Land Use and Land Cover Change in CESM

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(With thanks to the TSS group for their many contributions)

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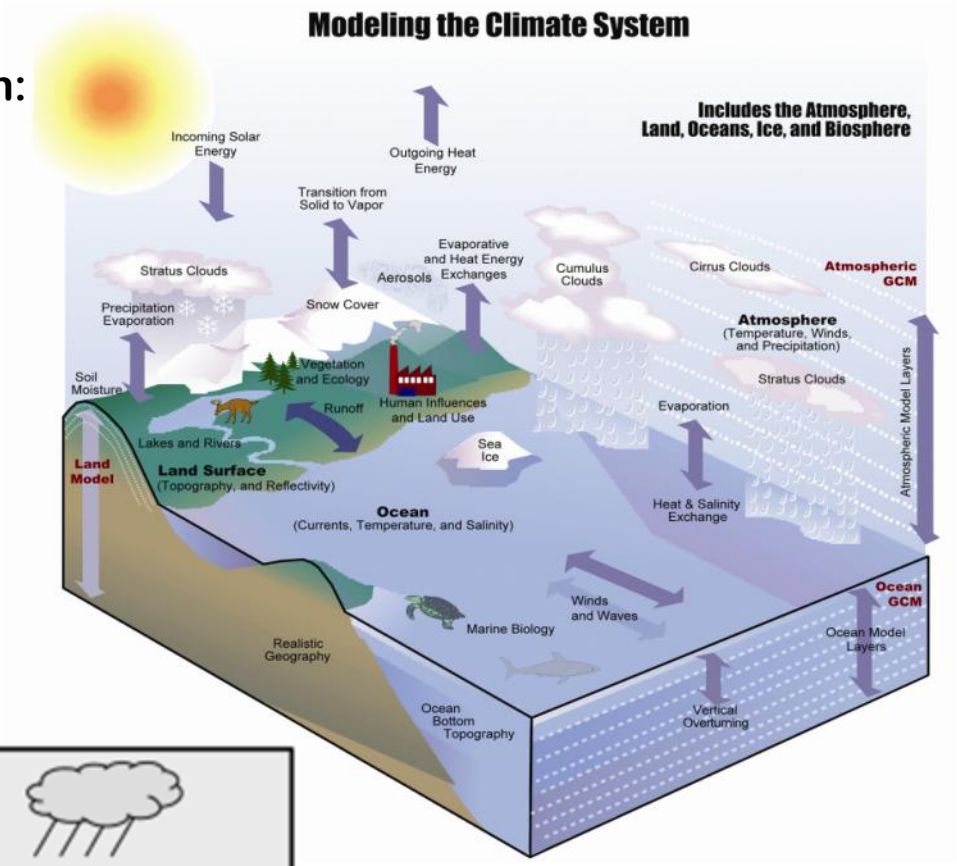
Understanding Human Land Use in the Climate System: Investigations with an Earth System Model (NCAR CESM)

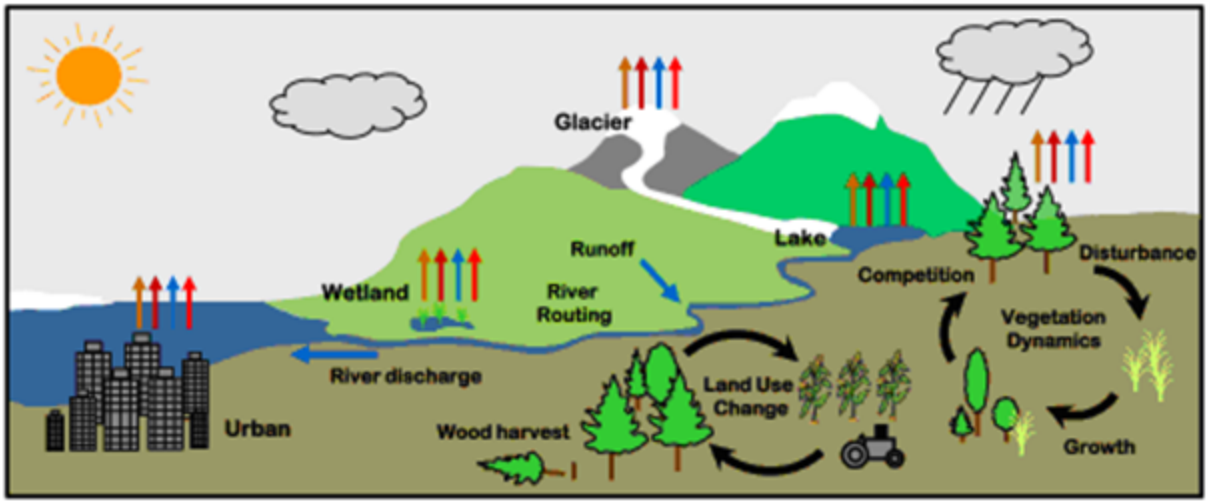
The land is a critical interface through which:

1. **Climate and climate change impacts humans and ecosystems**

and

2. **Humans and ecosystems can force global environmental and climate change**





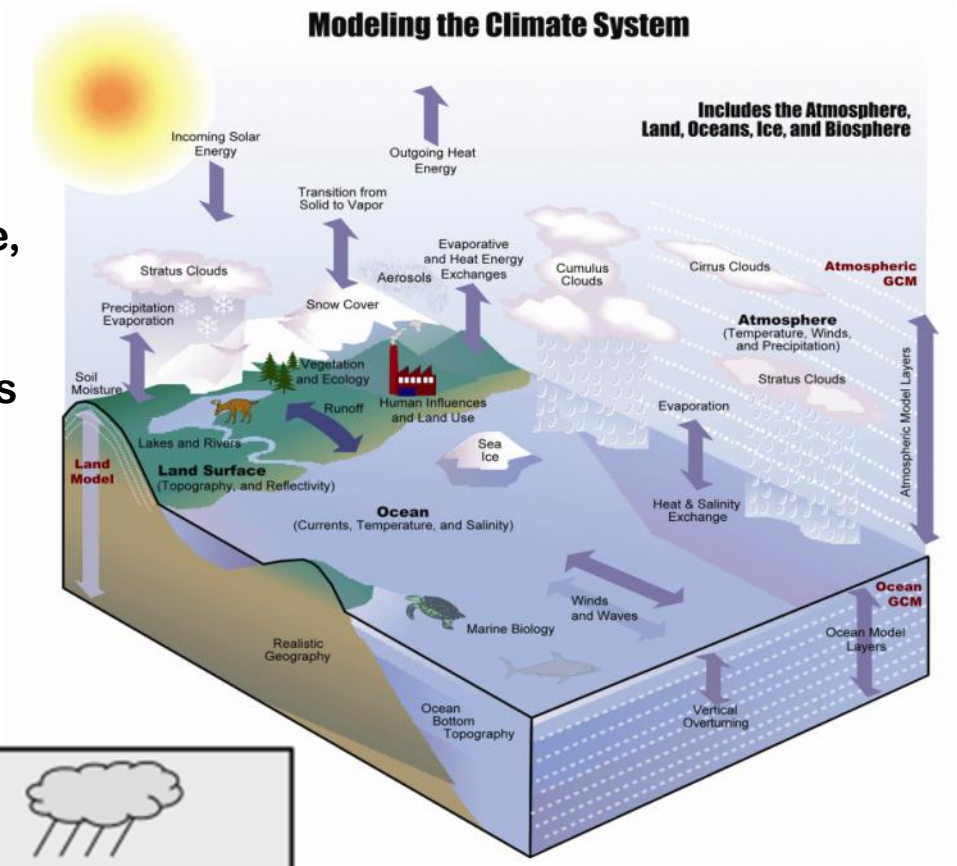
Understanding Human Land Use in the Climate System: Investigations with an Earth System Model (NCAR CESM)

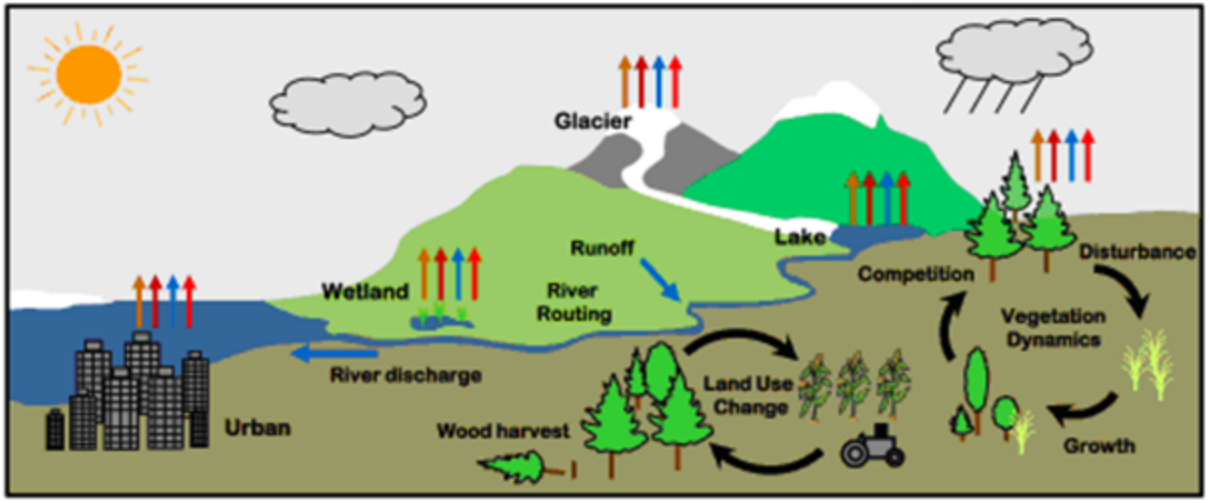
Land Management in CESM:

- How are we transforming Natural Ecosystems through Deforestation, Pasture, Wood Harvesting, or Afforestation?

- How will Natural and Disturbed Ecosystems respond to changes in climate and CO_2?

- How will Humanity Feed itself as the population grows, society becomes more affluent, and agriculture is impacted by climate and changing CO_2?





Land Use in the Climate System Changes

1. Surface Energy Fluxes:
- Solar Energy Fluxes (Albedo – Vegetation, Snow, Soils)
- Long Wave Energy Fluxes (Surface Temp & Emissivity)
- Latent Heat Fluxes (Transpiration, Evaporation)
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2. Surface Hydrology:
- Rain and Snow (Vegetation, Snow Pack, Runoff)
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- Climate Feedback through Precipitation Changes

3. Biogeochemistry (Carbon and Nitrogen Cycles):
- Plant Photosynthesis and Respiration

$$6\ CO_2 + 6\ H_2O + light \rightarrow C_6H_{12}O_6 + 6\ O_2$$

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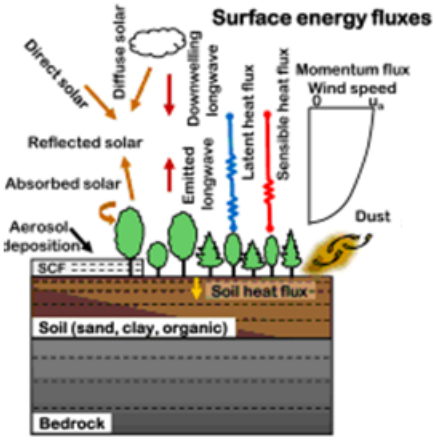
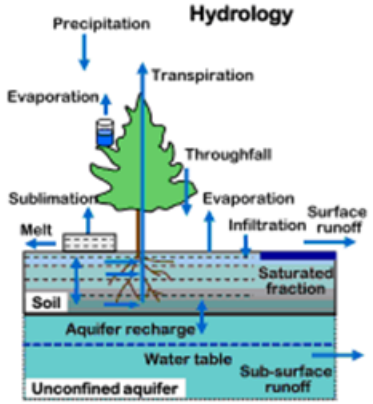
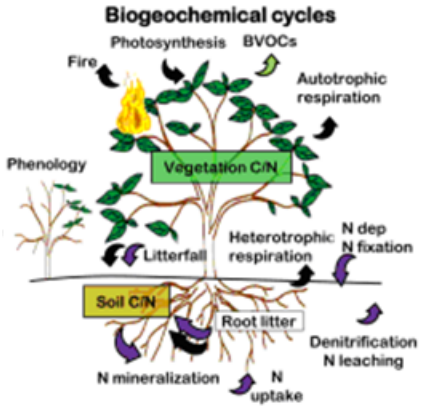
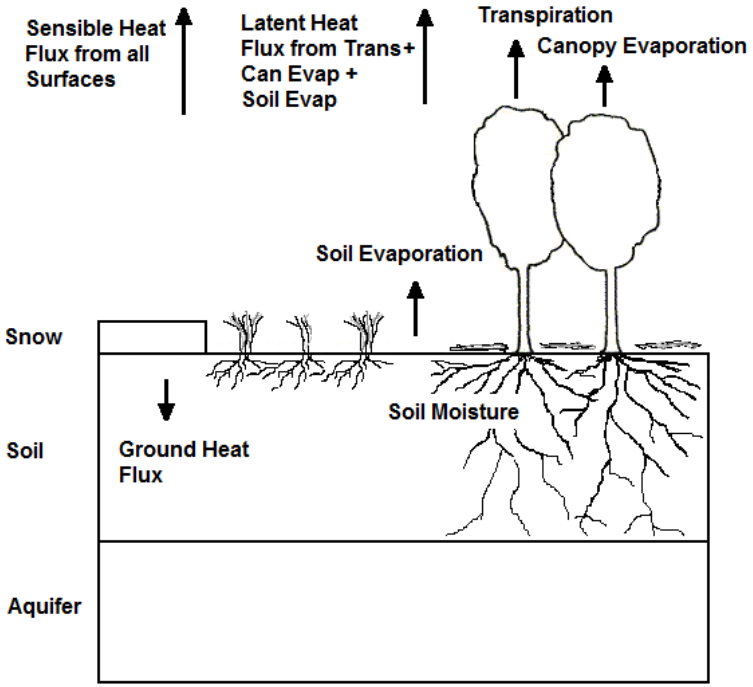


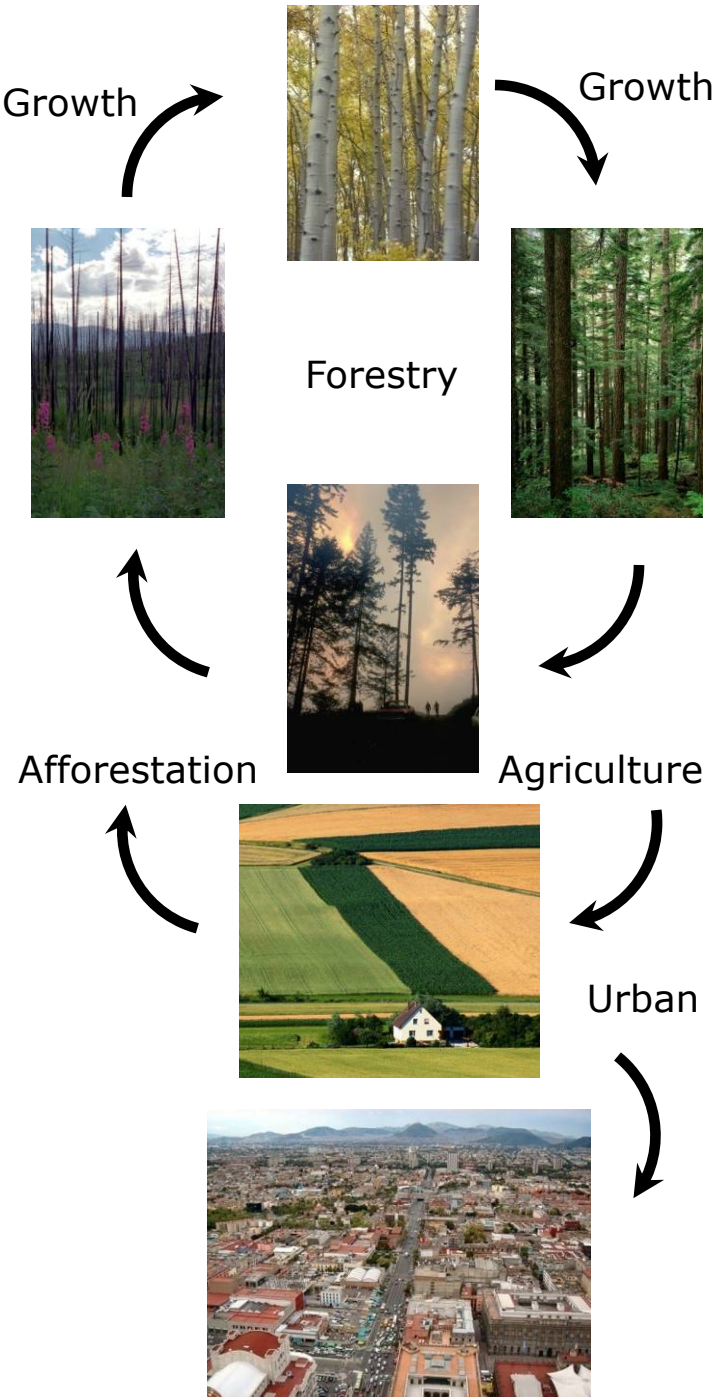




Land Cover Change Biogeophysics

CLM4 Heat Fluxes





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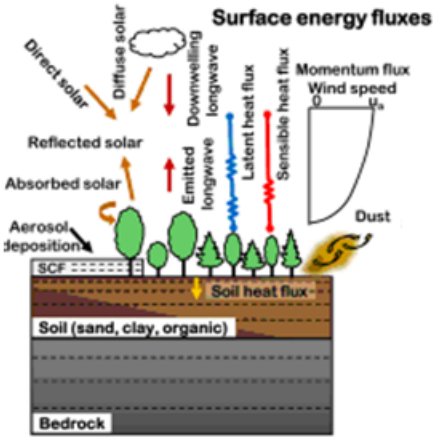

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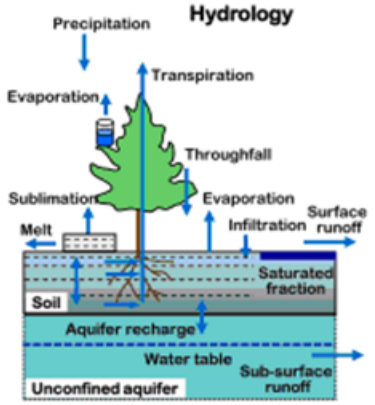

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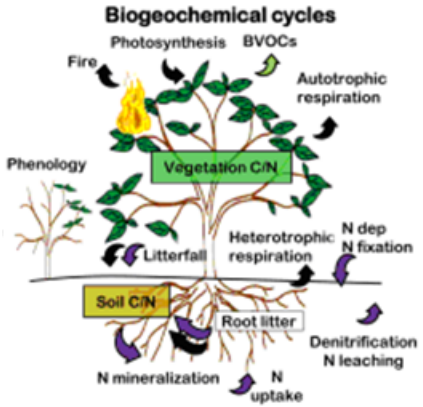

Land Cover Change Hydrology Field Studies

Based on the relationship between Deforestation and Agriculture in 171 catchments, *Zhang et al.* (2001) developed a simplistic vegetation based relationship between Annual Precipitation and Evapo-Transpiration:

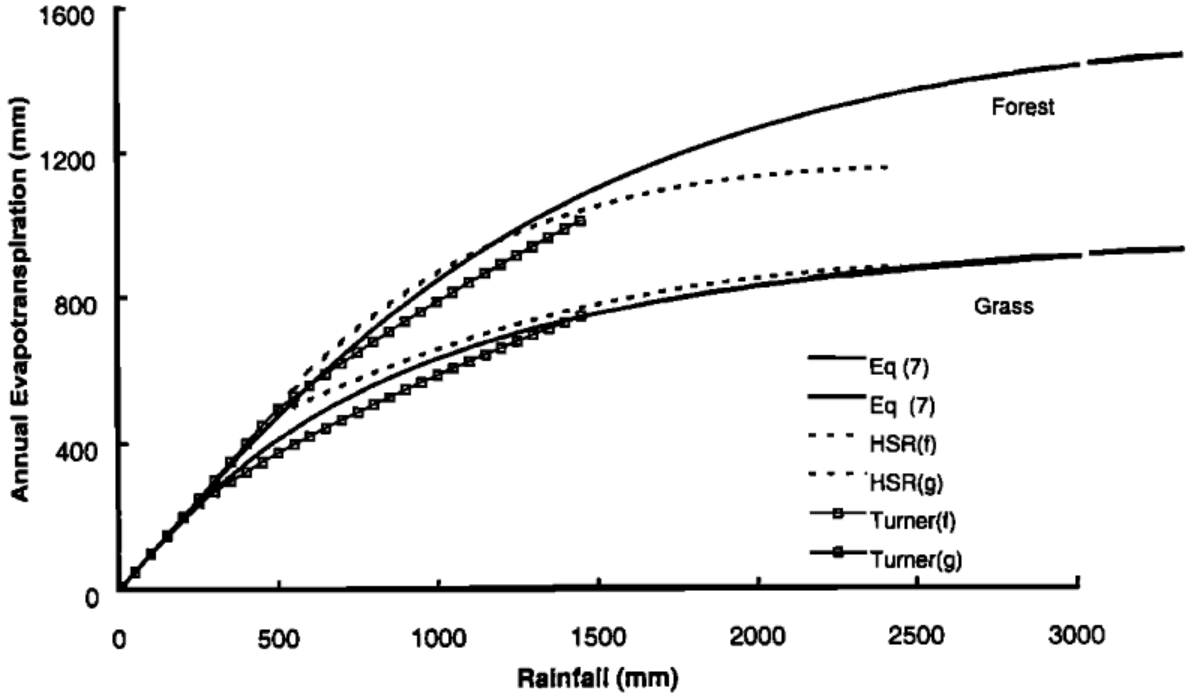

Figure 8. Comparison of equation (8) with the empirical relationships developed by *Holmes and Sinclair* [1986] and *Turner* [1991] for forested and grassed catchments.

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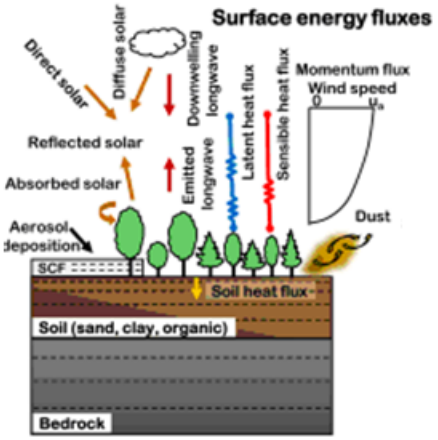
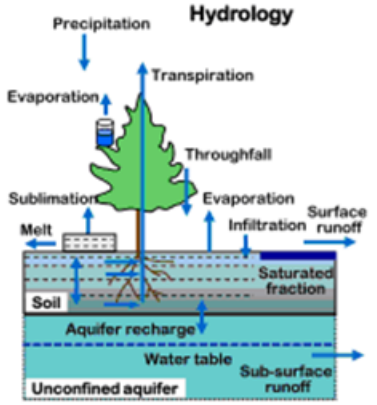
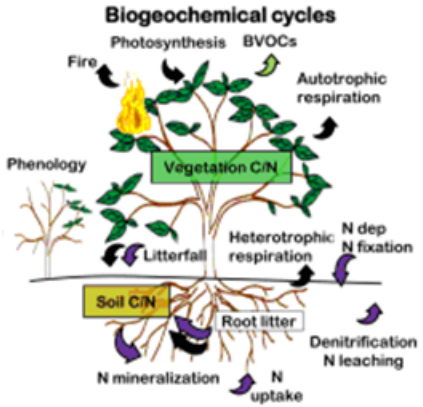
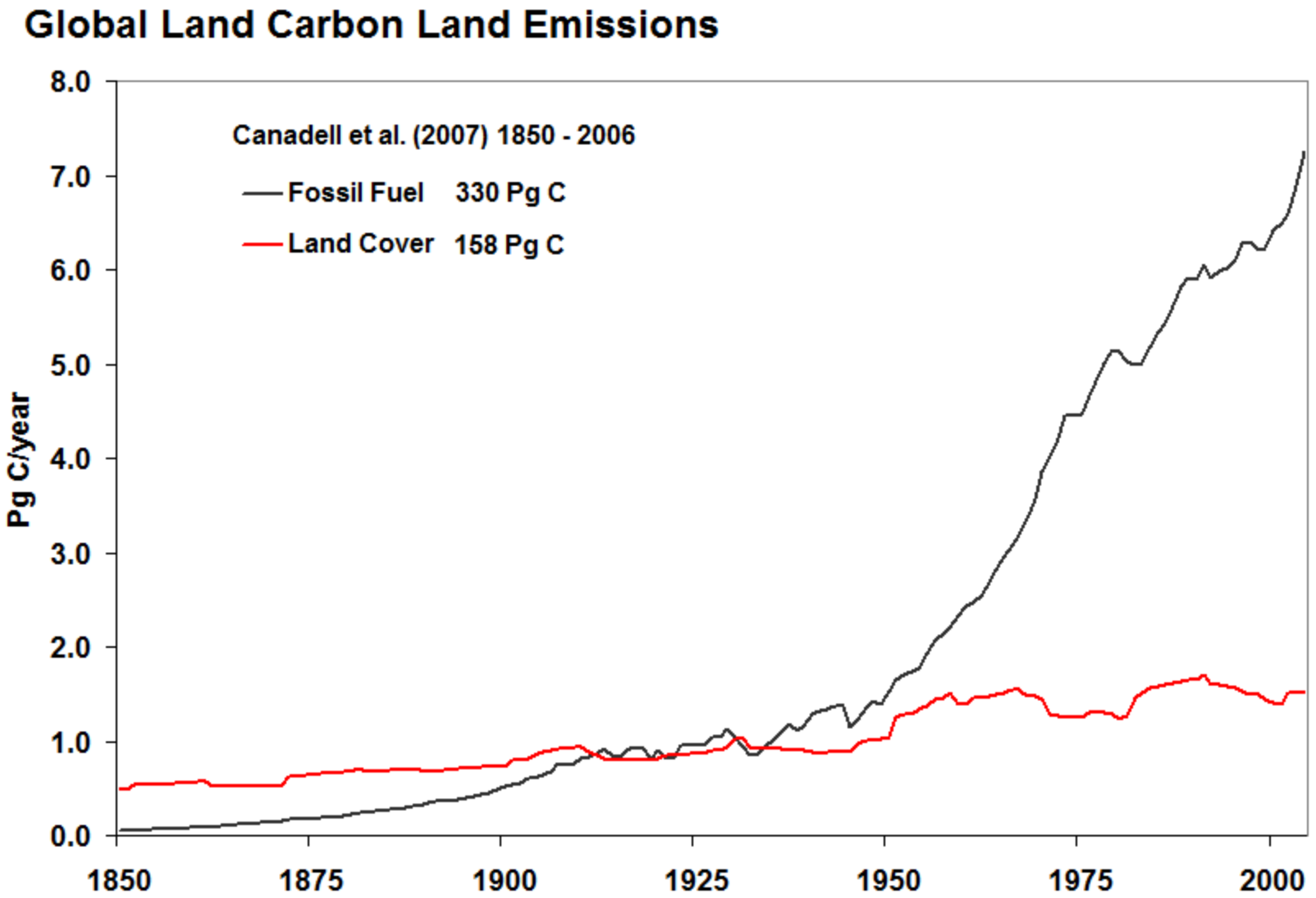


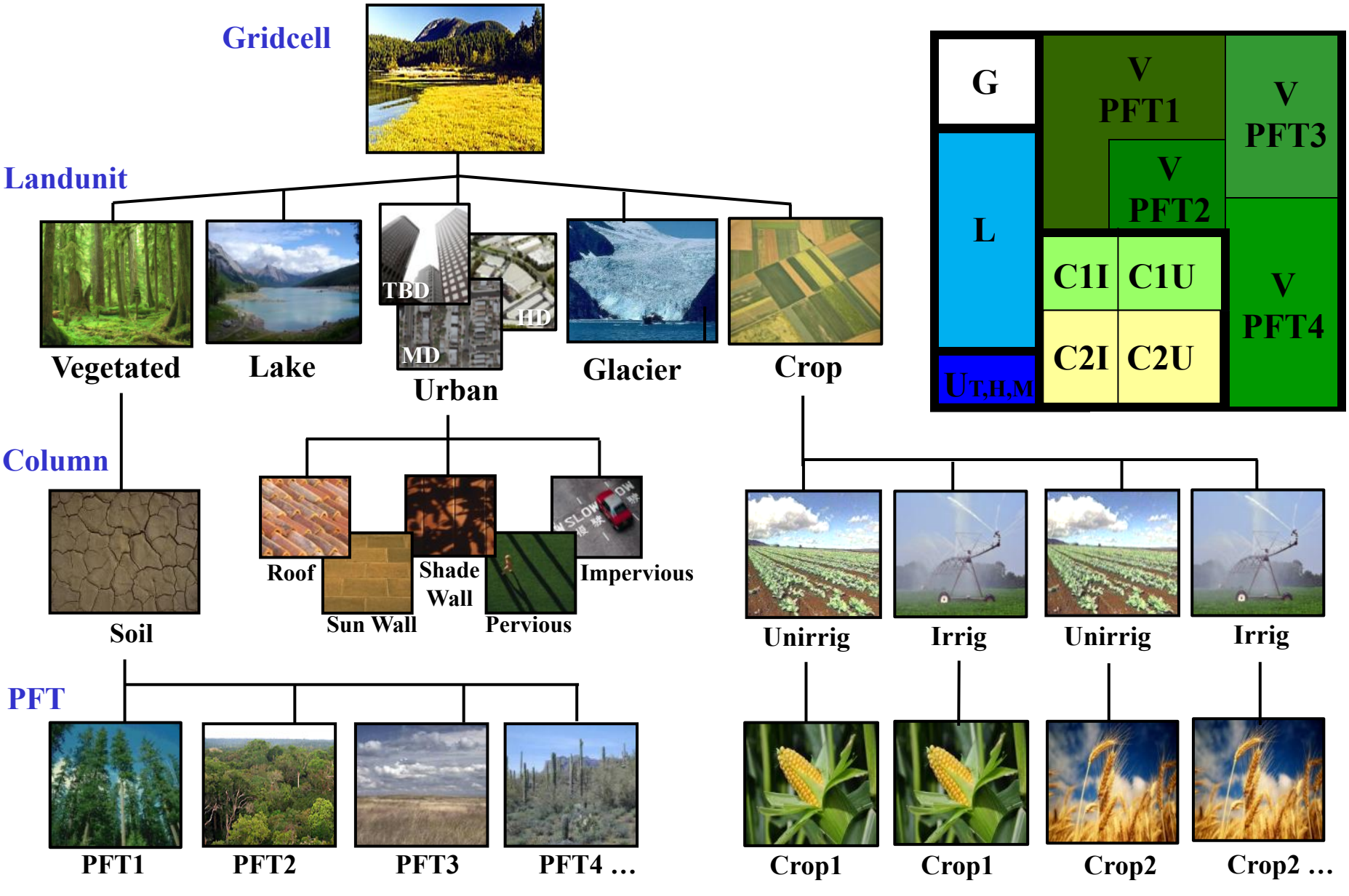




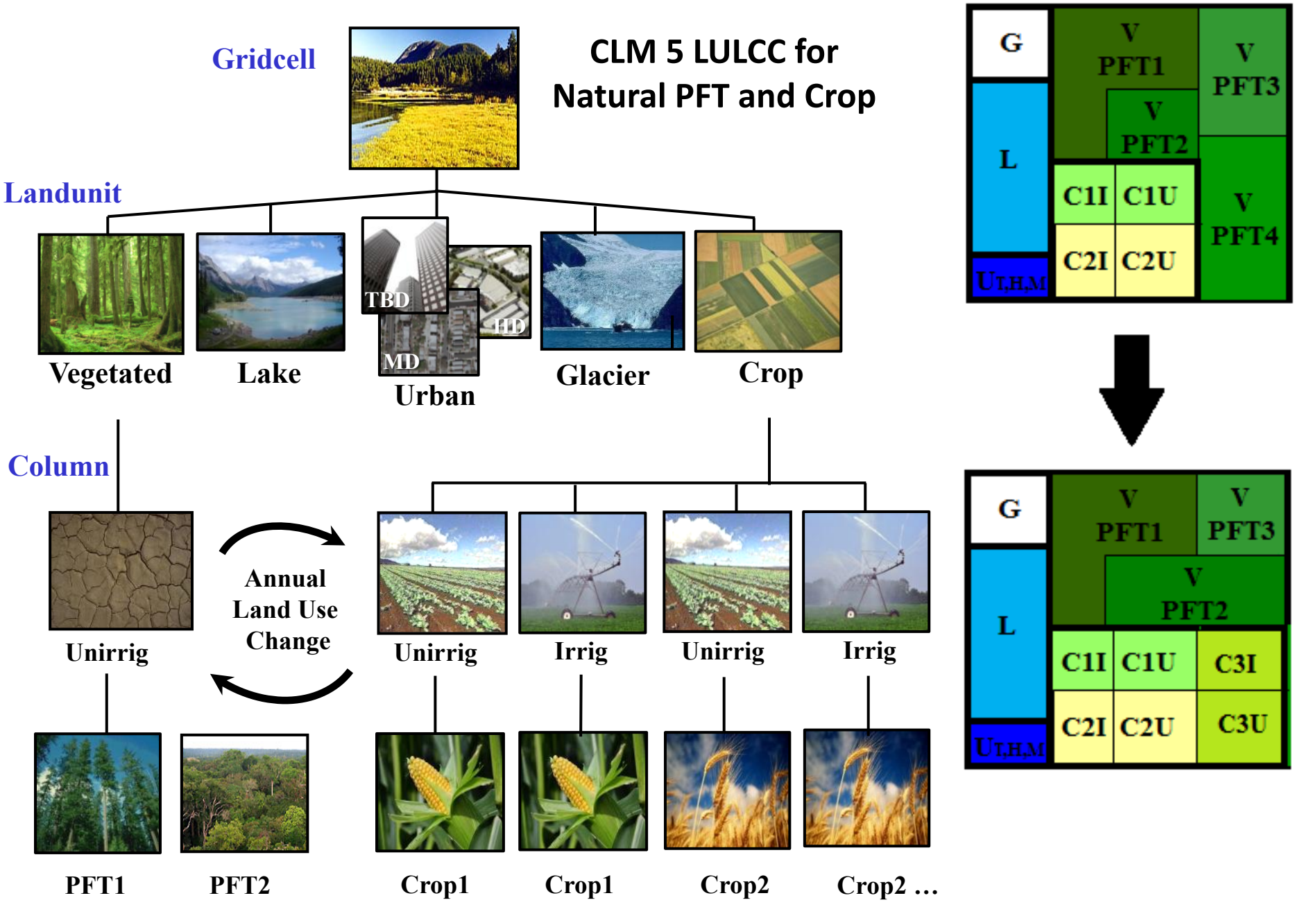
Land Cover Change Contribution to Carbon Emissions



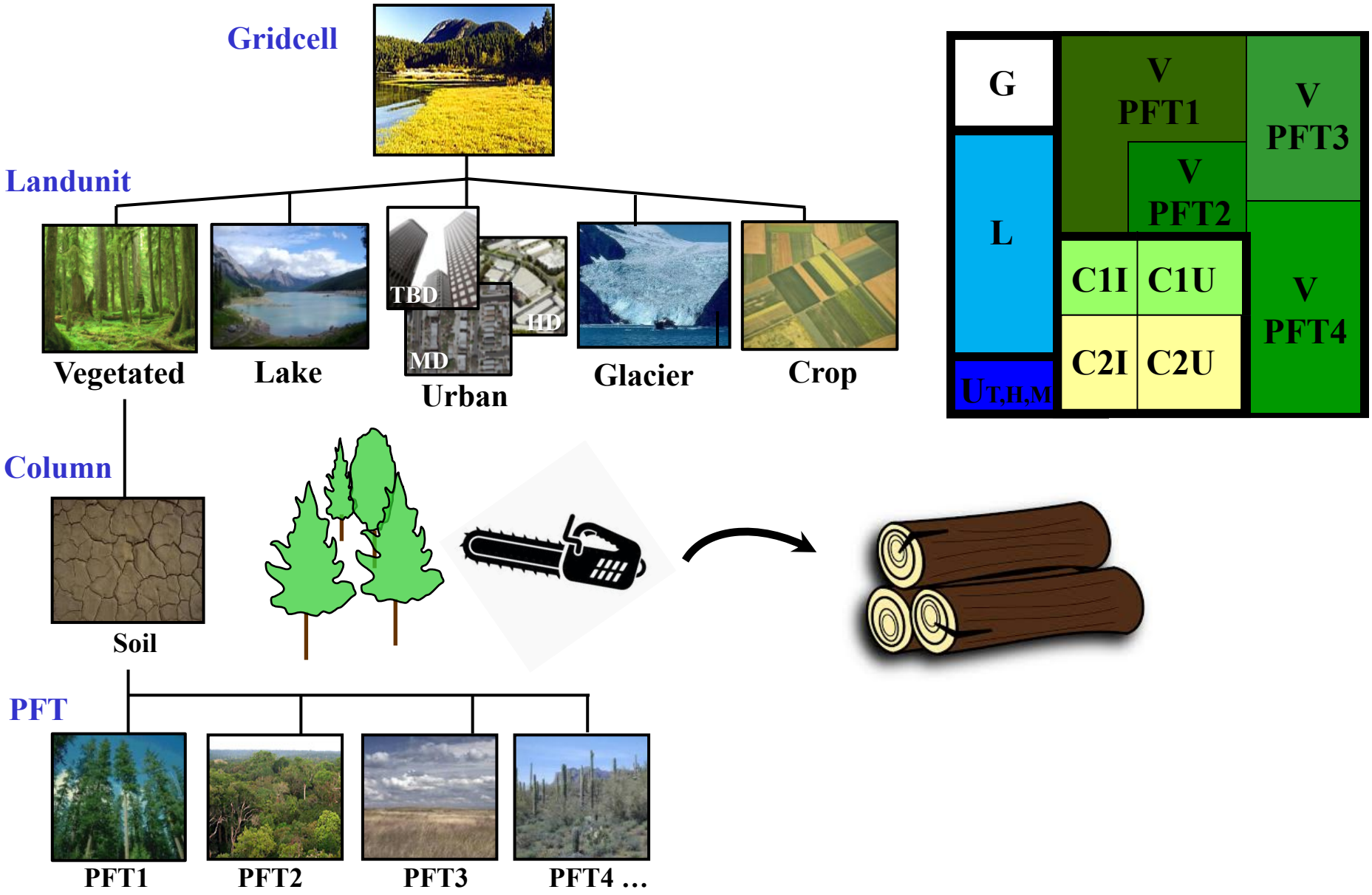
CLM5 Land Use and Land Cover Change Representation



CLM5 Land Cover Change – Prescribed Annual Changes



CLM5 Land Use – Prescribed Wood Harvest (biomass)



CLM5 Land Use – Crop Model Prescribed Management

Gridcell

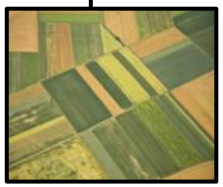
Landunit

Vegetated

Lake

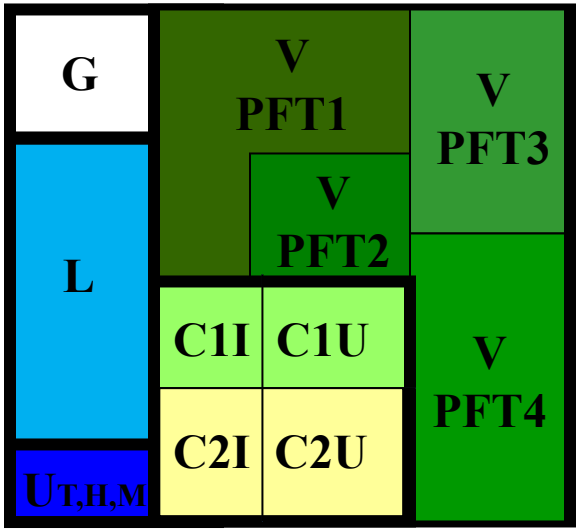
Urban

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 Climate and Carbon Cycle impacts of Land Cover Change

1. We can assess the Climate and Carbon Cycle responses of Land Use Land Cover Changes (LULCC) in CLM5 for a given period under changing climate and CO_2.

2. To do this we run CLM5 simulations with changing or transient LULCC compared to the same simulations performed without the LULCC.

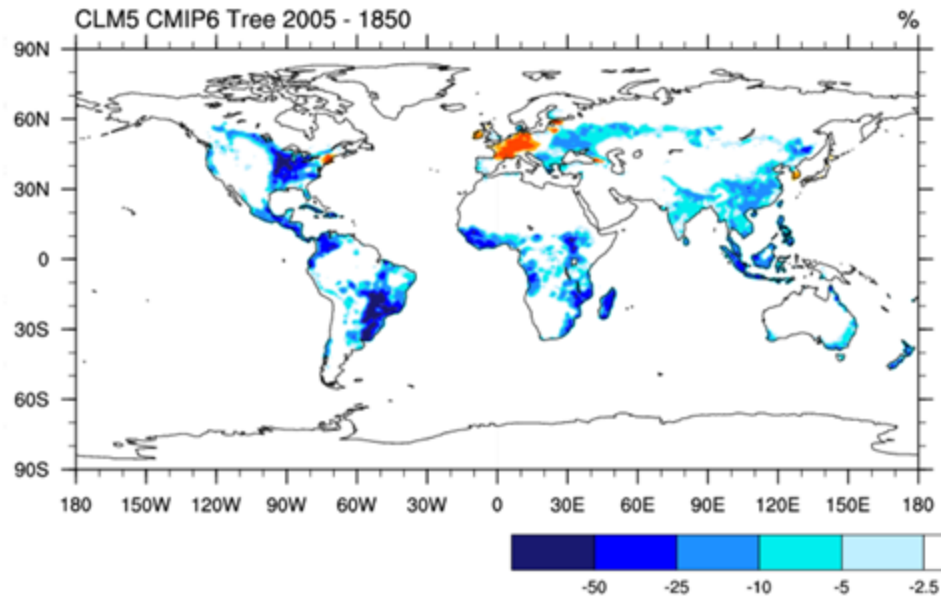
3. The CLM5 LULCC impacts are assessed through looking at differences between the simulations.

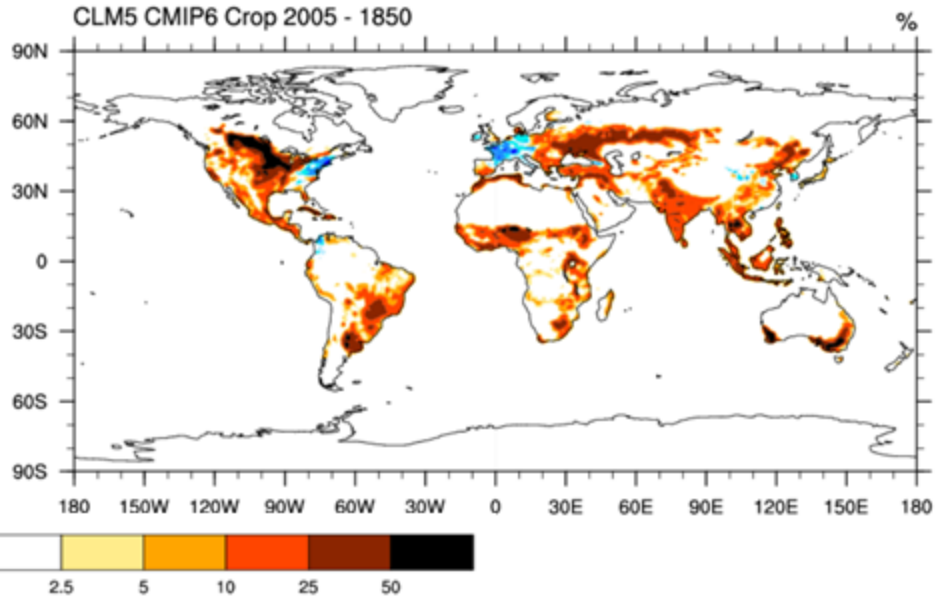
4. Differences in climate are assessed over the last 20 years of both simulations to provide robust statistics against back ground variability. Differences in the carbon cycle are looked at over the length of the simulations.

5. All experiments use 1850 – 2010 GSWP3 Prescribed Meteorology which has been shown to provide the best forcing and transient model response

6. There are no larger scale climate feedbacks in these studies as Meteorology is prescribed.

CLM5 WCRP – CMIP6 Land Cover in 1850 – 2005 Climate





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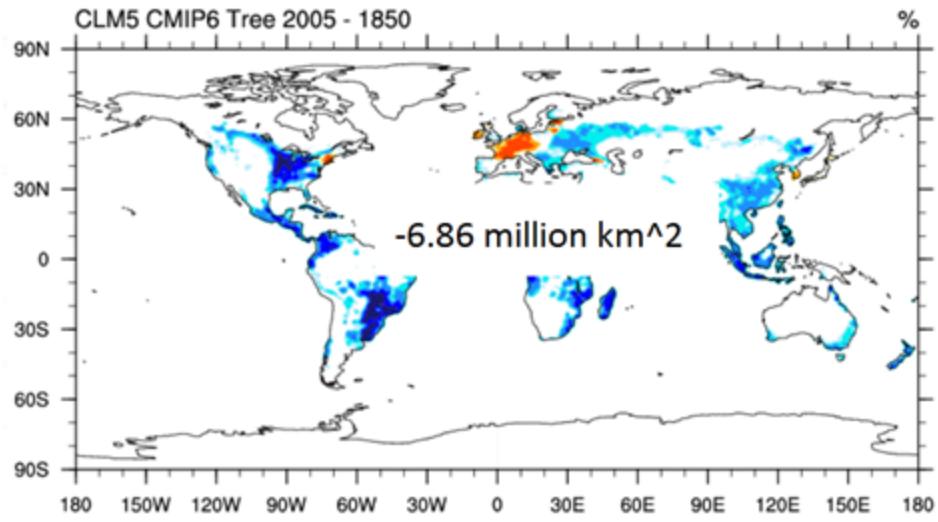

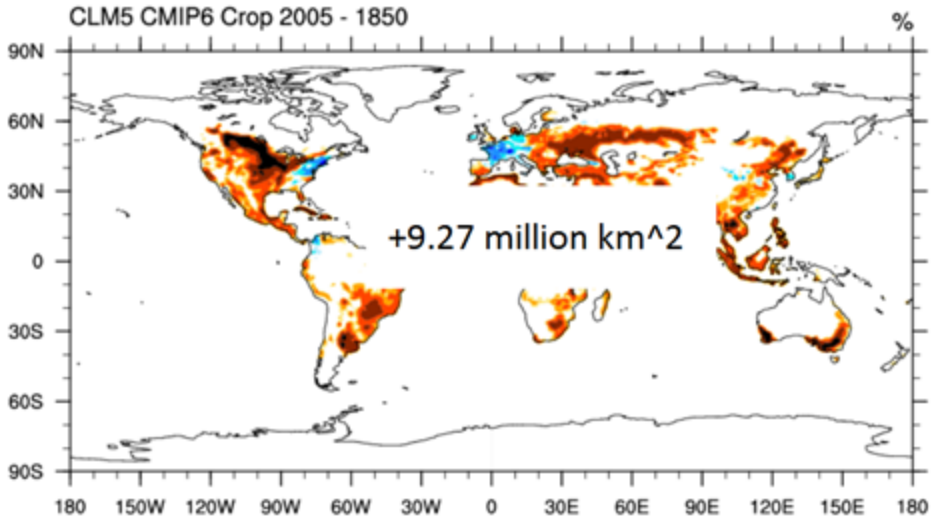

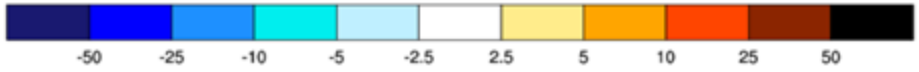

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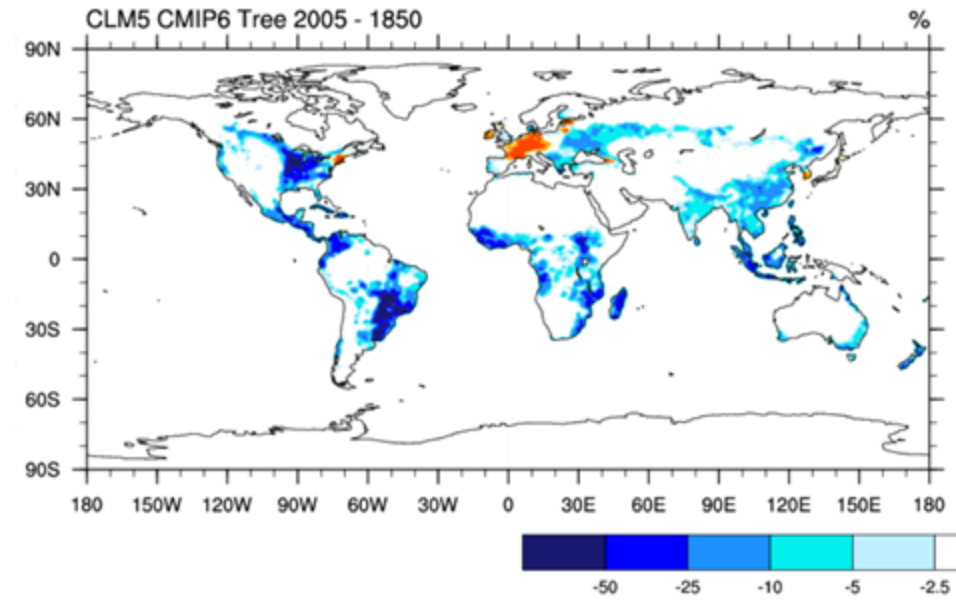

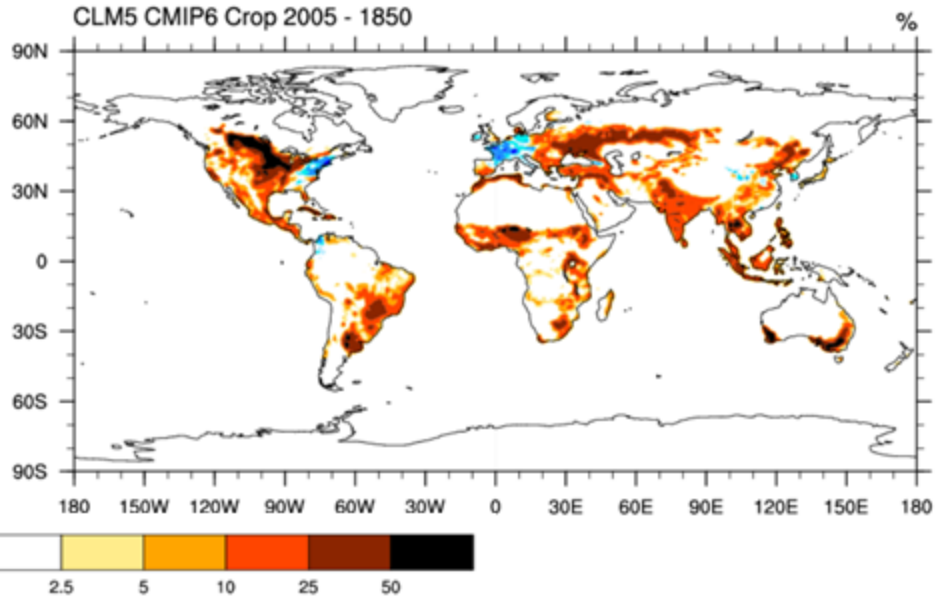

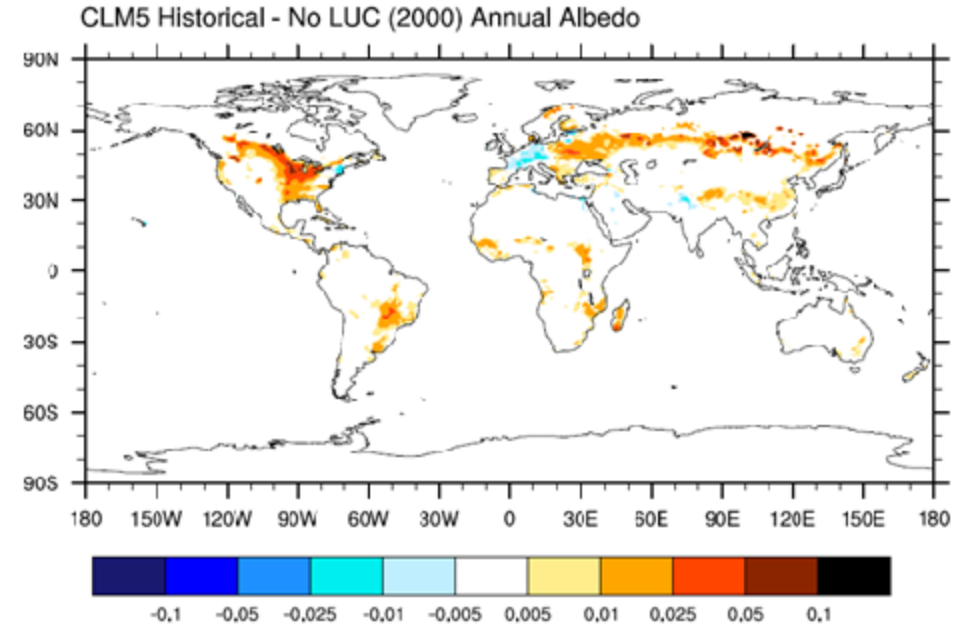

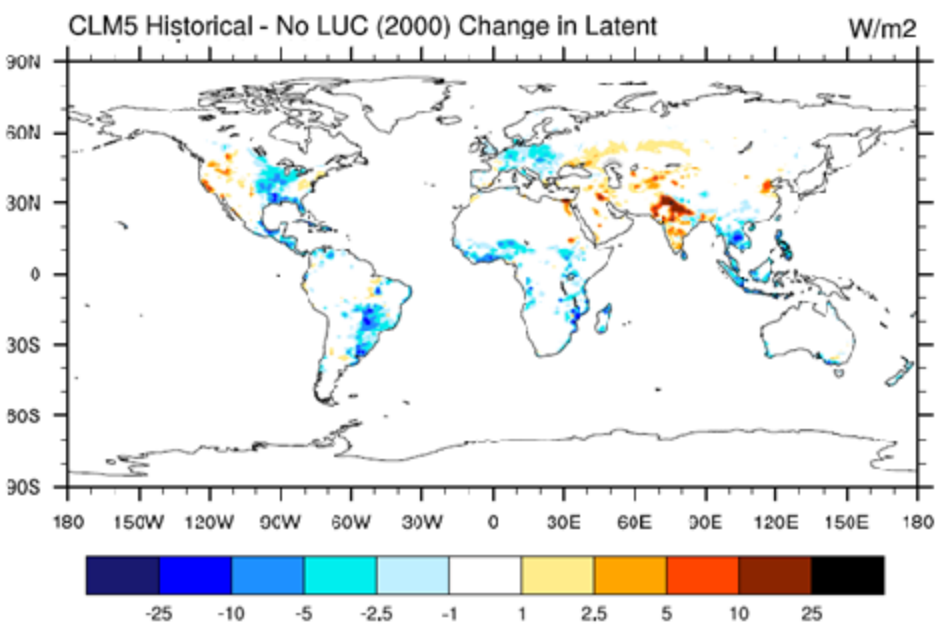

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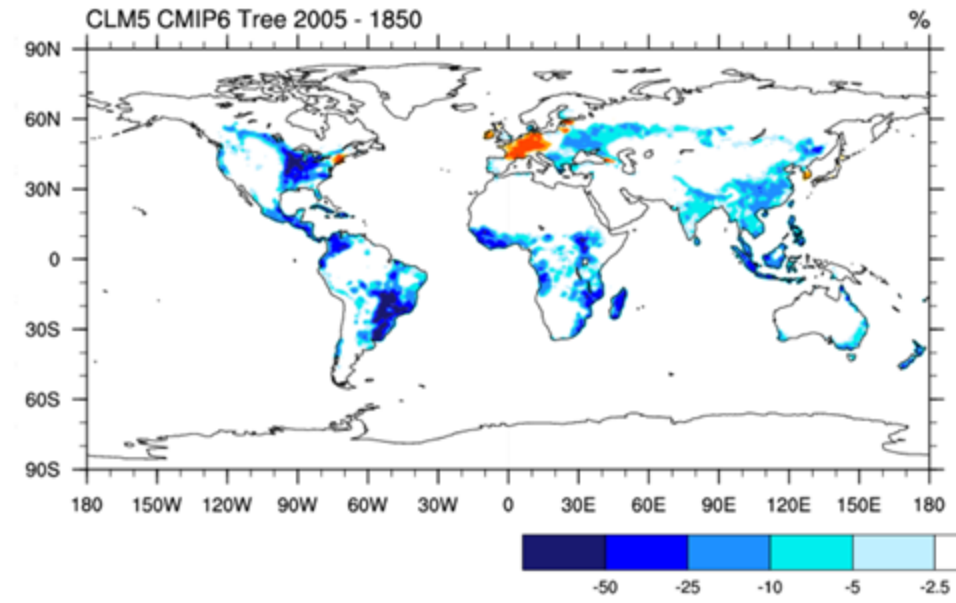

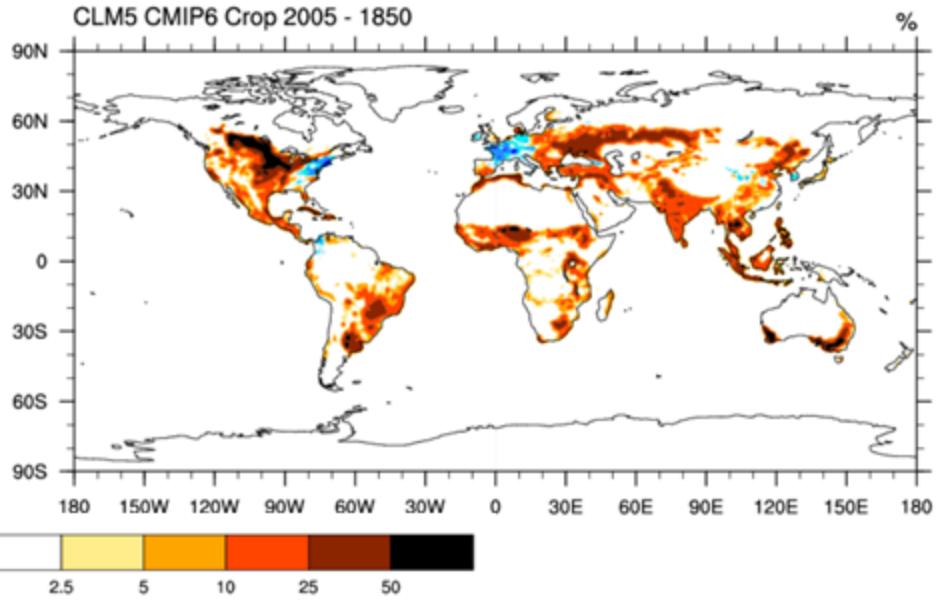

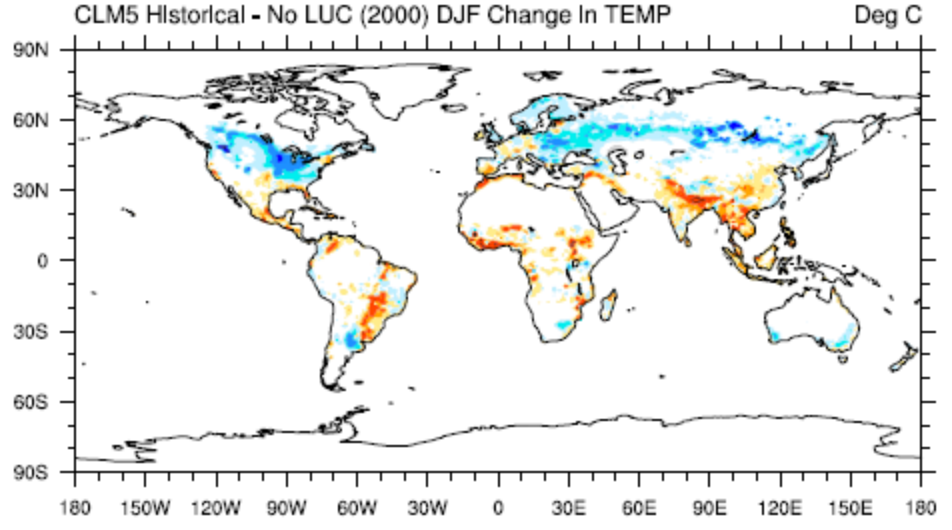

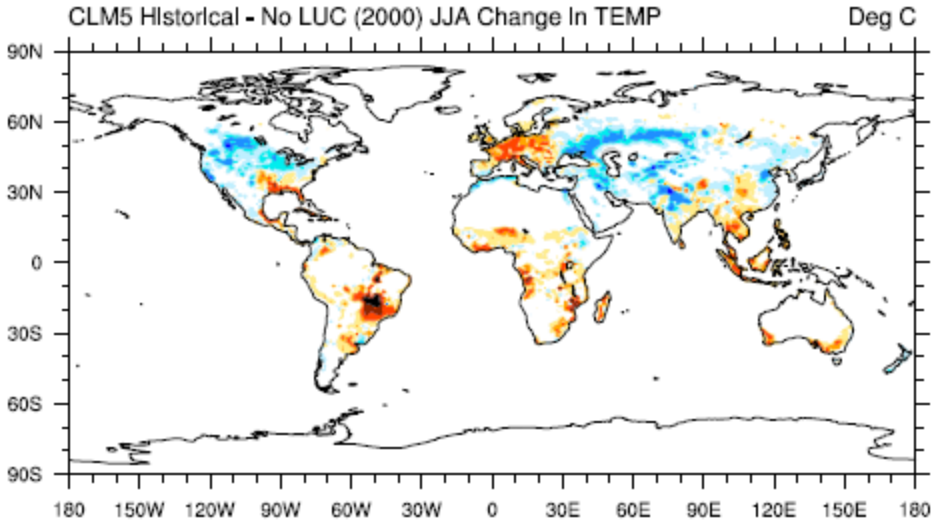

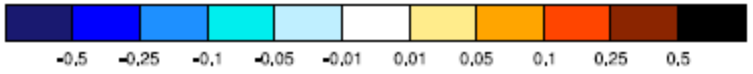

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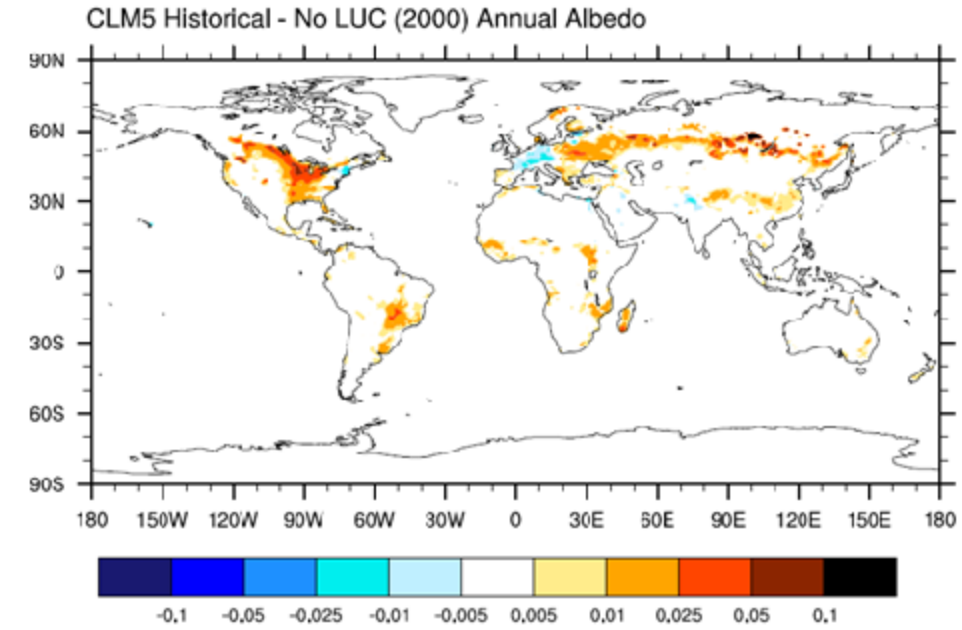
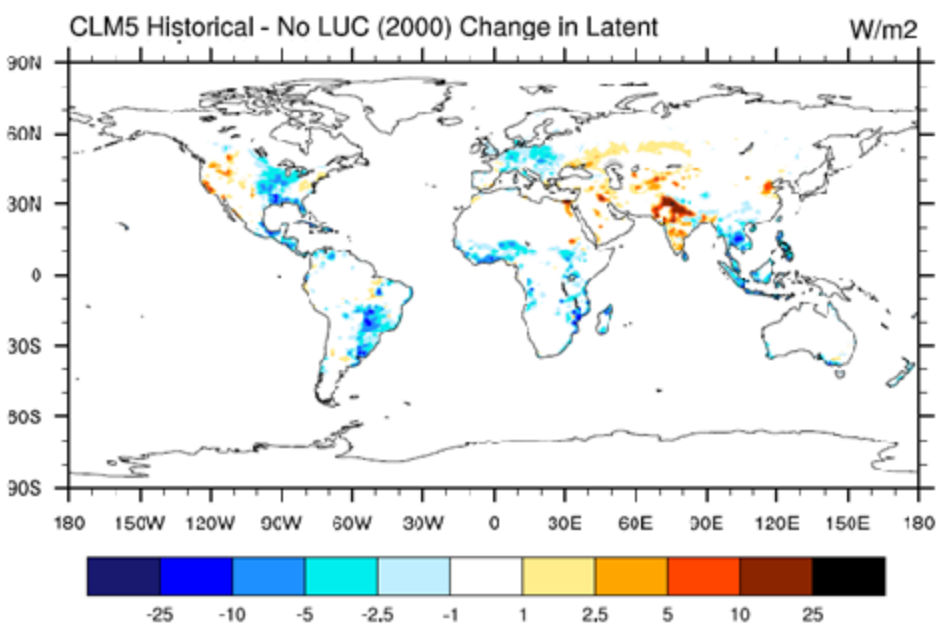
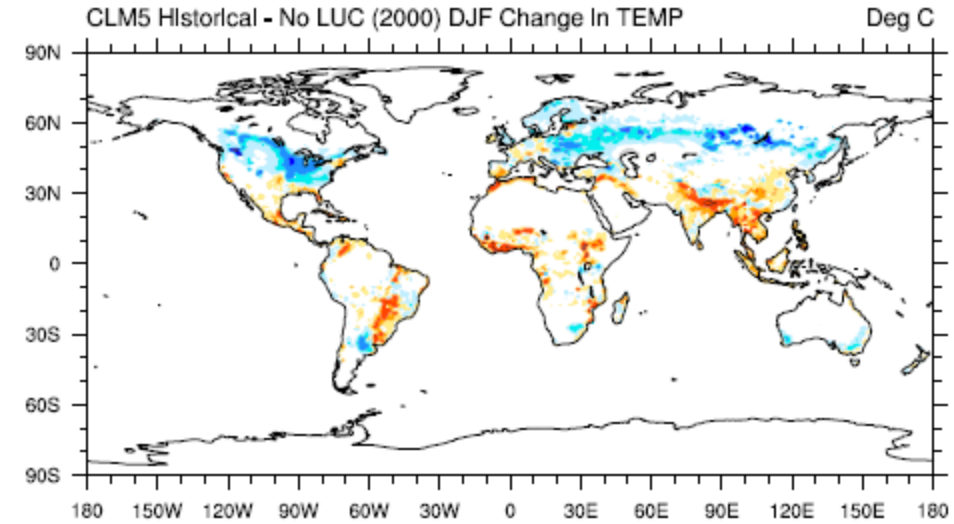
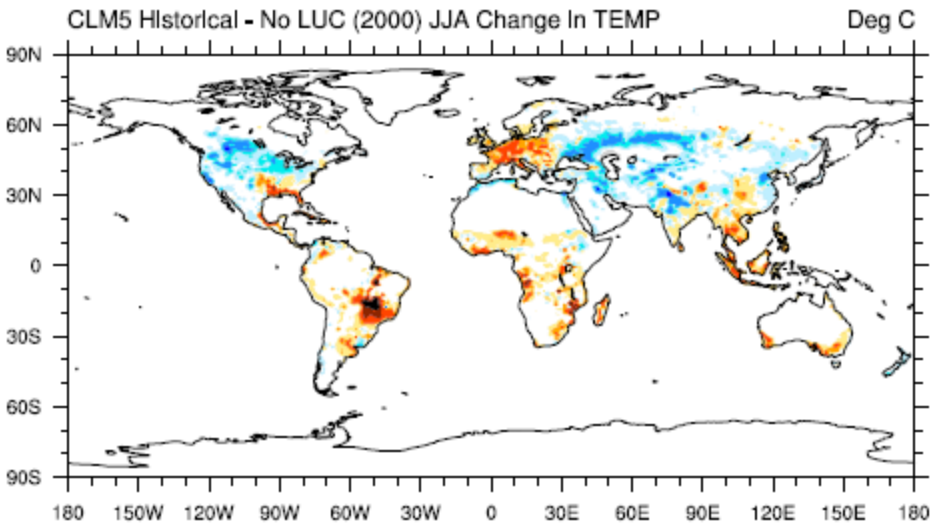
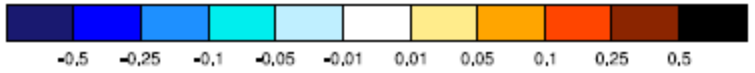


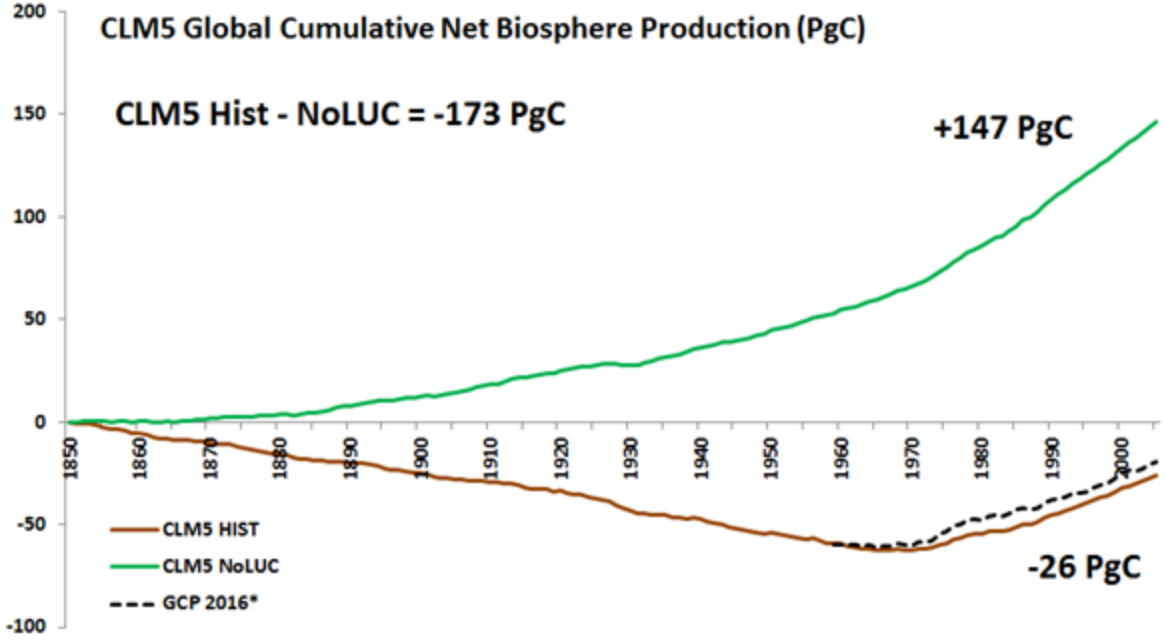








New CLM5 LUMIP vs CLM4 CMIP5 LULCC – NBP Carbon



CLM5 NoLUC had large uptake of carbon from CO_2 fertilization, Climate and N Deposition CLM5 +147 PgC

This is offset by LULCC in CLM5 = 173 PgC Global Estimates ~160 PgC

*Global Carbon Project Land Sink - LULCC 1959 – 2016

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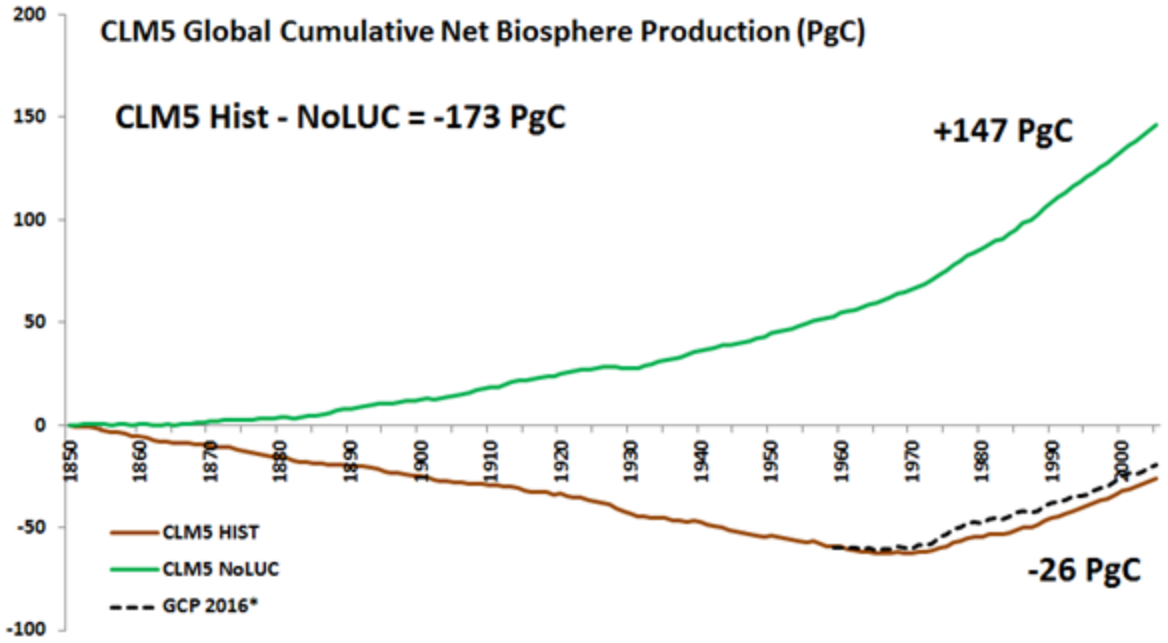

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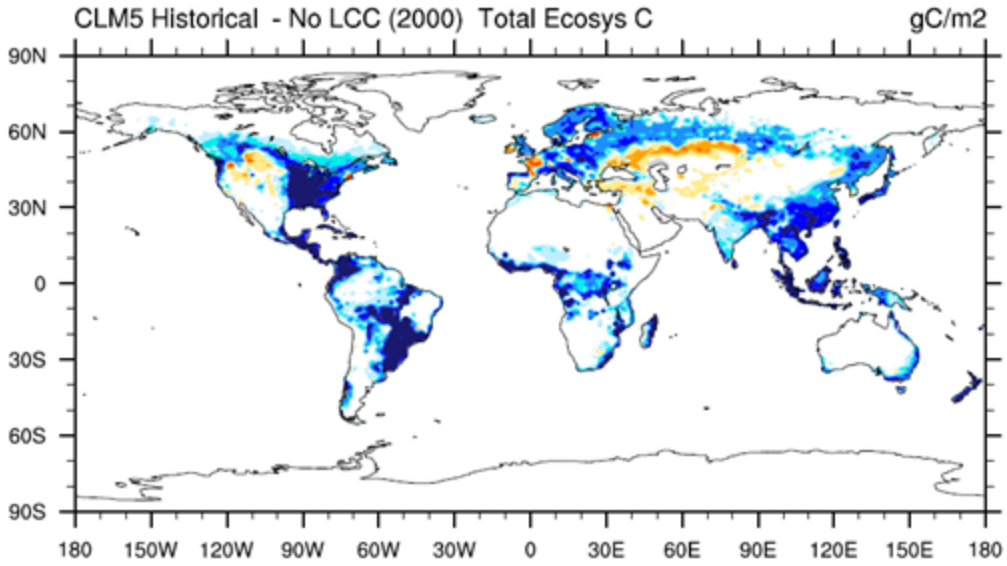

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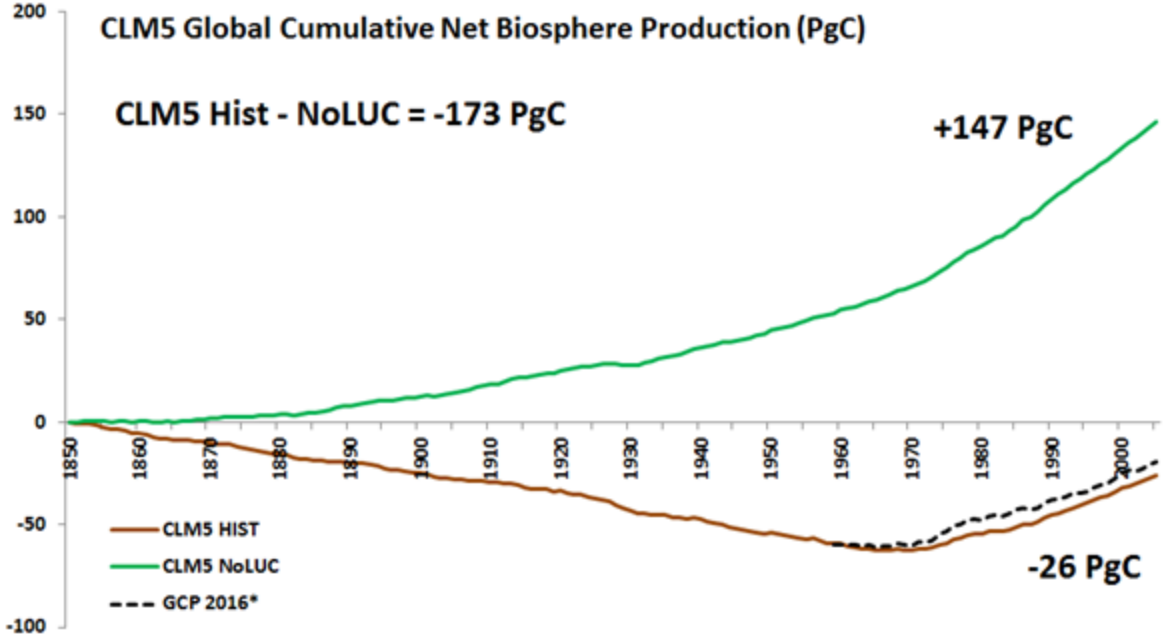

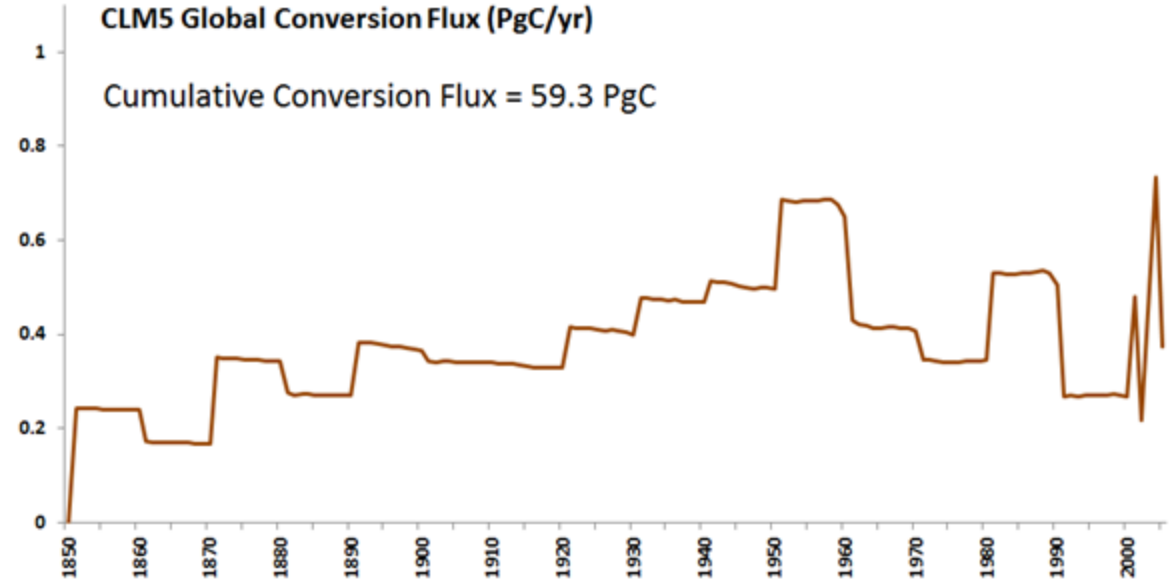

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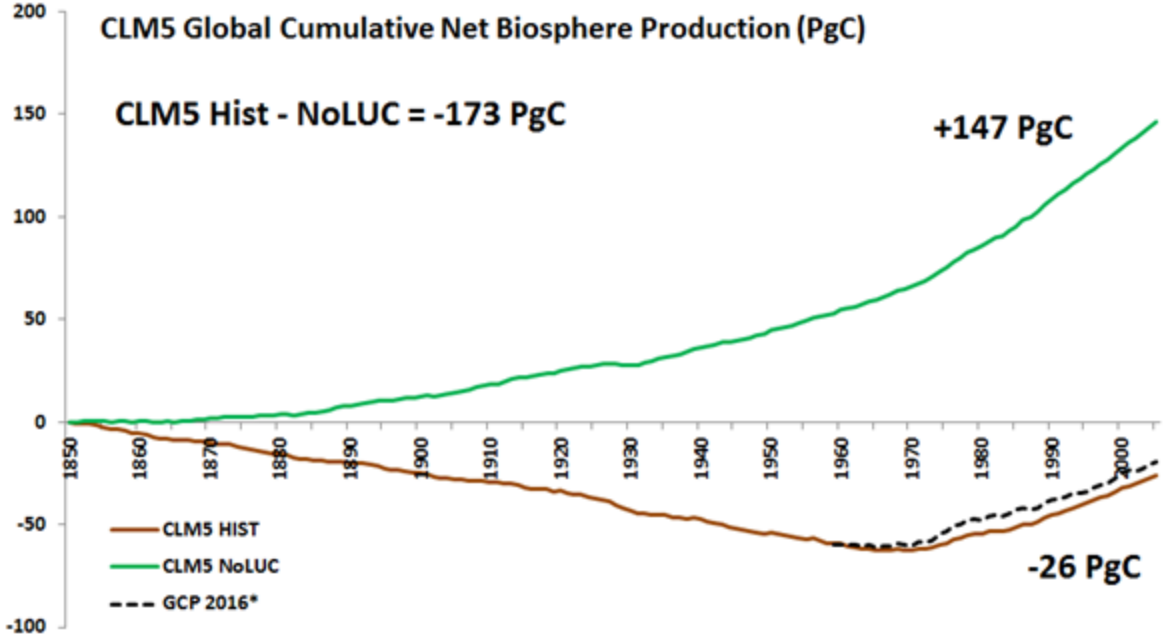
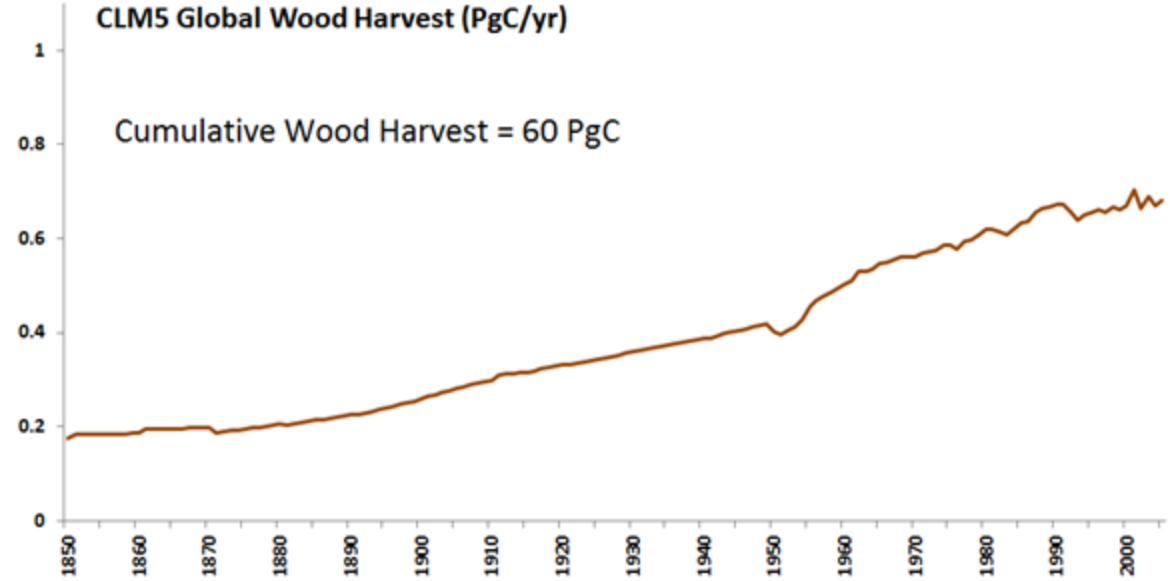
CLM5 conversion of PFTs and CFTs results in a cumulative loss of 59.3 PgC

New CLM5 LUMIP vs CLM4 CMIP5 LULCC – NBP Carbon





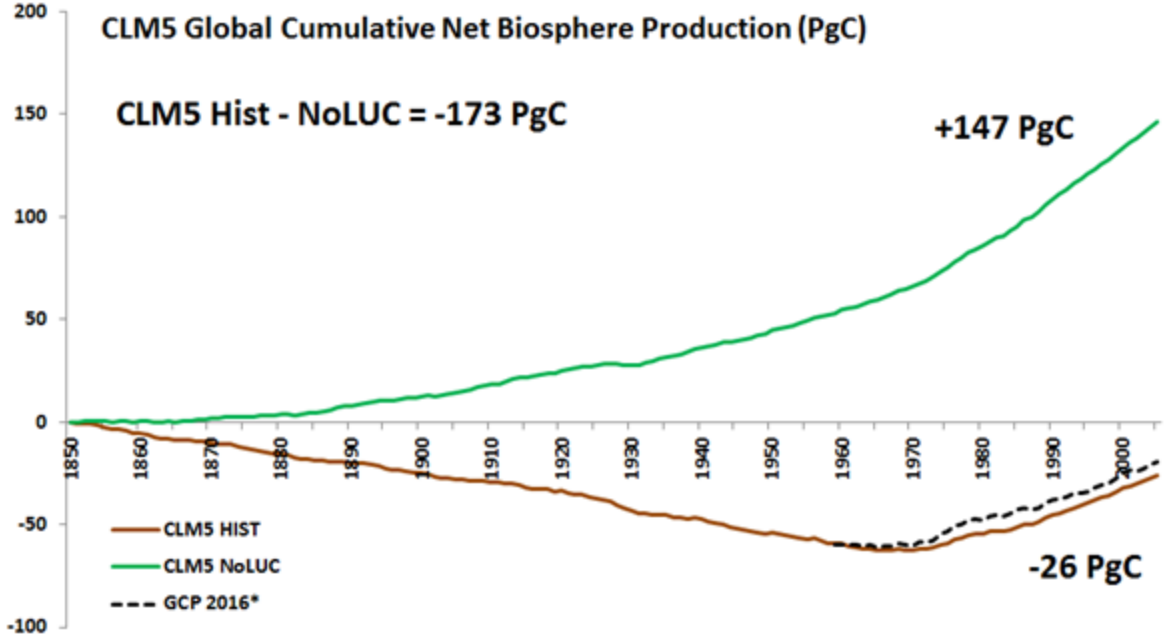
CLM5 NoLUC had large uptake of carbon from CO_2 fertilization, Climate and N Deposition CLM5 +147 PgC

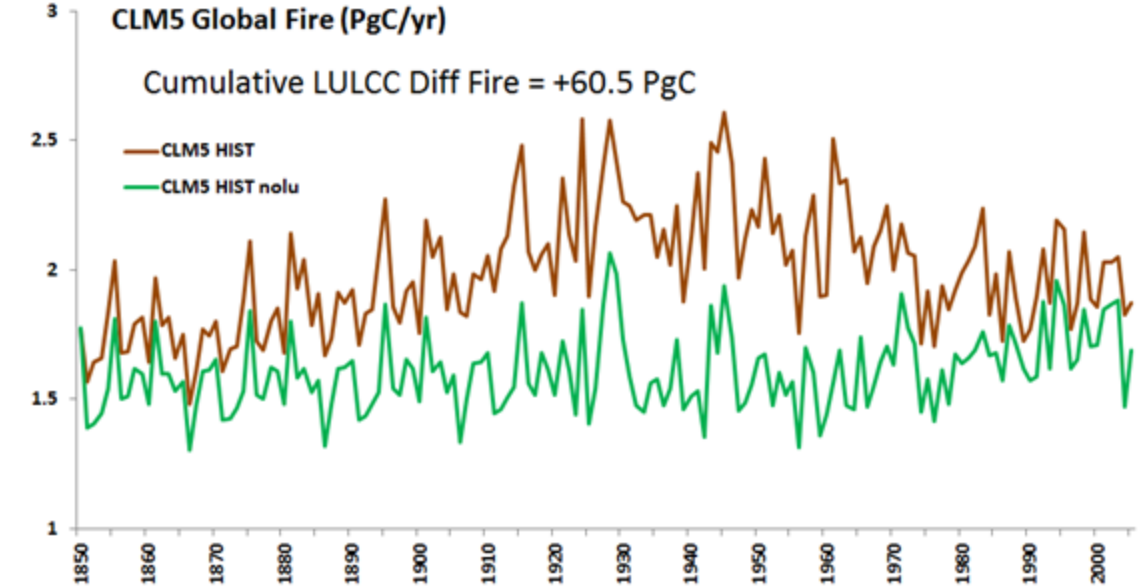
This is offset by LULCC in CLM5 = 173 PgC Global Estimates ~160 PgC

*Global Carbon Project Land Sink - LULCC 1959 – 2016

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

New CLM5 LUMIP vs CLM4 CMIP5 LULCC – NBP Carbon





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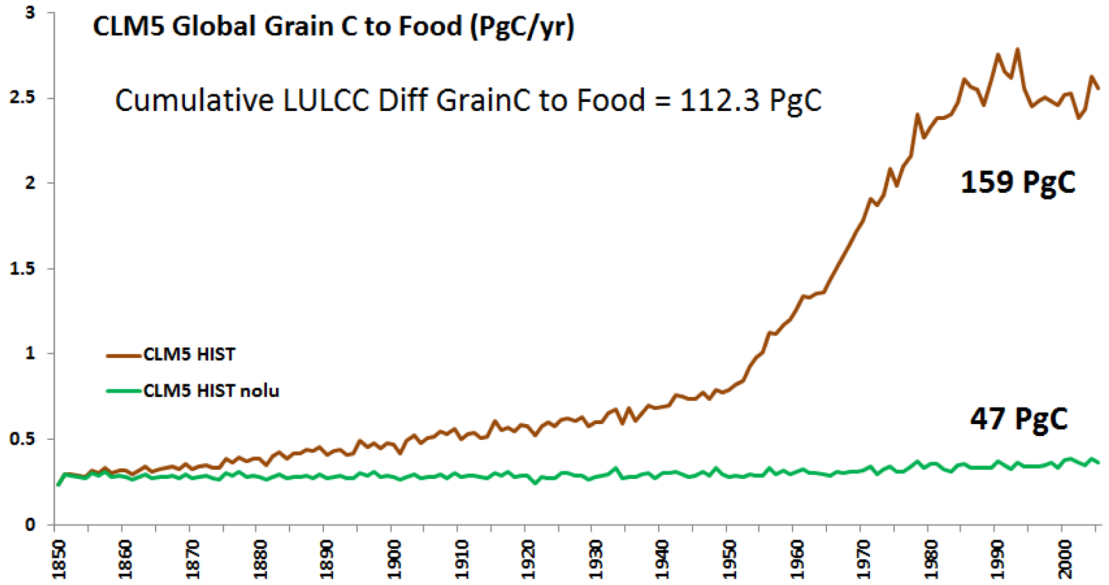
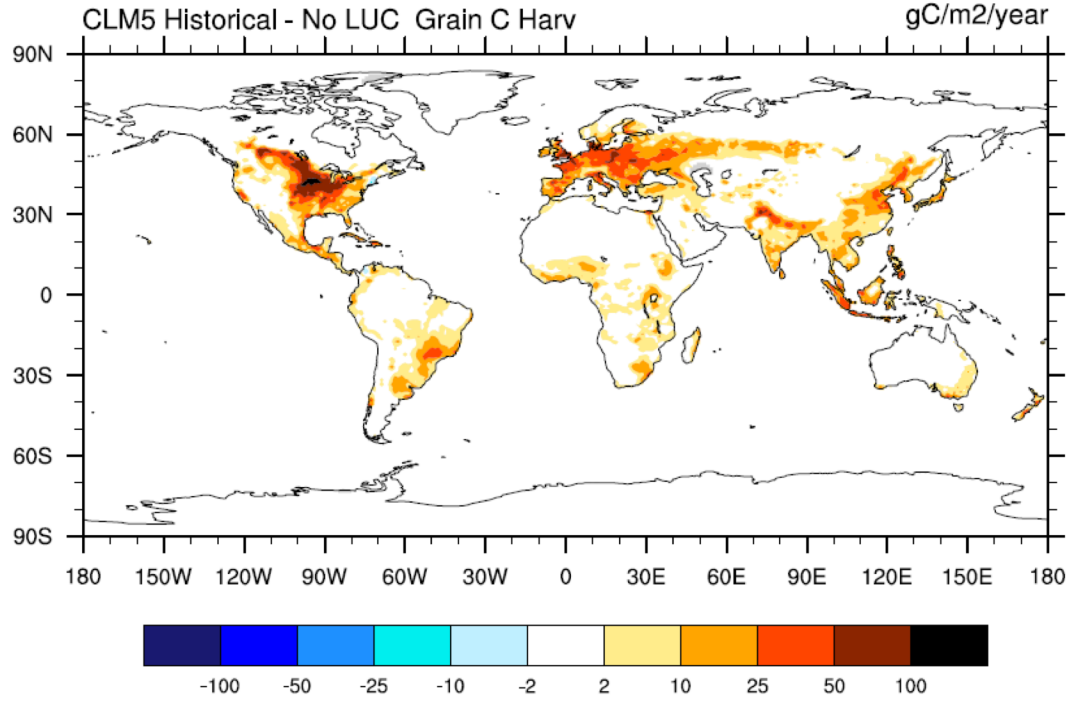
CLM5 LULCC results in large increase in carbon loss through increased fire of +60.5 PgC

New CLM5 LUMIP – Crop Harvest Grain Carbon





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 (organic matter decay) from harvest and residue management.

New CLM5 LUMIP – Crop Harvest Grain Food

Crop Yield