The Impact of Land Use Change in Amazonia on South American Climate using EDBRAMS

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Biology

work with:
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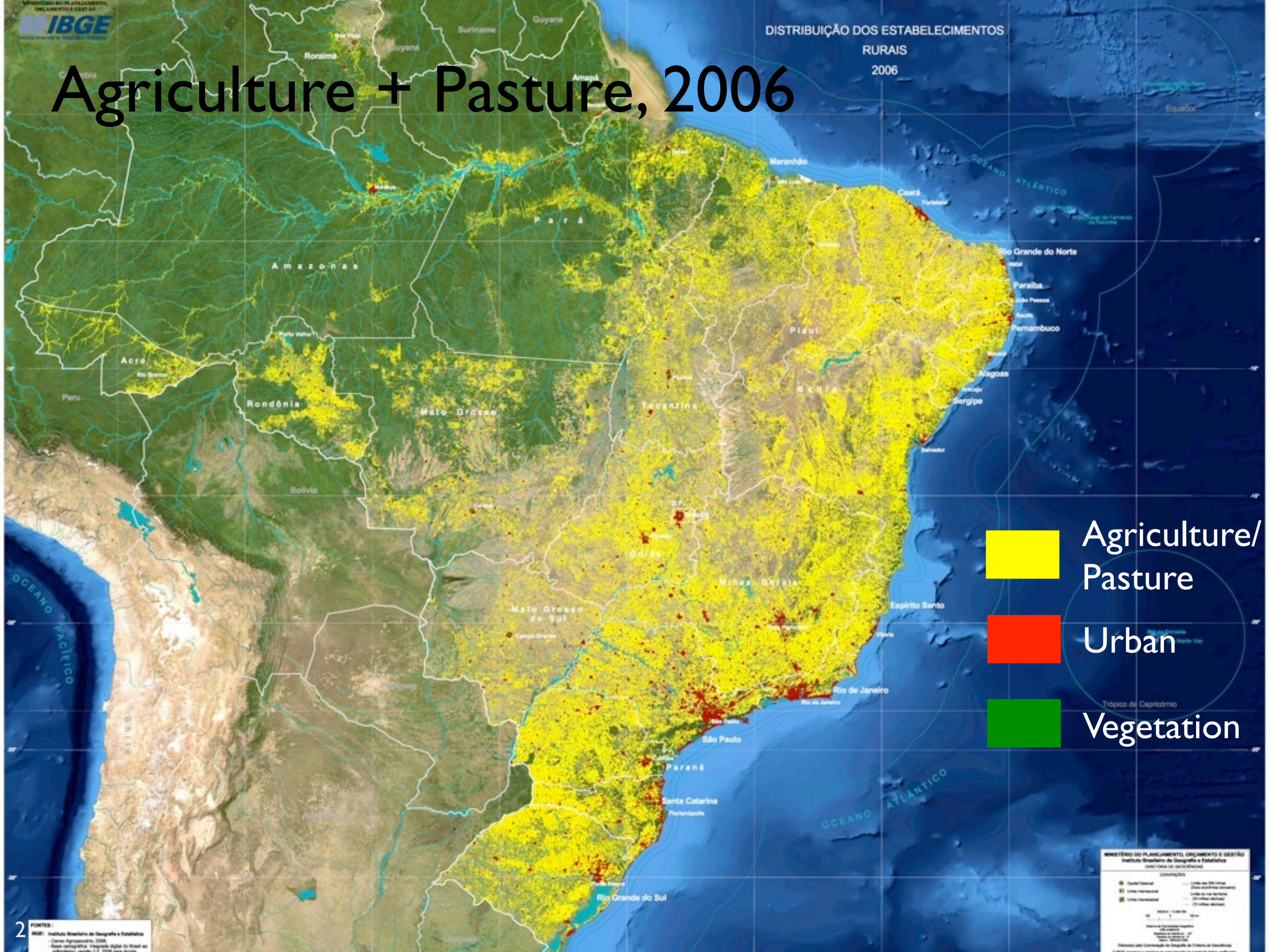
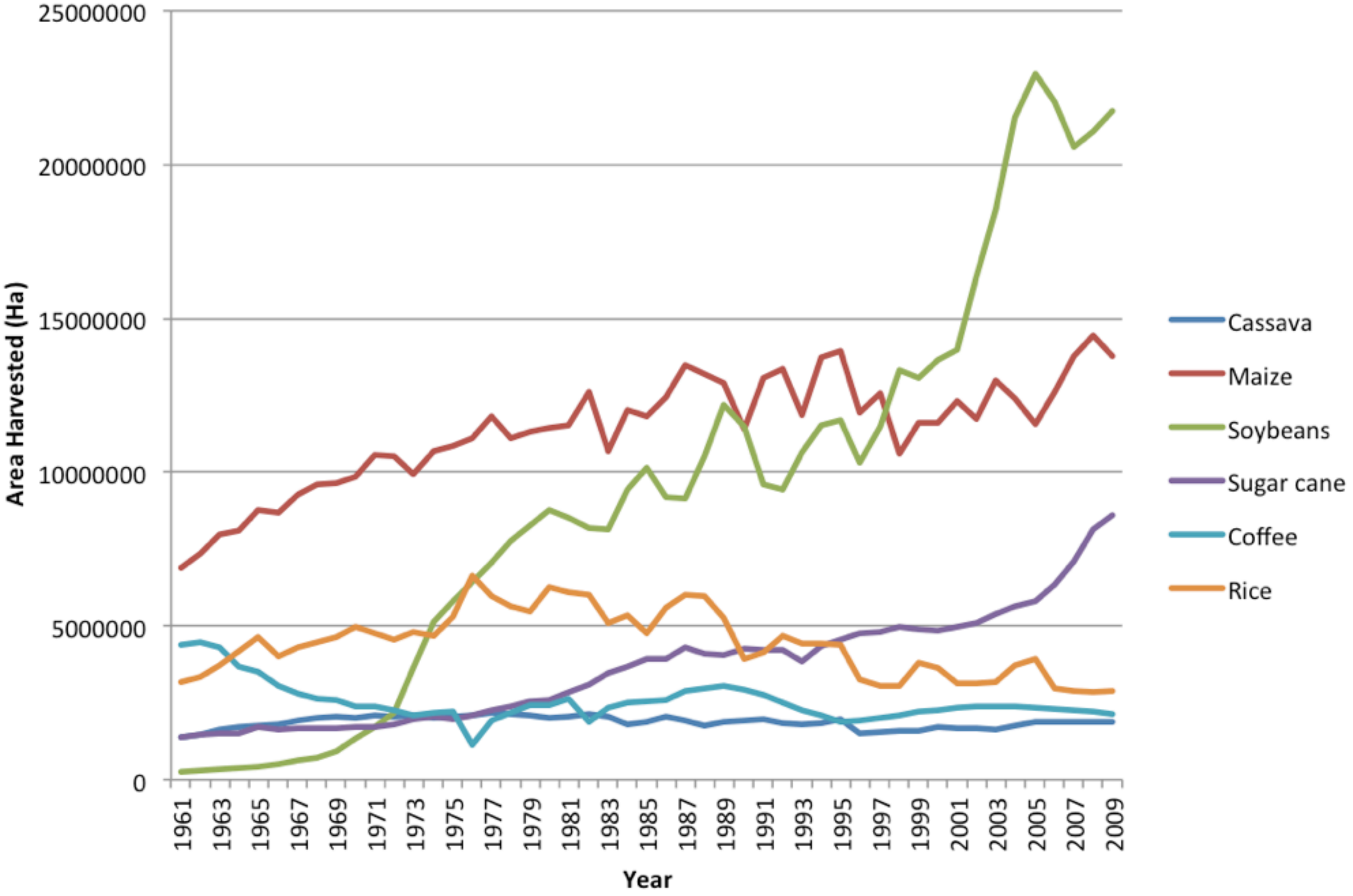
Steve Wofsy
Marcos Longo
Ryan Knox

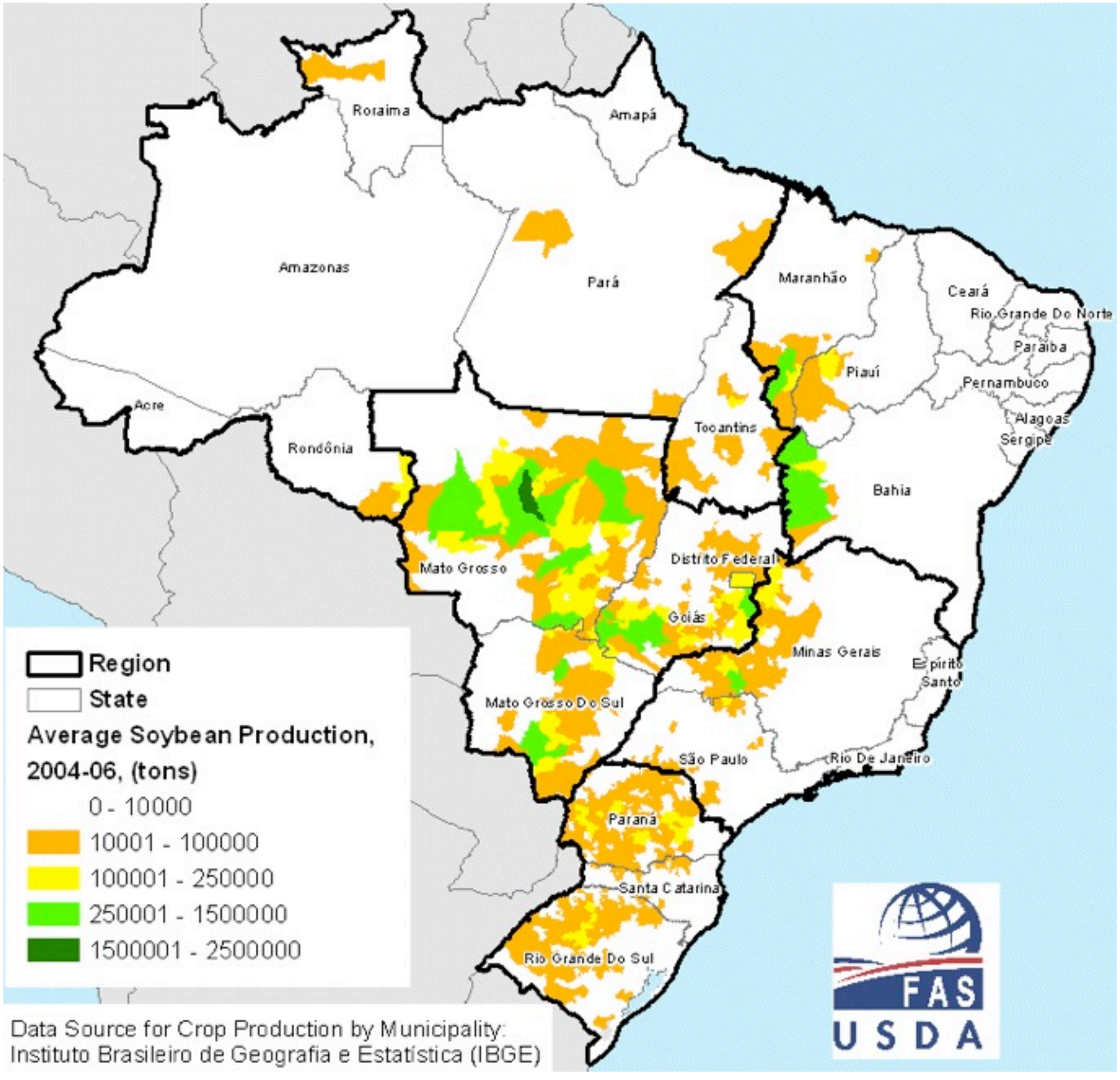
Agriculture + Pasture, 2006



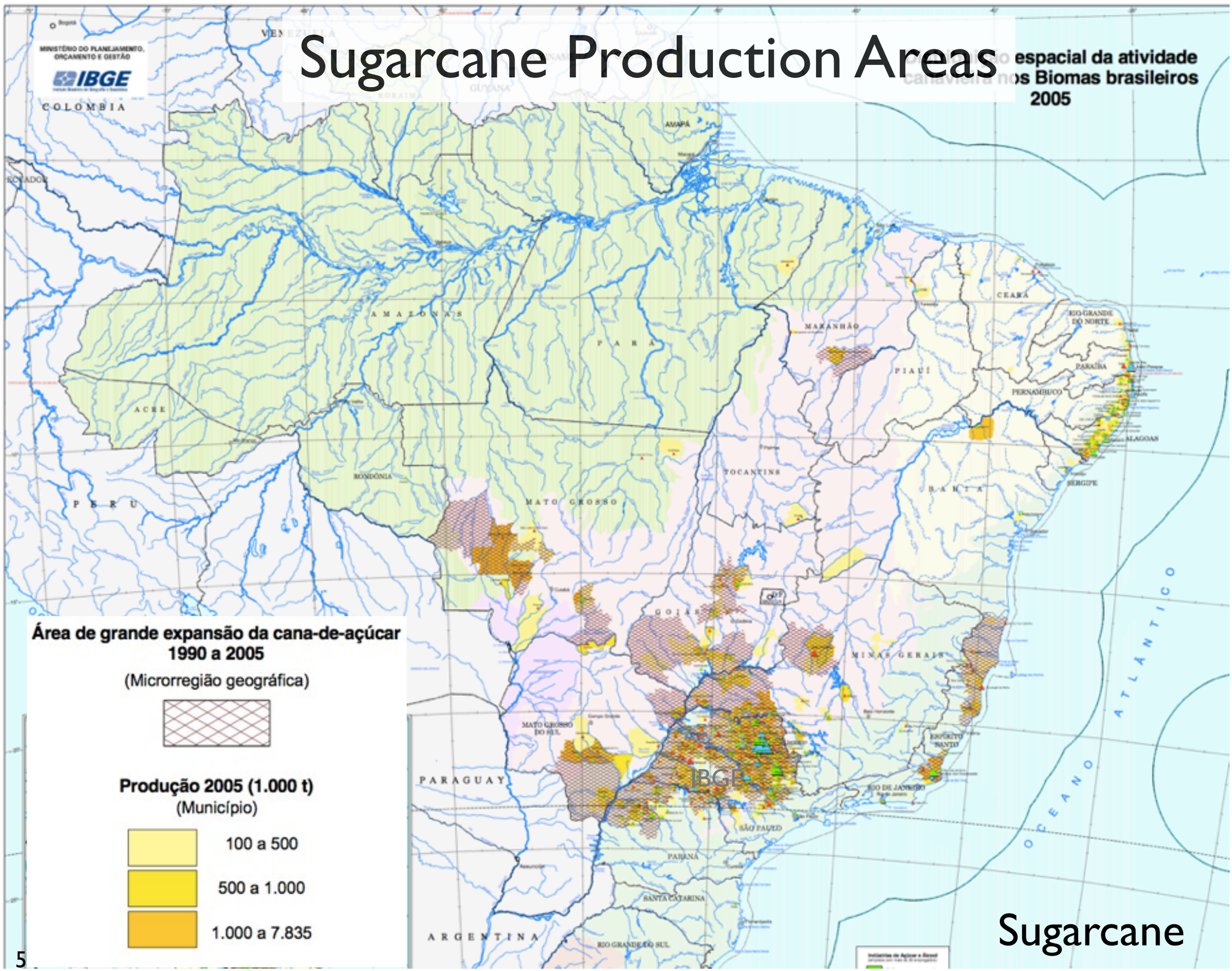
Agricultural Production in Brazil by Area



Soybean Production Areas

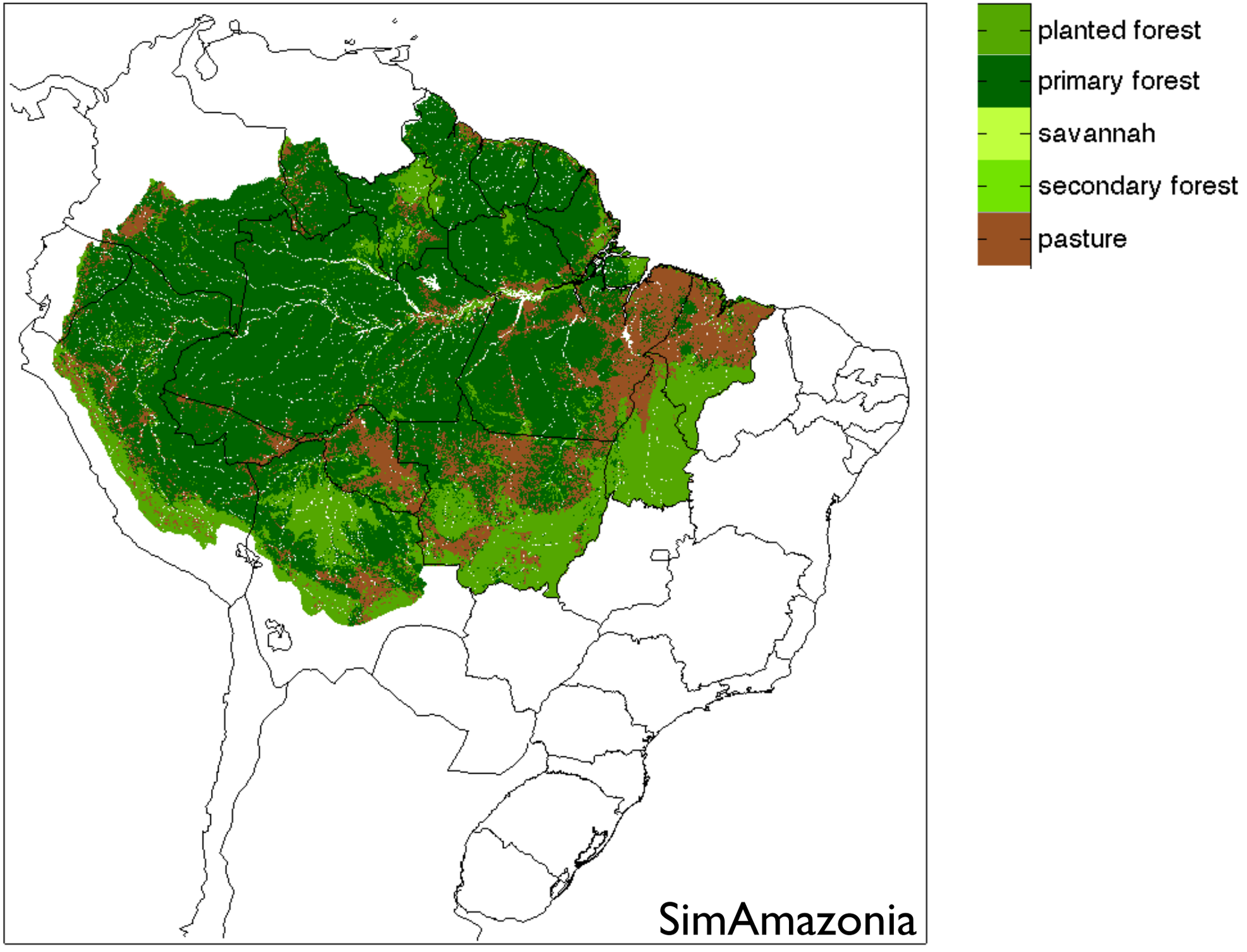


Sugarcane Production Areas



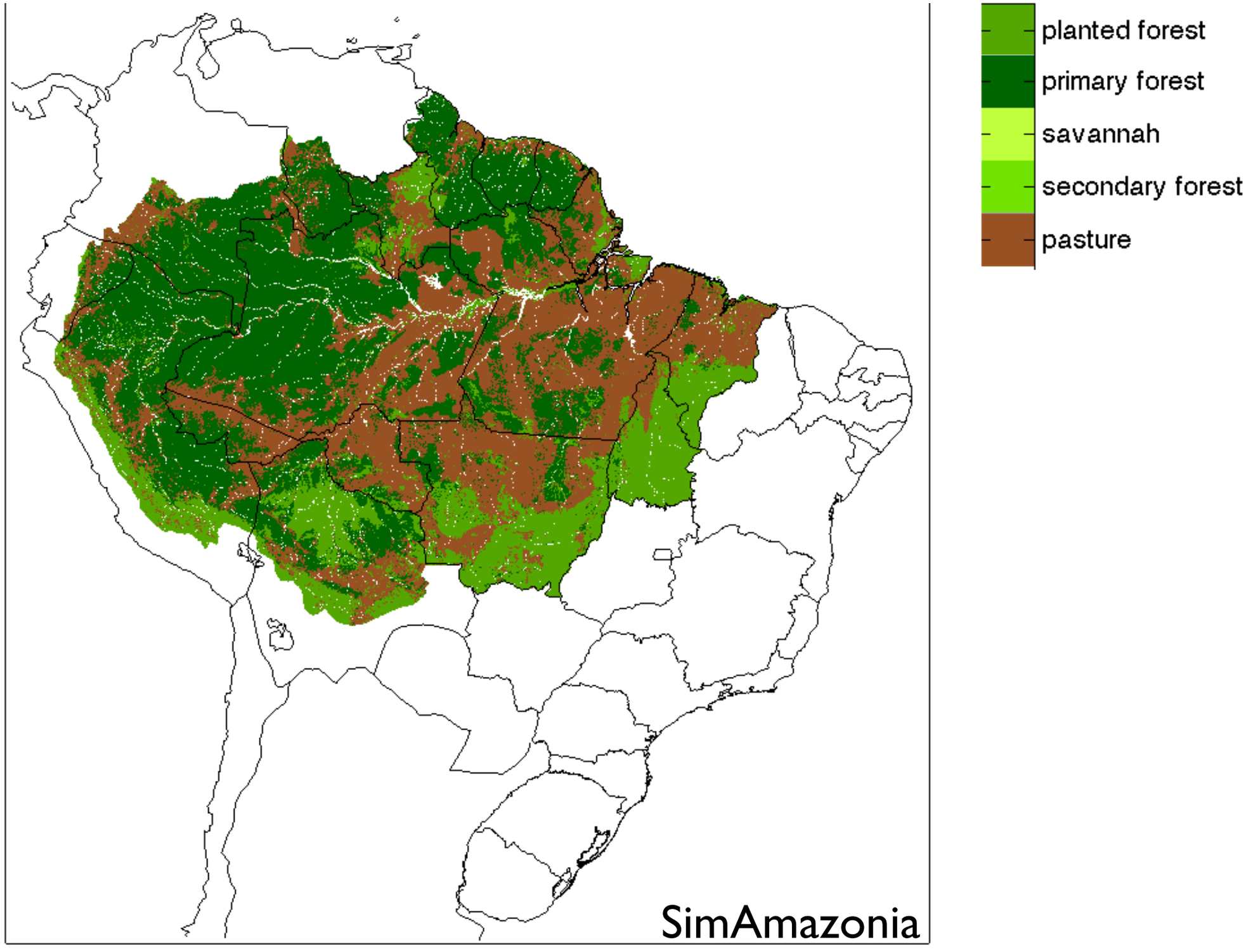
Sugarcane

Land Use in 2010



Soares-Filho et al. 2006

Land Use in 2050



Soares-Filho et al. 2006

Trees keep the surface cooler and wetter

Color:
trees darker than grass

Fluxes of Water:
trees>grasses

Roughness:
trees>grasses

Short
Wave

Long
Wave

depends on
temperature

Latent
Heat

Sensible
Heat

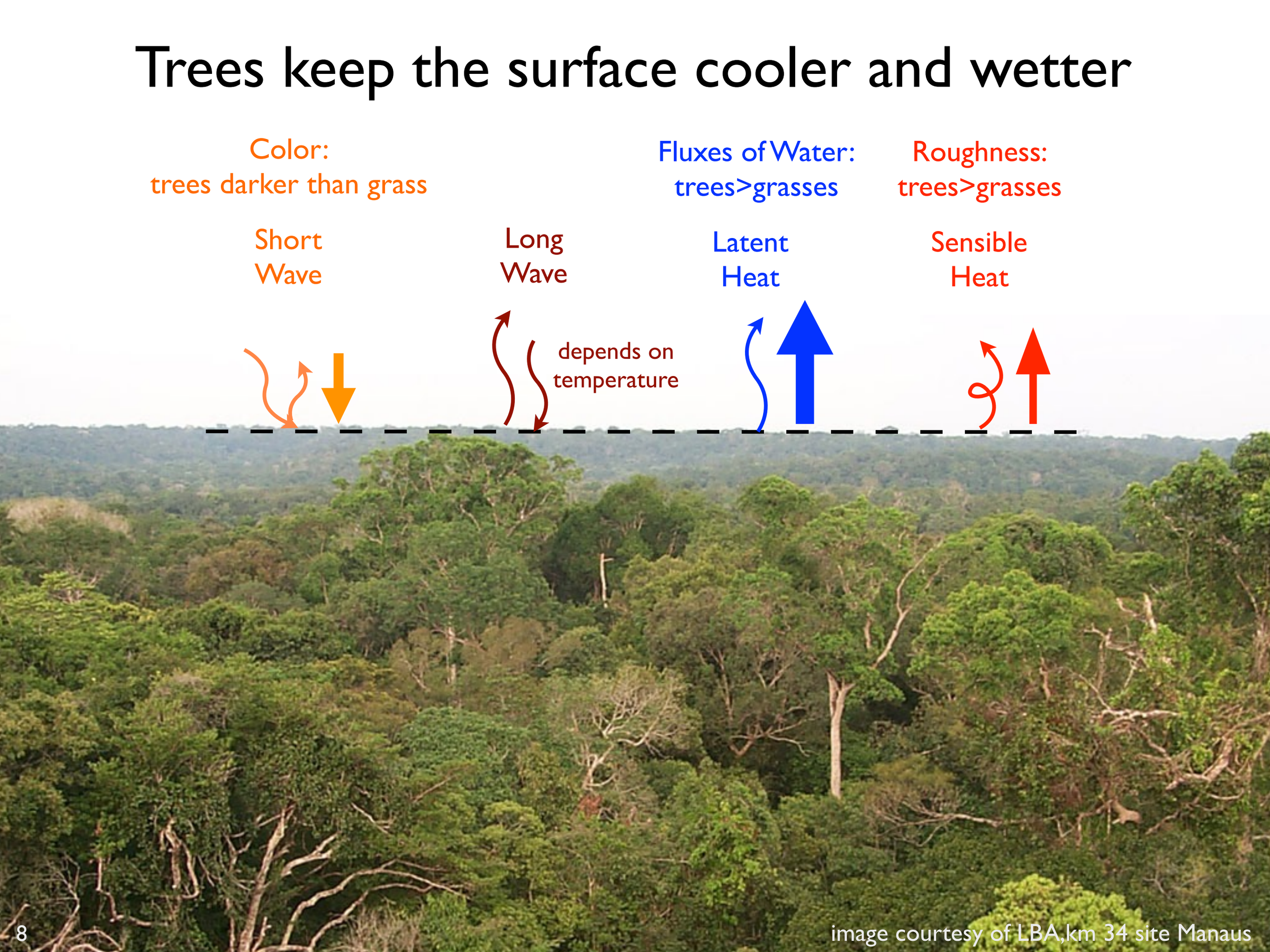
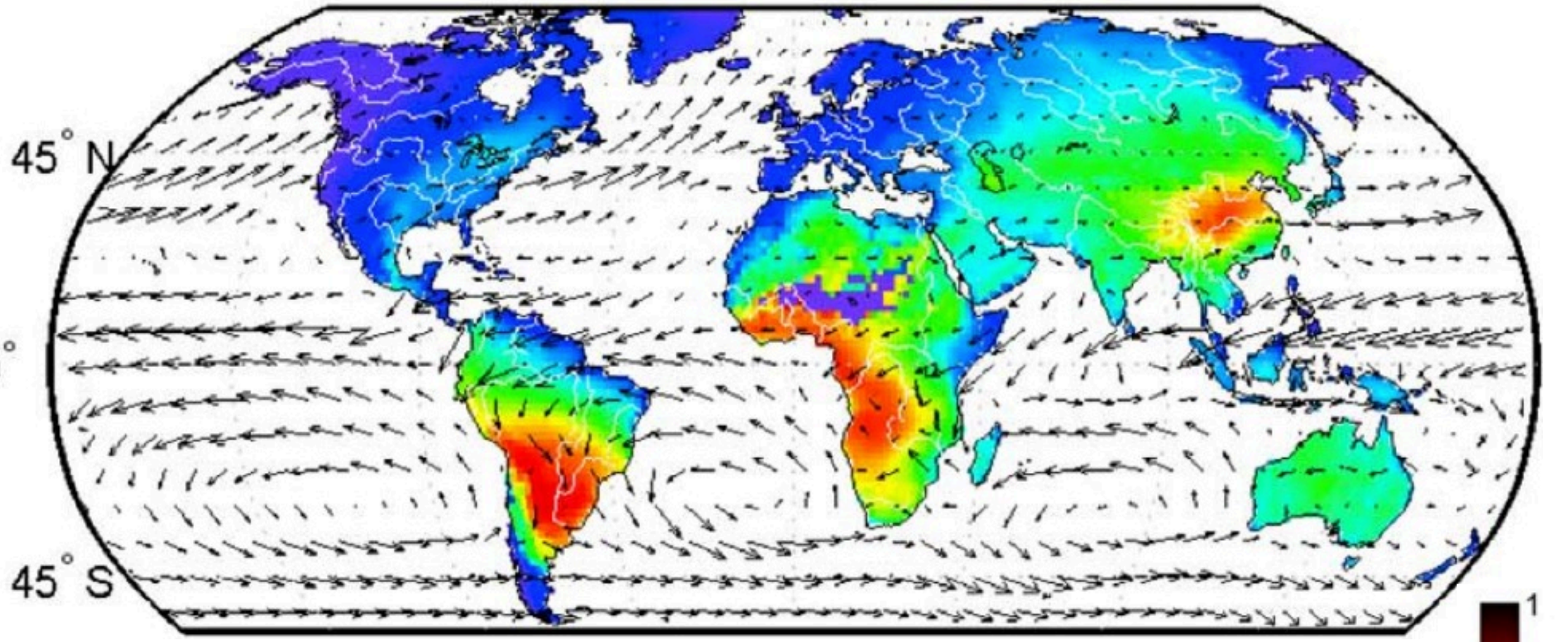


image courtesy of LBA,km 34 site Manaus

Precip depends on evapo-transpiration upwind



Fraction of precipitation originating from evaporation from the land surface

precip recycling ratio for January, van der Ent et al. 2010

What will happen when forest ⇒ crops?

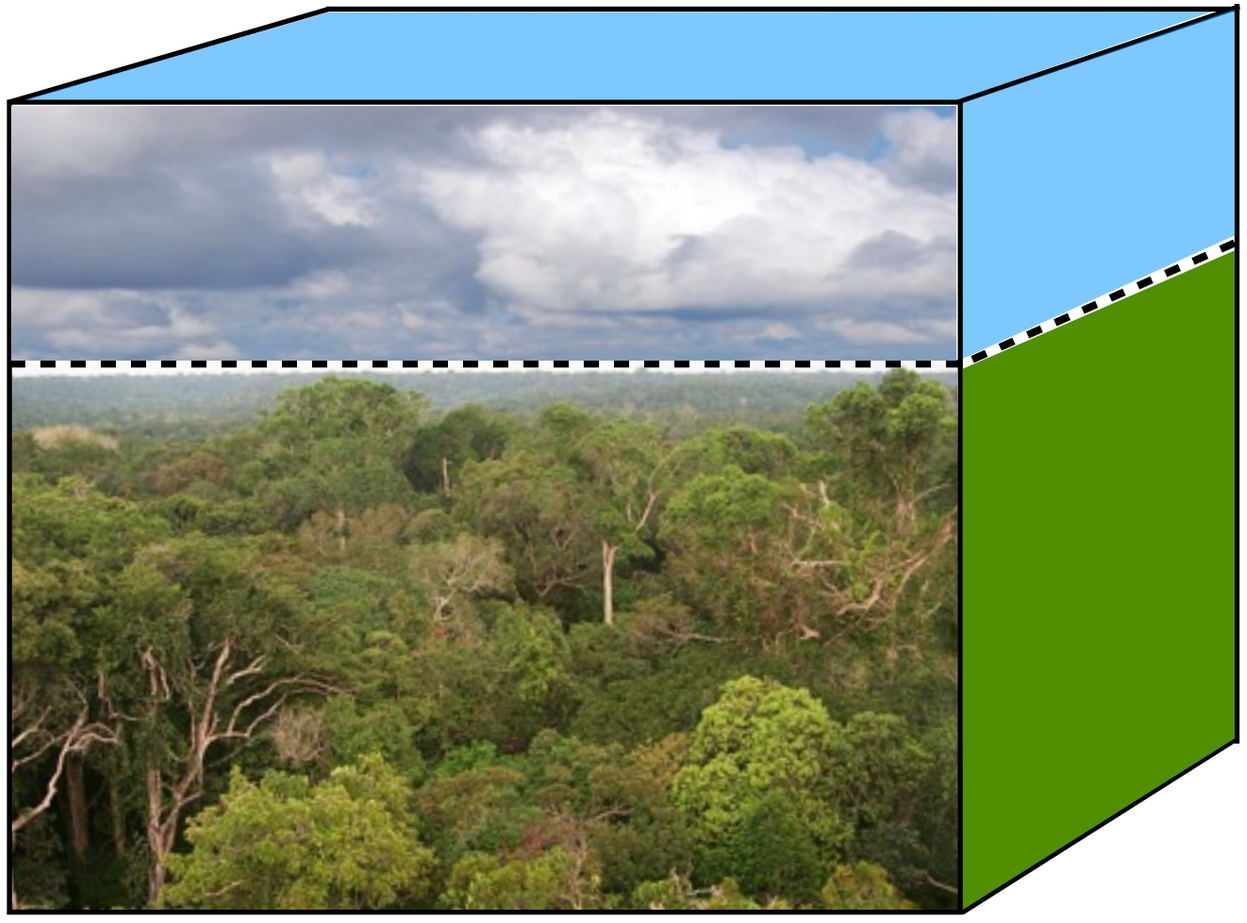
- changing from trees to crops will likely make it drier and therefore warmer
- drying and warming will effect the functioning of the forest itself, but may also impact precipitation over a larger region through atmospheric circulation.

Tools: Land and Atmosphere

Tool: a numerical model of the Amazon forest ecosystem (ED2) coupled to an atmosphere (BRAMS).

Atmosphere: BRAMS

Land Surface: ED2



convection
radiation
circulation
precipitation

photosynthesis
transpiration
evaporation
growth
mortality

Modeling Plants - Ecosystem Demography

1. direct competition for resources

+

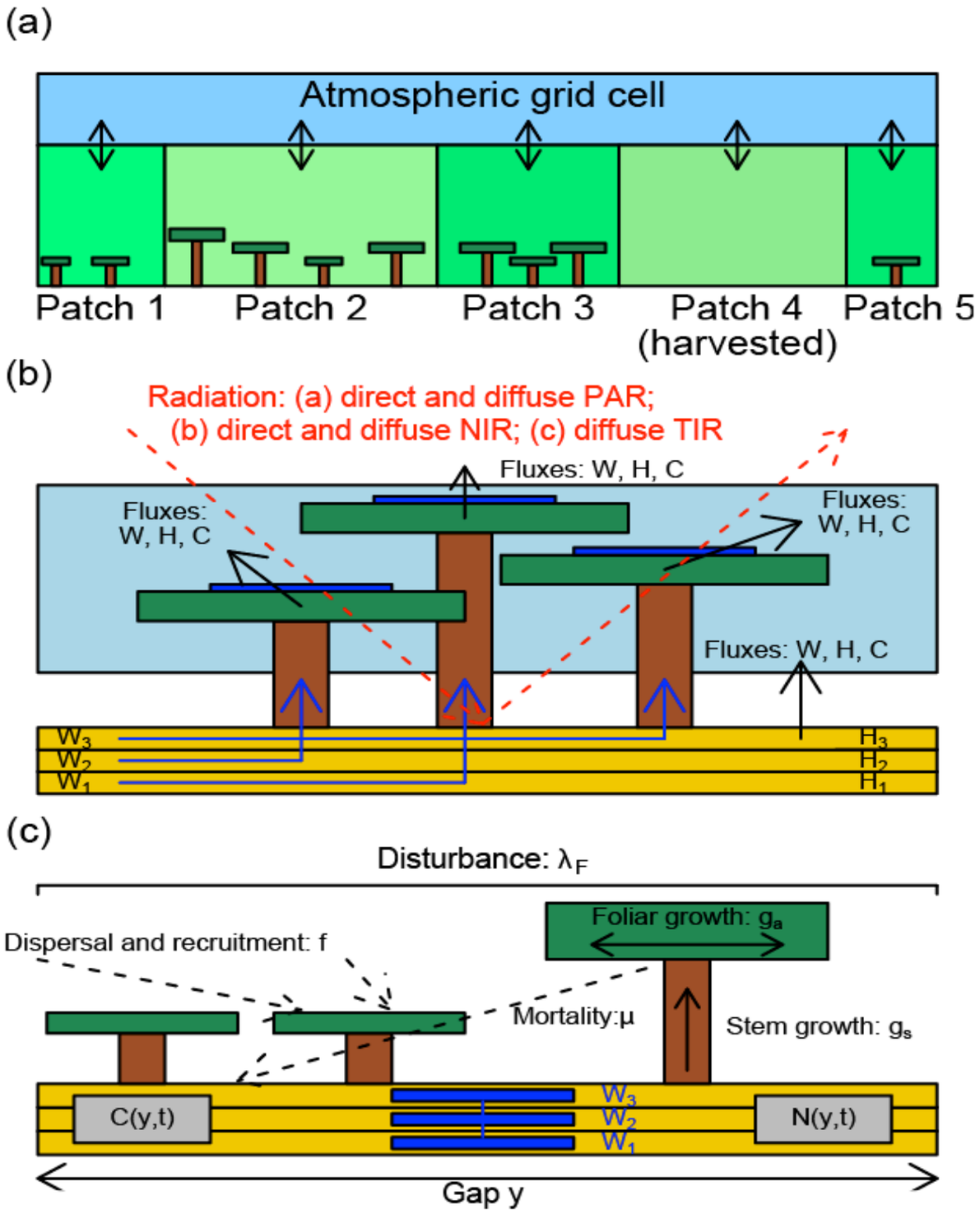
2. disturbance

=>distribution of patches with different disturbance histories (age)

=>distribution of sizes and types of plants in each patch

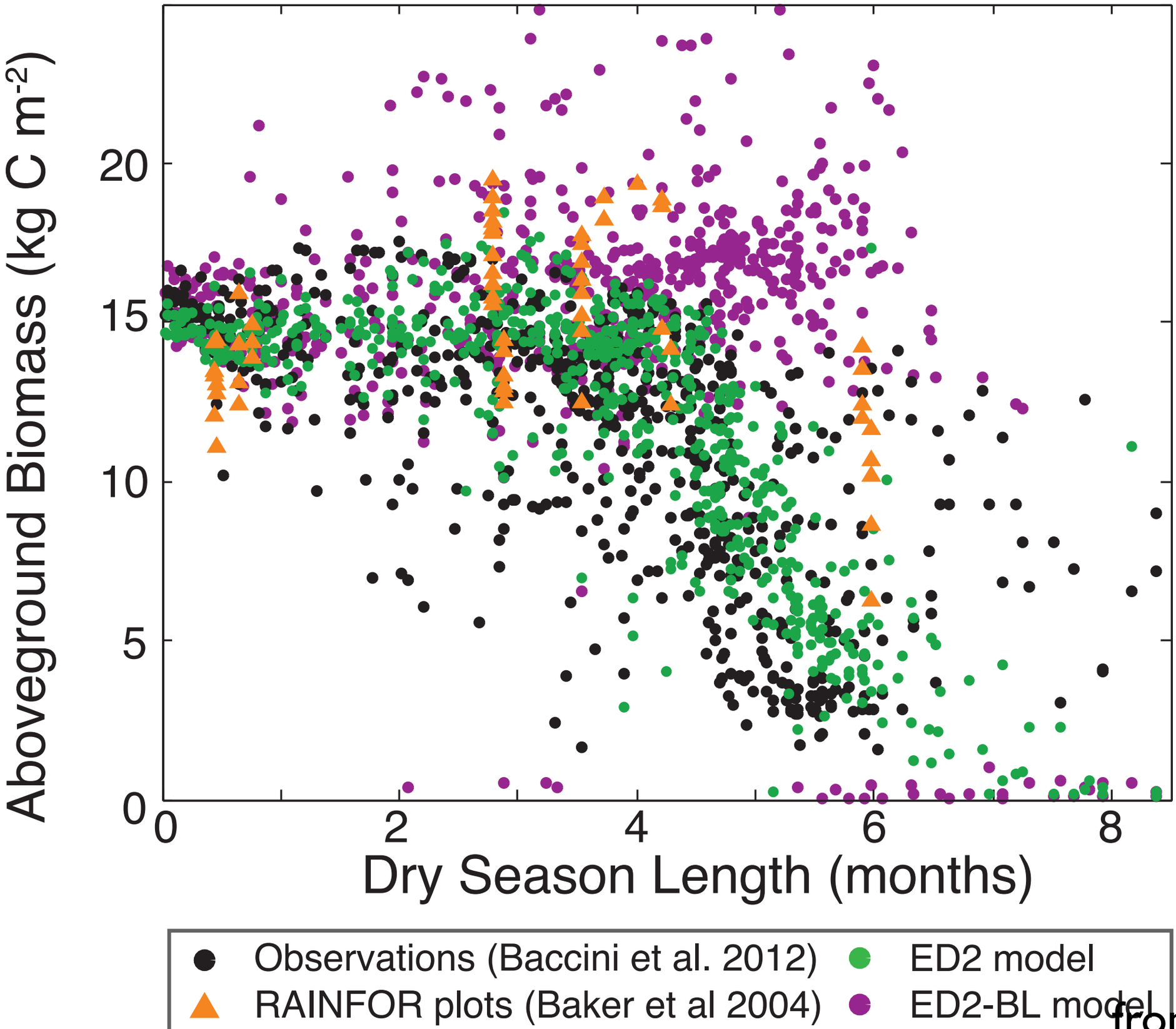
Tools: The Ecosystem Demography Framework

- The average of individuals does not equal the average individual
- Plants are defined by their physiologic properties
- Succession is an emergent property
- Timescale of change is emergent and variable



Moorcroft et al. 2001
Medvigy et al. 2009

ED captures spatial variability in biomass across the Amazon

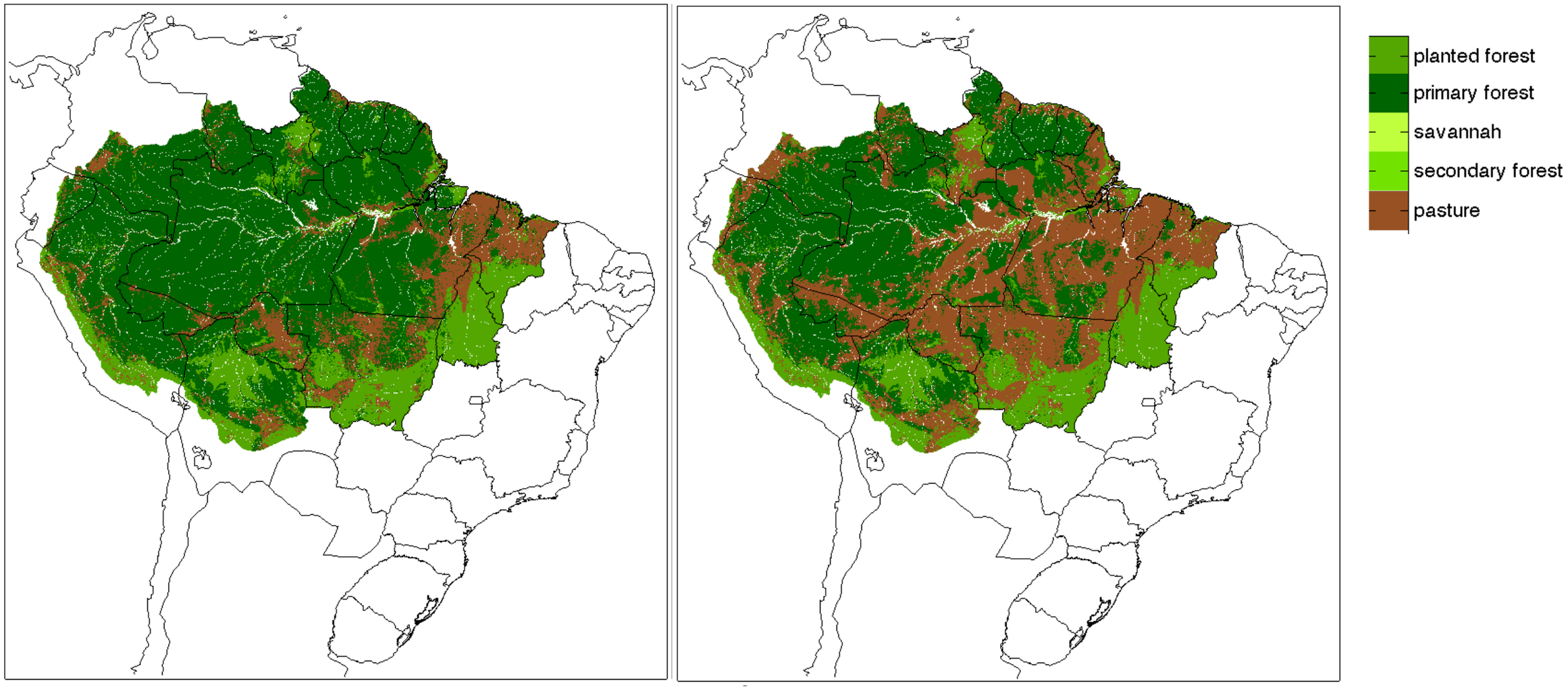


from N. M. Levine

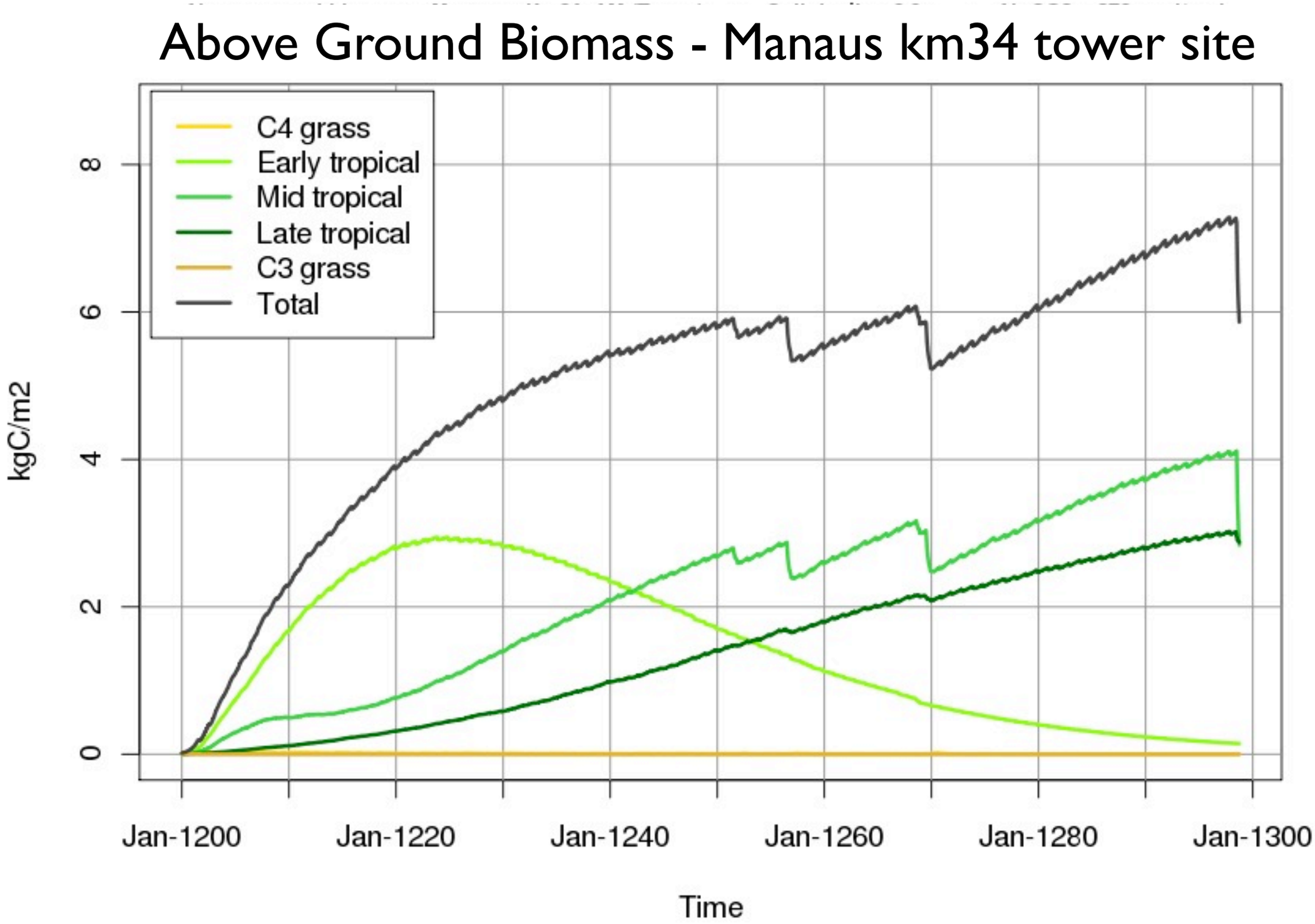
Imposed Land Use Change: 2010 to 2050

CLU = Current Land Use.

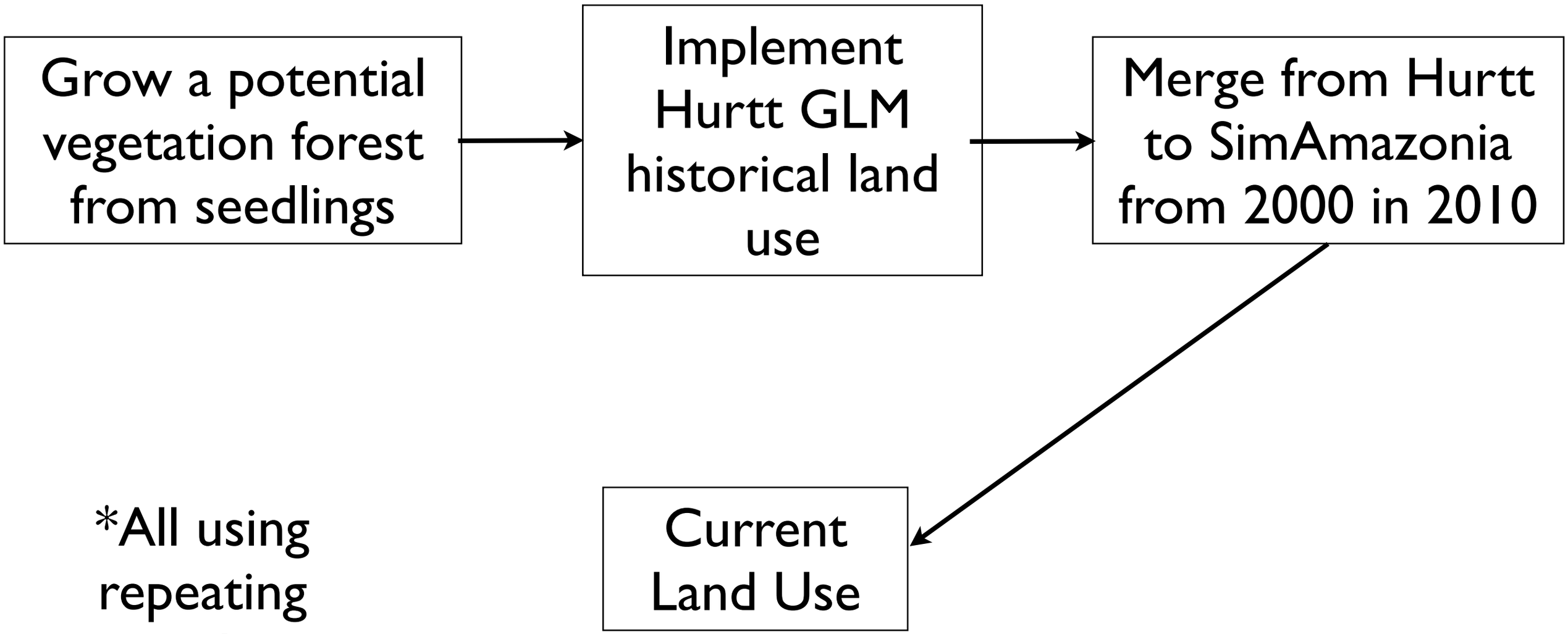
LU = Future Land Use. From SimAmazonia 1 in year 2050



Spin-up Process: grow seedlings to an equilibrium forest at every gridpoint



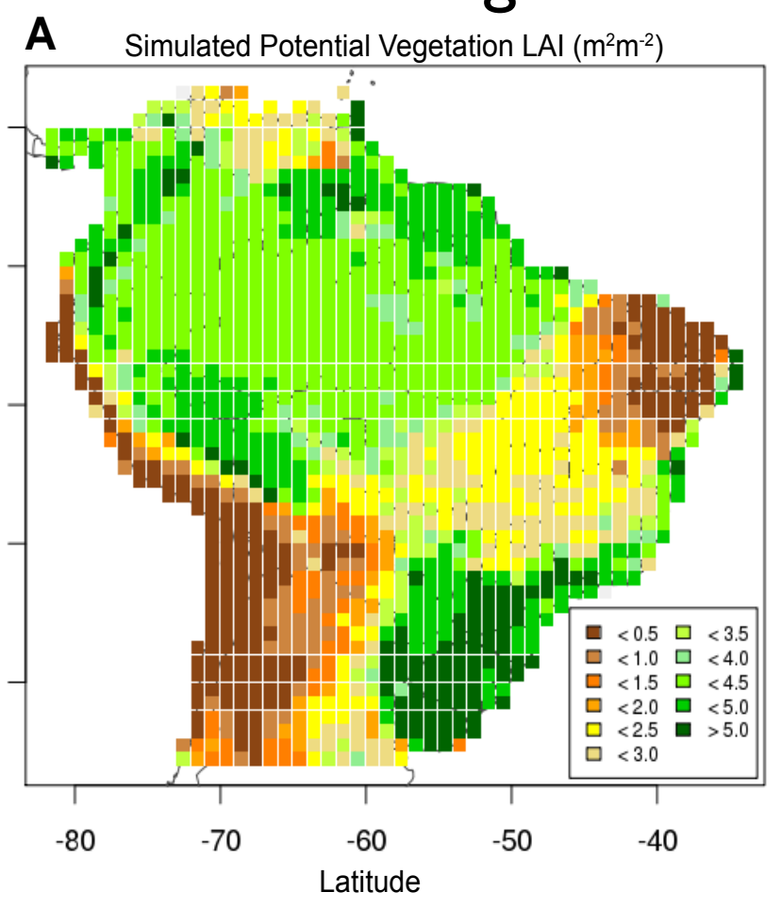
Spin-up Process - All offline land



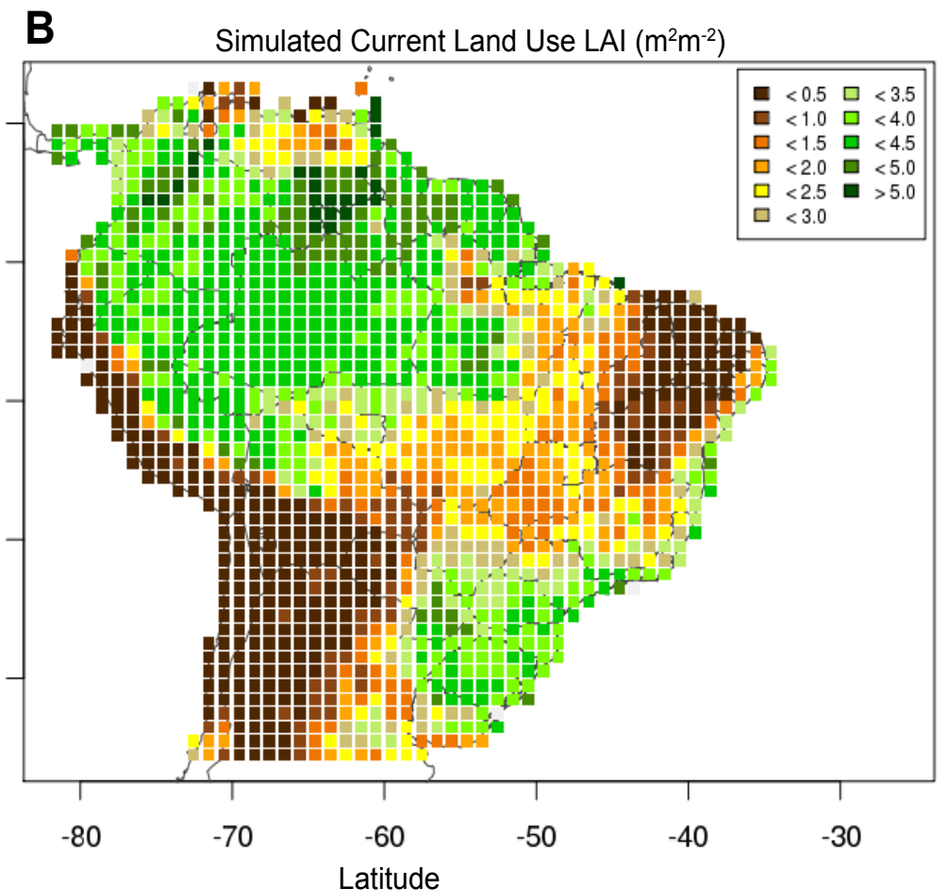
*All using repeating reanalysis (Sheffield)

Potential and Current Veg compared to Satellite

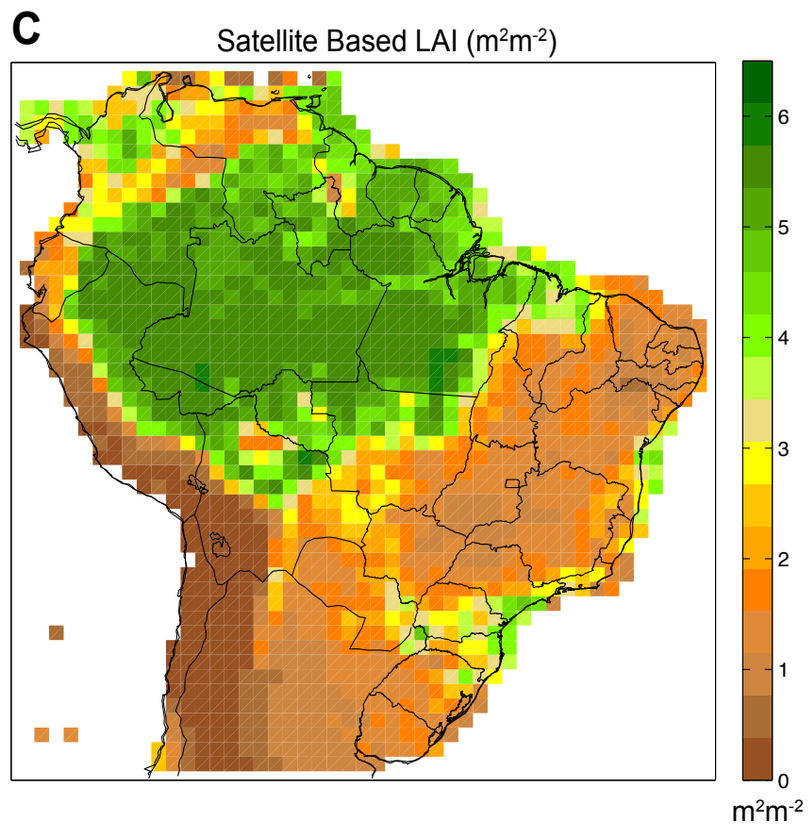
Potential Vegetation



Current Land Use



MODIS LAI

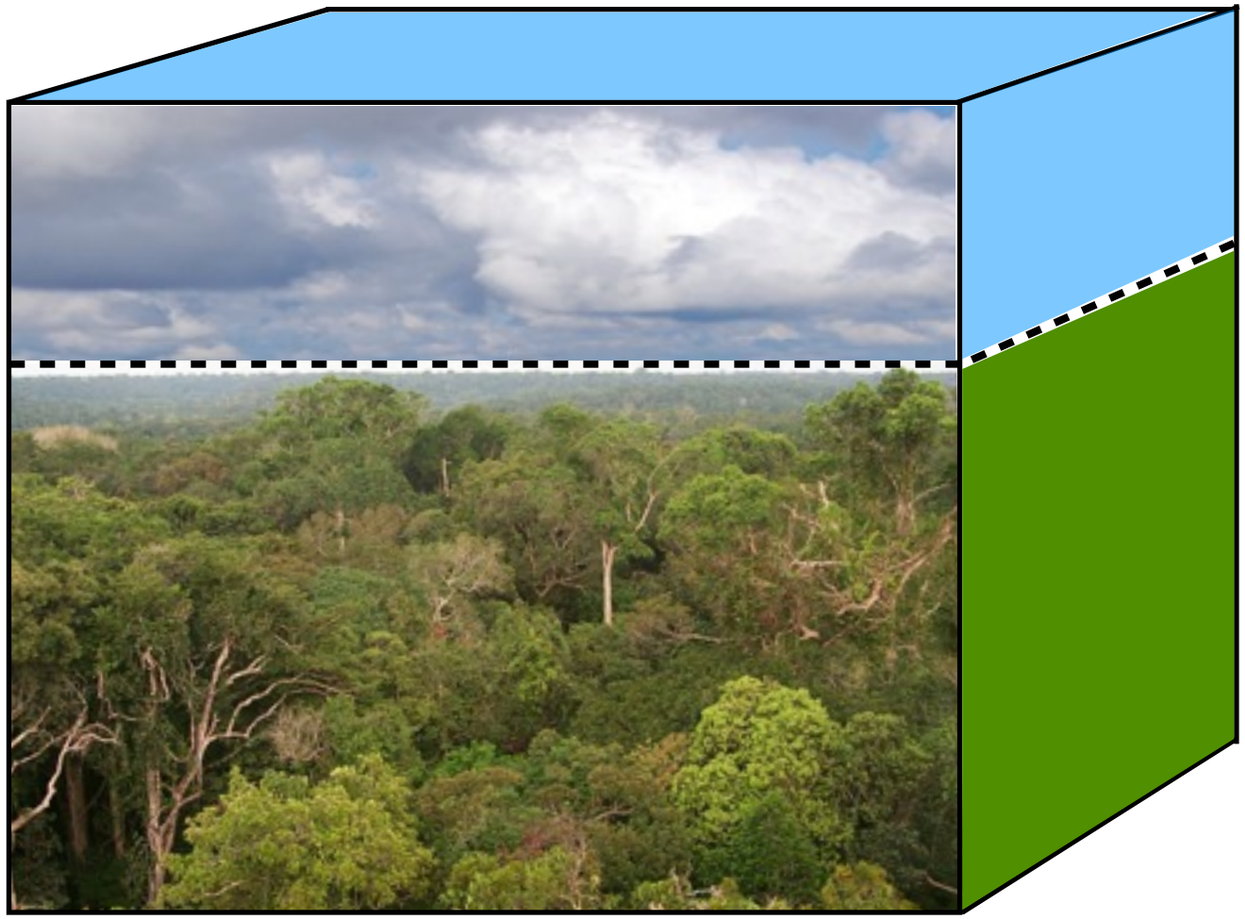


ED-BRAMS

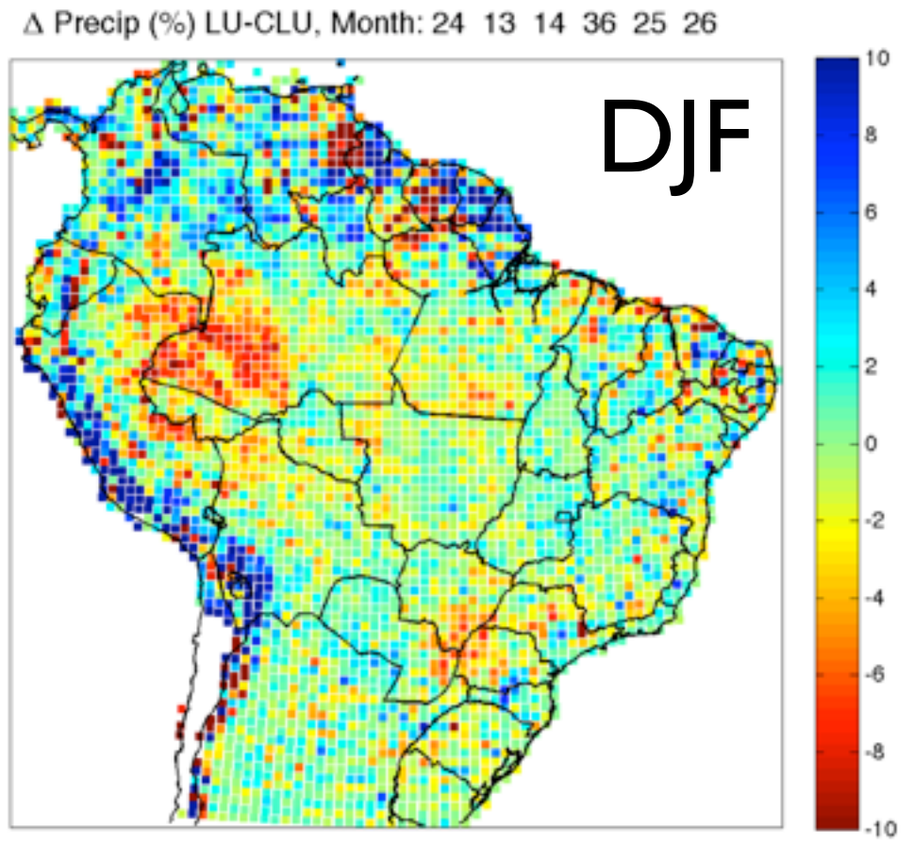
- Boundary conditions from ERA-Interim
- Identical simulations other than land use
- currently have 3 years of simulation
  - runs ~2 months simulation/day on 96 cores on the Harvard cluster

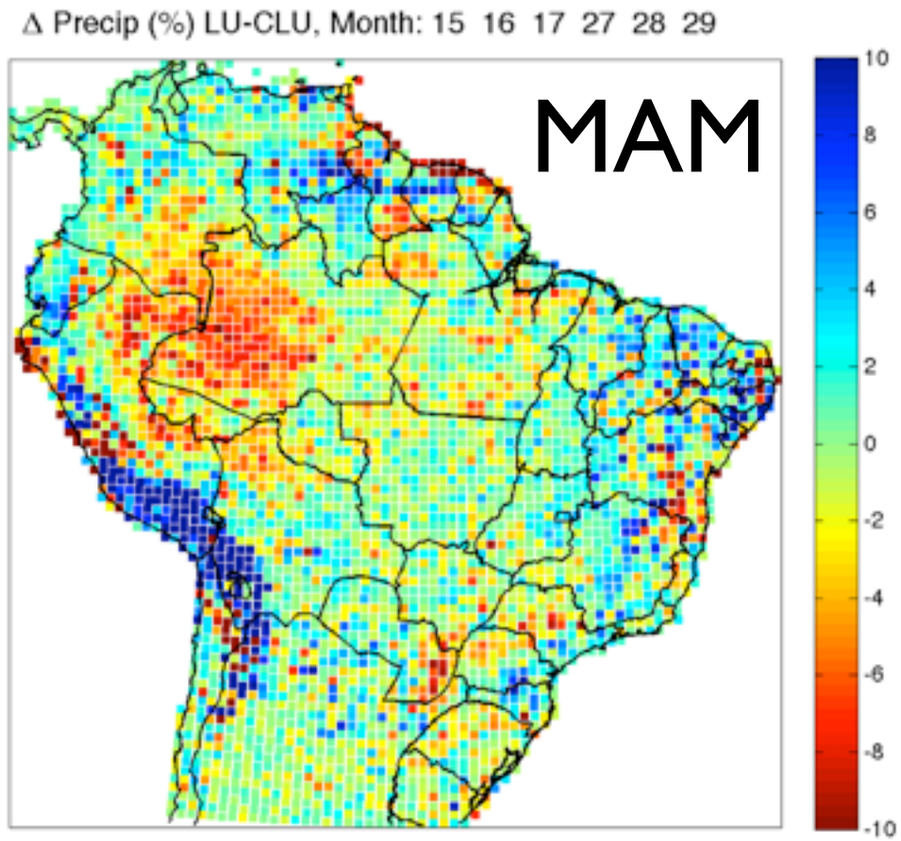
Atmosphere: BRAMS

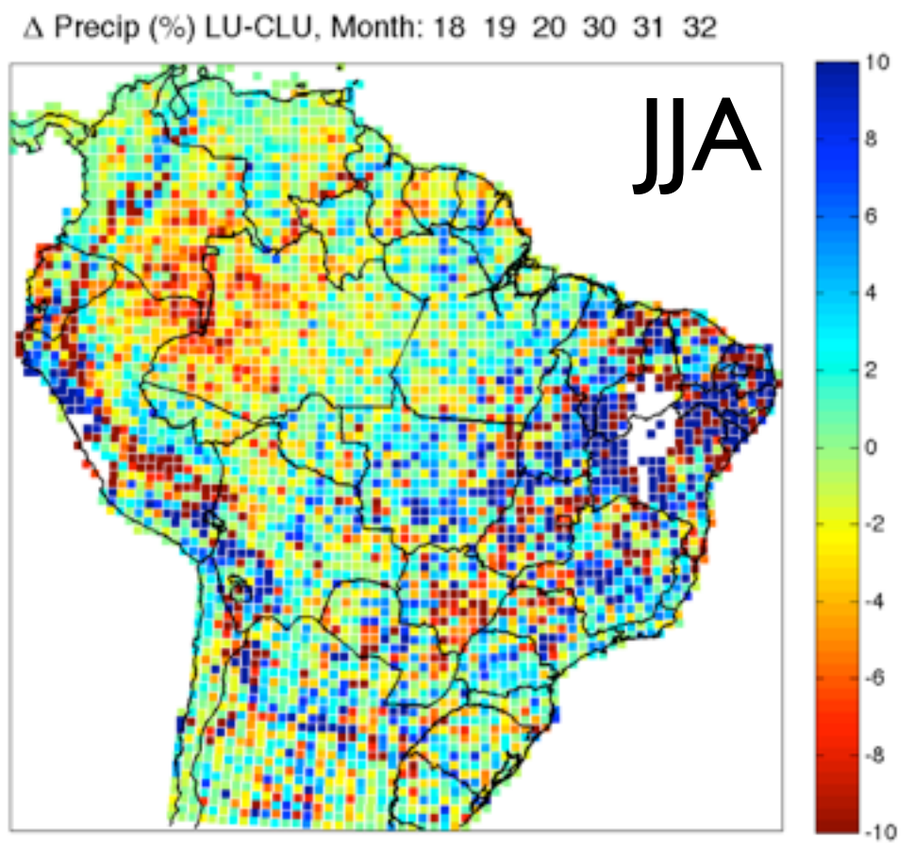
Land Surface: ED2

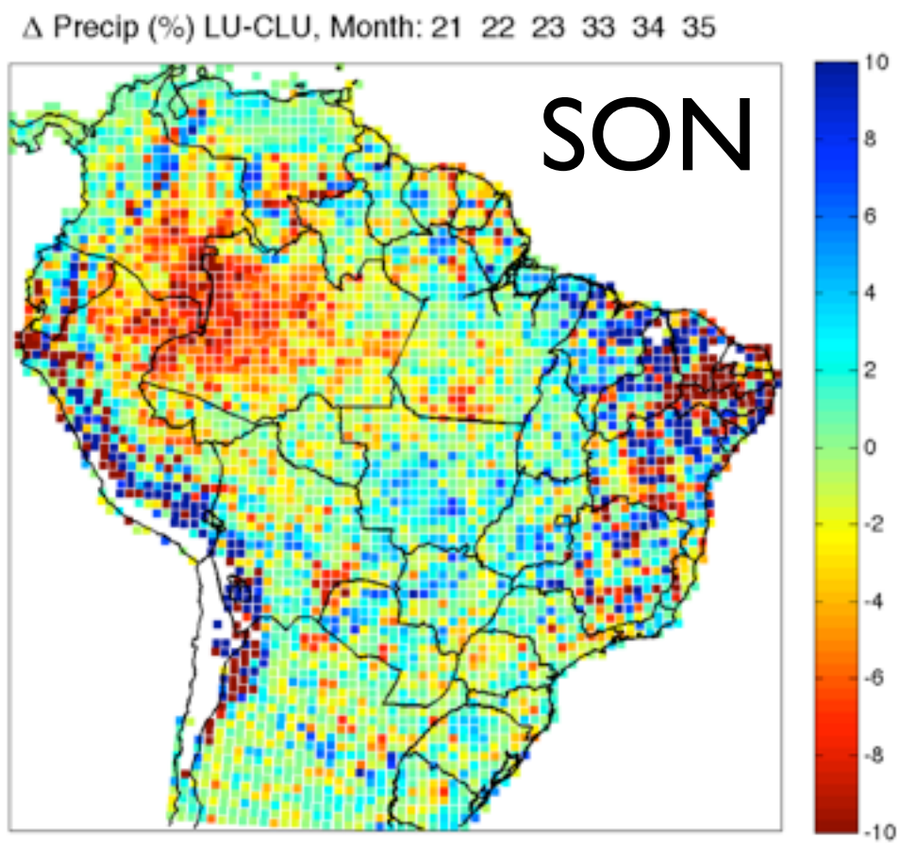


Delta Precipitation (%) (Future LU - Current LU)









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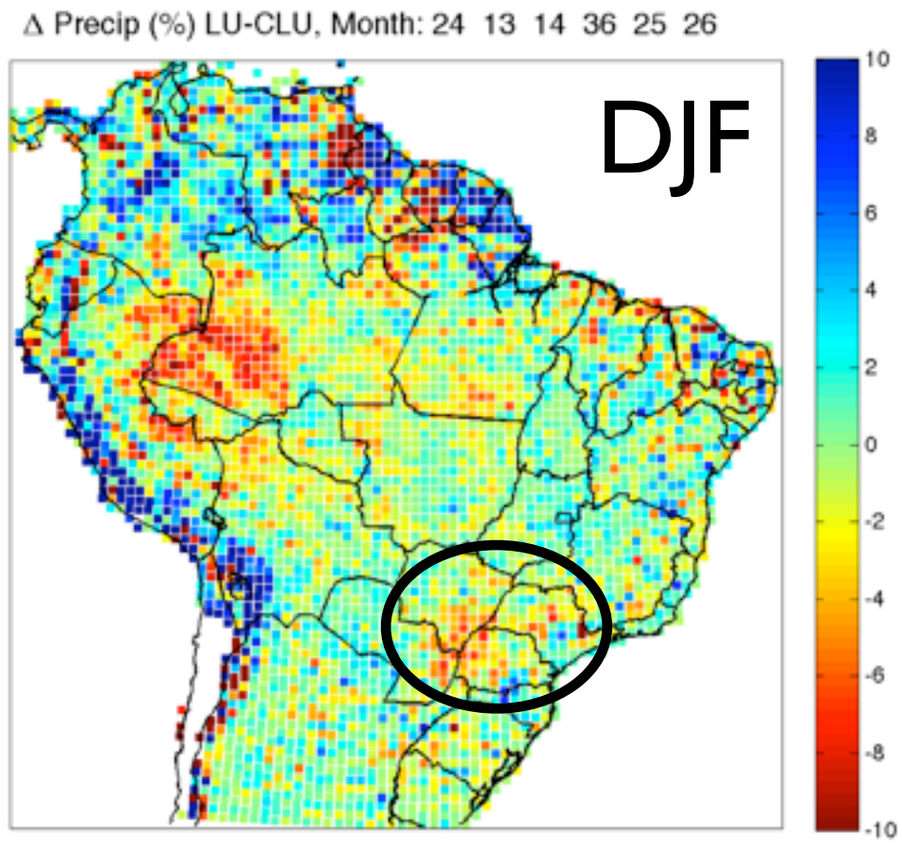
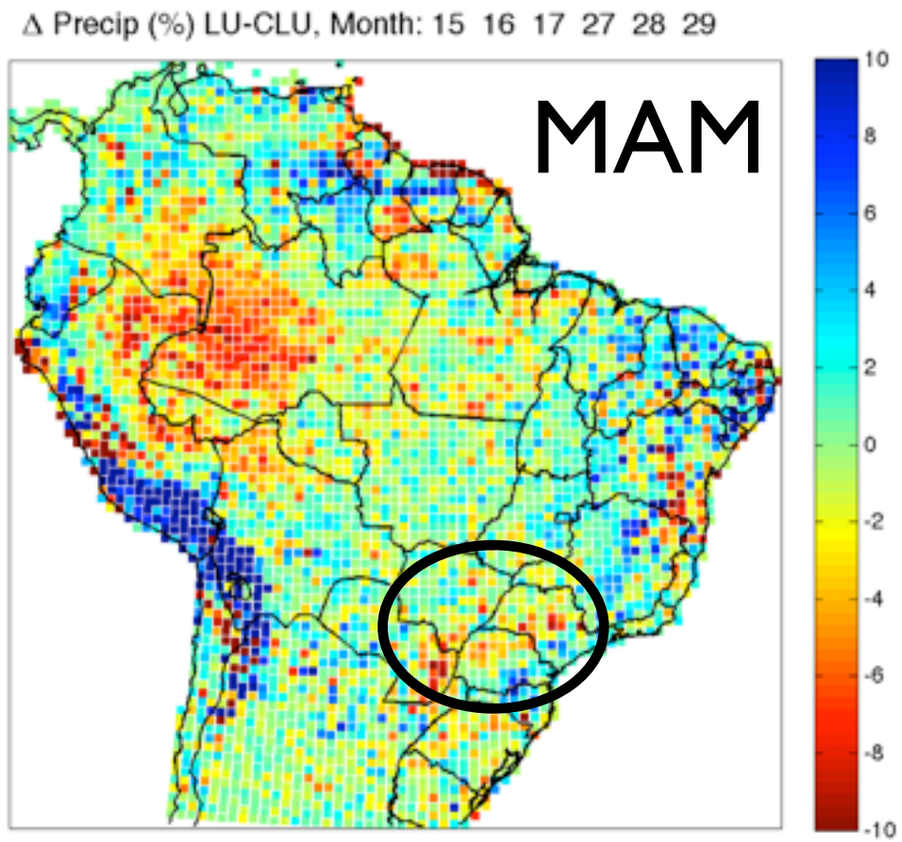
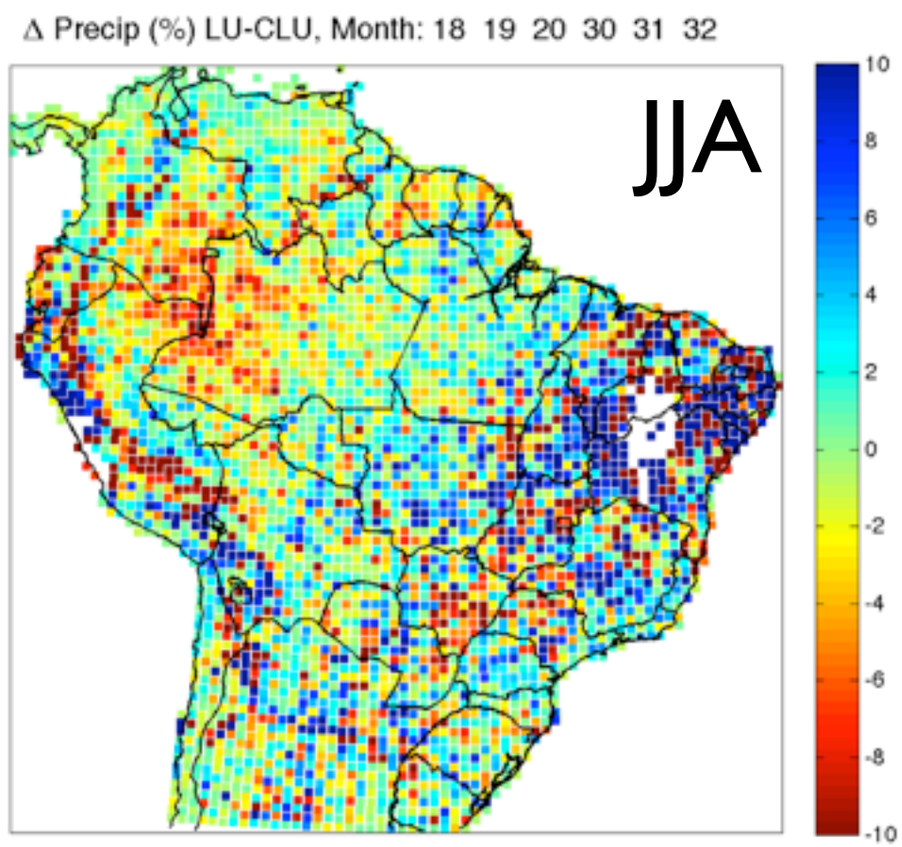
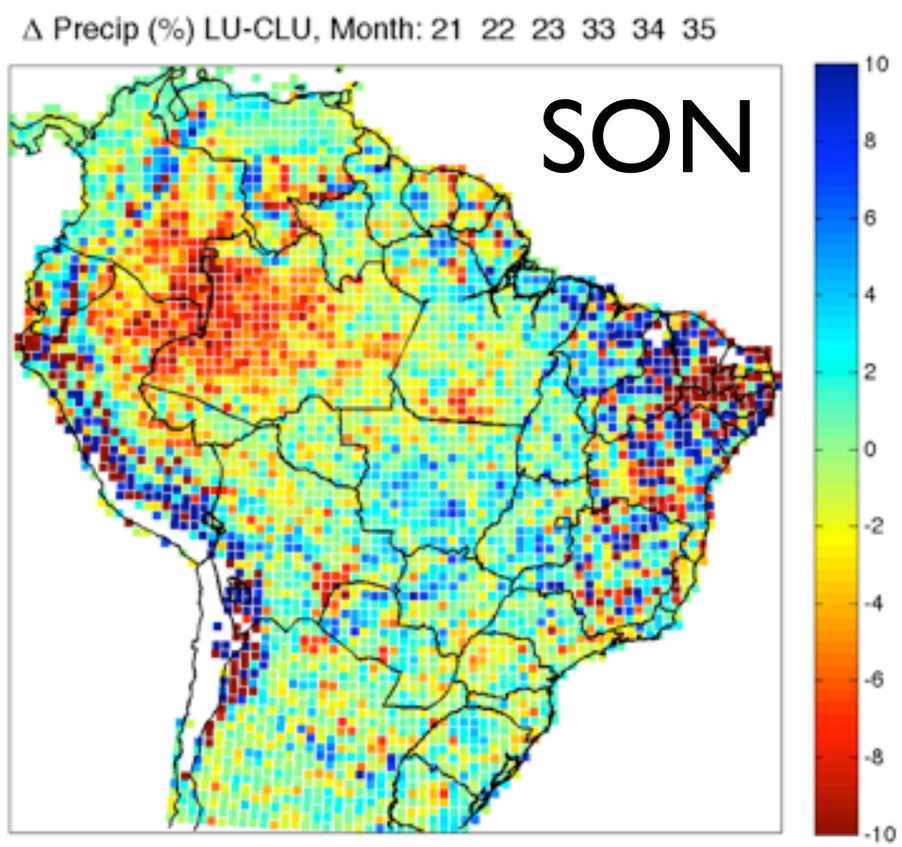
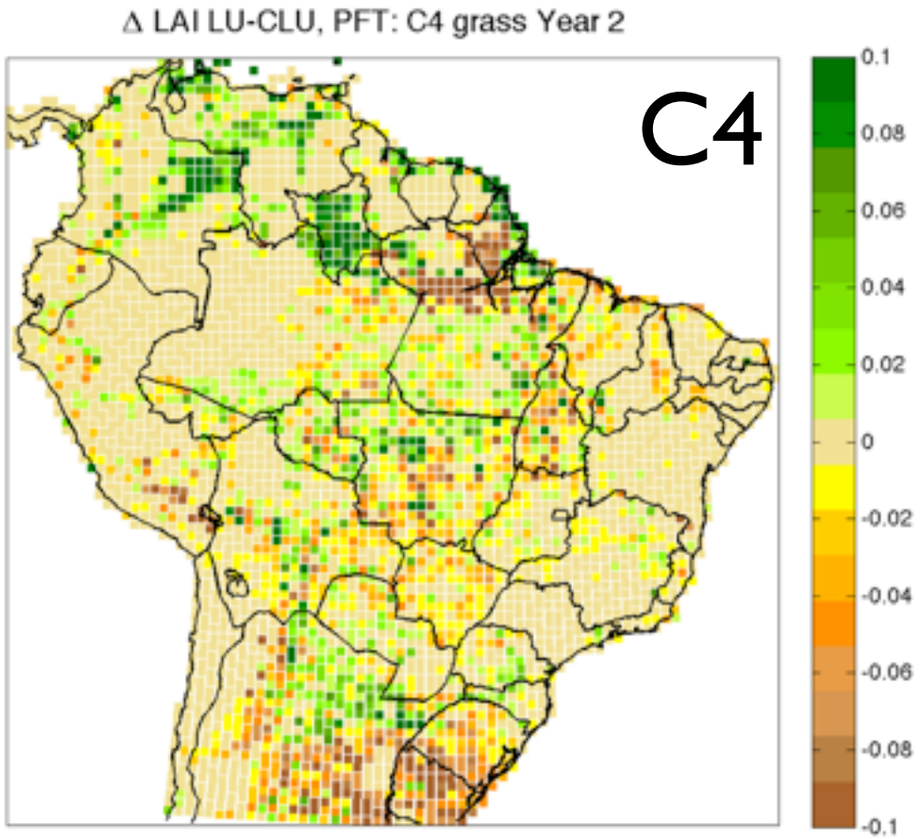


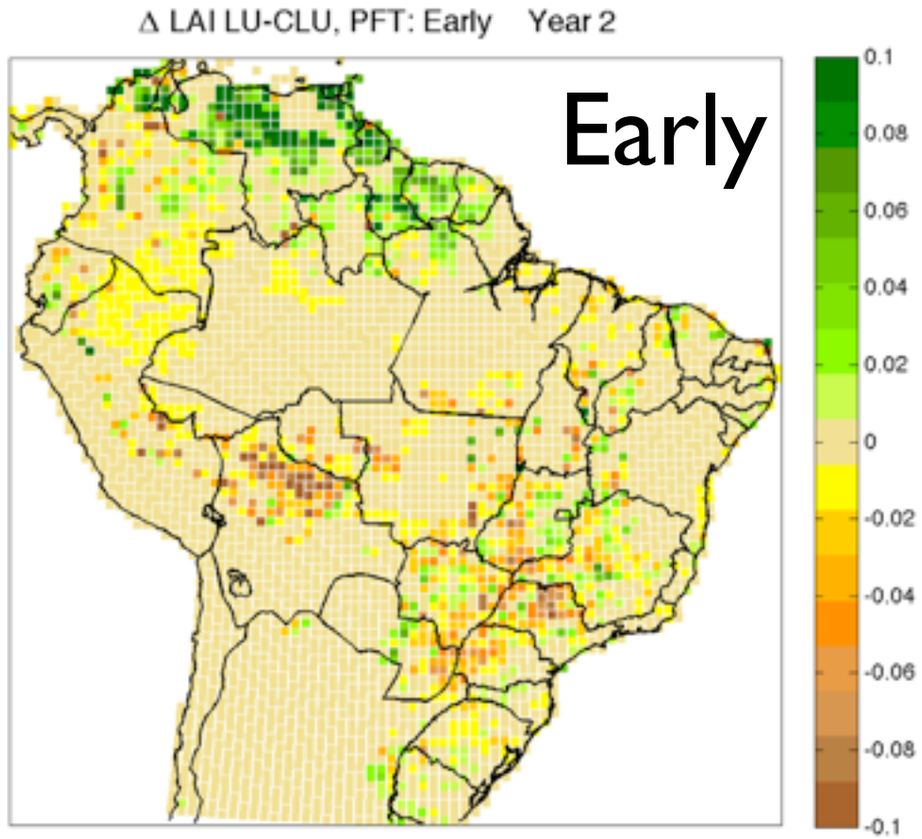


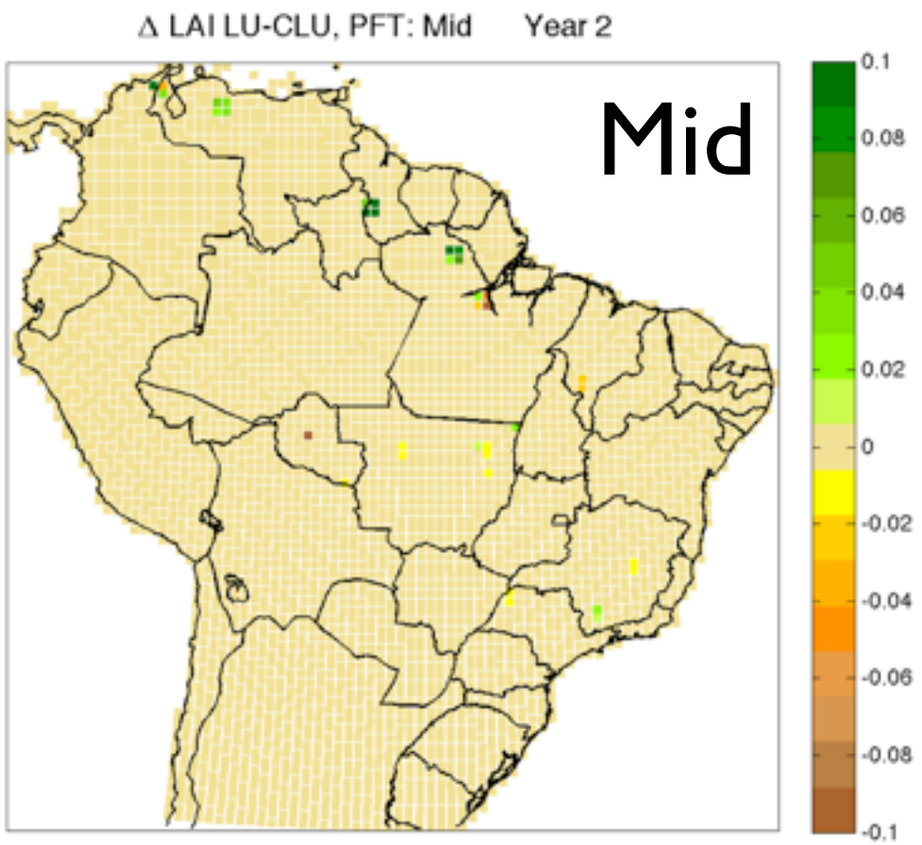


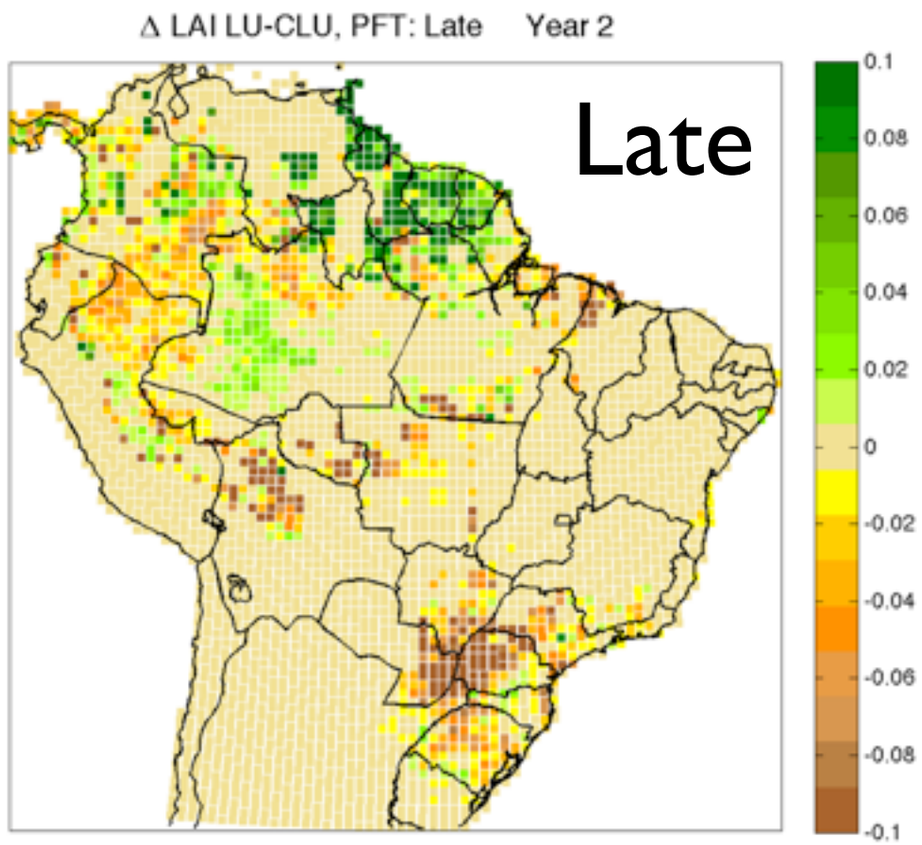


Delta LAI (m^2/m^2) (Future LU - Current LU)

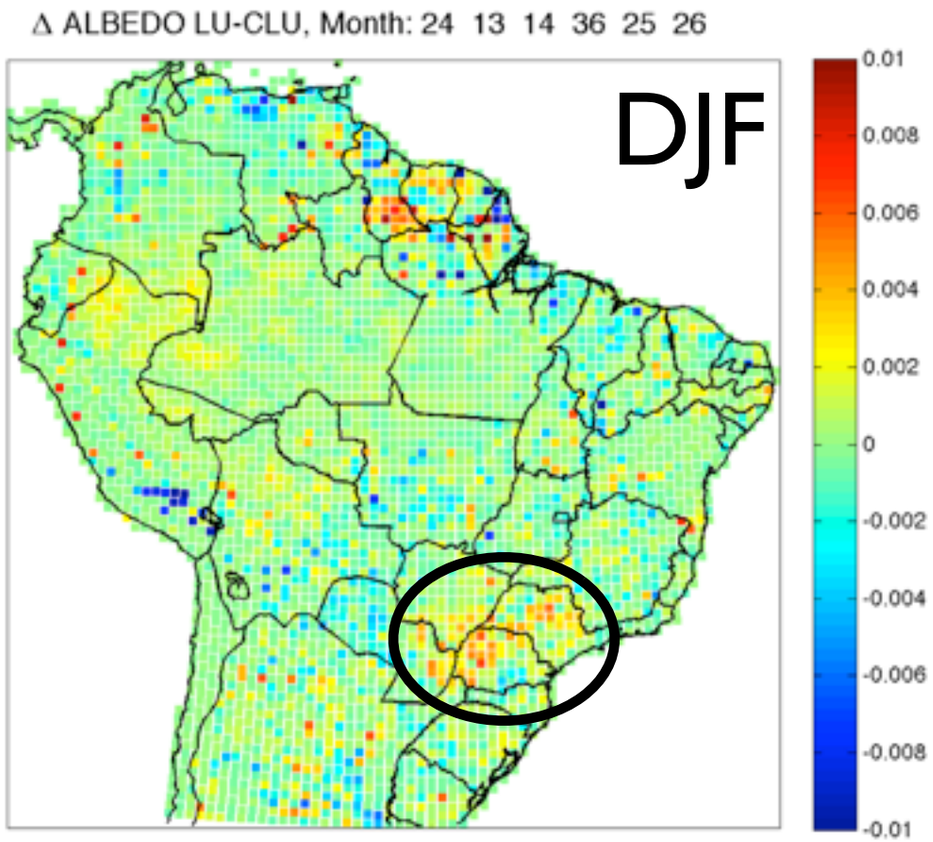


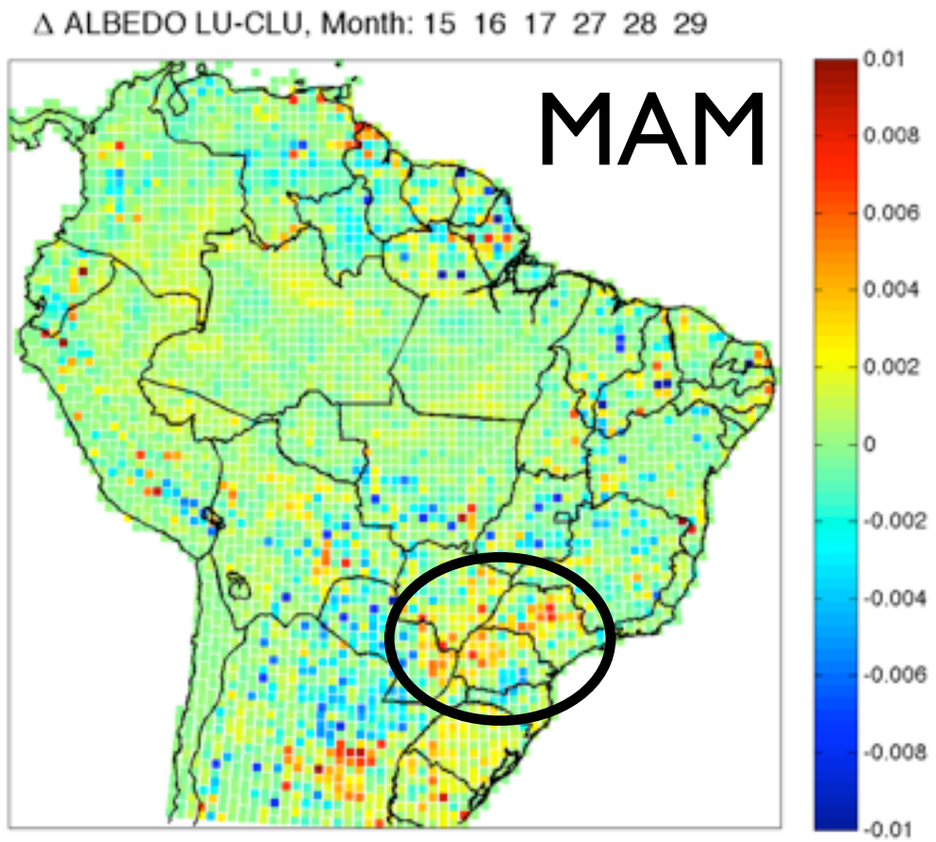


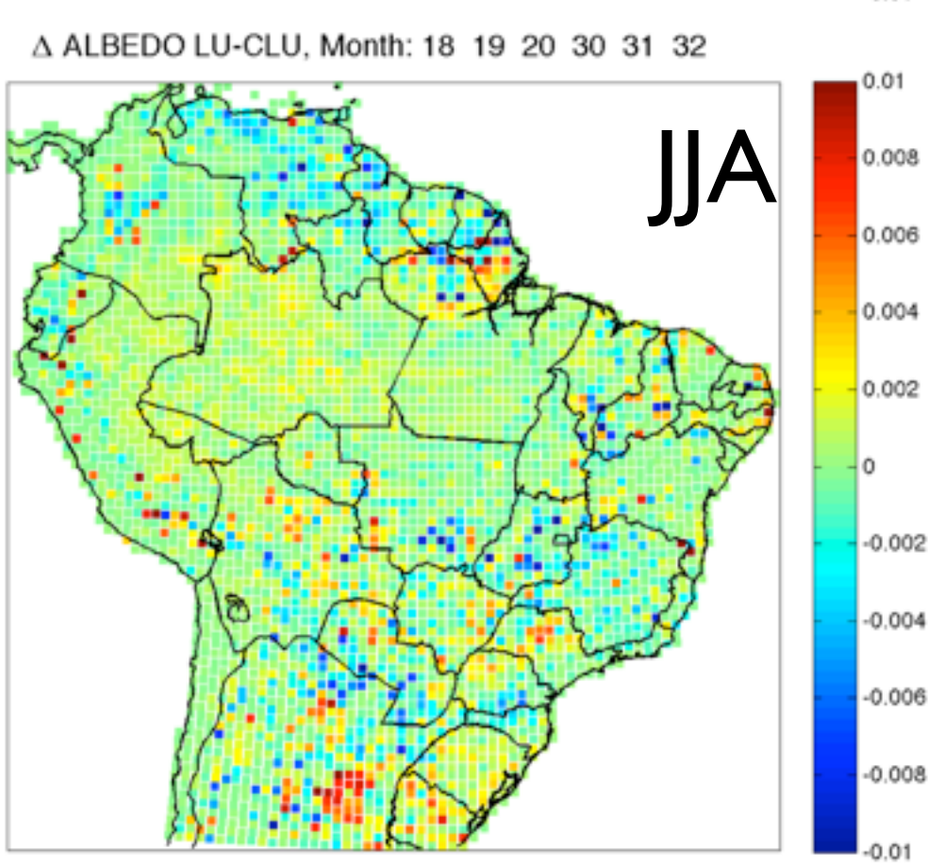


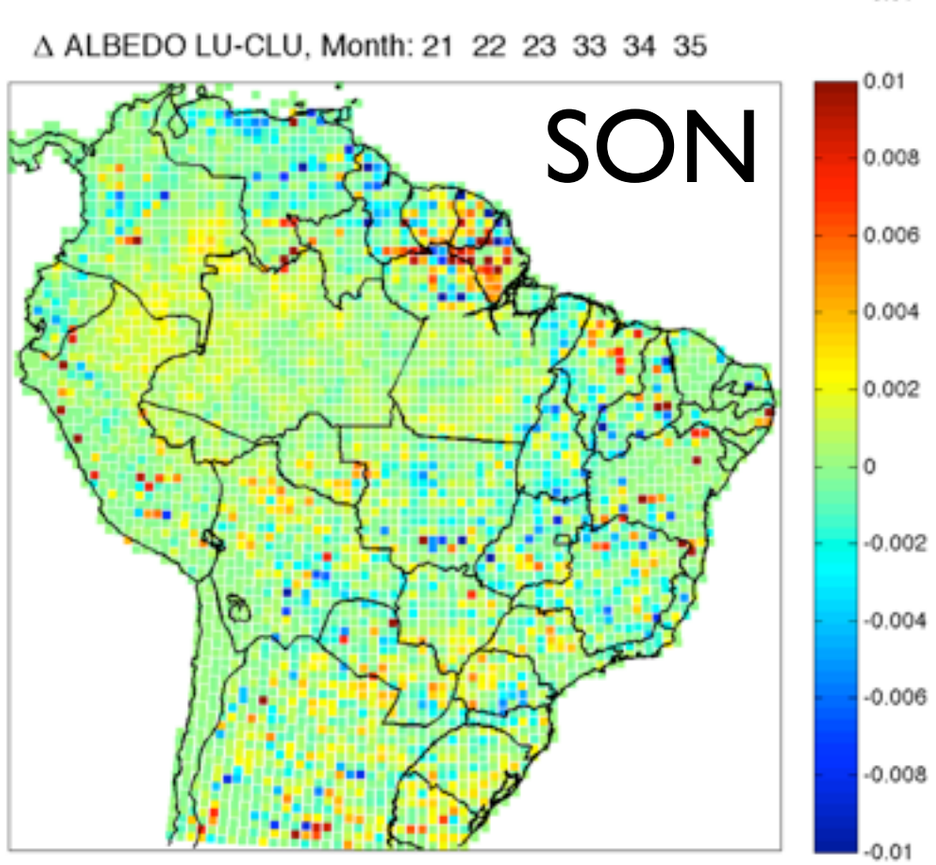


Delta Albedo (Future LU - Current LU)







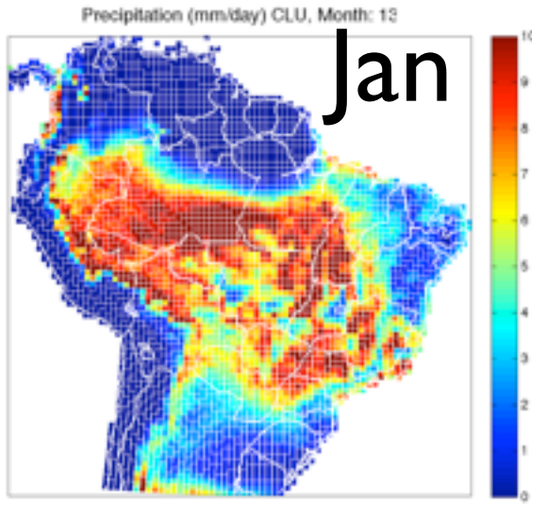


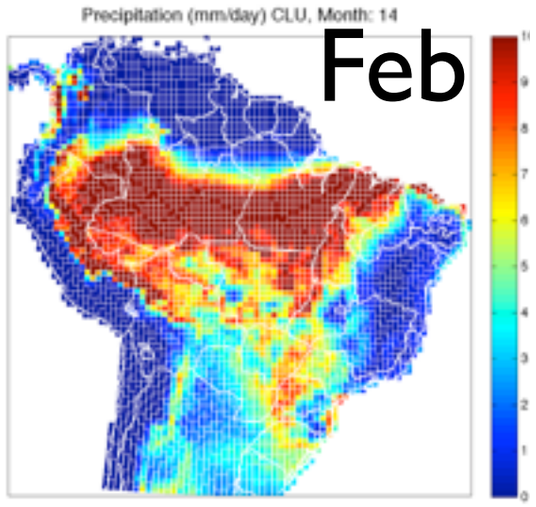
(Very Preliminary) findings from the impact of Land Use Change in the Amazon

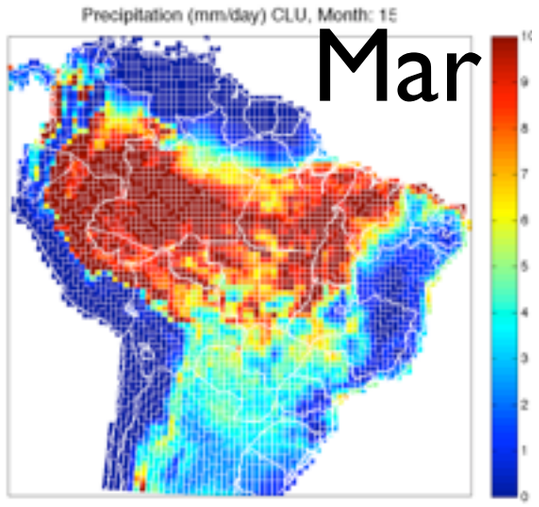
- Spin-up of model creates a reasonable starting point for future simulations
- There is a slight reduction of precipitation, LAI, and albedo over agricultural regions in Southern Brazil with Land Use Change
- More years of simulation are needed to detect significance of changes

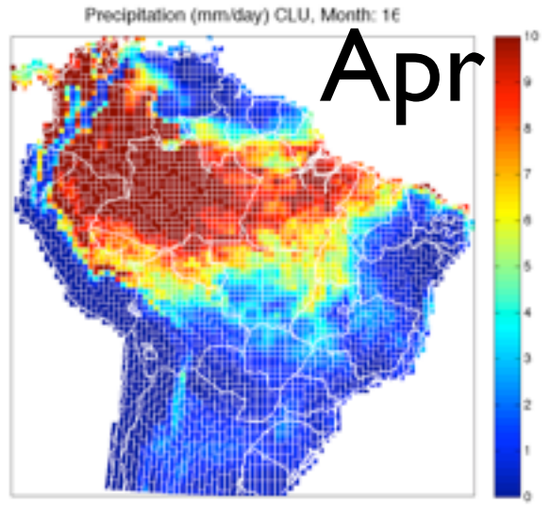
Thanks!

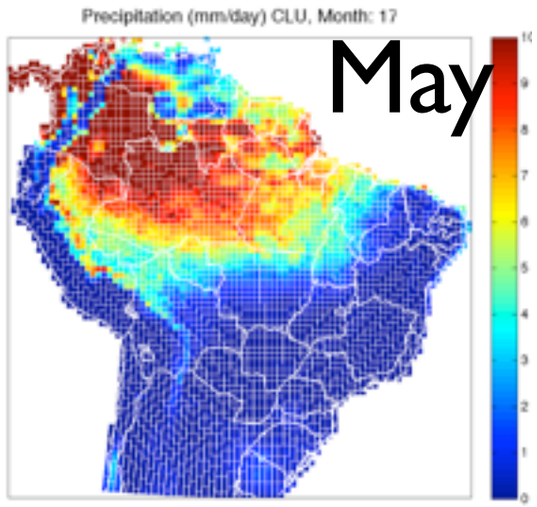
Precipitation (mm/day), current land use

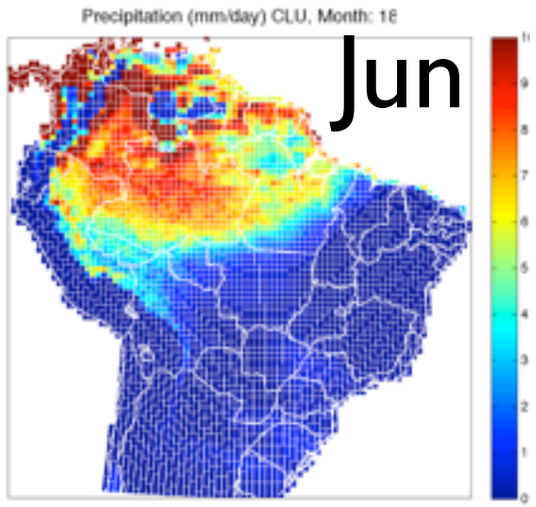


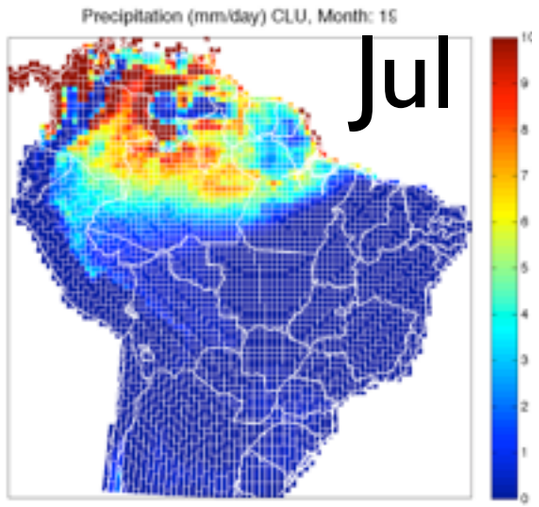


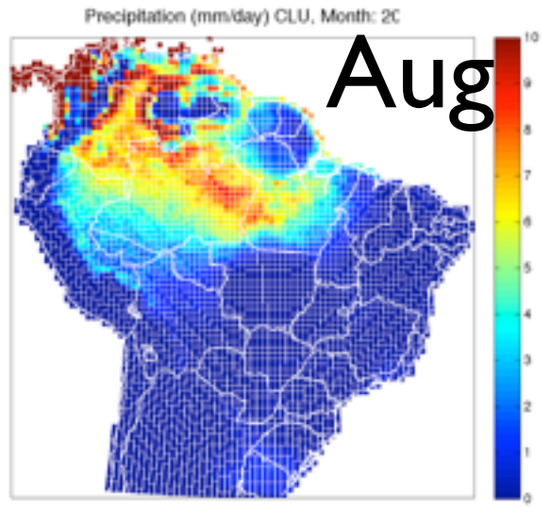


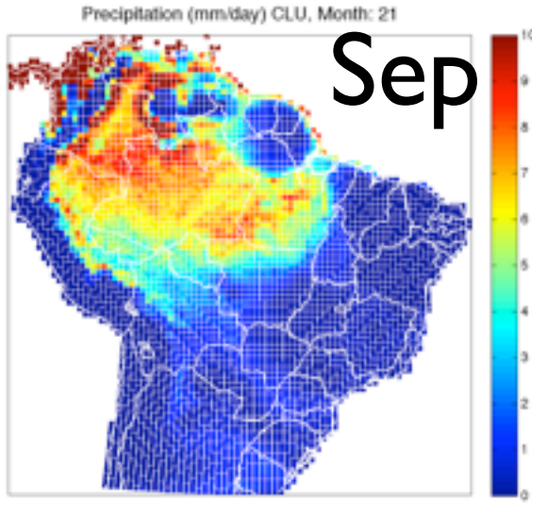


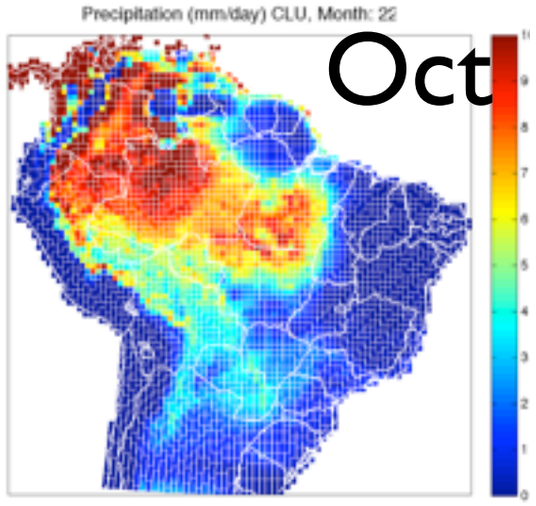


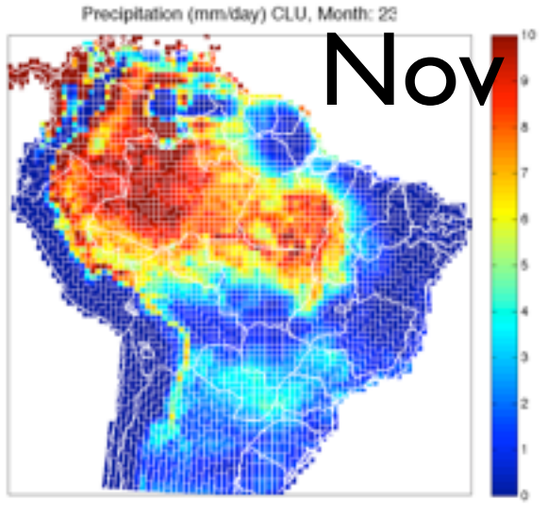


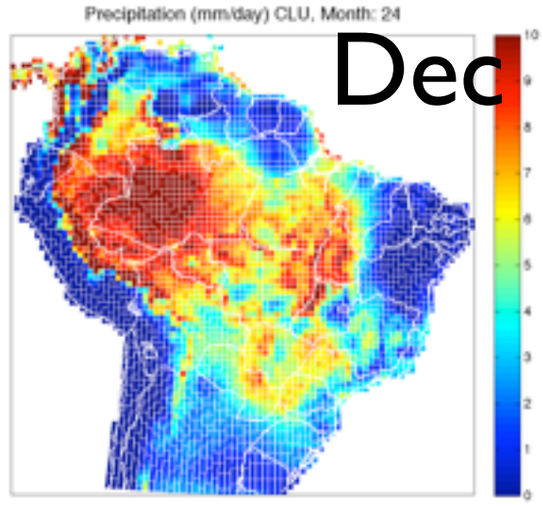




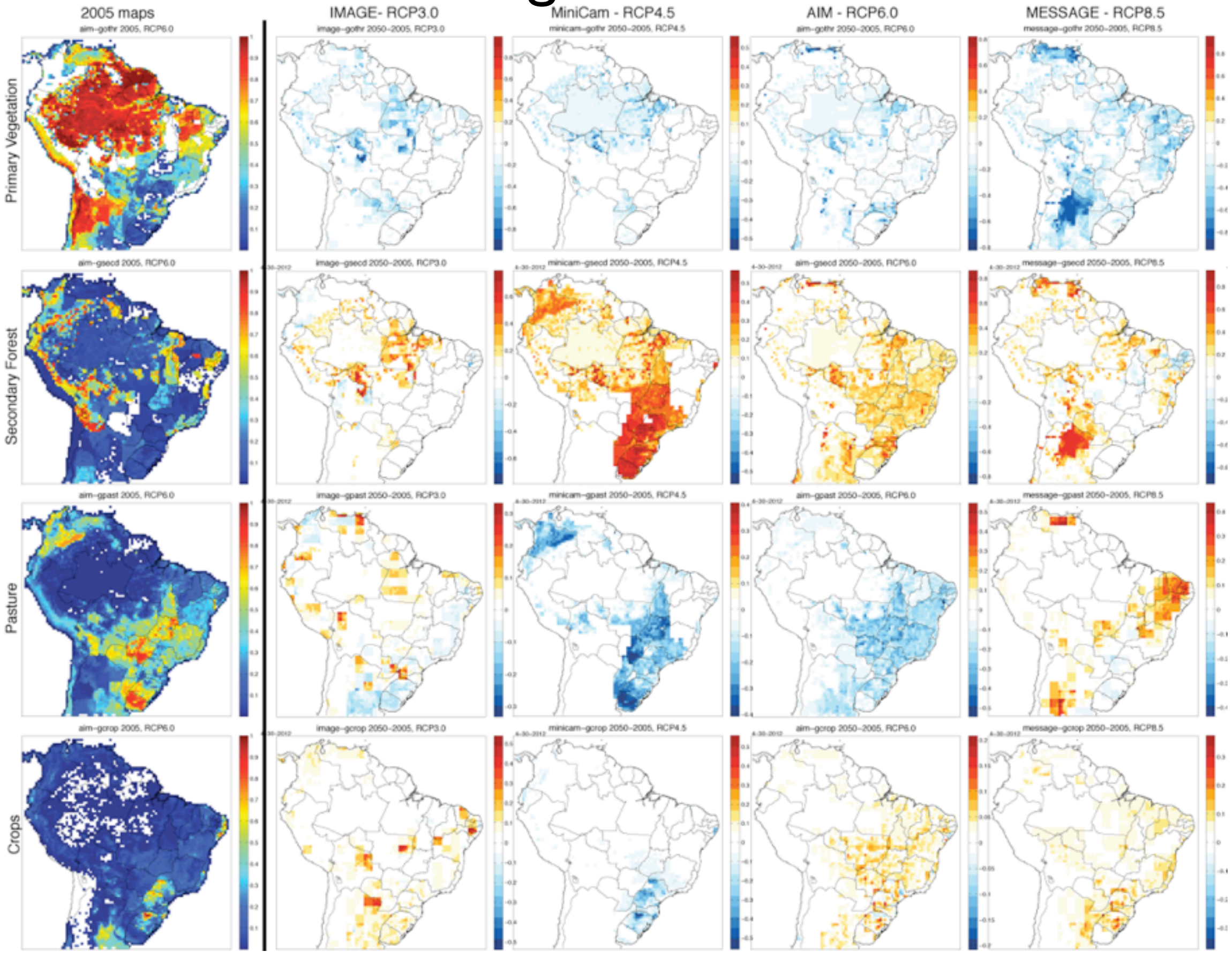




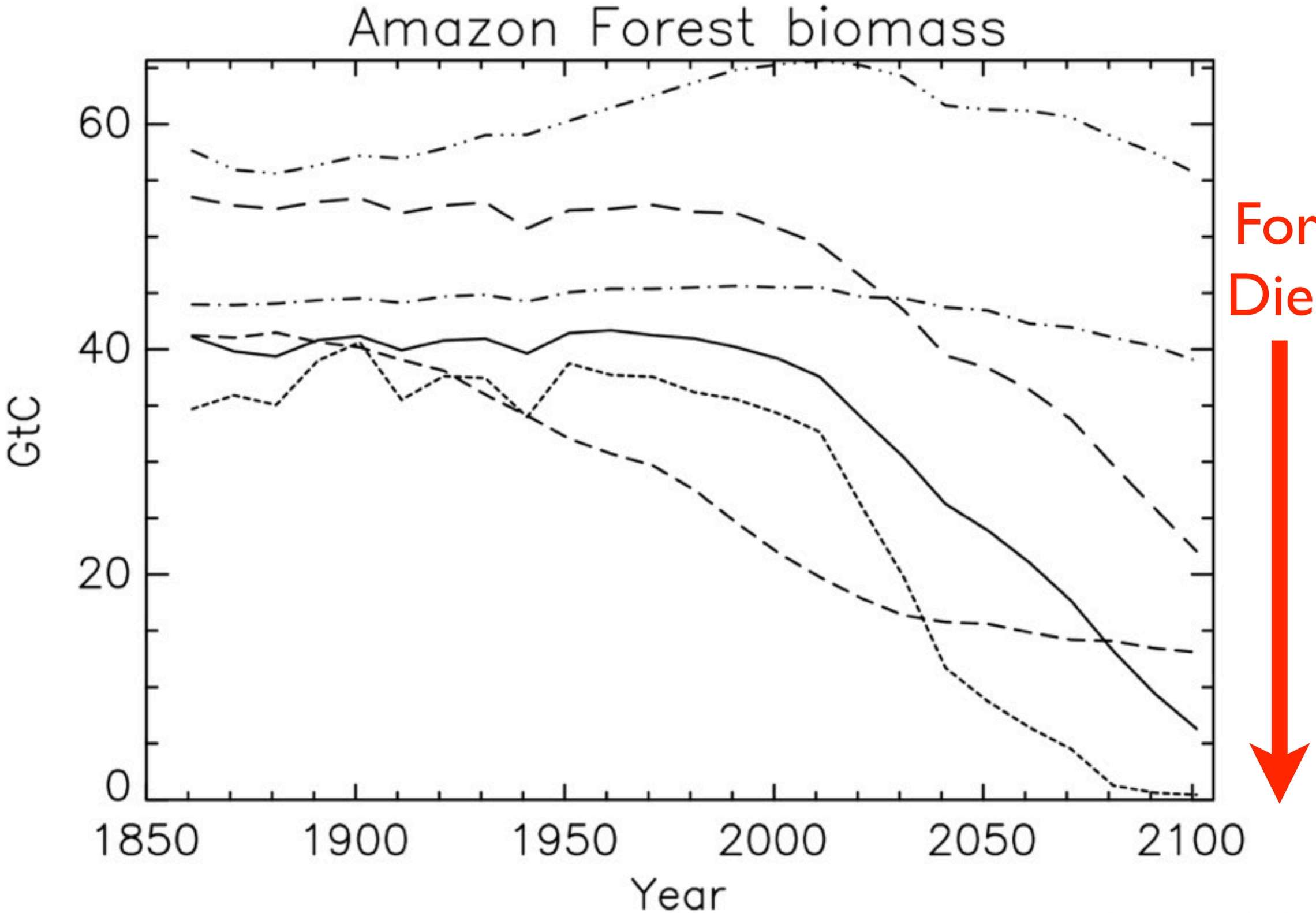




Land Use Change in 2050 from RCPs

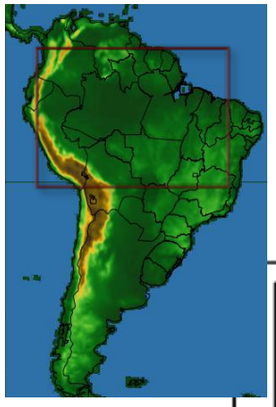


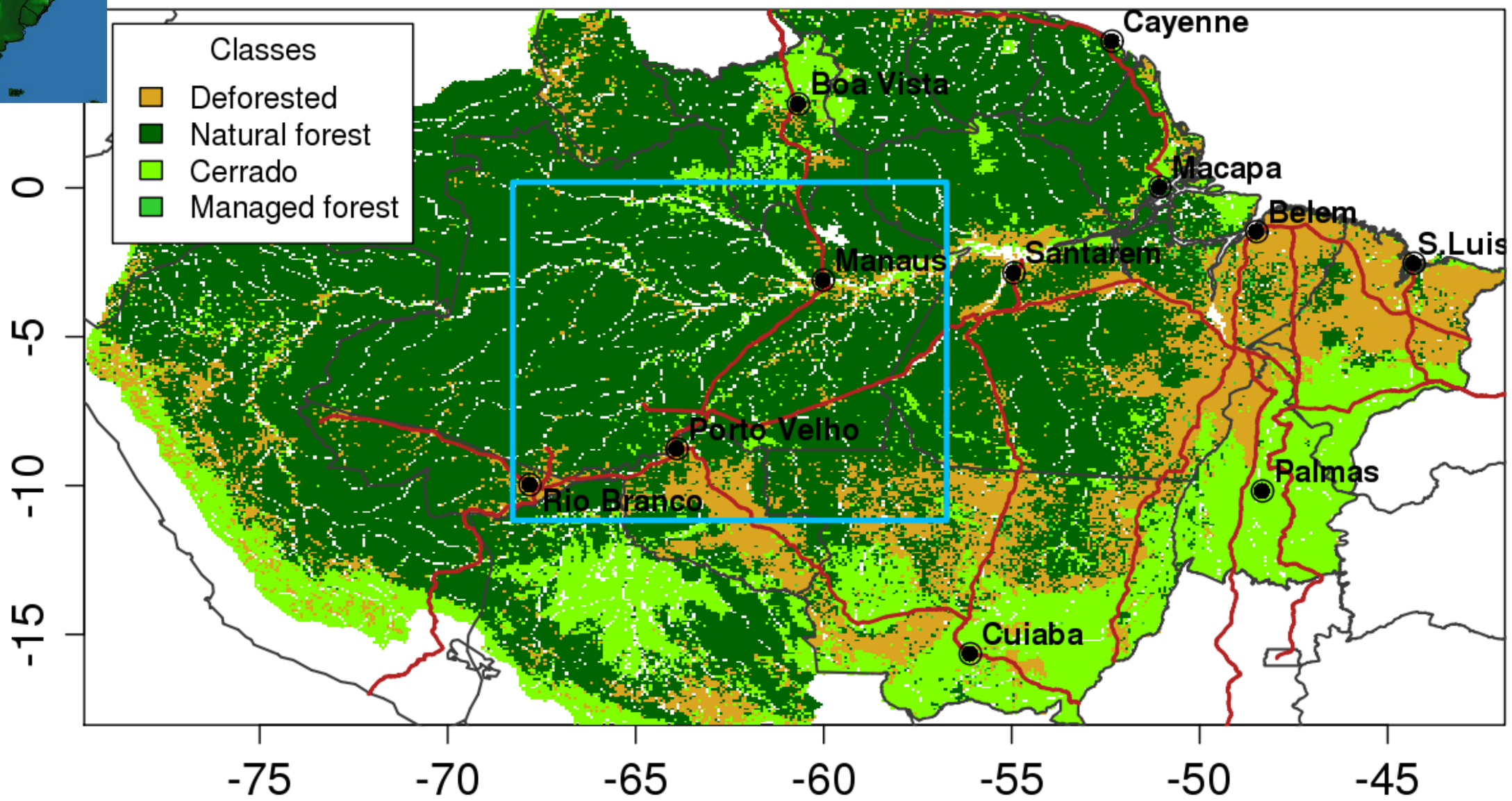
Response of the Terrestrial system is Uncertain



Cox et al. 2004

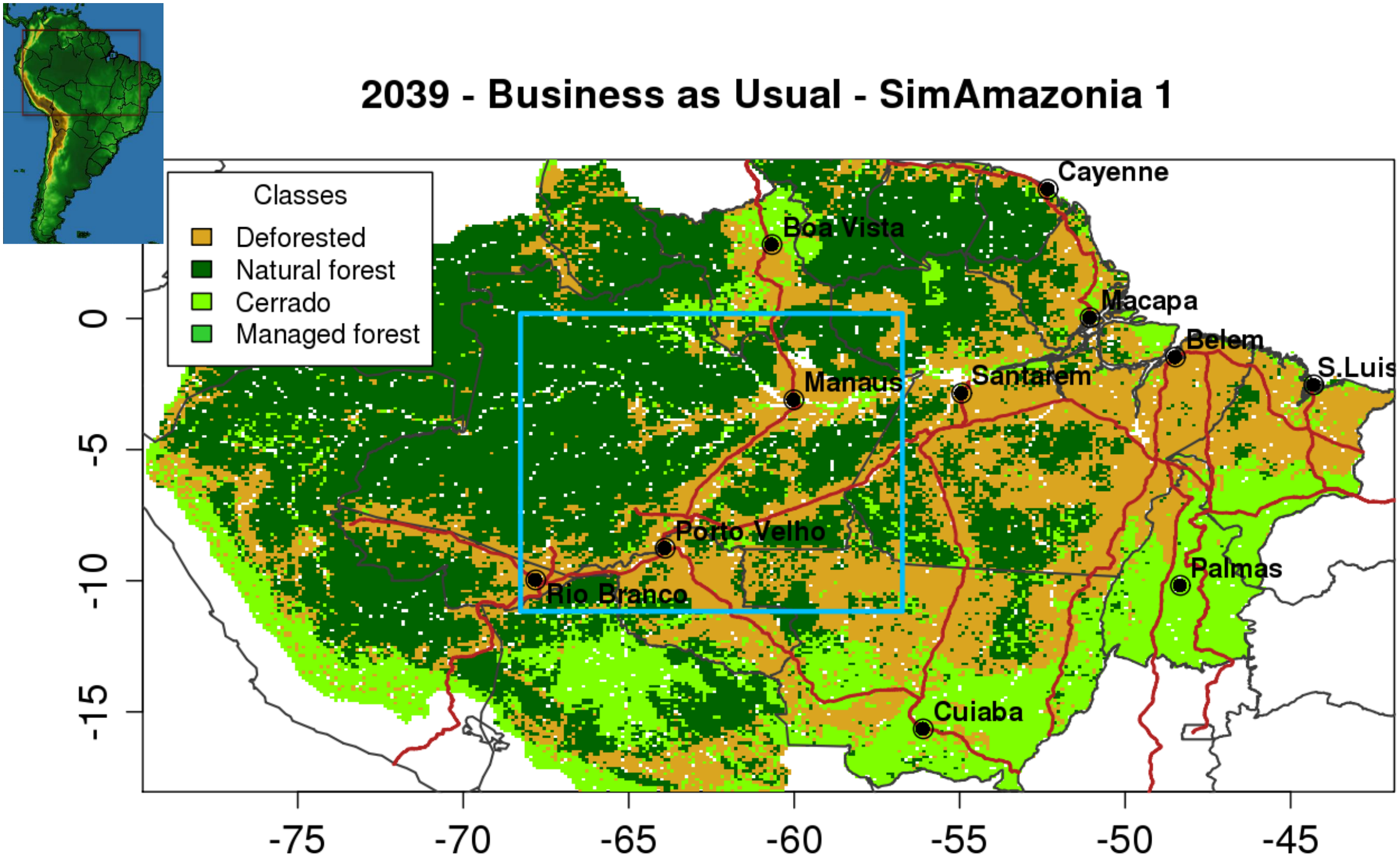
Current State of Deforestation in the Amazon





images courtesy of Marcos Longo, based on: Soares-Filho et al. 2006; Merry et al. 2009

Future Projected Deforestation in the Amazon



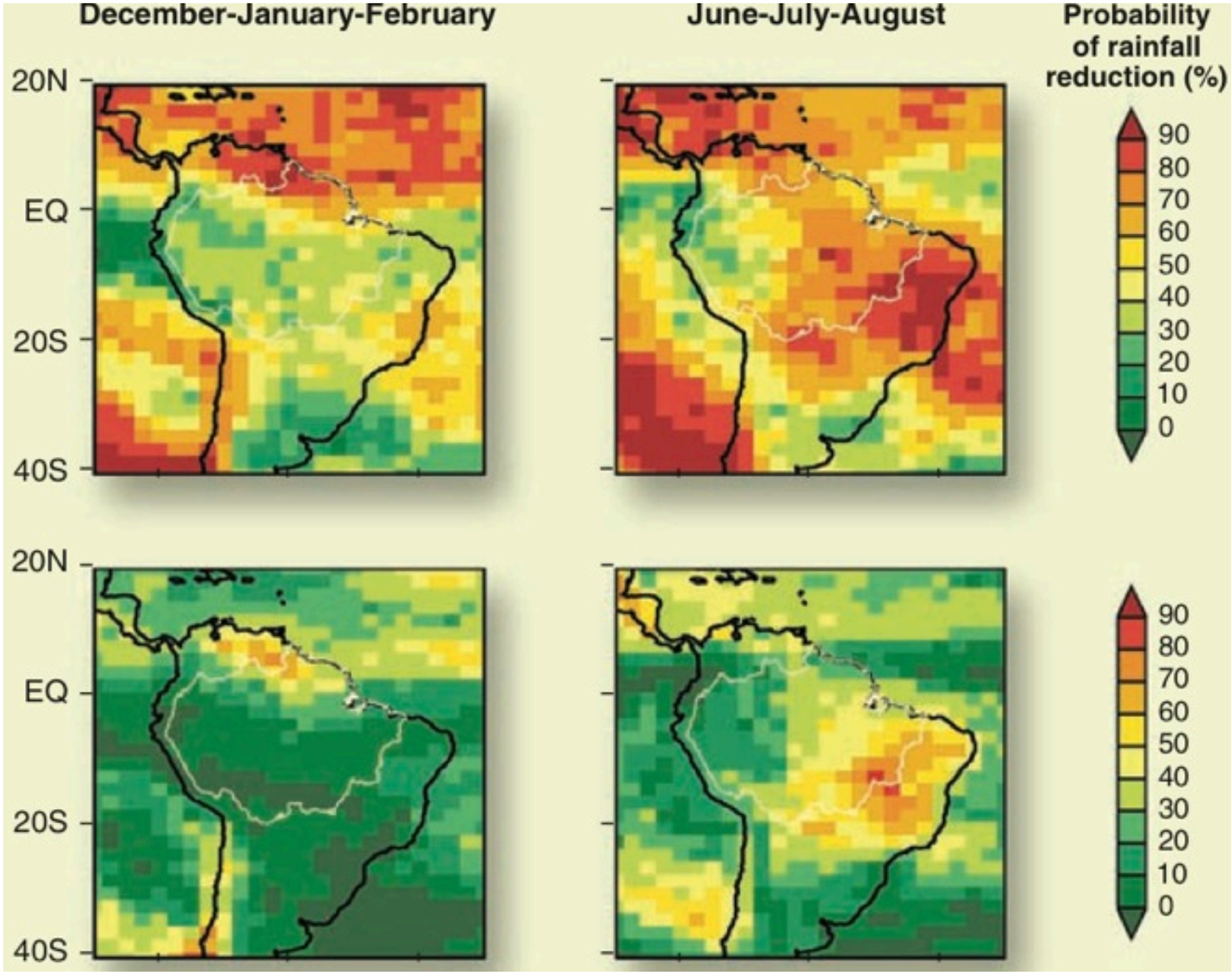
images courtesy of Marcos Longo, based on: Soares-Filho et al. 2006; Merry et al. 2009

Future Climate over Amazonia: Hotter and Drier

especially during the dry season...

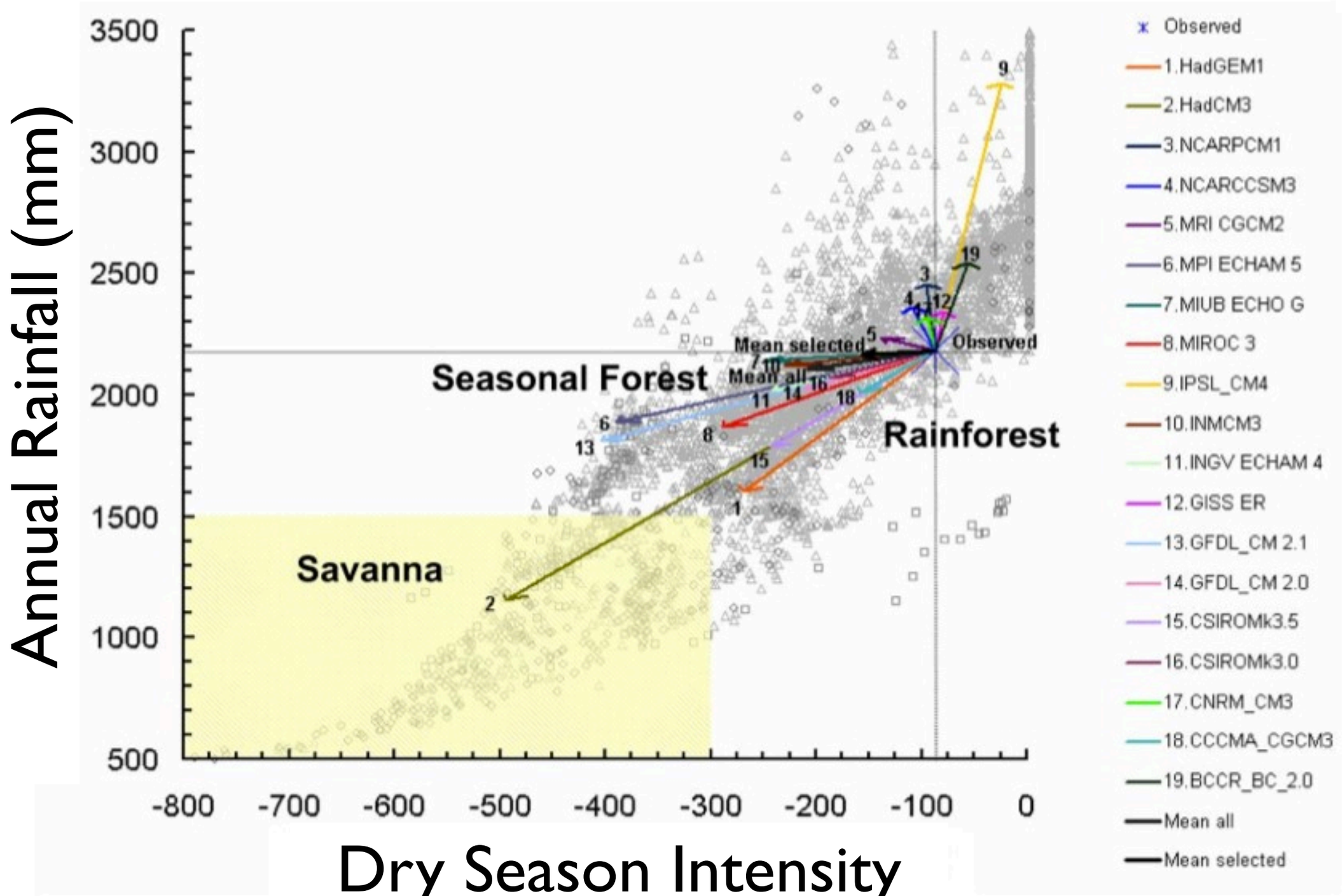
Any reduction in precip

>20% reduction in precip



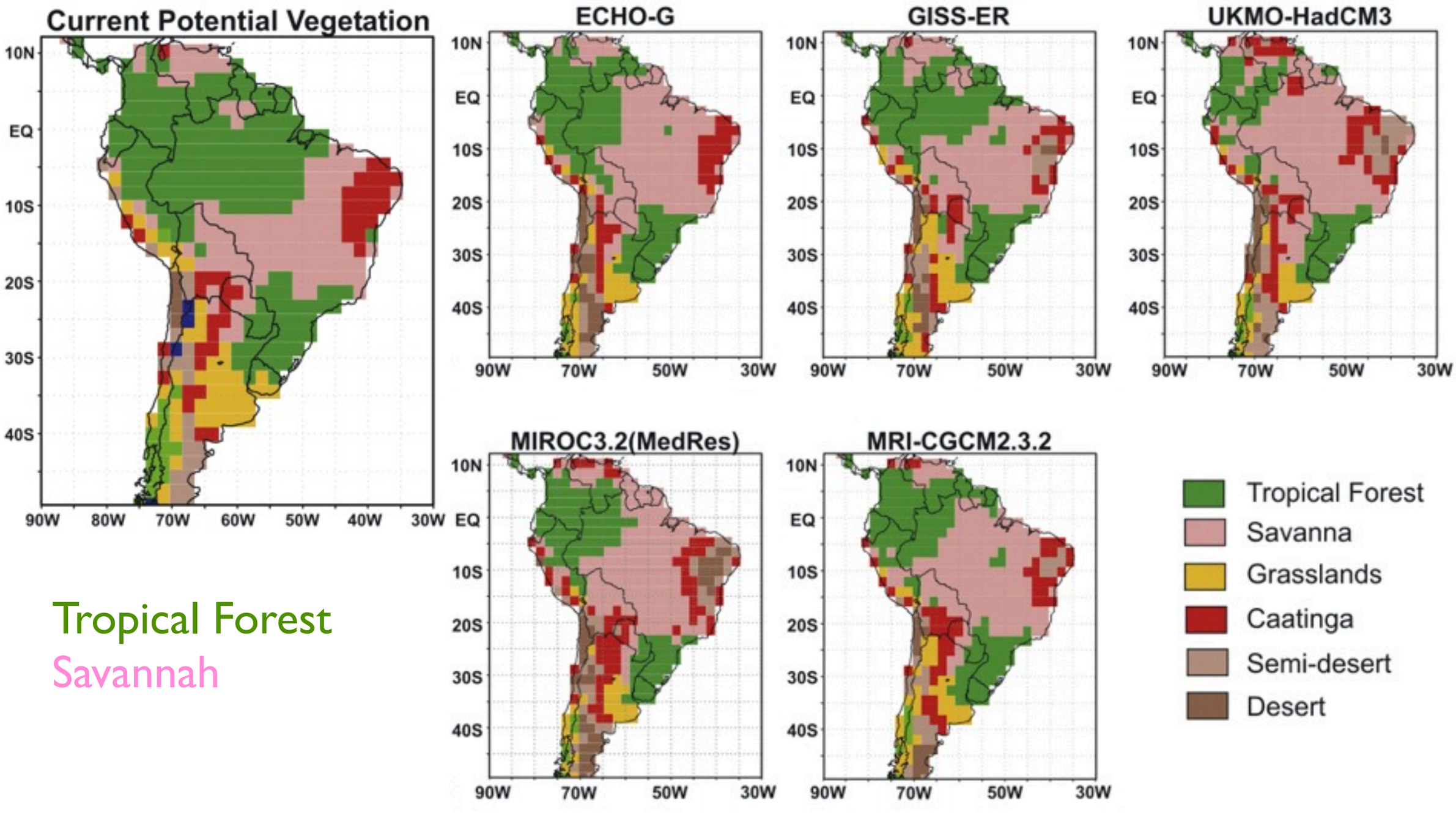
Malhi et al. 2008

Future Climate over Amazonia: More Intense Dry



Malhi et al. 2009

Future Climate may lead to Savannah-ization



Tropical Forest

Savannah

Projected Vegetation over South America under A2 for different models

Salazar et al. 2007

What will happen when forest ⇒ crops?

- changing from trees to crops will likely make it drier and therefore warmer
- drying and warming will effect the functioning of the forest itself, but may also impact precipitation over a larger region through atmospheric circulation.
- This may be compounded by a warmer and drier future climate

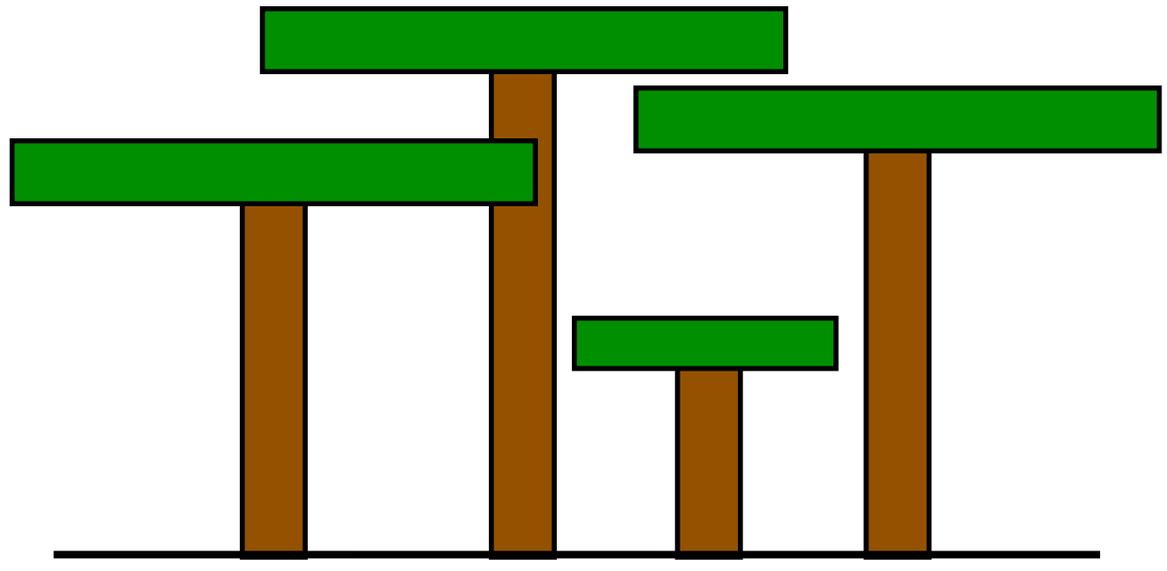
How will the expansion of agriculture within the Amazon forest impact other agricultural regions in Brazil?

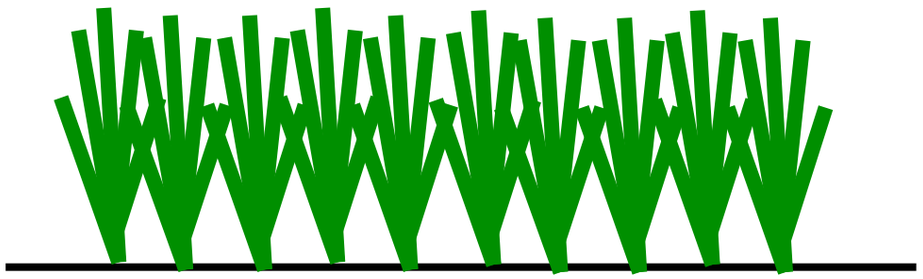
What will happen when forest ⇒ crops?

Tool: a numerical model of the Amazon forest ecosystem (ED2) coupled to an atmosphere (BRAMS).

1. Change grass structure and function to be more realistic
2. Add a representation of crops.
    - Sugarcane
    - Maize
    - Soy

Structural Changes: Forest vs. Grass





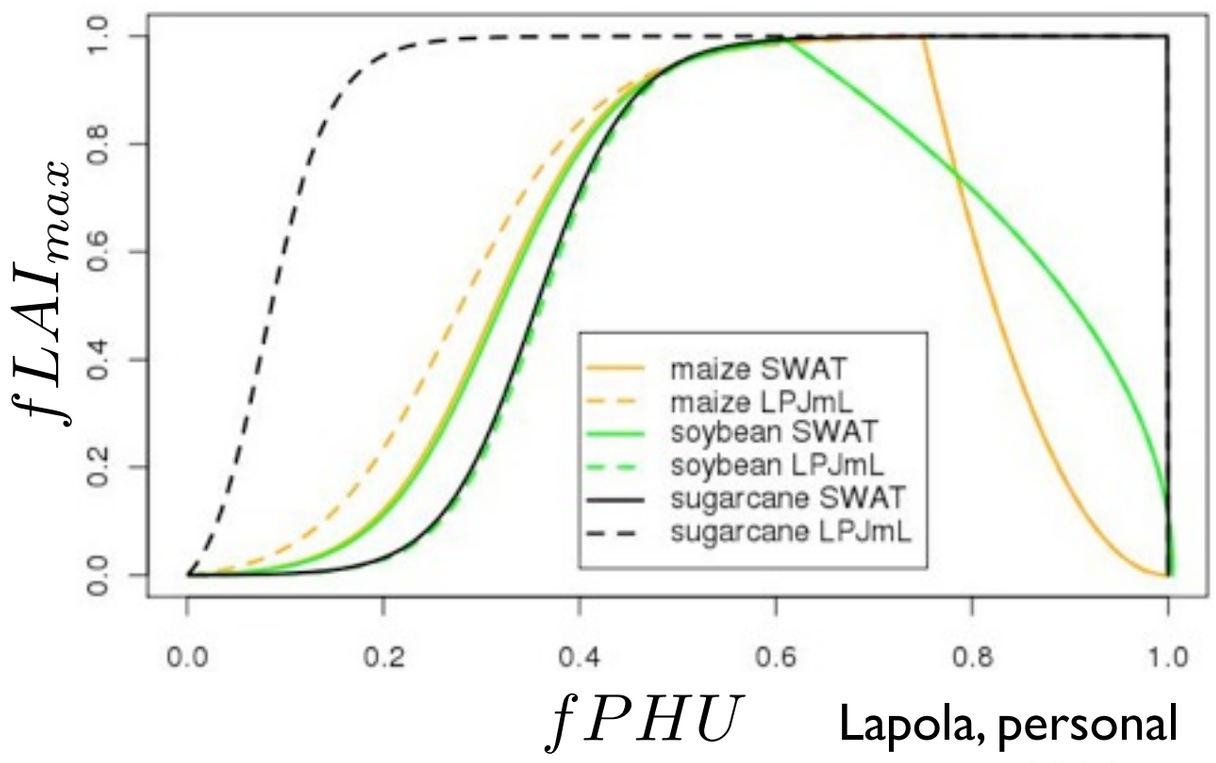
Behavioral Changes: Grass vs. Crops

sowing ⟶ growth ⟶ harvest

vegetative growth phase

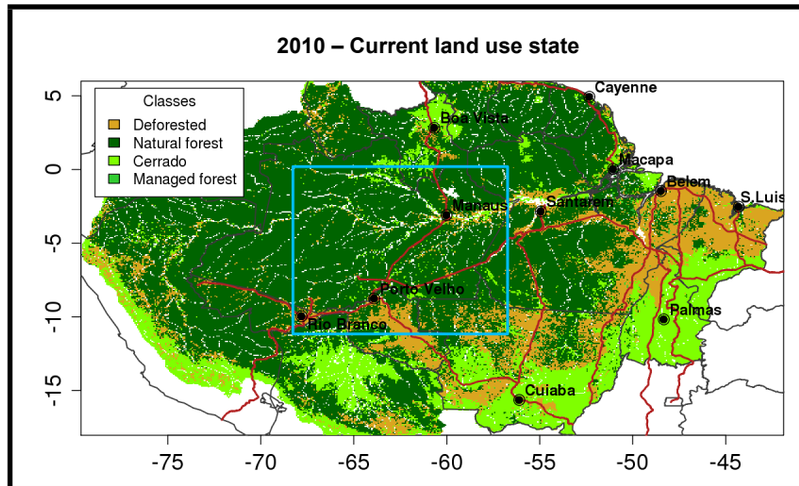
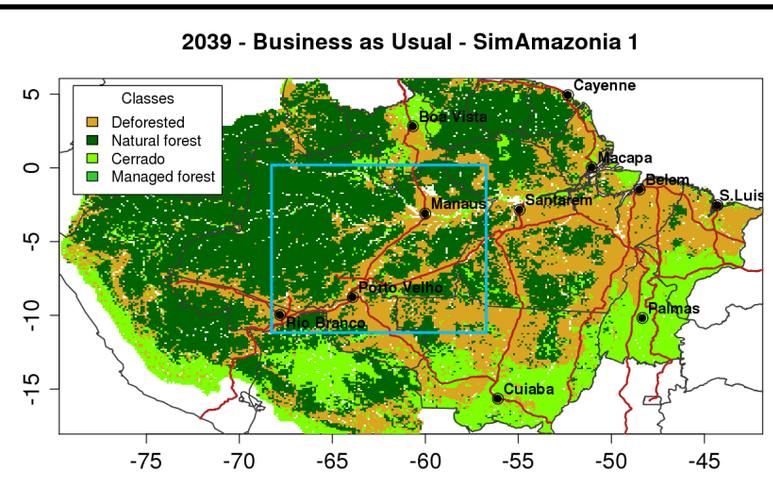
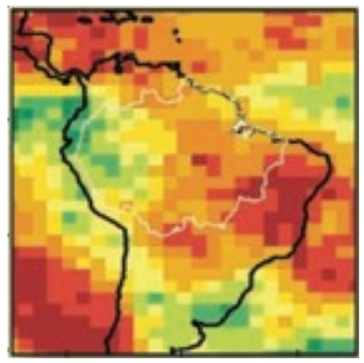
reproductive growth phase

Seasonal calendar of carbon allocation linked to heat units or growing degree days



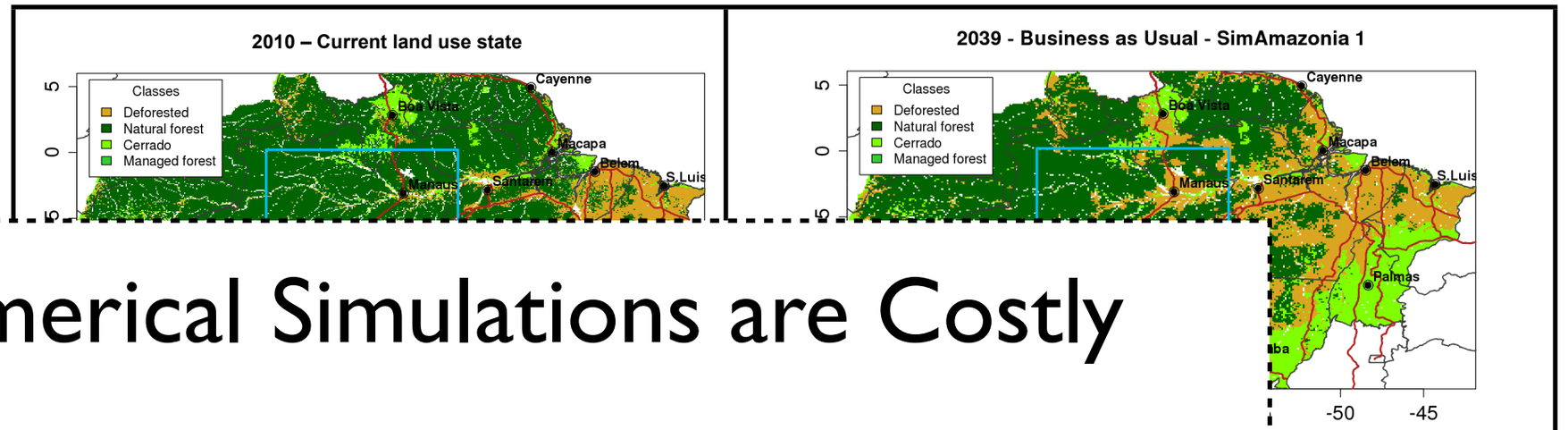
Lapola, personal com., 2010

Experiment Scenarios

Deforestation within the Amazon Forest		
Global Climate Conditions (driven by CO_2)	Present Day Climate driven by reanalysis	Future climate driven by climate models (CCSM3) 
Agricultural Expansion Scenarios	1. Current agricultural distribution 2. Historical land use	Projection of future agriculture distribution?

Experiment Scenarios

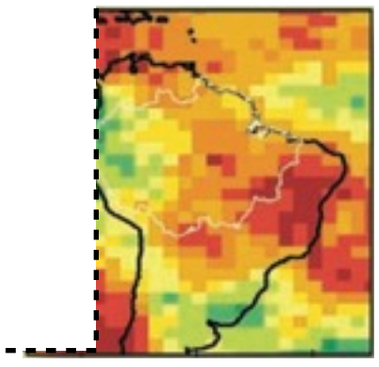
Deforestation within the Amazon Forest



Numerical Simulations are Costly

Land Only (no atmosphere):

- 0.5 degree (~55km pixels) = ~670 pixels
- 6 years in one day with one pixel per core



Global Conditic by

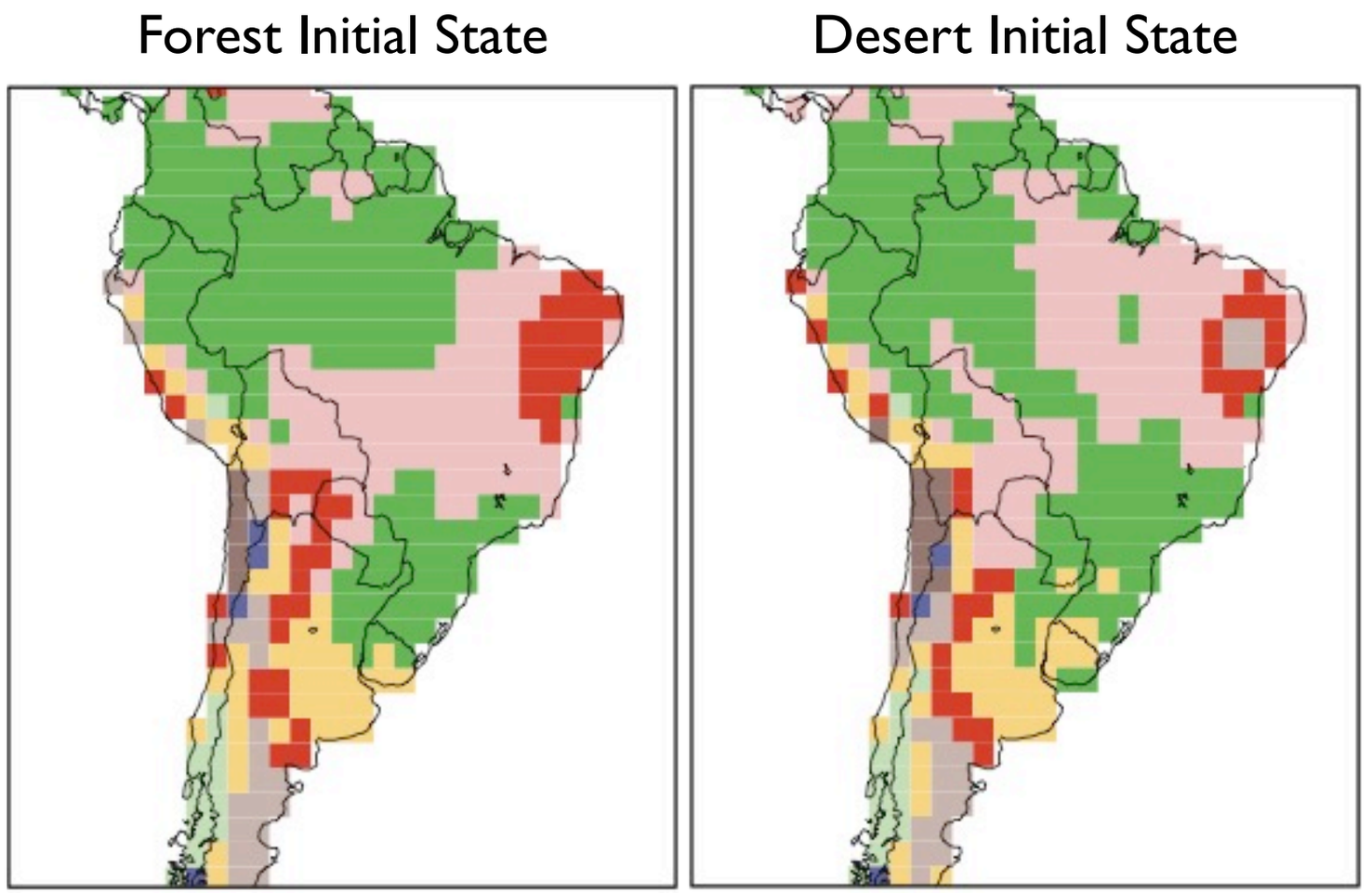
Agricultural Expansion Scenarios		
	1. Current agricultural distribution 2. Historical land use	Projection of future agriculture distribution?

Impacts of Deforestation and Climate Change

- How does precipitation change across Brazil?
- How much of this change is driven by land cover change vs. changing climate?
- Is there a positive interaction between the impacts of deforestation and climate on agricultural regions?
- Other impacts?

How will the expansion of agriculture within the Amazon forest impact other agricultural regions in Brazil?

Deforestation may lead to Savannah-ization



Oyama and Nobre 2003

Projected Vegetation over South America with different initial states