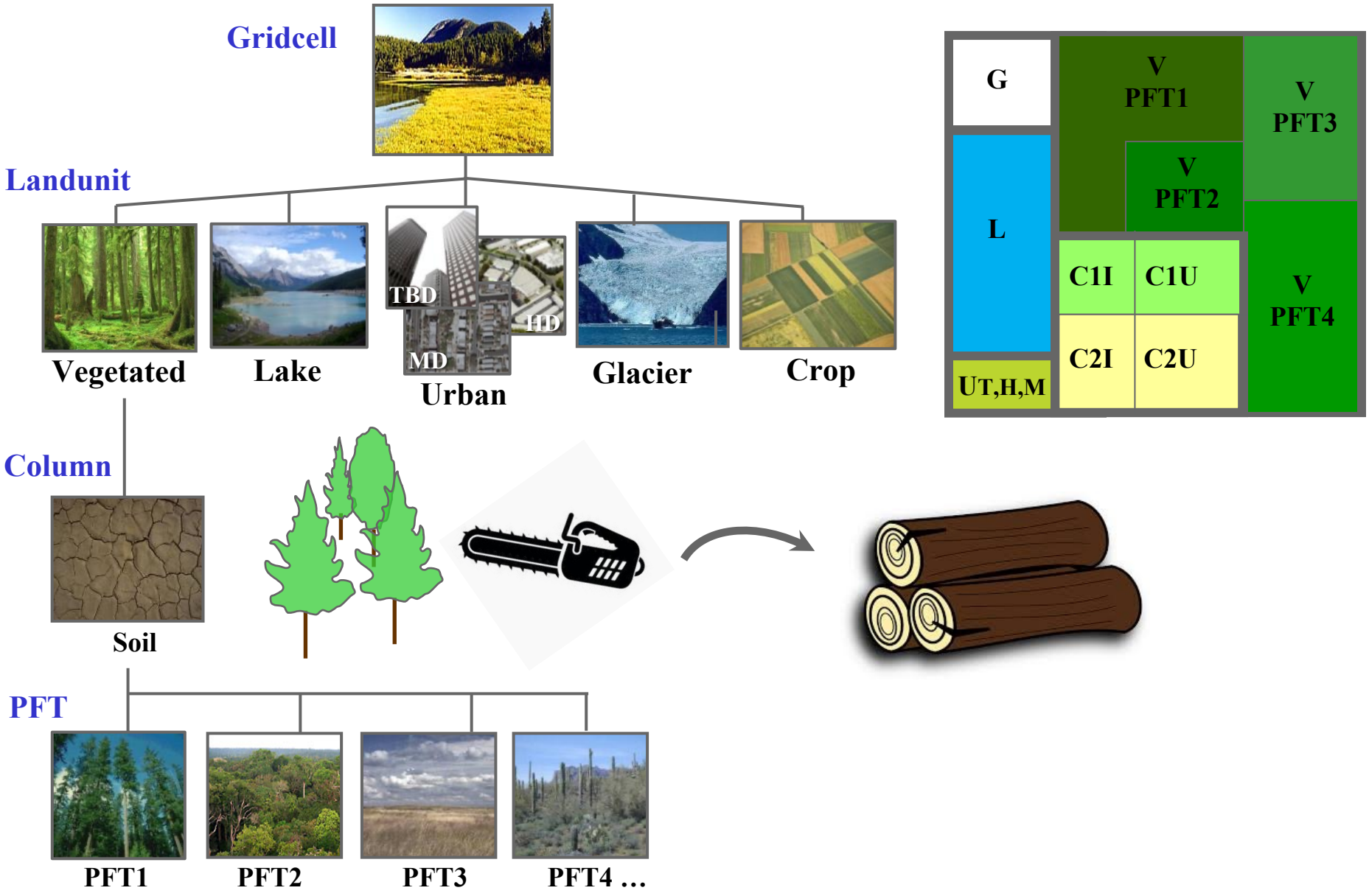


Lawrence et al. (2022) frontiers in Forests and Global Change

CLM5 Land Cover – Prescribed Annual Changes



CLM5 Land Use – Prescribed Wood Harvest (biomass)



CLM5 Land Use – Crop Model Prescribed Management

Gridcell

Landunit

Vegetated

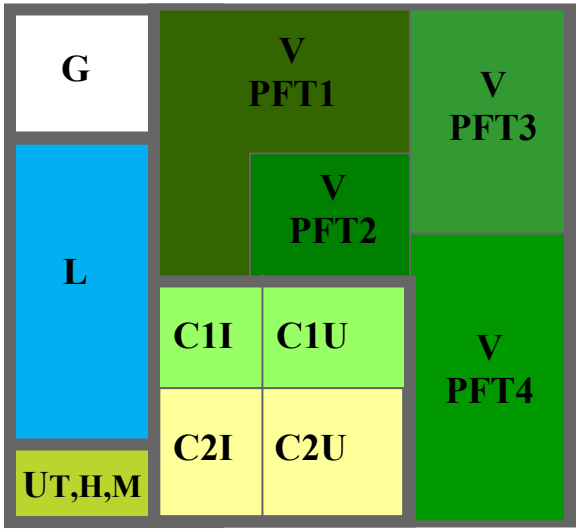
Lake

Urban

Glacier

Crop

CLM 5 LULCC for Natural PFT and Crop



Crop Model

Planting

Leaf emergence

Irrig / Fertilize

Grain fill

Harvest

Unirrig

Irrig

Unirrig

Irrig

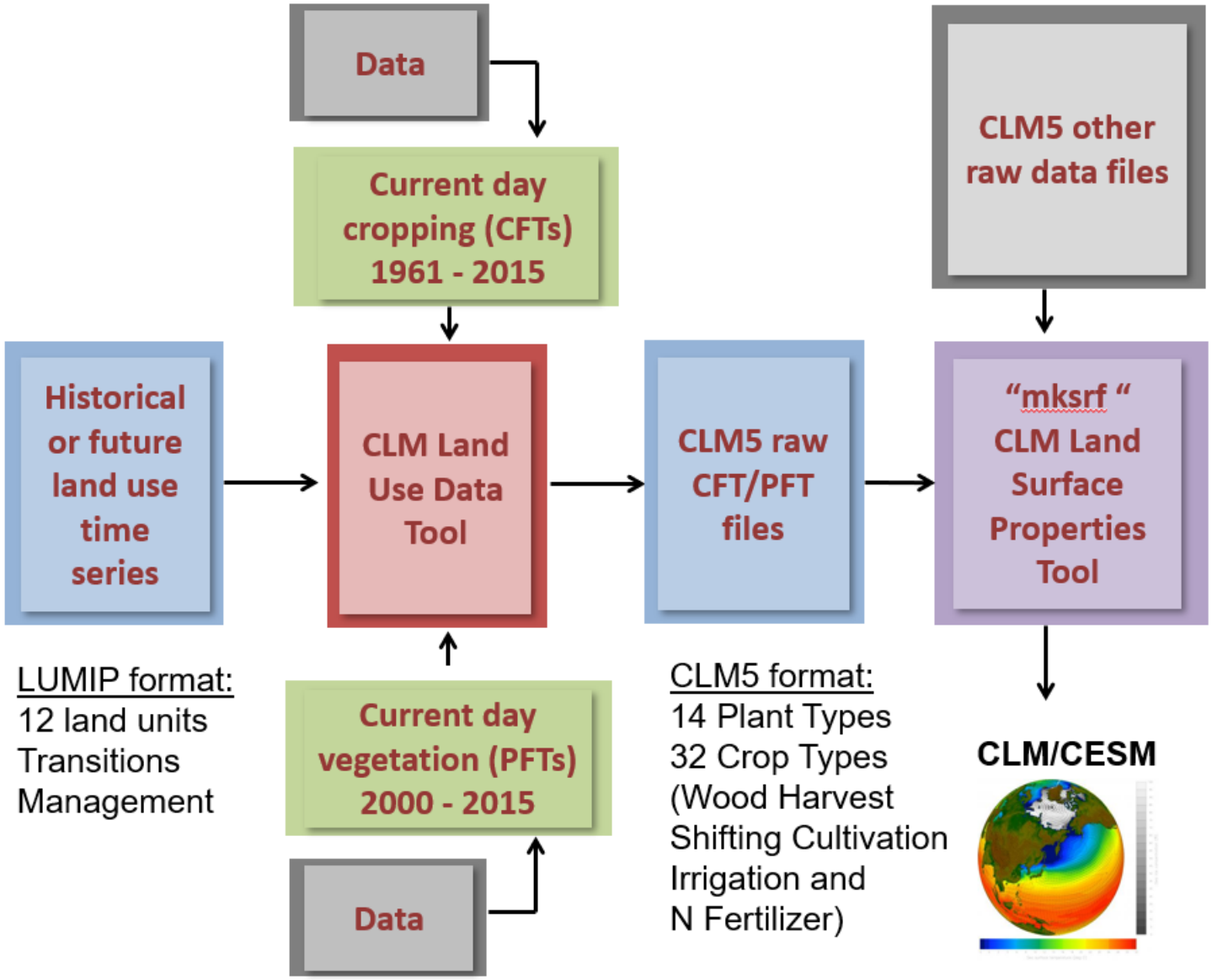
Crop1

Crop1

Crop2

Crop2 …

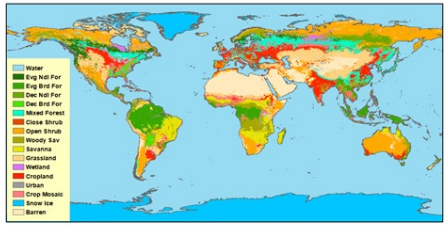
CLM5 Land Use Data Tool



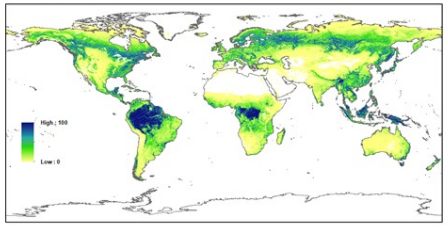
Land Representation - CLM5 Land Data Technote

Land Cover and Cropping Data

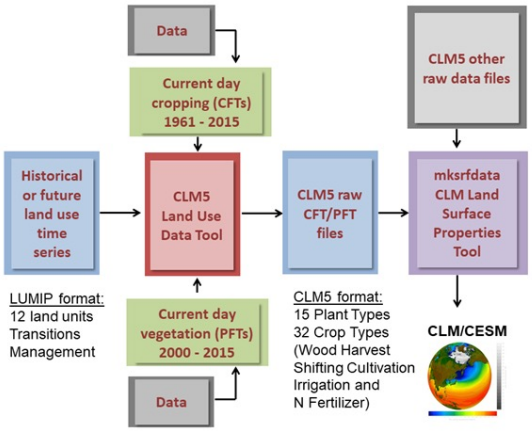
MODIS IGBP Land Cover



MODIS VCF Percent Tree

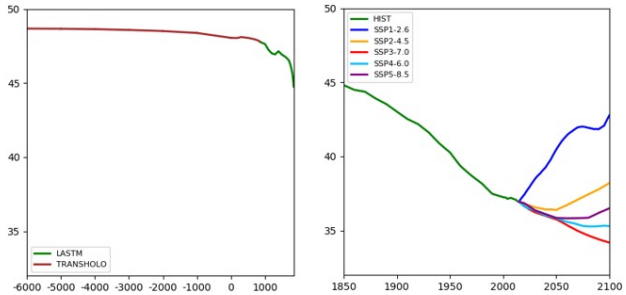


CLM5 Land Use Data Tool - Mksurfdata

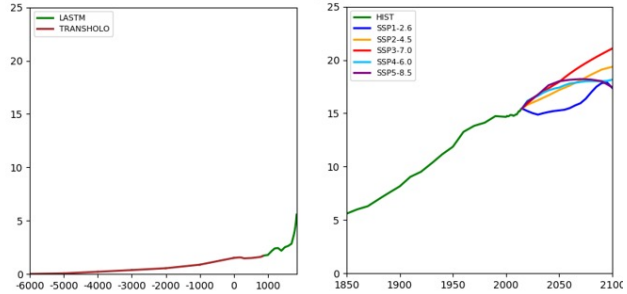


Time Series Data

Global LUH2 CLM5 Tree PFT Area Millions km^2

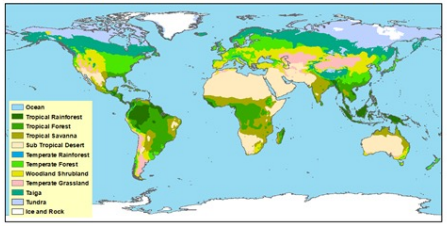


Global LUH2 CLM5 Crop CFT Area Millions km^2



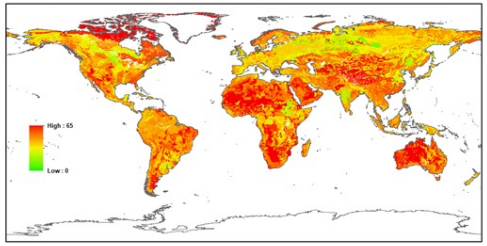
Climate Data

CRU Climate - Whittaker Biomes 2000 - 2015

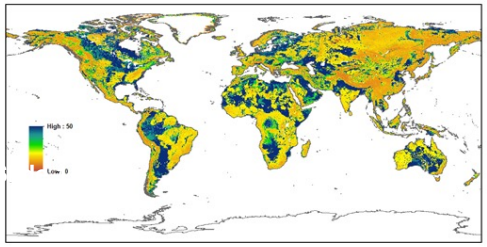


Soils Data

CLM5 Sand Content Top (avg 0 - 0.09m) (%)

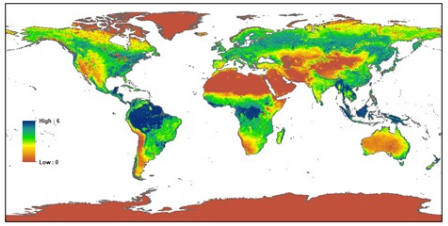


CLM5 Soil Depth (meters)



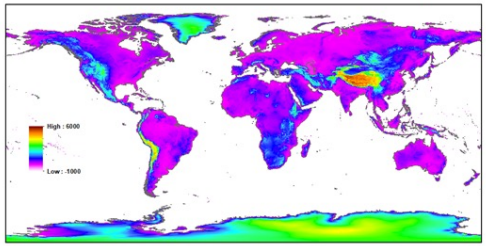
Leaf Area and Albedo Data

MODIS Maximum Annual Leaf Area Index (LAI) 2003 - 2015

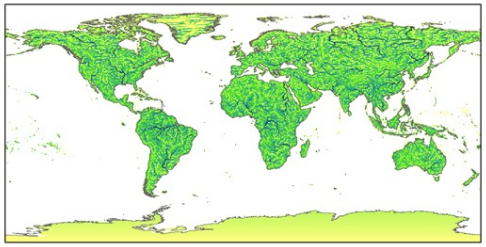


Topography and River Data

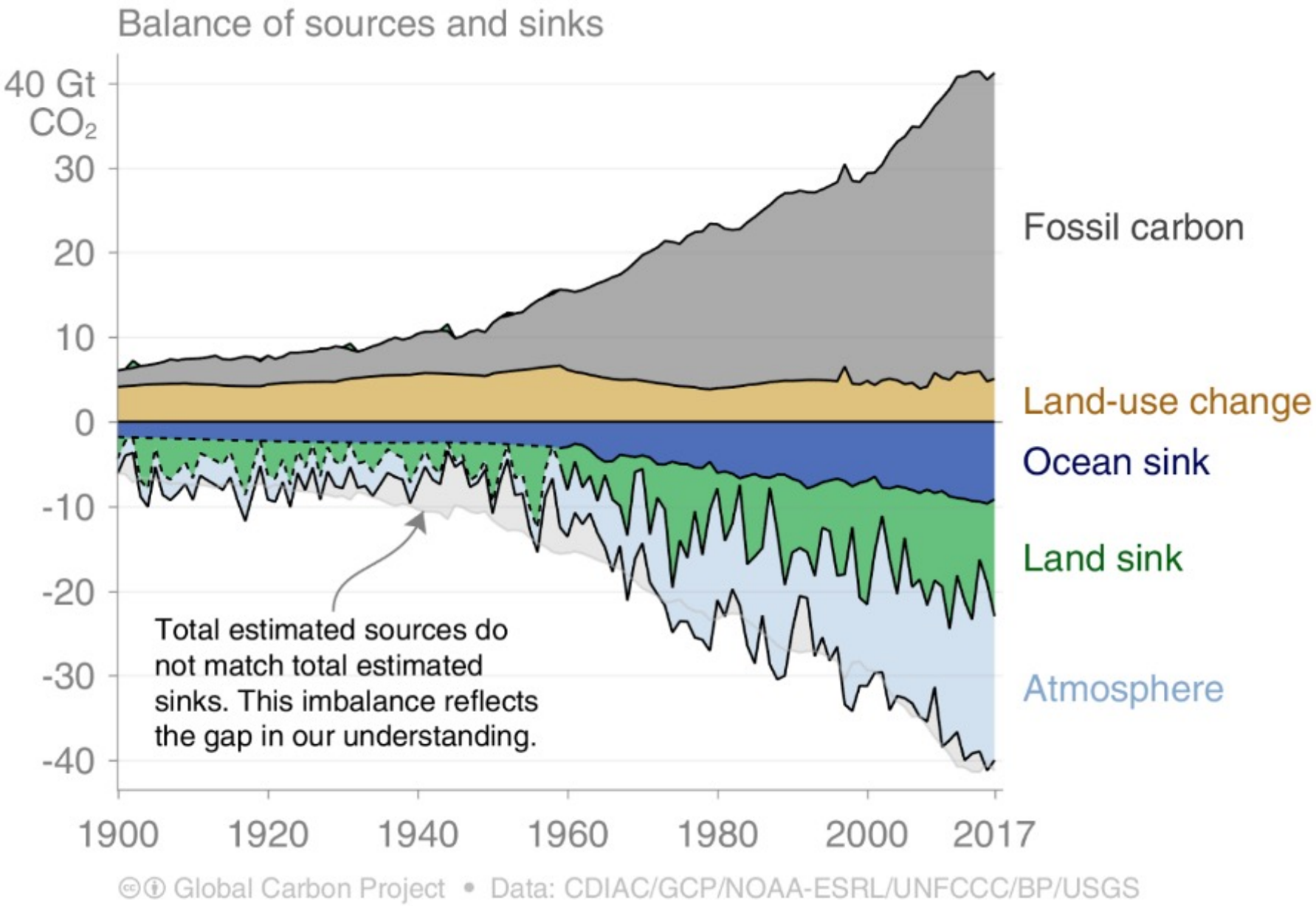
CLM5 Elevation (meters)



CLM5 MOSART River Network 0.5 Degrees

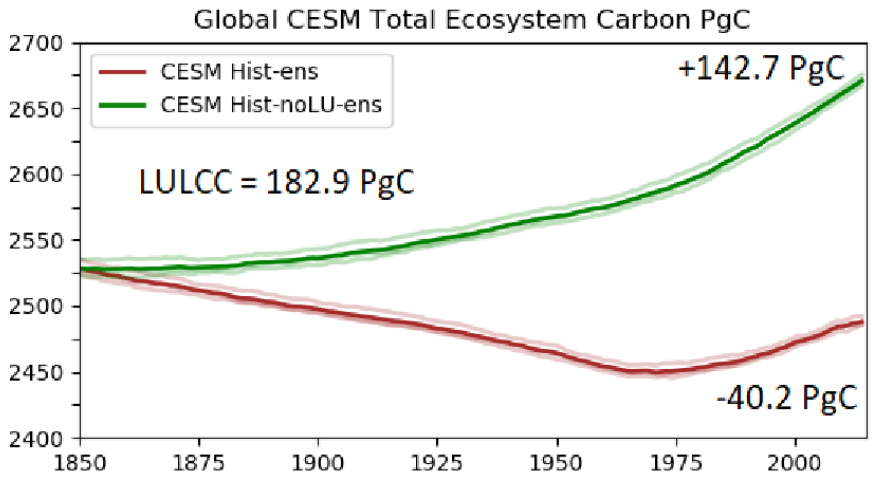


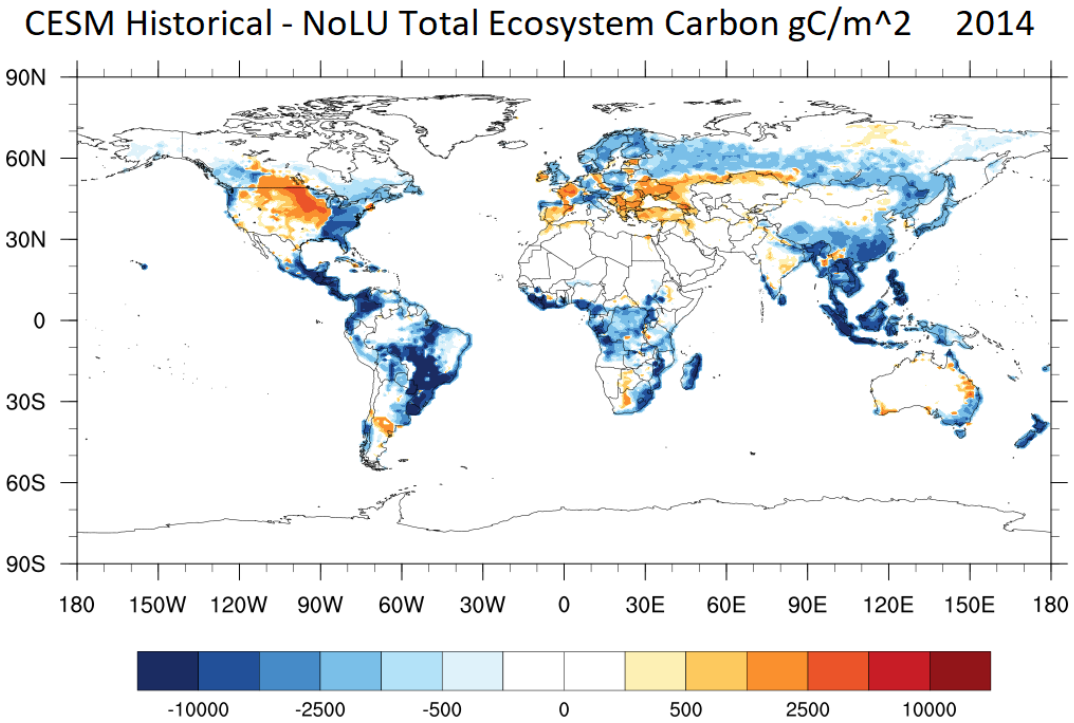
CESM Land Cover Change and Global Carbon Cycle



Slide 3 – IPCC Land Cover Change b

CESM LULCC vs no LULCC – Historic Eco Carbon

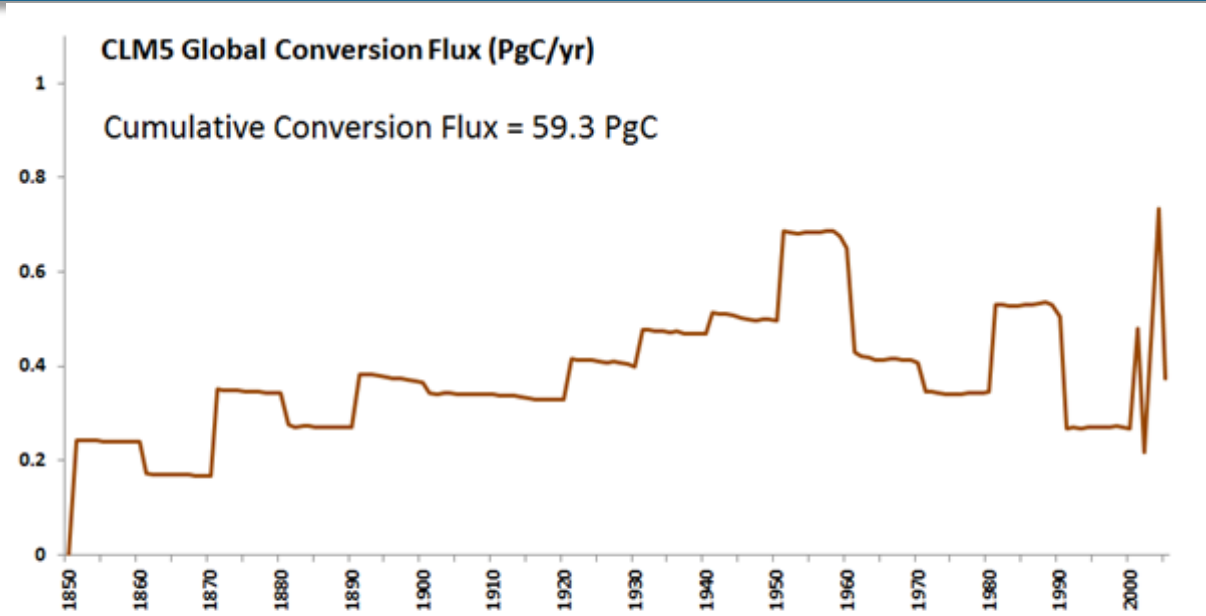


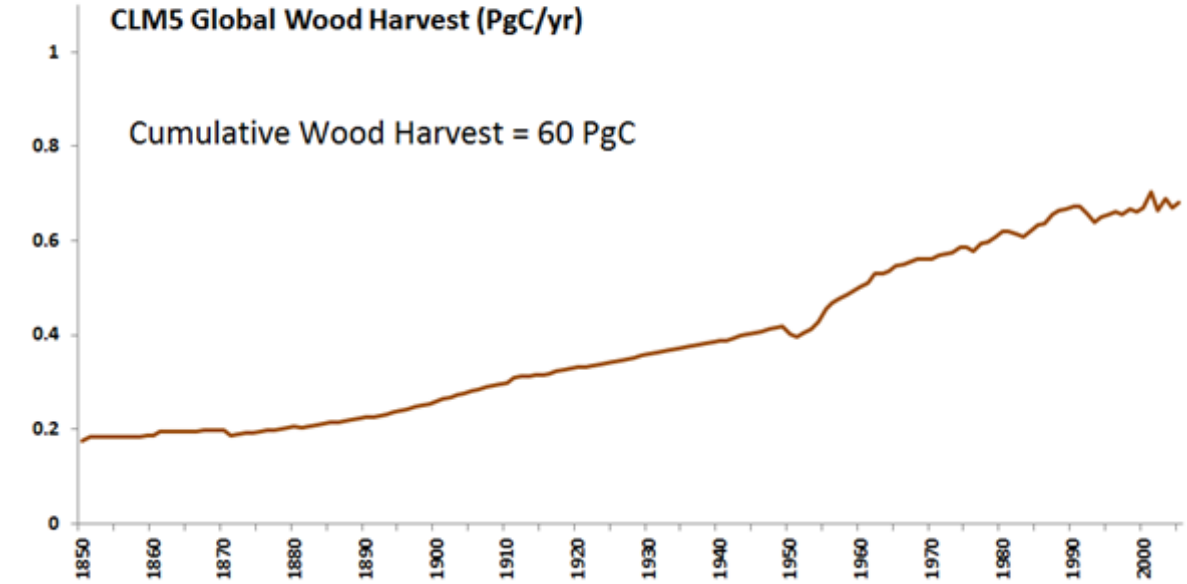


CESM NoLUC has large uptake of carbon from CO_2 fertilization, Climate and N Deposition CLM5 +142.7 PgC

This is offset by LULCC in CESM = 182.9 PgC Global Estimates ~160 PgC

CESM LULCC Conversion and Wood Harvest





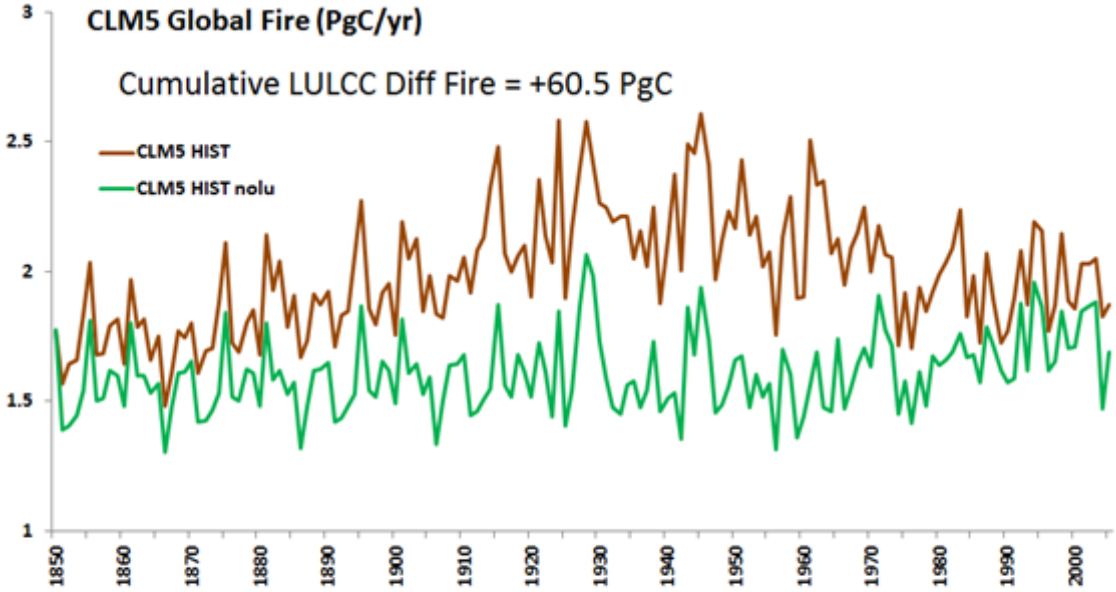
CESM NoLUC has large uptake of carbon from CO_2 fertilization, Climate and N Deposition CLM5 +142.7 PgC

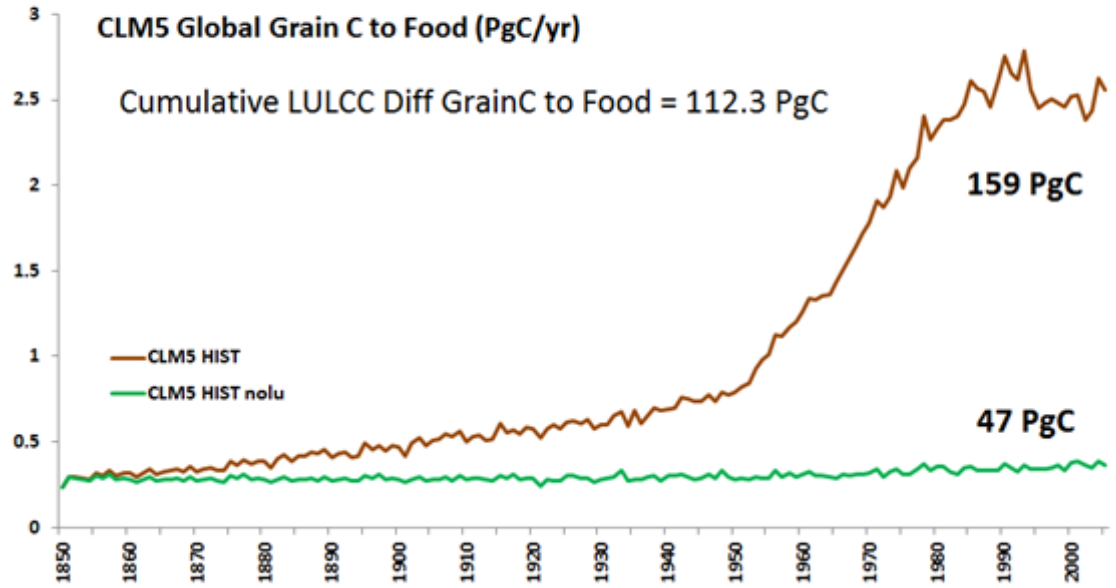
This is offset by LULCC in CESM = 182.9 PgC Global Estimates ~160 PgC

CLM5 conversion of PFTs and CFTs results in a cumulative loss of 59.3 PgC

CLM5 wood harvest of tree PFTs results in a cumulative loss of 60 PgC over the period.

CESM LULCC Fire and Food Harvest





CESM NoLUC has large uptake of carbon from CO_2 fertilization, Climate and N Deposition CLM5 +142.7 PgC

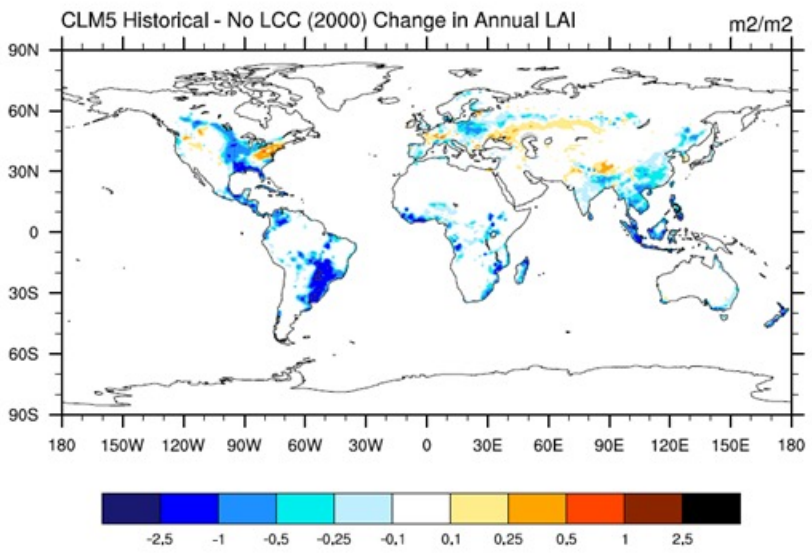
This is offset by LULCC in CESM = 182.9 PgC Global Estimates ~160 PgC

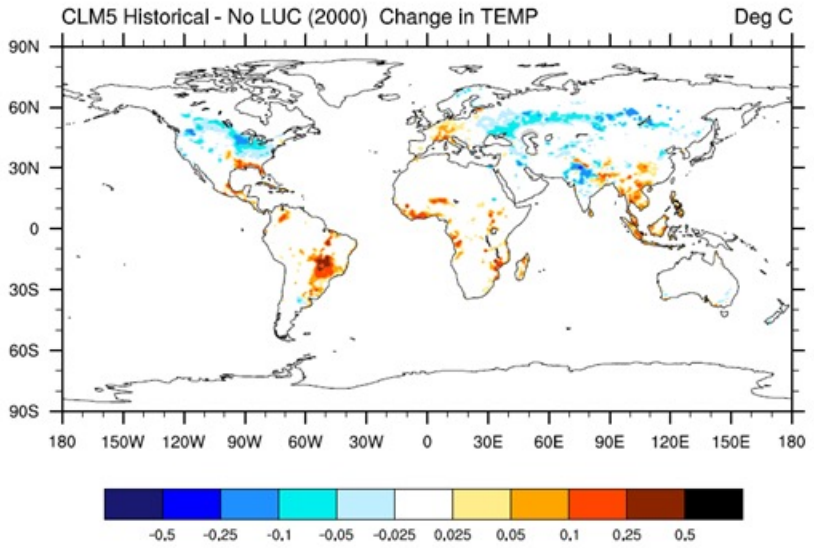
CLM5 LULCC results in large increase in carbon loss through increased fire of +60.5 PgC

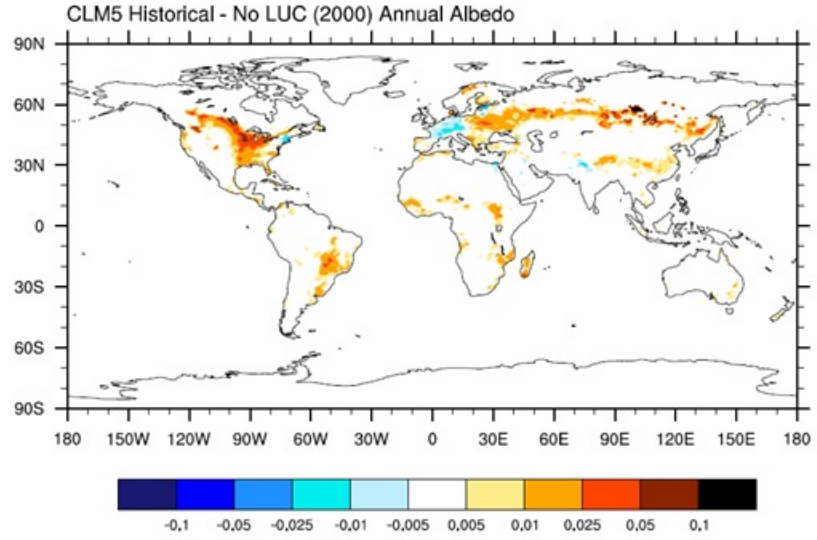
CLM5 LULCC results in large crop harvest flux out of the land of 159 PgC

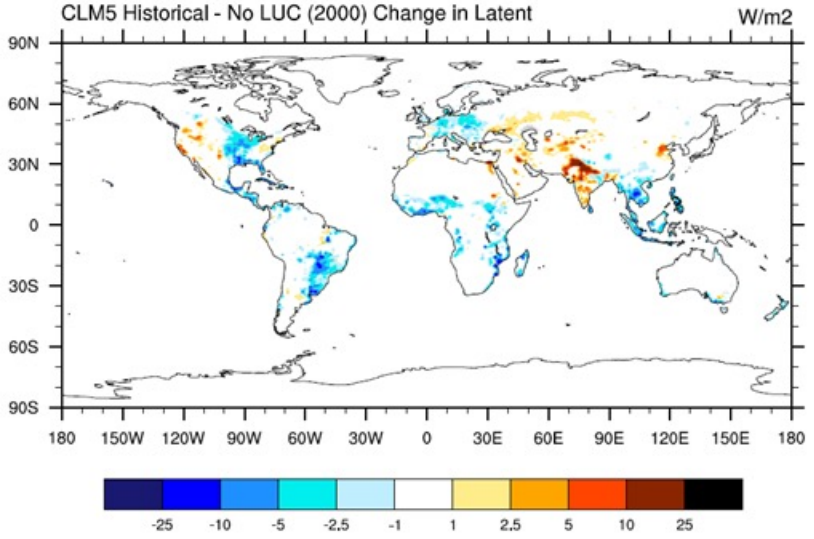
Much of the crop harvest flux is offset in the LULCC simulation by higher NPP from fertilizer and lower heterotrophic respiration

CLM5 LULCC vs no LULCC – Biogeophysics Change

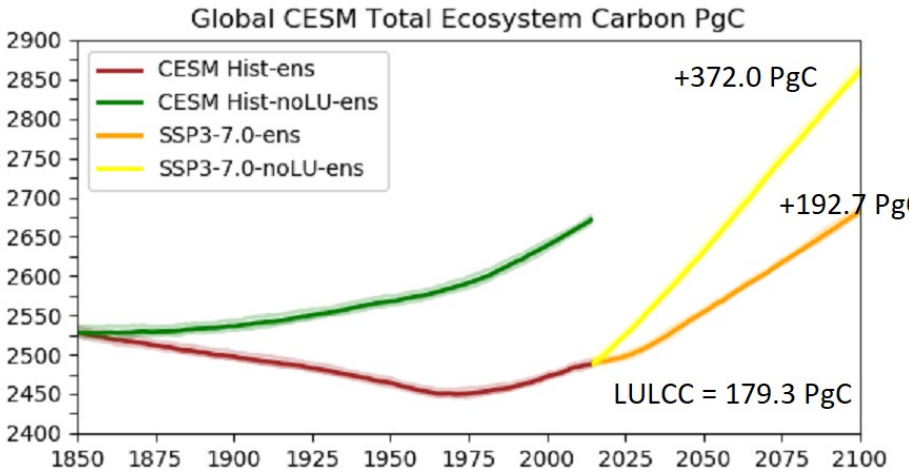


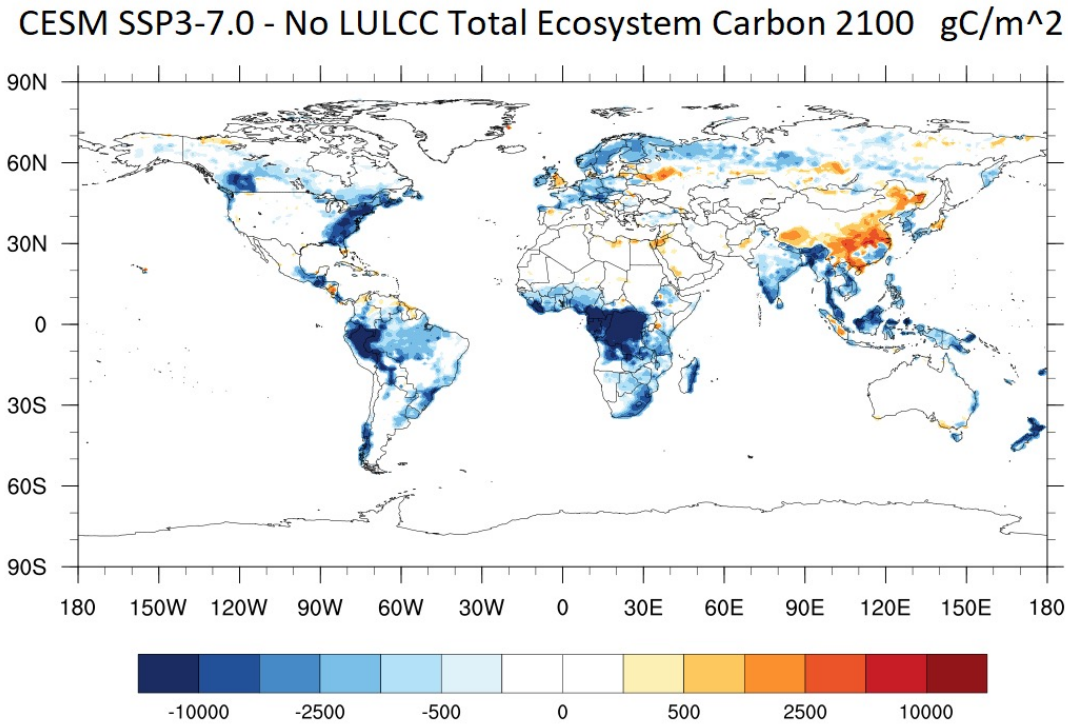






CESM LUMIP SSP3-7.0 vs no LULCC Tot Eco Carbon





CESM NoLUC had large even larger uptake of carbon from CO_2 in SSP3-7.0 with +372.0 PgC

This is offset by the very large LULCC in the scenario with CESM simulating a LULCC of 179.3 PgC

CESM – Carbon Dioxide Removal (CDR)

The carbon dioxide removal potential for large scale Reforestation and Afforestation has been receiving much attention in both the literature and the press.

nature climate change

Letter | Published: 27 May 2019

Potential for low-cost carbon dioxide removal through tropical reforestation

Jonah Busch, Jens Engelmann, Susan C. Cook-Patton, Bronson W. Griscom, Timm Kroeger, Hugh Possingham & Priya Shyamsundar

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NEWS FEATURE · 15 JANUARY 2019

How much can forests fight climate change?

Trees are supposed to slow global warming, but growing evidence suggests they might not always be climate saviours.

Gabriel Popkin

Science Contents News Careers Jou

The New York Times

Restoring Forests Could Help Put a Brake on Global Warming, Study Finds

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REPORT

The global tree restoration potential

Jean-Francois Bastin[1,*], Yelena Finegold[2], Claude Garcia[3,4], Danilo Mollicone[2], Marcelo Rezende[2], Devin Routh[1], Constantin...
+ See all authors and affiliations

Science 05 Jul 2019:
Vol. 365, Issue 6448, pp. 76-79
DOI: 10.1126/science.aax0848

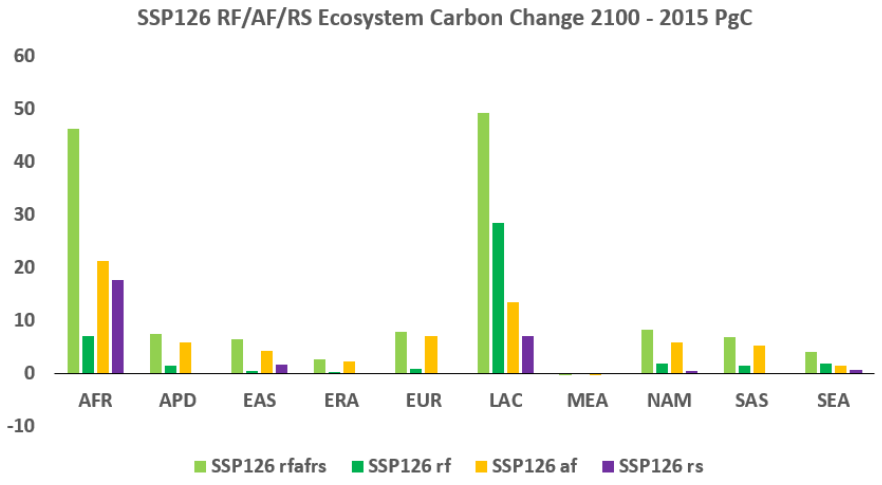
Natural climate solutions

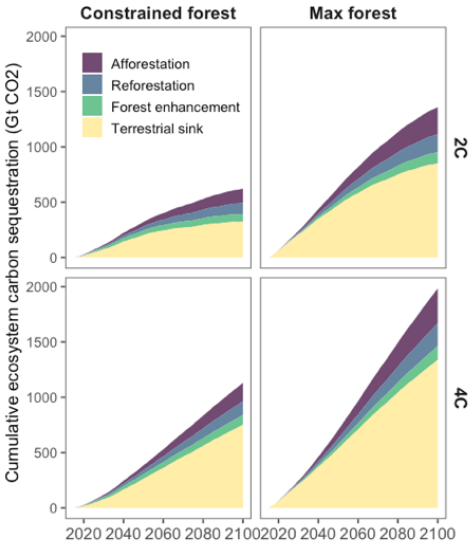
Bronson W. Griscom, Justin Adams, Peter W. Ellis, Richard A. Houghton, Guy Lomax, Daniela A. Miteva, William H. Schlesinger, David Shoch, Juha V. Siikamäki, Pete Smith, Peter Woodbury, Chris Zganjar, Allen Blackman, João Campari, Richard T. Conant, Christopher Delgado, Patricia Elias, Trisha Gopalakrishna, Marisa R. Hamsik, Mario Herr Joseph Kiesecker, Emily Landis, Lars Laestadius, Sara M. Leavitt, Susan Minnemeyer, Stephen Polasky, Peter Potapov, Francis E. Putz, Jonathan Sanderman, Marcel Silvius, Eva Wollenberg, and Joseph Fargione

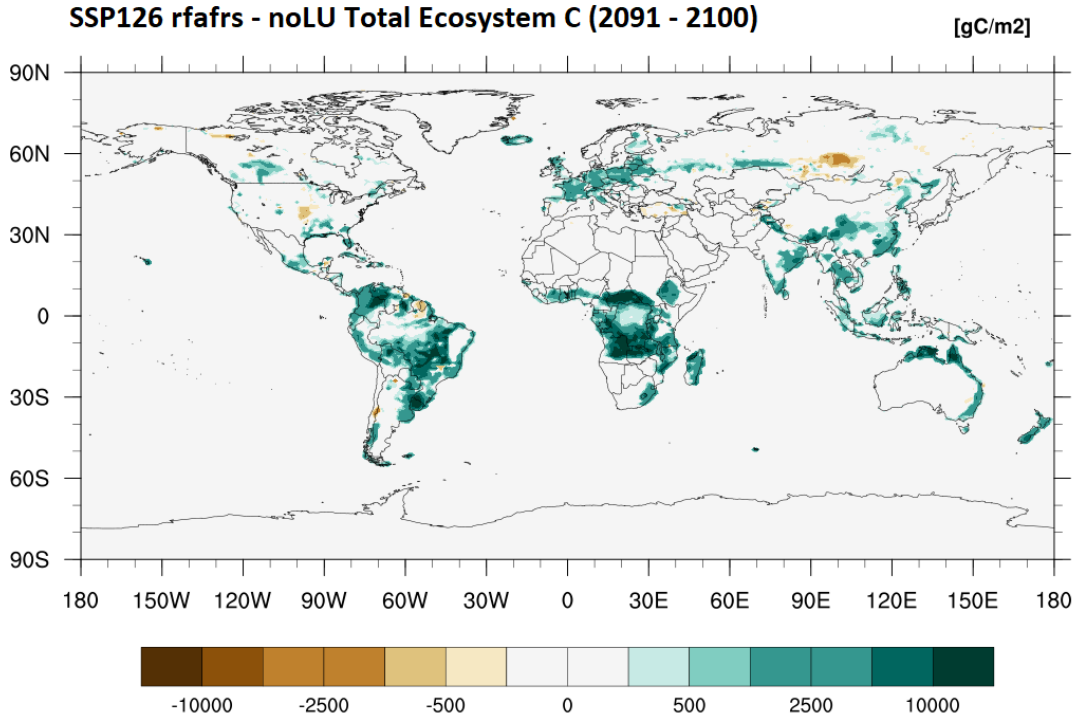
PNAS October 31, 2017 114 (44) 11645-11650; first published October 16, 2017 https://doi.org/10.1073/pnas.1

Range of results upper end has:
Re/Afforestation of 9 million km^2
With 205 PgC additional storage
(Cumulative emissions ~500 PgC)

CLM5 RCP 2.6 Re/Afforestation – Total Eco Carbon 139 PgC



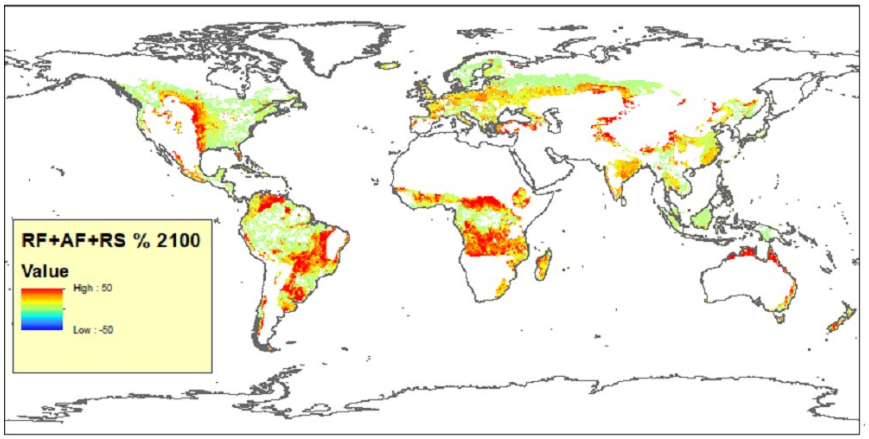


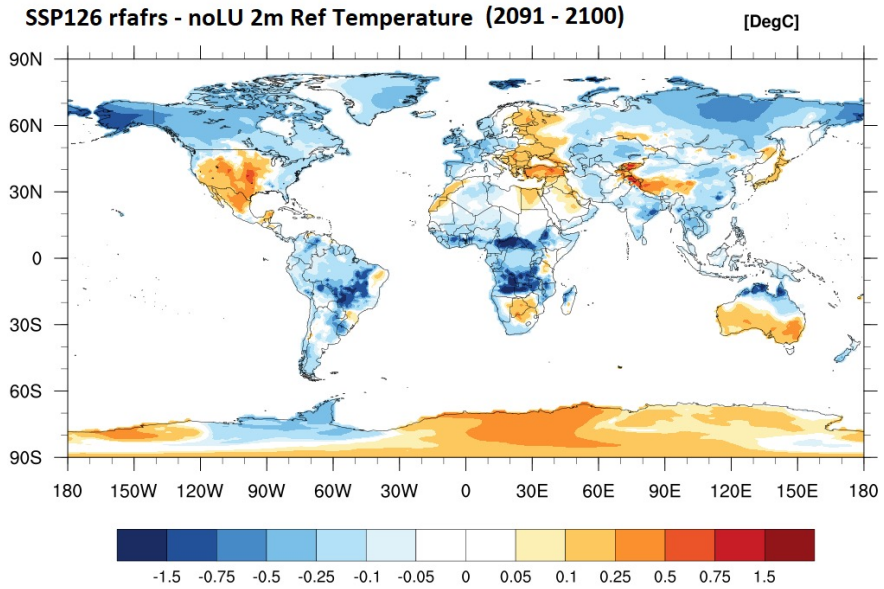


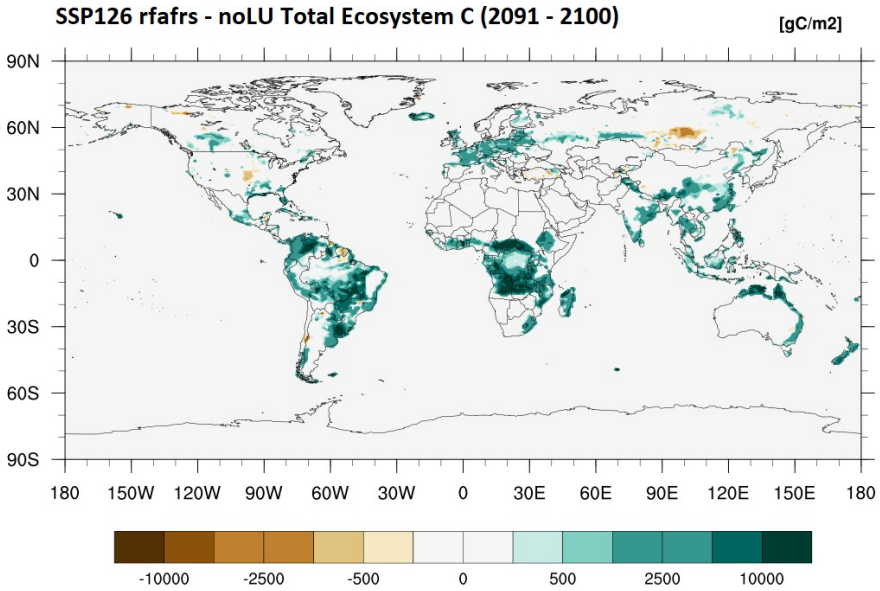
Terrestrial Sink Carbon Enhancement
SSP1-2.6 Max Forest

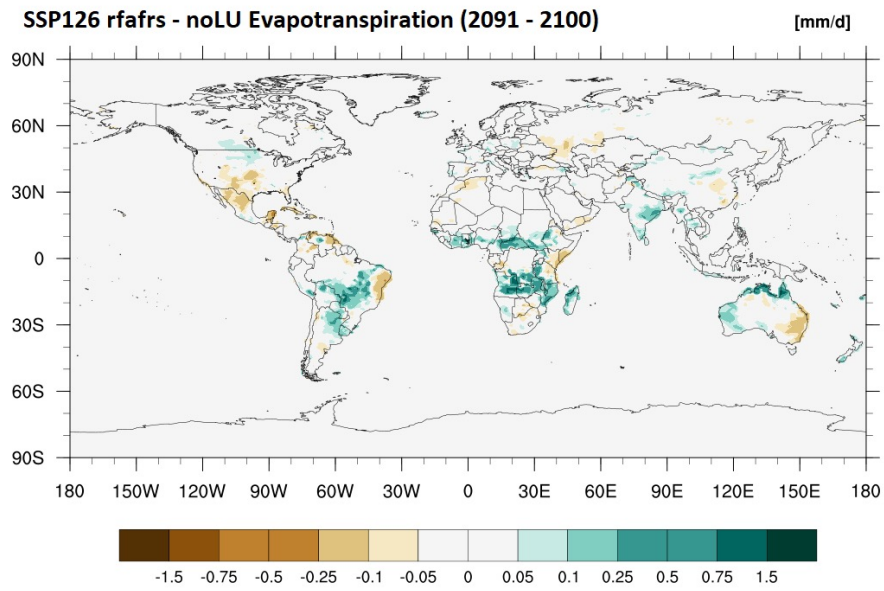
Reforestation	44 PgC
Afforestation	67 PgC
Restoration	28 PgC
Total	139 PgC

CLM5 RCP 2.6 Re/Afforestation – Air Temp / Evapotrans









CLM5 RCP 2.6 Re/Afforestation – Air Temp / Albedo / Solar