COPPE

PROGRAMA DE PLANEJAMENTO ENERGÉTICO
COPPE - UFRJ

cenergia

Instituto Luiz Alberto de Coimbra de Pós-graduação e Pesquisa em Engenharia

O CUSTO ECONÔMICO DOS RETROCESSOS AMBIENTAIS

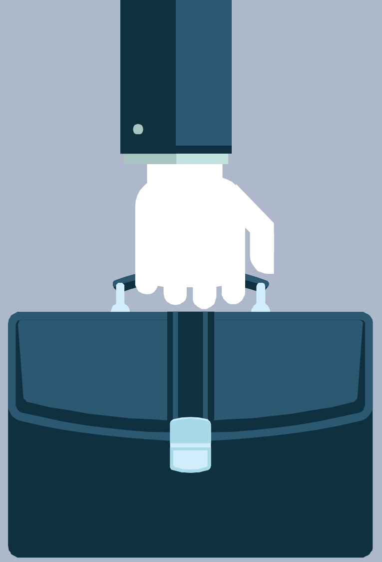
Programa de Planejamento Energético, COPPE,
Universidade Federal do Rio de Janeiro

Prof. Roberto Schaeffer

III CONGRESSO BRASILEIRO DA MAGISTRATURA E DO MINISTÉRIO PÚBLICO PARA O MEIO AMBIENTE

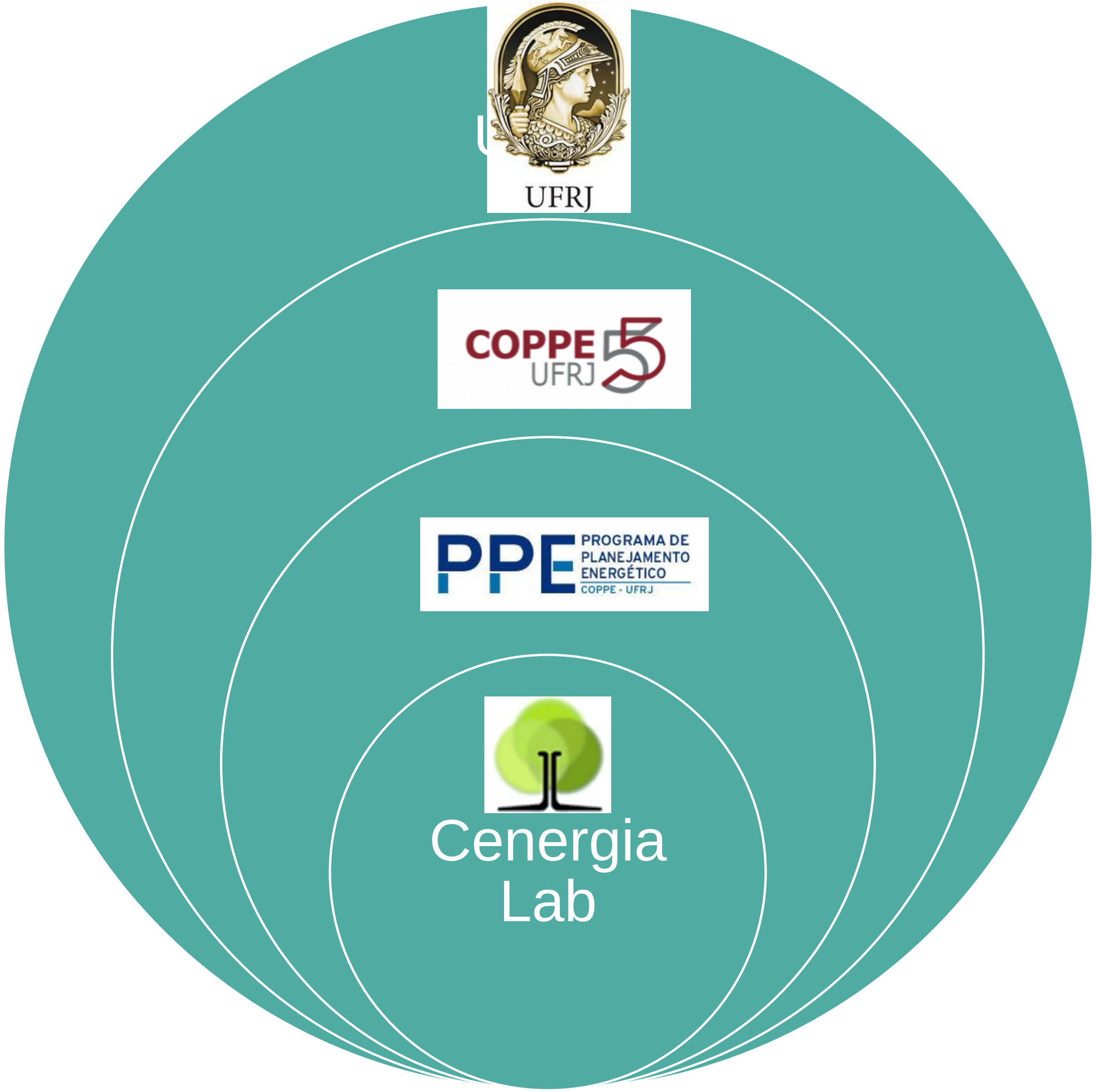
Araxá, 8 de agosto de 2019

Várias pessoas contribuíram para este trabalho



Em particular: Pedro R.R. Rochedo, Britaldo Soares-Filho, Eduardo Viola, Alexandre Szklo, Andre F.P. Lucena, Alexandre Koberle, Juliana Leroy Davis, Raoni Rajao e Regis Rathmann

E agradecimentos especiais a Pedro Artaxo, de quem pegamos emprestados vários slides que serão mostrados aqui também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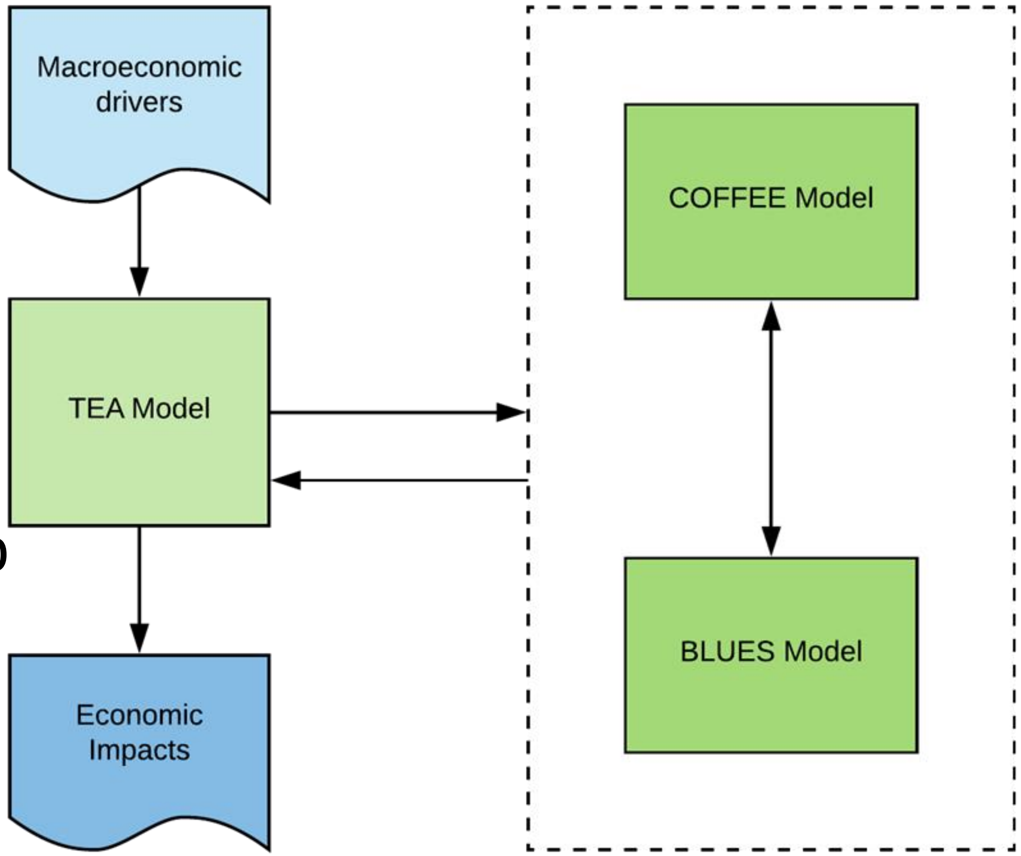
Cenergia Lab

Programa de Planejamento Energético da COPPE/UFRJ

- Criado em 1979 dentro do Programa de Engenharia Nuclear da COPPE
- 13 professores em tempo integral com dedicação exclusiva
- Todos os anos aceitamos:
  - 20-25 novos alunos de mestrado
  - 20-25 novos alunos de doutorado
- PPE é parte de um grupo selecto de programas de D.Sc./M.Sc. de Excelência no Brasil
  - Nota 6 (escala 1-7) da CAPES, no Comitê das Engenharias 3
  - Nota 6 ao longo das últimas 3 avaliações quadrianuais

Modelos de Avaliação Integrada do Cenergia

- Modelos e suas ligações:
  - TEA: Modelo Global de Equilíbrio Geral
  - COFFEE: Model Global de Otimização
  - BLUES: Modelo Nacional de Otimização
  - E outros modelos setoriais específicos

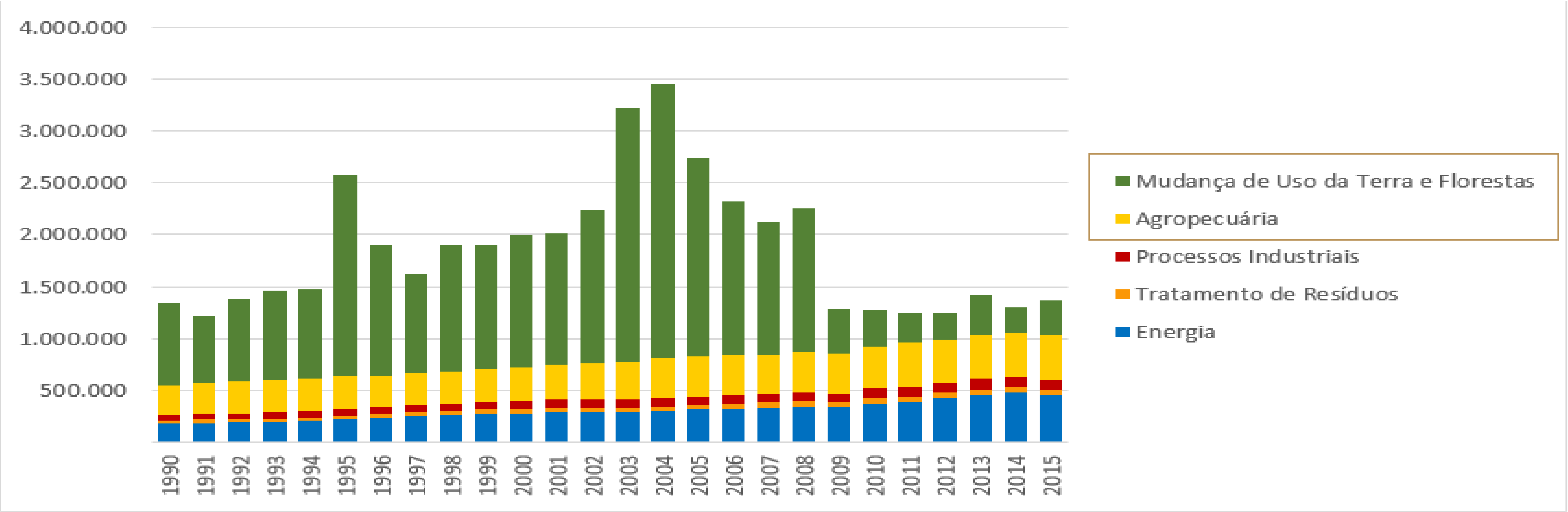


Modelos de Análise Integrada

- Centros de pesquisa com IAMs Globais

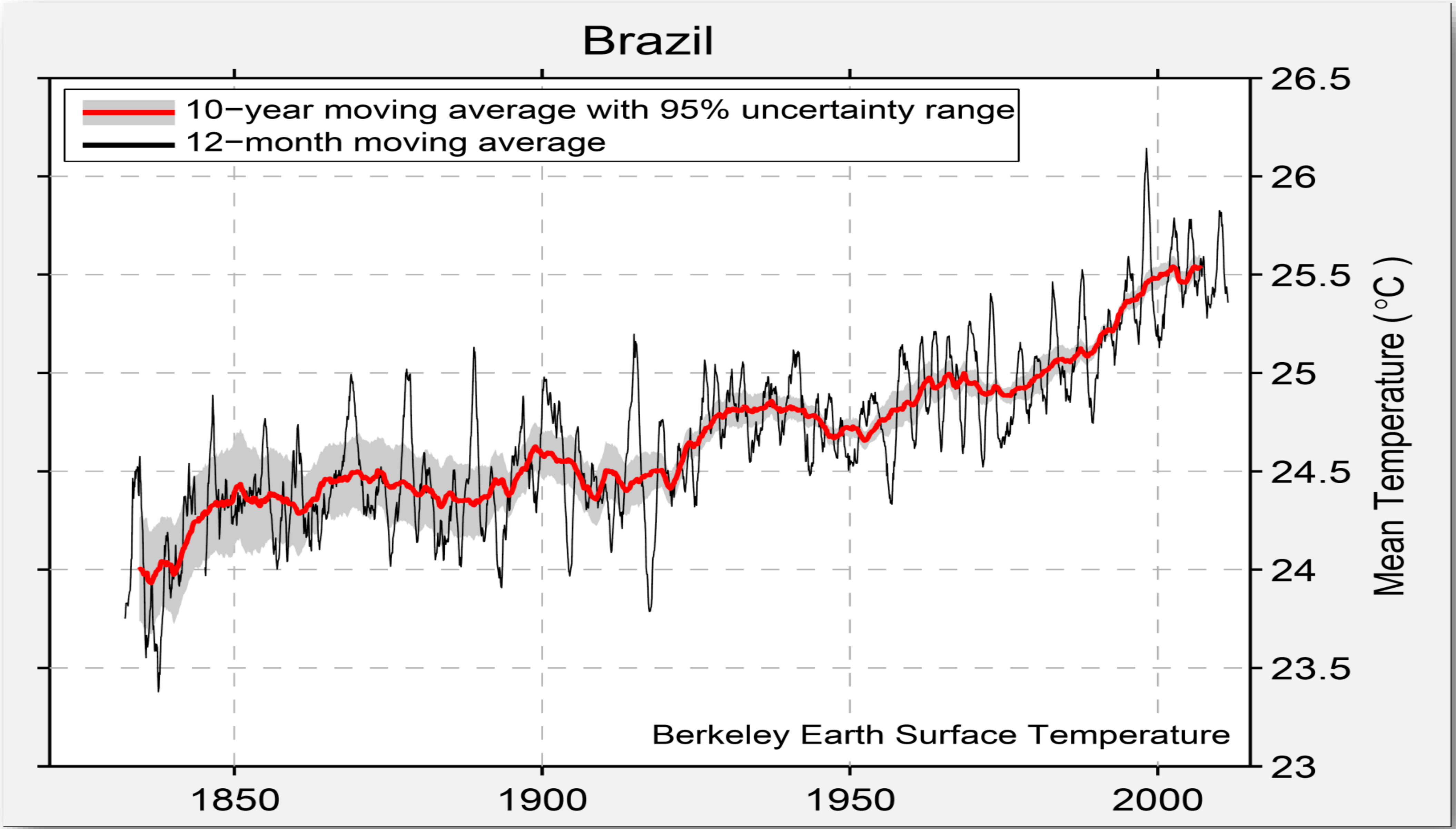
Algumas questões iniciais para melhor entendermos o custo econômico dos retrocessos ambientais no país

Emissões de GEE por setor no Brasil (Gg CO_2e)



Estimativas Anuais de Emissões de Gases de Efeito Estufa no Brasil disponíveis no SIRENE (http://dados.gov.br/dataset/sirene-sistema-deregistro-nacional-de-emissoes)

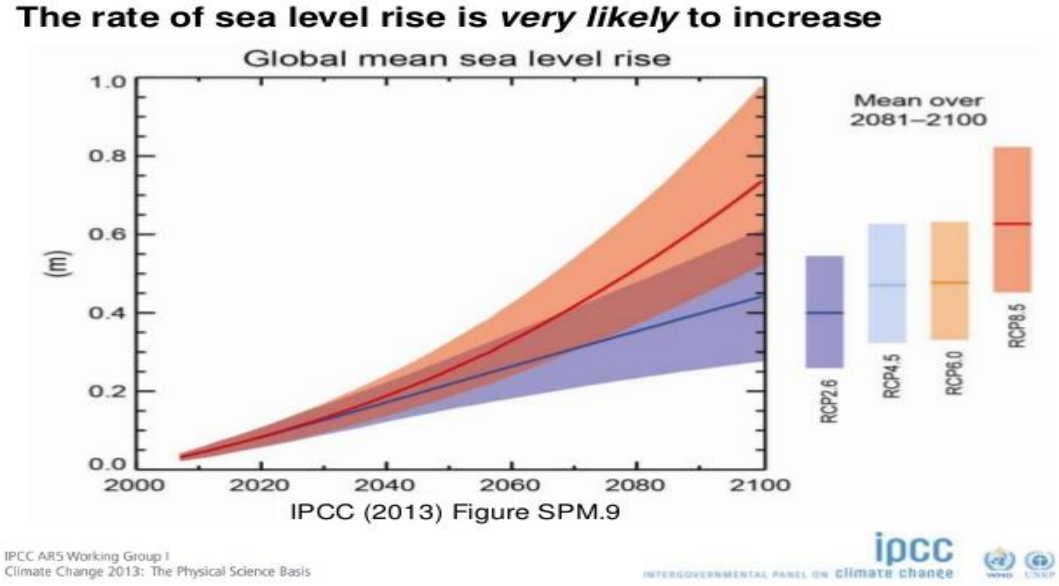
Aumento médio da temperatura no país



1.5º C

http://berkeleyearth.org/

Cidades brasileiras sob risco do aumento médio dos oceanos



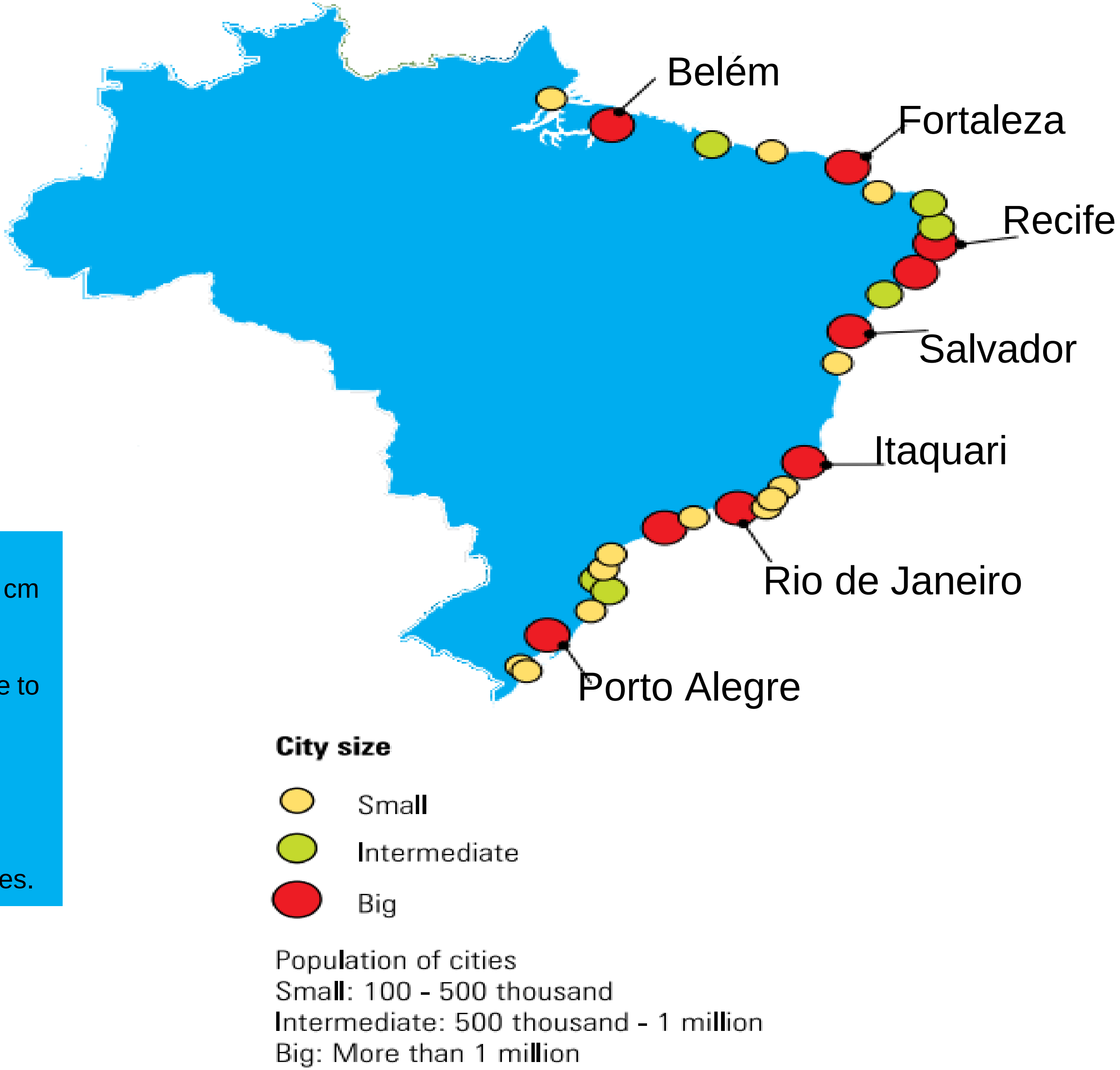
In the 20th century, sea levels rose by an estimated 23 cm, and the conservative global mean projections for sea-level rise between 1990 and 2080 range from 22 cm to 100 cm.

Oceans, which have been absorbing 80% of the temperature increase attributable to global warming, are expanding as ice sheets in the North and South poles melt.

These events have led to a rise in sea levels and increased flooding in coastal cities.

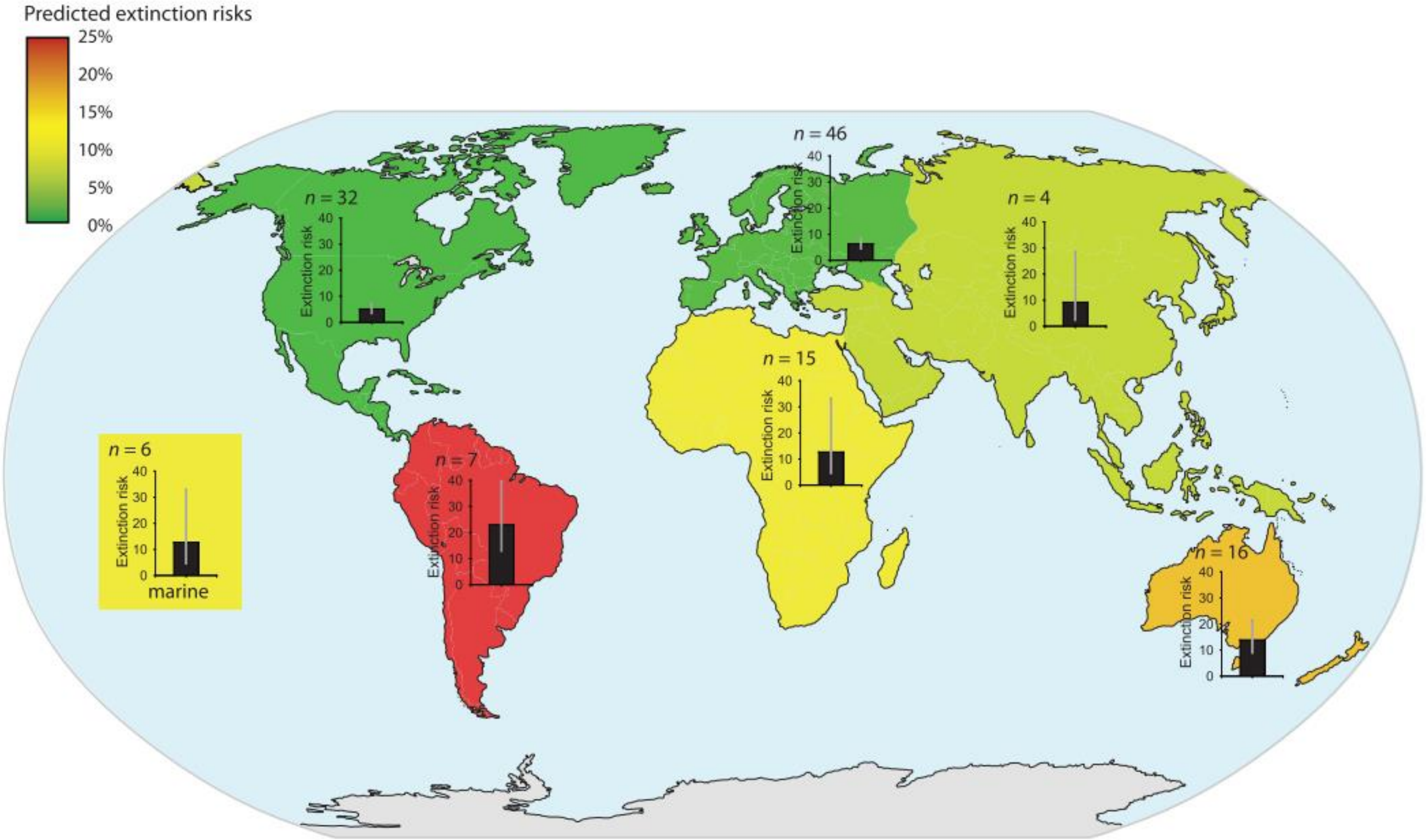
The projected rise in sea levels could result in catastrophic flooding of coastal cities.

Thirteen of the world's 20 megacities are situated along coastlines.



Source: *UN-HABITAT* Global Urban Observatory 2008 (adapted)

Riscos de extinção de espécies



Greatest risks: Australia and South America (14 to 23%)

Source: Urban M.C-Nature, 2015

Brazil – facing many challenges…

Water resources

Carbon stocks

Biodiversity

Social diversity

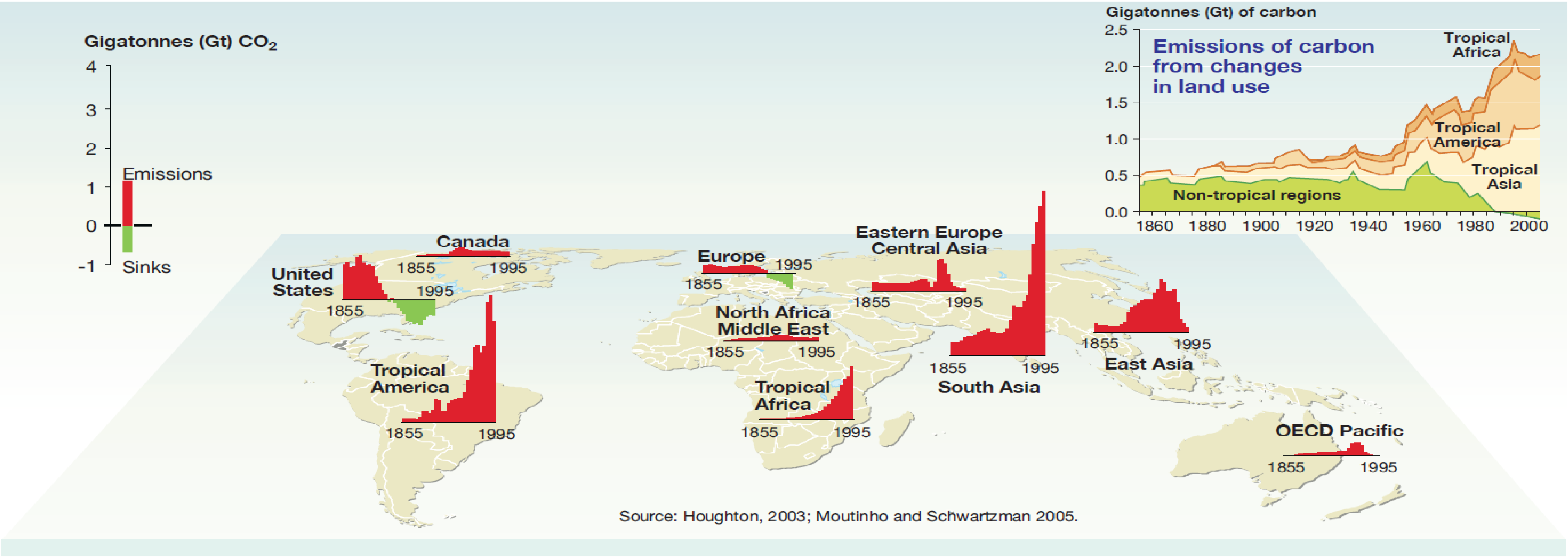
Changes in fire regime

Meat production

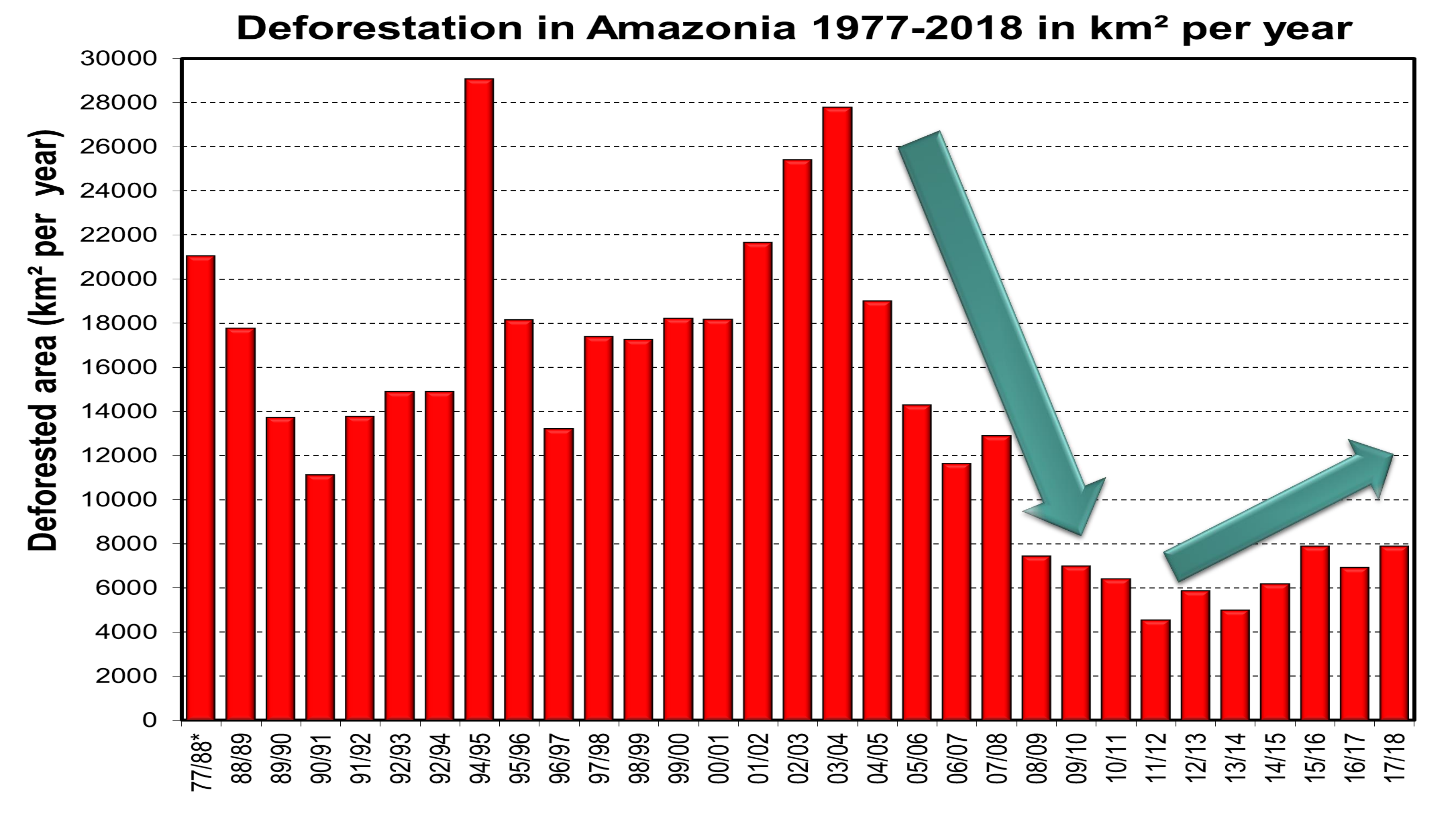
Grain Production

Bioenergy expansion

Balanço florestal histórico de carbon 1855-1995



FAO, State of the World's Forests 2009 (Rome, 2009)


Deforestation in Amazonia 1977-2018 in km² per year
Deforested area (km² per year)
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
77/88*
88/89
89/90
90/91
91/92
92/93
92/94
94/95
95/96
96/97
97/98
98/99
99/00
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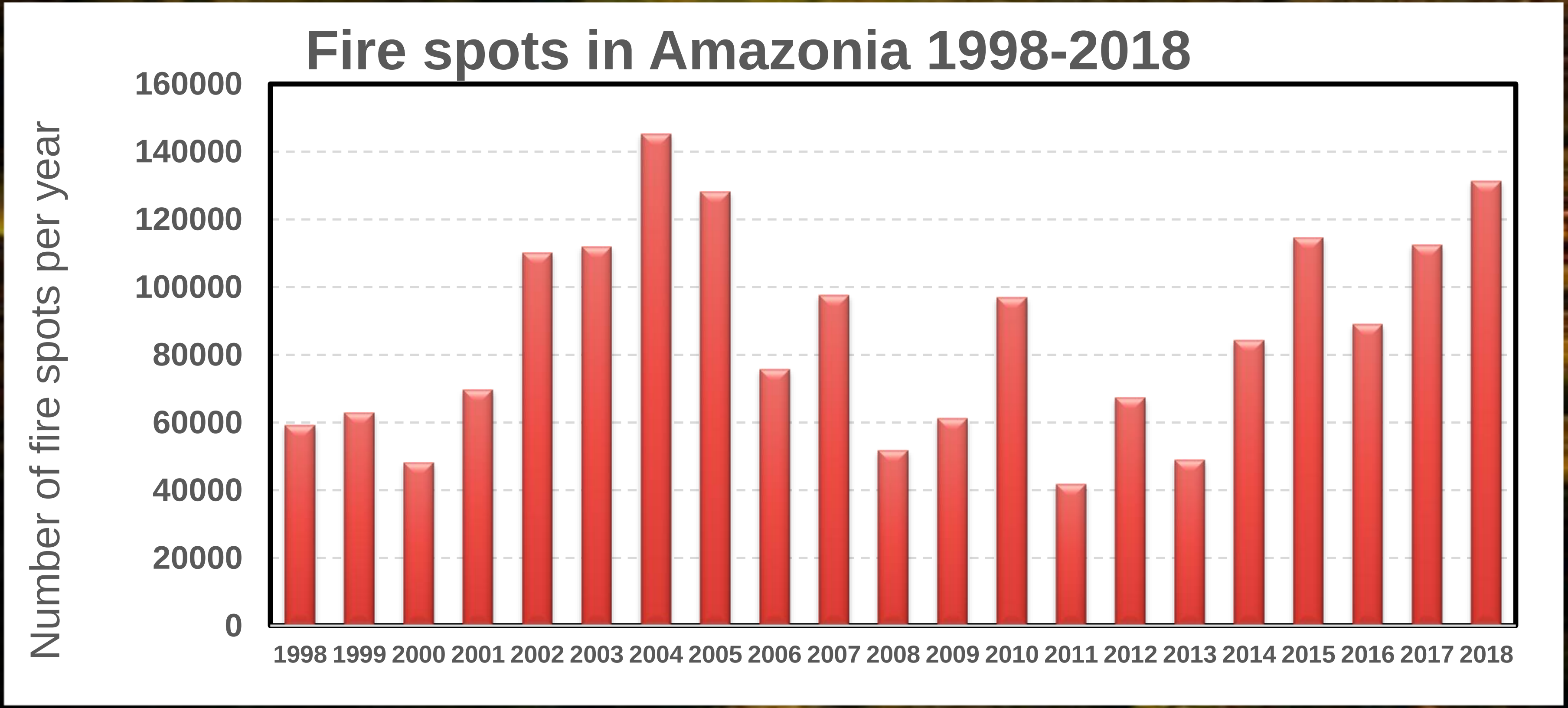
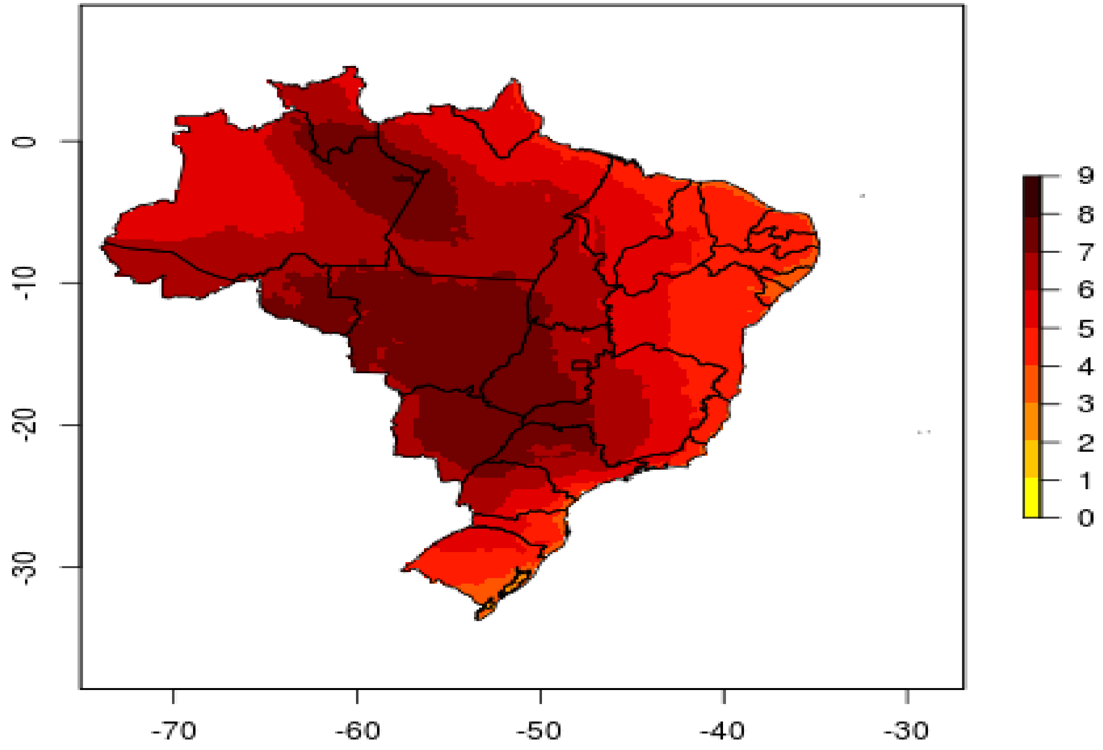
17/18

Biomass Burning…

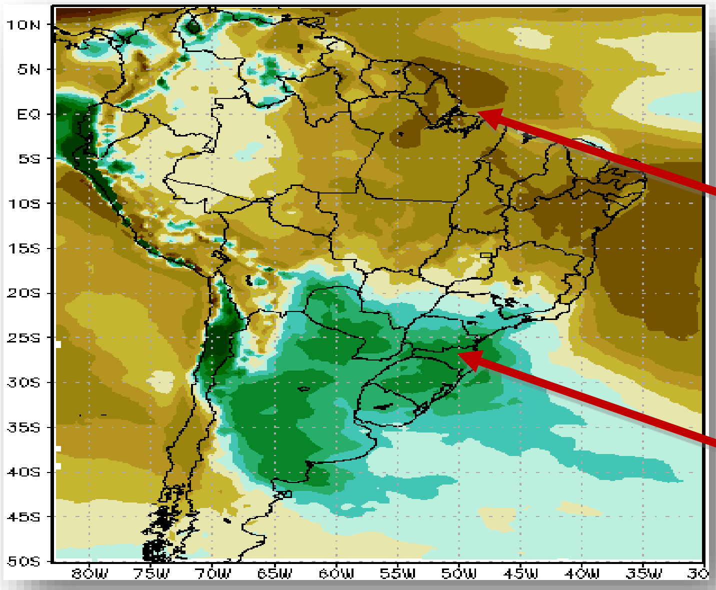


Average temperature increase expected for Brazil
2071-2099



Landed areas warm more than ocean areas

Precipitation change expected for Brazil
2071-2100



Precipitation changes (%) in 2071-2100 compared to 1961-90.

Amazon and Northeast Brazil → precipitation reduction

Southeast Suth America → precipitation increase

INPE, (RCP 8.5)

AMAZON ECOSYSTEMS AT A GLANCE

Maintenance of global carbon cycle

- 15% of global NPP and a key carbon sink for anthropogenic CO_2
- Stores about 120 billion tonnes of carbon in the biomass

Climate stabilization

- Key heat source for the atmosphere
- Annual rainfall = 2,400 mm

Powerful hydrology

- 18% of fresh water flow into the global oceans
- Amazon river discharge of 220,000 m^3/s

Helps to maintain cultural and ethnic diversity

- Over 300 indigenous populations, language diversity

Biodiversity richness

- > 10% of species

Sistema climático da Amazônia tem oscilado entre dois extremos ao longo dos últimos 14 anos

OSCILAÇÃO EM
NÍVEL DE GRANDES BACIAS

SECAS

3 eventOs (1/200)
nos últimos 14 anos

2005
2010
2015/16 (El Niño-related)

CHEIAS

3 eventos (1/200)
nos últimos 14 anos

2009
2012
2014 (over SW Amazon)

‘TIPPING POINTS’ OF FOREST-CLIMATE EQUILIBRIUM IN THE AMAZON

A) Tropical forest in equilibrium with current climate

One stable equilibrium state

Amazon covered mostly by forests

B) Savanna state triggered by climate change and/or deforestation

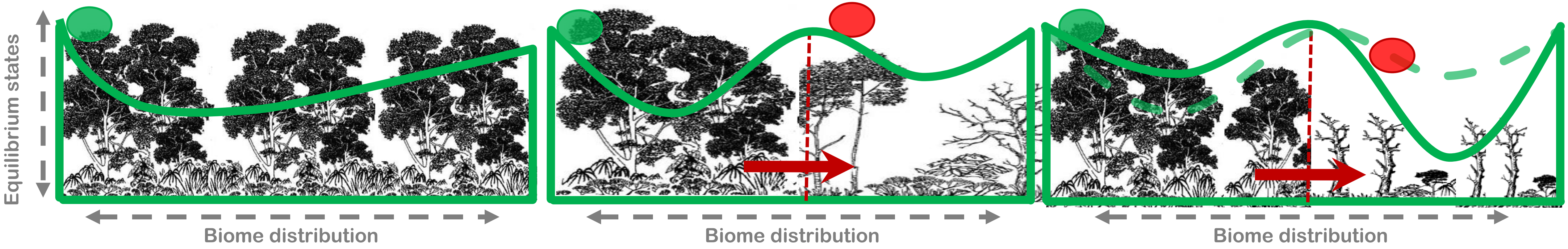
Two stable equilibrium states

Forests in the West

Savannas in the East-Southeast

C) Stability of second equilibrium state

Savanna enhanced by increased /intensity of droughts and forest fires

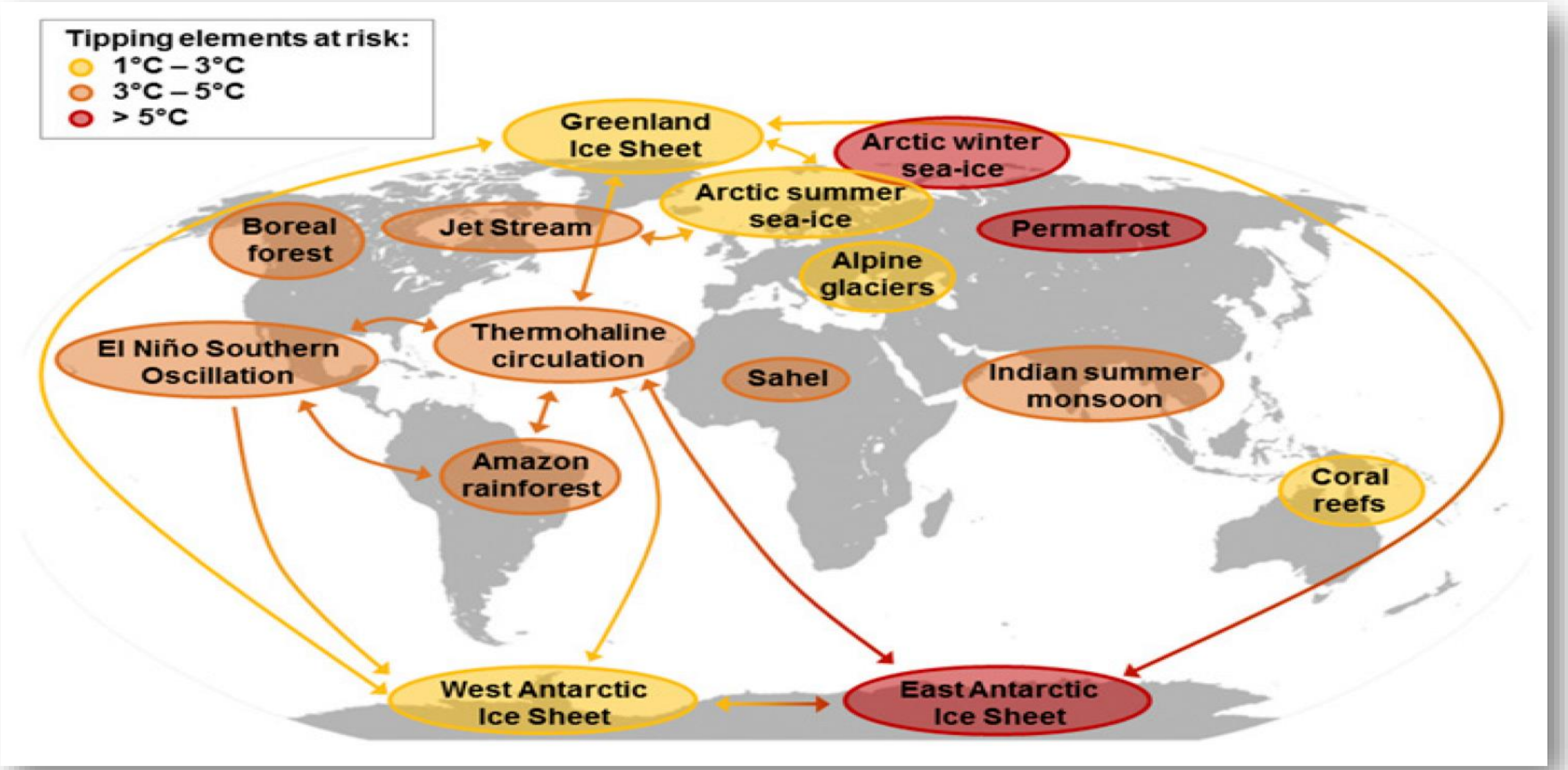


Thresholds for tipping
from state A to state B ≈ 4ºC Amazon warming or
≈ 40% of total deforested area

- Observations: ΔT ≈ 1.1 to 1.5ºC
- Deforestation: ≈ 18%
- Forest fire frequency (increasing)
- Lengthening of dry season (increasing)
- Increasing climate extremes

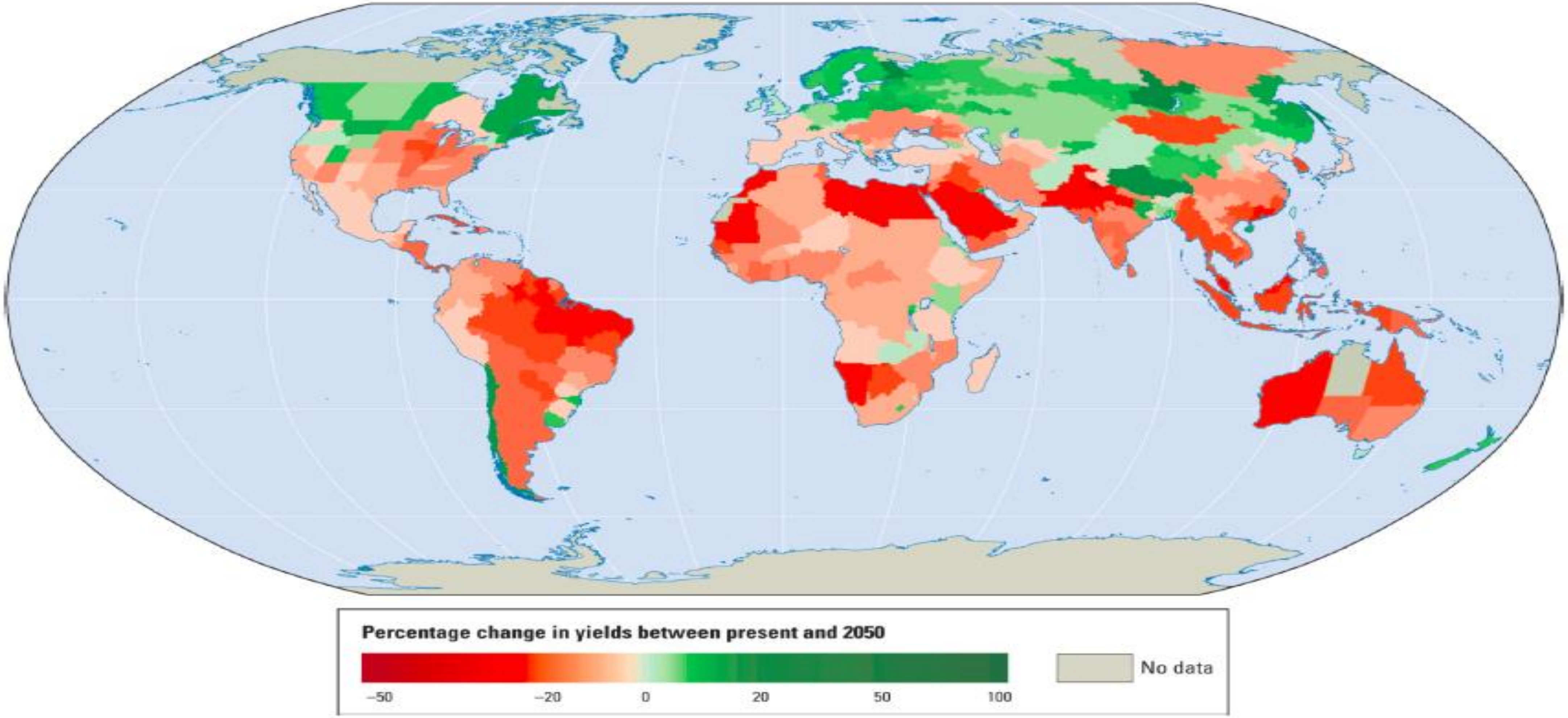
Adapted from Cardoso and Borma, 2010; Borma, Nobre and Cardoso, 2013, Nobre et al., 2015, 2016

Tipping points of the Earth climate system



UNEP GEO-6 2019

Food production impacts in a 3°C-warmer World



World Economic Forum: Global Risks 2016

A aí chegamos à questão …

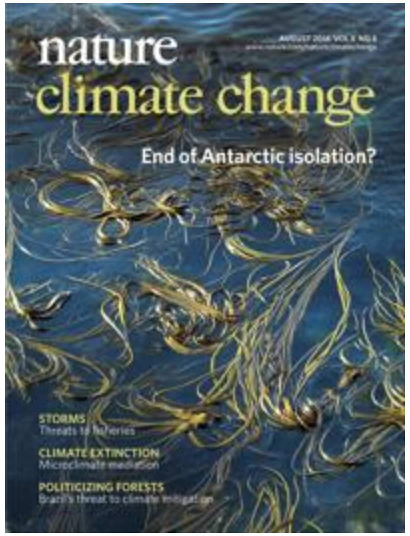
nature climate change

LETTERS

https://doi.org/10.1038/s41558-018-0213-y

The threat of political bargaining to climate mitigation in Brazil

Pedro R. R. Rochedo[1], Britaldo Soares-Filho[2], Roberto Schaeffer[1]*, Eduardo Viola[3], Alexandre Szklo[1], André F. P. Lucena[1], Alexandre Koberle[1], Juliana Leroy Davis[2,4], Raoni Rajão[4] and Regis Rathmann[1]



Nature Climate Change
volume 8, pages 695–698 (2018)

Disponível online desde 9 de julho de 2018

Rochedo et al, 2018

nature climate change LETTERS
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The threat of political bargaining to climate mitigation in Brazil

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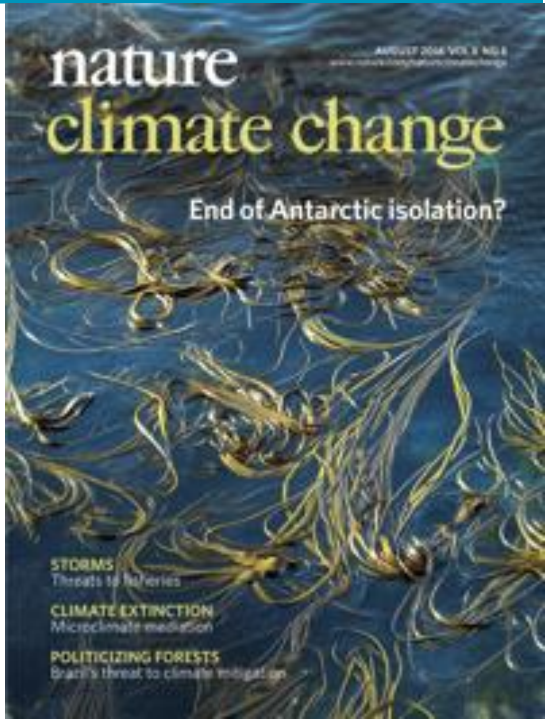
- In exchange for political support, the Brazilian government has been signaling landholders to increase deforestation in Amazônia and Cerrado
- The (former) President of Brazil has signed provisionary acts and decrees lowering environmental licensing requirements, suspending the ratification of indigenous lands, reducing the size of protected areas and facilitating land grabbers to obtain the deeds of illegally deforested areas
- Using the BLUES model, we explored 2 °C-compliant scenarios estimating the effort needed in other sectors of the economy to compensate for the weakening of environmental governance

Scenario Building Procedure

https://doi.org/10.1038/s41558-018-0213-y



1- pre-2005, with very poor governance despite the passage of some important laws that were not implemented;

2- 2005-2010, with dramatic improvement in the governance (good governance) and very effective results in reducing deforestation; and

3- 2011-2017, the stagnation of deforestation reduction policies and growing political signals incentivizing new clearings led to a gradual erosion of the governance (poor governance), the end of the deforestation reduction trend in 2012 and a sharp increase in deforestation during the 2015-17 period.

Scenario Building Procedure

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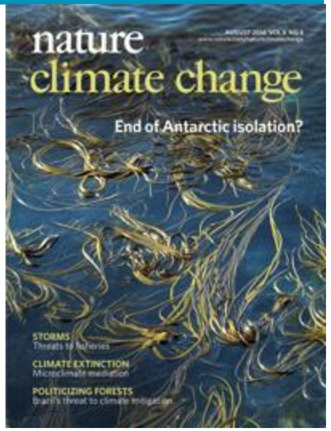


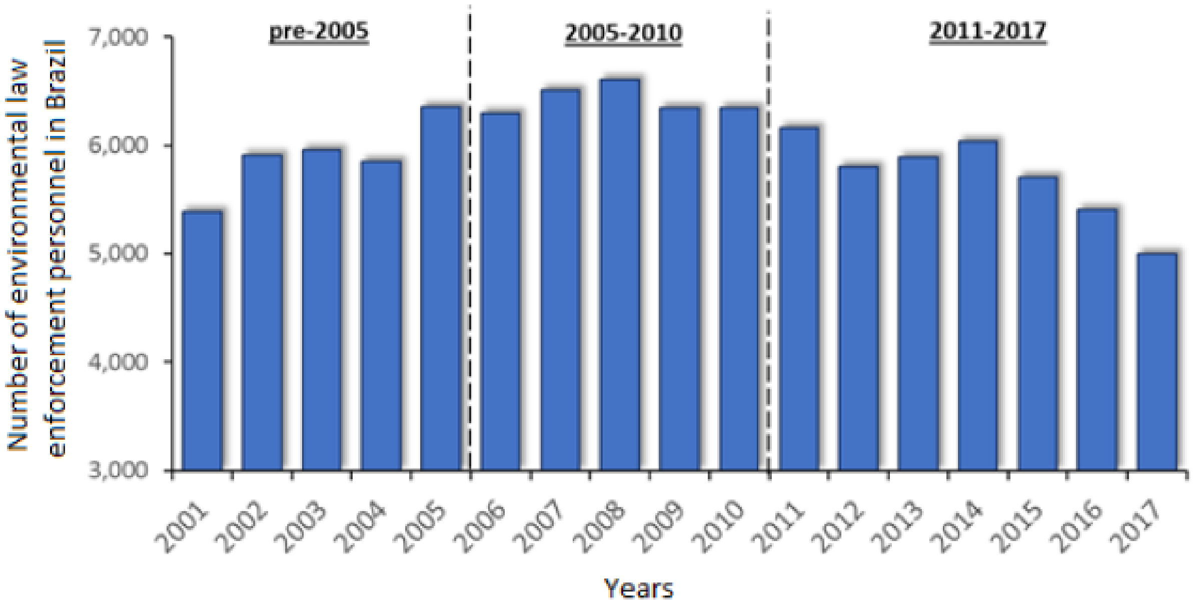


Figure S2 – Number of environmental law enforcement personnel in Brazil

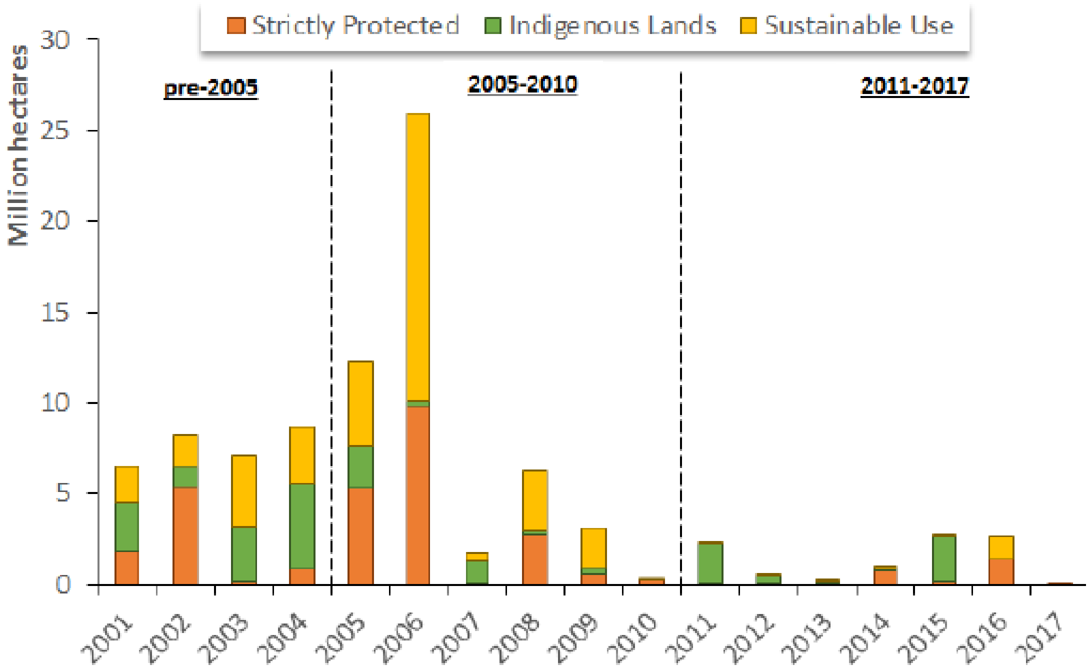
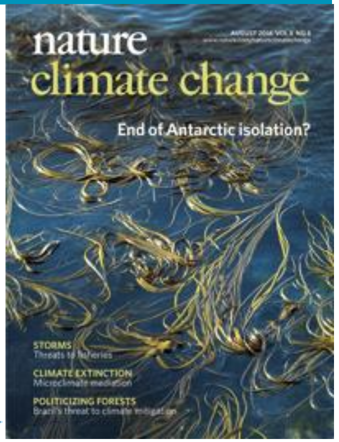


Figure S3 – Creation of new Protected Areas in Brazil

Scenario Building Procedure

https://doi.org/10.1038/s41558-018-0213-y



Weak environmental governance

The weak environmental governance (WEG) scenario assumes the abandonment of current deforestation control policies, as well as strong political support for predatory agricultural practices. In practice, by 2025 this scenario represents the annulling of governance gains achieved since 2005. This represents the worst-case scenario and should be understood as a complete deconstruction of environmental governance in Brazil, with severe impacts on deforestation rates, which could potentially return to pre-2005 levels. Such a return of deforestation rates to the peak levels of the last decade would lead to annual losses of more than 27,000 and 18,000 km^2 of the Amazon and Cerrado biomes, respectively, by 2025. Cumulative CO_2 emissions from deforestation could escalate to 23.1 $GtCO_2$ from 2010 to 2030.

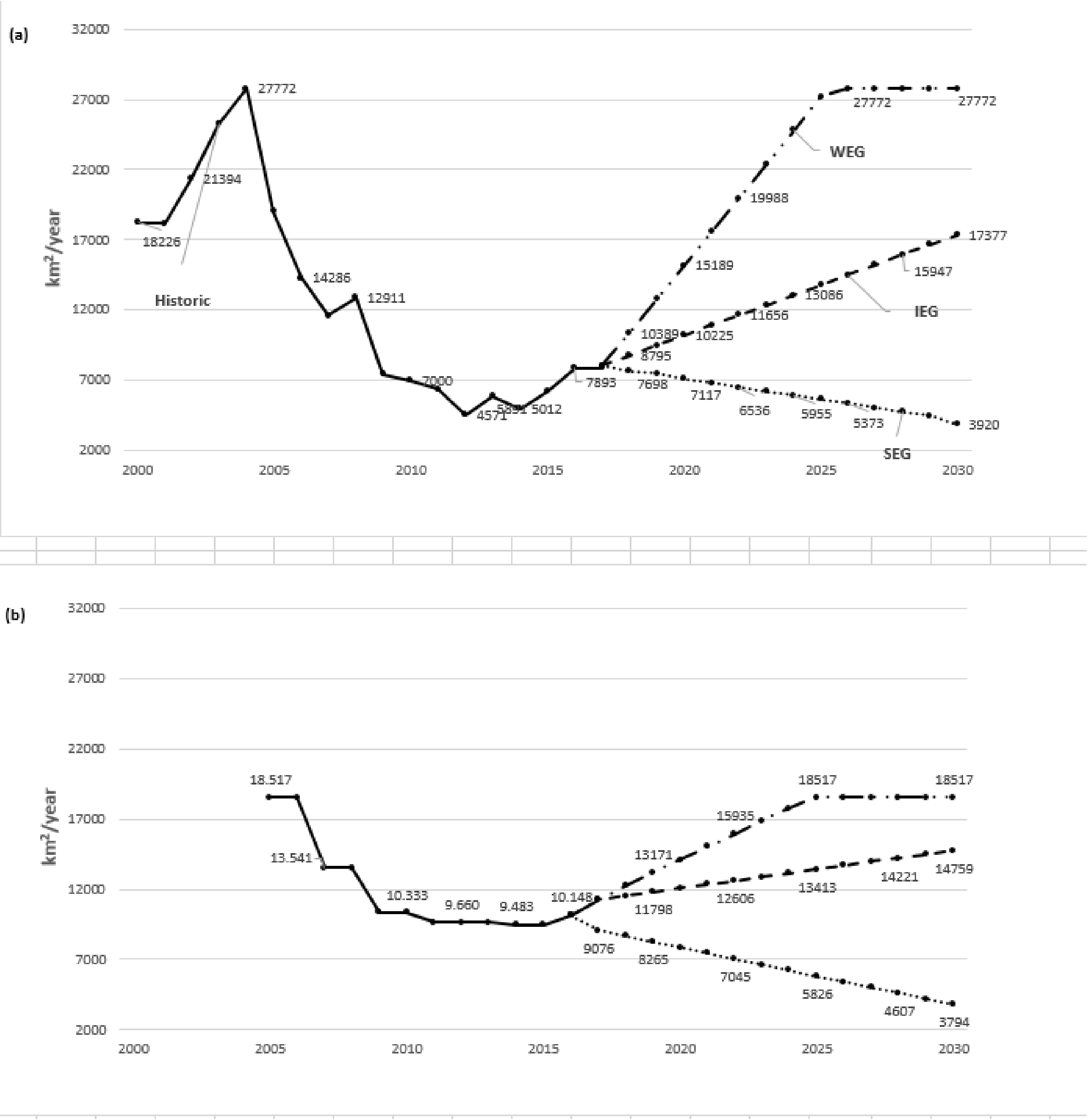
Intermediate environmental governance

The intermediate environmental governance (IEG) scenario assumes the maintenance of current deforestation control policies, while, contradictorily, considering growing political support for predatory agricultural practices. This includes legal support for land-grabbing practices, the creation of fewer protected areas and the downgrading, downsizing and degazettement of key protected areas together with lax enforcement of the Forest Code. IEG represents the current business-as-usual scenario in Brazil, according to which the increasing deforestation trend observed in the Amazon since 2013 is extended until 2030. As a result, annual deforestation would reach some 17,000 and 15,000 km^2 in the Amazon and Cerrado biomes, respectively, by 2030. This implies cumulative emissions from deforestation of 16.3 $GtCO_2$ for the same 2010–2030 period.

Strong environmental governance

The strong environmental governance (SEG) scenario assumes the expansion of current deforestation command-and-control policies and full political support for the environmental agenda in the country, including full implementation of the Forest Code alongside economic incentives for forest conservation. Annual deforestation in the Amazon and Cerrado biomes would be reduced from 7,989 and 9,483 km^2 in 2016 and 2015[14], respectively, to under 4,000 km^2 by 2030. Associated cumulative emissions from deforestation reach 9.6 $GtCO_2$ from 2010 to 2030.

Scenario Building Procedure



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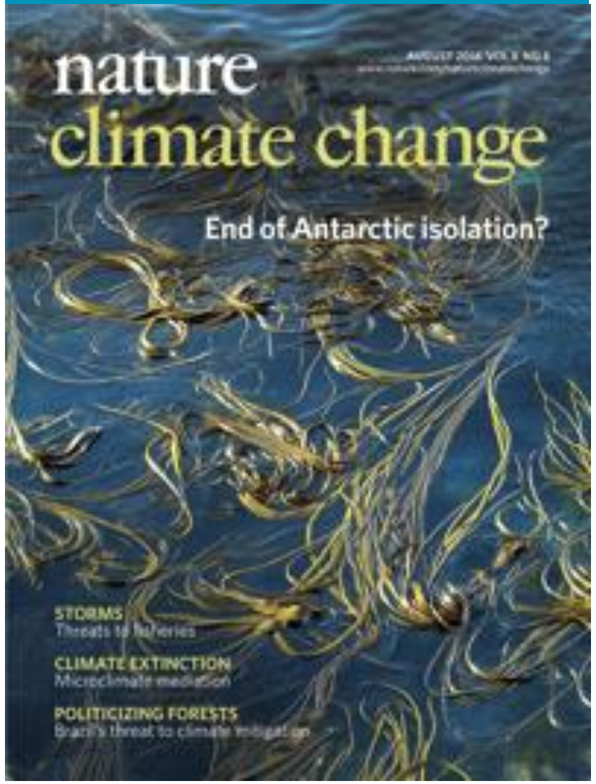
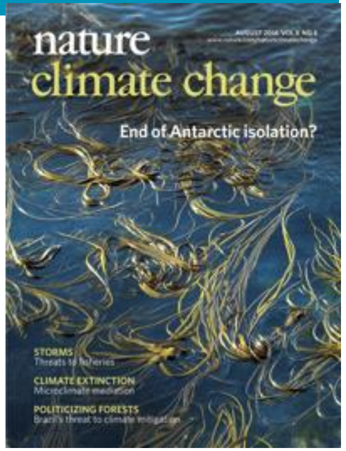


Total CO_2 budget for Brazil

Table S1 – Literature values for the Brazilian CO_2 budget from 2010 to 2050

Period	Budget Gt CO_2	Probability < 2°C	How was budget determined?	Reference
2010-2050	21.0	67%	Allocation (per-capita)	15
2014-2050	18.0	RCP2.6	Allocation (C&C)	16
2010-2050	16.0	67%	PRIMAP model (min)	17
2010-2050	41.0	67%	PRIMAP model (max)	
2010-2050	19.8	n/a	Allocation TISS-DSF ScenA	18
2010-2050	21.1	n/a	Allocation TISS-DSF ScenA	
2010-2050	29.6	n/a	Allocation TISS-DSF ScenA	
2010-2050	41.4	n/a	Allocation TISS-DSF ScenA	
2010-2050	22.0	n/a	Allocation WWF-Ecofys CDC	
2010-2050	25.0	n/a	Allocation WWF-Ecofys GDR	
2010-2050	26.0	n/a	Allocation WWF-Ecofys C&C	
2010-2050	23.0	n/a	Allocation IEA (WEO2013)	
2010-2050	41.3	67%	Allocation (population)	19
2010-2050	4.7	67%	AIM/CGE - INDC 1000	20
2010-2050	0.5	67%	AIM/CGE - NPi 1000	
2010-2050	16.0	67%	COPPE-COFFEE 1.0 - INDC 1000	
2010-2050	23.6	67%	COPPE-COFFEE 1.0 - NPi 1000	
2010-2050	7.5	67%	DNE21+ V.14 - INDC 1000	
2010-2050	13.1	67%	DNE21+ V.14 - NPi 1000	
2010-2050	37.9	67%	IMAGE 3.0 - INDC 1000	
2010-2050	37.5	67%	IMAGE 3.0 - INDC 1000	
2010-2050	37.6	67%	IMAGE 3.0 - NPi 1000	
2010-2050	**23.8**	-	**Average value from literature**	

https://doi.org/10.1038/s41558-018-0213-y



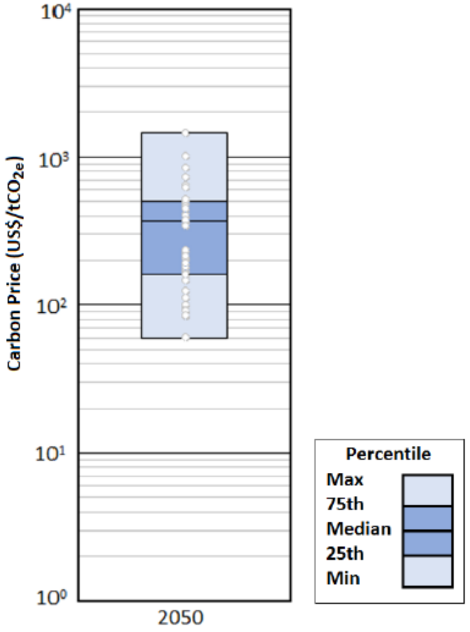


Figure S4 – Carbon price range, in 2050, for a "below 2°C" world

Total CO_2 budget for Brazil

https://doi.org/10.1038/s41558-018-0213-y

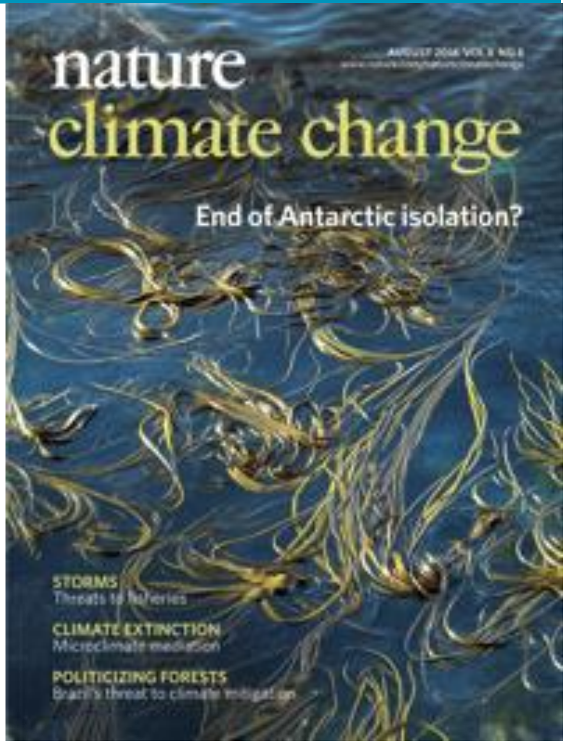


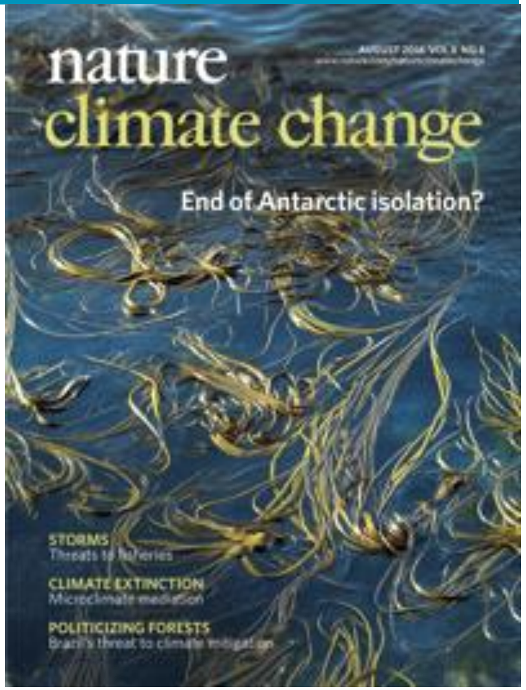
Table S2 – Brazilian "below 2°C" world CO_2 budget for deforestation and other sectors according to scenario

Scenario	CO_2 Budget (2010-2050)	
	Deforestation	Other Sectors
Strong Environmental Governance (SEG)	9.6	14.4
Intermediate Environmental Governance (IEG)	16.3	7.7
Weak Environmental Governance (WEG)	23.1	0.9

Note: Other sectors include: energy-related emissions, industrial processes and residues.

Land use modelling

https://doi.org/10.1038/s41558-018-0213-y



OTIMIZAGRO

The model framework, developed using the Dinamica EGO platform (6), is structured in four spatial levels: (i) Brazil's biomes, (ii) IBGE micro-regions, (iii) Brazilian municipalities, and (iv) a raster grid with 25 ha spatial resolution.

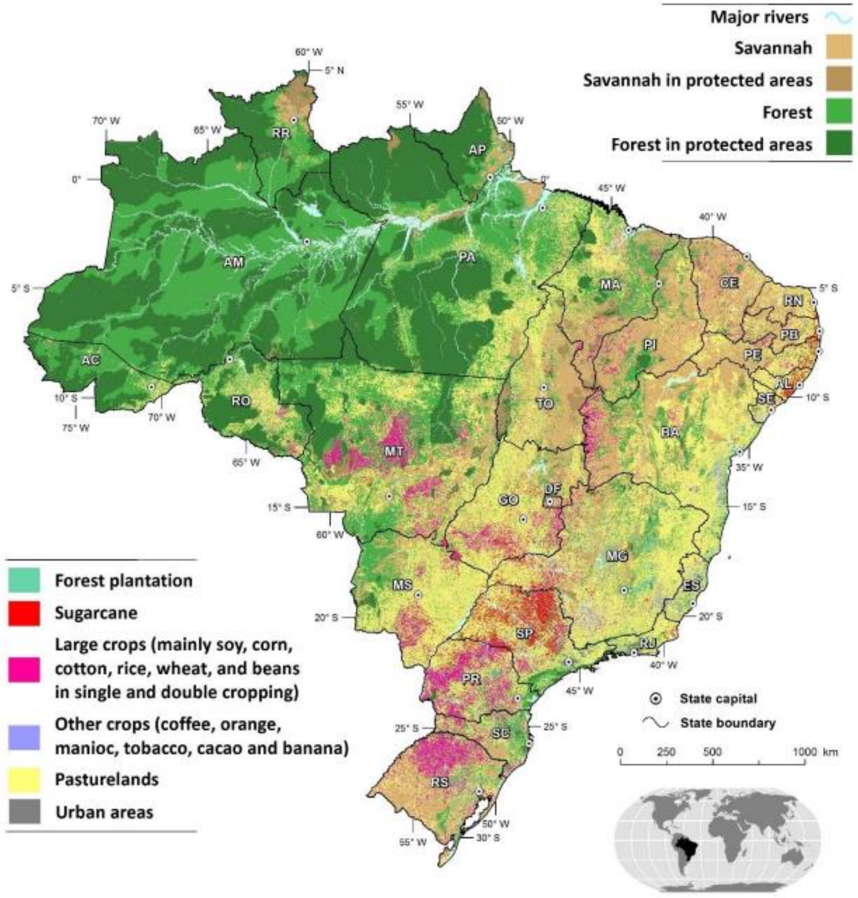


Figure S5 – Land use in Brazil as of 2012

Land use modelling

https://doi.org/10.1038/s41558-018-0213-y

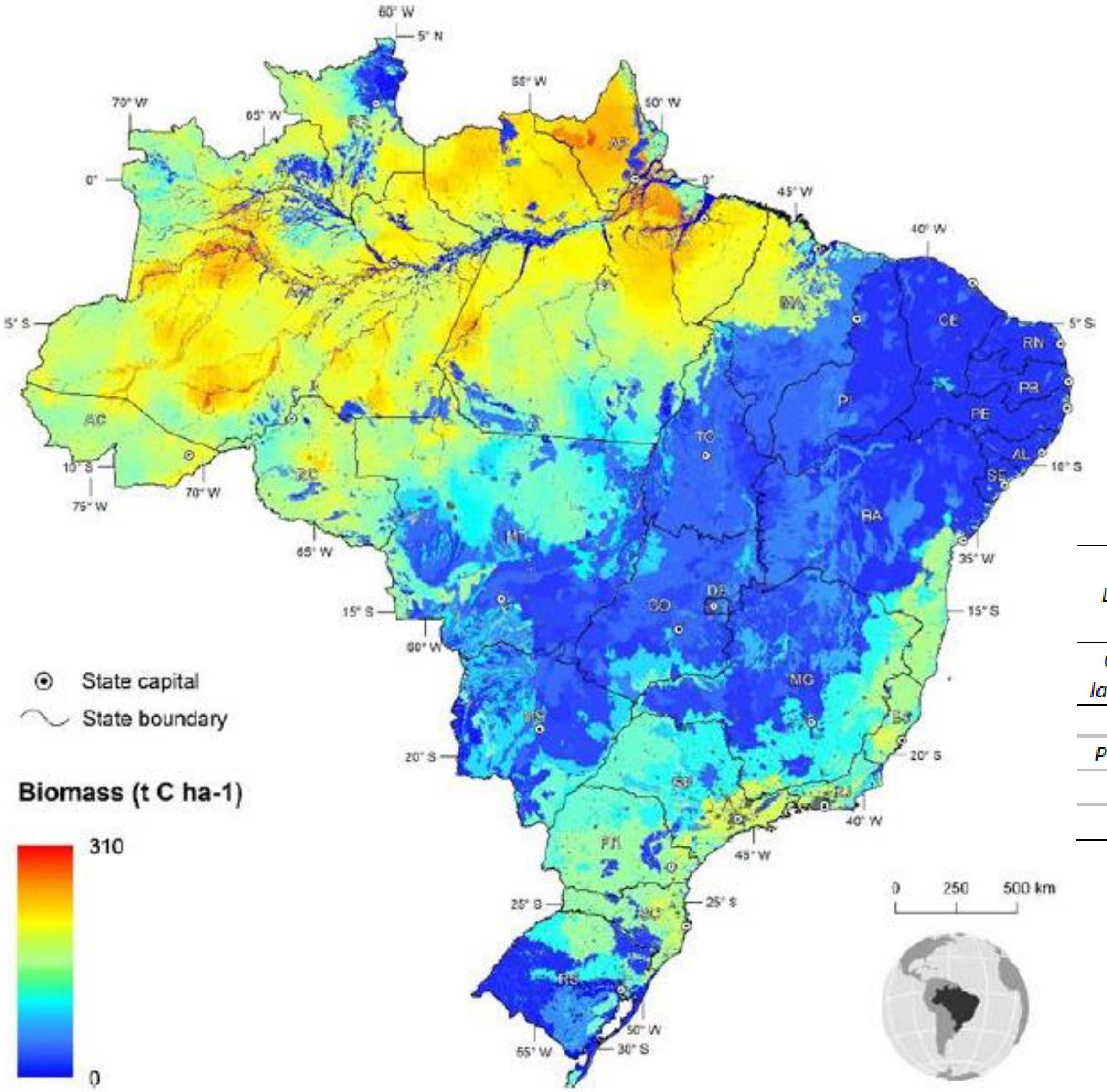


Figure S6 – Above and below ground biomass

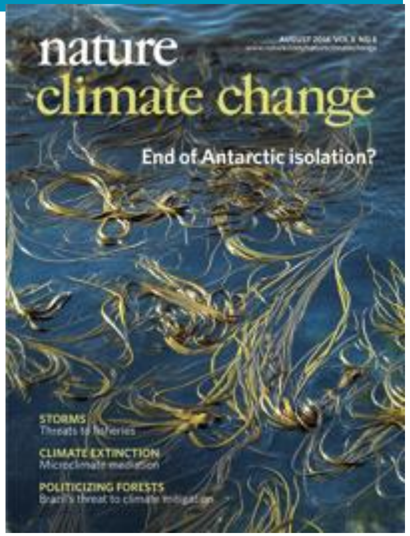
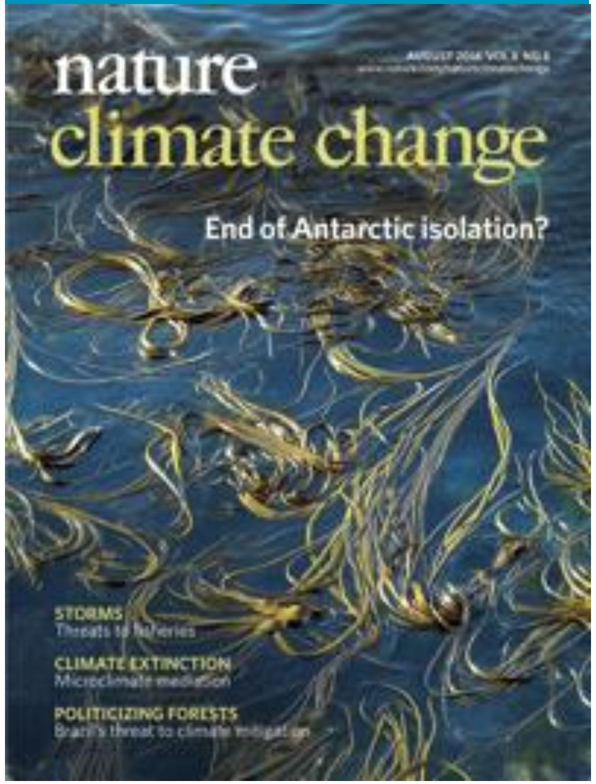


Table S3 – Carbon Removal factors for vegetation regrowth for Brazil's biomes land use transitions

Land use transitions	(tC/ha/year) Amazon	Cerrado	Atlantic Forest	Caatinga	Pampas	Pantanal	Reference
Grasslands or other land use to Grasslands	0.52	0.52	0.52	0.52	0.52	0.52	60-61
Forest to Forest	4.96	1.72	5.35	0.6	1.76	2.77	57-59, 61-69
Pastureland to Forest	2.85	2.85	2.85	2.85	2.85	2.85	61,70
Cropland to Forest	4.73	4.73	4.73	4.73	4.73	4.73	57,61
Others to Forest	0.59	0.59	0.59	0.59	0.59	0.59	61, 71

Energy-system modelling

https://doi.org/10.1038/s41558-018-0213-y



Base year: 2010

Horizon: 2010-2050 each 5 years

Seasonality: 12 months

Load curve: 24 hours

6 regions (electricity, gas, oil, oil products and CO_2)

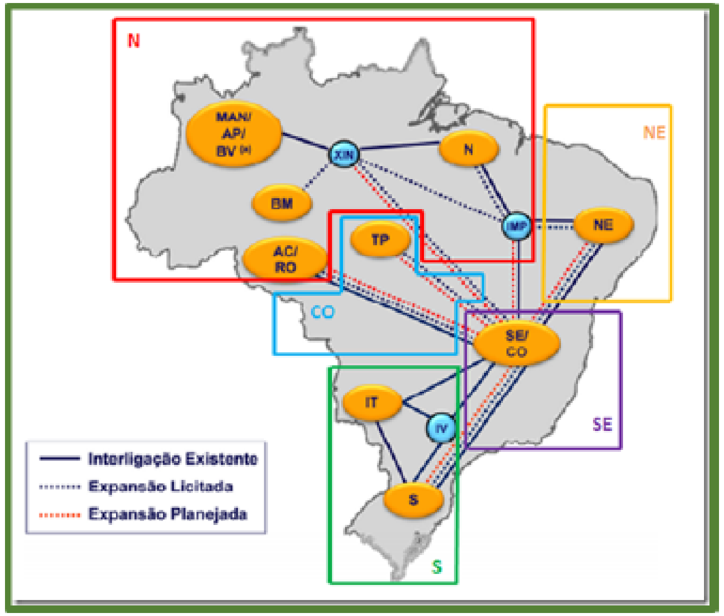


Figure S7 – Spatial and temporal resolution of the BLUES model.

Energy-system modelling

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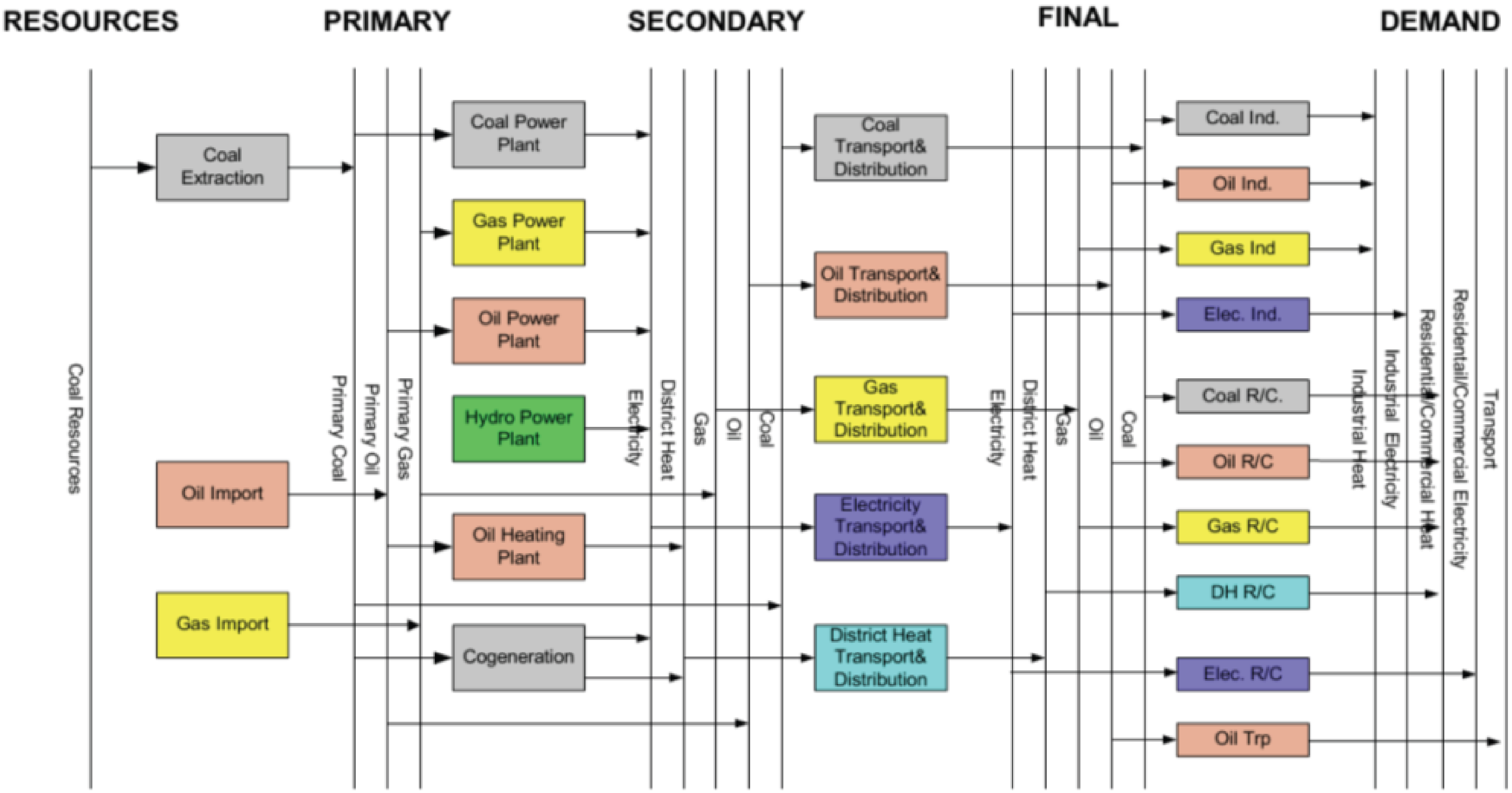
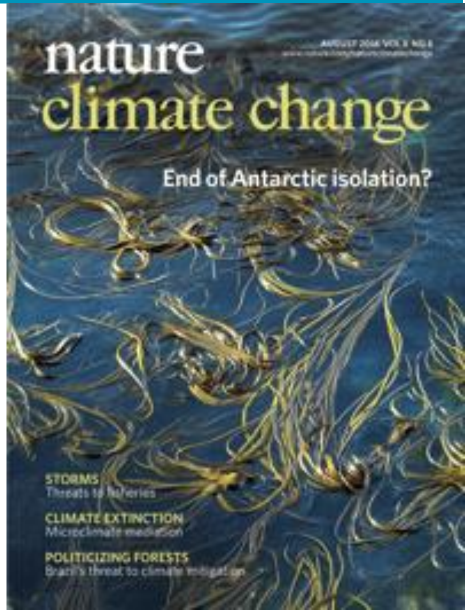
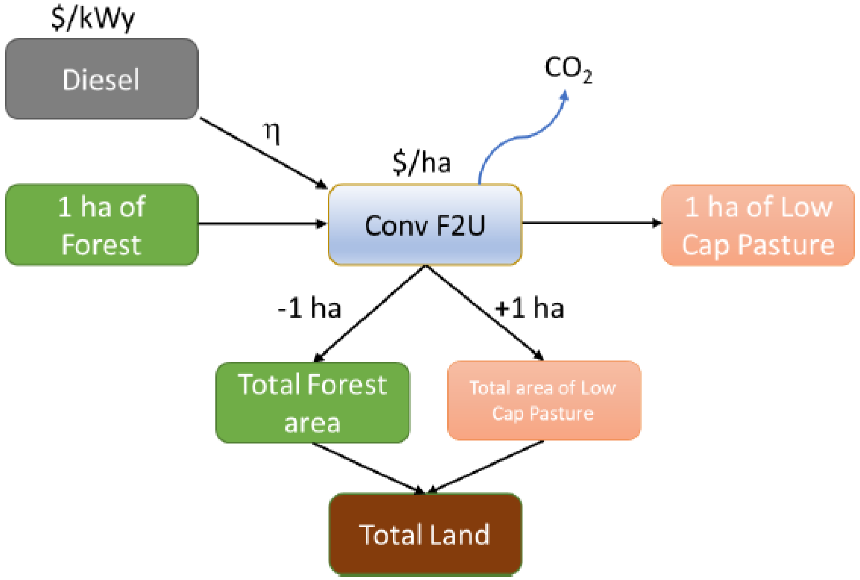




Energy-system modelling

https://doi.org/10.1038/s41558-018-0213-y



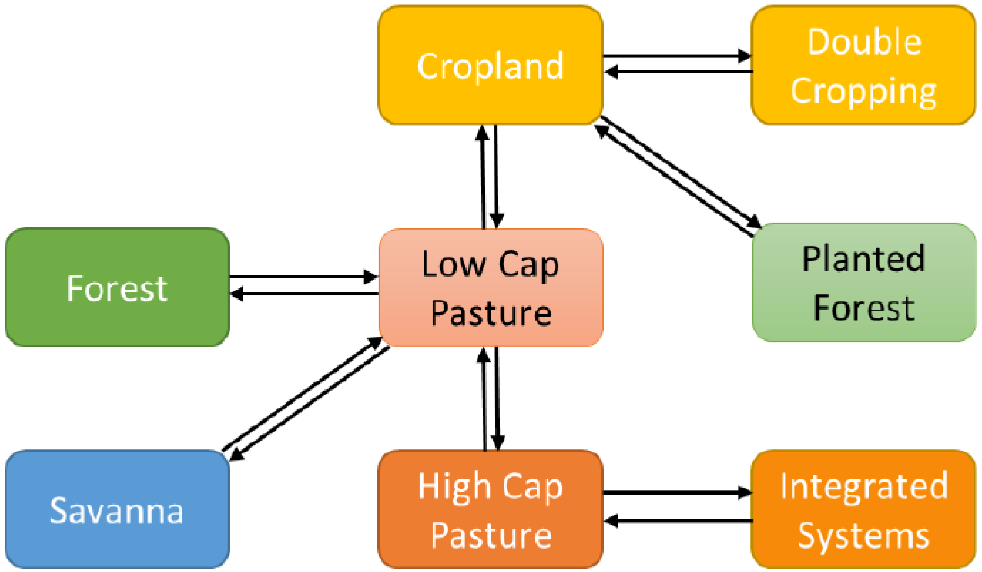
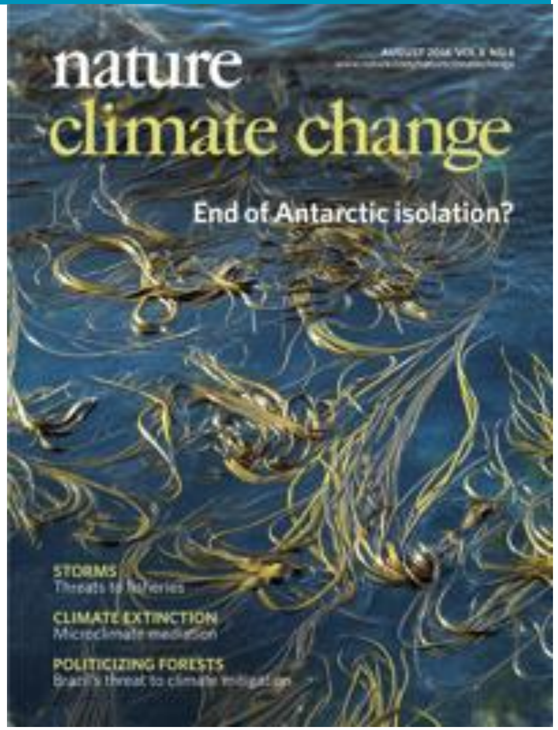
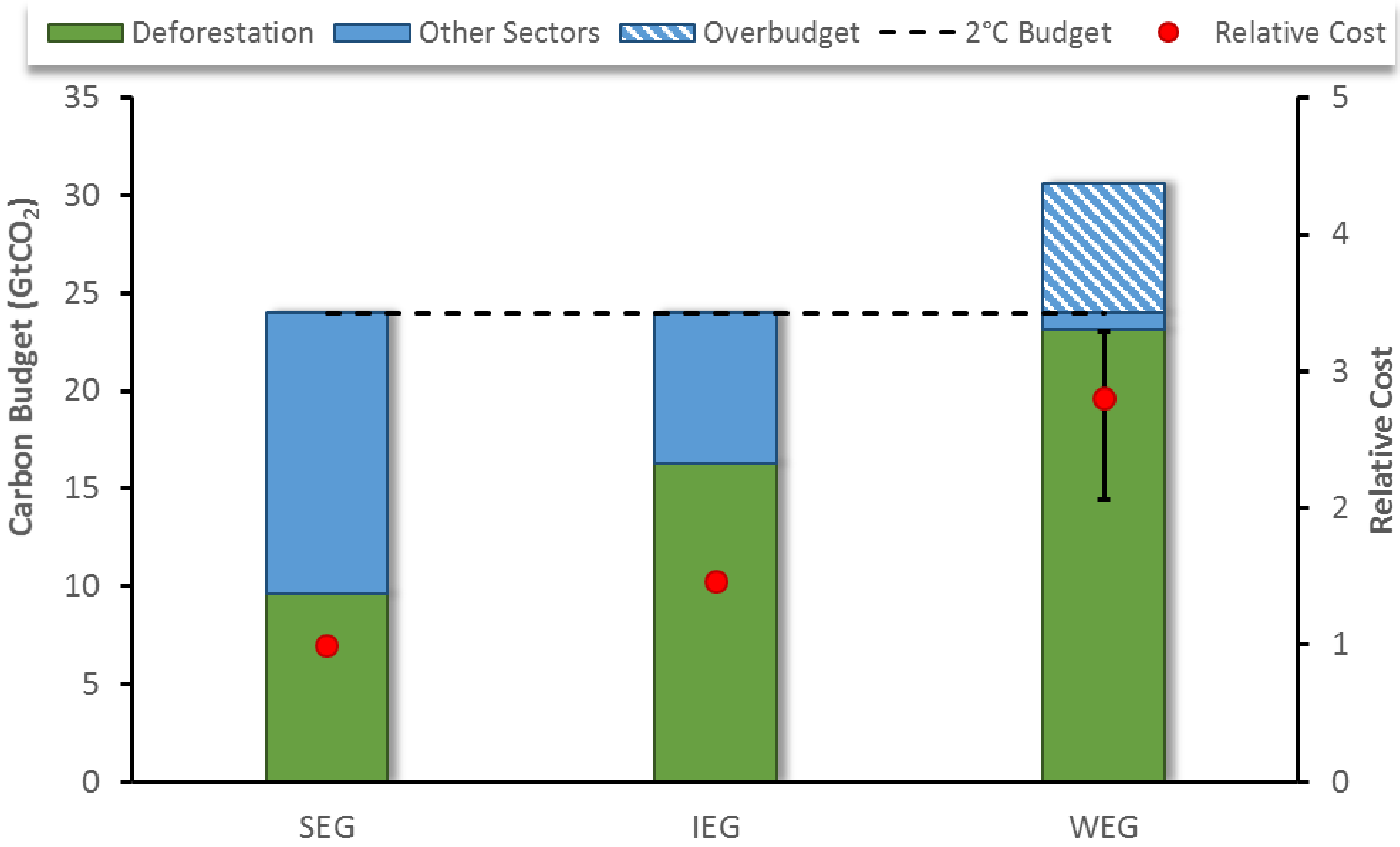


Figure S11 – Land use transitions modelled in BLUES



Results



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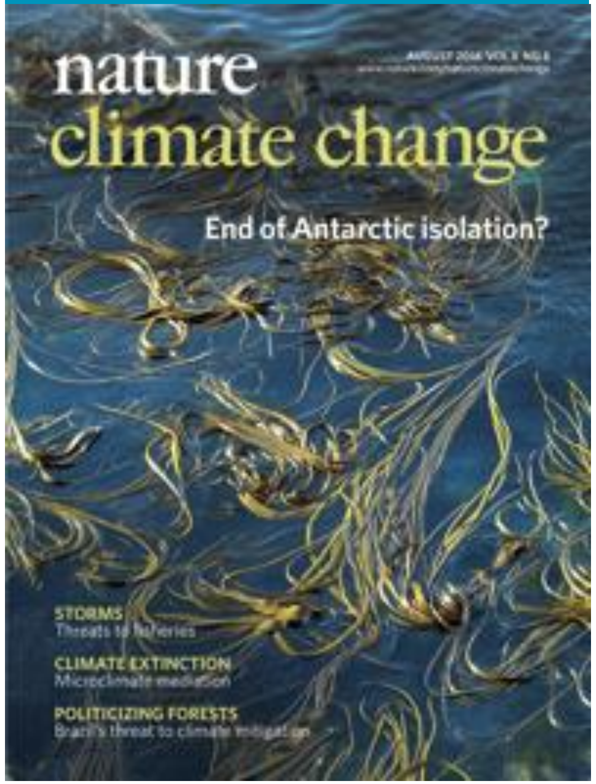


Results

Energy-system results

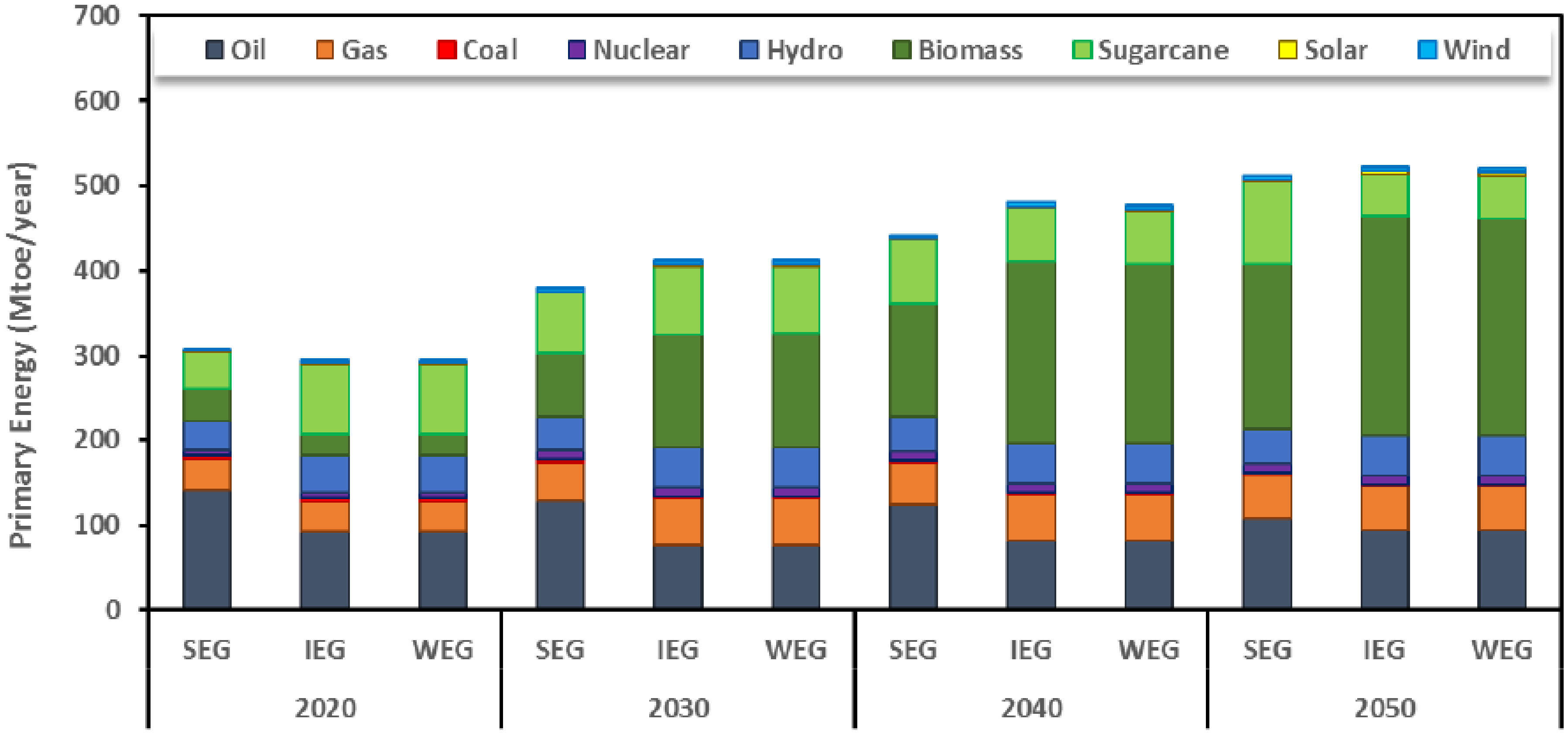
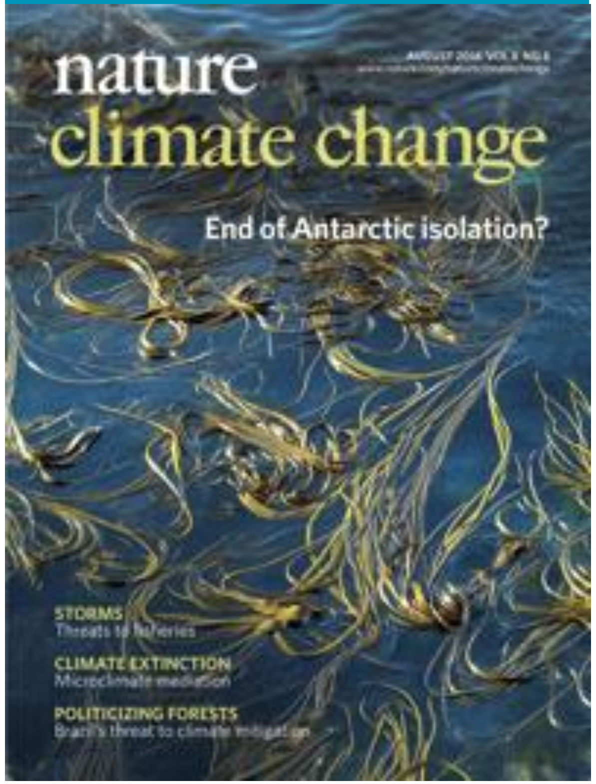


Figure S16 – Primary energy consumption (Mtoe/year) for Brazil

https://doi.org/10.1038/s41558-018-0213-y



Results

Energy-system results

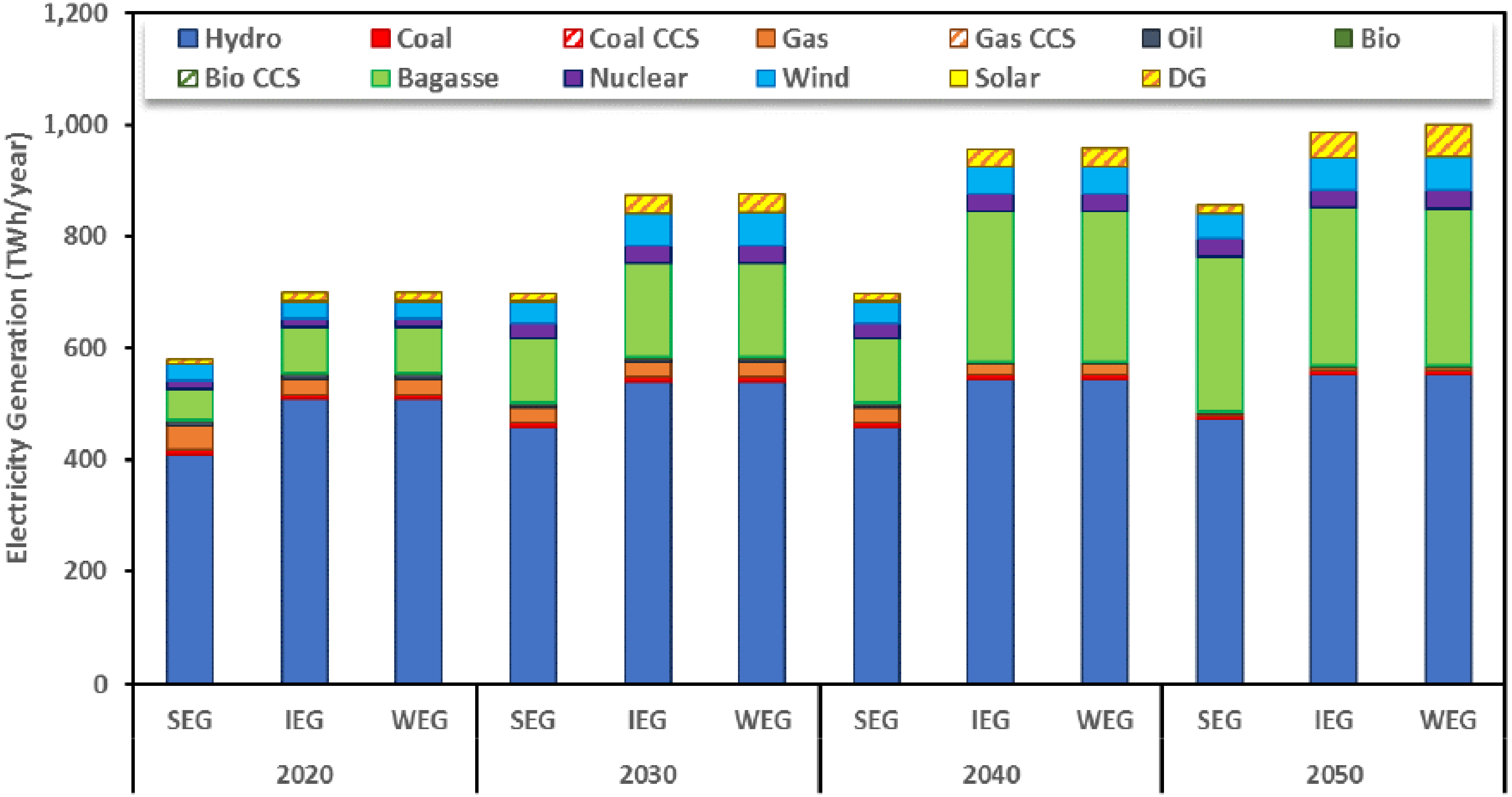
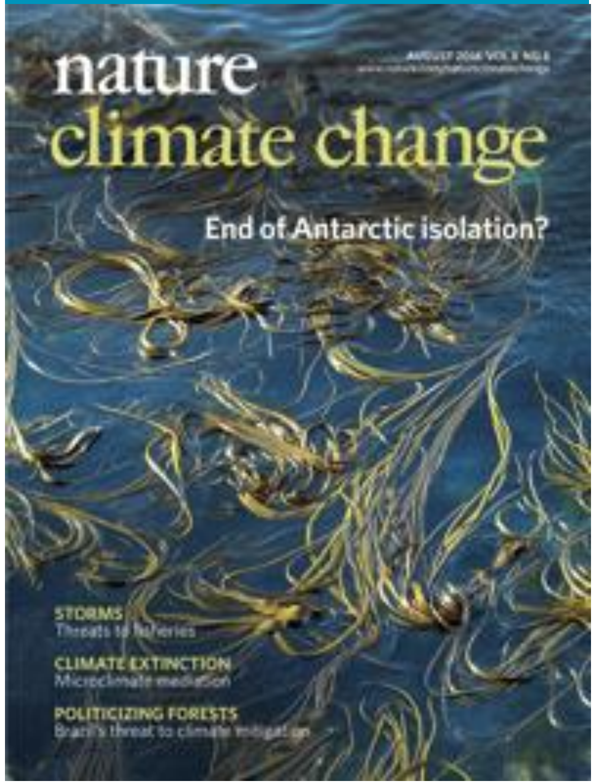


Figure S17 – Electricity generation (TWh/year) in Brazil

https://doi.org/10.1038/s41558-018-0213-y



Results

Energy-system results

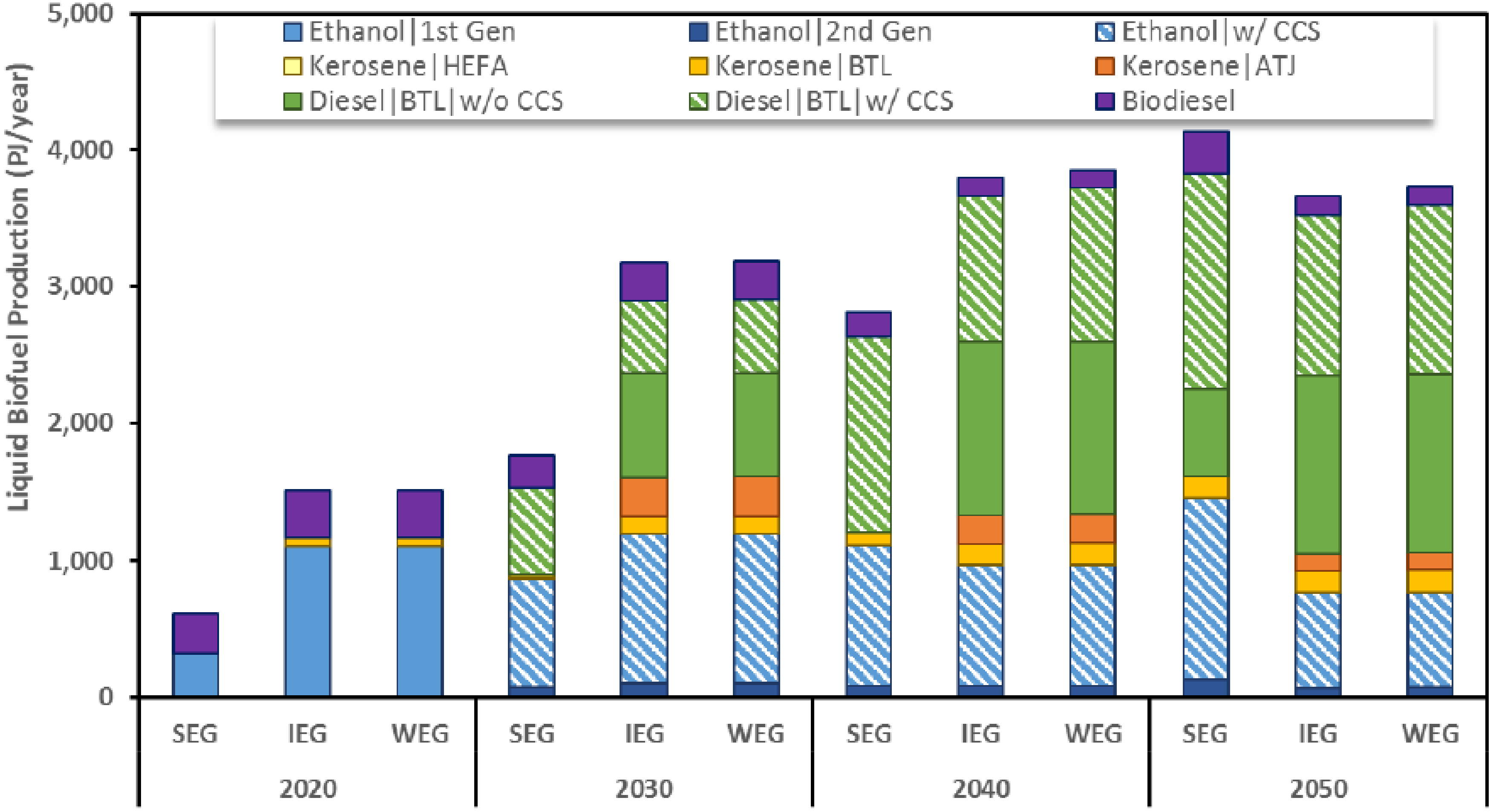
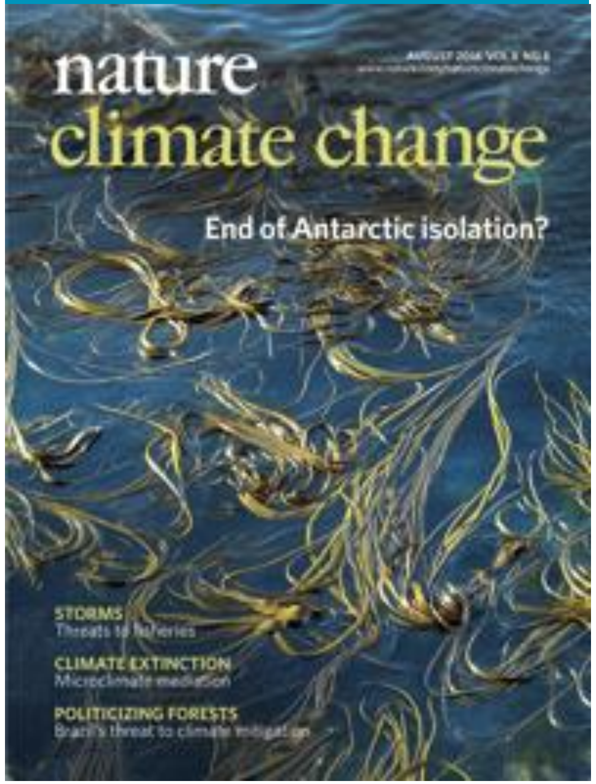


Figure S18 – Liquid biofuel production (PJ/year) in Brazil

https://doi.org/10.1038/s41558-018-0213-y



Results

Energy-system results

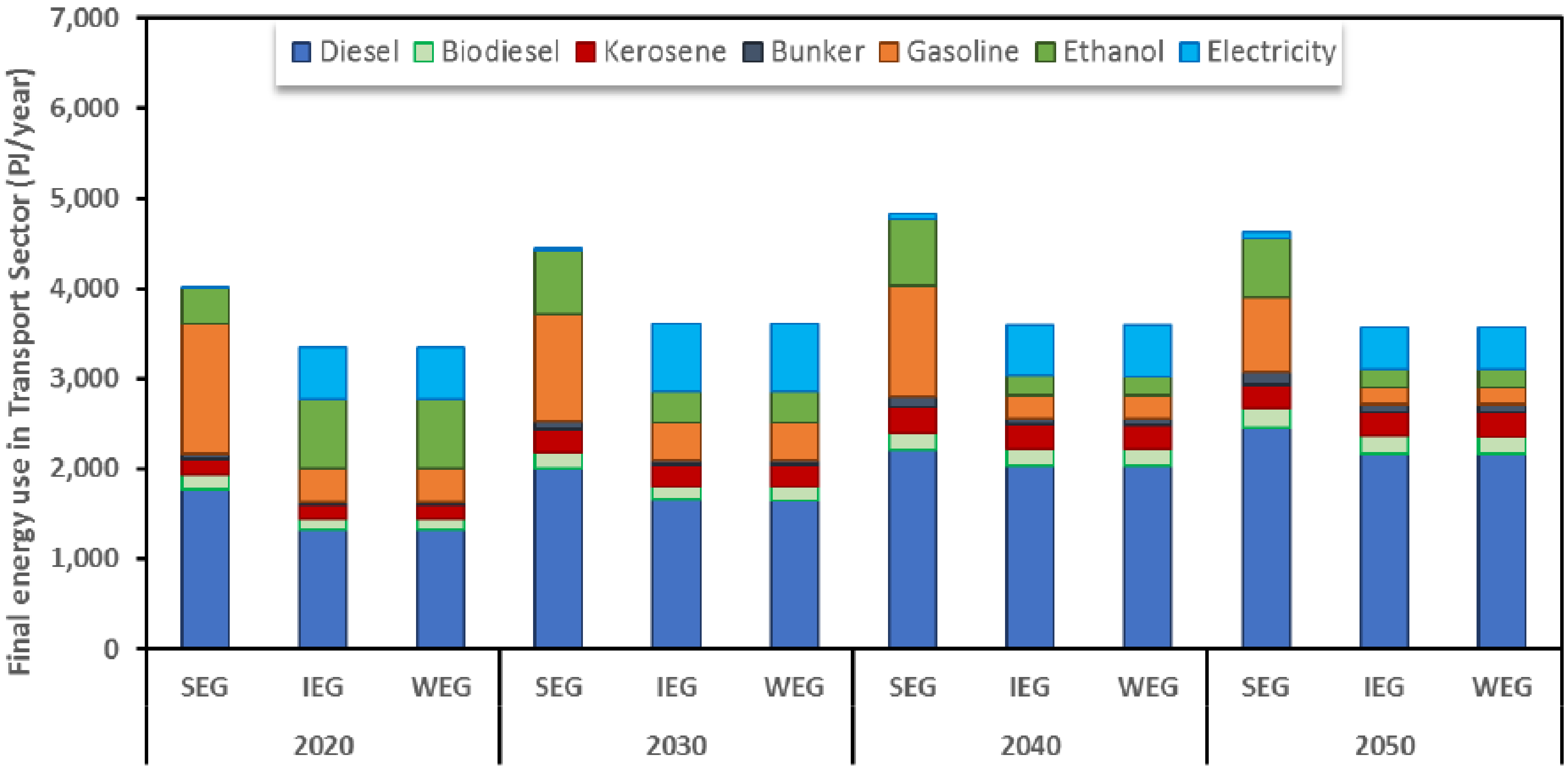
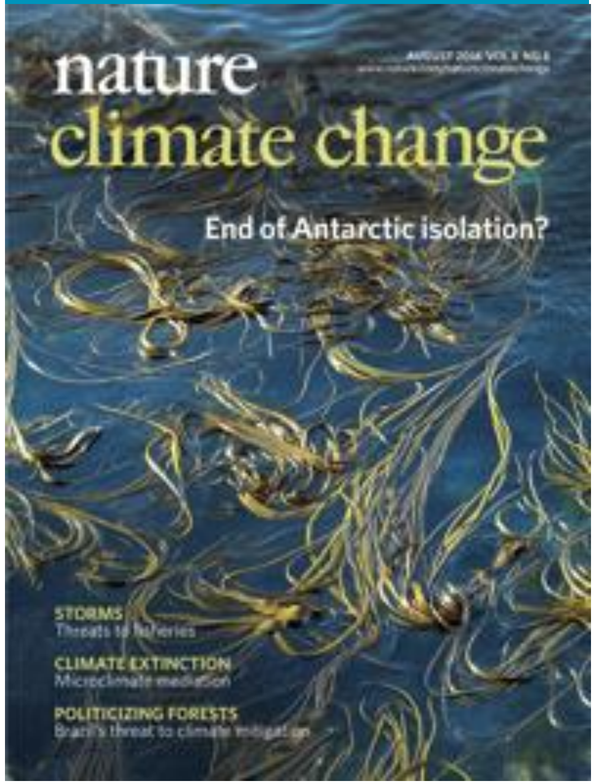
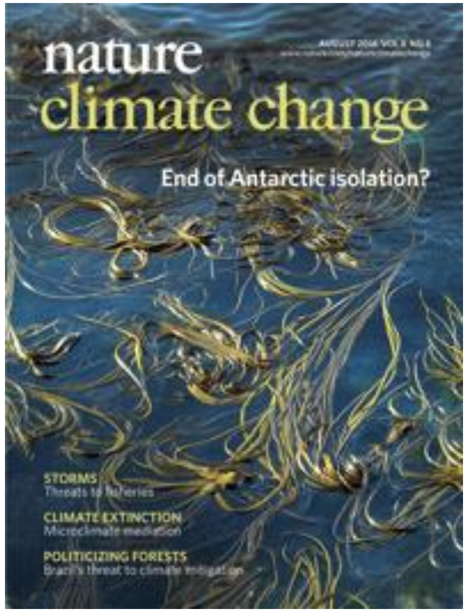


Figure S19 – Transport sector final energy consumption (PJ/year) in Brazil

https://doi.org/10.1038/s41558-018-0213-y



Resultados finais



- Grande necessidade de investimentos adicionais
- Altos impactos econômicos em setores outros

Table S4 – Total costs across scenarios

Sector	SEG (10^9 US$_{2010}$)		IEG (10^9 US$_{2010}$)		WEG (10^9 US$_{2010}$)	
	Investment	O&M	Investment	O&M	Investment	O&M
Fuels[1]	622	381	1,132	418	1,142	417
Power	367	86	641	109	675	109
Industrial	48	52	49	65	49	65
Others	164	136	167	137	167	138
Penalty	-	-	-	-	-	2,440 (1,069-3,333)[2]
Total	1,201	654	1,989	729	2,033	3,169 (1,798-4,062)[2]

Note: 1 – Fuels Sector include primary energy production, oil refineries, biofuel production and energy-related CCS infrastructure; 2 – Values relative to median, 25th and 75th percentile of the carbon price (respectively). See Figure S1.

Nossa análise mostra que o Brasil é altamente vulnerável às mudanças climáticas, e que domesticamente a melhor maneira de reduzir nossas emissões de GEE é reduzindo o desmatamento

Caso contrário, outros setores da economica pagarão o custo (muito mais alto) de reduzir suas emissões para além do que seria necessário

Muito obrigado!

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