Developing Global Reforestation and Afforestation Scenarios for Land Carbon Mitigation in CESM

Peter Lawrence, Dave Lawrence, Deborah Lawrence, Anton Seimon, Stephanie Roe, and Simone Tilmes

NCAR Climate Intervention Strategy Workshop

July 30, 2019

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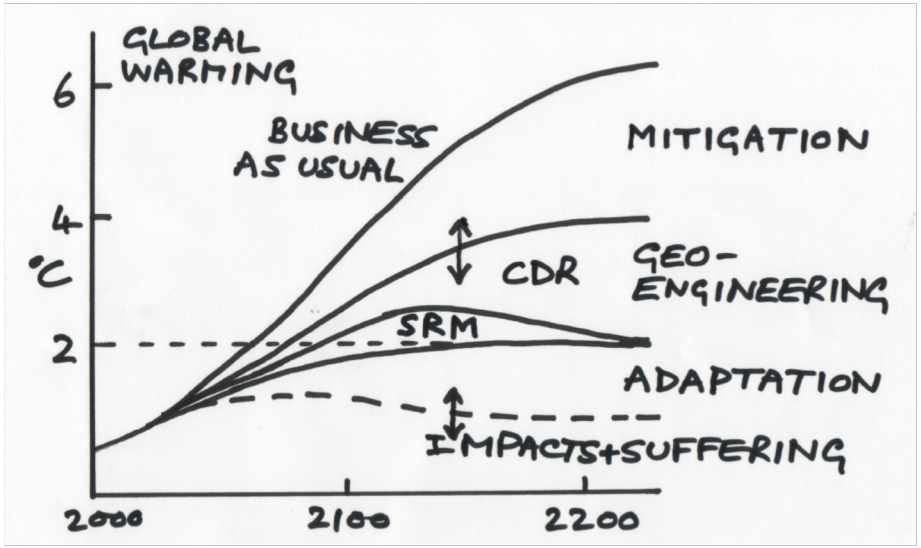
CDR and Mitigation through Land Management

Napkin Diagram: Warming and Suffering



Jane Long and John Shepherd, 2014

Land Based Carbon Dioxide Removal (Negative Emissions)

- Reforestation on previously forested land
- Afforestation on climate suitable for trees but not previously forested
- Other ecosystem restoration (wetlands, shrublands etc)
- Bio-energy with carbon capture and storage (BECCS) of CO2 in geological reservoirs
- Biochar generation through burying charred wood or other plant matter in soils

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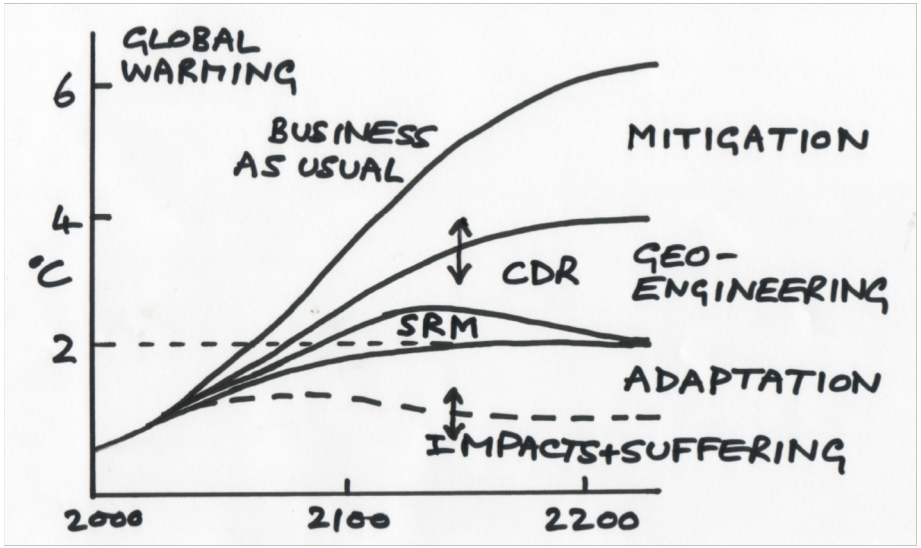
Napkin Diagram: Warming and Suffering



Jane Long and John Shepherd, 2014

Land Based Mitigation (Reduced Emissions)

- Avoided deforestation through reduced demand for agricultural and forestry land from current natural forested land
- Conservation agriculture on existing cropped land through changed farming practices like no till, residue management after harvesting, and natural vegetation restoration within the farm site
- Conservation forestry through plantation forestry reducing the demand and disturbance of natural forests

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CDR through Land Management

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

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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

The New York Times

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

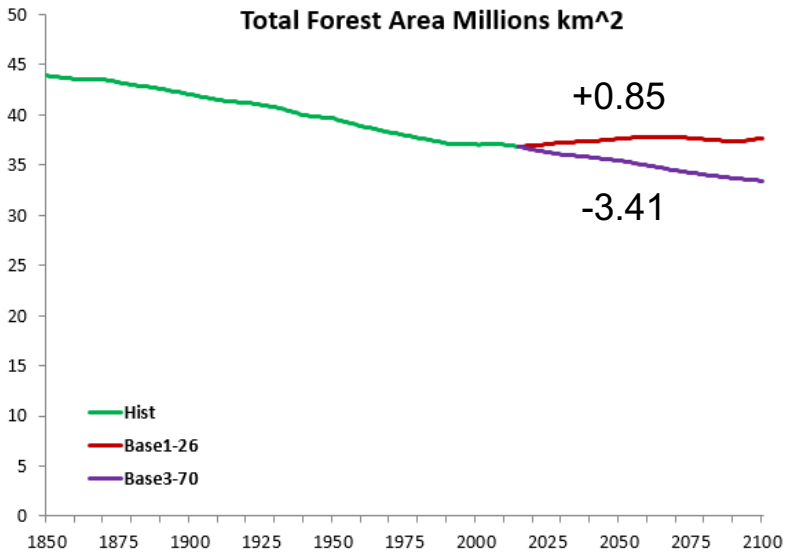
Natural climate solutions

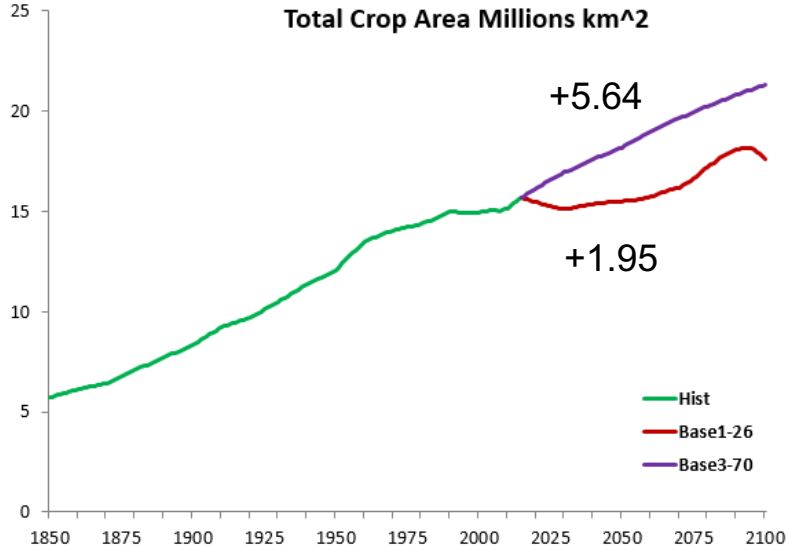
Bronson W. Griscom, Justin Adams, Peter W. Ellis, Richard A. Houghton, Guy Lomax, Daniela A. Miteva, William H. Schlesinger, David Shoch, Juha V. Siikamäki, Pete Smith, Peter Woodbury, Chris Zganjar, Allen Blackman, João Campari, Richard T. Conant, Christopher Delgado, Patricia Elias, Trisha Gopalakrishna, 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

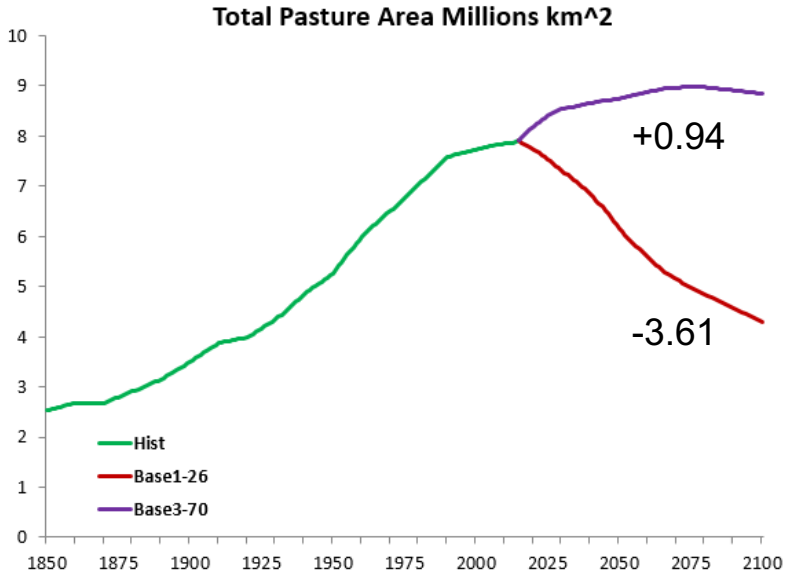
PNAS October 31, 2017 114 (44) 11645-11650; first published October 16, 2017 https://doi.org/10.1073/pnas.1

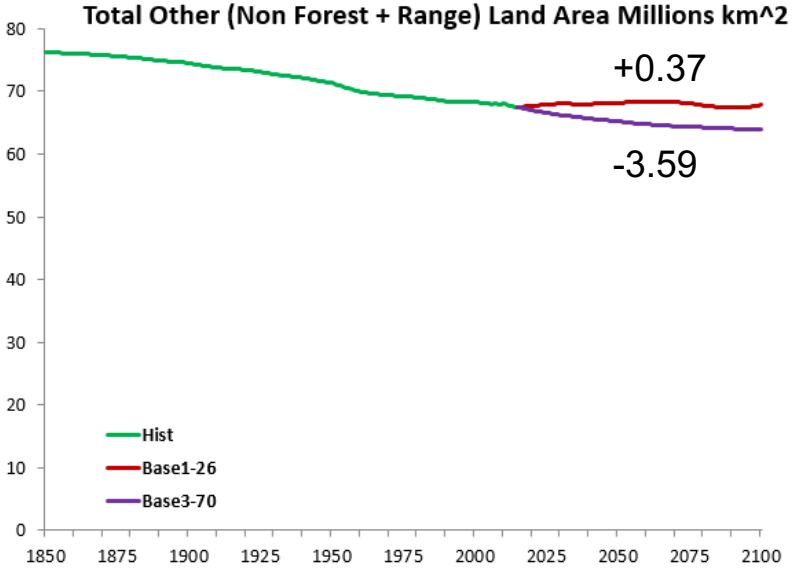
Range of results upper end has:
Re/Afforestation of 9 million km^2
With 205 PgC additional storage
(Cumulative emissions ~500 PgC)

CESM – CMIP6 SSP 1-26 and 3-70 Baseline LULCC









CESM Afforestation and Reforestation Potentials

NCAR, University of Virginia, Appalachian State and MacArthur Foundation

New CMIP6 Reforestation / Afforestation Land Use Land Cover Change Scenarios

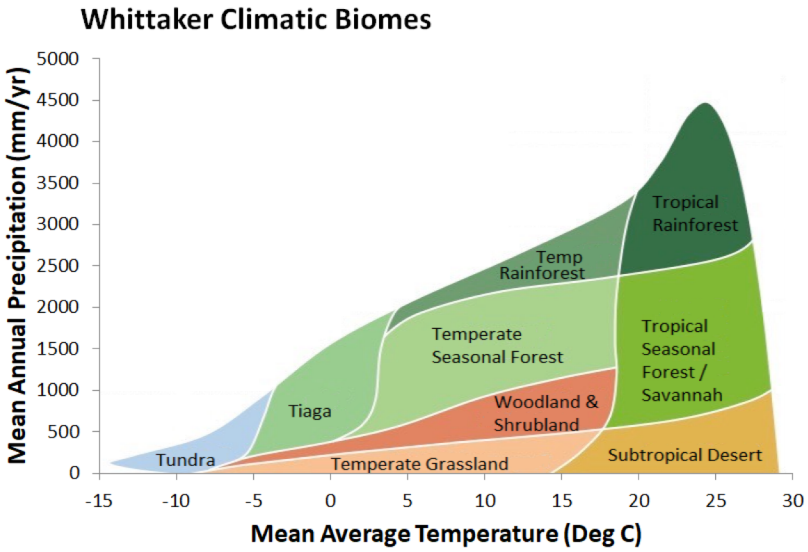
- Current Land Use (NoLULCC 2015)
- SSP1-2.6 Sustainable World Baseline (SSP126Base)
- SSP3-70 High Population and Agriculture Baseline (SSP370Base)

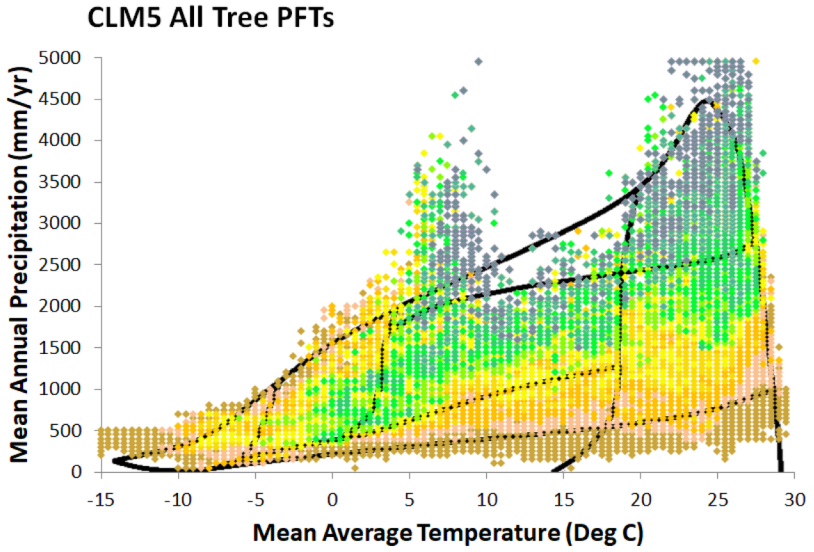
Two Climate Scenarios (Land Only and Coupled Concentration driven CESM2)

- SSP1-2.6 Reduced emissions and CO_2 concentrations
- SSP3-7.0 High emissions and CO_2 concentrations

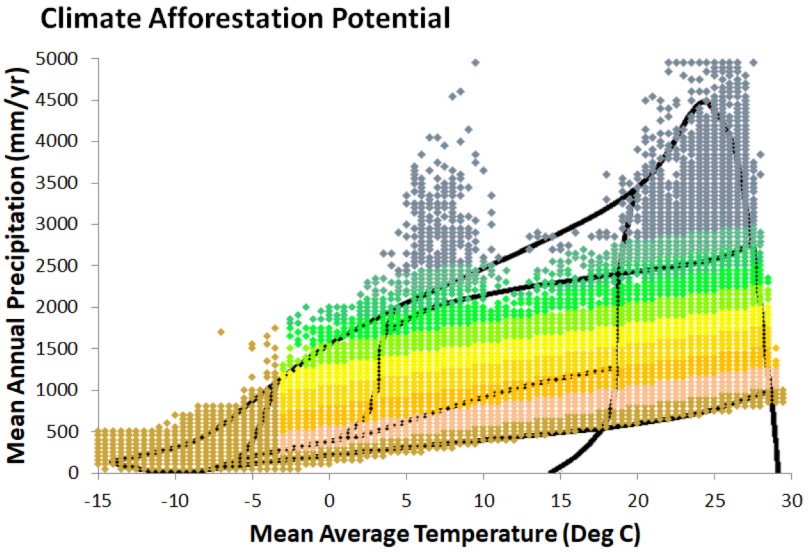
		Climate			
		2.6 (2C)		7.0 (4C)	
Land used for agriculture (Food security)	SSP3 (High agriculture)	I.	1. Baseline (BAU)	IV.	10. Baseline (BAU)
			2. Reforestation		11. Reforestation
			3. Reforestation + Afforestation		12. Reforestation + Afforestation
	Current 2015 (Static land use)	II.	4. Baseline	V.	13. Baseline
			5. Reforestation		14. Reforestation
			6. Reforestation + Afforestation		15. Reforestation + Afforestation
	SSP1 (Low agriculture)	III.	7. Baseline	VI.	16. Baseline
			8. Reforestation		17. Reforestation
			9. Reforestation + Afforestation		18. Reforestation + Afforestation

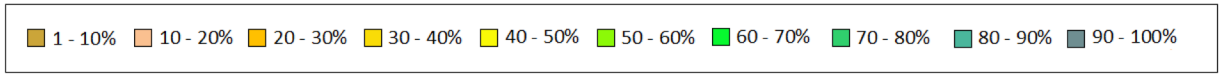
CESM Re/Afforestation Climate Index



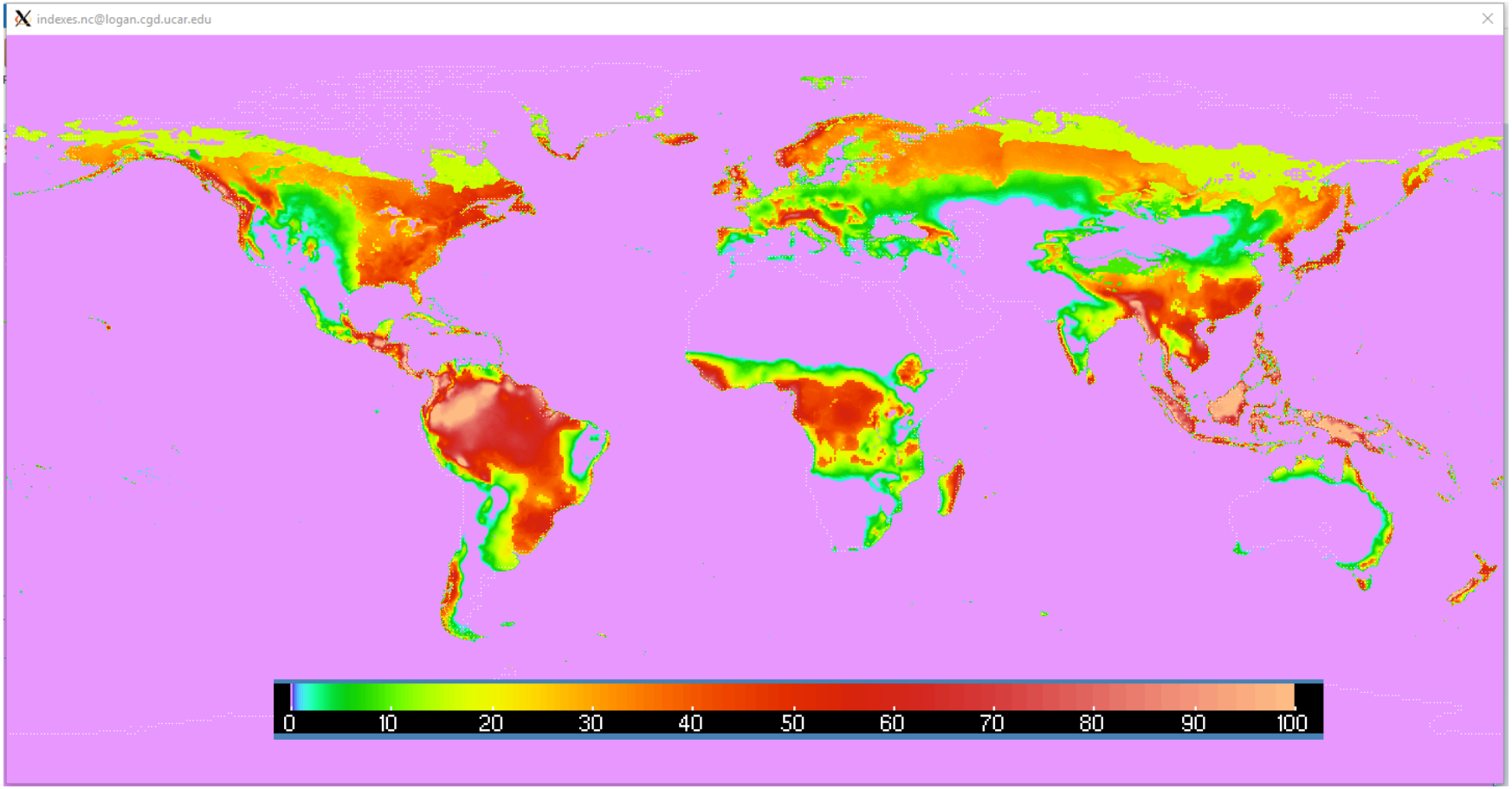


Climate Index =
((AnnPrecip-700)/2500-(AnnAvgTemp-25)/100))*100

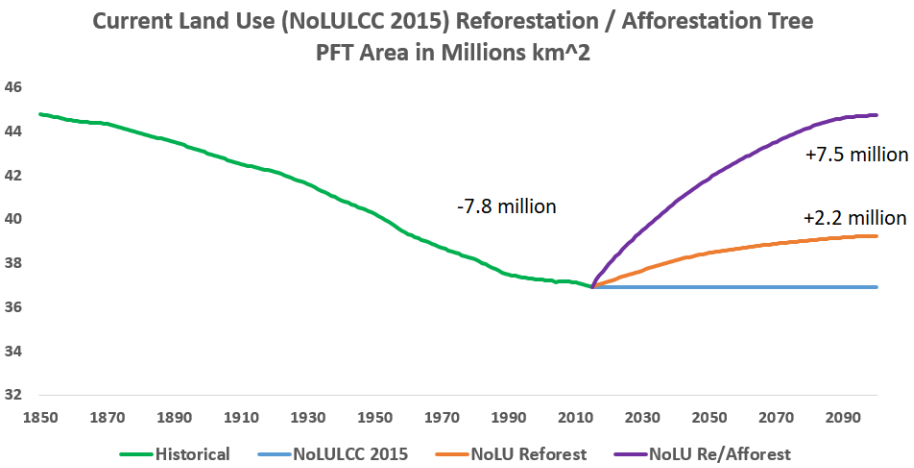


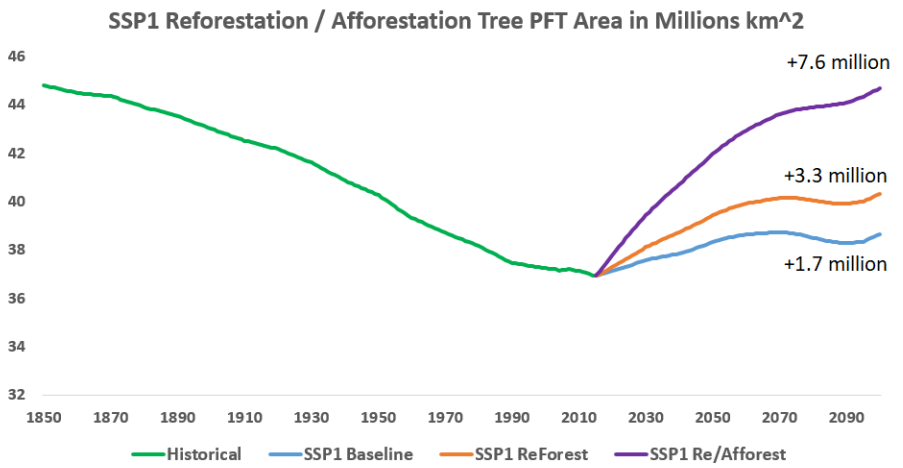


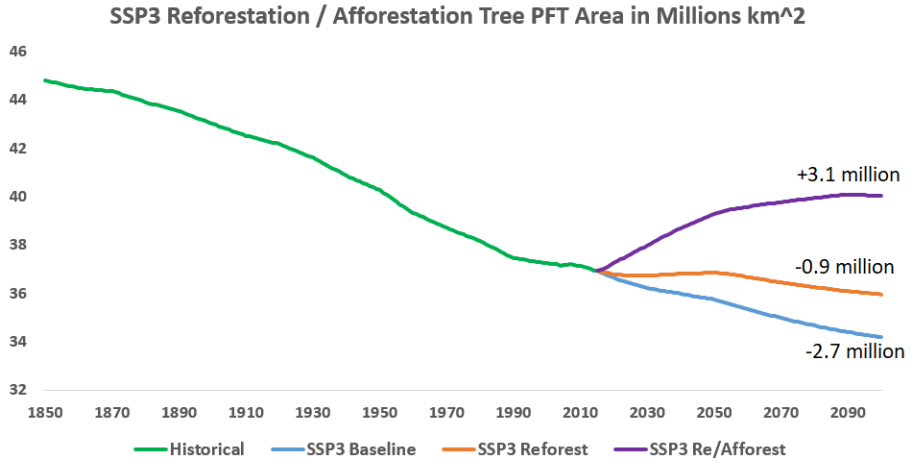
CESM 2 Re/Afforestation Index

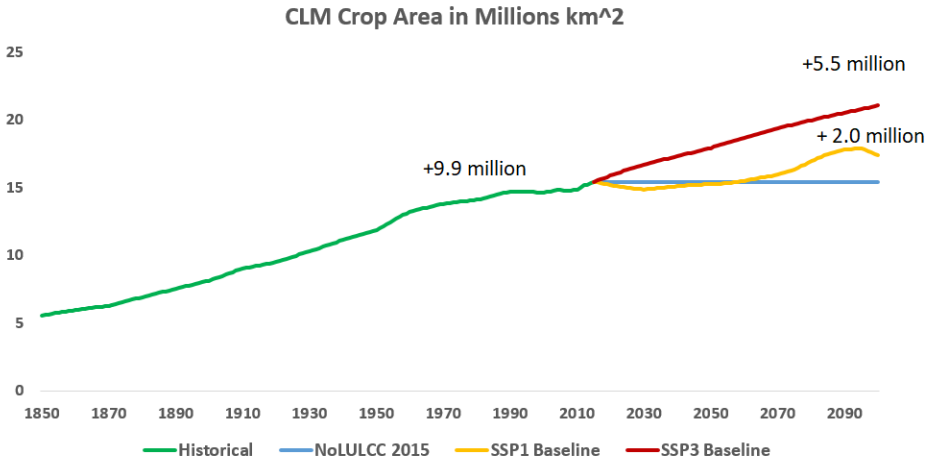


CTSM – SSP Potential Land CDR Scenarios Tree PFTs

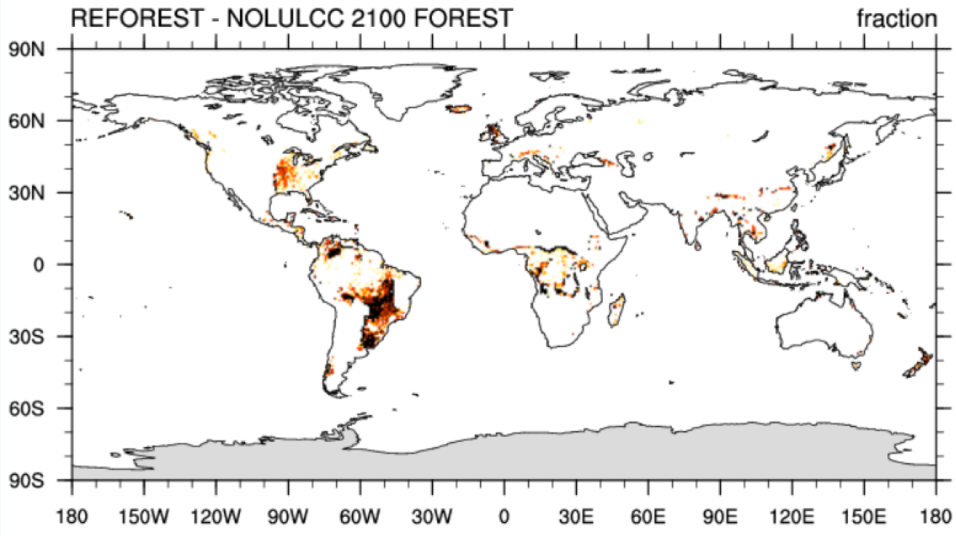


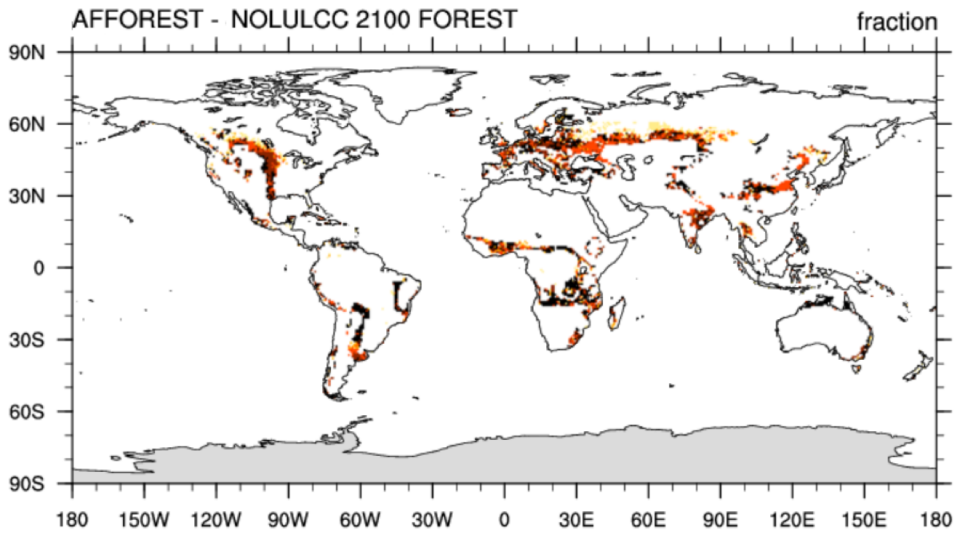


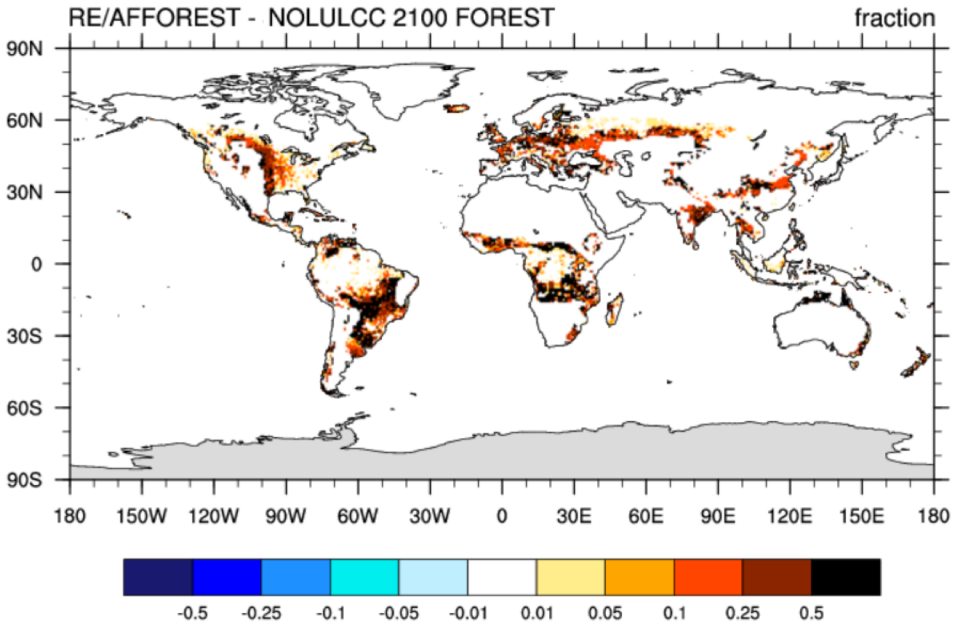




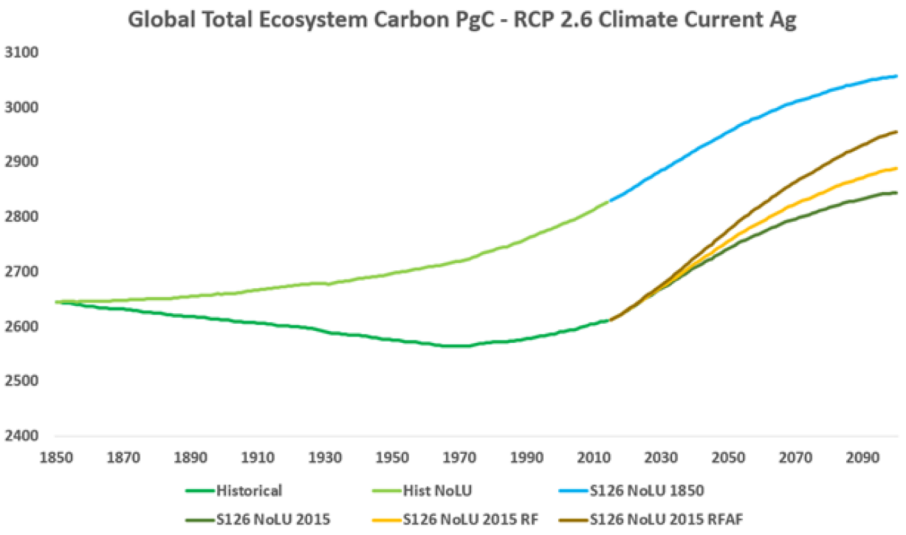
Land Based CDR Reforest / Afforest Tree PFTs

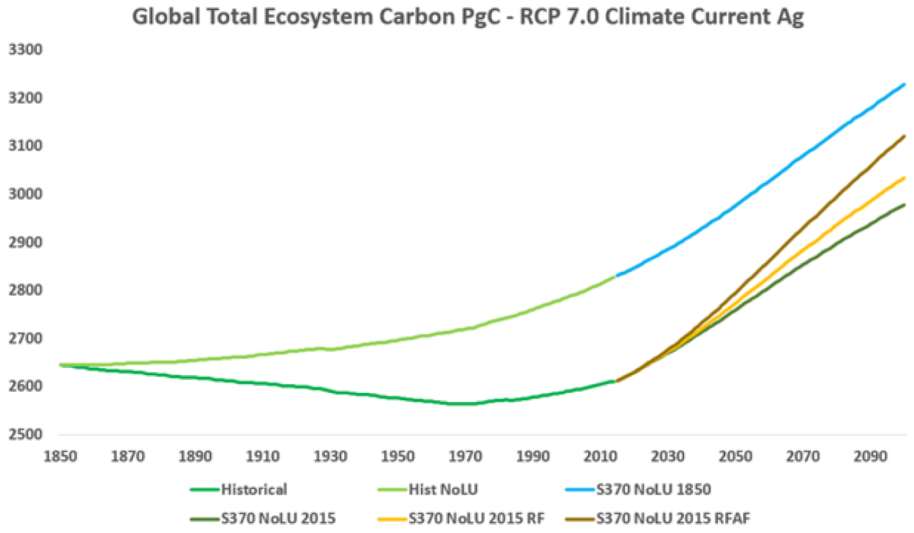


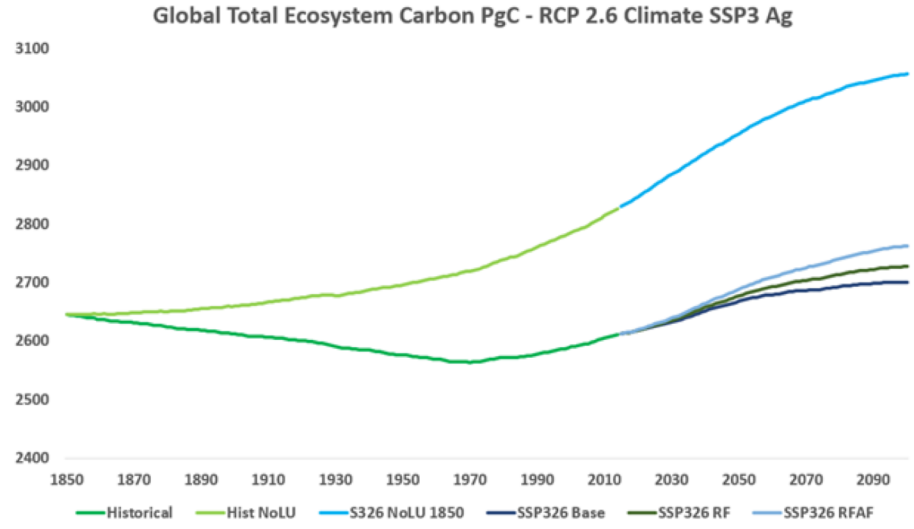


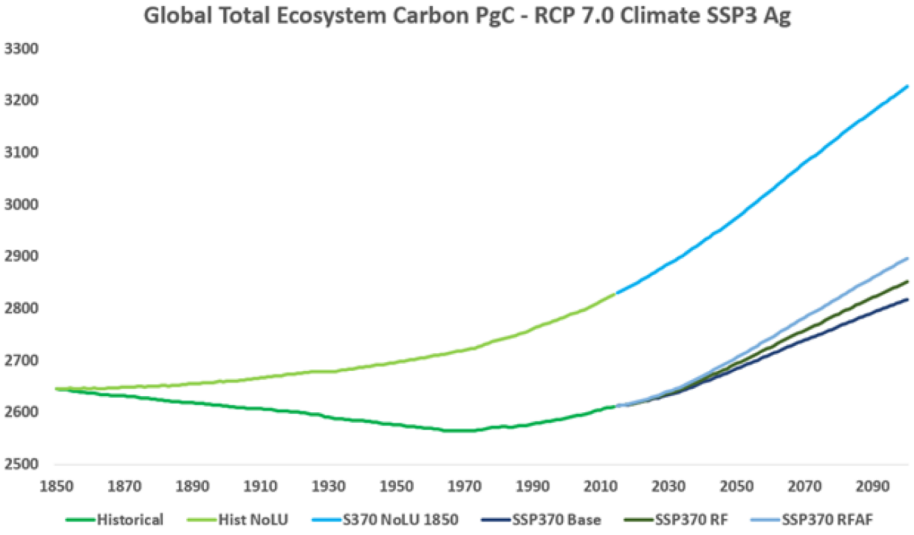


CTSM – Total Ecosystem Carbon Land CDR Scenarios

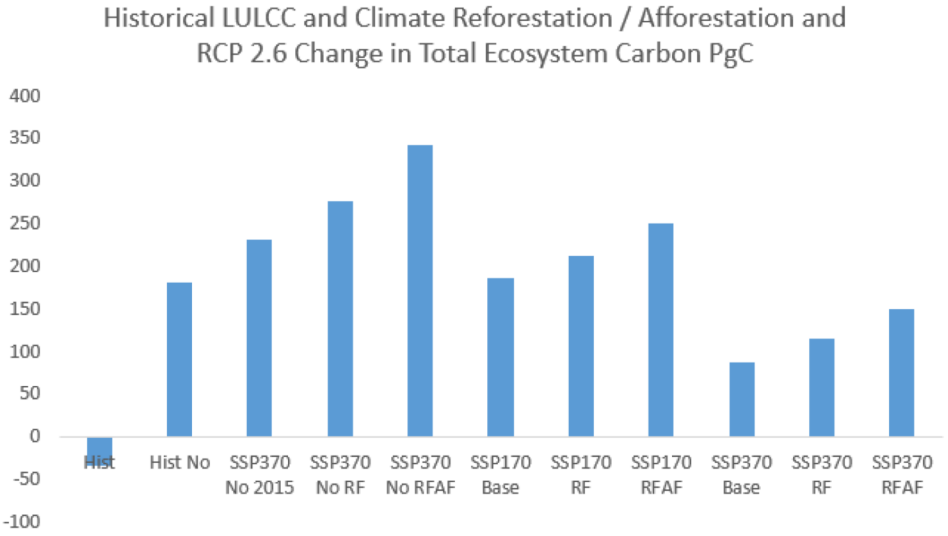


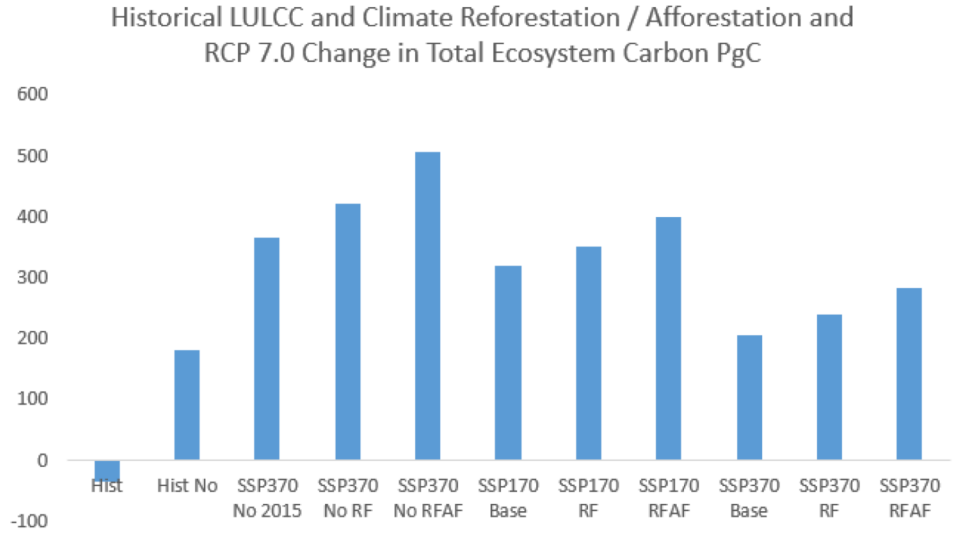


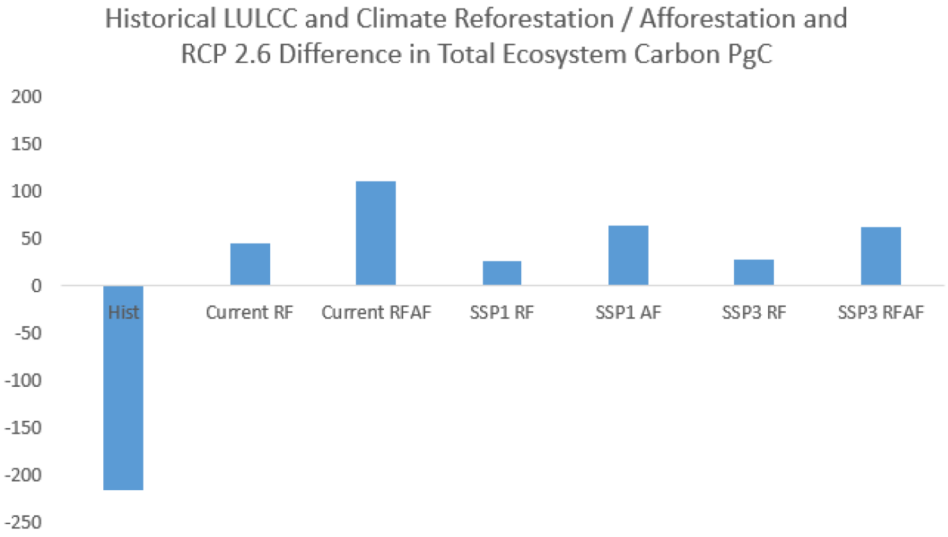


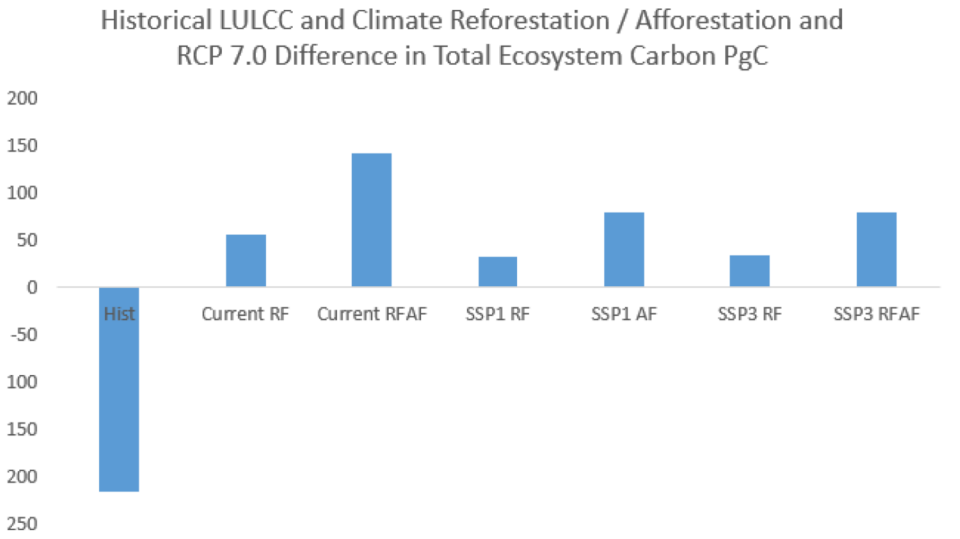


CESM – Total Ecosystem Carbon Land CDR Scenarios









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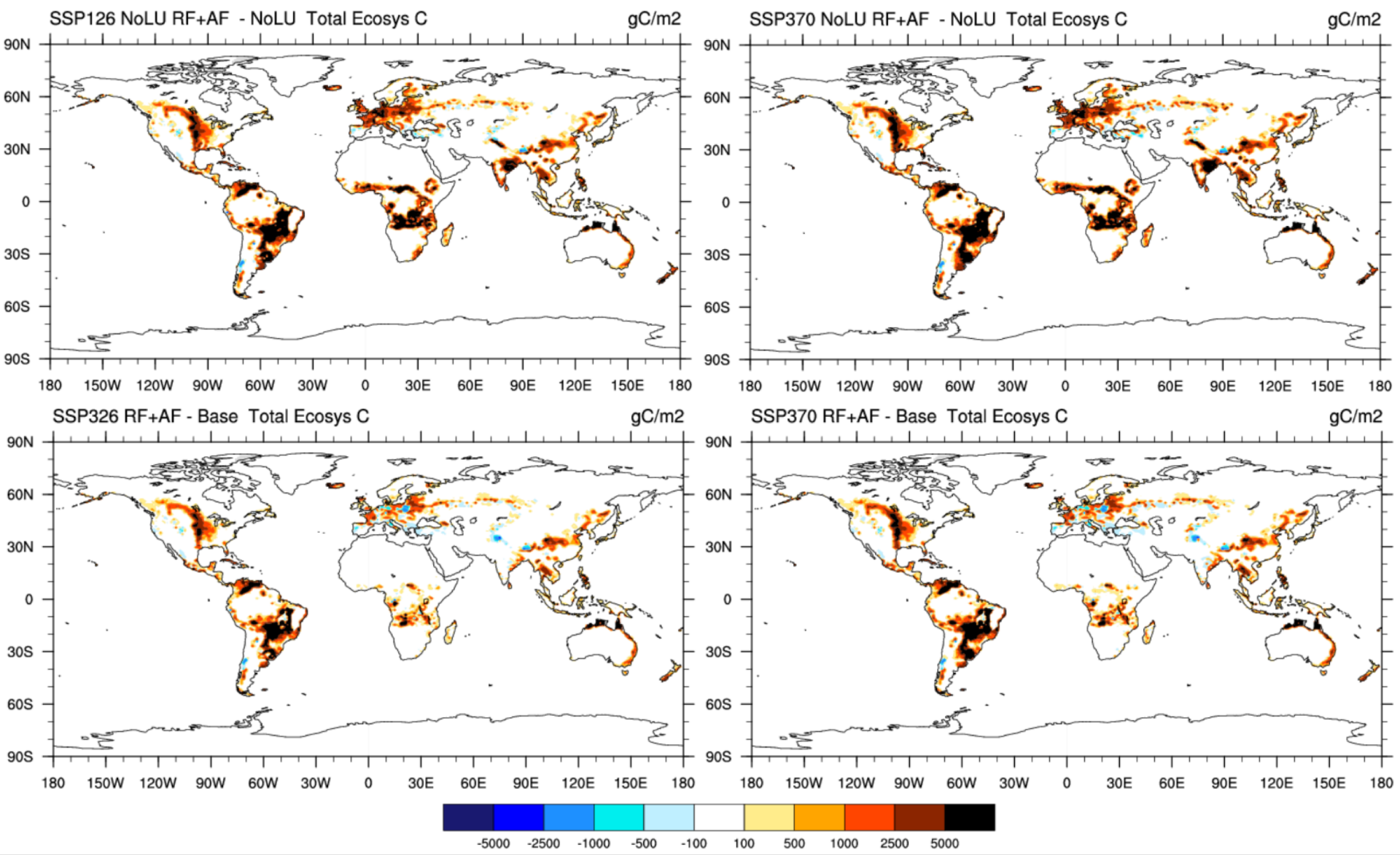

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CDR through Land Management – Next Steps

The carbon dioxide removal potential for large scale Bioenergy with Carbon Capture and Storage (BECCS).

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REVIEW

Cellulosic biofuel contributions to a sustainable energy future: Choices and outcomes

G. Philip Robertson[1,2,3,*], Stephen K. Hamilton[1,3,4], Bradford L. Barham[5,6], Bruce E. Dale[3,7], R. Cesar Izaurralde[3,8,9], Randall ...

+ See all authors and affiliations

Science 30 Jun 2017:

ELSEVIER

Journal of Integrative Agriculture

Volume 16, Issue 6, June 2017, Pages 1197-1210

ELSEVIER

Global Environmental Change

Volume 42, January 2017, Pages 153-168

REVIEW

Modeling the biomass of energy crops: Descriptions, strengths and prospective

Rui JIANG [a, b], Tong-tong WANG [a], Jin SHAO [c], Sheng GUO [a], Wei ZHU [a], Ya-jun YU [a], Ryusuke HATANO [e]

The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview

Keywan Riahi [a], Detlef P. van Vuuren [b], Elmar Kriegler [c], Jae Edmonds [d], Brian C. O'Neill [e], Shinichiro Fujimori [f],

All SSP Mitigation Scenarios use Bioenergy with Carbon Capture and Storage in some form to provide renewable liquid fuels to reduce fossil fuel emissions

NCAR Climate Intervention Strategies
CDR through Land Management

The carbon dioxide removal potential for large scale Bioenergy with Carbon Capture and Storage (BECCS).

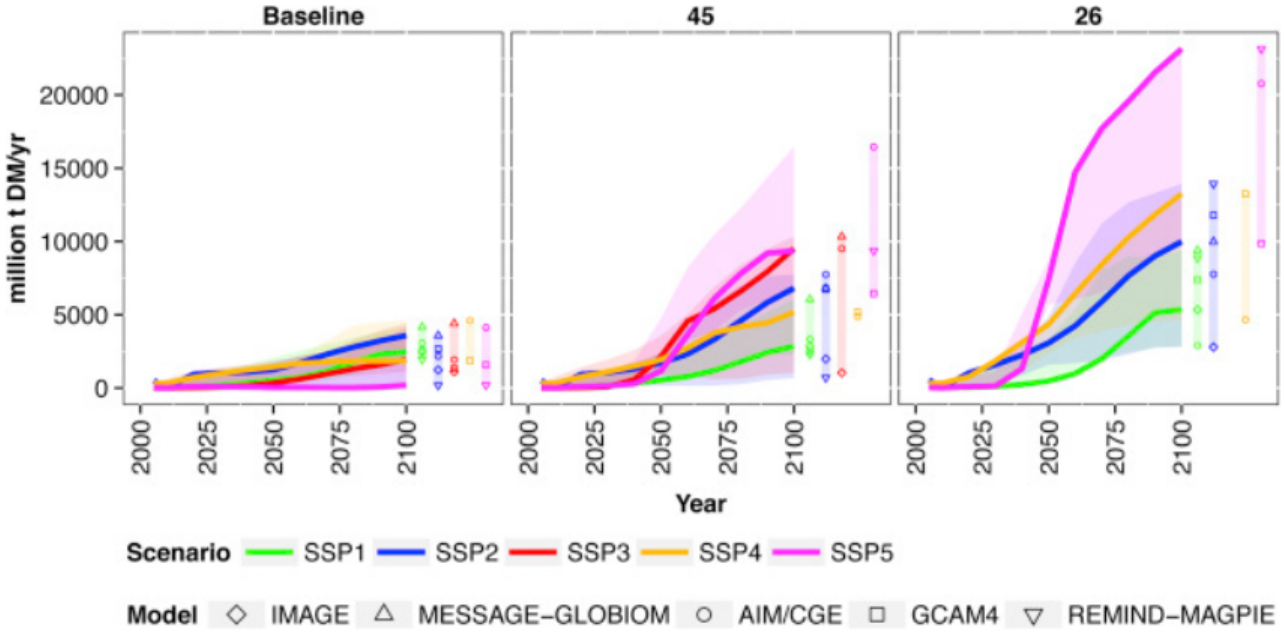

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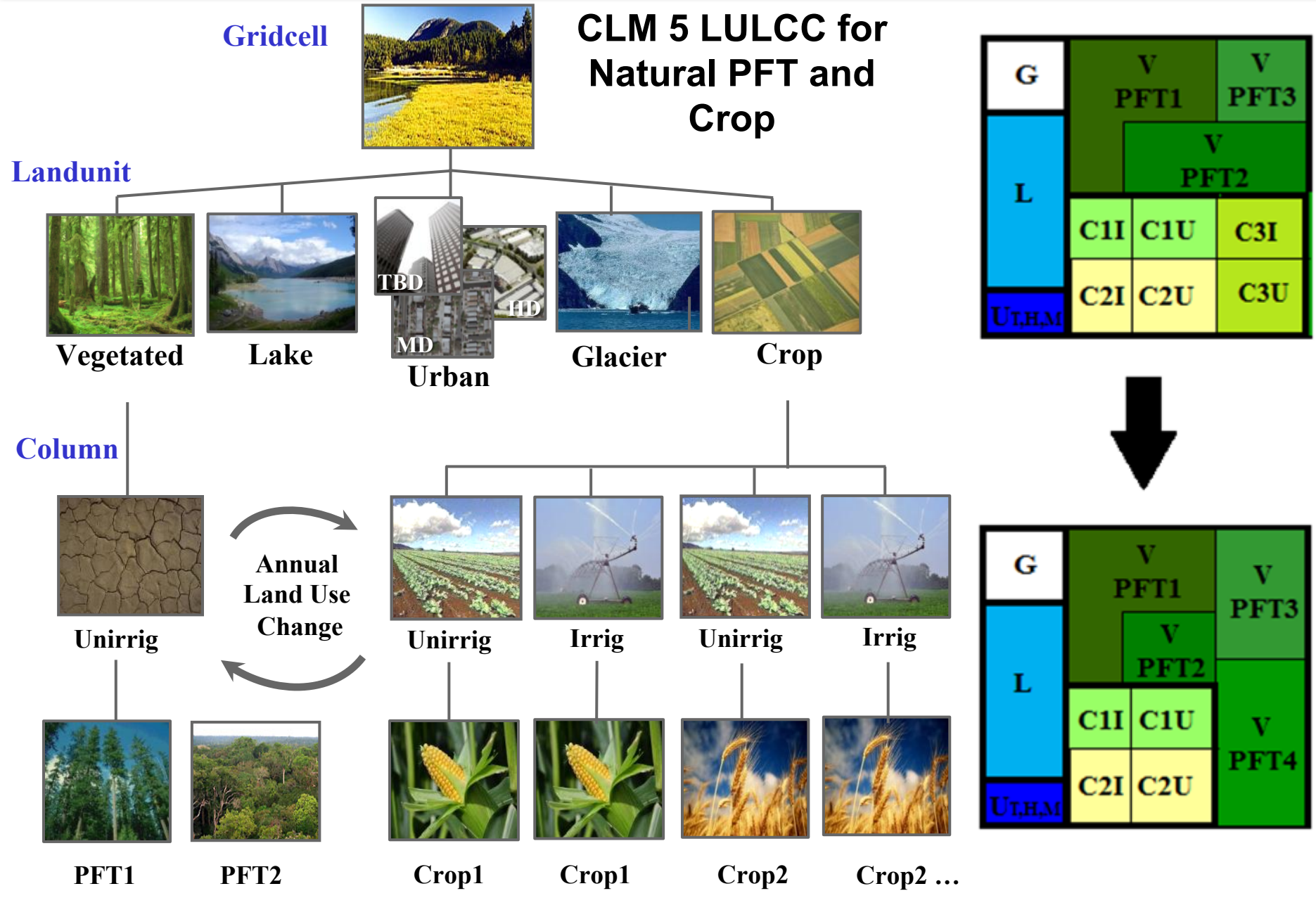
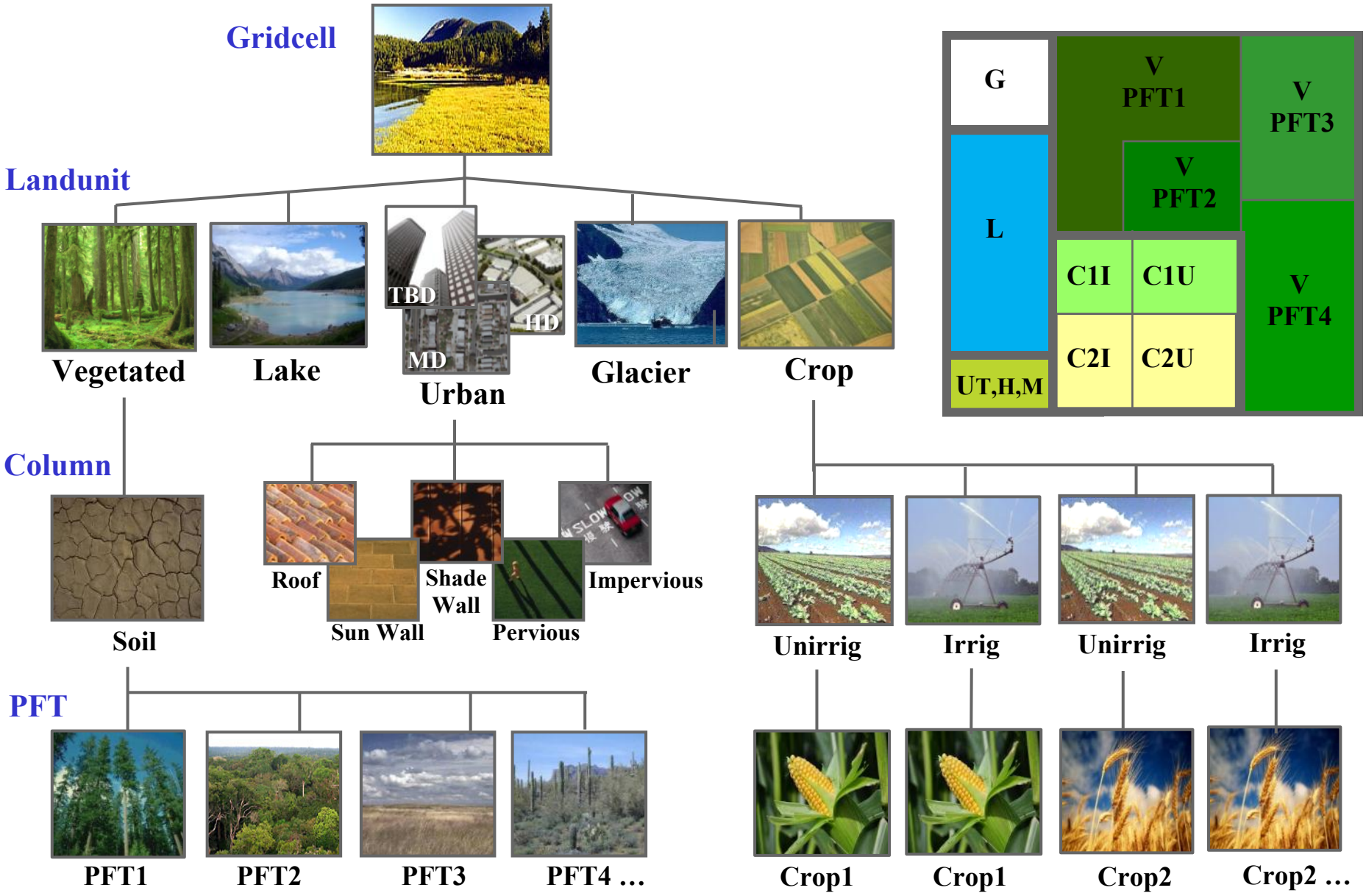
Fig. 2. Global demand for dedicated 2nd generation bioenergy crops of the five SSP marker scenarios for the baseline (left column), RCP4.5 (middle column) and RCP2.6 (right column) cases. Colored lines

All SSP Mitigation Scenarios use Bioenergy with Carbon Capture and Storage in some form to provide renewable liquid fuels to reduce fossil fuel emissions

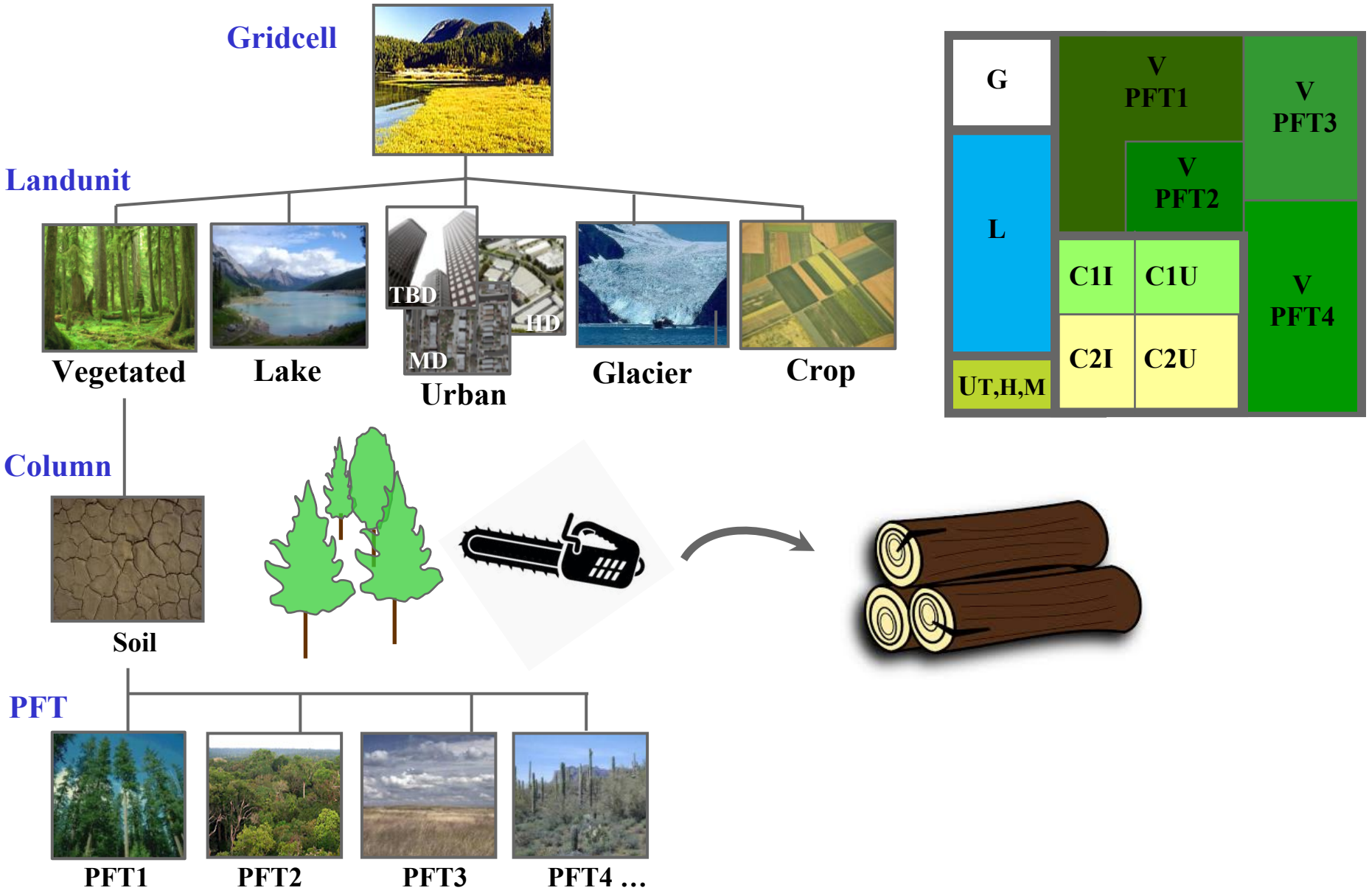
CLM5 Land Cover Change – Prescribed Re/Afforestation



CLM5 Land Use and Land Cover Change Representation



CLM5 Land Use – Changing Wood Harvest (biomass)



CLM5 Land Use – Crop Model for Bioenergy Production

Gridcell

Landunit

Vegetated

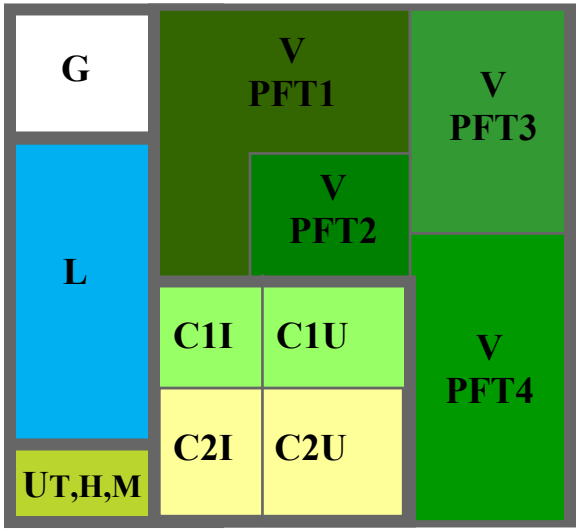
Lake

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 – Crop Model Updates for Biofuels

Yanyan Cheng et al. – PNNL / DOE

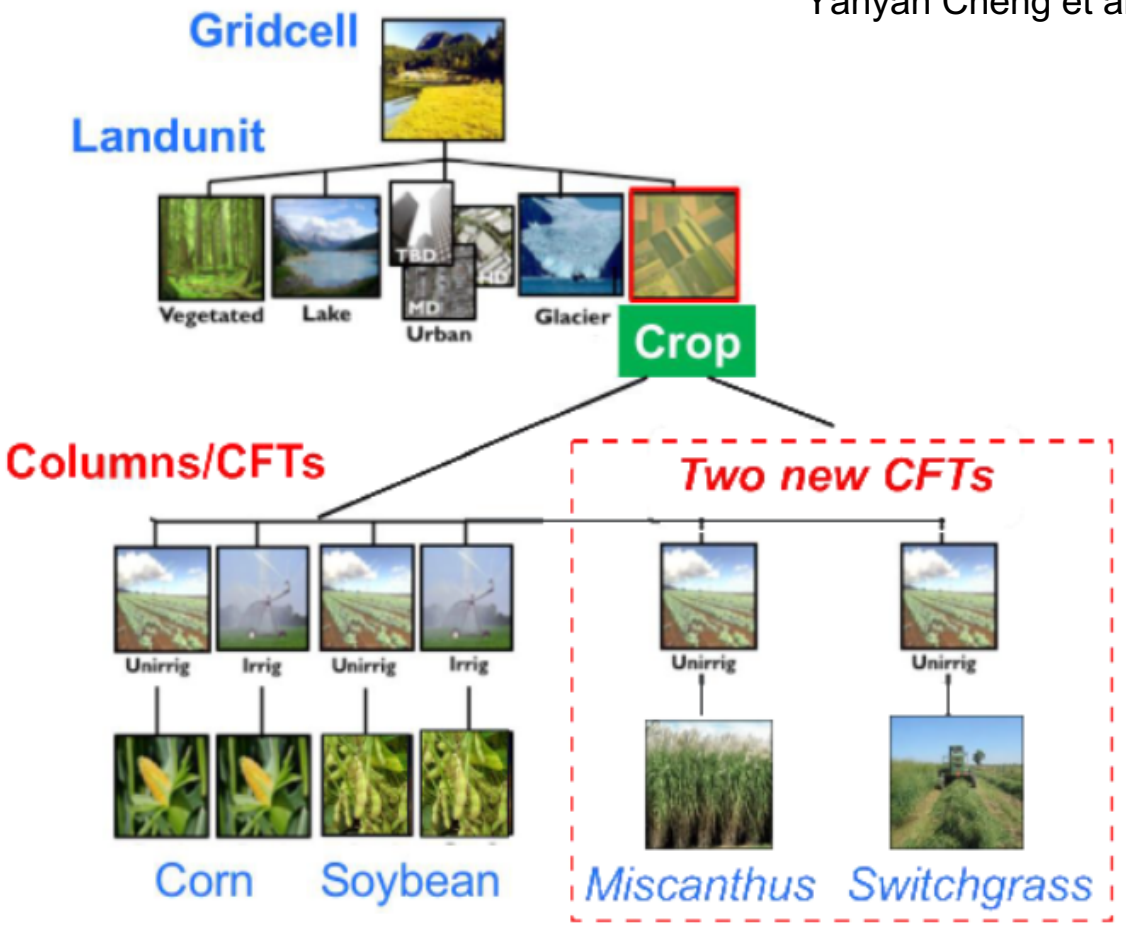
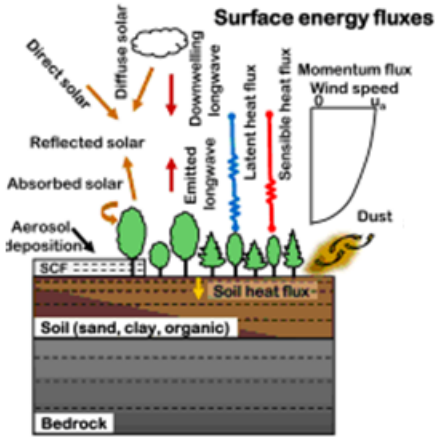
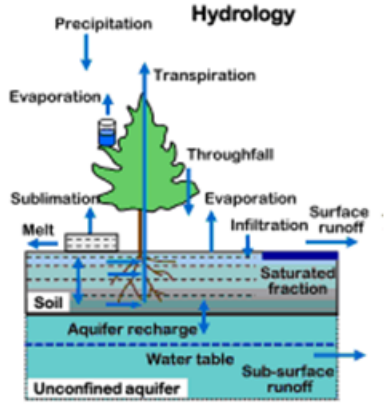


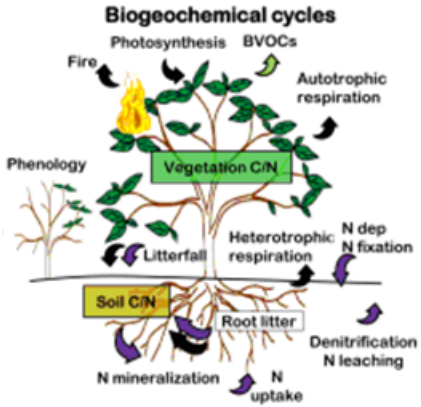
Figure 2: Schematic representation of the implementation of two new perennial bioenergy grasses, Miscanthus and switchgrass, into one typical Community Land Model grid cell, modified from Figure 2.1 in Lawrence et al. (2018). CFTs = Crop Functional Types.

Land Use in the Climate System Changes

Surface Energy Fluxes:
- Solar Energy Fluxes (Albedo – Vegetation, Snow, Soils)
- Long Wave Energy Fluxes (Surface Temp & Emissivity)
- Latent Heat Fluxes (Transpiration, Evaporation)
- Sensible Heat Fluxes (Surface Temp & Roughness)

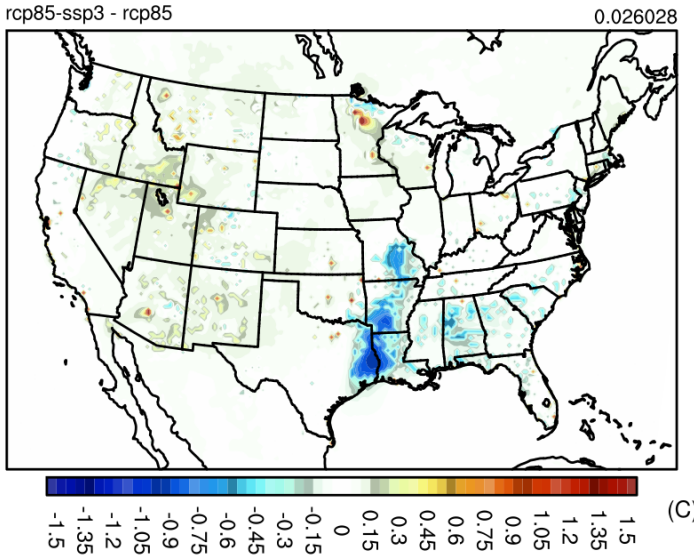


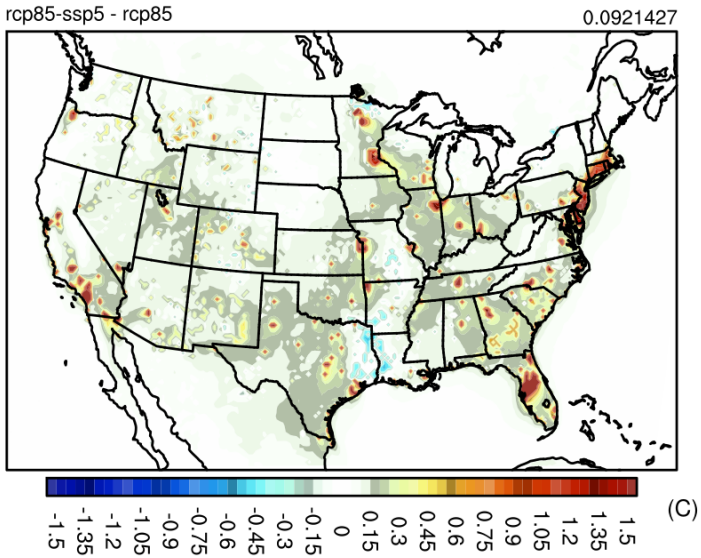


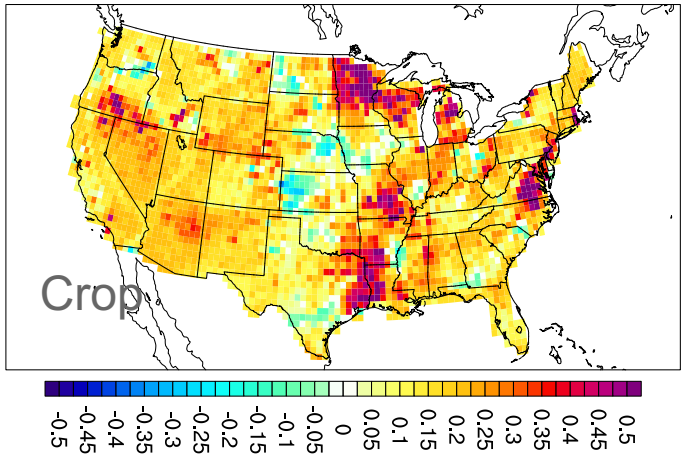


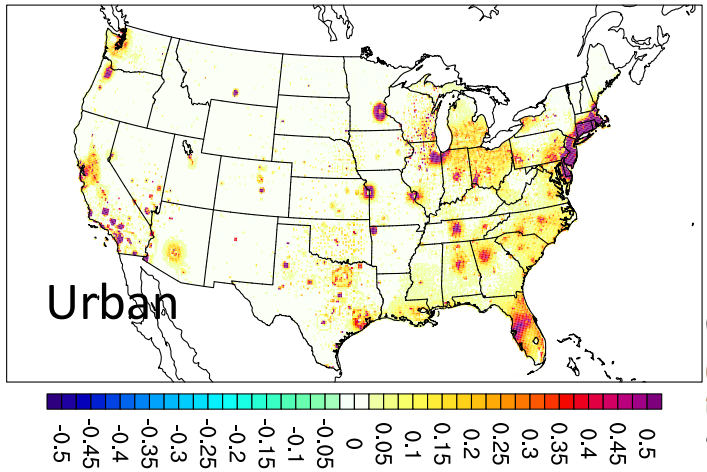
Land Use in the Climate System Changes

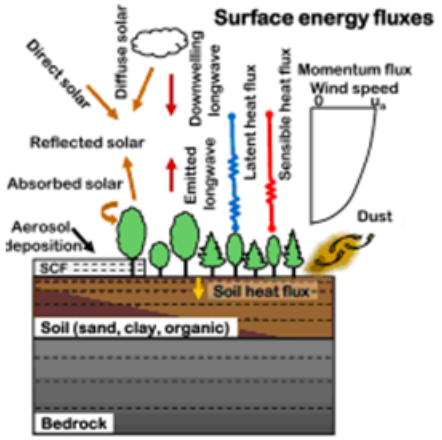
Effect of LULCC in Climate Change Projections in WRF
DJF, 1980-2005 vs. RCP 8.5 for SSP3 (left), SSP5 (right)

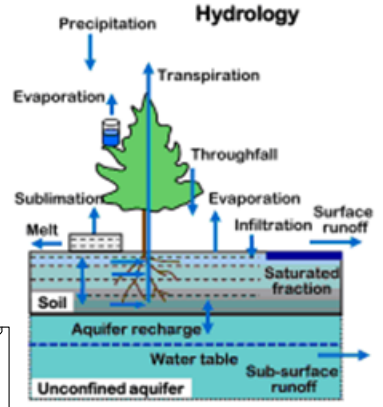


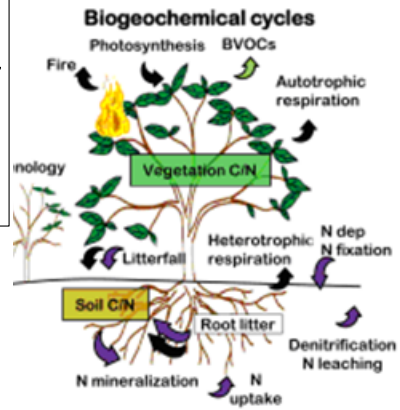












Melissa Bukovsky CISL, RISC

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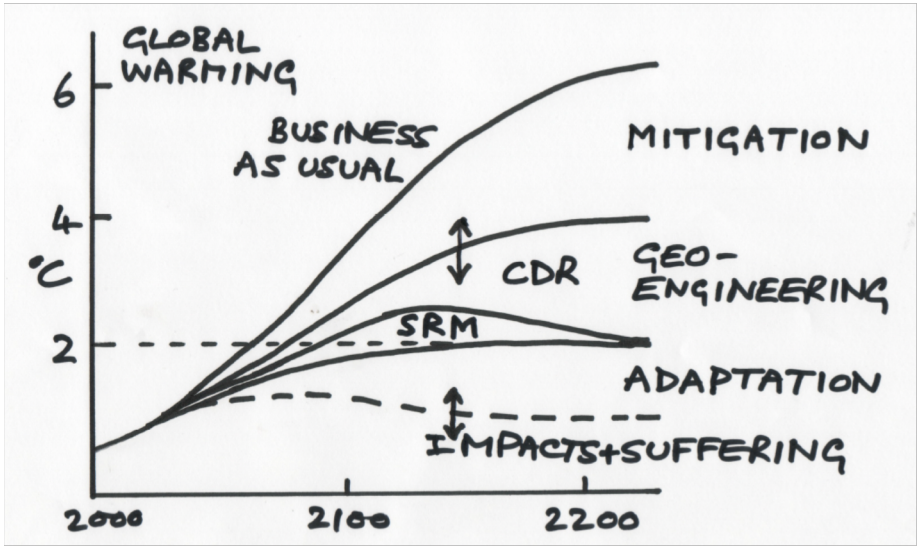
Napkin Diagram: Warming and Suffering



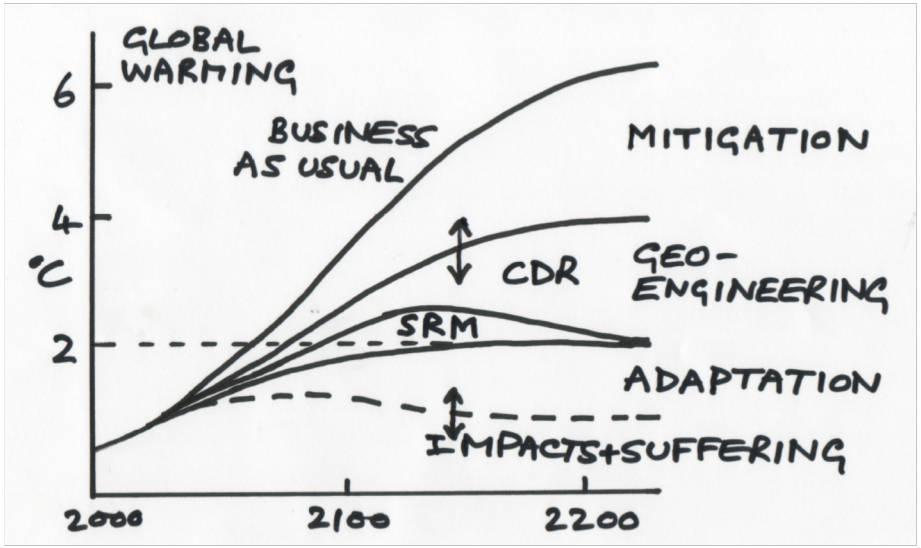
Jane Long and John Shepherd, 2014

Land Based Carbon Dioxide Removal (Negative Emissions)

- Reforestation on previously forested land
- Afforestation on climate suitable for trees but not previously forested
- Other ecosystem restoration (wetlands, shrublands etc)
- Bio-energy with carbon capture and storage (BECCS) of CO2 in geological reservoirs
- Substitution of high-emission material such as steel and concrete with wood-based construction
- Biochar generation through burying charred wood or other plant matter in soils

NCAR Climate Intervention Strategies
CDR and Mitigation through Land Management

Napkin Diagram: Warming and Suffering



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Land Based Mitigation (Reduced Emissions)

- Avoided deforestation through reduced demand for agricultural and forestry land from current natural forested land
- Conservation agriculture on existing cropped land through changed farming practices like no till, residue management after harvesting, and natural vegetation restoration within the farm site
- Conservation forestry through plantation forestry reducing the demand and disturbance of natural forests
- Biofuels generation through grain based and cellulosic ethanol and diesel production

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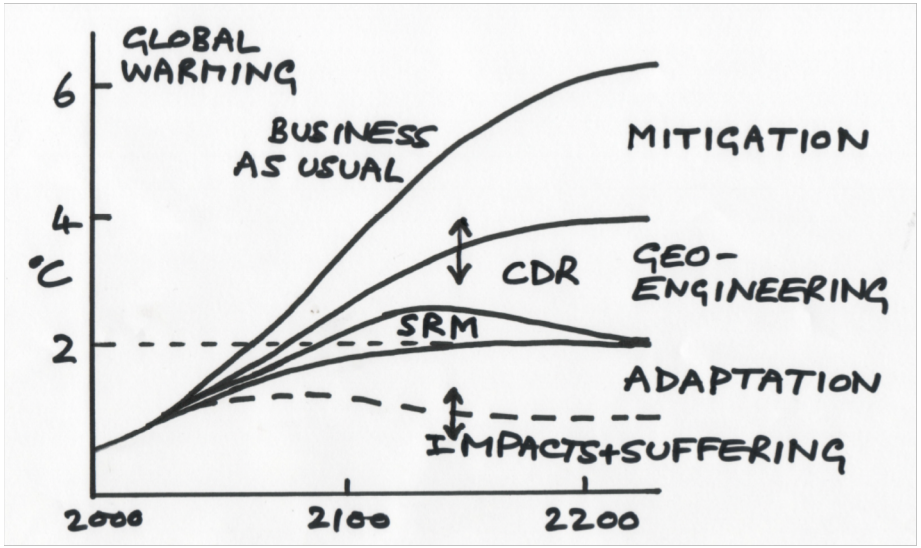
Napkin Diagram: Warming and Suffering



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Questions?