Impact of Land Use and Climate Changes on Amazonia: an Assessment of Vulnerability

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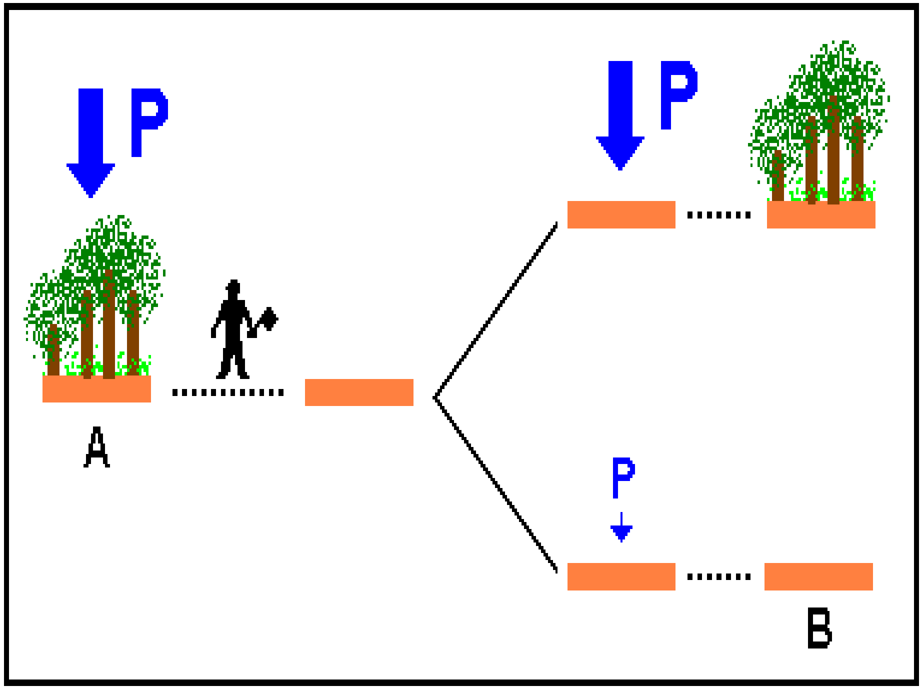
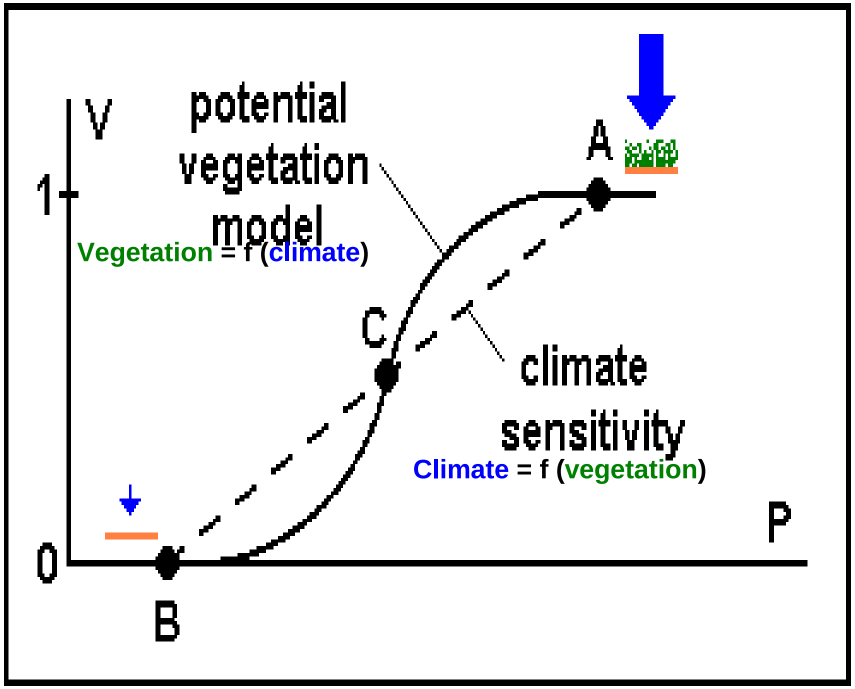
Climate Equilibrium States



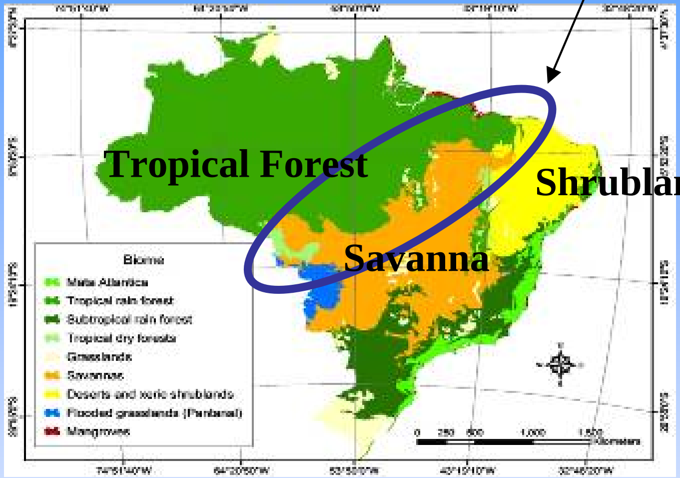


Oyama, 2002

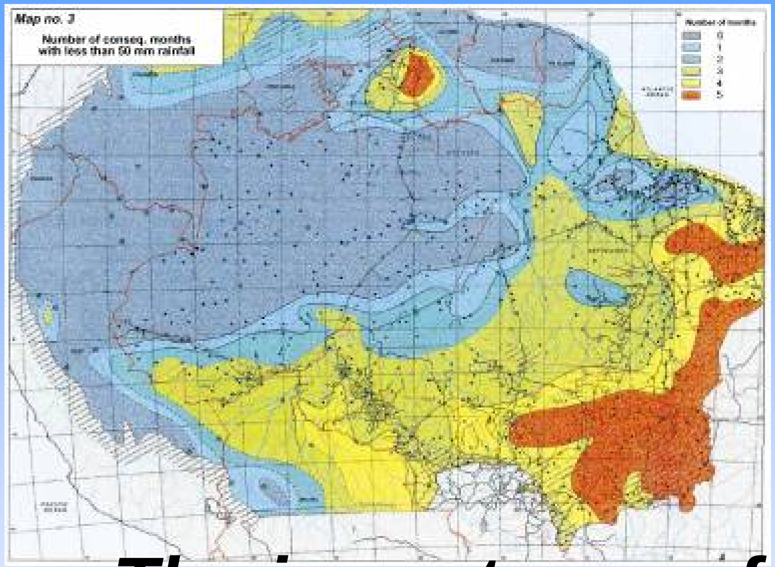
Biomes of tropical south America and precipitation seasonality

Tropical Forest-Savanna Boundary

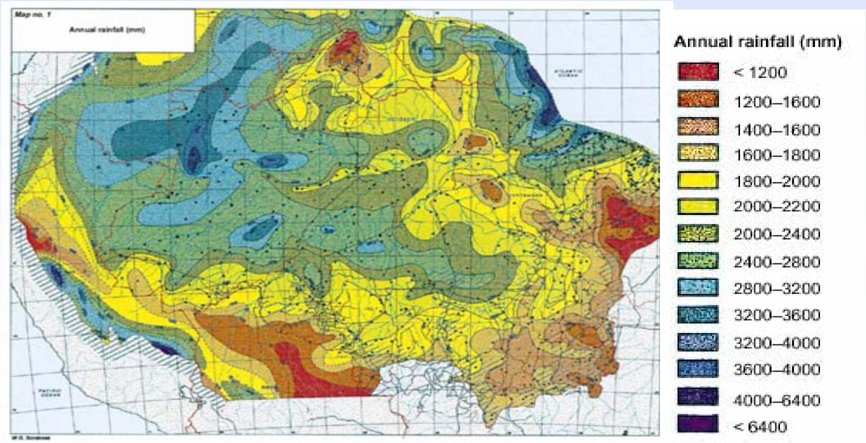
Biomes of Brazil



Number of consecutive months with less than 50 mm rainfall



Annual Rainfall

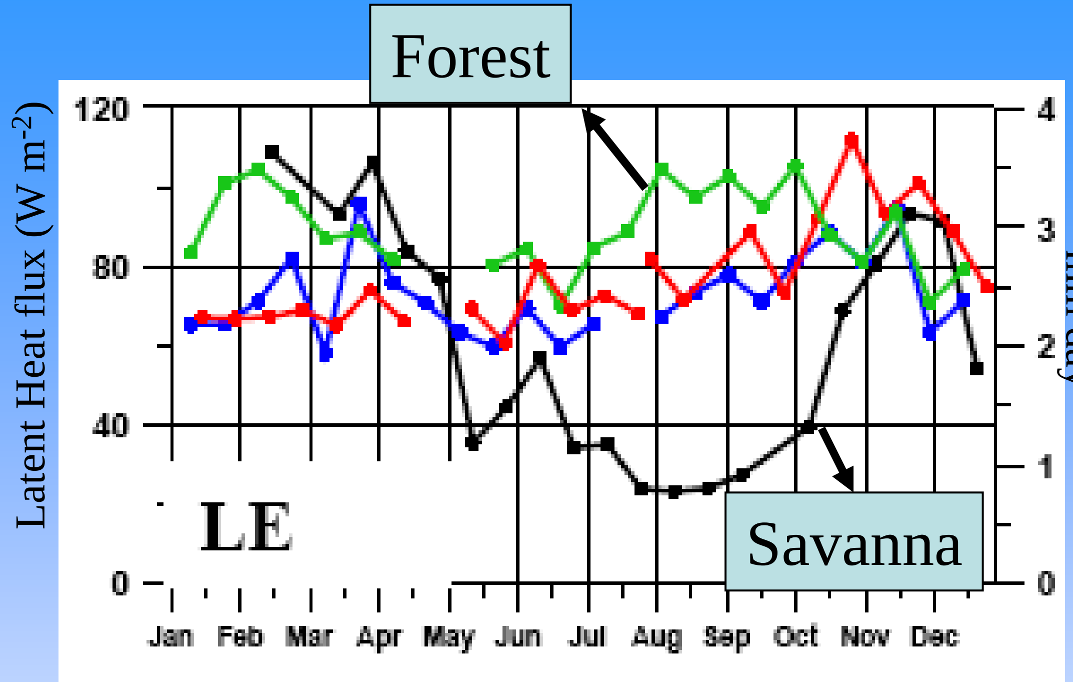


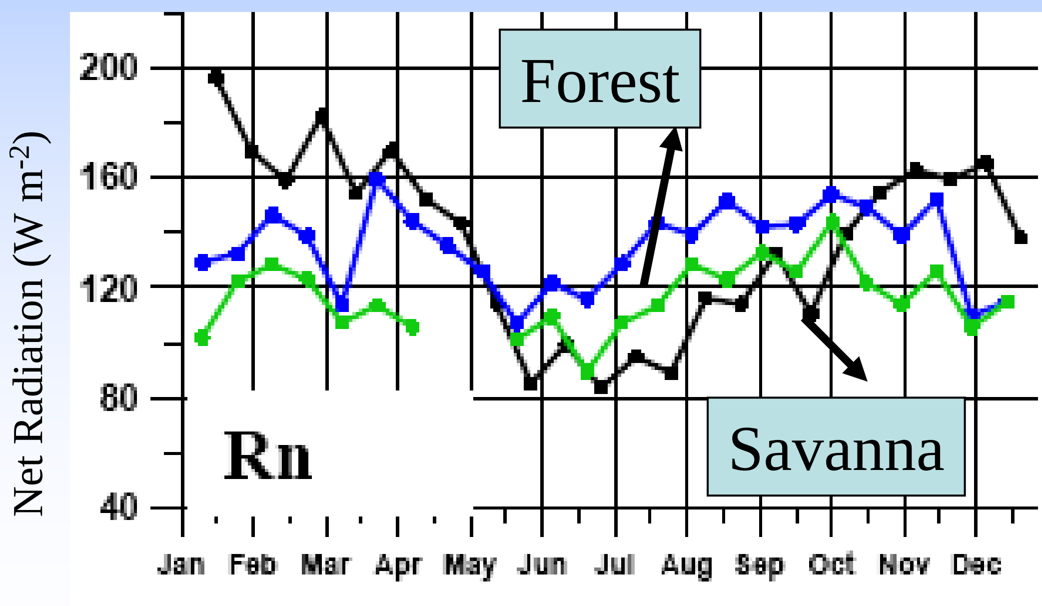
The importance of rainfall seasonality (short dry season) for maintaining tropical forests all over Amazonia

Sombroek 2001, Ambio

Evapotranspiration seasonality in the Amazon tropical forest and savanna

Source: Rocha (2004)





- Cerrado s.s. SP
- Floresta trop RO
- Floresta trop Manaus
- Floresta trop Santarém

The Hypothesis of Amazonian ‘*Savannization*’

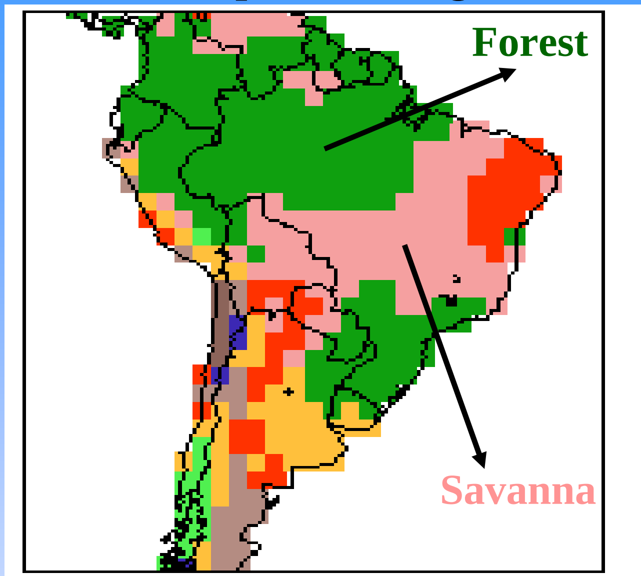
- Nobre et al. (1991) proposed that a post-deforestation climate in Southern Amazonia would be warmer, drier and with longer dry season, typical of the climate envelope of the tropical savanna (Cerrado) domain of Central South America.

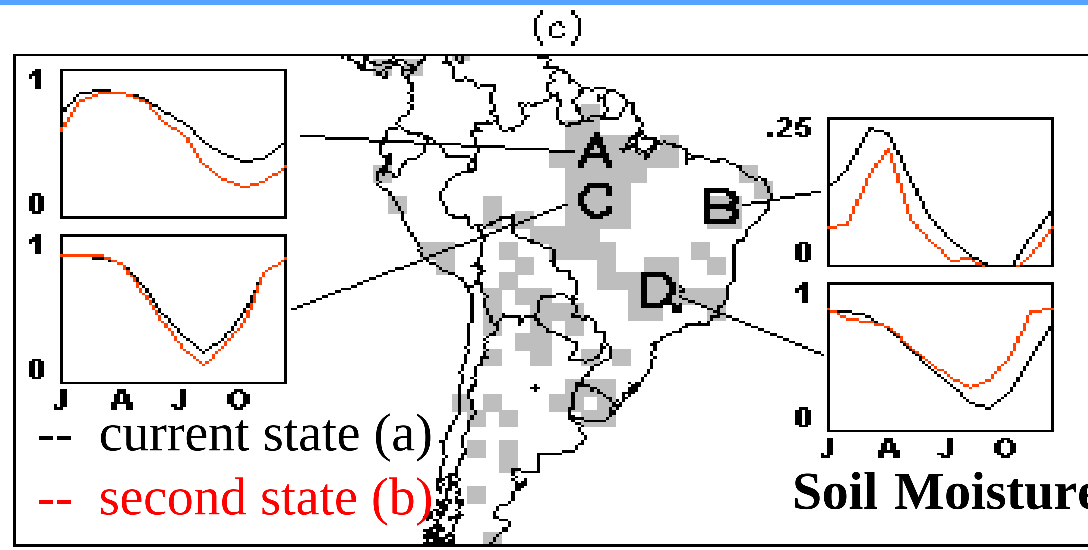
- ‘*Savannization*’ in this context is a statement on regional climate change and not intended to describe complex ecological processes of vegetation replacement.

Is the current Climate-Biome equilibrium in Amazonia the only stable equilibrium possible?

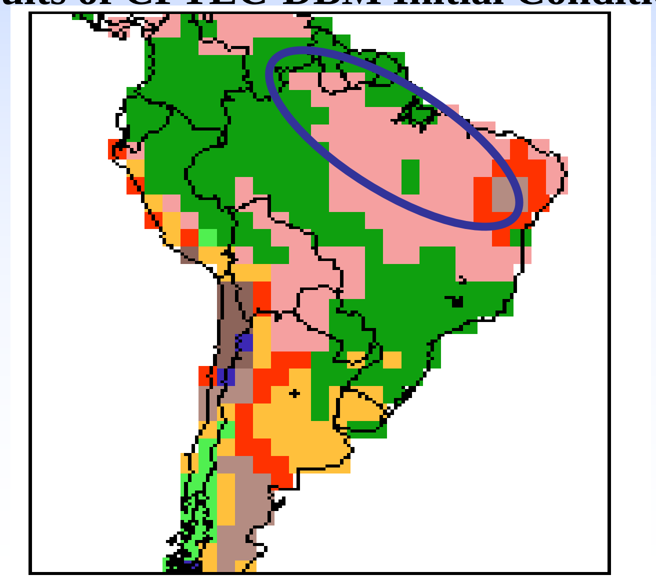
Two Biome-Climate Equilibrium States found for South America

Current potential vegetation

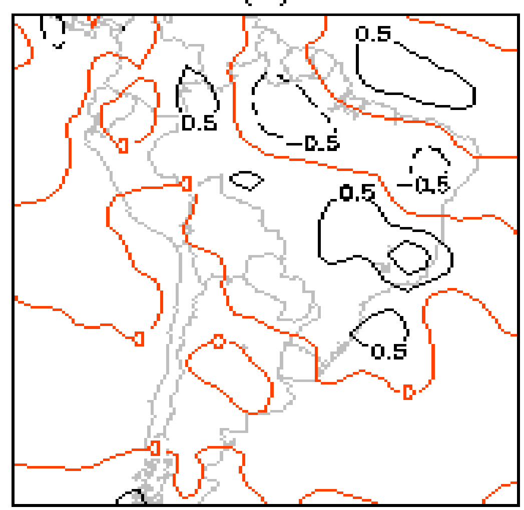




Second State
Results of CPTEC-DBM Initial Conditions : desert



(d)



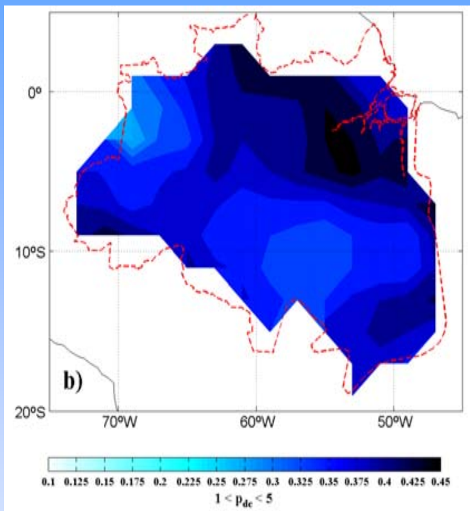
Rainfall anomalies

Source: Oyama and Nobre, 2003

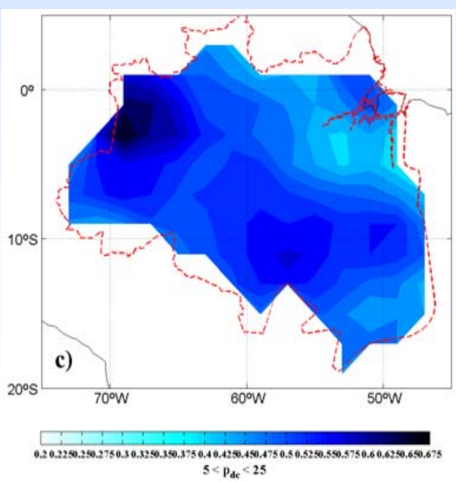
Precipitation mechanism in the Amazon

Unconditional probability of a wet day.
The daily data spans 1979 to 1993

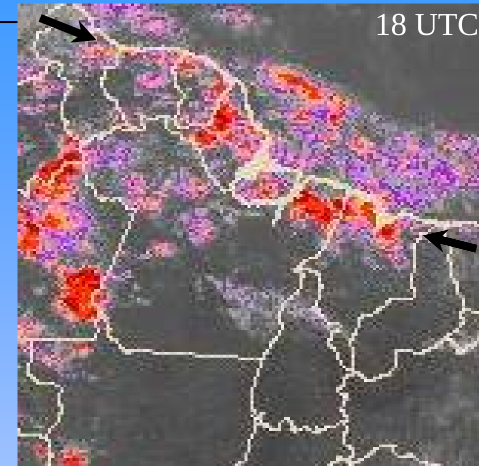
1 mm < P < 5 mm

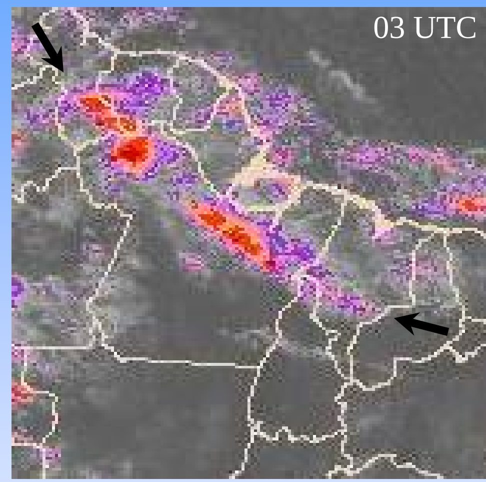


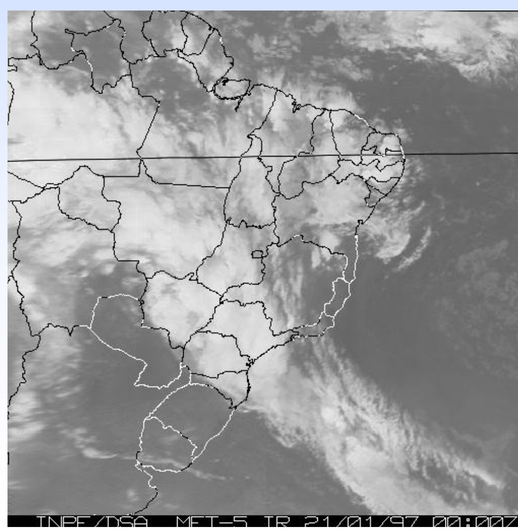
5 mm < P < 25 mm



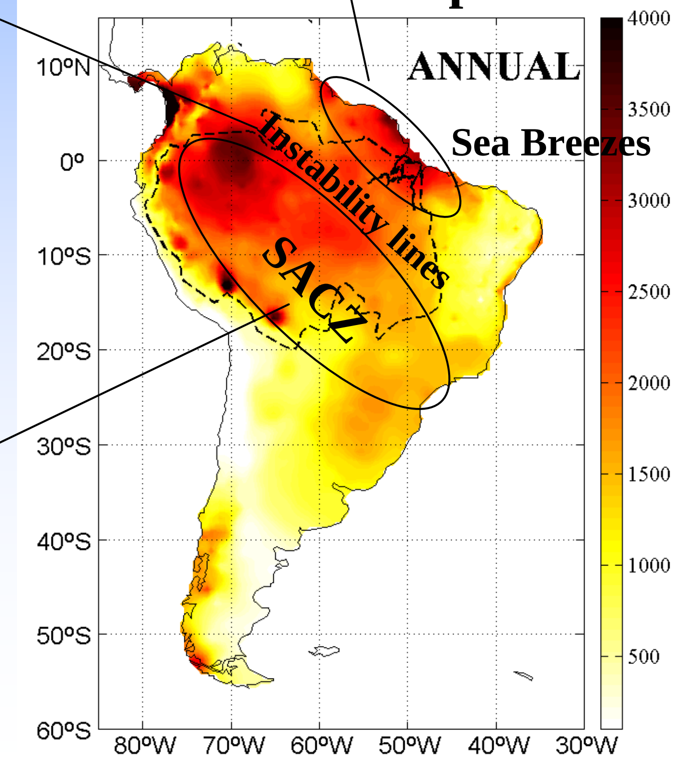
Source: Obregon, 2001



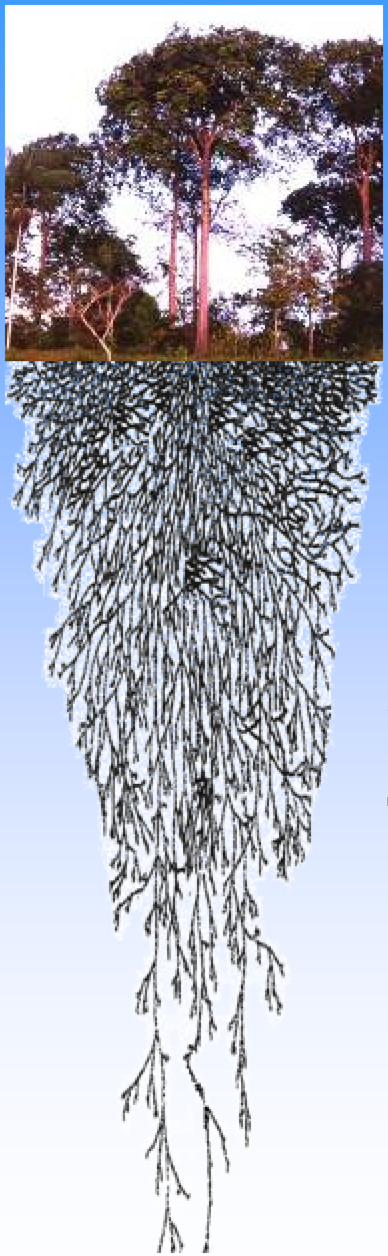


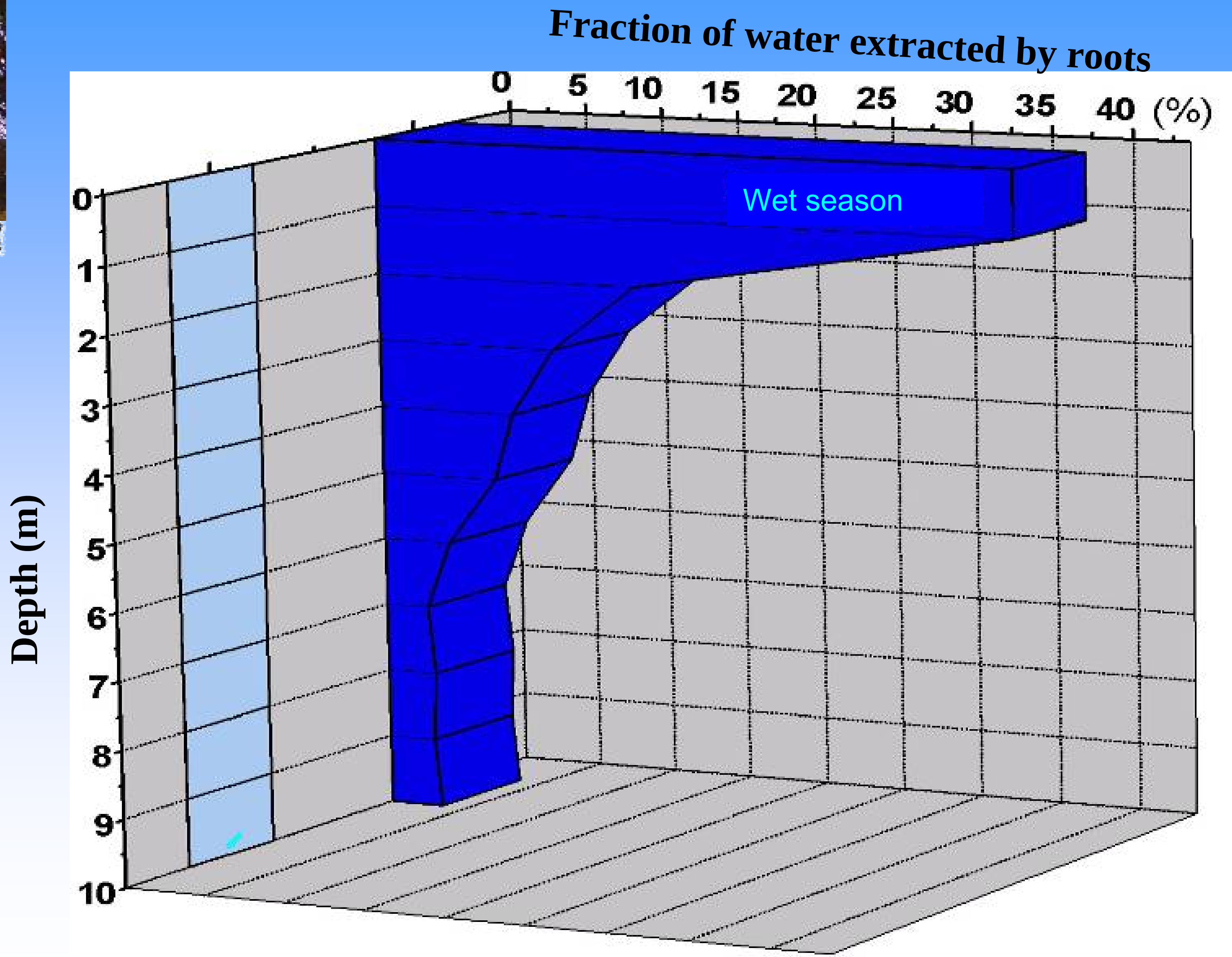


Annual Precipitation



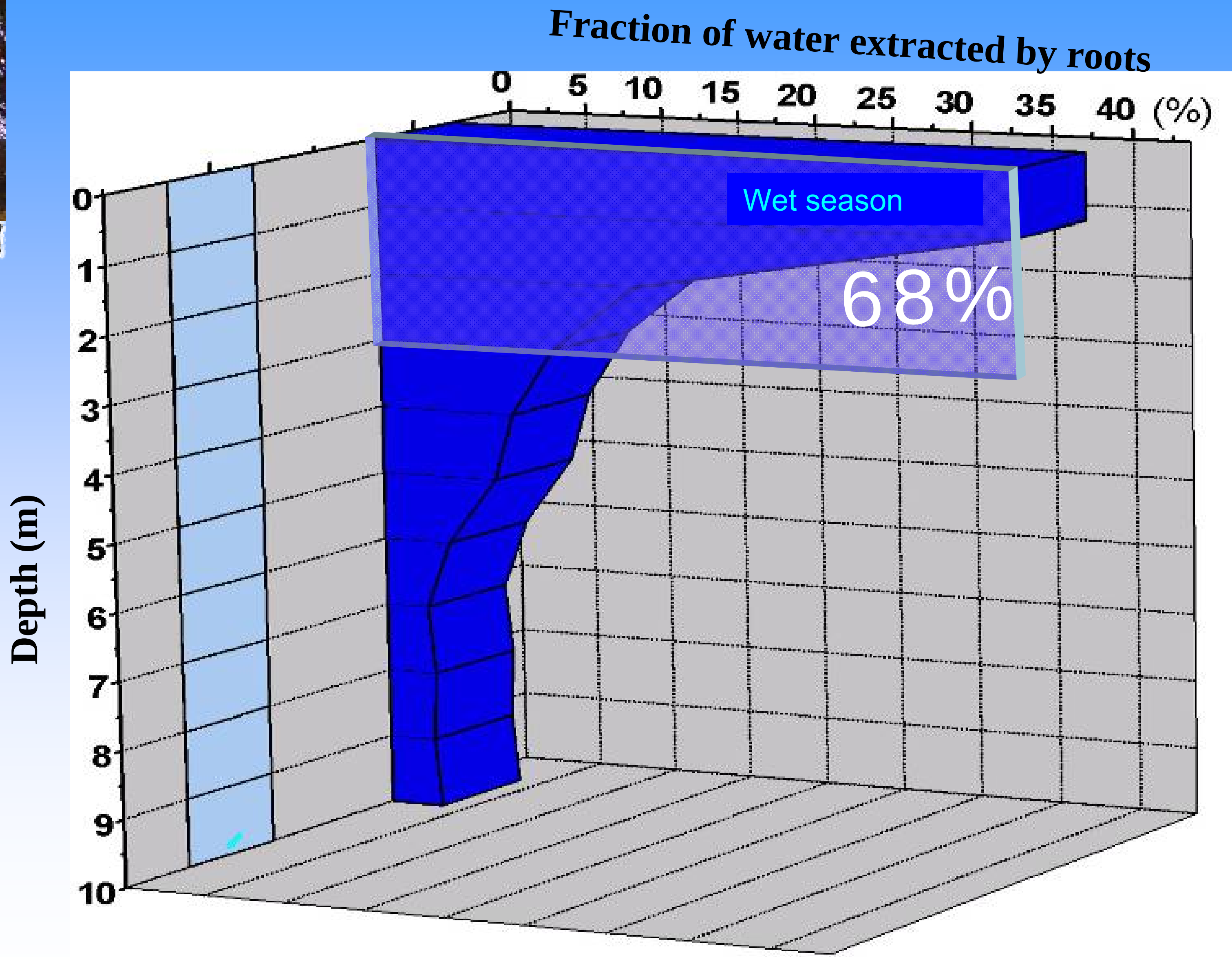
Ecological adaptation I: Deep rooting





Source: Bruno et al., 2005 – Tropical forest data in Santarem km83

Ecological adaptation I: Deep rooting



Source: Bruno et al., 2005 – Tropical forest data in Santarem km83

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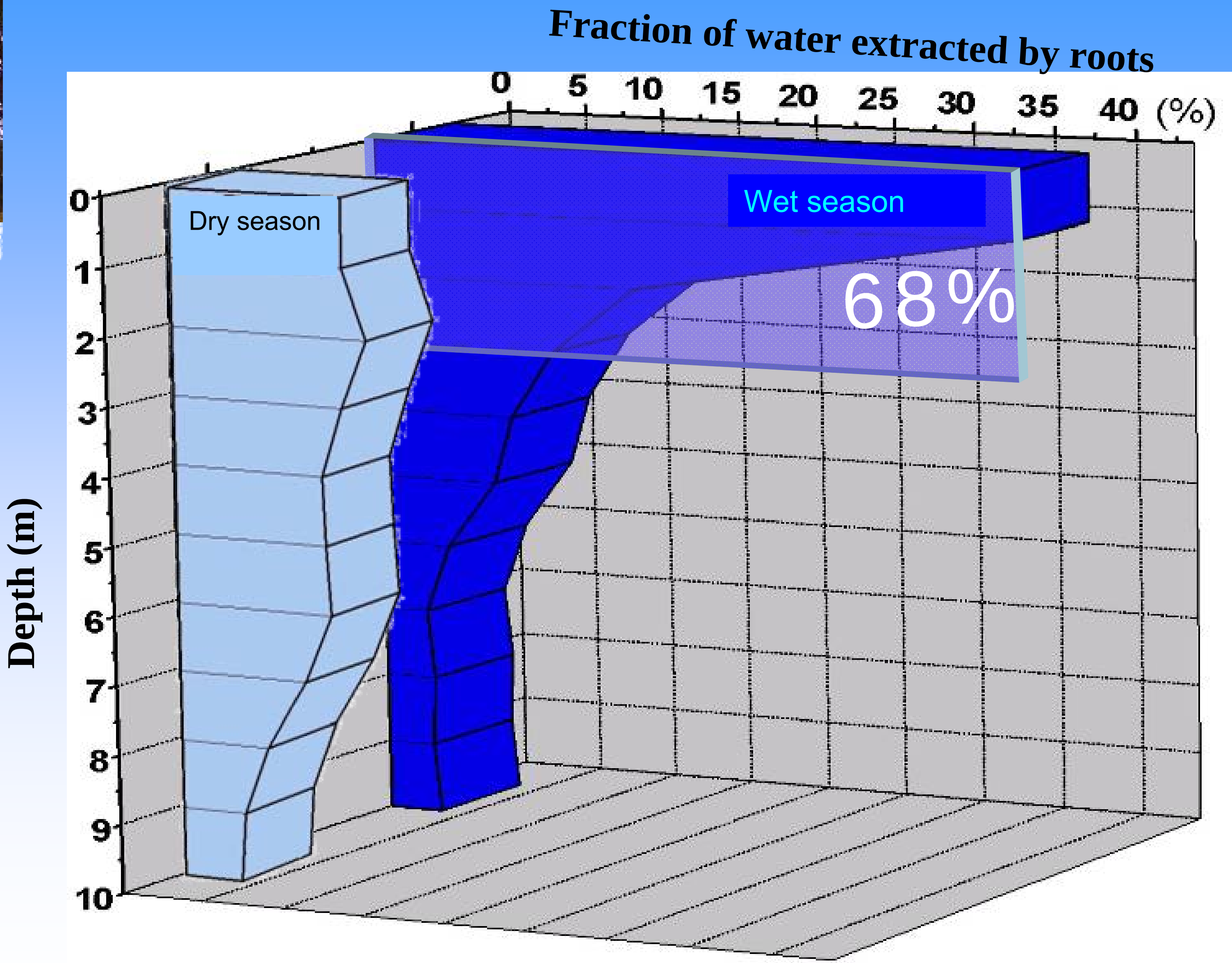
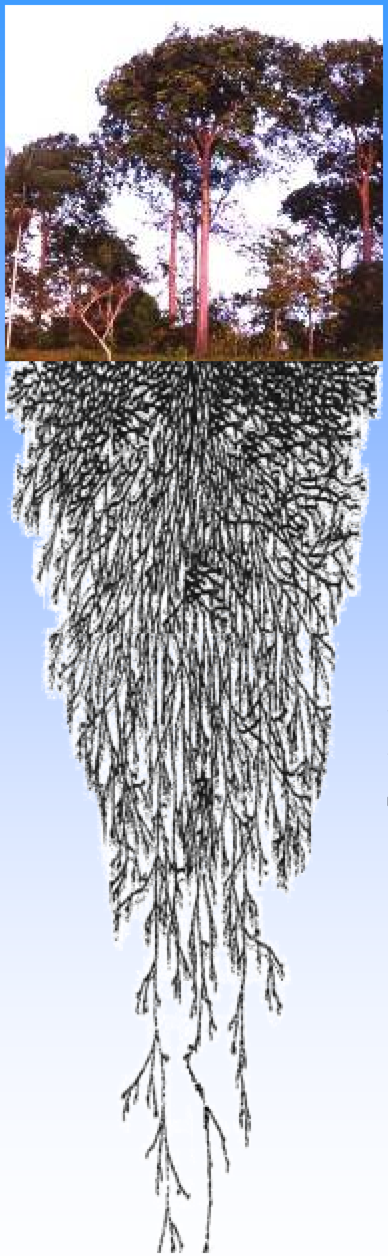
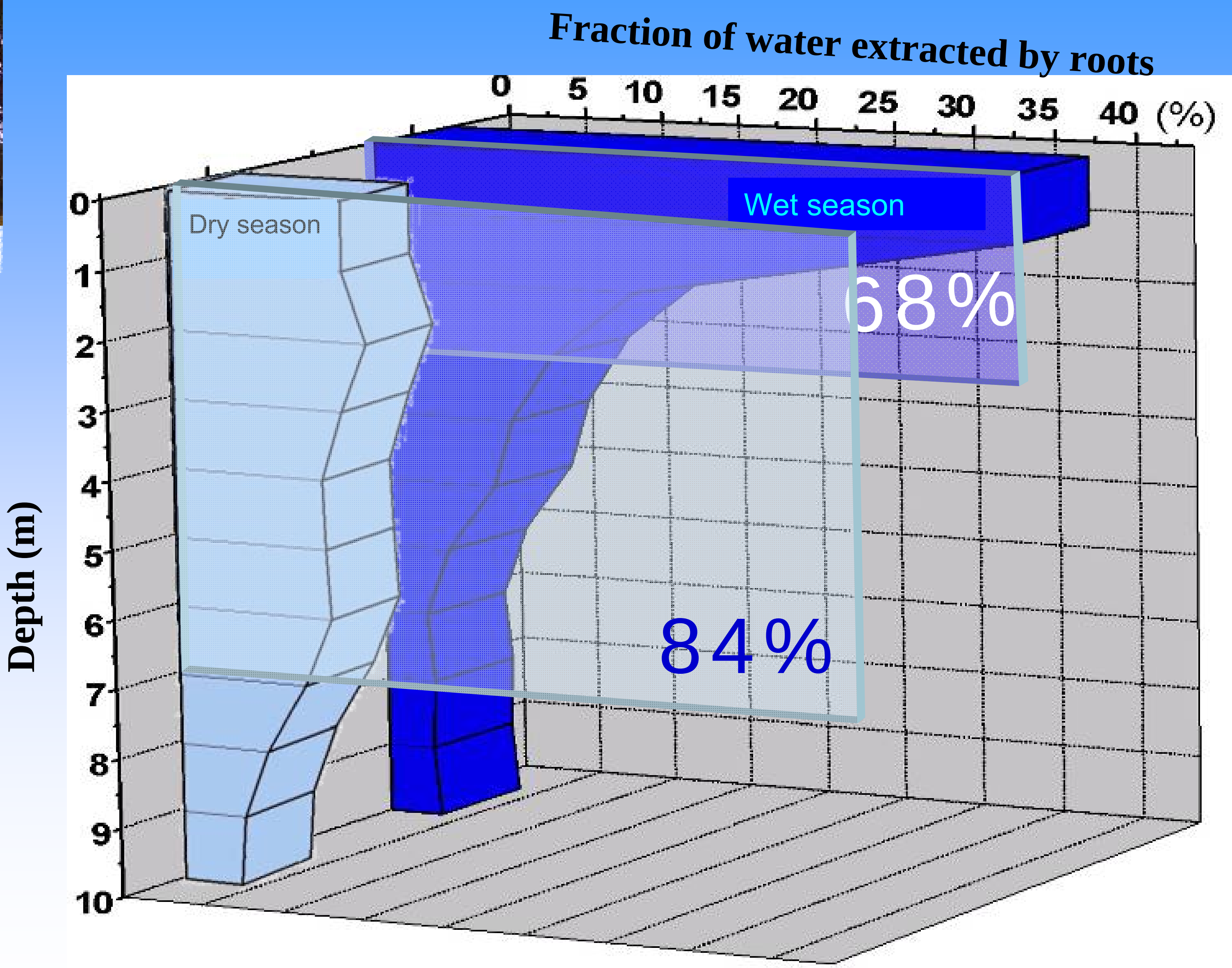


Source: Bruno et al., 2005 – Tropical forest data in Santarem km83

Ecological adaptation I: Deep rooting





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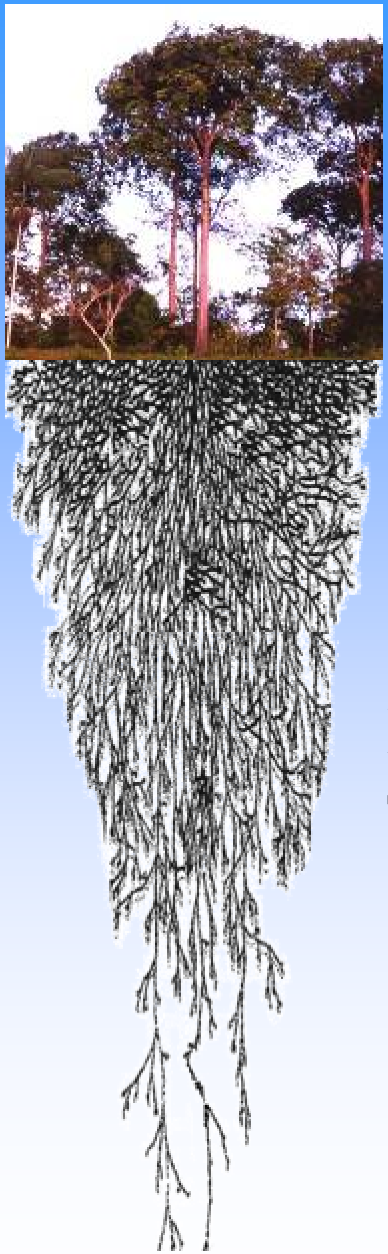
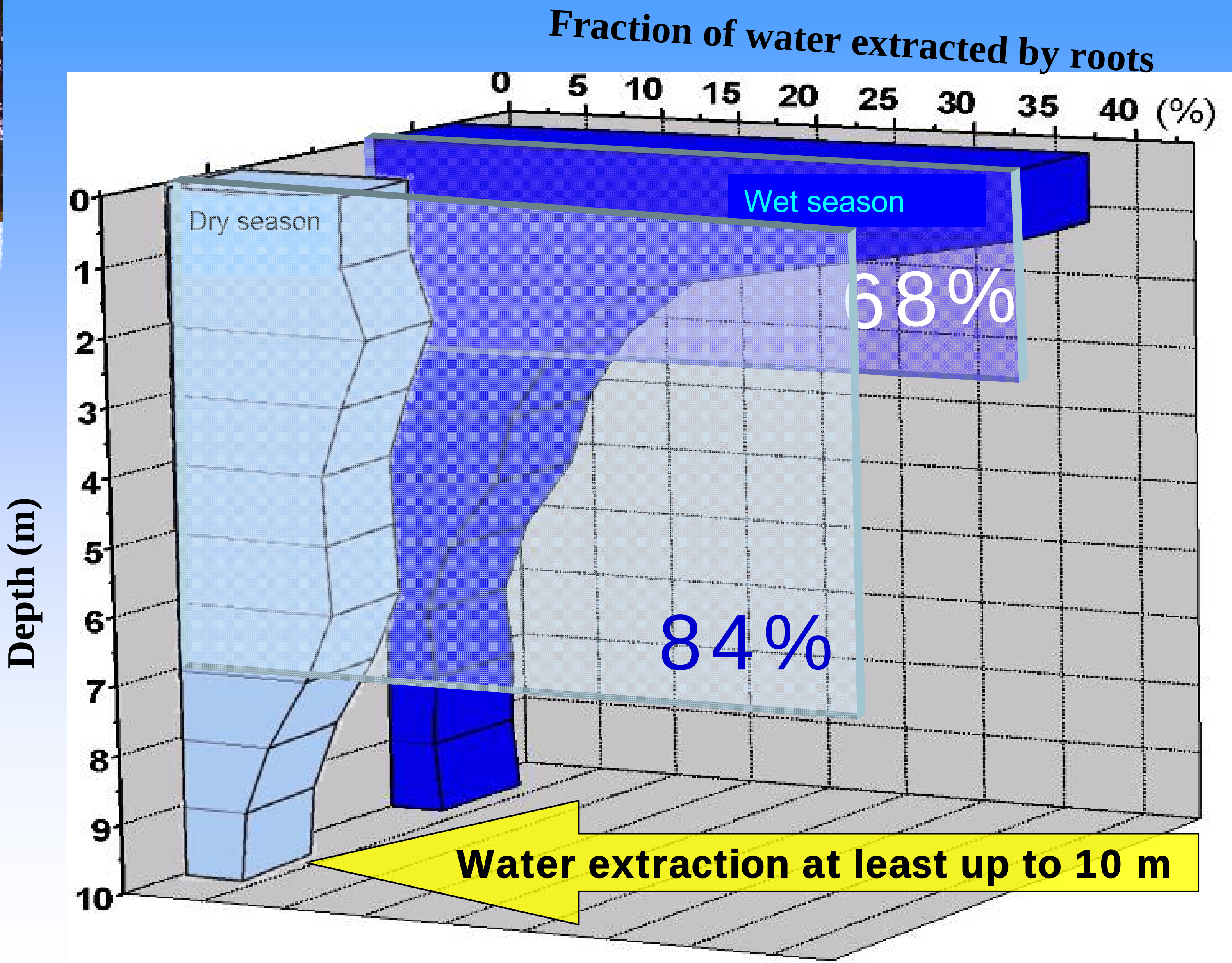
Ecological adaptation I: Deep rooting

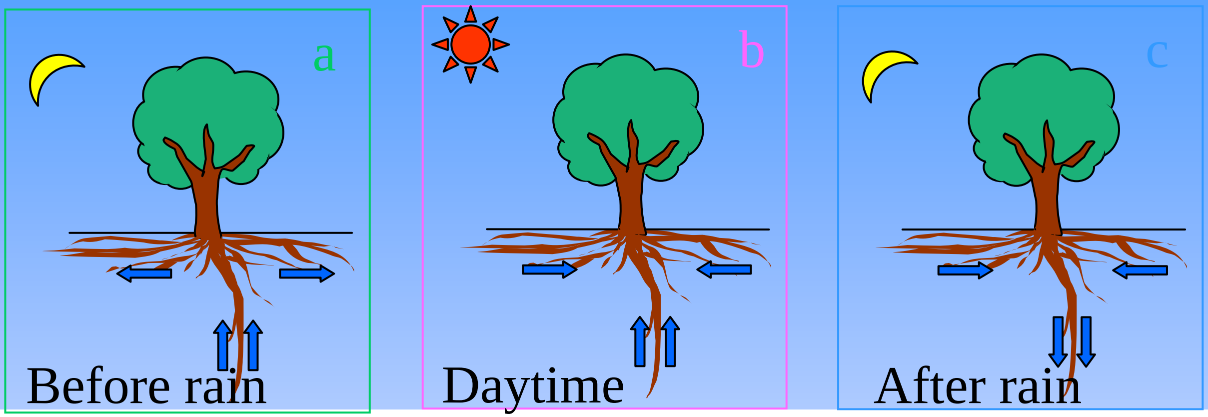


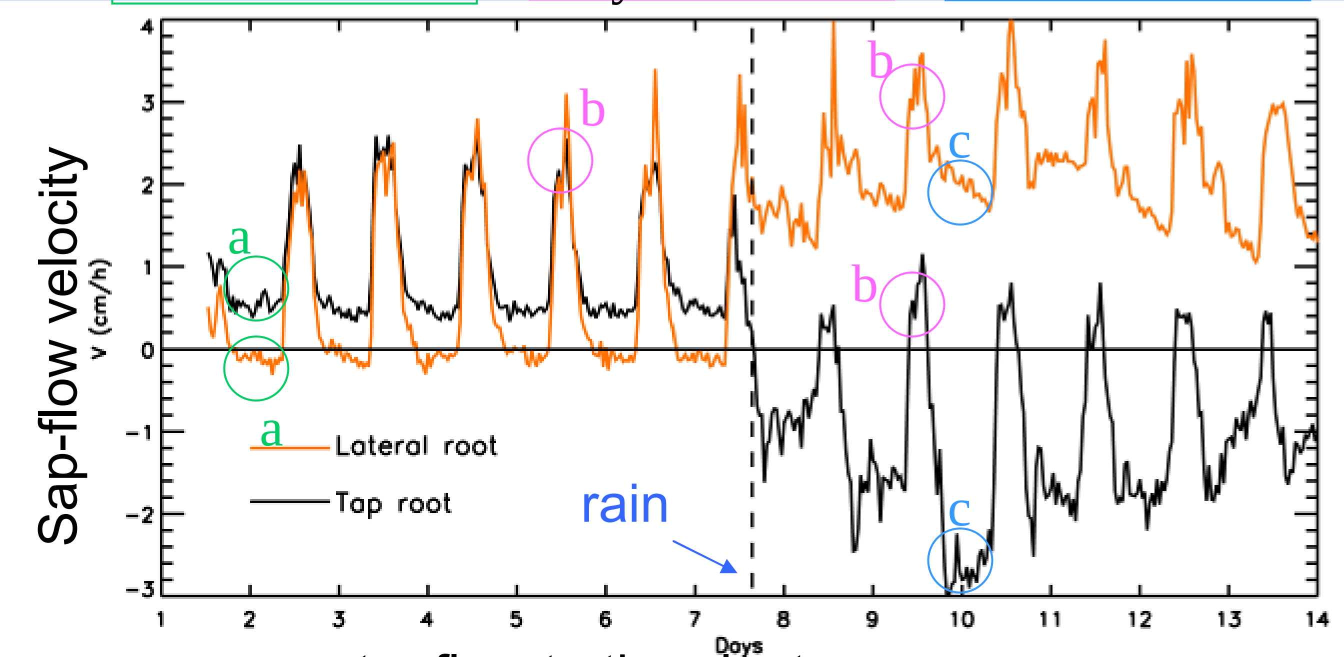


Source: Bruno et al., 2005 – Tropical forest data in Santarem km83

Ecological adaptation II: Hydraulic redistribution

Source: R. Oliveira



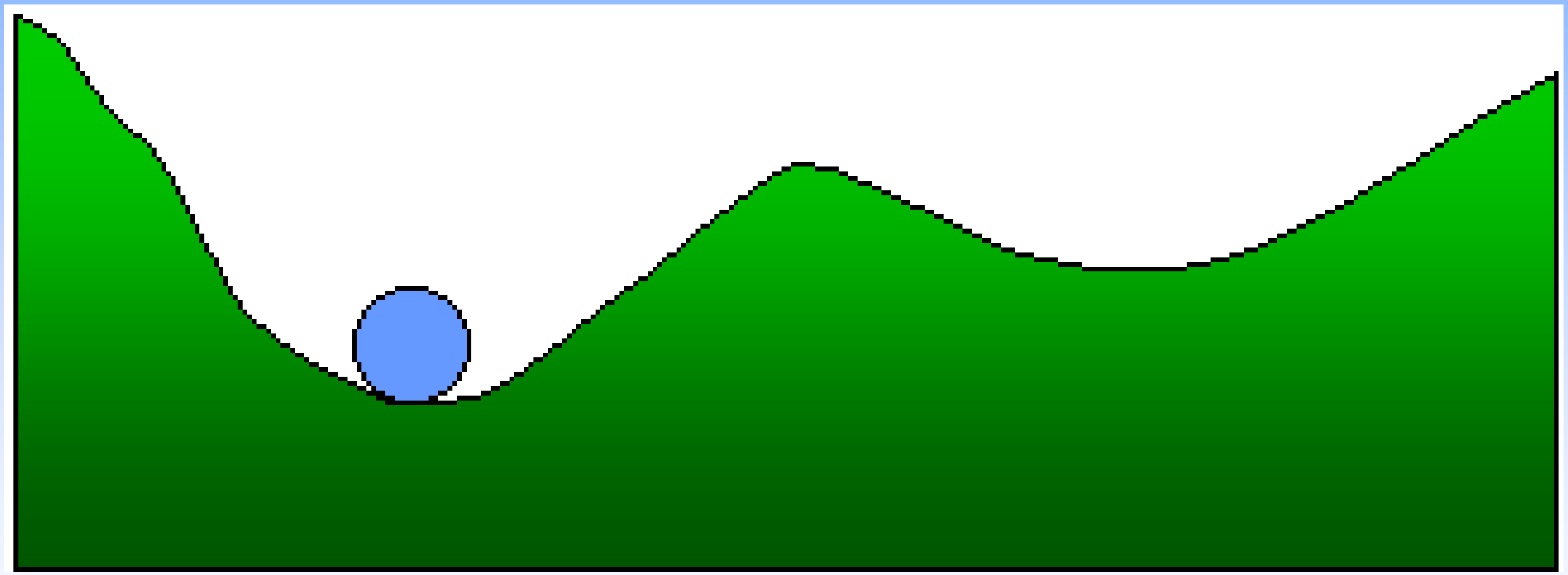


+: water flow to the plant

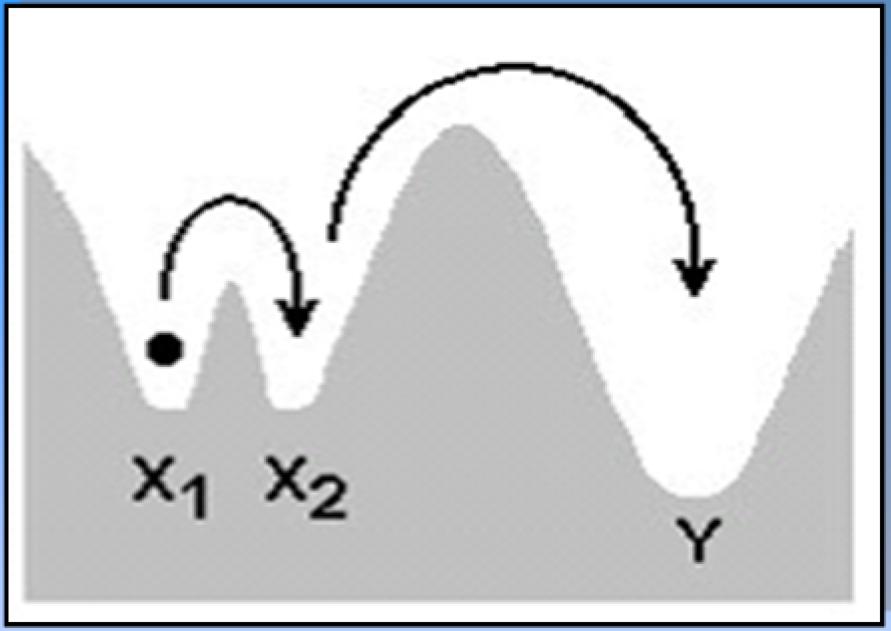
-: water flow away from the plant

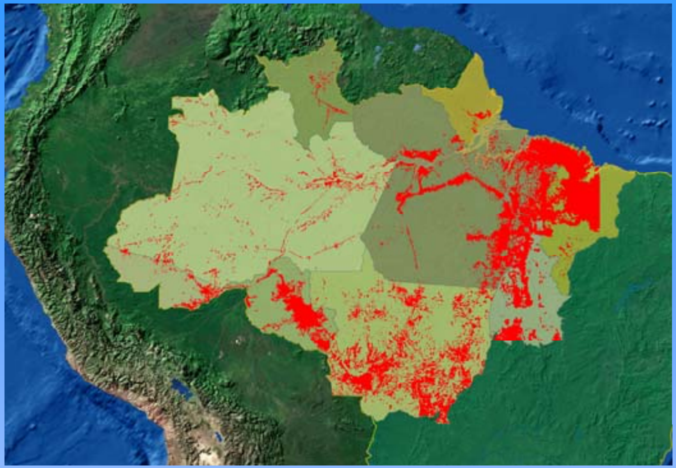
Source: Oliveira et al., 2005

Externally driven equilibrium change



Let us examine ways to change the equilibrium states





In 2007, total deforested area (clear-cutting) is 700,000 km² in Brazilian Amazonia (18%)

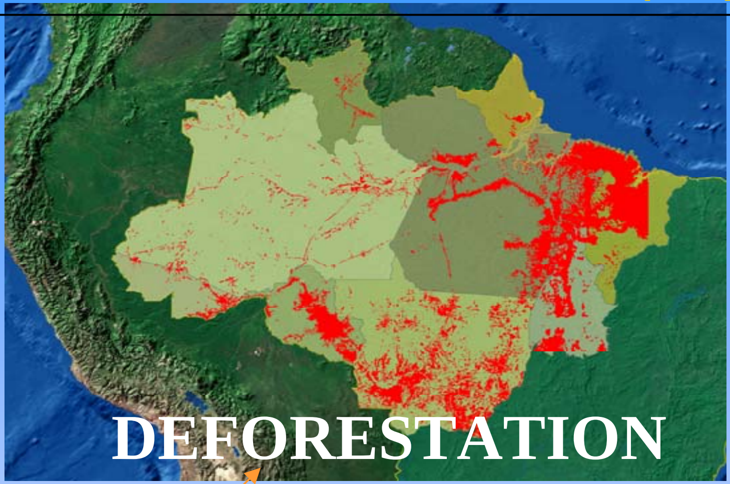
Resilience **Stochastic Perturbations**

Gradual Perturbations affect Resilience (e.g., deforestation, fire, Fragmentation, global warming, etc.)

Source: Greenpeace/Daniel Beltra

Does *climate variability (severe droughts)* play the key role linking together climate change, edaphic factors, and human use factors?

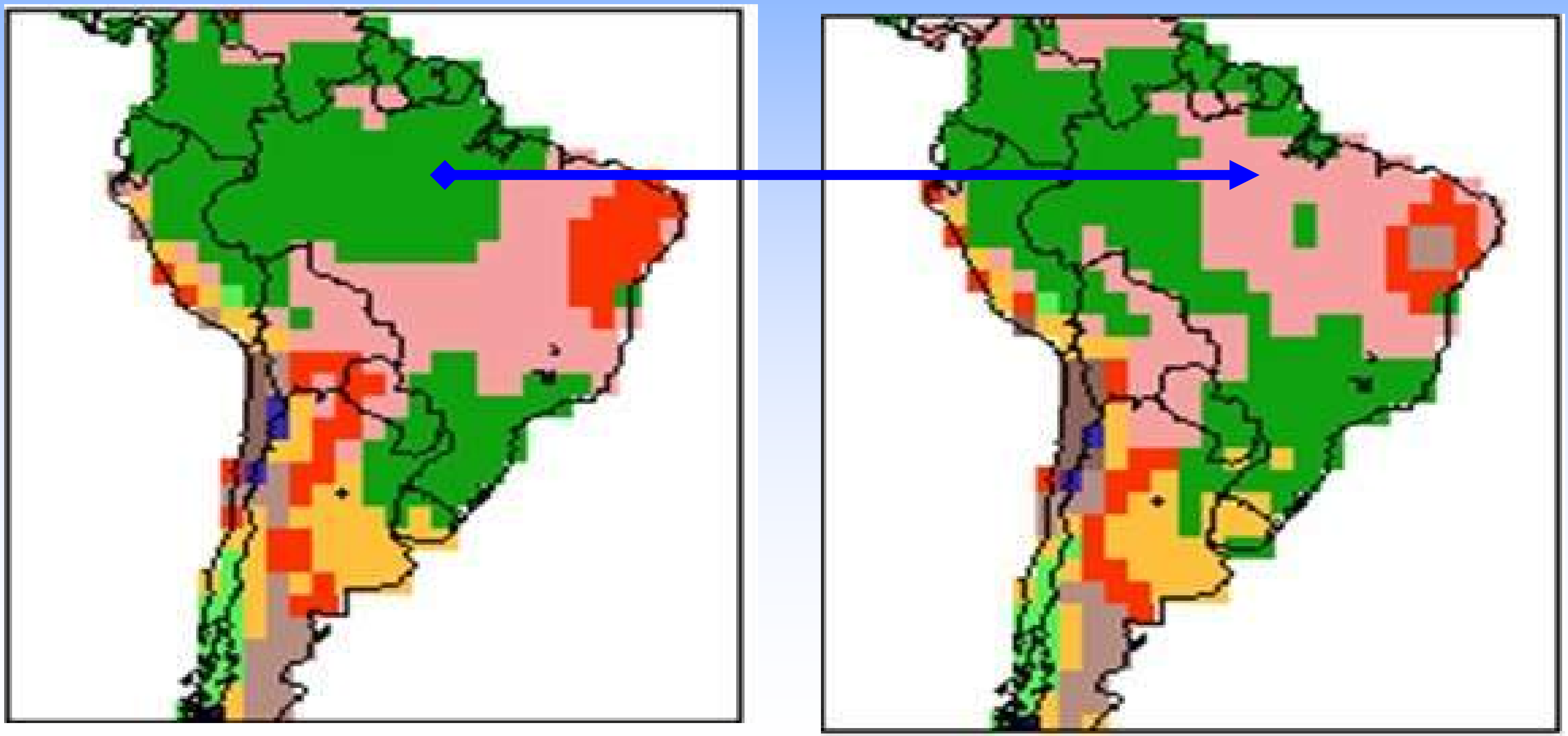
In 2007, total deforested area (clear-cutting) is 700,000 km2 in Brazilian Amazonia (18%)



Anthropoenic and Natural Drivers of Environmental Change in Amazonia

Source: Greenpeace/Daniel Beltra

Question: Is there a "tipping point" of deforestation to induce abrupt changes to the second biome-climate stable equilibrium?

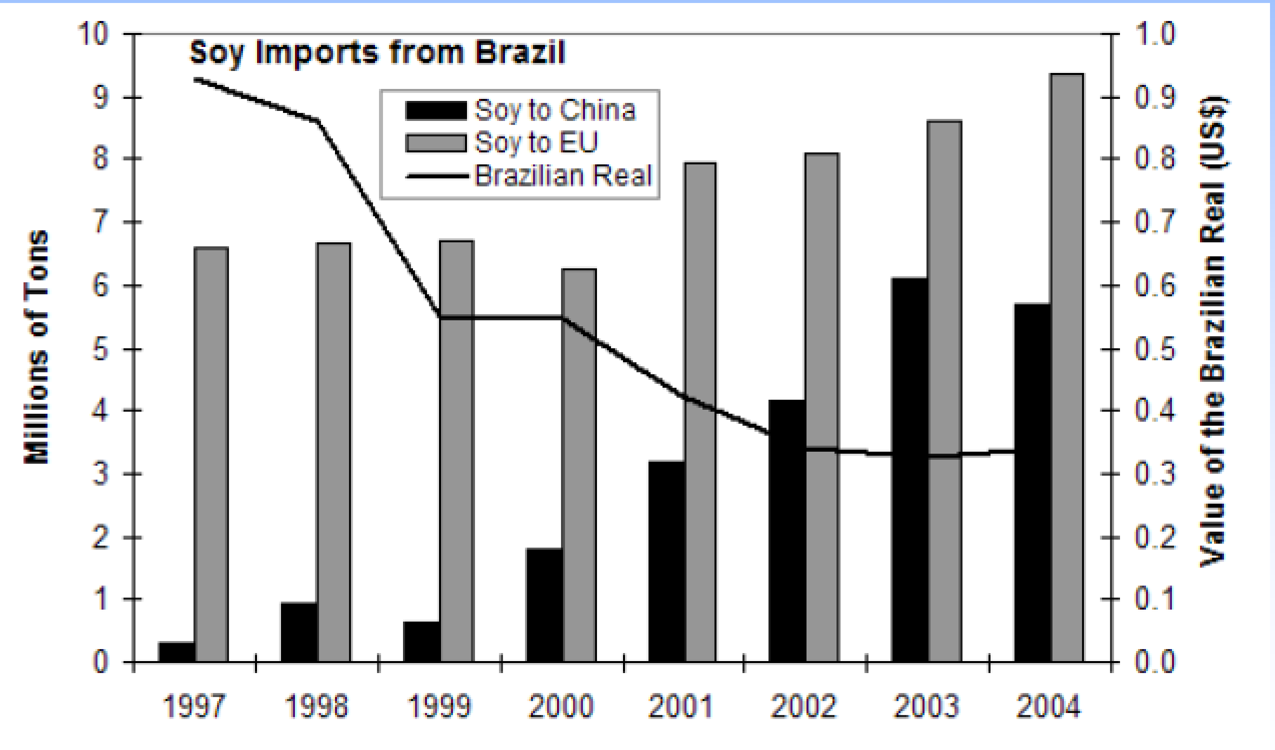


I - LAND USE AND COVER CHANGE

DEFORESTATION AND BURNING AROUND THE XINGU INDIGENOUS PARK, MATO GROSSO STATE, BRAZIL, 2004.
Source: Tropical deforestation and climate change / edited by Paulo Moutinho and Stephan Schwartzman. -- IPAM - Instituto de Pesquisa Ambiental da Amazônia, 2005.

International trade: new axis

- China, India and Brazil: now among the main drivers of the world's economy

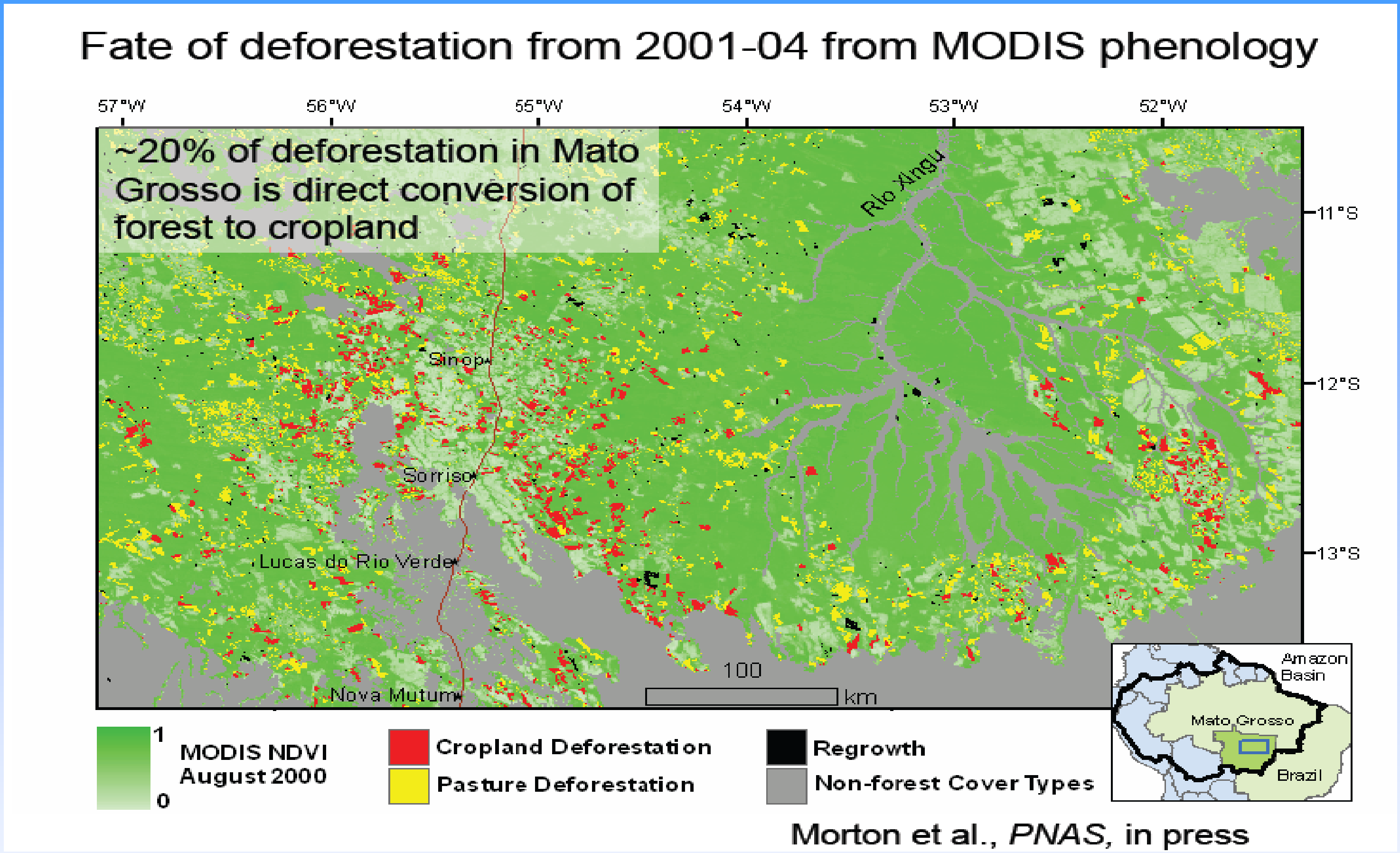


China's GDP has grown on average 9,6% per year in the last quarter century

China replaced EU as the main importer of Brazilian soybeans

Nepstad et al., *Conservation Biology* (2006)

Socioeconomic teleconnections

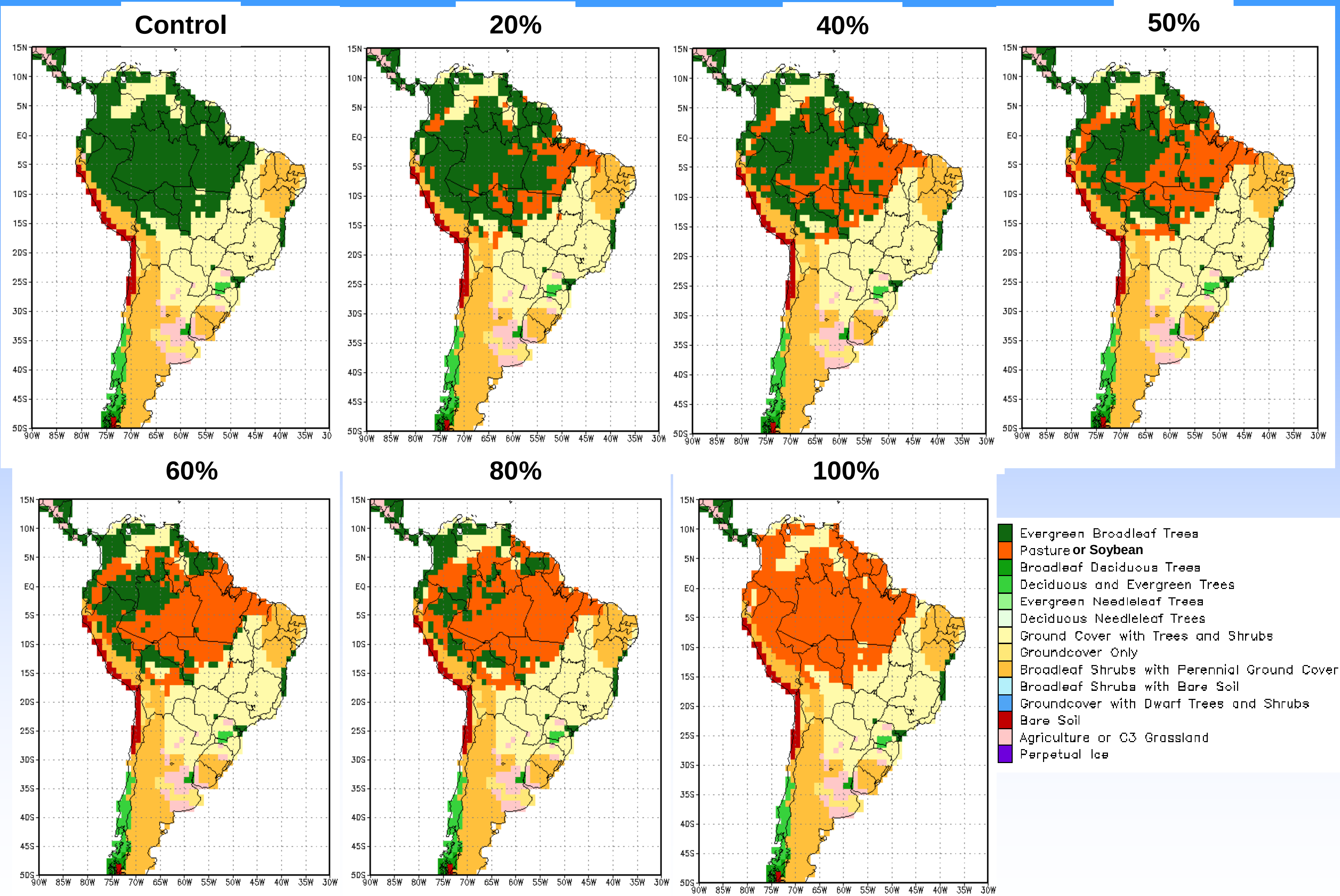


- China and Brazil are trying to fight poverty
- Increasing commodity trade is driving deforestation, though
- Pollution, disease, loss of biodiversity and CO_2 emissions are the results

Earth System Science Partnership

GLOBAL IGBP CHANGE

PROJECTED LAND COVER CHANGE SCENARIOS

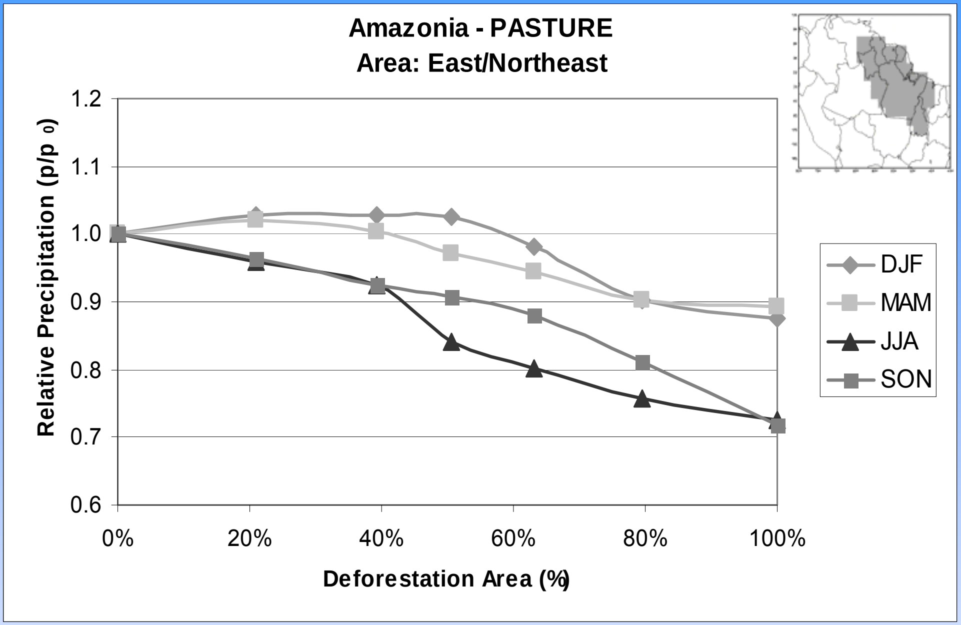


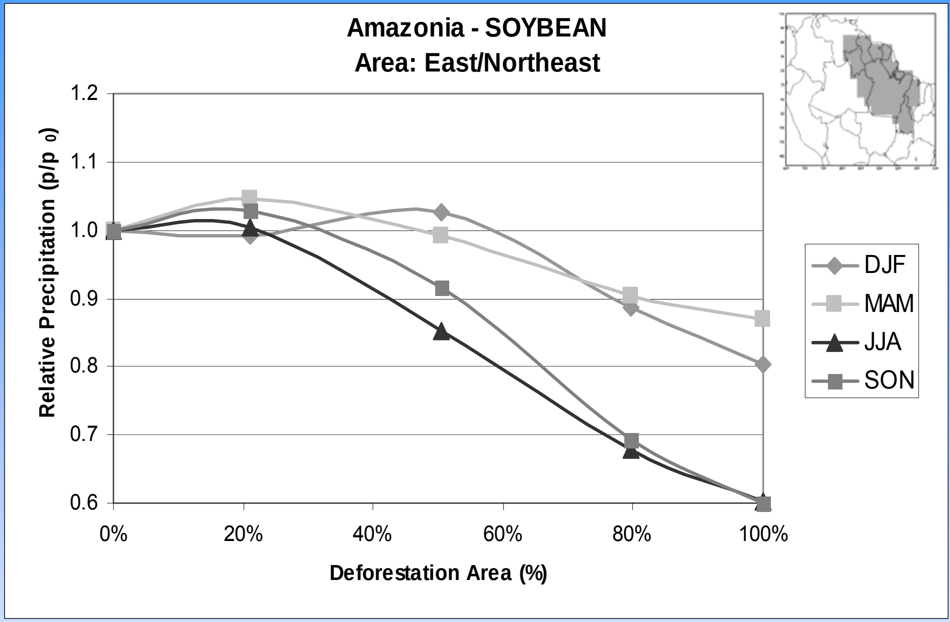
Source: Soares-Filho et al., 2006 - Amazon Scenarios Project, LBA

Sampaio et al., GRL, 2007

Precipitation

PASTURE | **SOYBEAN**





Precipitation Anomaly (%)

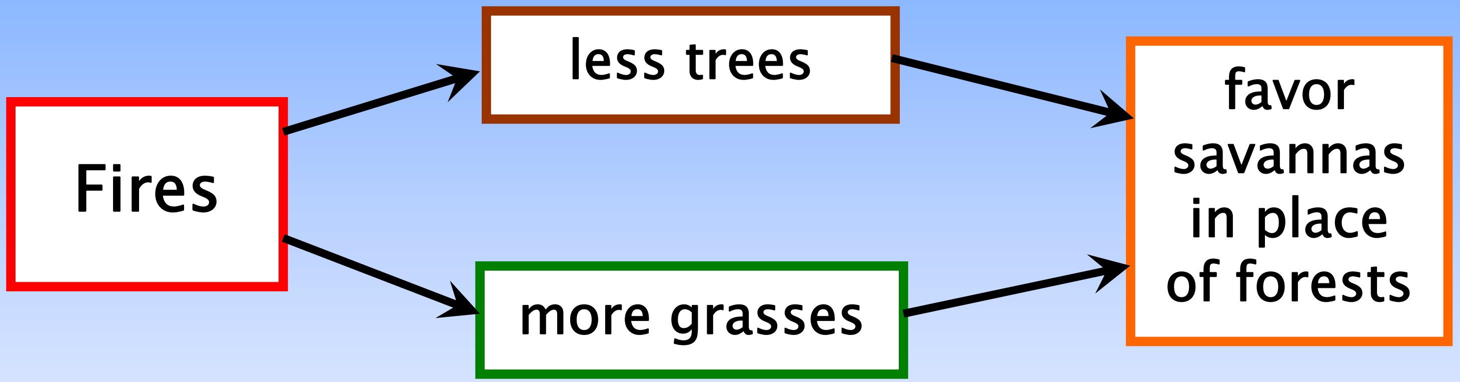
Season	All Pasture	All Soybean
JJA	**-27.5%**	**-39.8%**
SON	**-28.1%**	**-39.9%**

The reduction in precipitation is larger during the **dry season**, and is more evident when the deforested area is larger than 40% !

Sampaio et al., GRL, 2007

II The effect of fires

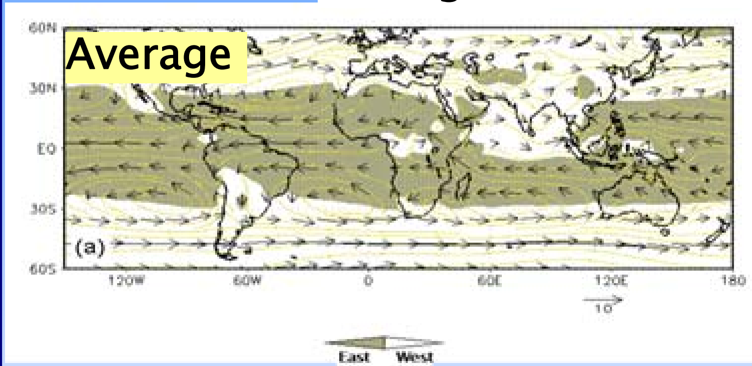
At long term, fires have also important effects on biomes distribution:

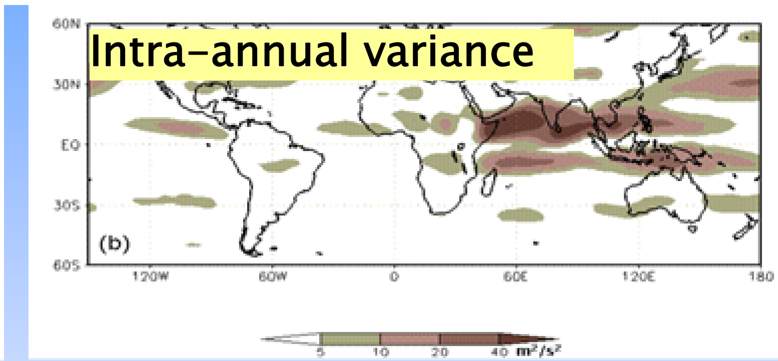


To account for fires when estimating the distribution of the natural biomes, we developed a new long-term fire parameterization based on the potential for lightning during dry-wet season transitions

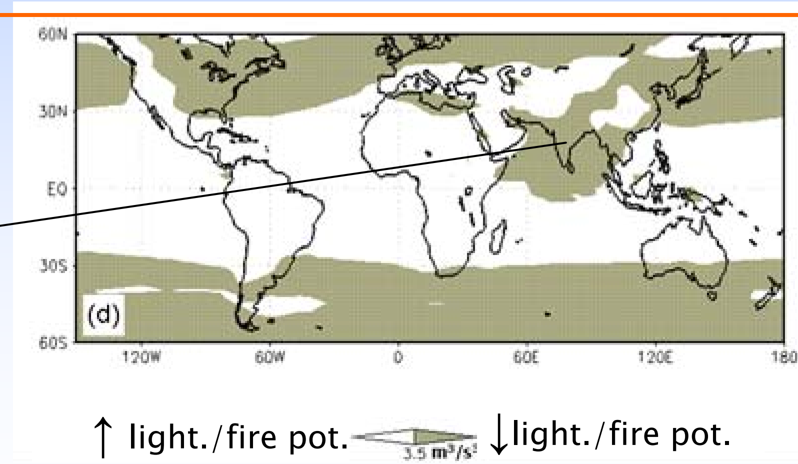
The new long-term natural fires parameterization is based on major circulation patterns:

Long-term characteristics of the zonal wind





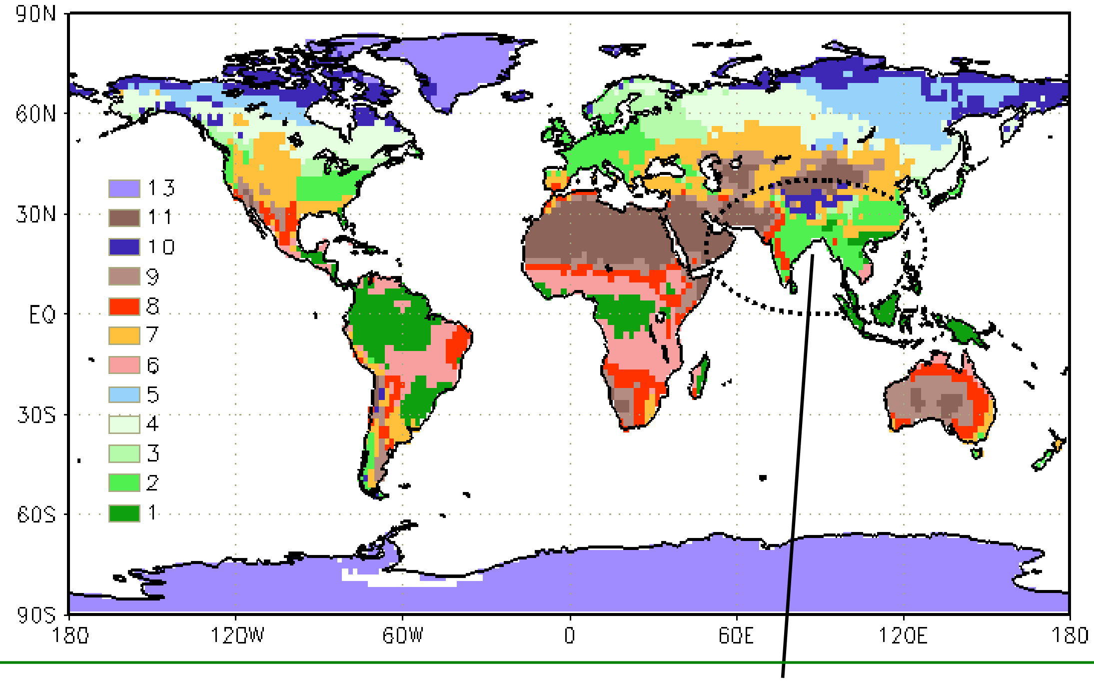
The potential for lightning/fires in the tropics is higher were combined long-term average and intra-annual variance of the zonal wind is lower than 3.5 m^3/s^3 (in grey):



Cardoso et al. (2007), GEB

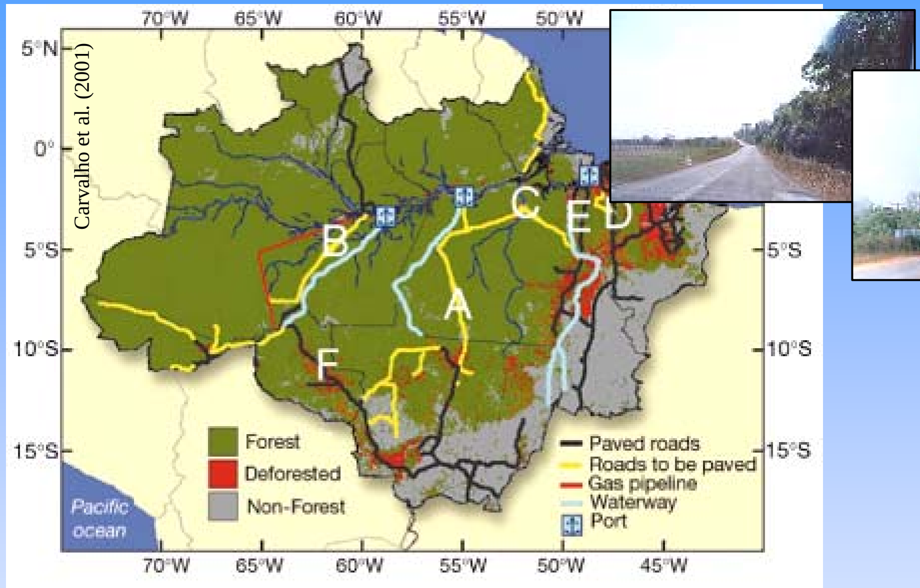
Impact of using the new fire parameterization in the biome estimates of the CPTEC Potential Vegetation Model:

Major vegetation types:
(1) broadleaf-evergreen trees (tropical forest),
(2) broadleaf-deciduous trees (temperate forest),
(3) broadleaf and needleleaf trees (mixed forest),
(4) needleleaf-evergreen trees (boreal forest),
(5) needleleaf-deciduous trees (larch),
(6) broadleaf trees with groundcover (savanna),
(7) groundcover only (prairie, steppes),
(8) broadleaf shrubs with perennial groundcover (caatinga),
(9) broadleaf shrubs with bare soil (semi-desert),
(10) dwarf trees and shrubs with groundcover (tundra),
(11) bare soil (desert),
(13) ice.



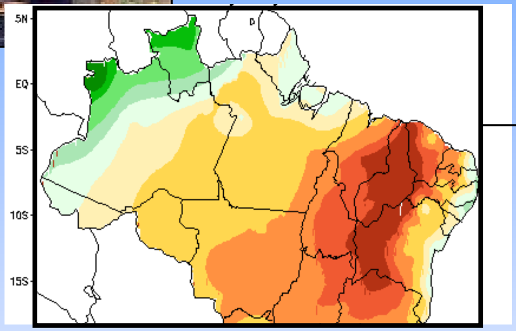
Accounting for fires corrected important differences between previous model estimates and reference data for the position of natural savannas in the tropics. In specific, large areas in India and SE Asia that were initially estimated as savannas are now corrected to dry forests.

Cardoso et al. (2007), GEB



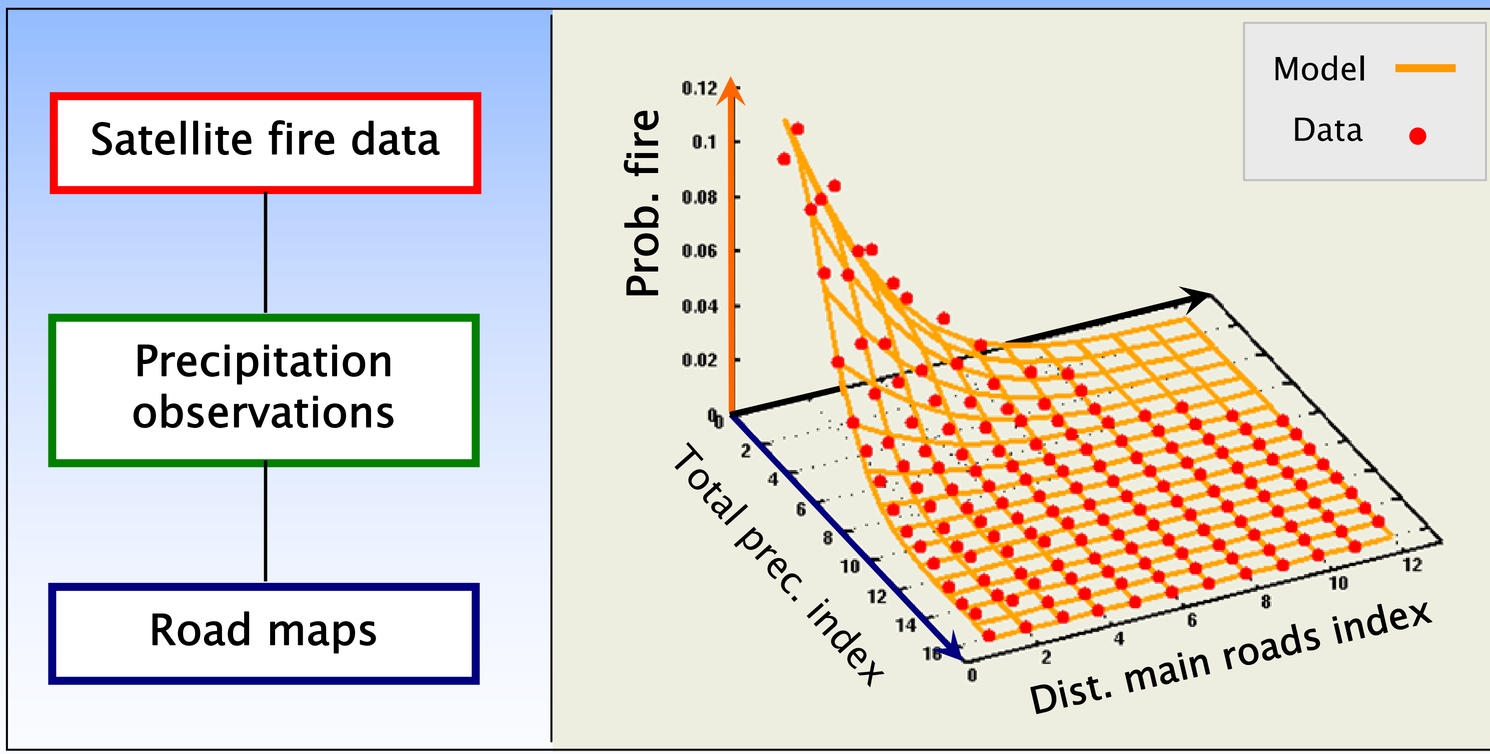
Land use

Dry season



At annual-decadal time scales, the majority of fires in Amazonia occur during the dry season as a result of land use

Using remote-sensing fire data, we found new statistical relations between precipitation and distance to main roads, which are the major drivers for yearly-decade fire activity in the region:

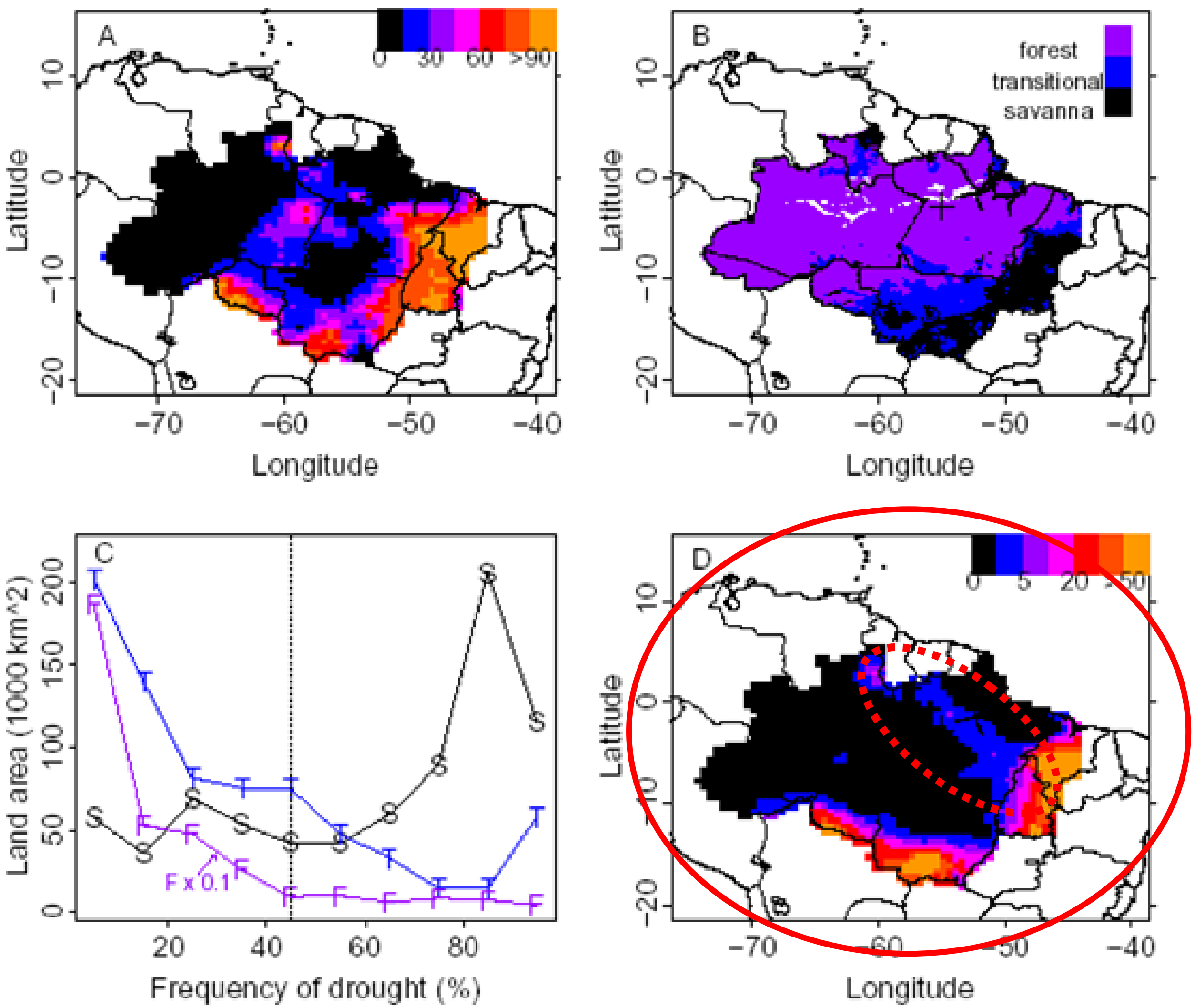


Cardoso et al. (2003, 2007)

III - CLIMATE EXTREMES

The impact of droughts

Vegetation vulnerability to droughts



Percent attainment of the Nix criteria [1983] for savanna in the last 100 years

Climate conditions for tropical savannas (Nix 1983)

T_{mean} > 24 C

13 C < $T_{coldest\ month}$ < 18 C

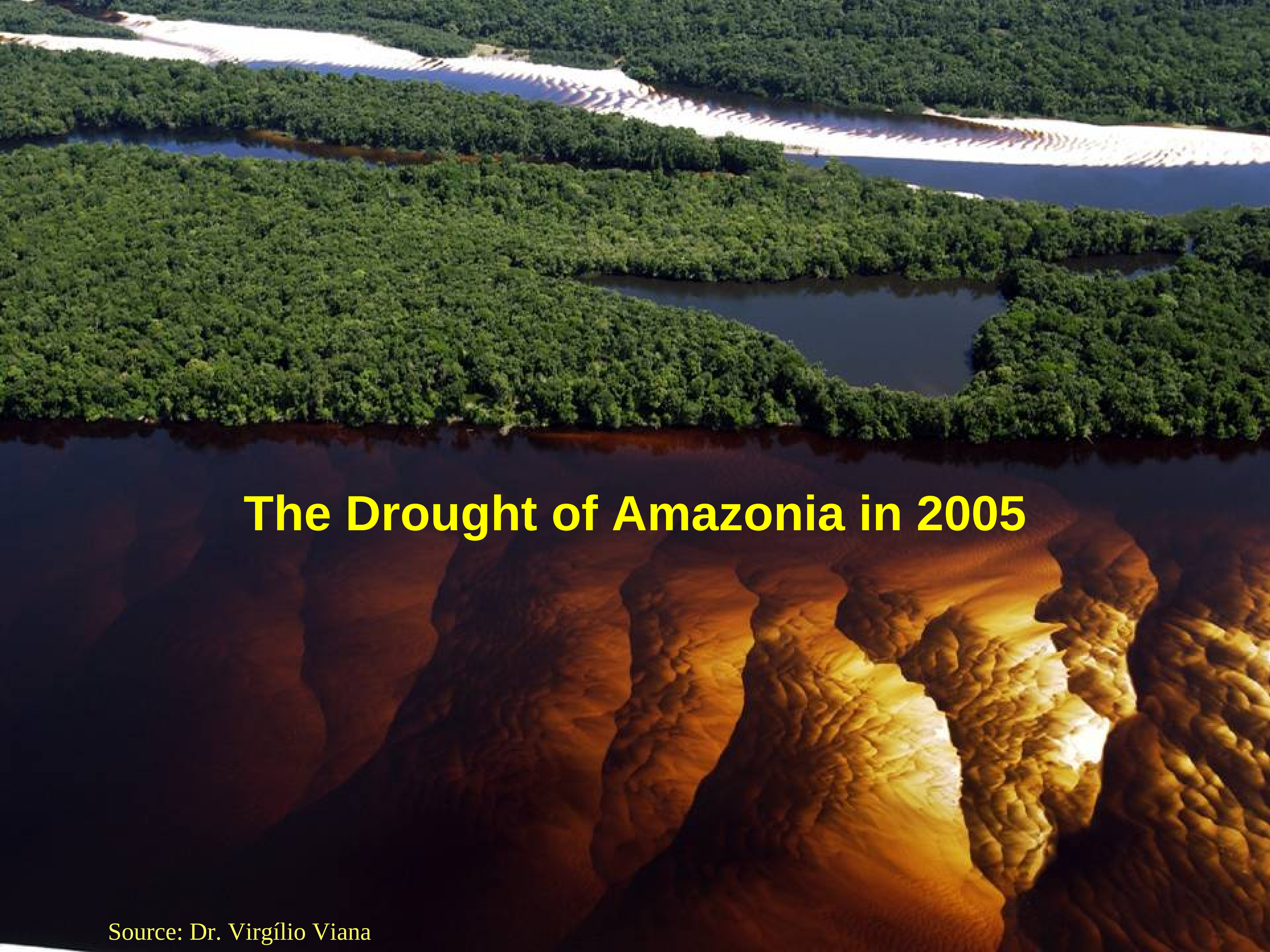
P(3 driest months) < 50 mm

P(6 wettest months) > 600 mm

1000 mm < P_{annual} < 1500 mm

(A) Observed drought frequency (% years); (B) distribution of savanna, transitional vegetation, and forest across the legal Brazilian Amazon; (C) Land area (1000 km2) of vegetation types for pixels with given drought frequency (%), forest land area is multiplied by 0.1 for scaling; (D) percent attainment of the Nix [1983] criteria for savanna vegetation in the last 100 years.

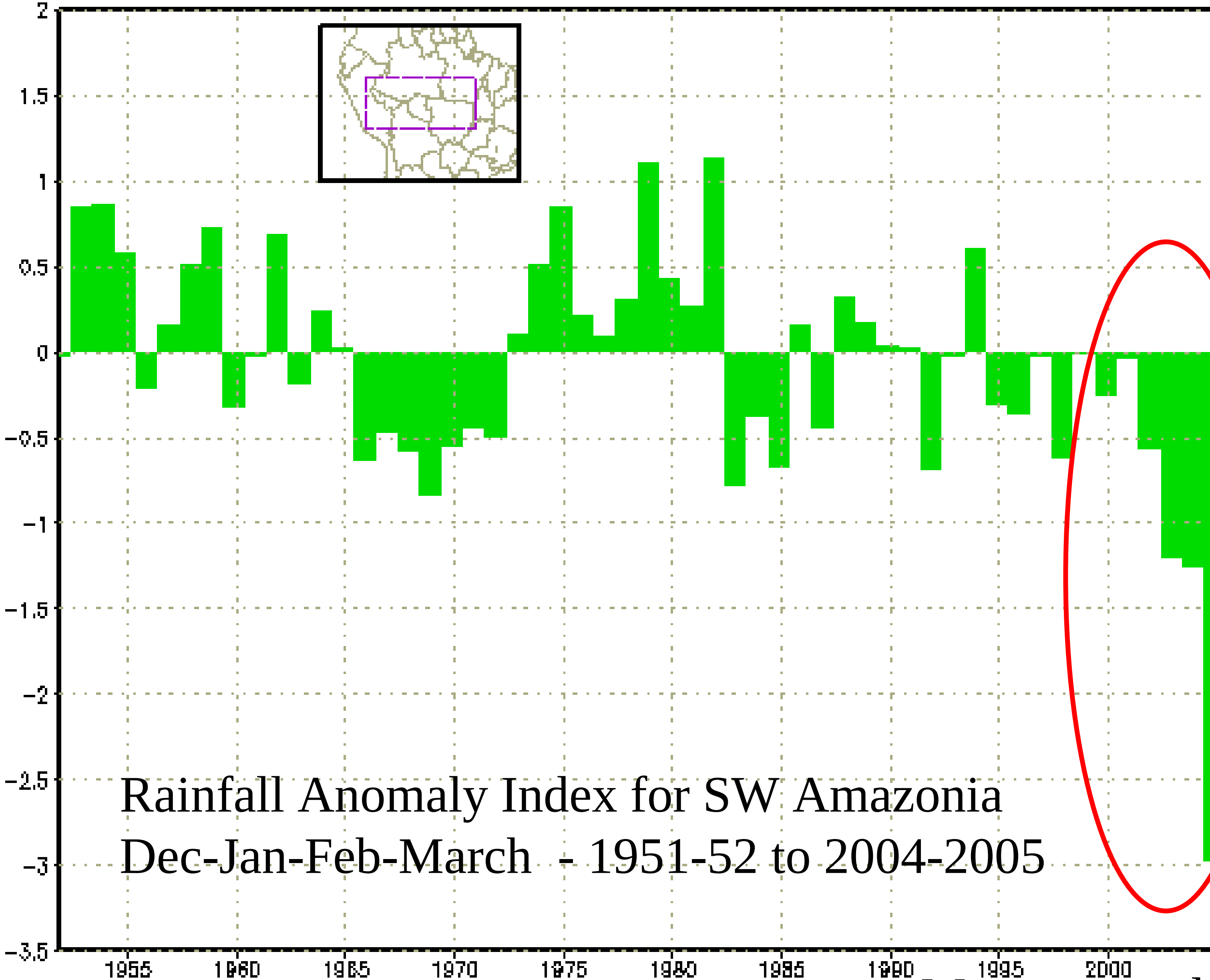
Source: Hutyara et al, 2005


The Drought of Amazonia in 2005
Source: Dr. Virgílio Viana

Are hydrological extremes becoming more frequent?

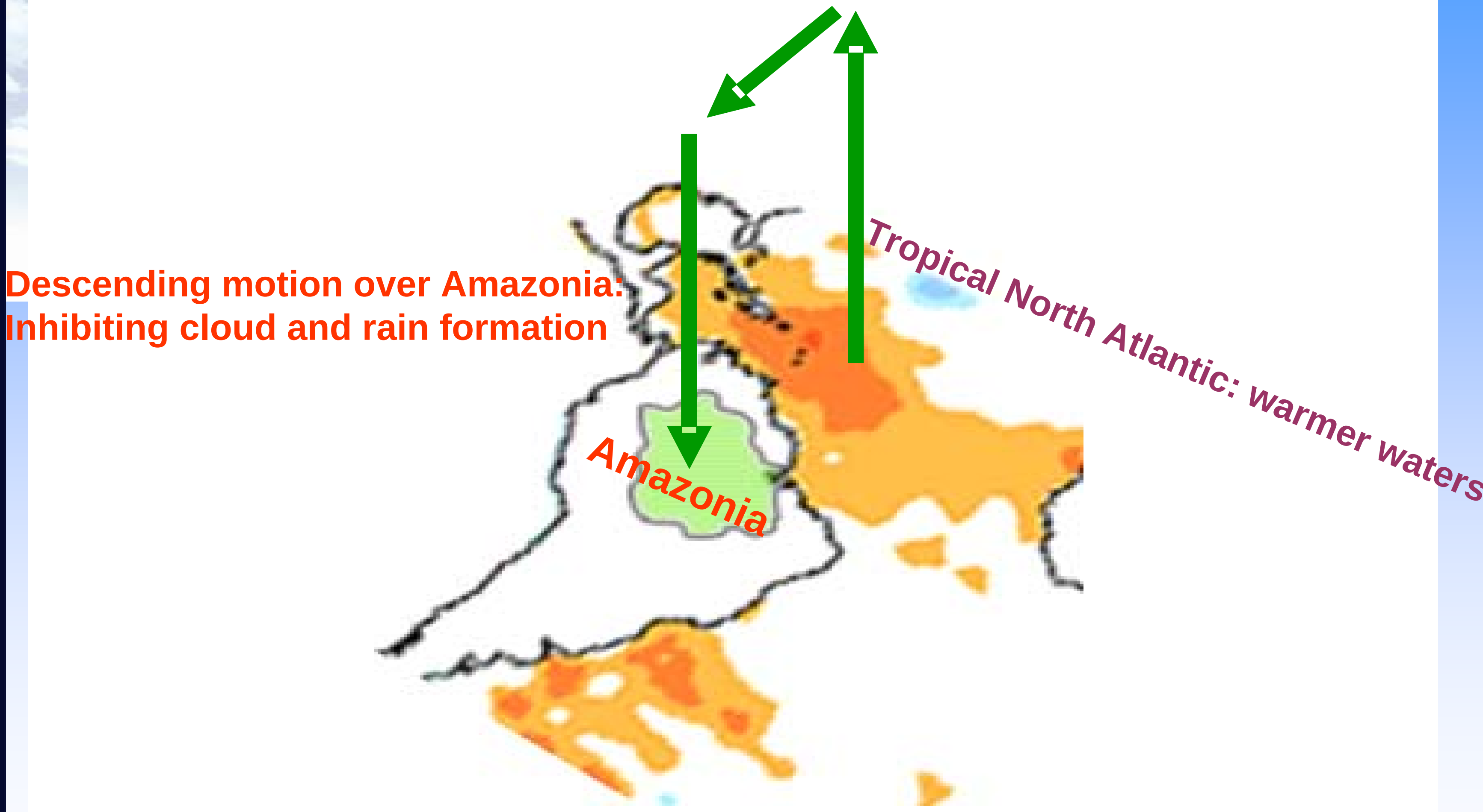
“The 2005 Western Amazon drought: one of the the most intense drought of the last 100”

Anomalia de Precipitação
Dez-Jan-Fev-Mar de 1951/52 a 2004/05



Marengo et al., 2007

Anomalous enhancement of Hadley Cell-type circulation in September 2005



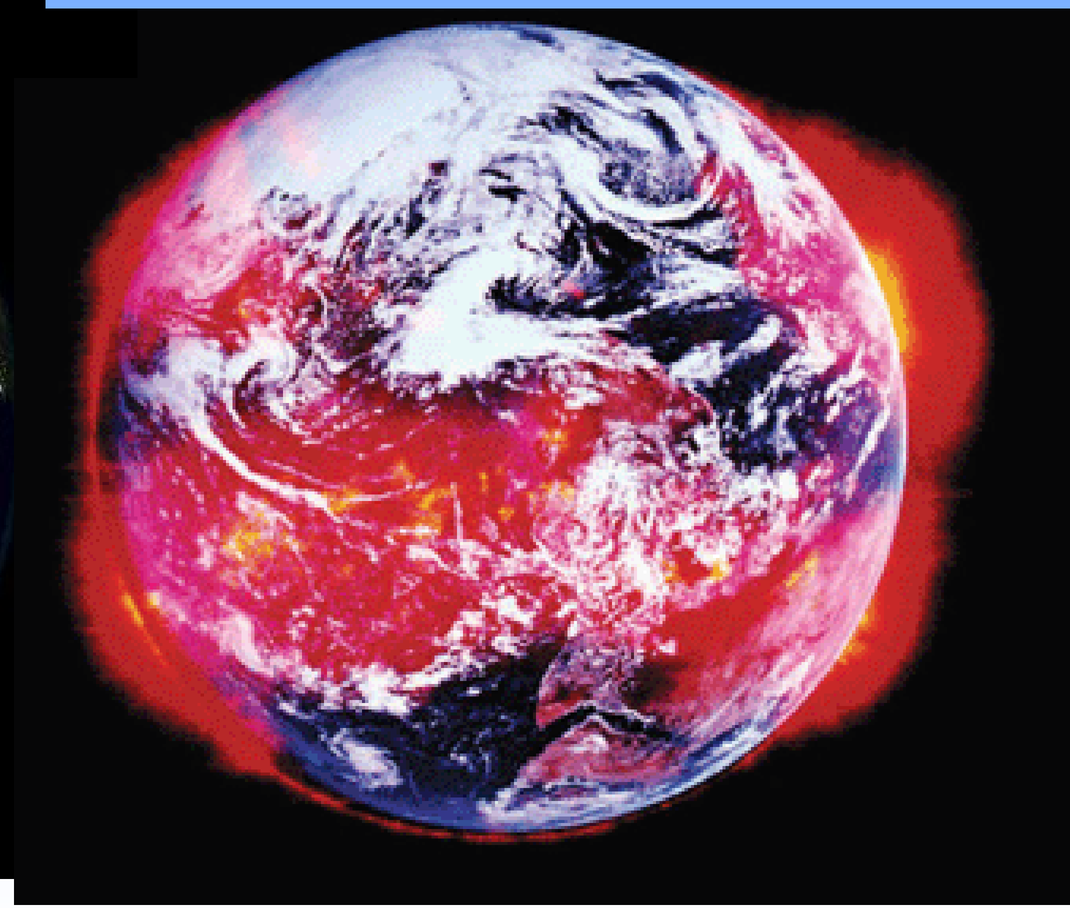
Cortesia: Jacy Saraira - SIPAM

A word of caution:

- A recent result (Saleska et al., 2007 Science) showed that the ecological systems thrived over drought-stricken SW Amazonia in 2005.

- Therefore, look for second order effect of fires (e.g., increased forest fires during the dry season) or change in the frequency of droughts.

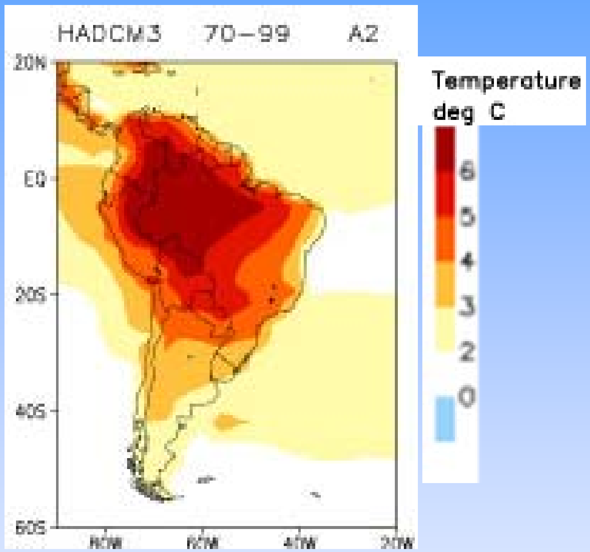
IV – GLOBAL WARMING

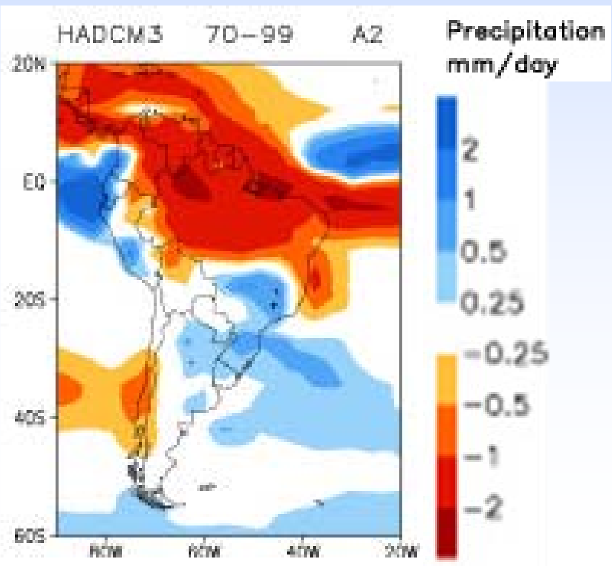


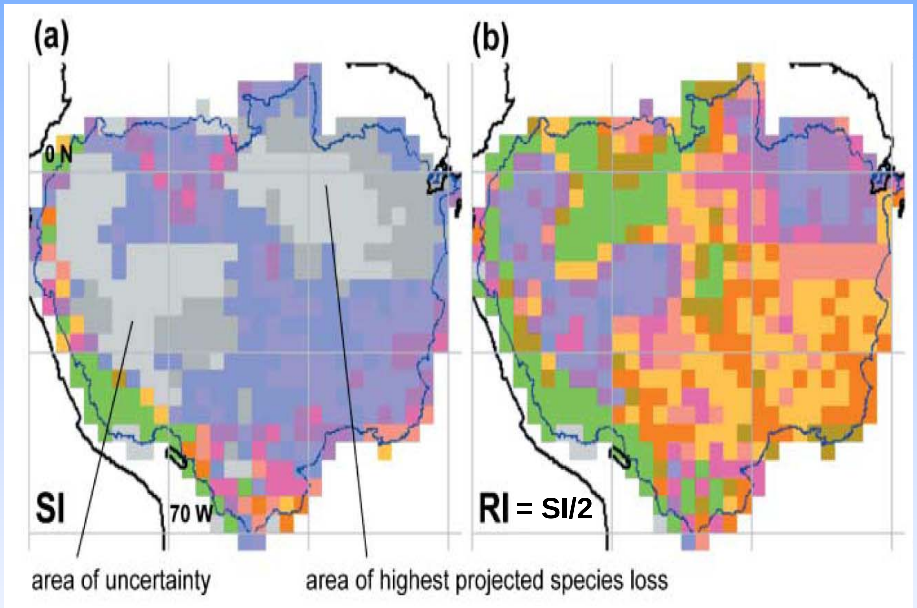
What are the likely biome changes in Tropical South America due to Global Warming scenarios of climate change?

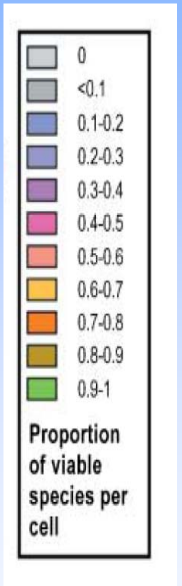
The impact of global climate change on tropical forest biodiversity in Amazonia.

Climate Model: HADCM2GSa1
1% CO_2 increase/yr



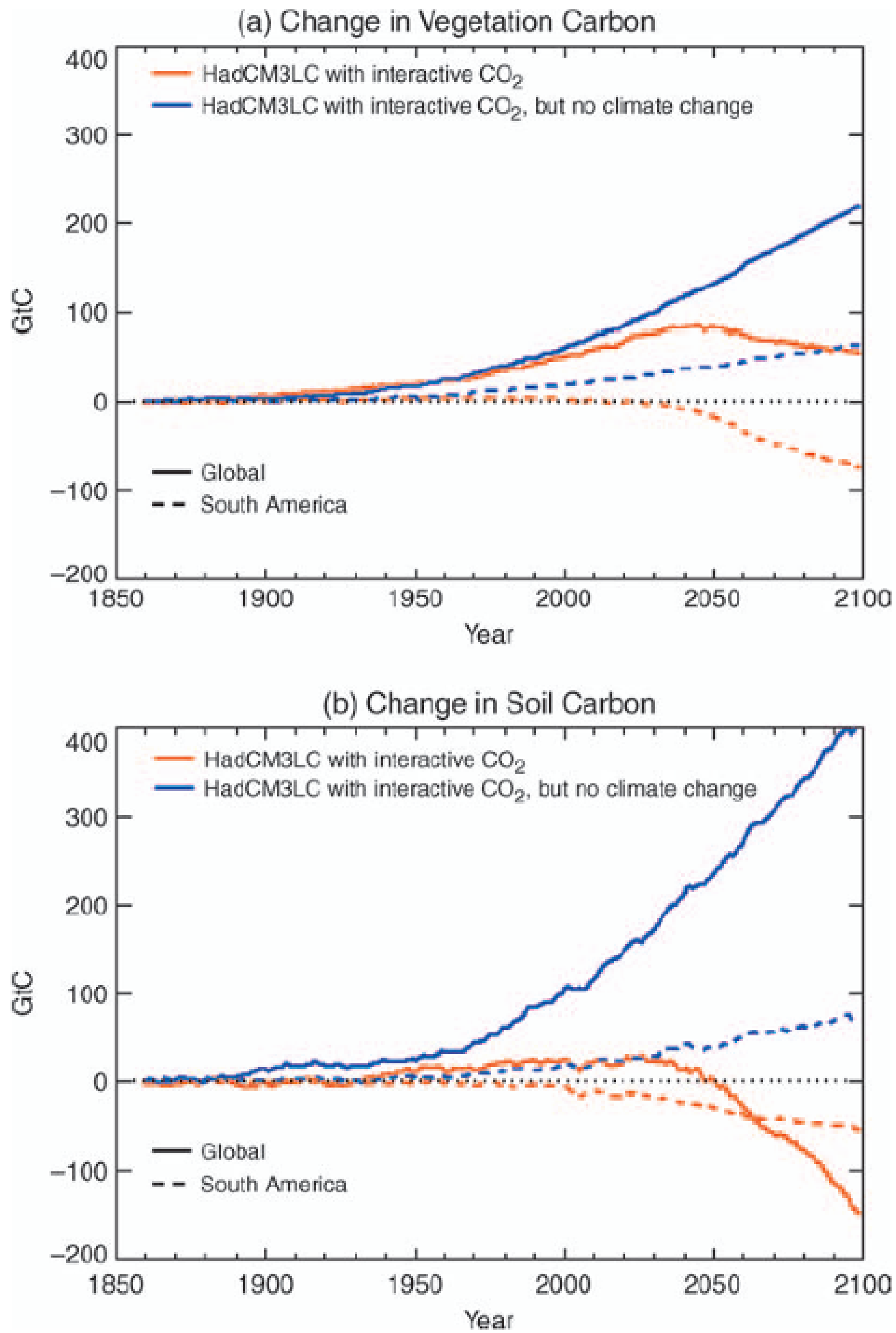






43% of 69 species of *Angiosperms* become non-viable by 2095!

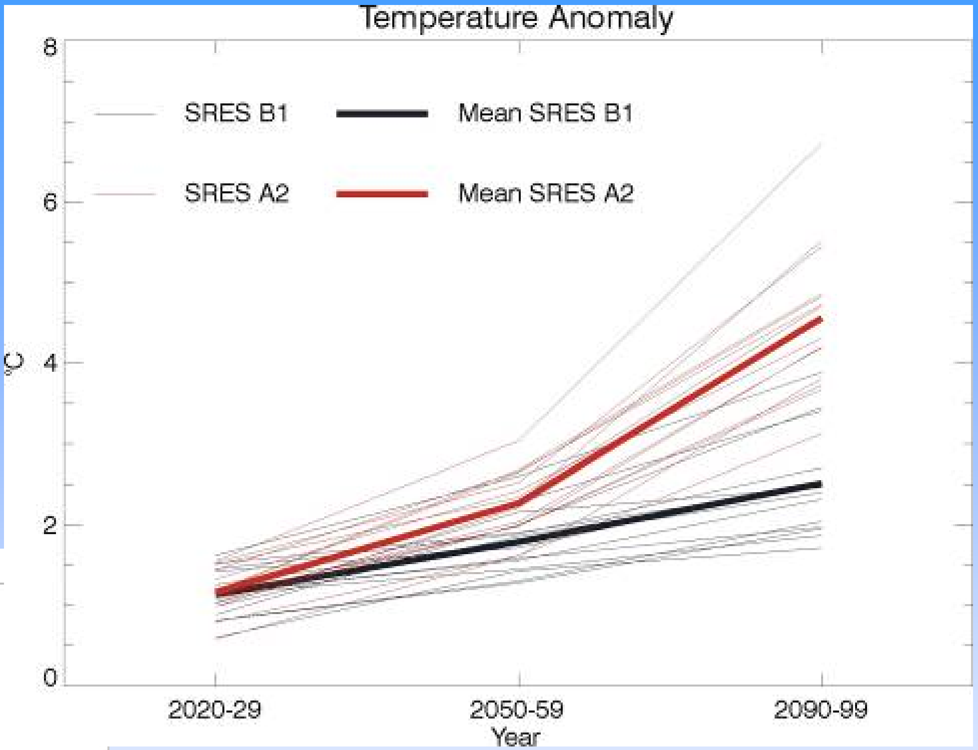
Source: Miles et al. 2004.

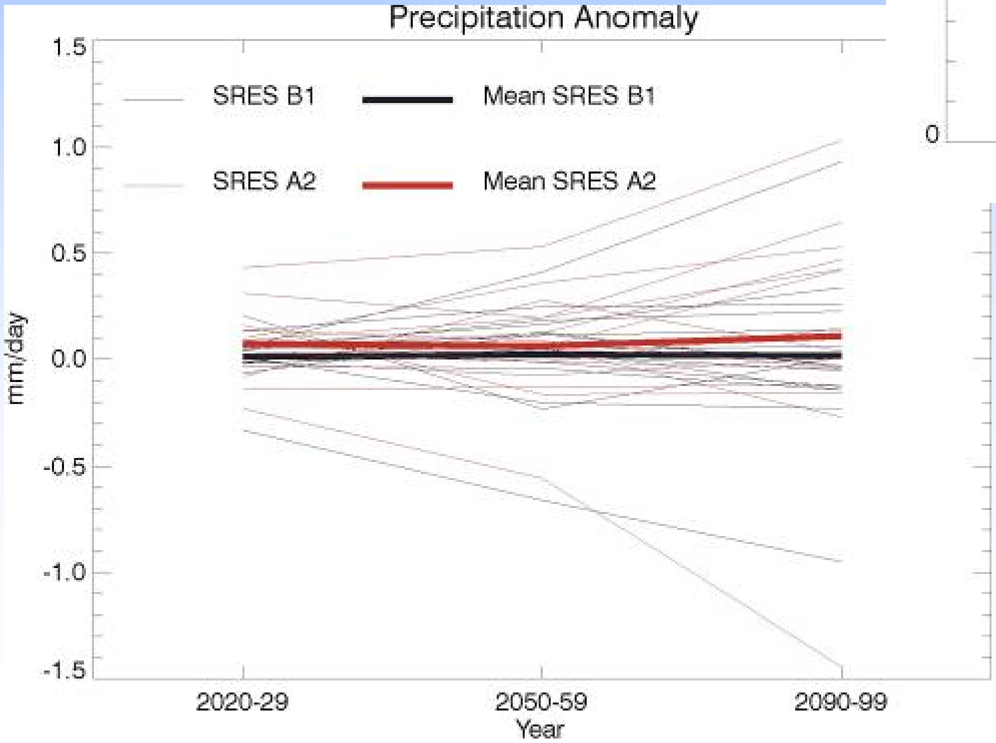


Betts et al., 2004

Fig. 10. Timeseries of changes in Global and South American terrestrial carbon stores with and without climate-carbon cycle feedbacks. **(a)** Vegetation carbon **(b)** soil carbon

Climate Change Scenarios for Amazonia

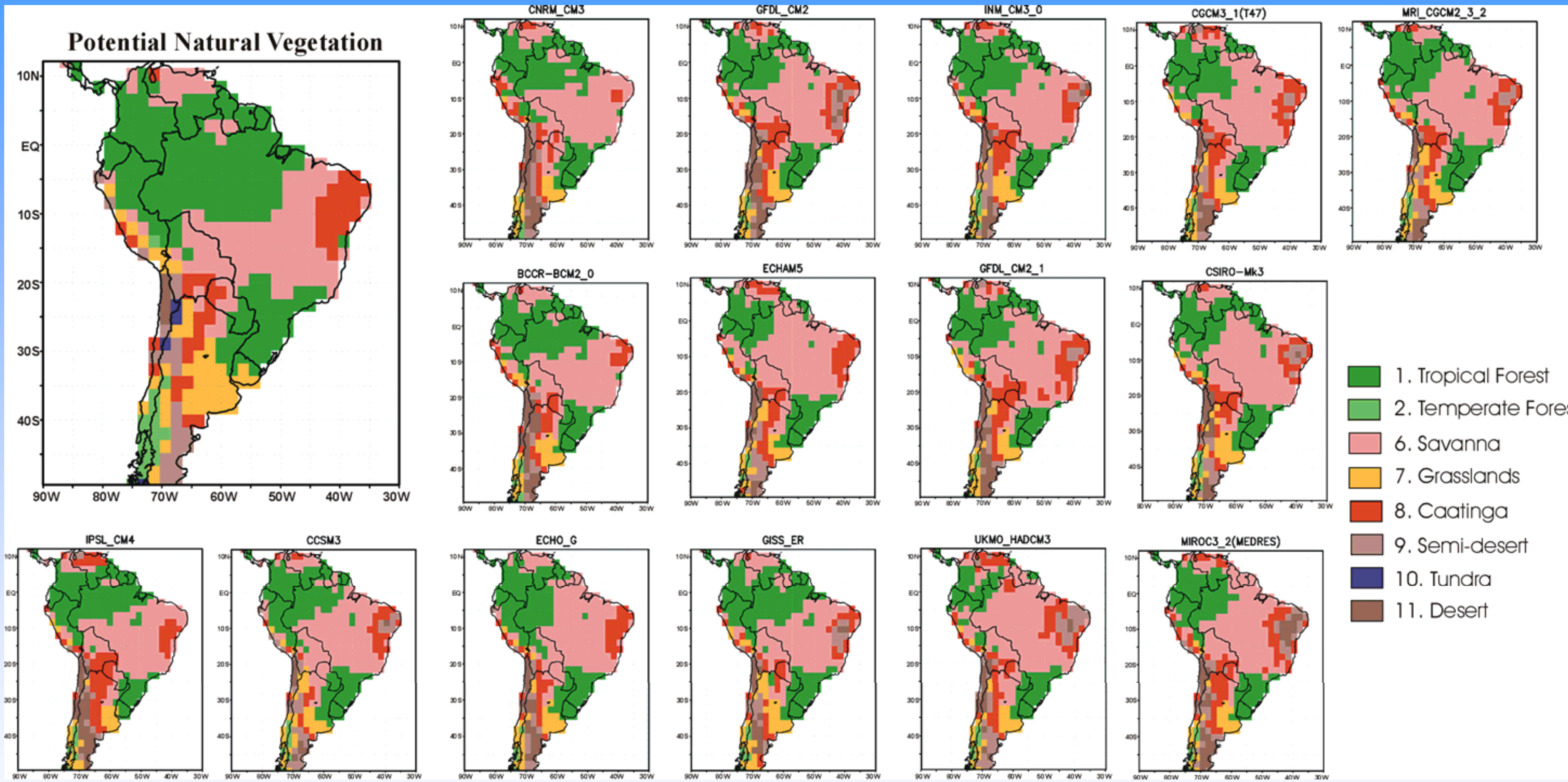




Results from 15 AOGCMs for the SRES A2 and B1 emissions scenarios, prepared for the IPCC/AR4.

Models: BCCR-BCM2.0, CCSM3, CGCM3.1(T47), CNRM-CM3, CSIRO-MK3, ECHAM5, GFDL-CM2, GFDL-CM2.1, GISS-ER, INM-CM3, IPSL-CM4, MIROC3.2 (MEDRES), MRI-CGCM2.3.2, UKMO-HADCM3, ECHO-G

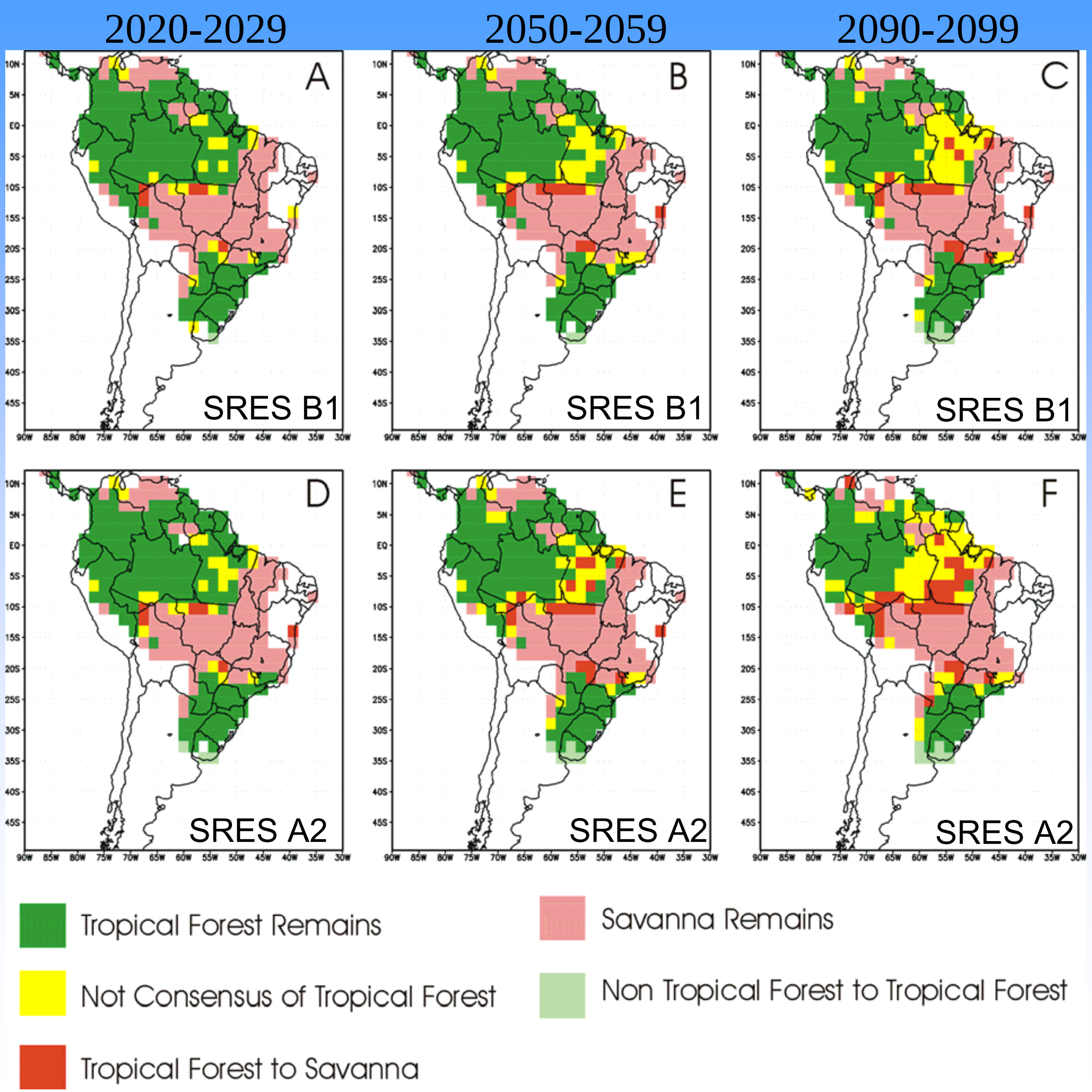
Climate Change Consequences on the Biome distribution in tropical South America



Projected distribution of natural biomes in South America for 2090-2099 from 15 AOGCMs for the A2 emissions scenarios, calculated by using CPTEC-INPE PVM.

Salazar et al., 2007

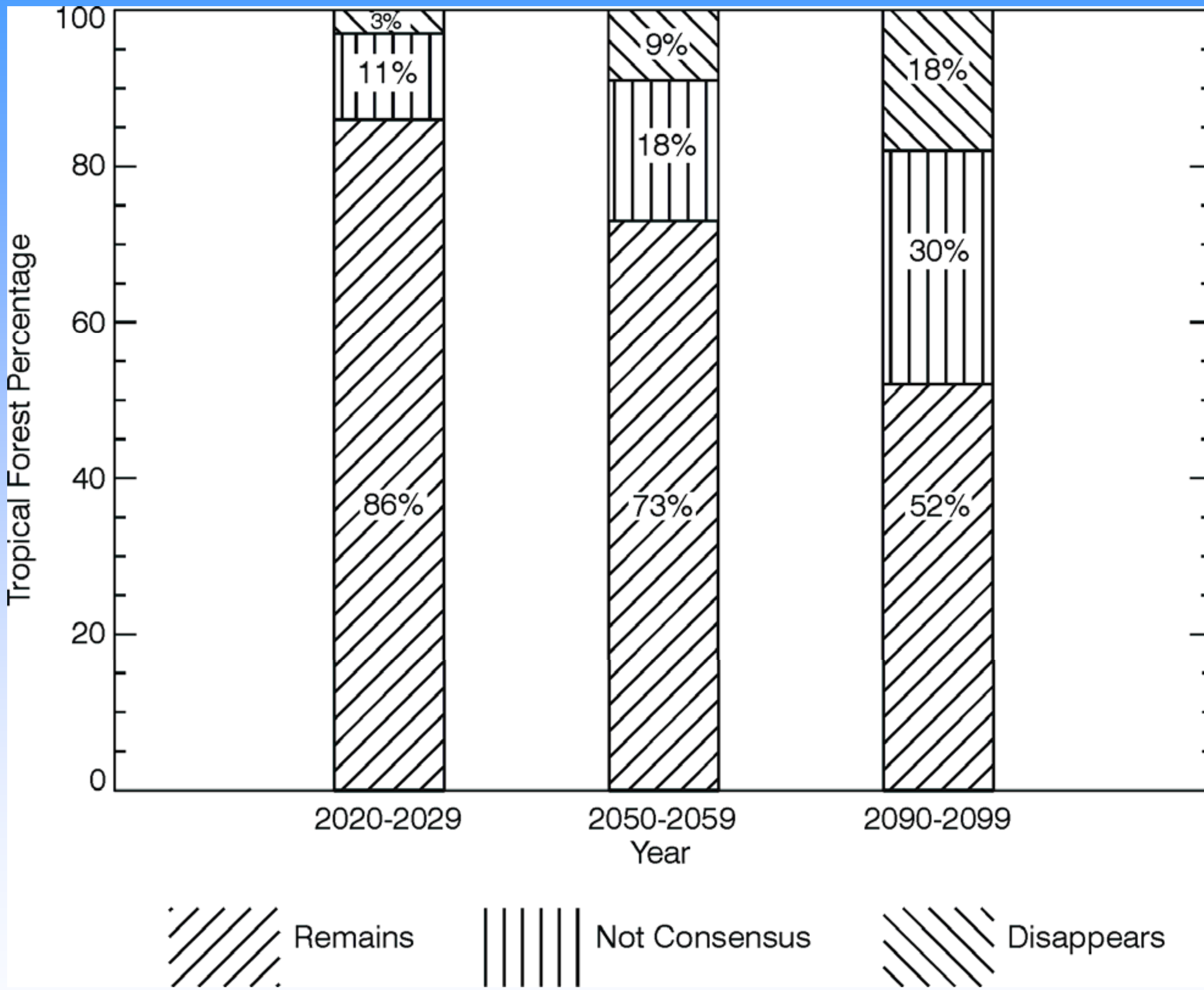
Climate Change Consequences on the Biome distribution in tropical South America



Grid points where more than 75% of the models used (> 11 models) coincide as projecting the future condition of the tropical forest and the savanna in relation with the current potential vegetation. The figure also shows the grid points where a consensus amongst the models of the future condition of the tropical forest was not found. for the periods (a) 2020-2029, (b) 2050-2059 and (c) 2090-2099 for B1 GHG emissions scenario and (d), (e) and (f) similarly for A2 GHG emissions scenario.

Salazar et al., 2007 GRL (accepted)

Climate Change Consequences on the Biome distribution in tropical South America



Percentage of the area where more than 75% of the experiments for the A2 GHG scenarios, coincide as projecting the permanence or disappearance of the current potential tropical forest, and where there is not a conclusive consensus amongst models

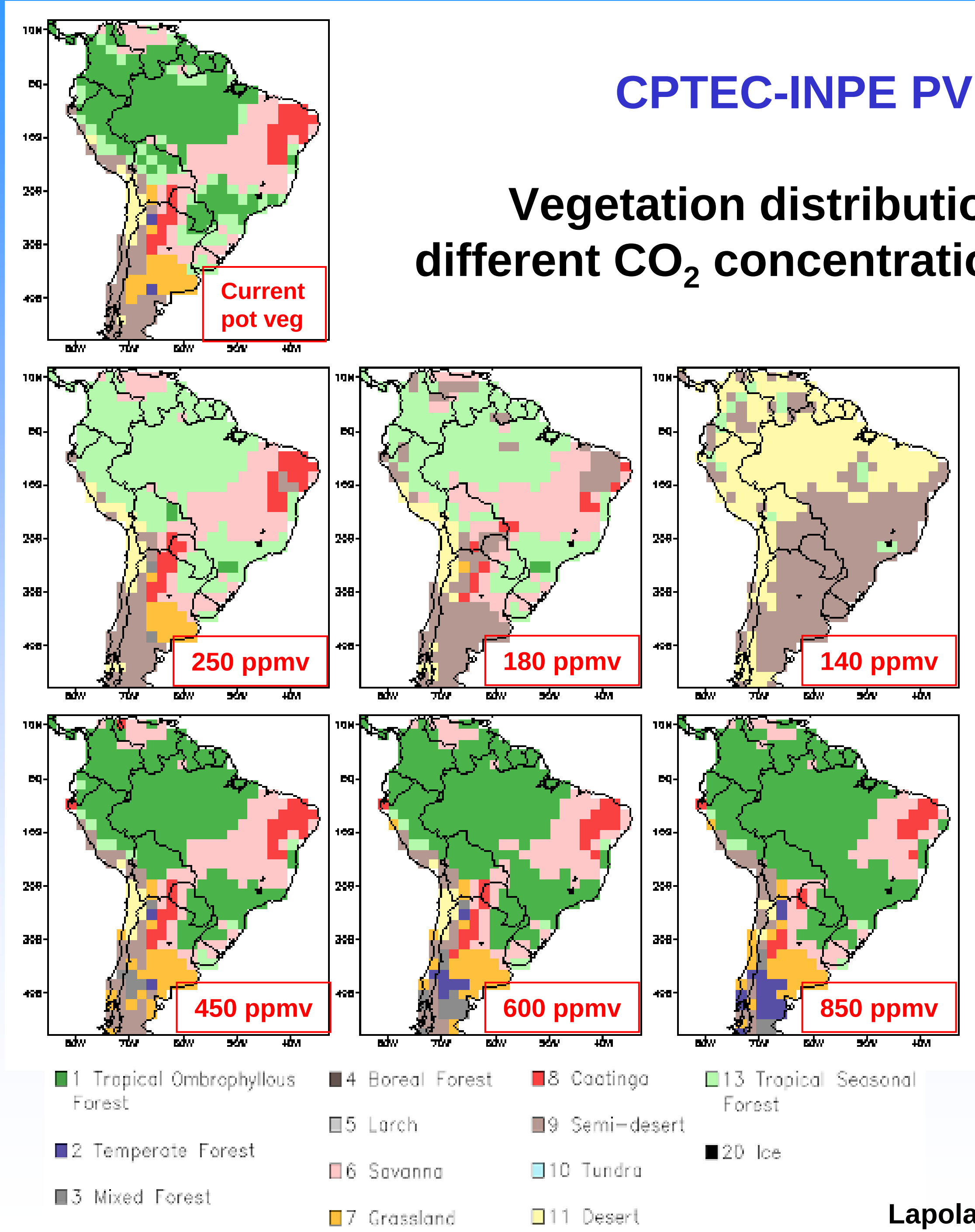
Salazar et al., 2007 GRL (accepted)

The previous calculation does not take into consideration changes in the ecological functioning of vegetation in response to elevated CO_2.

What happens when this effect is incorporated?

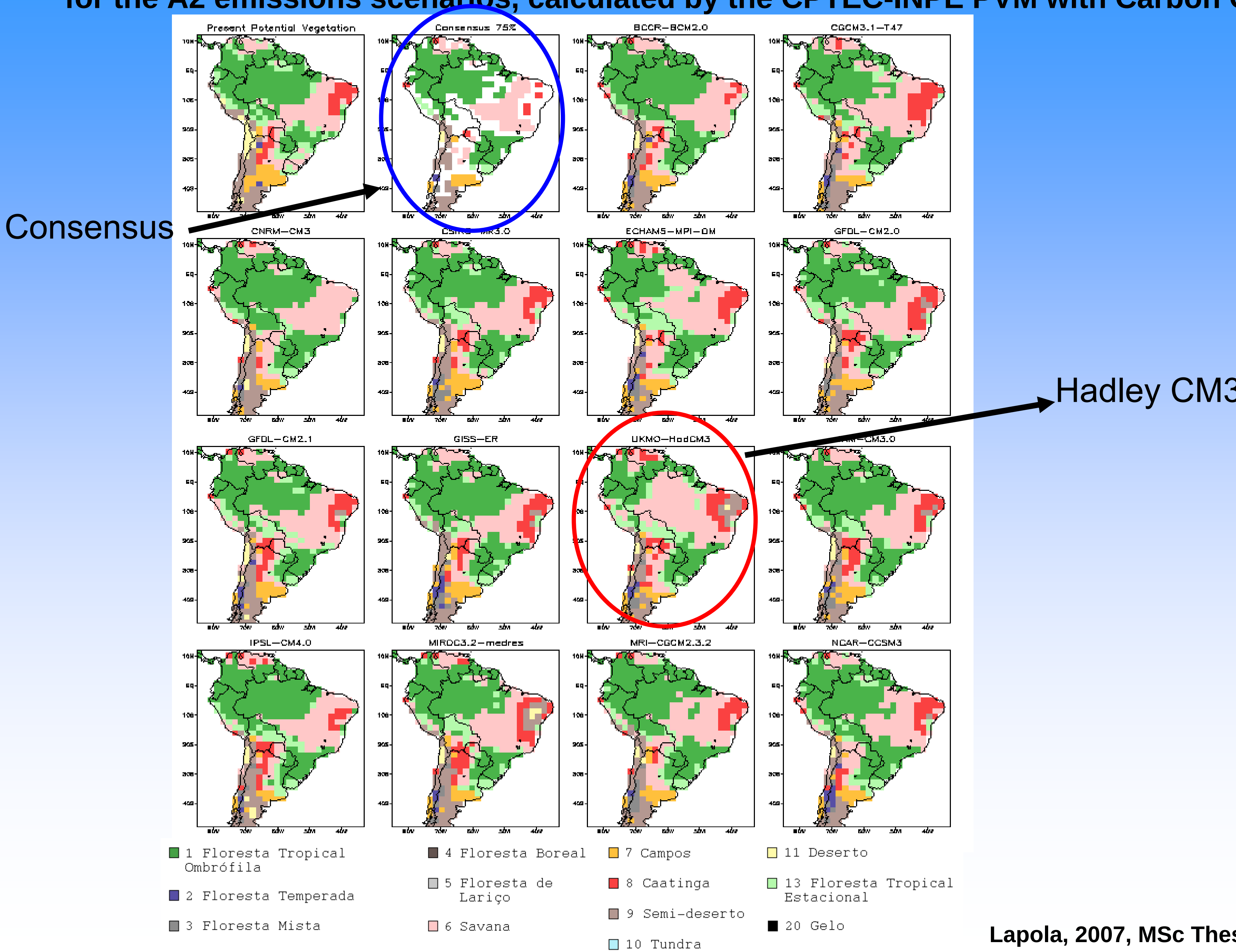
CPTEC-INPE PVM 2

Vegetation distribution under different CO_2 concentration scenarios



Lapola, 2007 MSc Thesis at INPE

Projected distribution of natural biomes in South America for 2090-2099 from 14 AOGCMs for the A2 emissions scenarios, calculated by the CPTEC-INPE PVM with Carbon Cycle



Lapola, 2007, MSc Thesis at INPE

Conclusions
The future of biome distribution in Amazonia in face of land cover and climate changes

- Natural ecosystems in Amazonia have been under increasing land use change pressure.

- Tropical deforestation, global warming, increased forest fires and intense/more frequent droughts all act to reduce the resilience of the tropical forest.

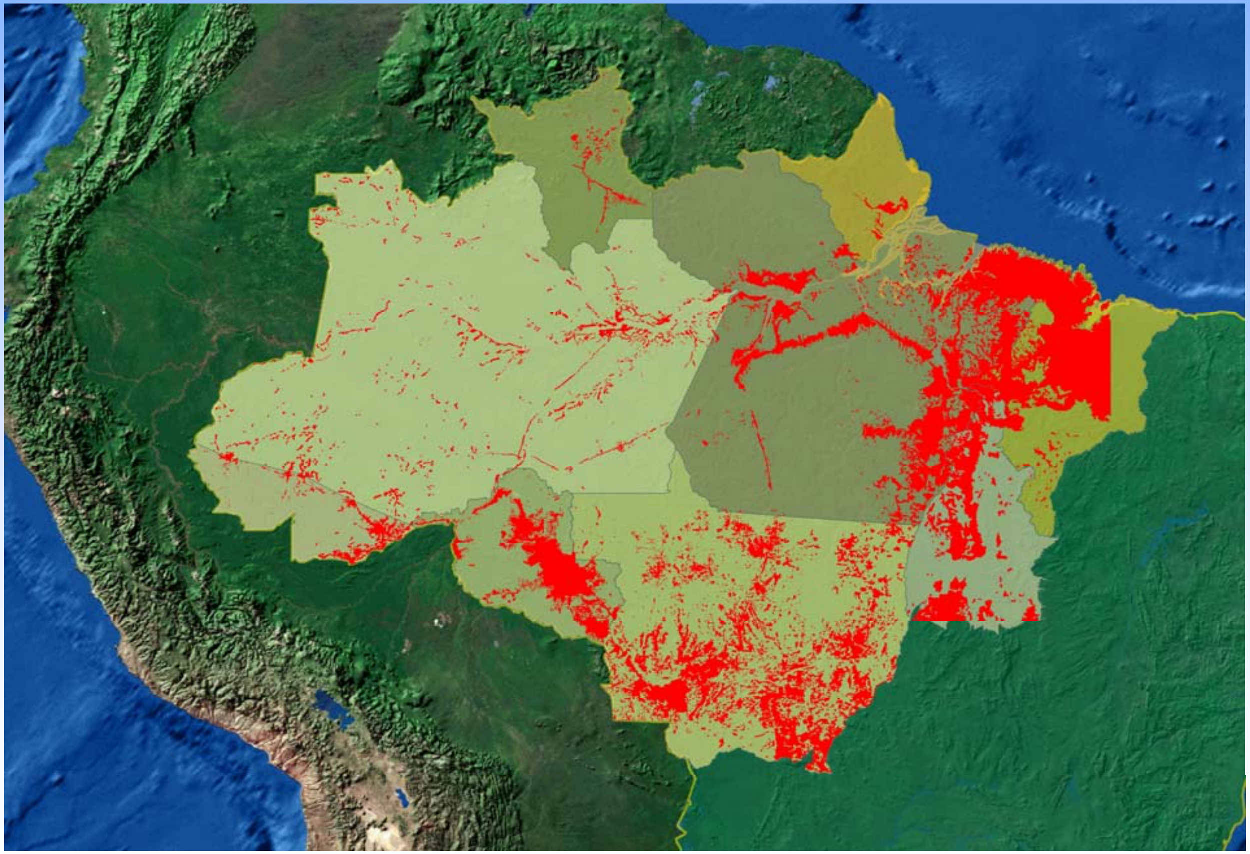
- The synergistic combination of regional climate changes caused by both global warming and land cover change over the next several decades, exacerbated by increased drought and forest fire frequency, could tip the biome-climate state to a new stable equilibrium with '*savannization*' of parts of Amazonia and catastrophic species losses.

Final Considerations …

Brazil: an ‘**environmental**’ power?

Amazonia:
greatest liability for Brazil to become an ‘environmental’ power!

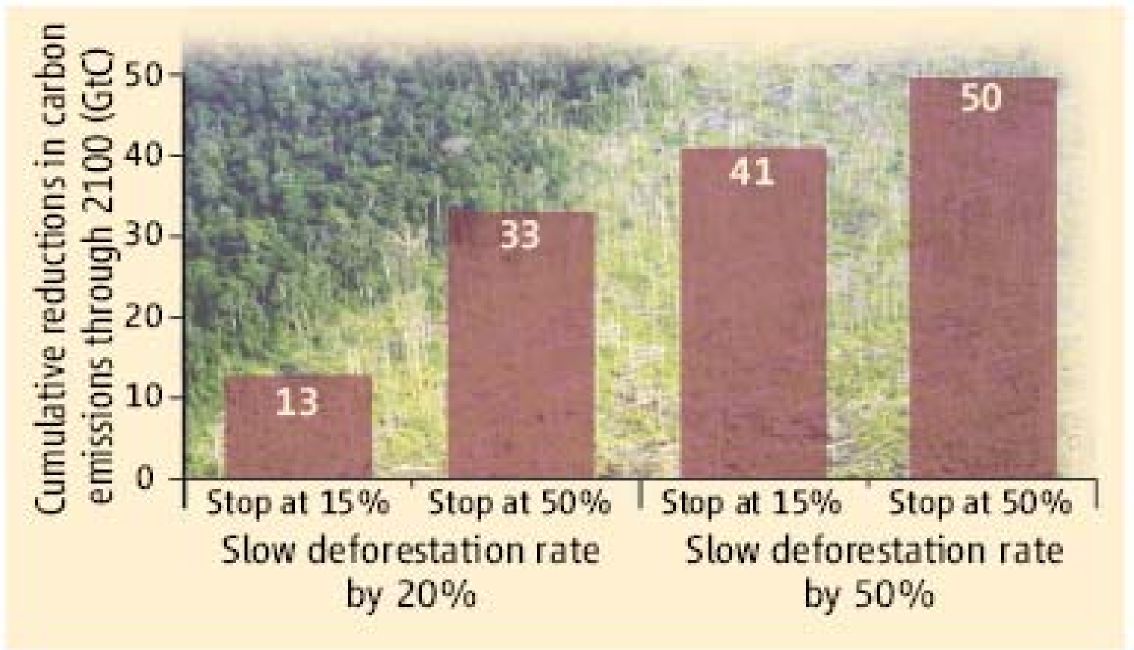
- 70% to 80% of CO_2 emissions arising from land cover change in Brazil
- Unknown impacts on biodiversity
- Unsustainable pathways to development



In 2007, total deforested area (clear-cutting) reached about 700,000 km² in Brazilian Amazonia (18%)

Main services of Tropical Forests

- Decreasing tropical deforestation rates by 50% up to 2050
- Up to 15% of avoided CO_2 emissions for stabilization at 550 ppm



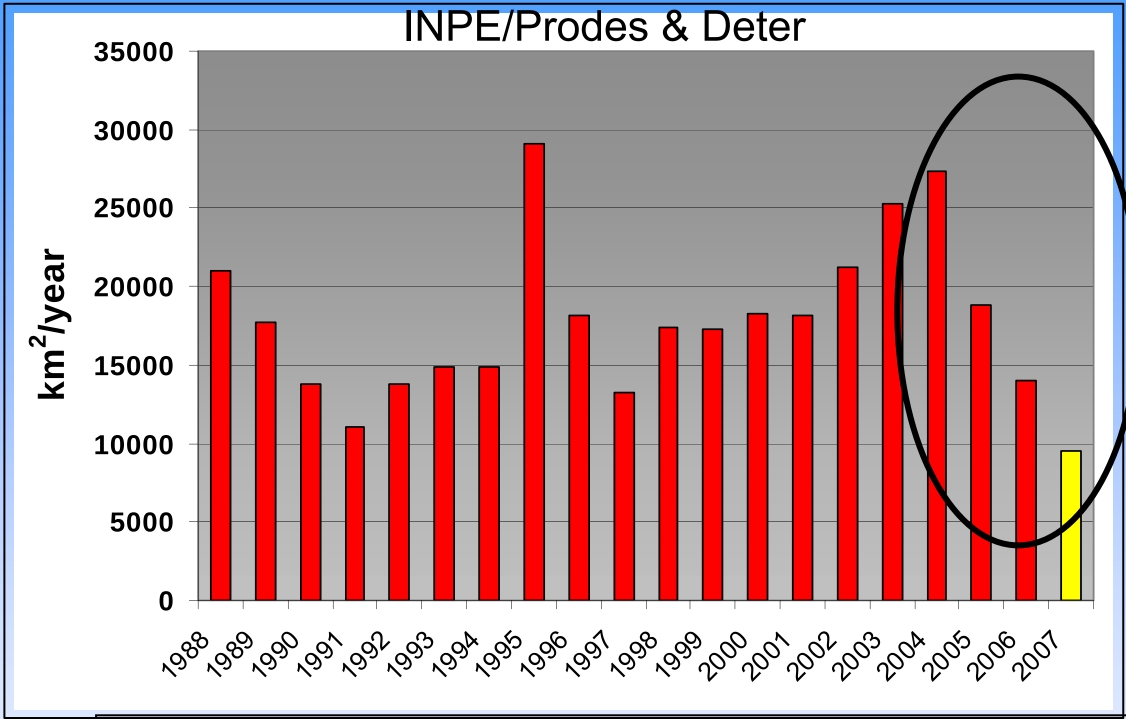
Estimated cumulative reductions in carbon emissions achievable by 2100 through reducing tropical deforestation. Calculations assume (i), deforestation rates observed in the 1990s decline linearly from 2010–50 by either 20 or 50%, and (ii) that deforestation stops altogether when either 15 or 50% of the area remains in each country that was originally forested in 2000 (*1*).

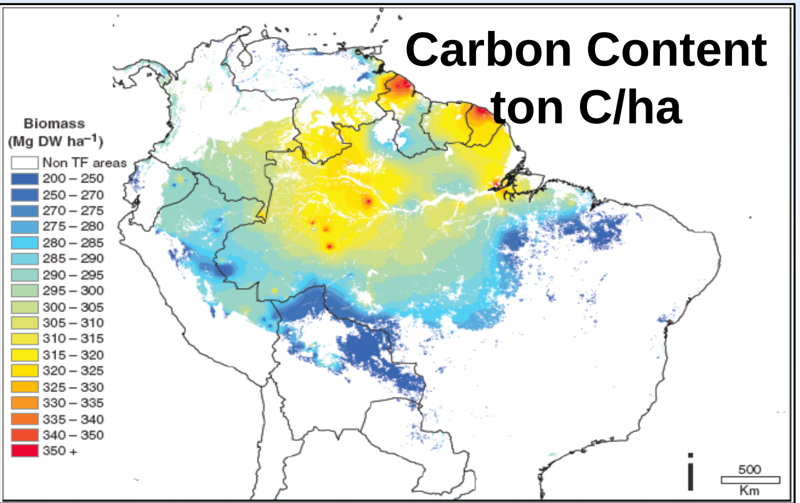
Gullison et al., 2007 Science

Avoided emissions from deforestation reductions make more sense

• 2004: 27.361 km² deforested in Brazilian Amazon

• 2005 – 2007: ~60% reduction in deforestation





≈17,000 km² avoided deforestation in 3 years (base line at 20,000 km^2/year)

220 Mton C avoided emissions

~ US$ 2.2 bn value in carbon

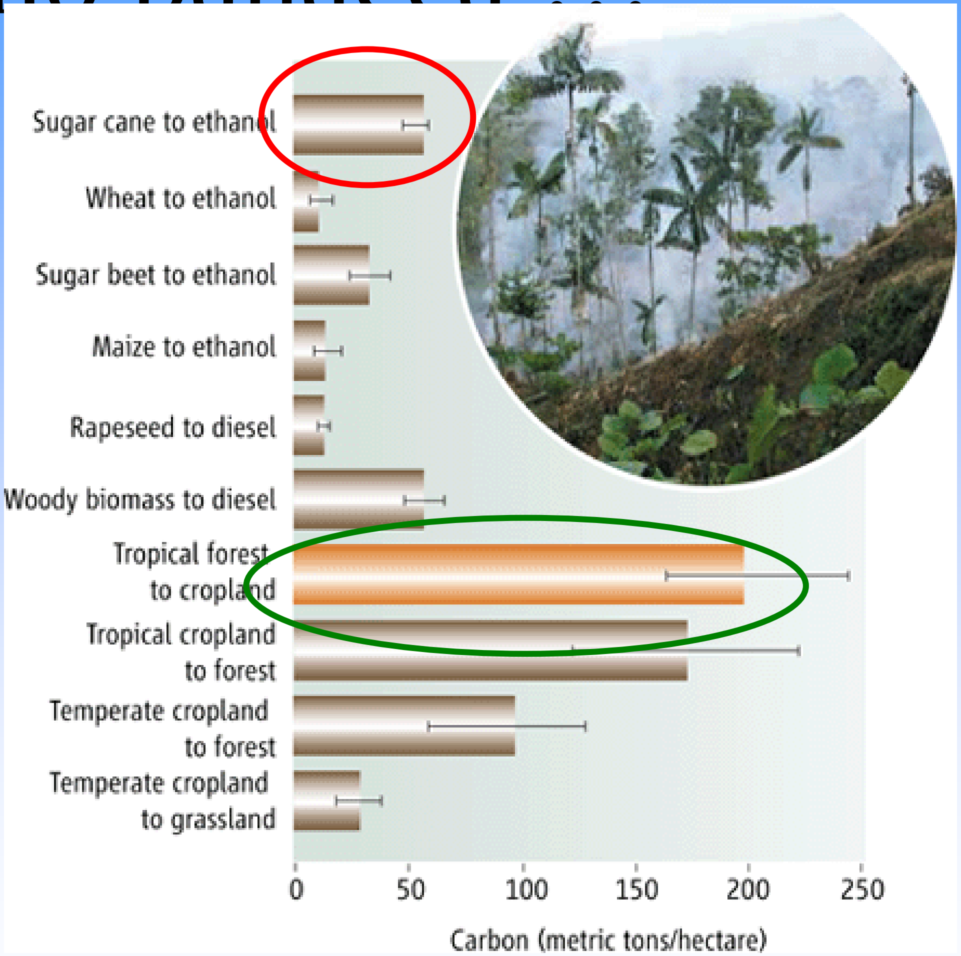
First step: do no/less harm

Downward trend in deforestation rates might not be sustainable, though:

- Food commodity prices on the rise (soy, corn, beef, milk)
- Biofuel production competes for available land (pasture) => further clearing
- Amazon last frontier for tropical timber

Biofuels are no panacea …

- If the prime object of biofuels is mitigation of CO_2-driven global warming, in the short term (30 years or so) it is better to focus on increasing the efficiency of fossil fuel use
- Conversion of large areas of land to biofuel crops may place additional strains on the environment



Righelato and Spracklen, *Science* 17.Aug.2007

Biofuels no panacea …

Atmos. Chem. Phys. Discuss., 7, 11191–11205, 2007
www.atmos-chem-phys-discuss.net/7/11191/2007/

Atmospheric Chemistry and Physics Discussions

N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels

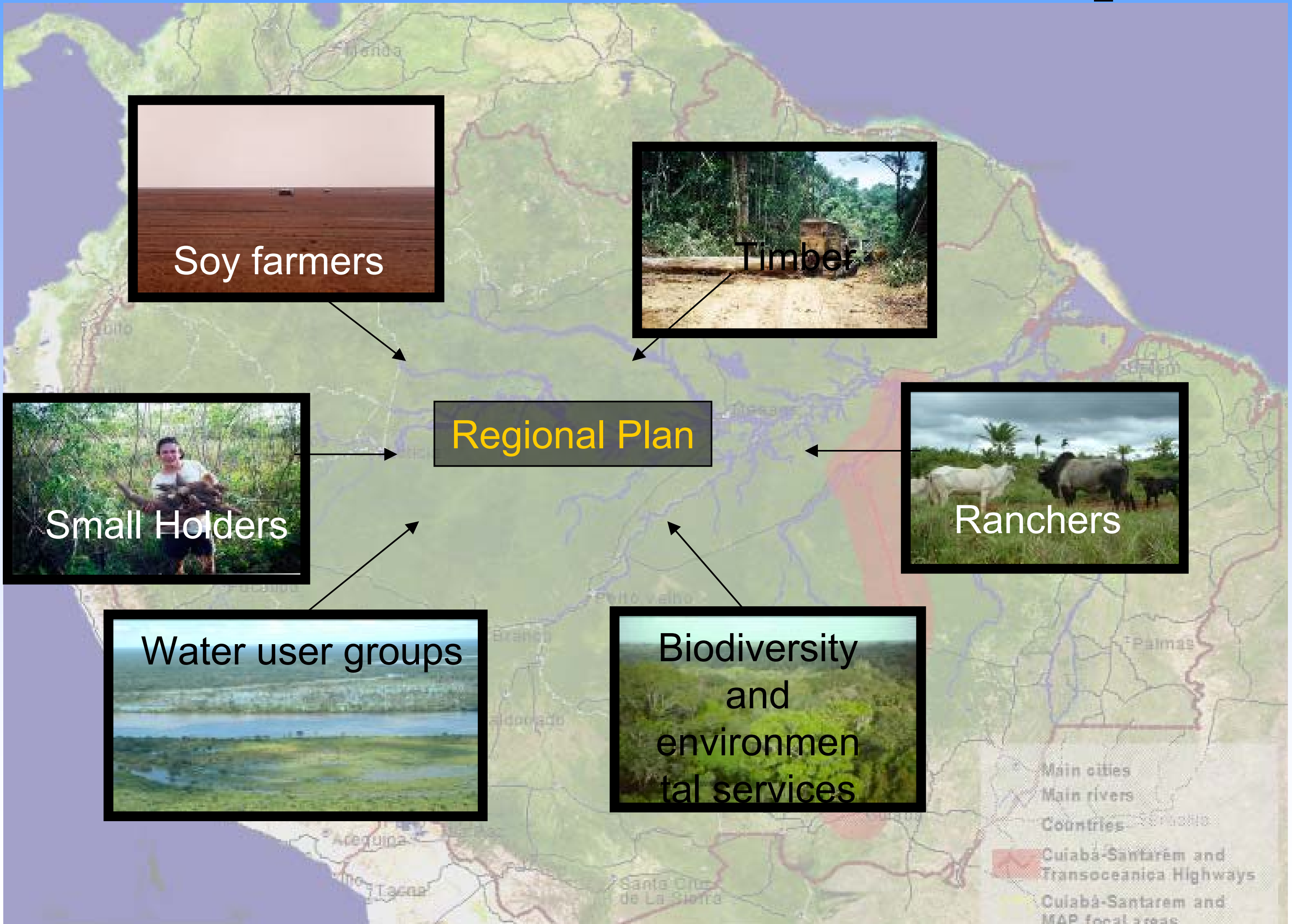
P. J. Crutzen[1,2,3], A. R. Mosier[4], K. A. Smith[5], and W. Winiwarter[3,6]

Production of commonly used biofuels, such as biodiesel from rapeseed and bioethanol from corn, can <u>contribute as much or more to global warming</u> by N2O emissions <u>than cooling by fossil fuel savings</u>

Crop	r_N (gN/kg dry matter)	relative warming (Meq/M)	type of fuel produced
Rapeseed	39	1.0–1.7	Bio-diesel
Wheat	22	1.3–2.1	Bio-ethanol
Barley, Oat	19	1.1–1.9	Bio-ethanol
Maize	15	0.9–1.5	Bio-ethanol
Sugar cane	7.3	0.5–0.9	Bio-ethanol

Relative warming derived from N2O production for crops used in the production of biofuels

Need for a new model in the tropics




Obrigado!