

Identifying sustainable pathways with GLOBIOM-Brazil model

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+ many colleagues



Supported by:



Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

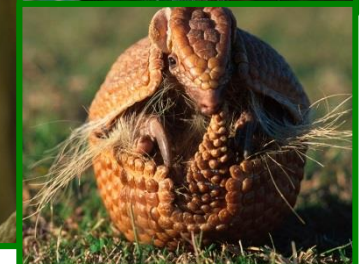
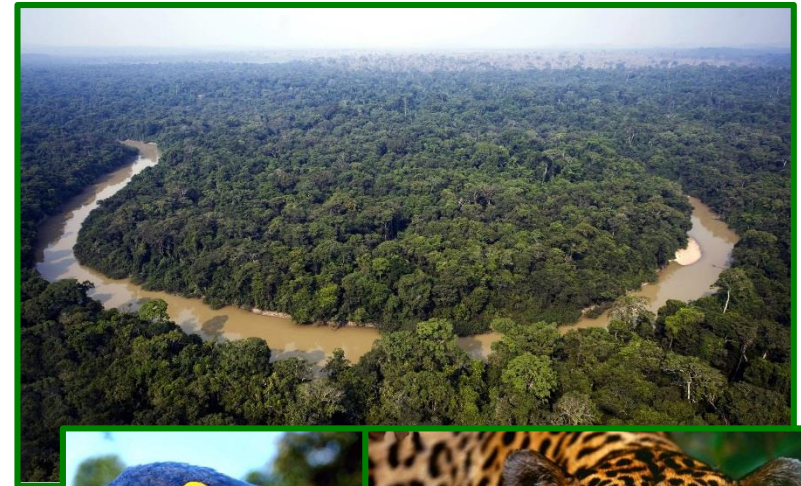
based on a decision of the German Bundestag

Conflicting interests












PRODUCTION



PROTECTION

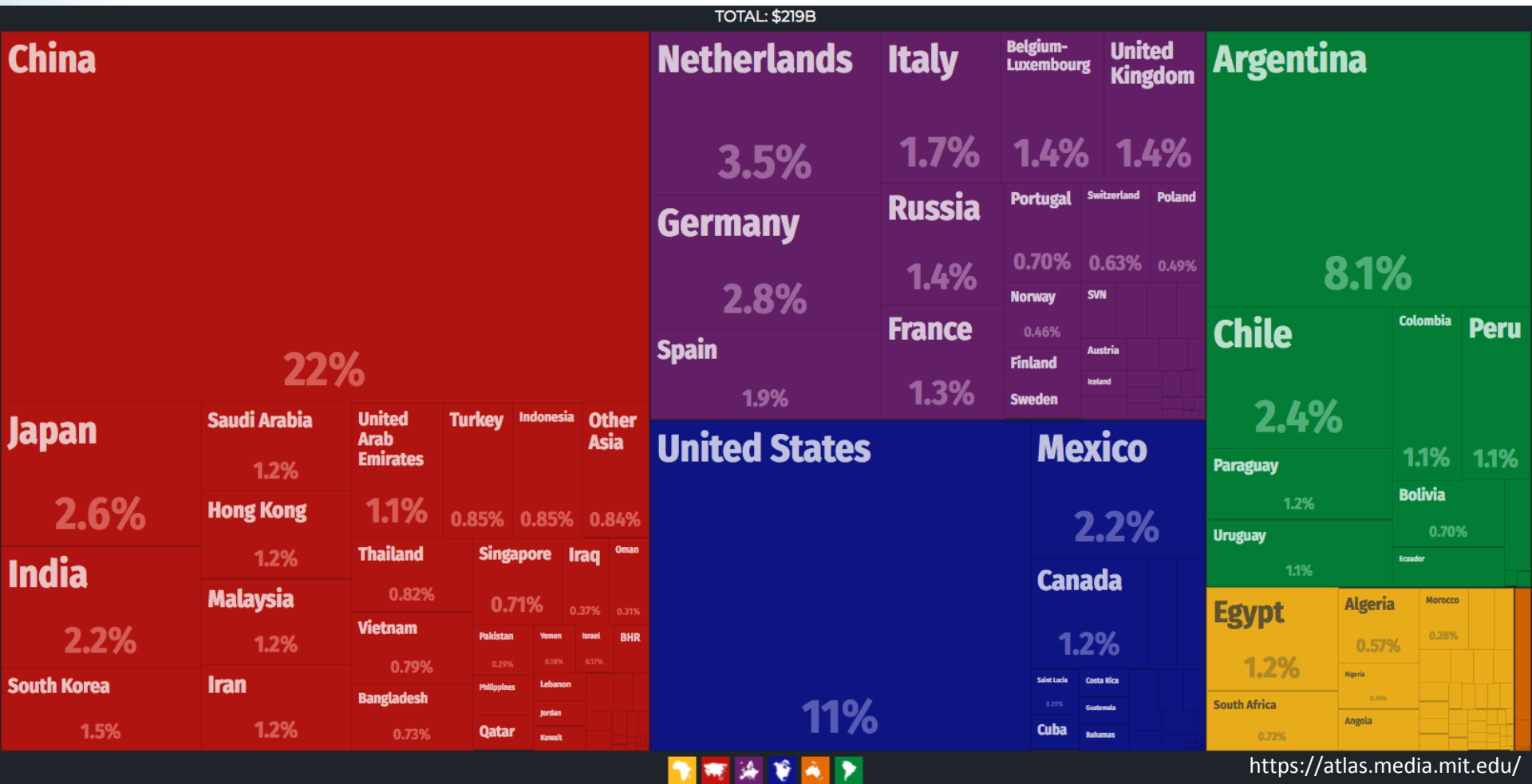


Brazilian position

Major Products		Brazil – Global ranking	
		Production	Exports
Sugar		1º	1º
Coffee		1º	1º
Orange juice		1º	1º
Bovine meat		2º	1º
Poultry meat		2º	1º
Corn		3º	3º
Soy grains		2º	1º
Soy cake		4º	2º
Soy oil		4º	2º
Cotton		4º	2º
Pig meat		4º	4º

Source: USDA, 2017

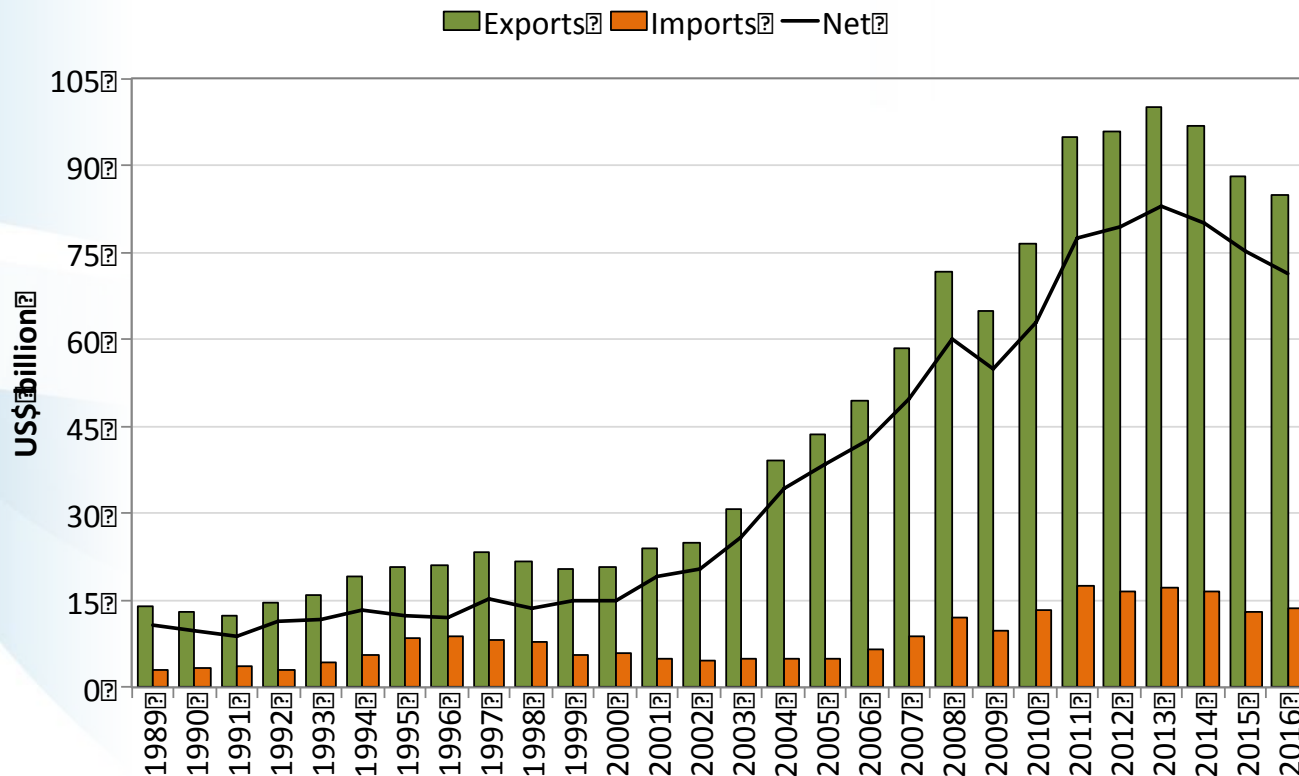
Where does Brazil export to? (2017)



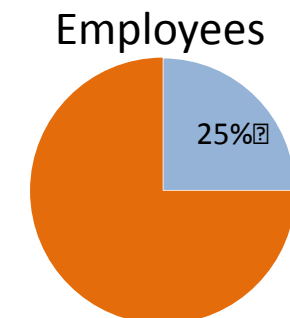
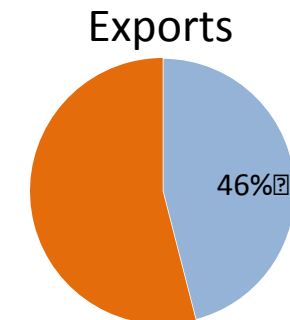
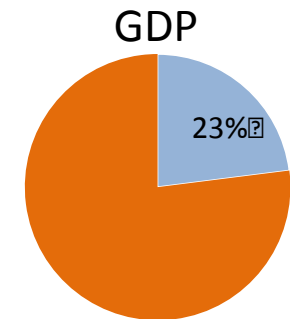
<https://atlas.media.mit.edu/>

Brazil's agriculture trade balance

Brazil's agribusiness



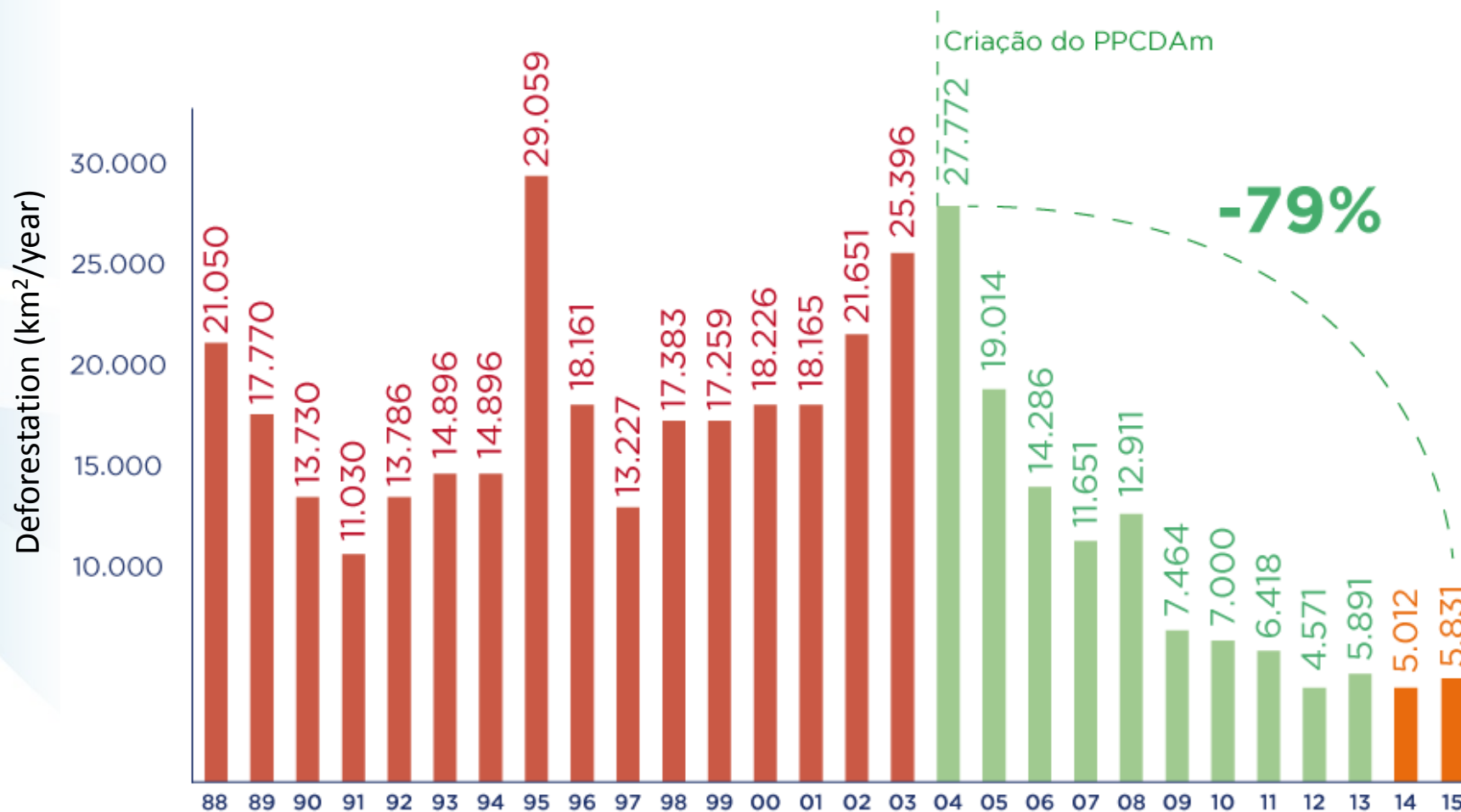
Source: <https://www.embrapa.br/visao/trajetoria-da-agricultura-brasileira>



1/3 of world's rainforest (2/3 of Amazon)

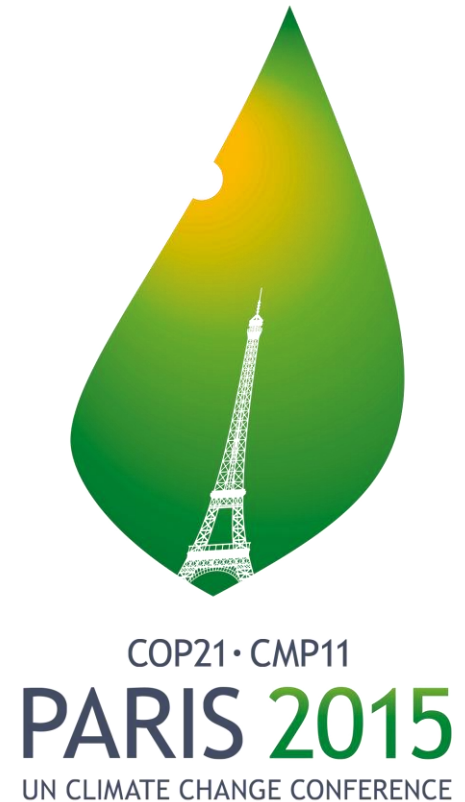


Amazon Deforestation



Source: PRODES/INPE

The Paris Agreement on Climate Change



After 21 years of negotiations, the UN delivered a universal 'legally binding' climate change deal

The Paris Agreement on Climate Change



FEDERATIVE REPUBLIC OF BRAZIL
INTENDED NATIONALLY DETERMINED CONTRIBUTION

Contribution: Brazil intends to commit to reduce greenhouse gas emissions by **37% below 2005 levels in 2025**

Subsequent indicative contribution: reduce greenhouse gas emissions by **43% below 2005 levels in 2030**

After 21 years of negotiations, the UN delivered a universal 'legally binding' climate change deal

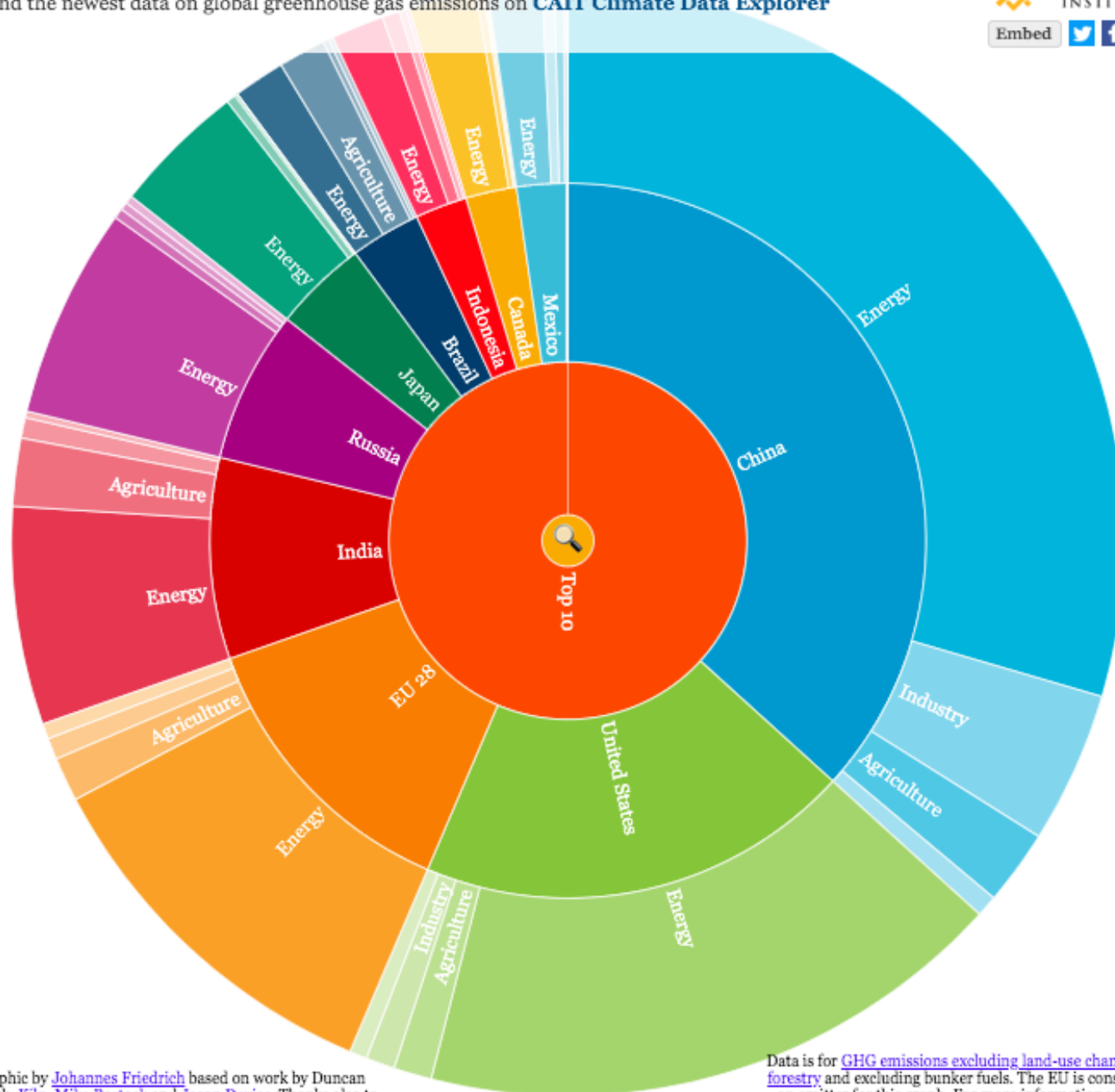
Explore the World's Greenhouse Gas Emissions

Find the newest data on global greenhouse gas emissions on [CAIT Climate Data Explorer](#)



WORLD
RESOURCES
INSTITUTE

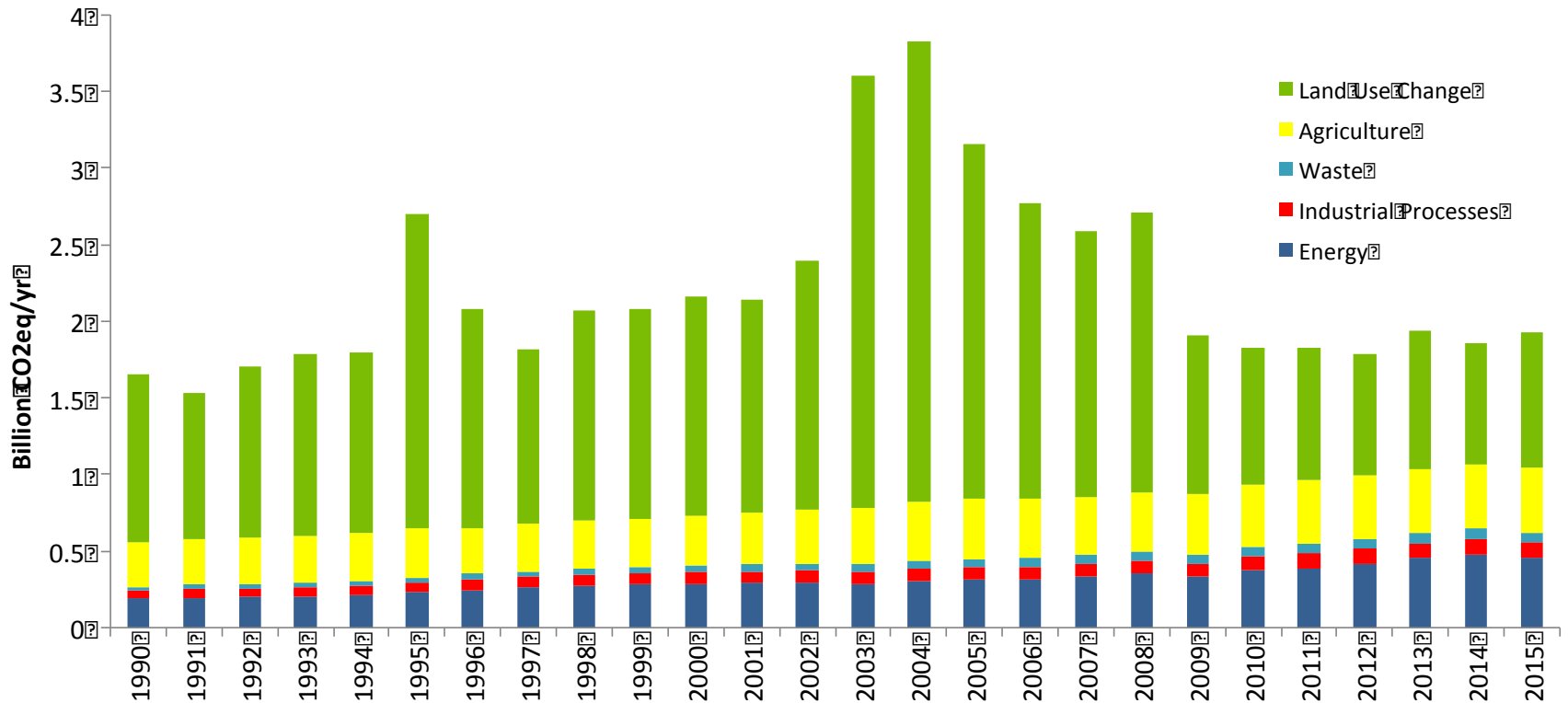
Embed



Graphic by [Johannes Friedrich](#) based on work by Duncan Clark, [Kilin](#), [Mike Bostock](#) and [Jason Davies](#). Thanks also to Jamie Cotta.

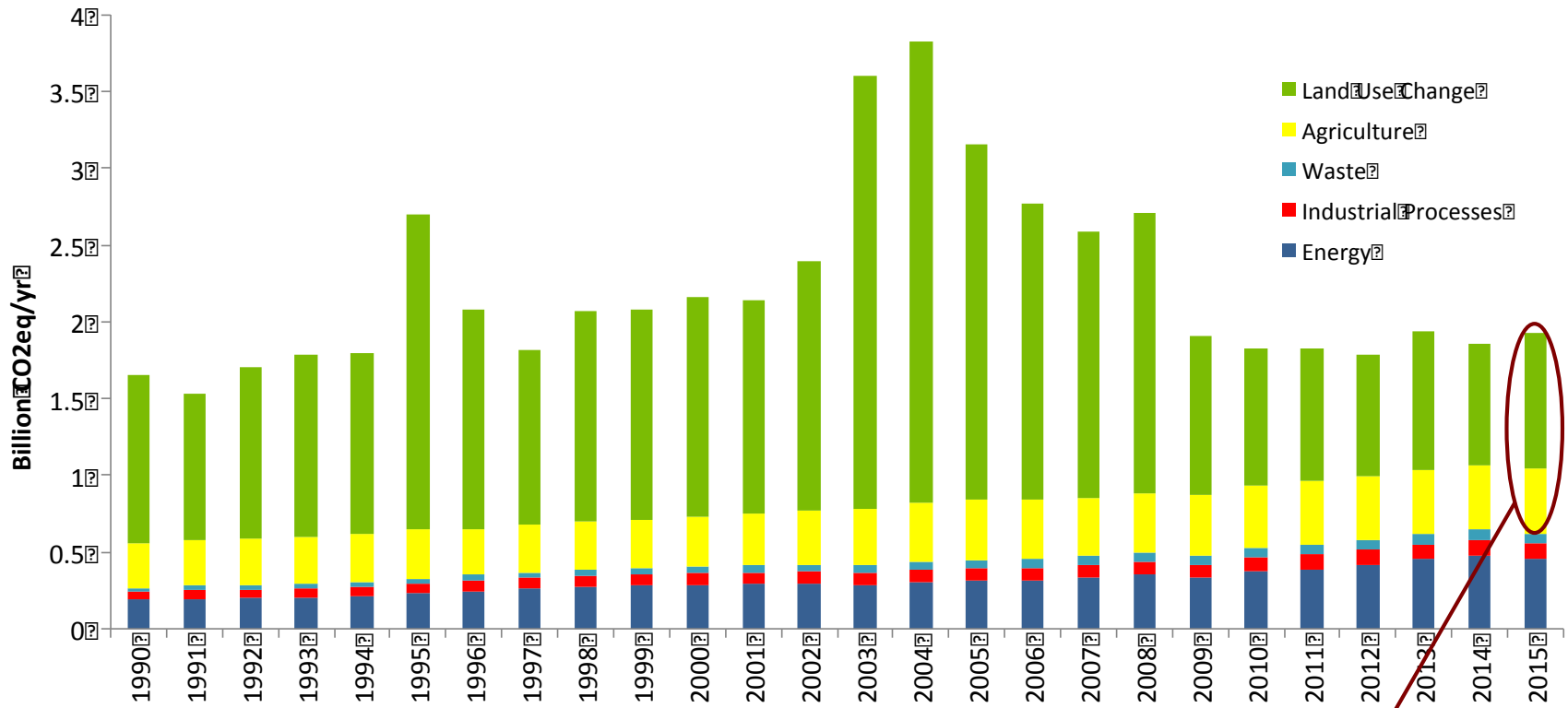
Data is for [GHG emissions excluding land-use change and forestry](#) and excluding bunker fuels. The EU is considered an emitter for this graph. For more information visit our [WRI blog](#).

Brazil's emissions by sector



Source: SEEG (System for the Estimation of Greenhouse Gases)

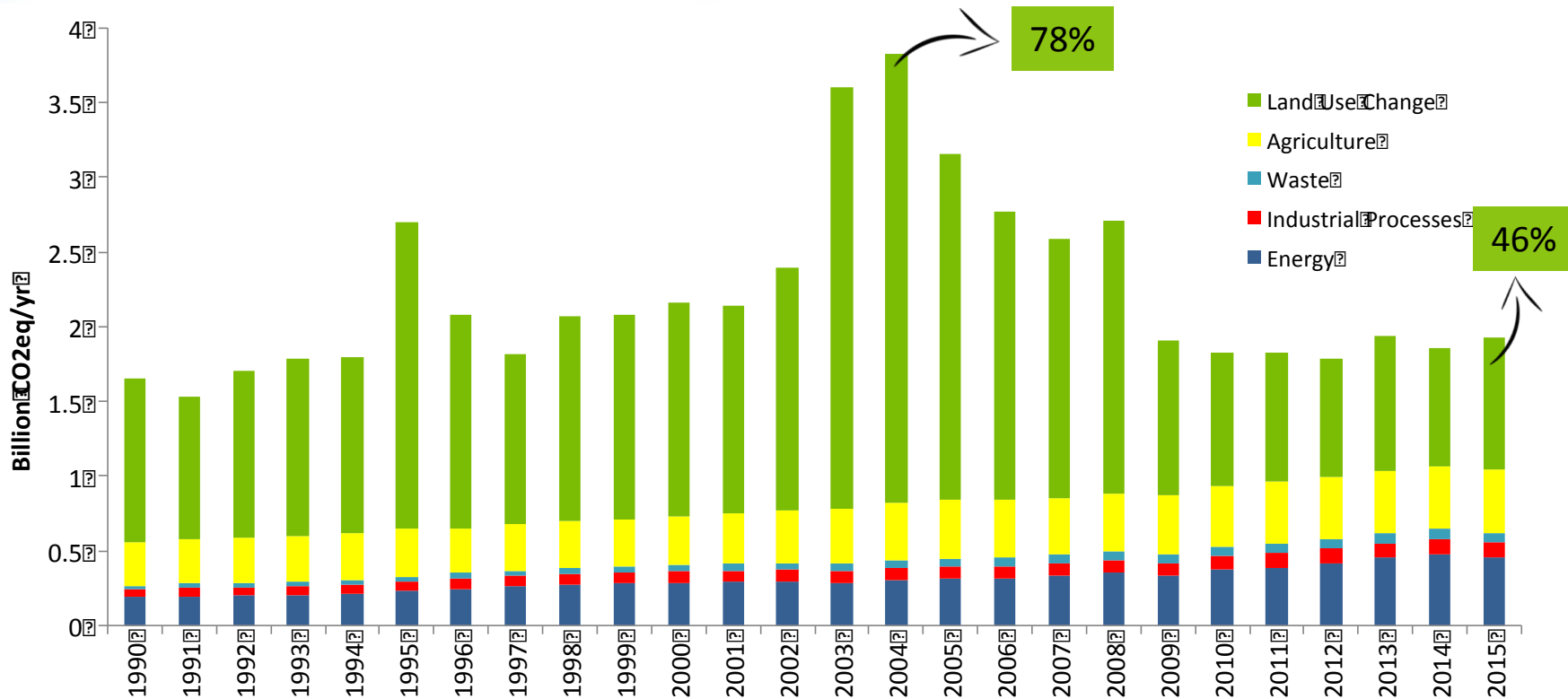
Brazil's emissions by sector



Source: SEEG (System for the Estimation of Greenhouse Gases)

~70% of Brazil's emissions come from **Land Use Change** and **Agriculture** sectors

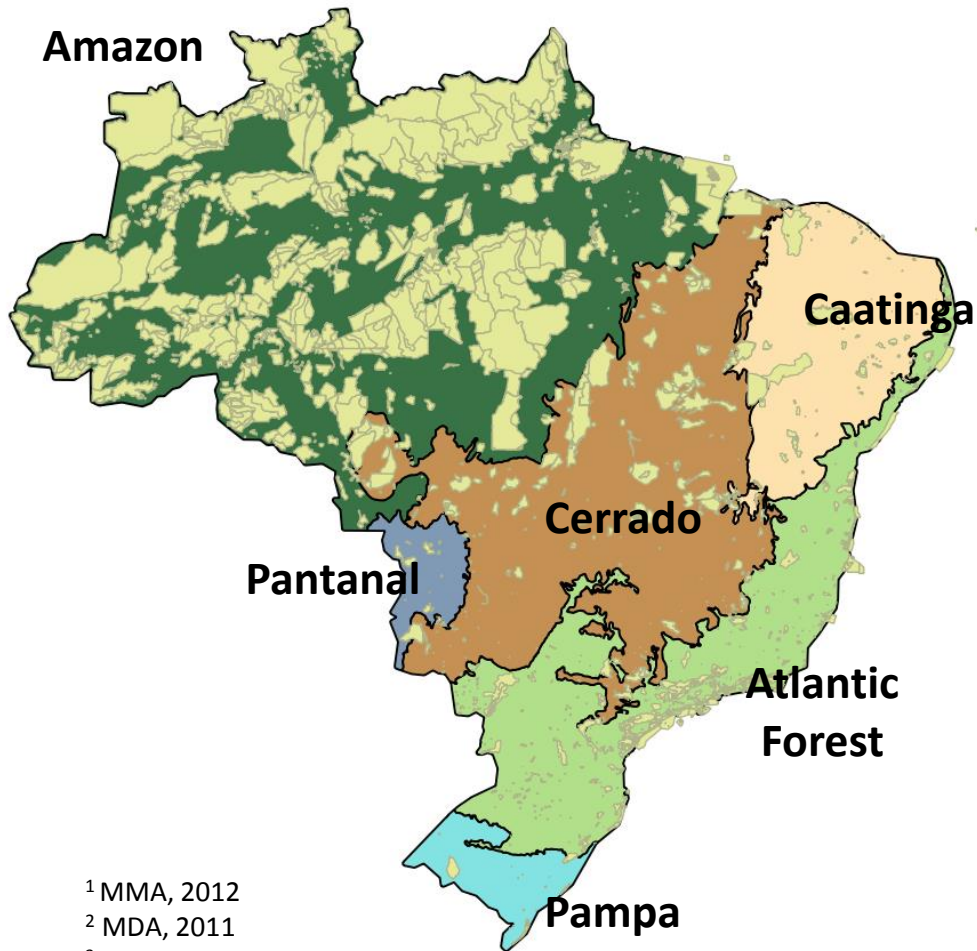
Brazil's emissions by sector



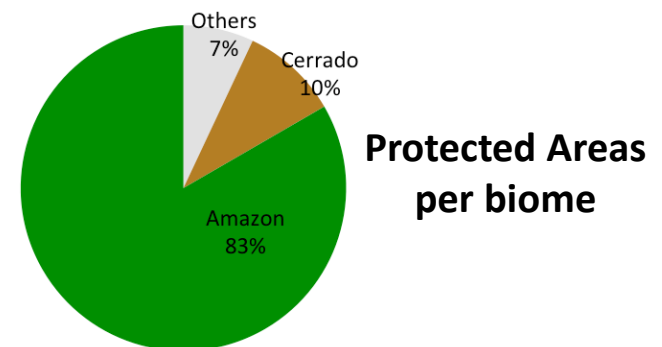
Source: SEEG (System for the Estimation of Greenhouse Gases)

~70% of Brazil's emissions come from **Land Use Change** and **Agriculture** sectors

Brazilian territory



- Area: 850 million ha (Mha)
- Protected areas: 243 Mha (28%)¹
- Private properties: 569 Mha (67%)²
- ~50% of Brazil's native forests are inside private properties³



¹ MMA, 2012

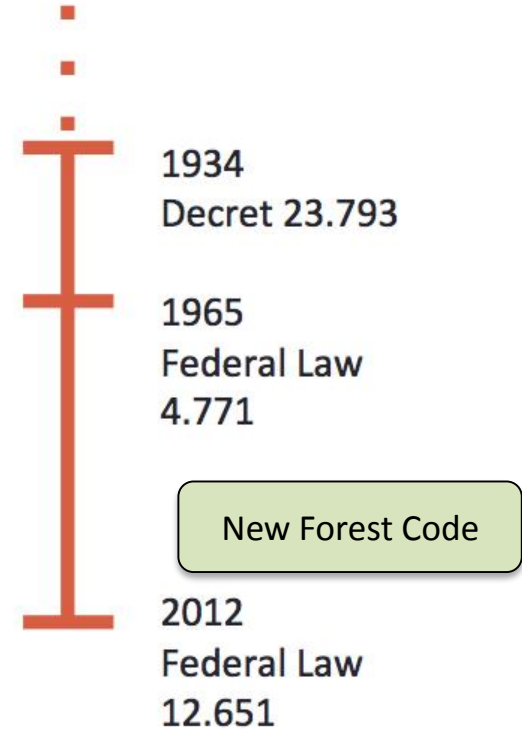
² MDA, 2011

³ Soares-Filho et al, 2014

2012 Brazil's Forest Code



Yasuyoshi Chiba/AFP/Getty Images

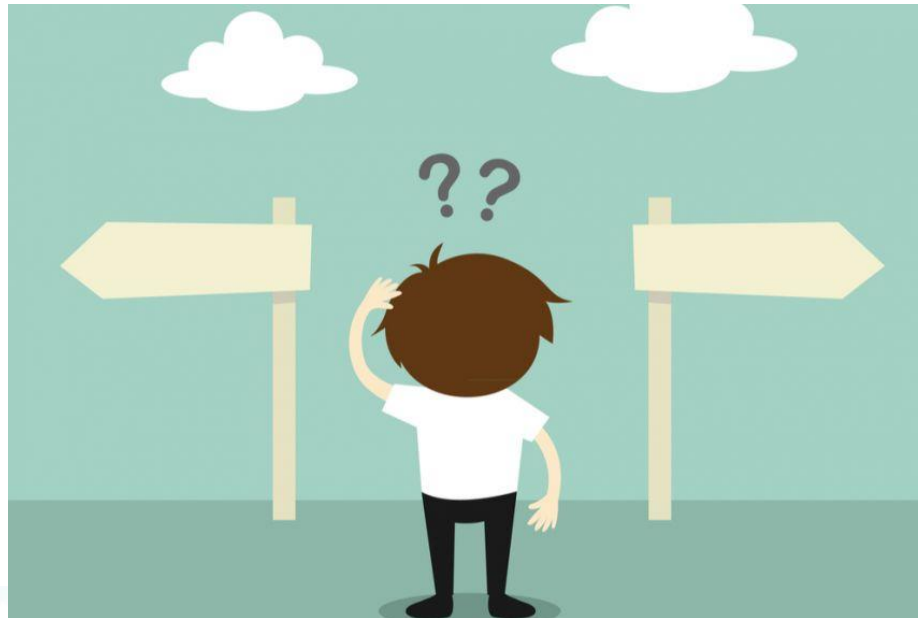


CRA
(Environmental
Reserve Quotas)

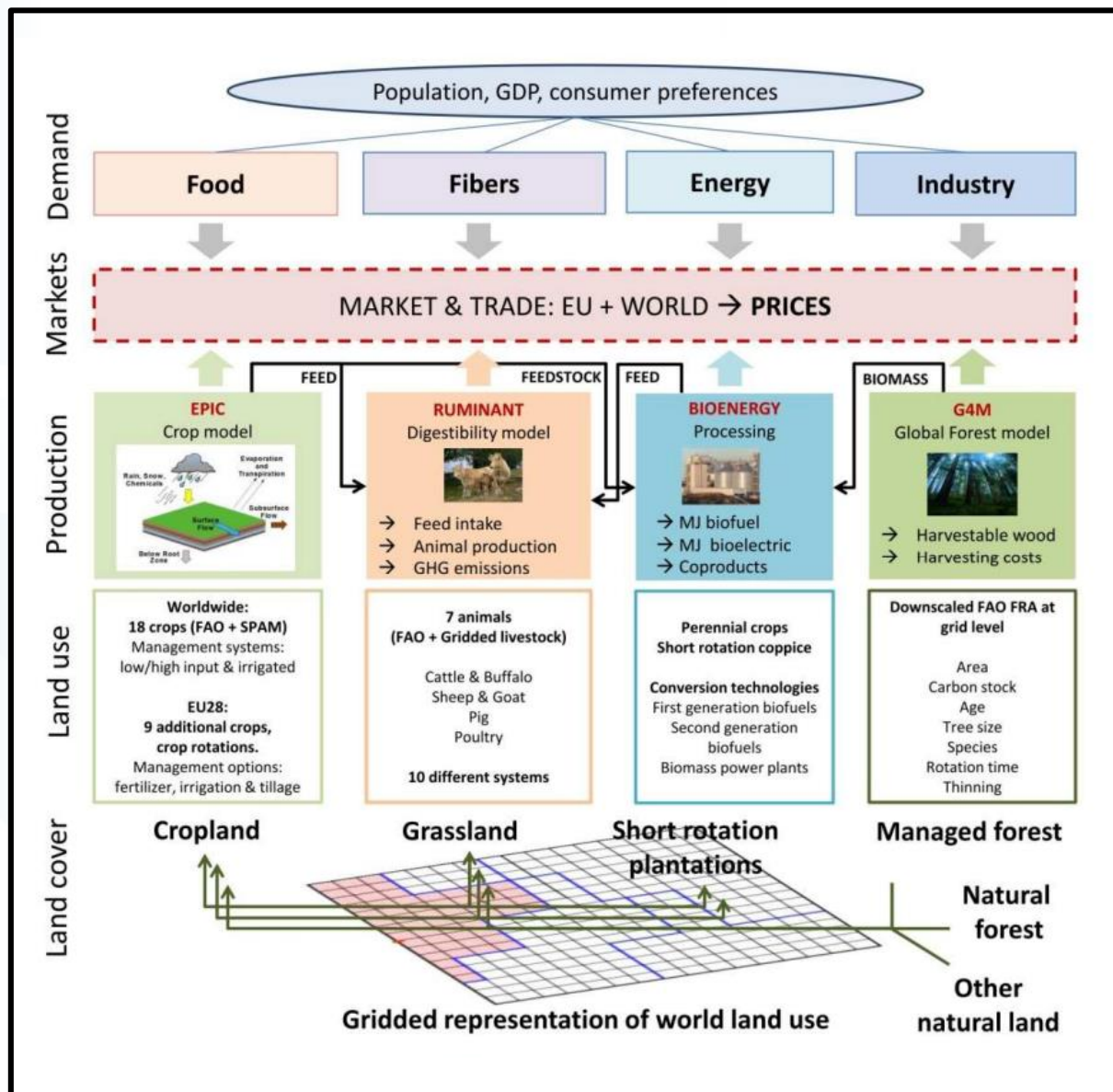
CAR
(Rural Environmental
Registry)

SFA
(Small Farms
Amnesty)

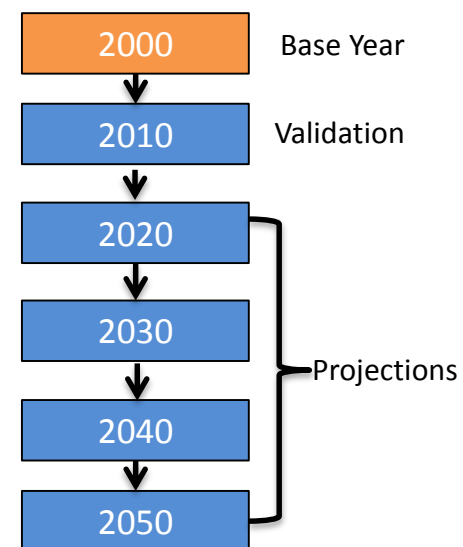
- Is the 2012 Forest Code enough to reconcile protection and production in Brazil?
- Can Brazil achieve its INDC commitments by enforcing the 2012 Forest Code?



GLOBIOM Model

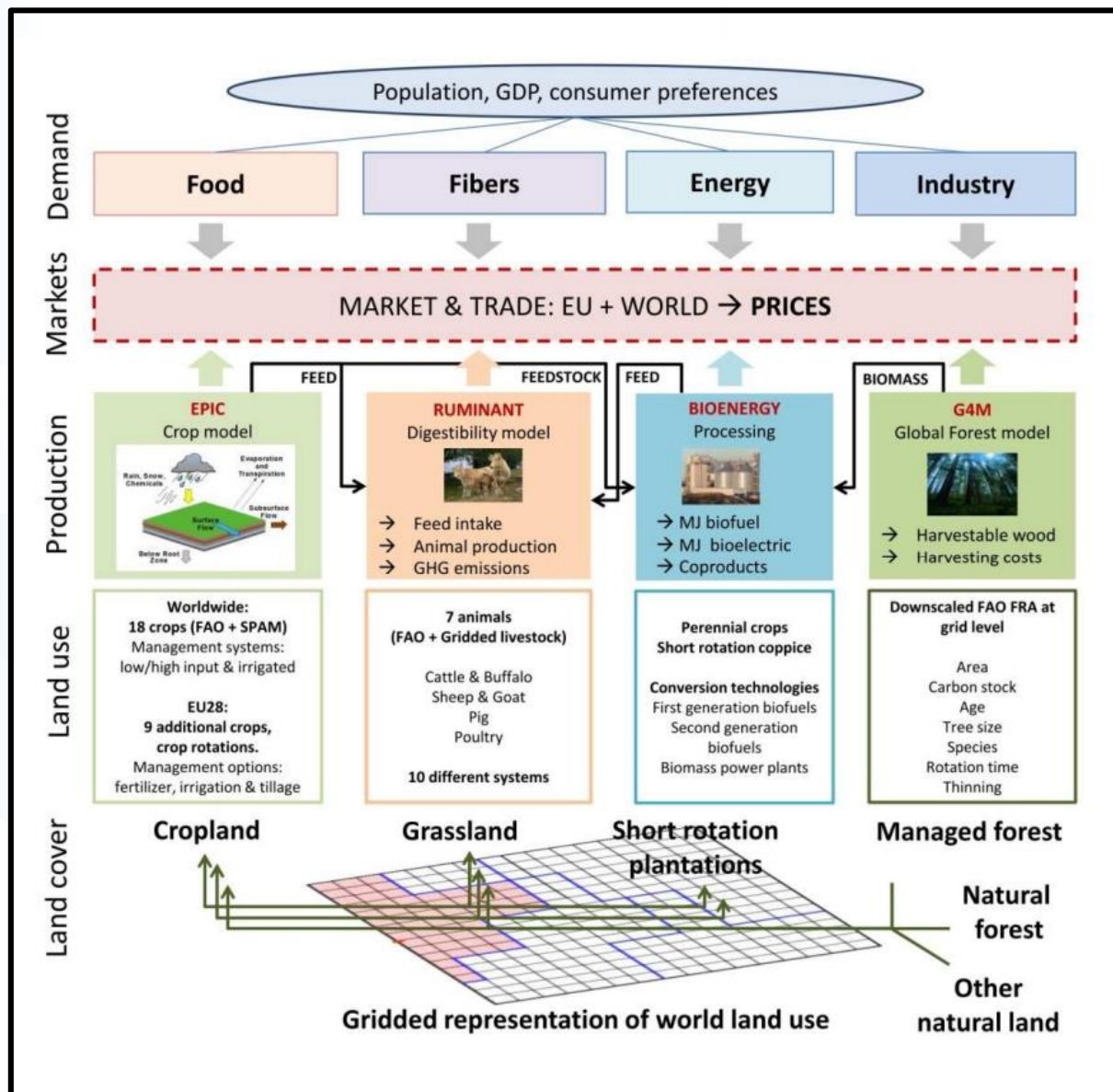


Time Resolution

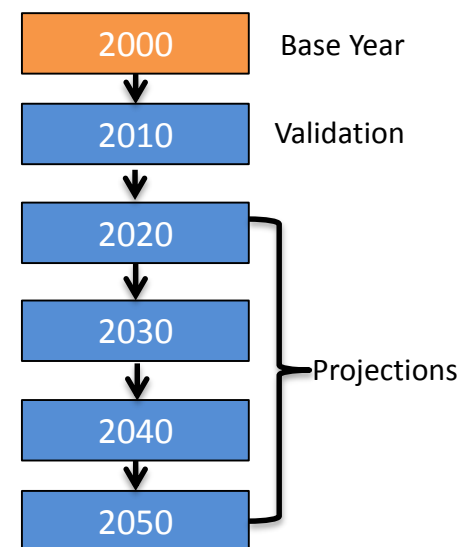


**GLOBIOM-Brazil
can be run up to
2100**

GLOBAL BIOSphere Management Model

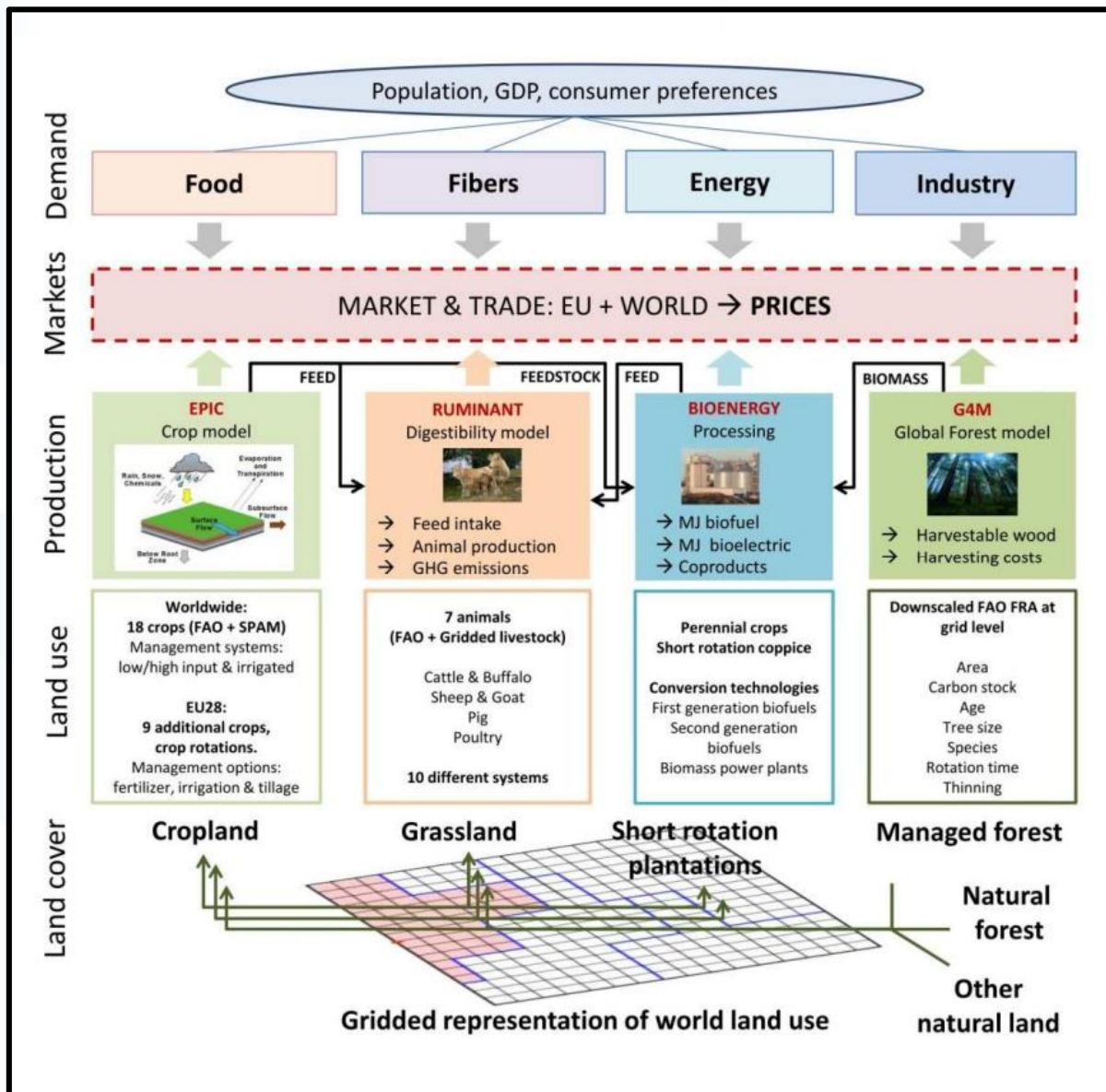


Time Resolution

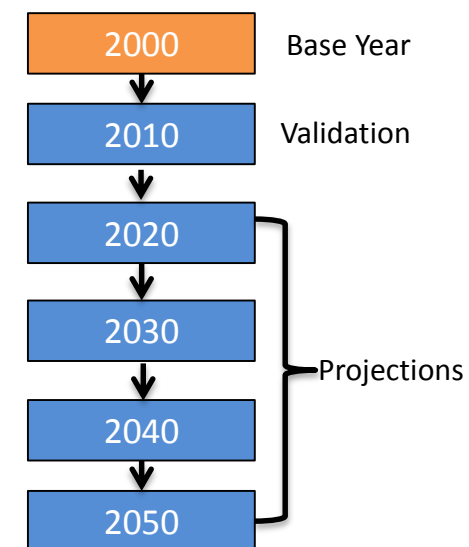


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global – bottom-up – partial – equilibrium

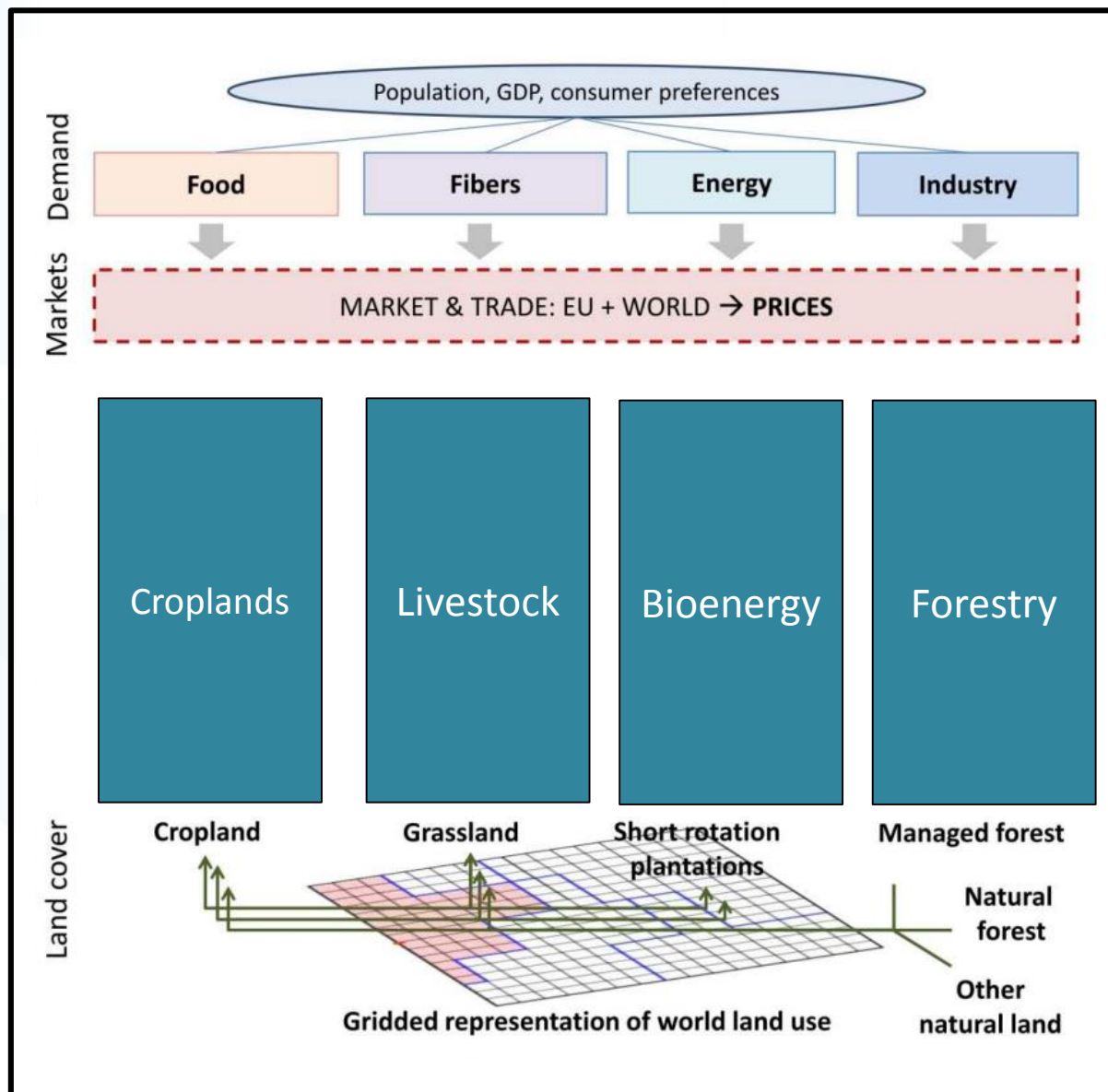


Time Resolution

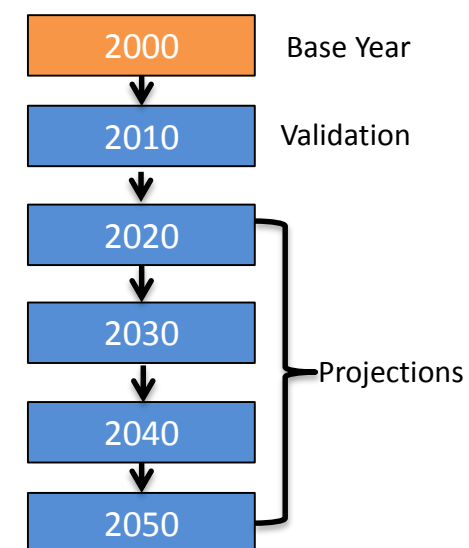


GLOBIOM-Brazil
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global – bottom-up – **partial** – equilibrium

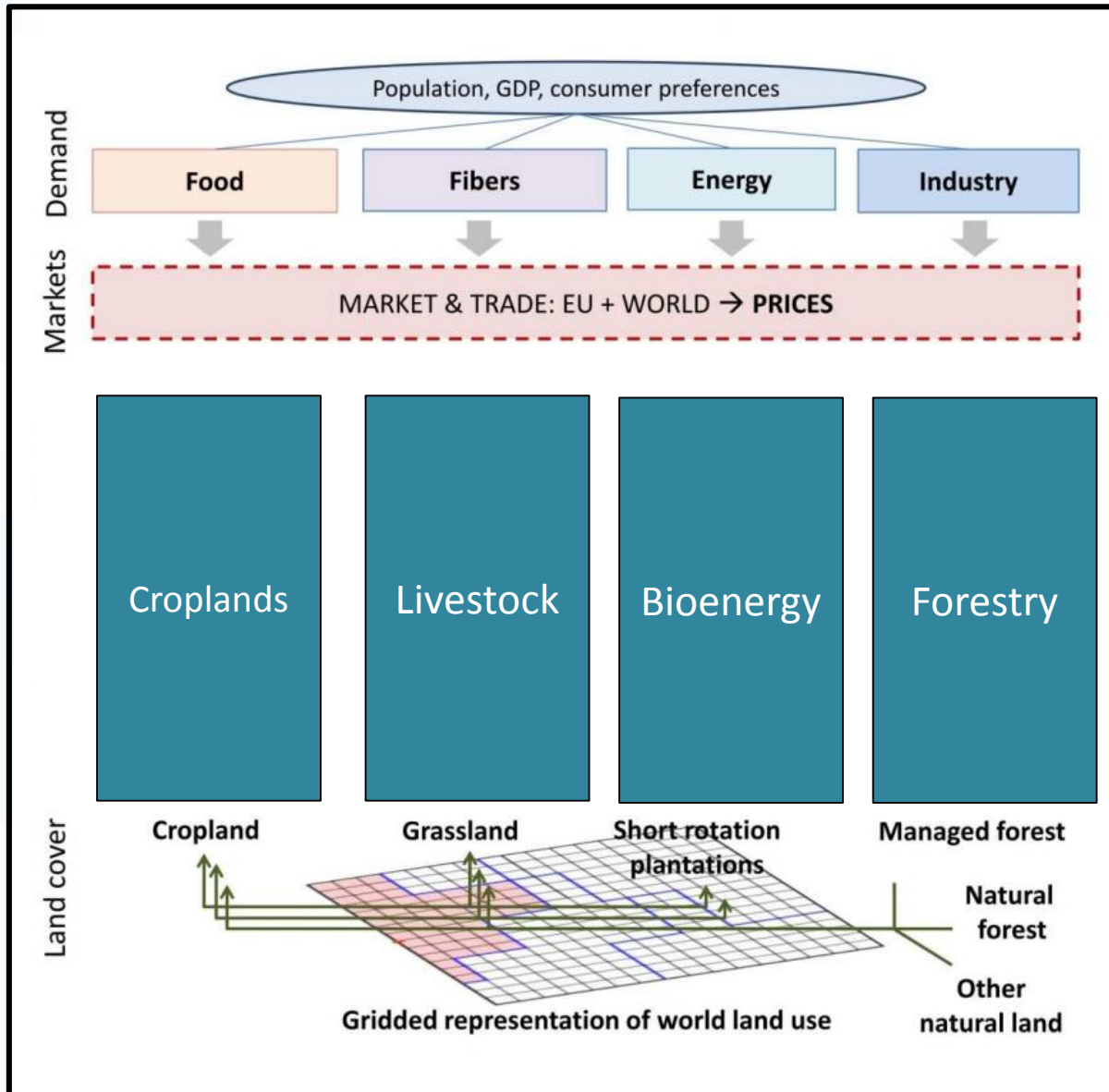


Time Resolution

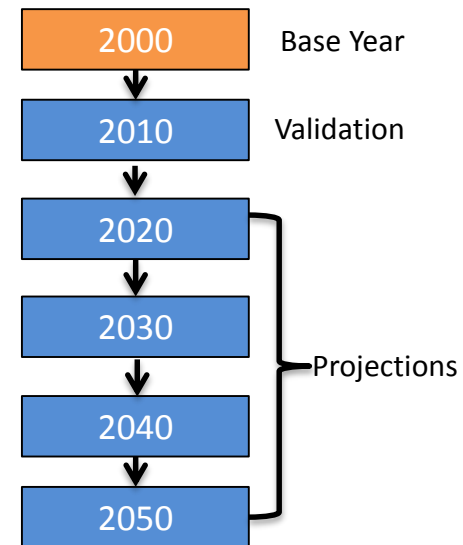


**GLOBIOM-Brazil
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global – bottom-up – partial – equilibrium

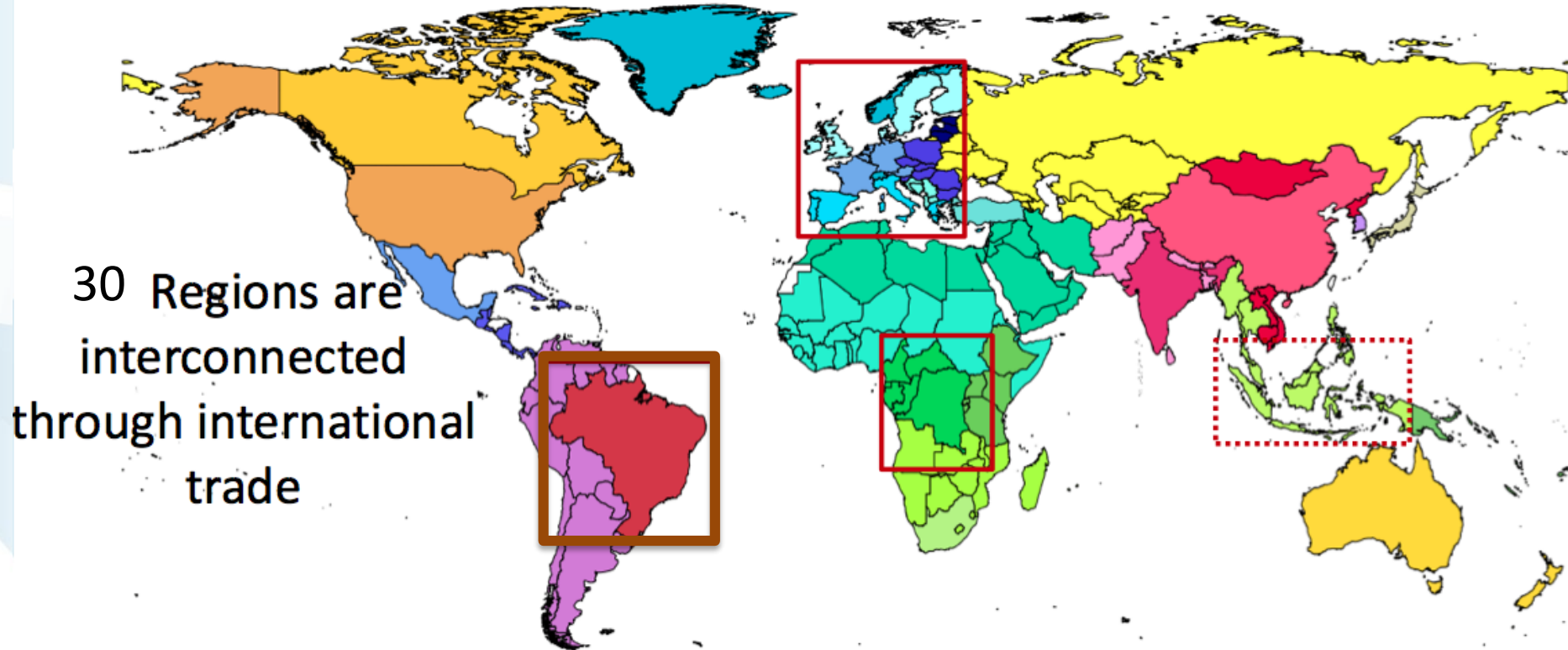


Time Resolution



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GLOBIOM-Brazil: regional version of GLOBIOM

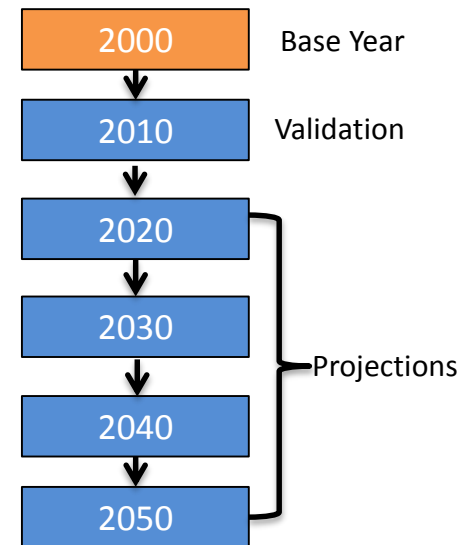


Regional zooming allows detailed spatial representation of land (50x50km) and introduction of regional policies

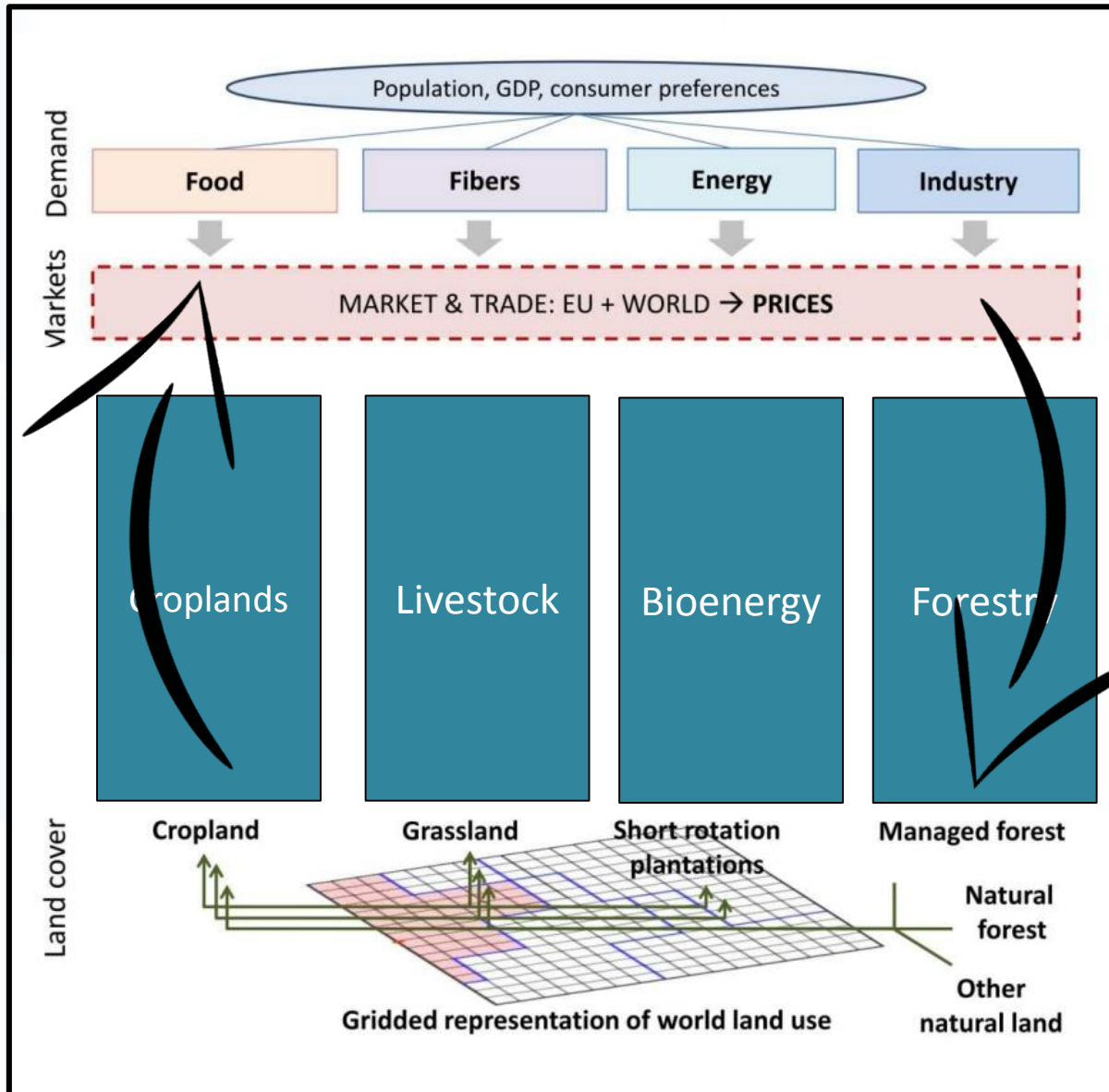
global – **bottom-up** – partial – equilibrium

recursive dynamic

Time Resolution



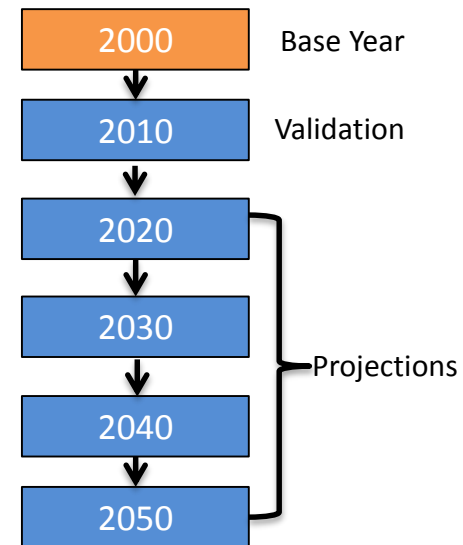
**GLOBIOM-Brazil
can be run up to
2100**



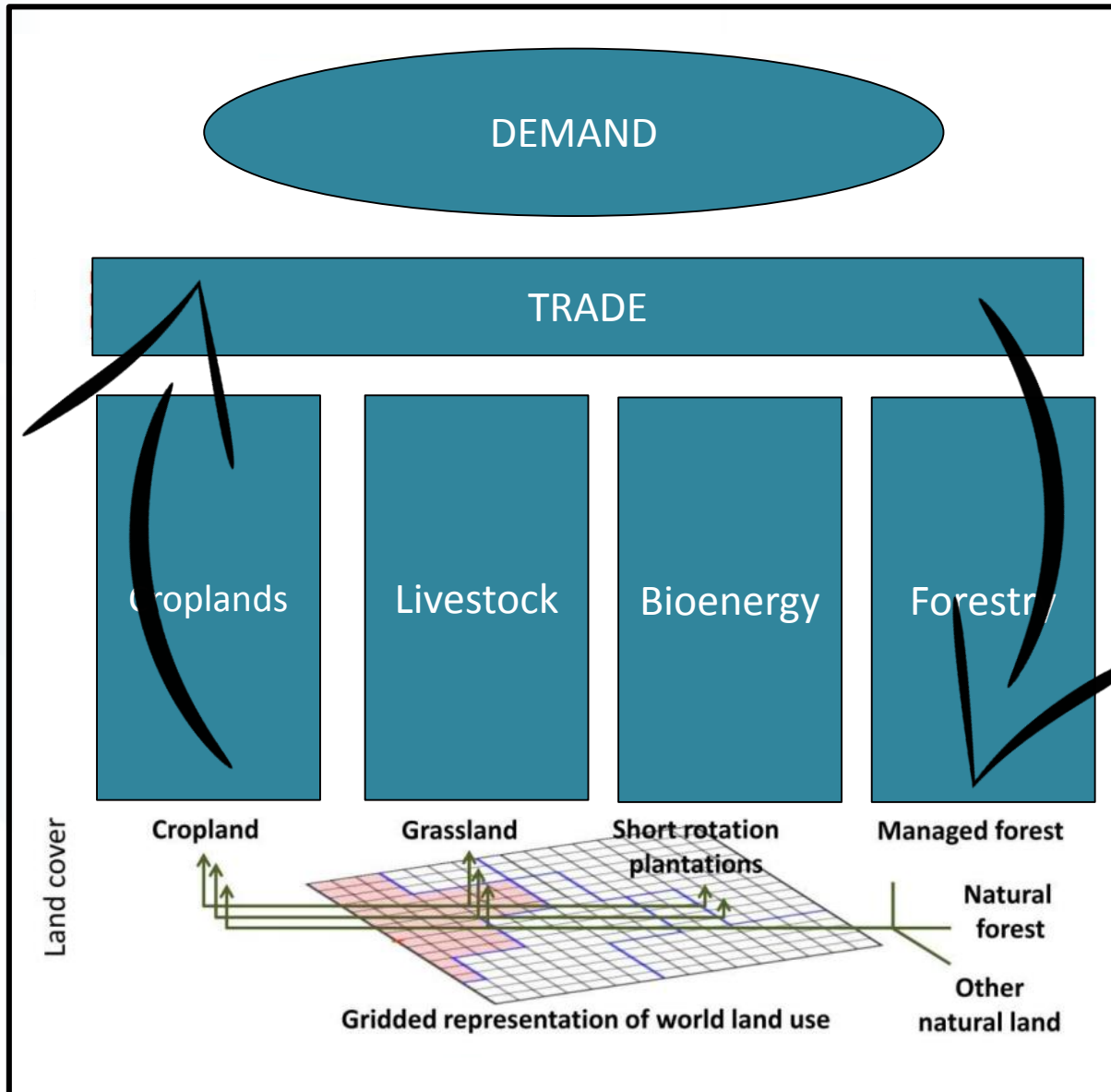
global – **bottom-up** – partial – equilibrium

recursive dynamic

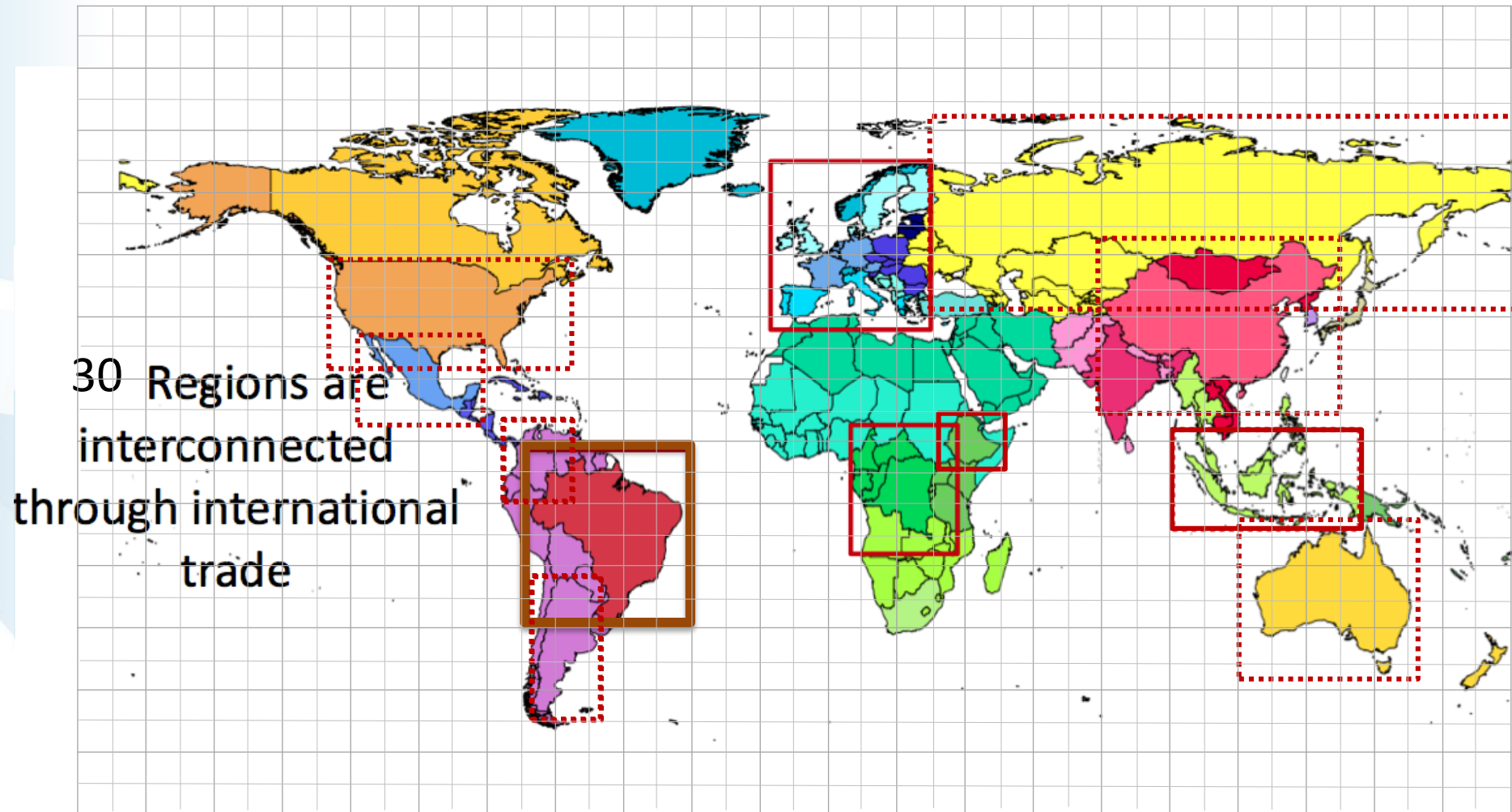
Time Resolution



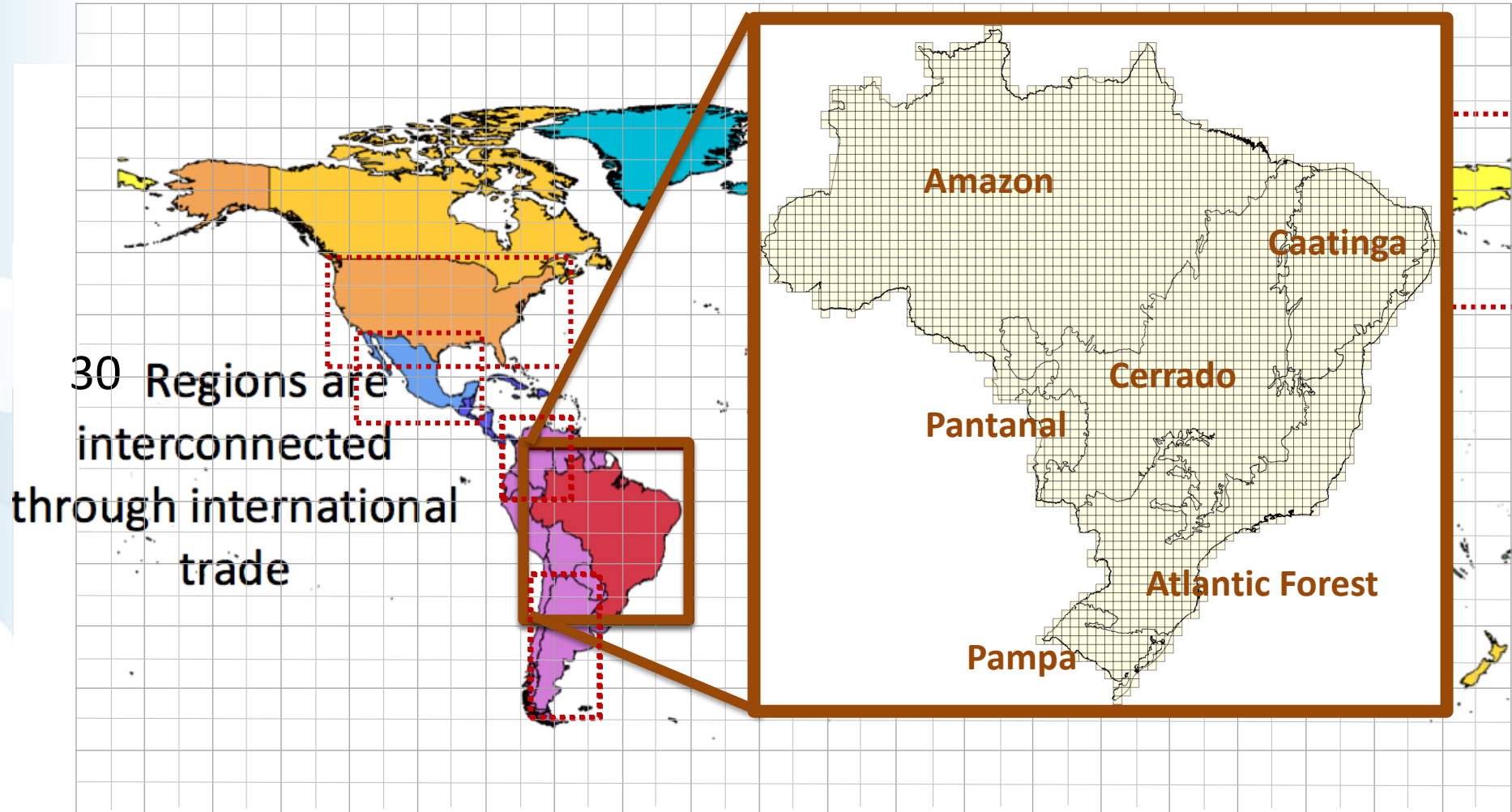
GLOBIOM-Brazil
can be run up to
2100



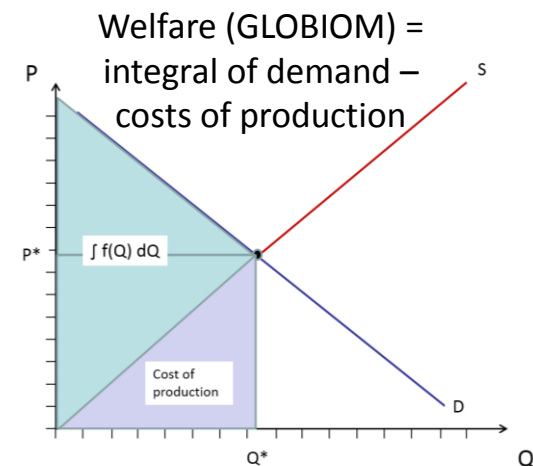
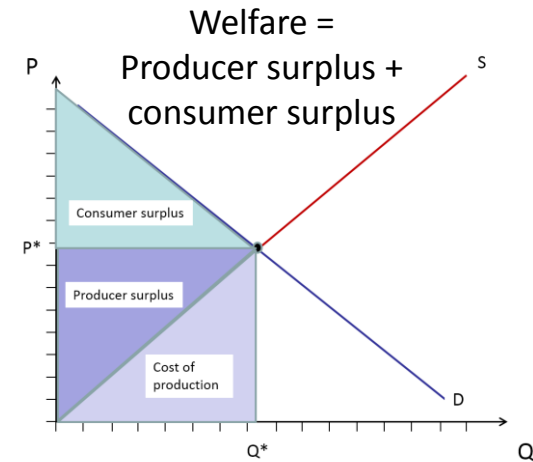
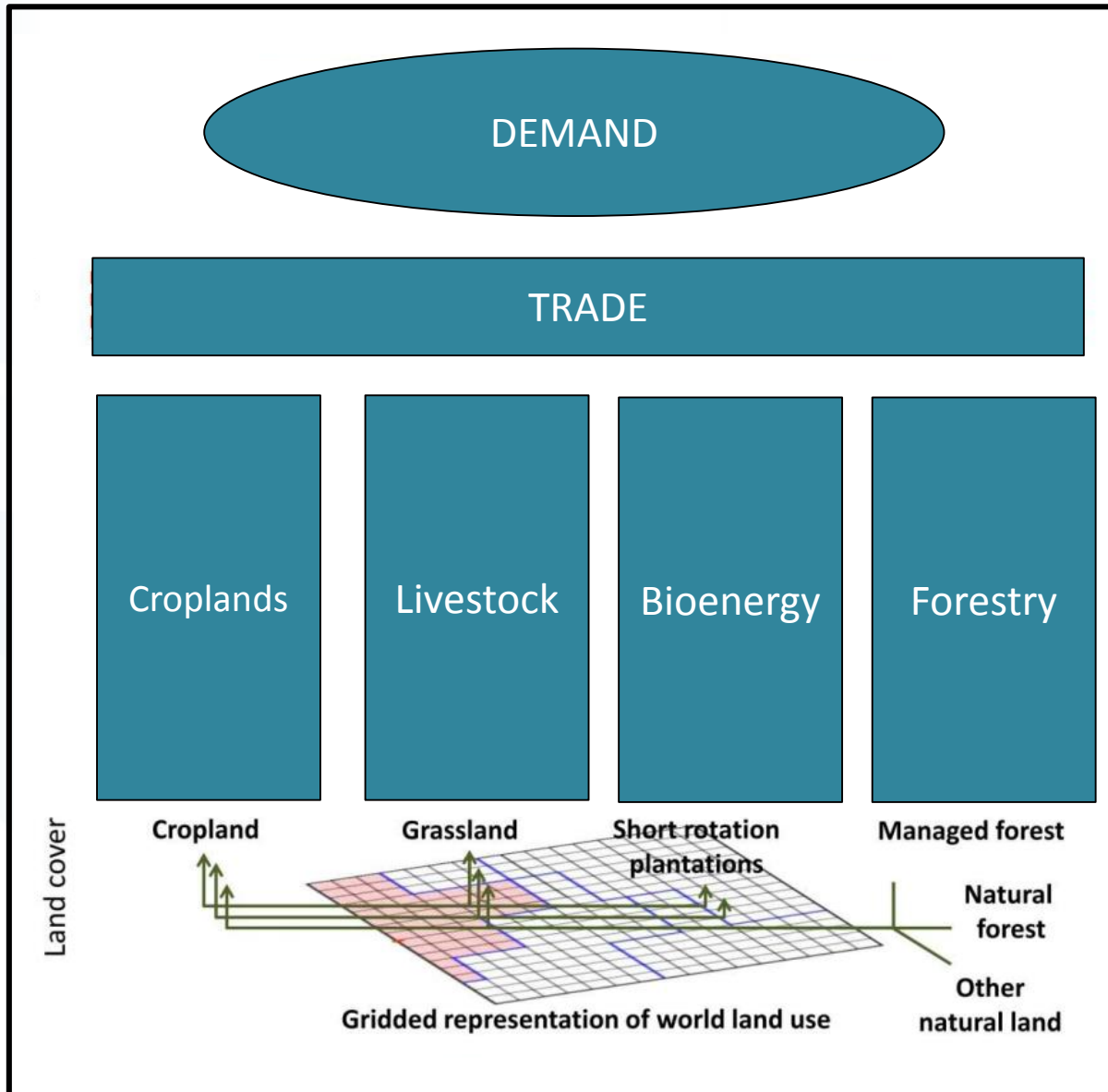
Default resolution 250 km X 250 km



GLOBIOM-Brazil: 50 km x 50 km in Brazil



global – bottom-up – partial – **equilibrium**



global – bottom-up – partial – **equilibrium**

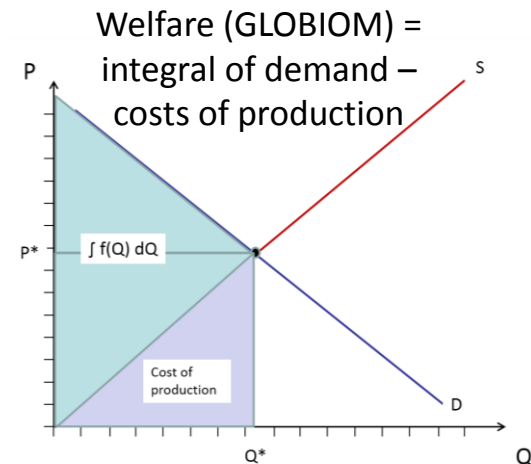
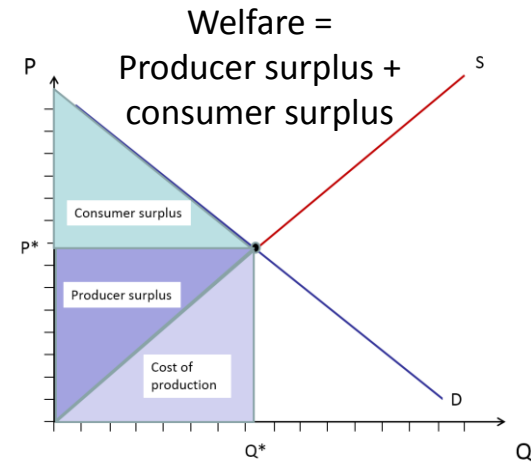
DEMAND

$$\begin{aligned}
 \text{Max } WELF_t = & + \sum_{r,y} \left[\int \phi_{r,t,y}^{demd} (D_{r,t,y}) d(\cdot) \right] \\
 & - \sum_{r,l,\tilde{l}} \left[\int \phi_{r,l,\tilde{l},t}^{lucc} \left(\sum_{c,o,p,q} Q_{r,t,c,o,p,q,l,\tilde{l}} \right) d(\cdot) \right] \\
 & - \sum_{r,c,o,p,q,l,s,m} \left(\tau_{c,o,p,q,l,s,m}^{land} A_{r,t,c,o,p,q,l,s,m} \right) \\
 & - \sum_r \left(\tau_r^{live} B_{r,t} \right) - \sum_{r,m} \left(\tau_{r,m}^{proc} P_{r,t,m} \right) \\
 & - \sum_{r,\tilde{r},y} \left[\int \phi_{r,\tilde{r},t,y}^{trad} (T_{r,\tilde{r},t,y}) d(\cdot) \right]
 \end{aligned}$$

$$D_{r,t,y} \geq d_{r,t,y}^{targ}$$

$$\begin{aligned}
 D_{r,t,y} \leq & \sum_{c,o,p,q,l,s,m} \left(\alpha_{t,c,o,p,q,l,s,m,y}^{land} A_{r,t,c,o,p,q,l,s,m} \right) + \alpha_{r,t,y}^{live} B_{r,t} \\
 & + \sum_m \left(\alpha_{r,m,y}^{proc} P_{r,t,m} \right) + \sum_{\tilde{r}} T_{r,\tilde{r},t,y} - \sum_{\tilde{r}} T_{r,\tilde{r},t,y}
 \end{aligned}$$

Havlik et al. (2011)



global – bottom-up – partial – **equilibrium**



Max $WELF_t = +$

demand

–

land-use change costs

–

land management costs

–

livestock production costs

–

processing costs

–

trade cost function

demand

\geq

demand target

demand

\leq

crop or wood quantity

+

live prod quantity

+

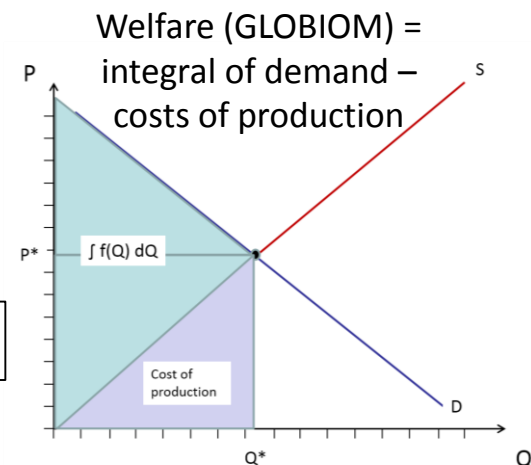
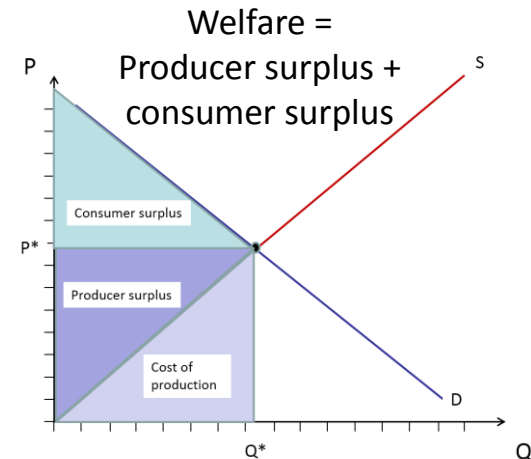
processed quantity

+

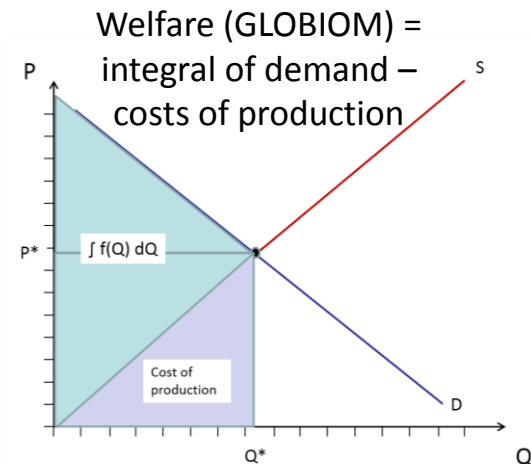
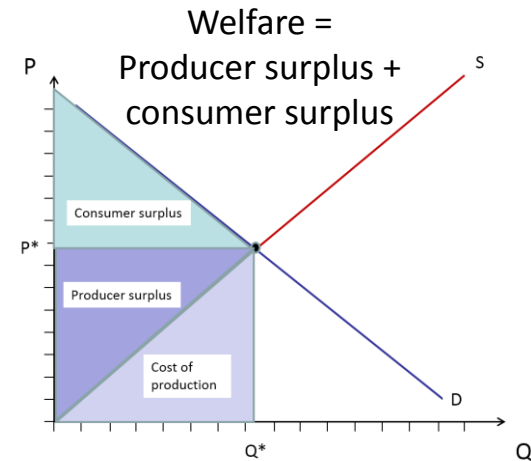
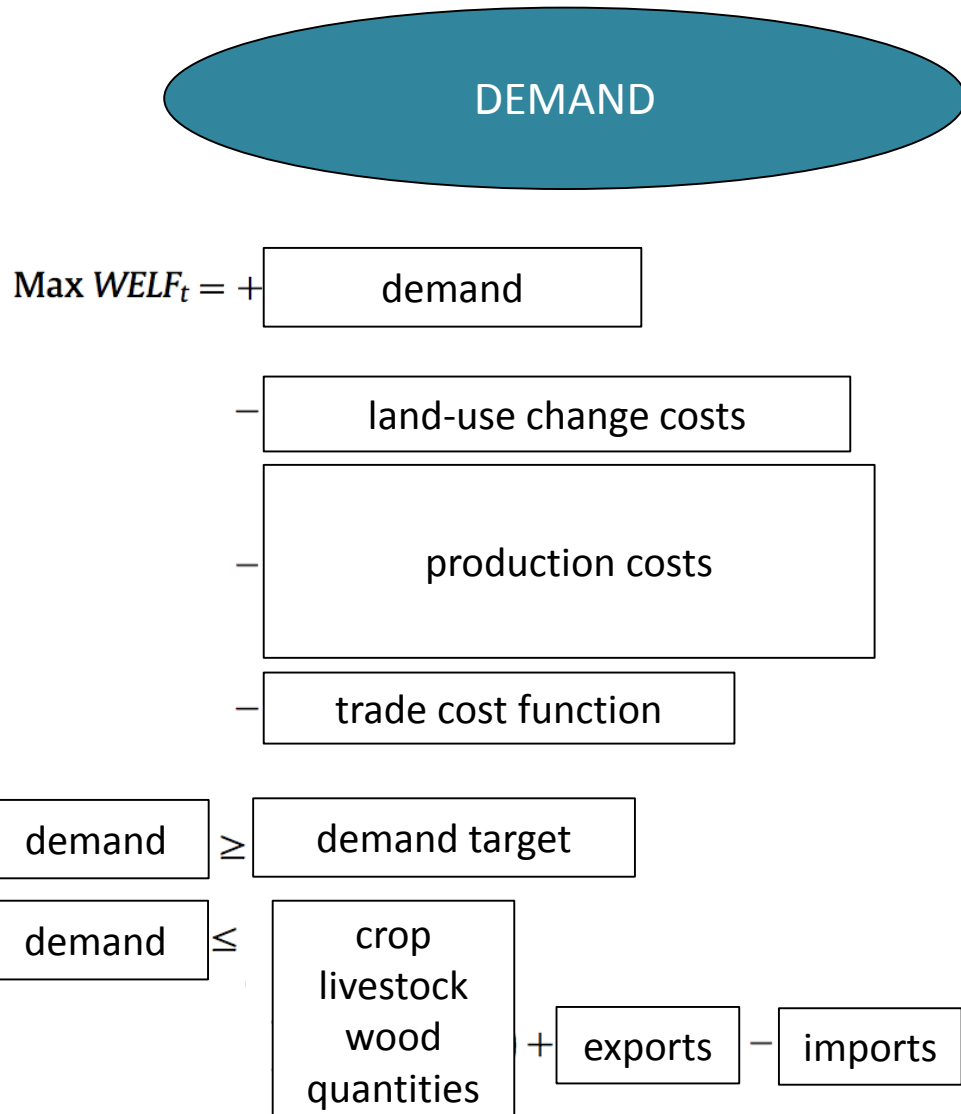
exports

–

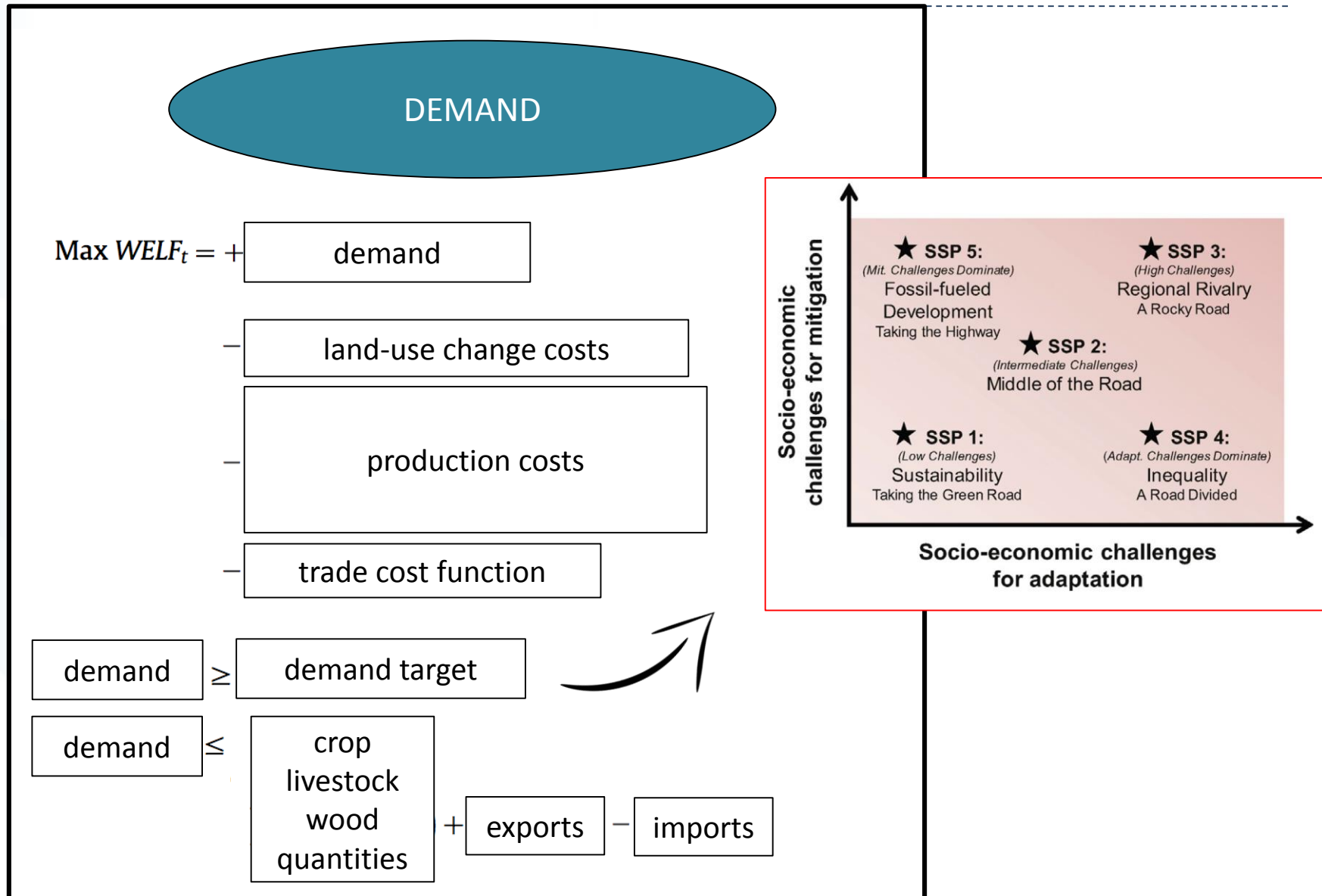
imports



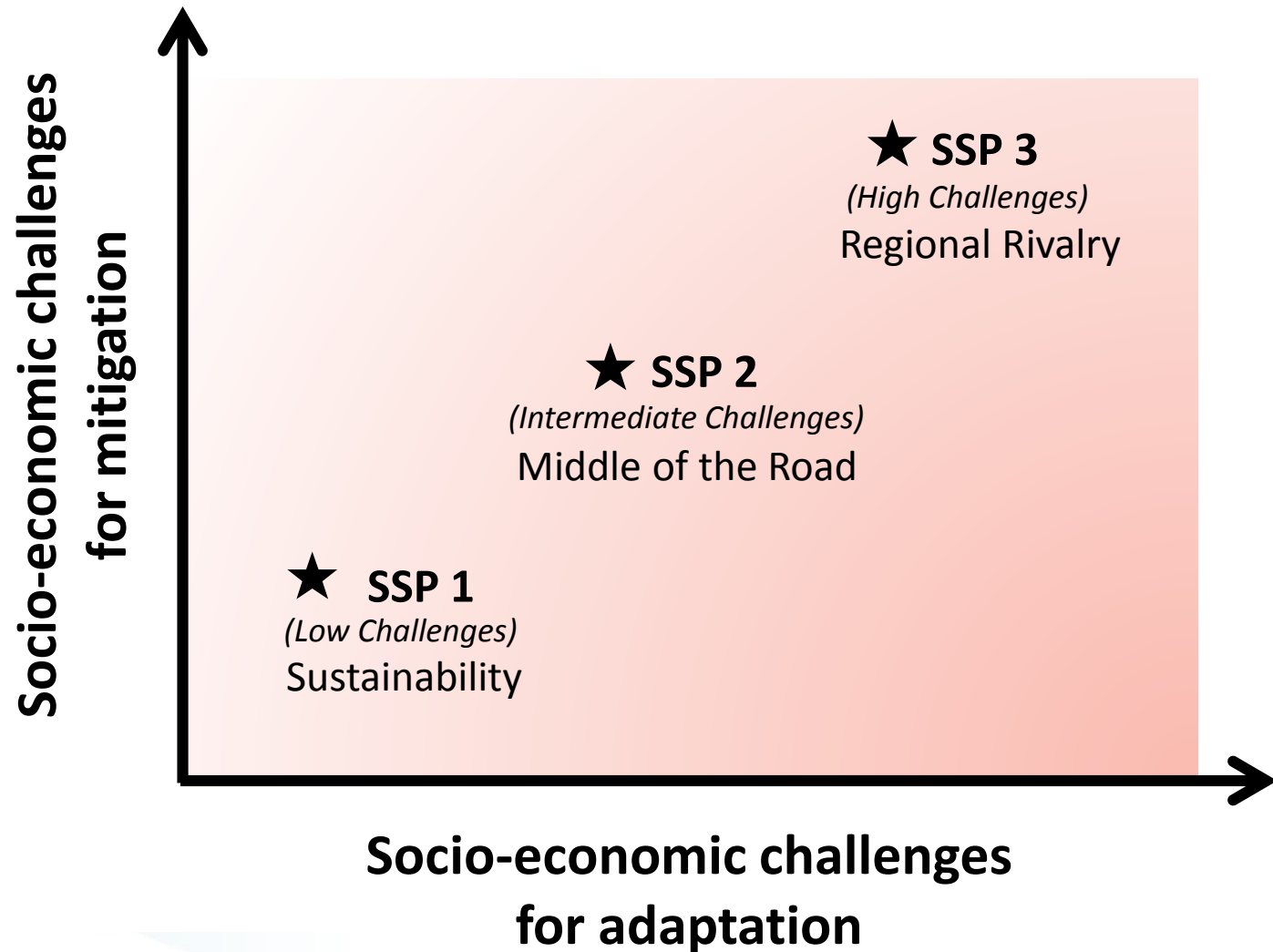
global – bottom-up – partial – **equilibrium**



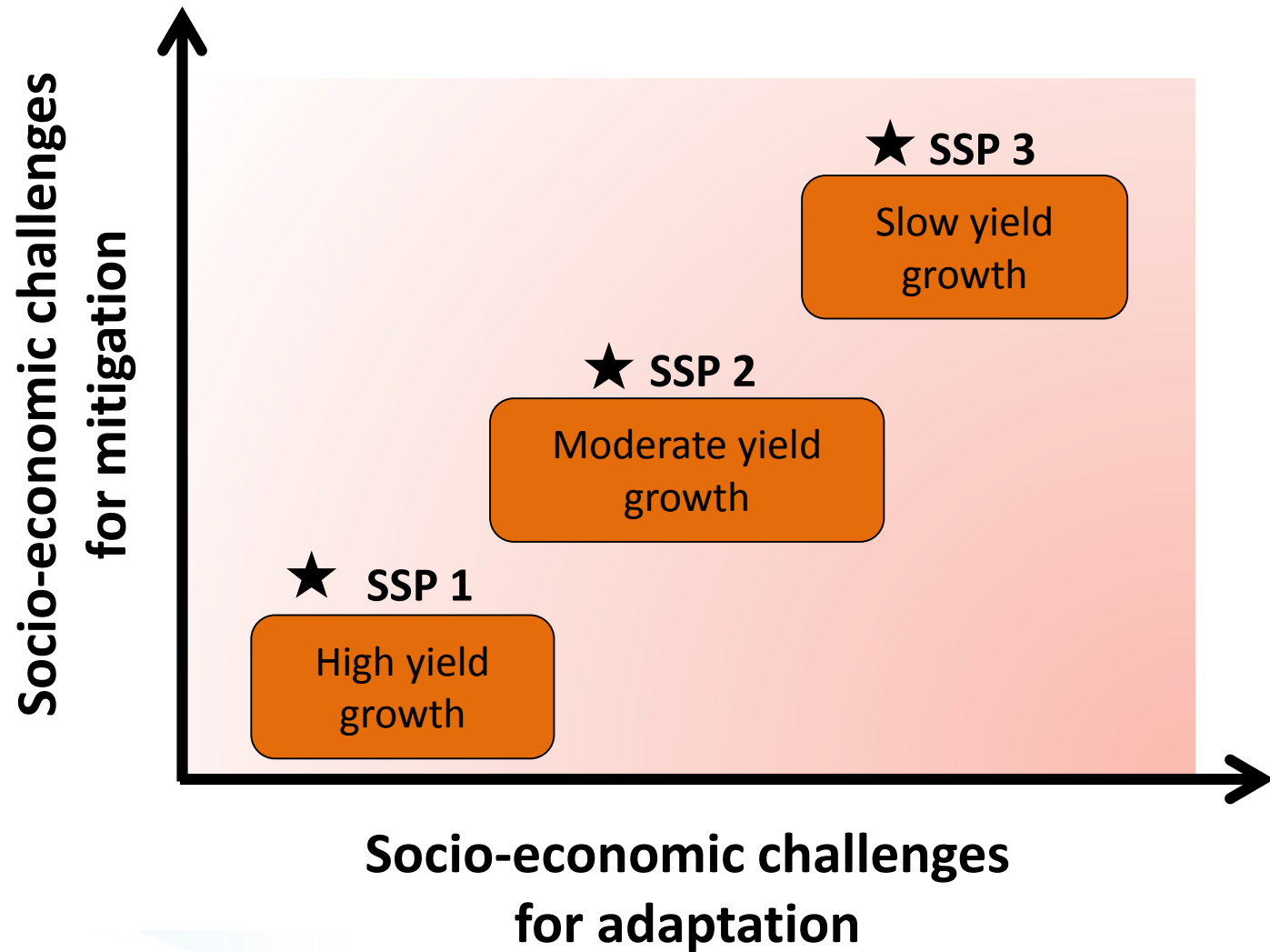
global – bottom-up – partial – **equilibrium**



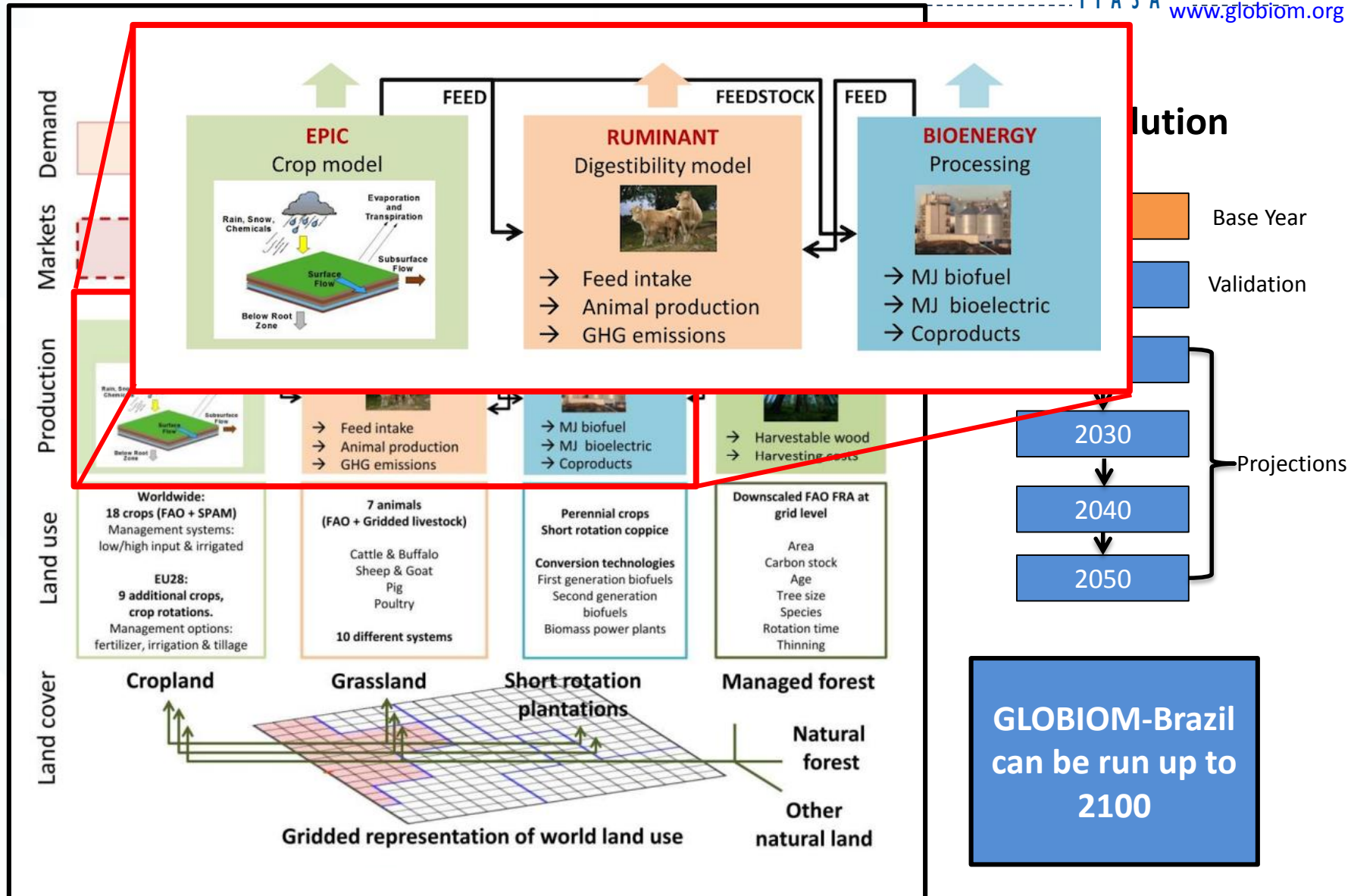
Shared Socioeconomic Pathways (SSP)



Crop yields

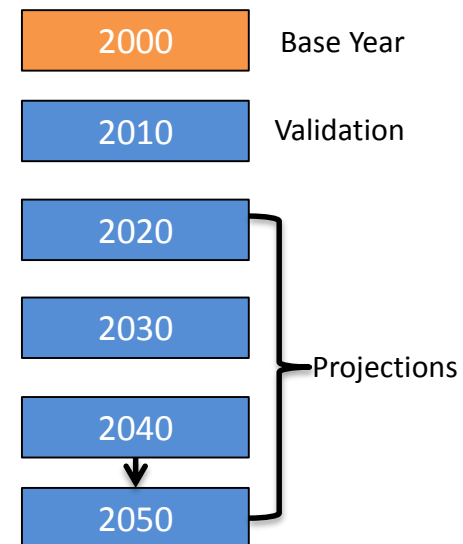


GLOBIOM Model

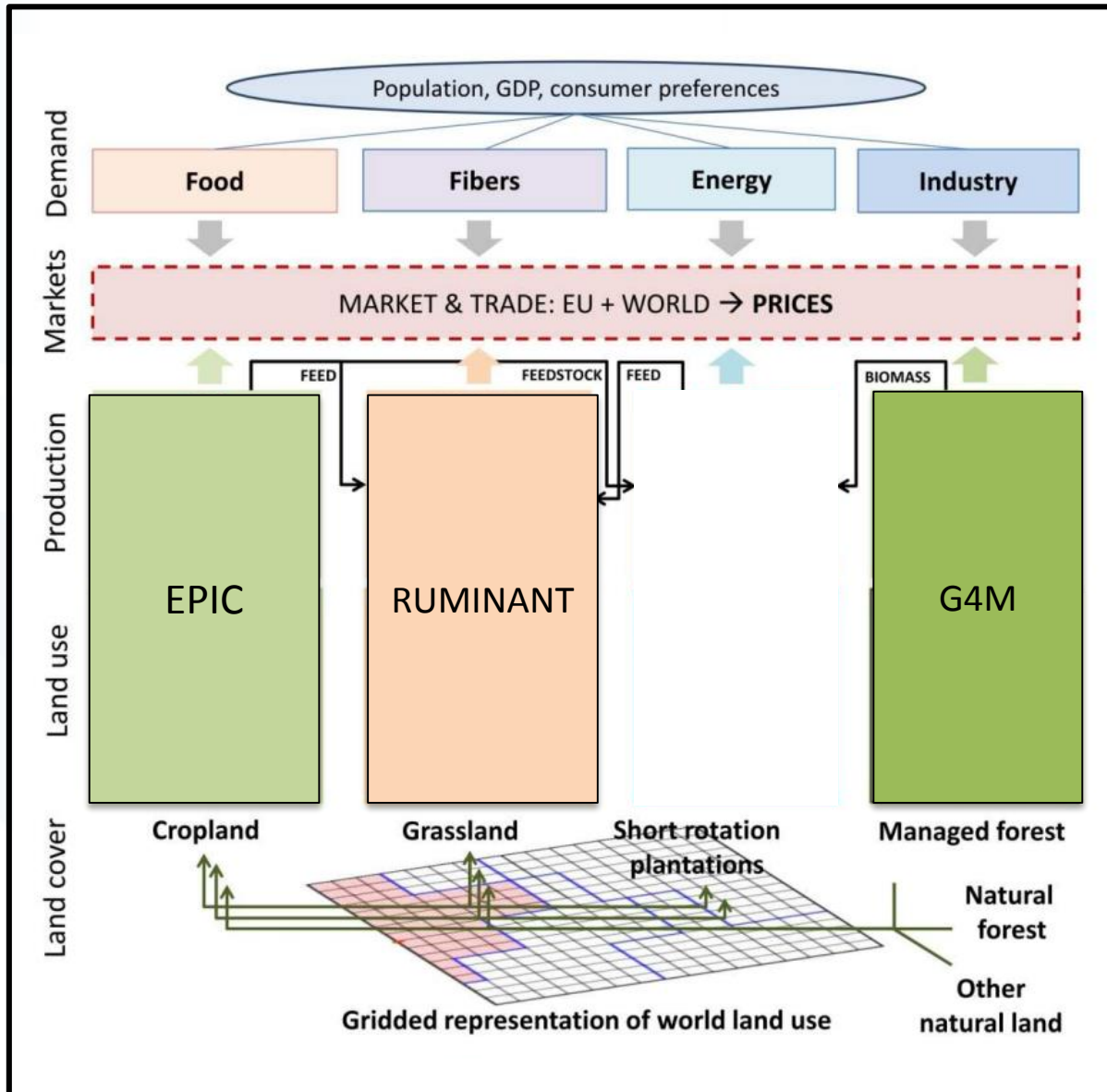


GLOBIOM Model

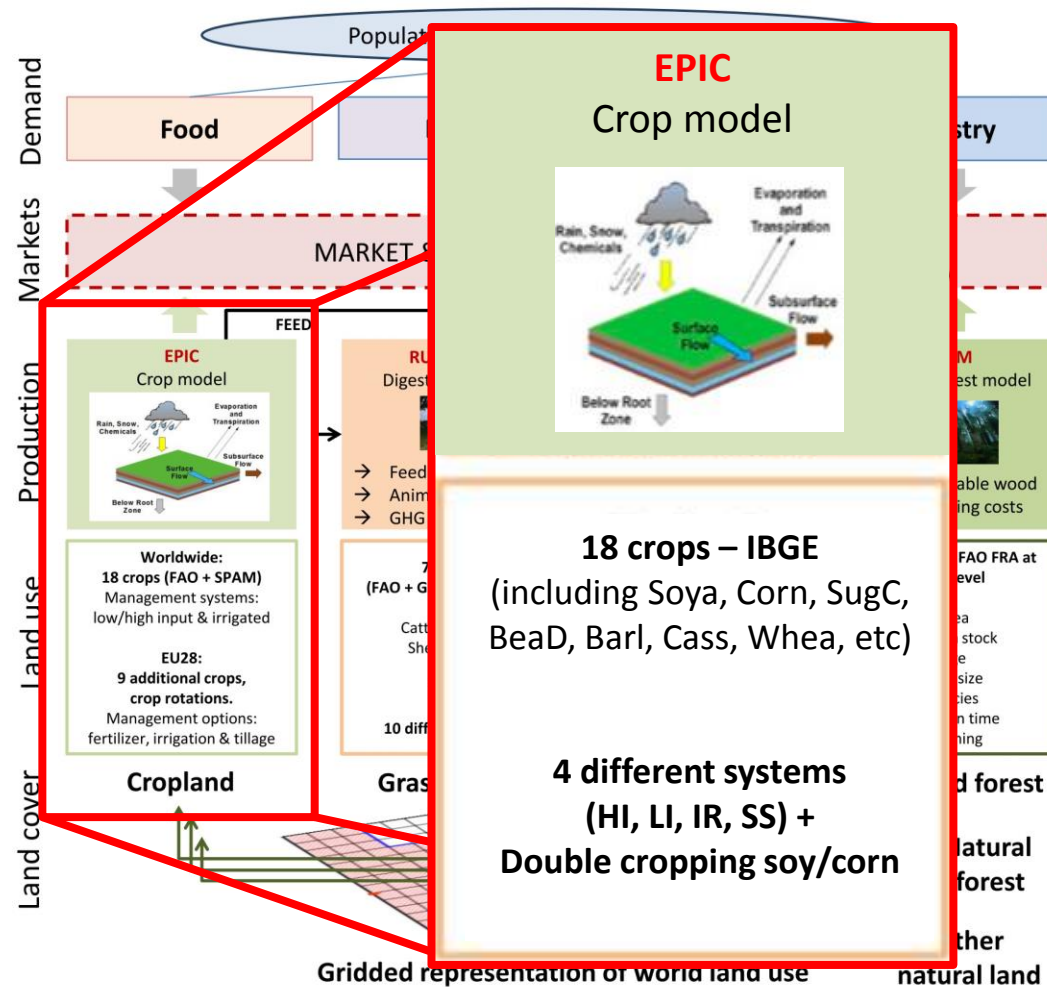
Time Resolution



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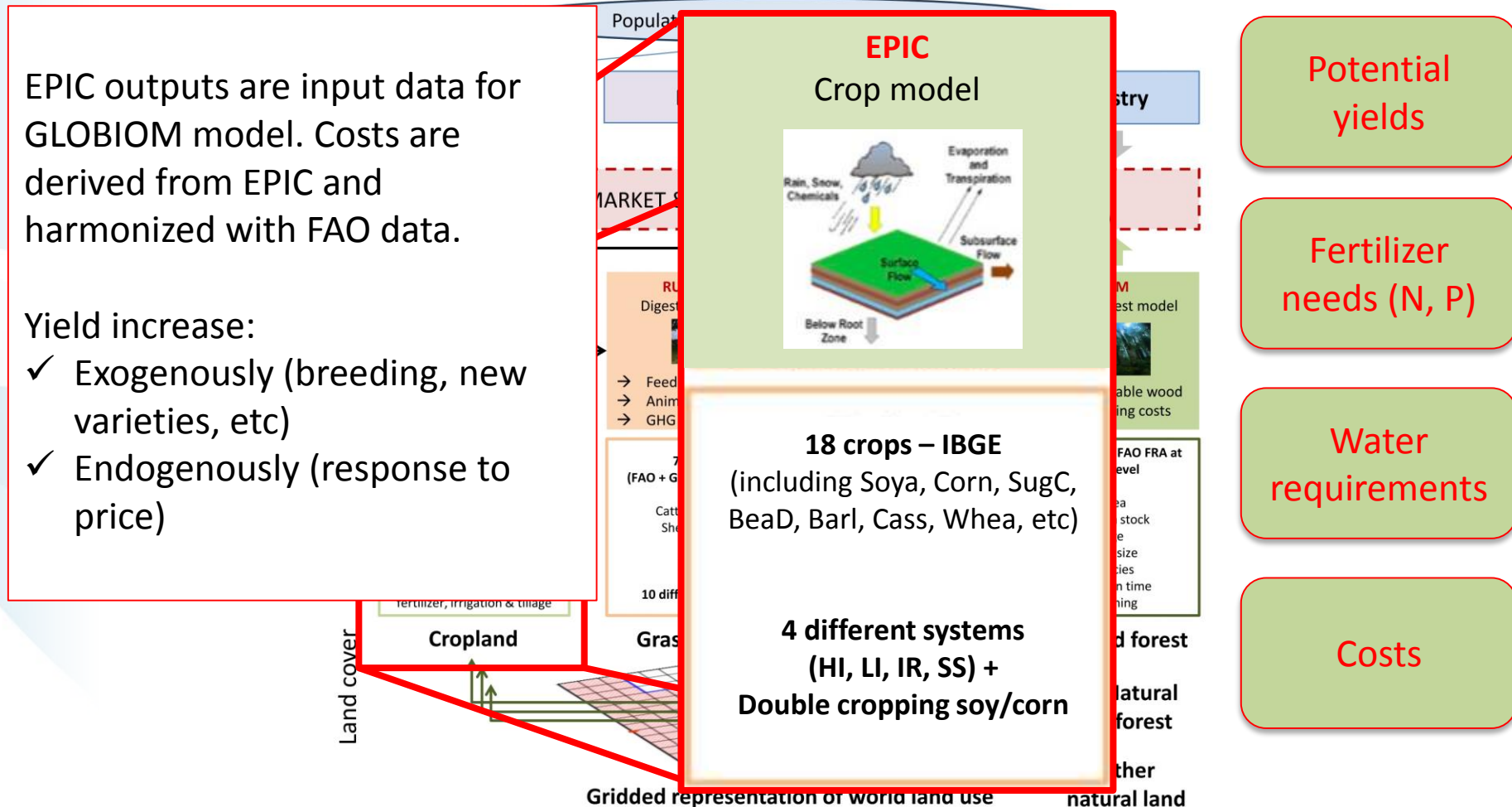


Cropland sector



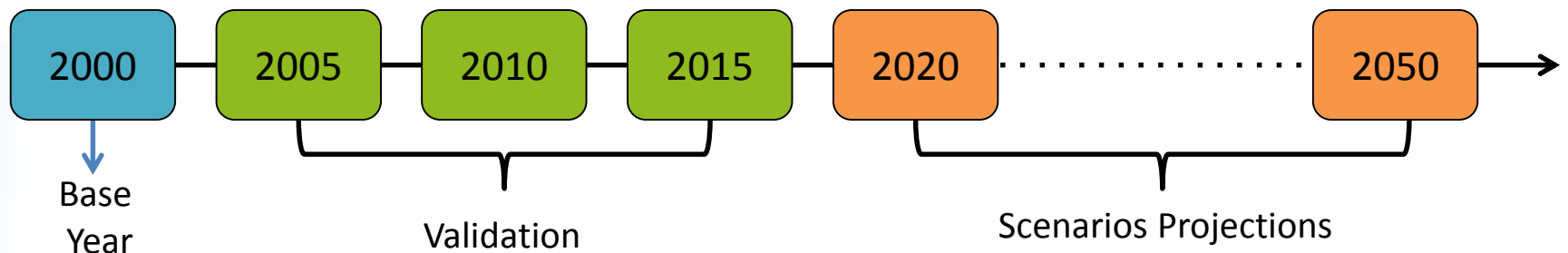
EPIC: Environmental Policy Integrated Climate Model

Cropland sector

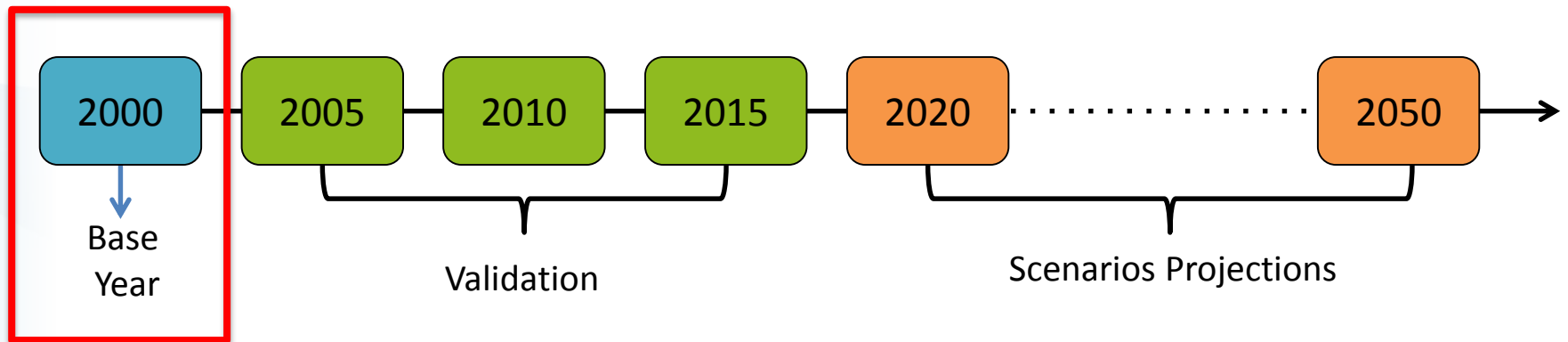


EPIC: Environmental Policy Integrated Climate Model

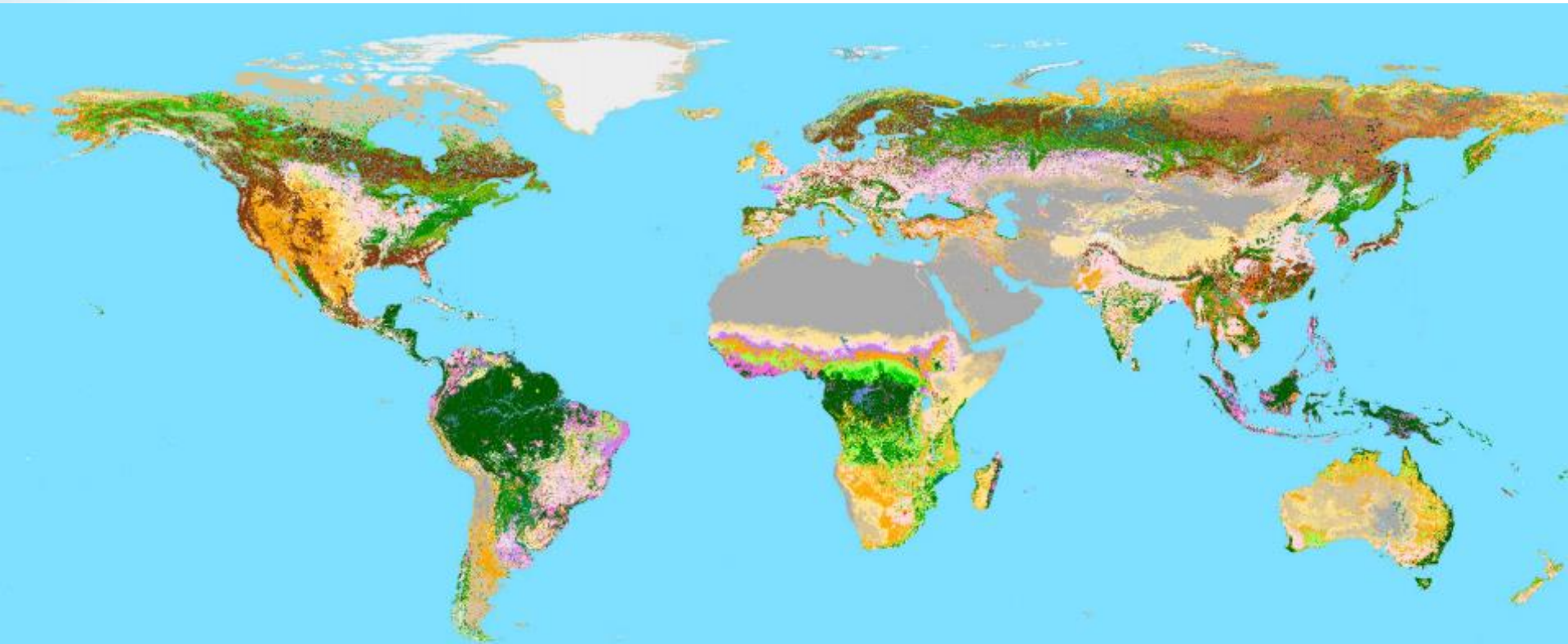
Model steps



Model steps



GLOBIOM default initial land cover map

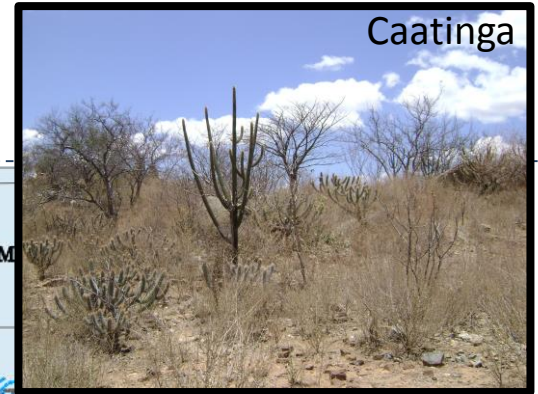


GLOBIOM model uses Global Land Cover (GLC) 2000 by JRC

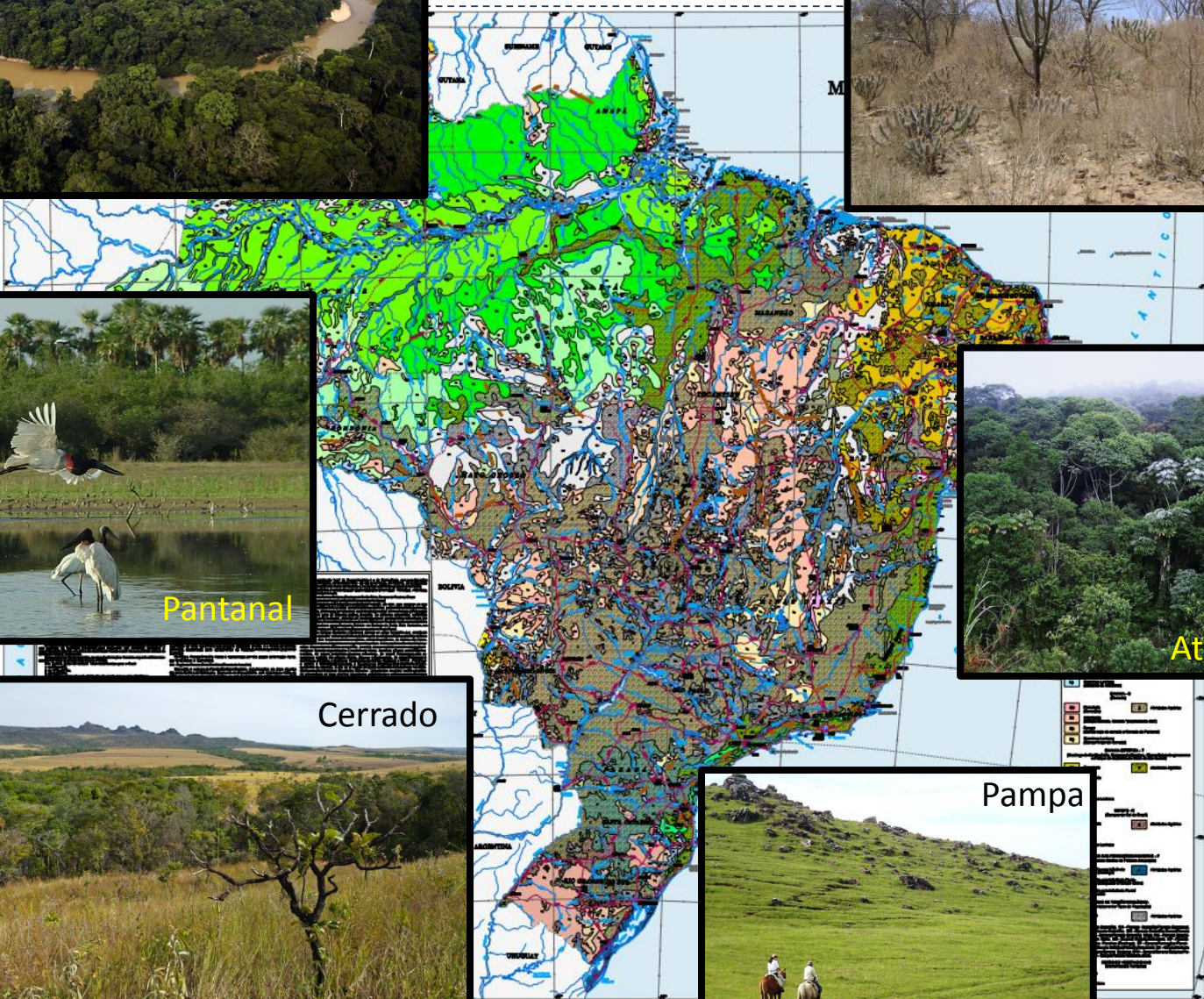
Mapa de Vegetação do Brasil, elaborado pelo IBGE (Instituto Brasileiro de Geografia e Estatística). O mapa mostra a distribuição das principais formações vegetais do Brasil, coloridas de acordo com o tipo de vegetação. O mapa inclui uma escala de 0 a 1000 km, uma legenda detalhada das formações vegetais e uma lista de siglas para as Unidades da Federação. O mapa também mostra os limites dos estados e municípios, bem como os nomes dos estados e municípios. O mapa é uma obra do IBGE, Instituto Brasileiro de Geografia e Estatística.



Amazon



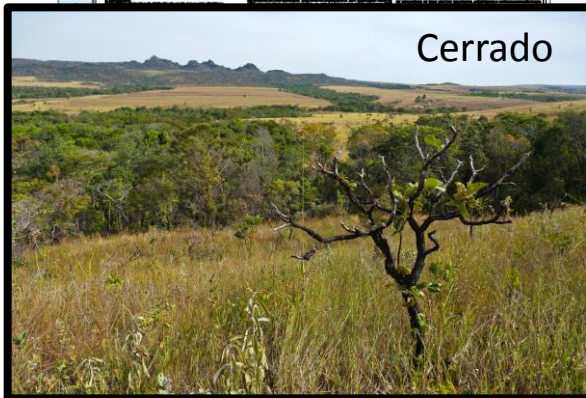
Caatinga



Pantanal



Atlantic Forest

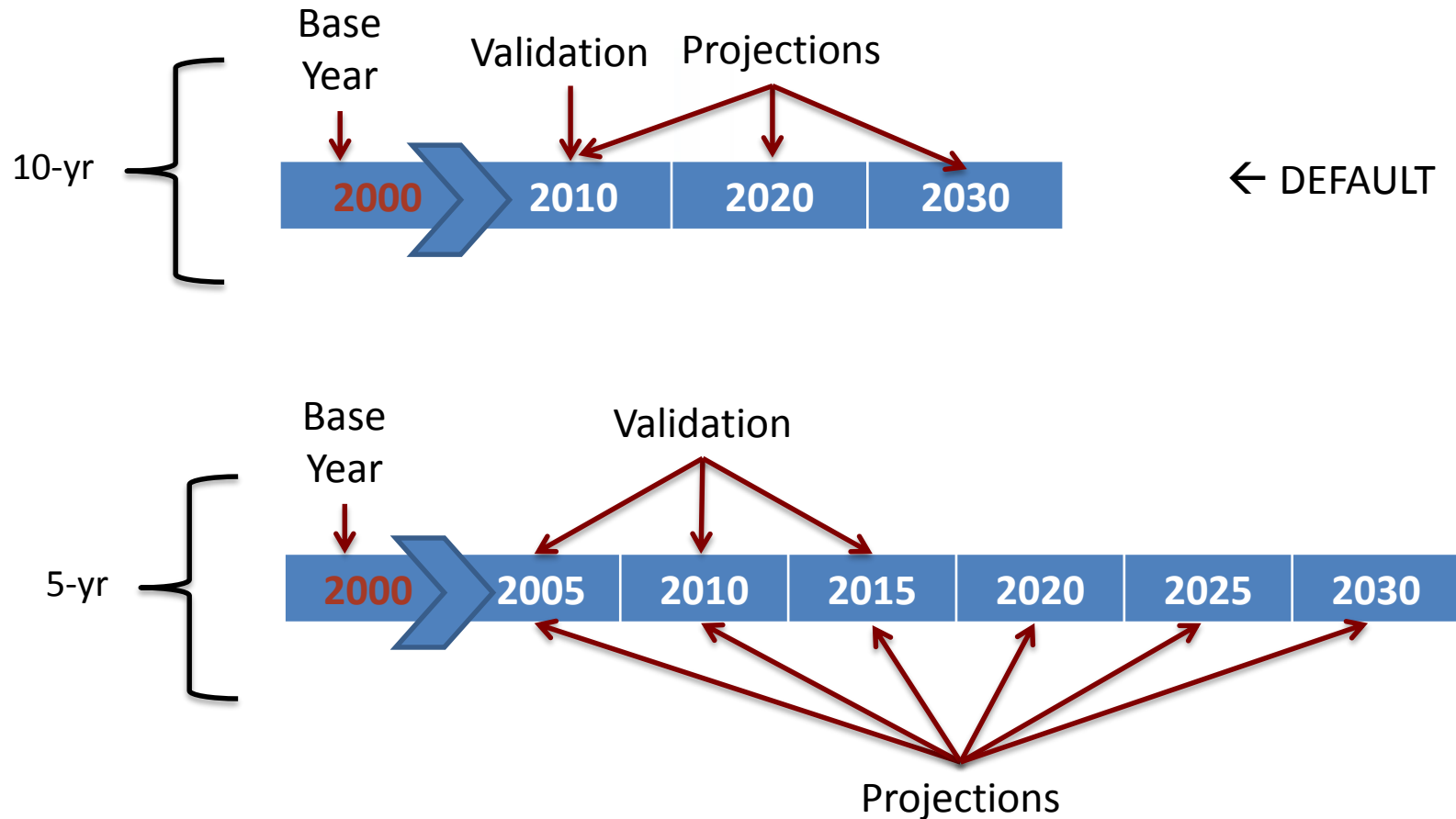


Cerrado



Pampa

Changing the time steps



Double cropping – New management system

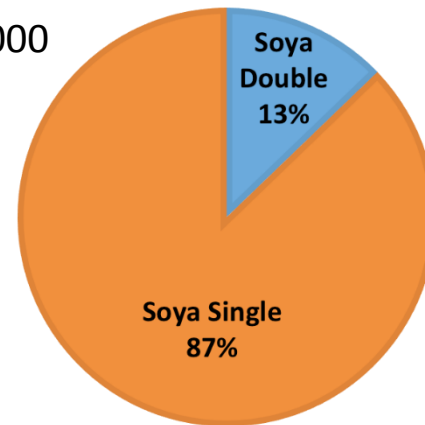
Double cropping soy-corn



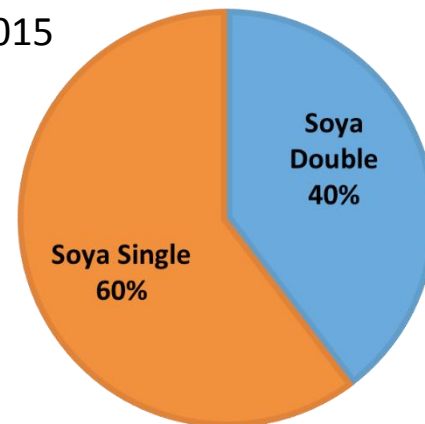
Two crops are grown in sequence within an agricultural year on the same piece of land

Double cropping area soy-corn in Brazil increased 400% between 2000 and 2015

2000

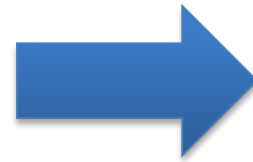
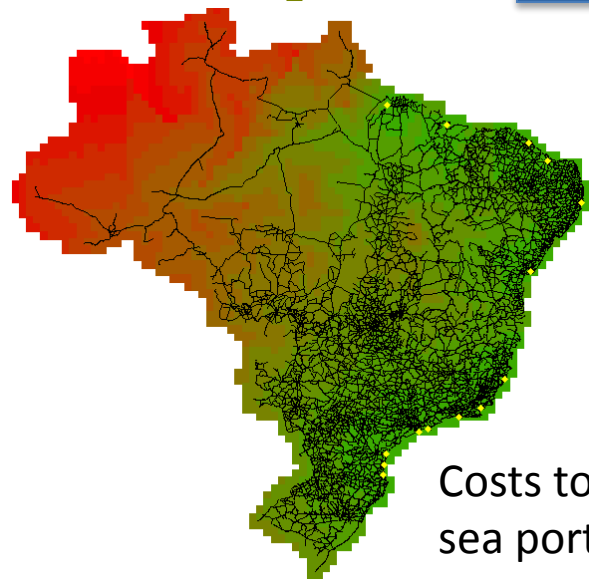
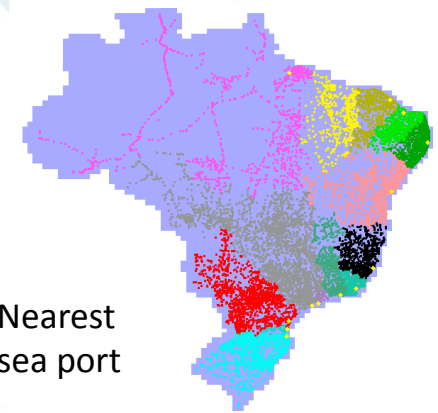
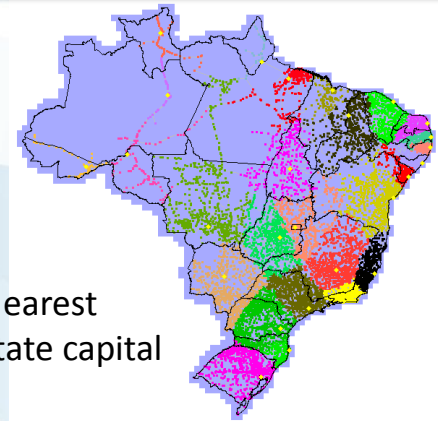
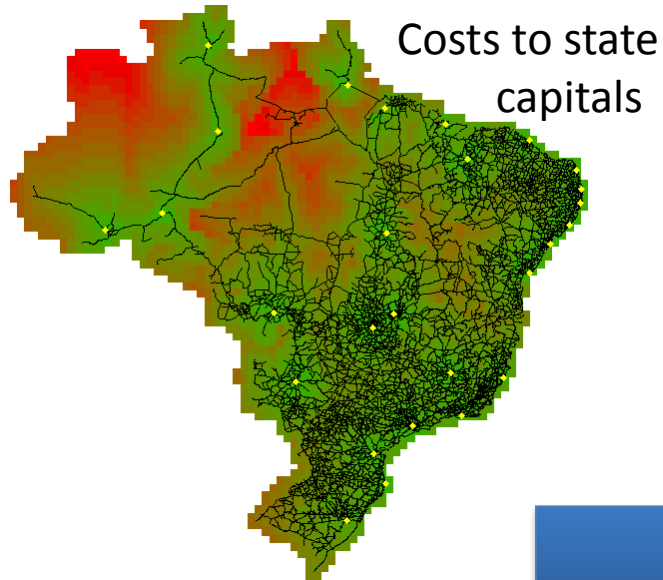
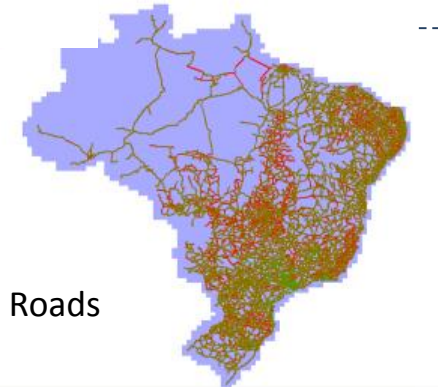


2015

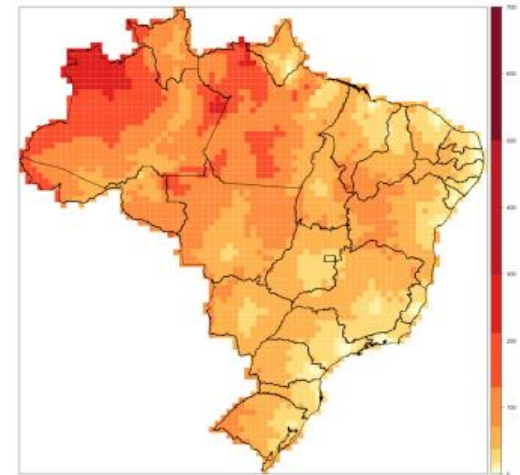
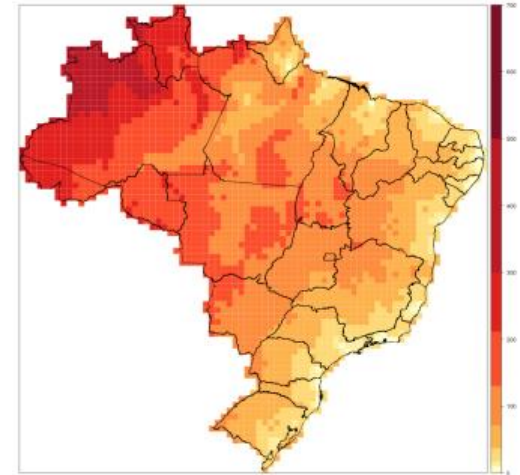


IBGE/PAM*

Internal Transportation Costs (per product and destination)

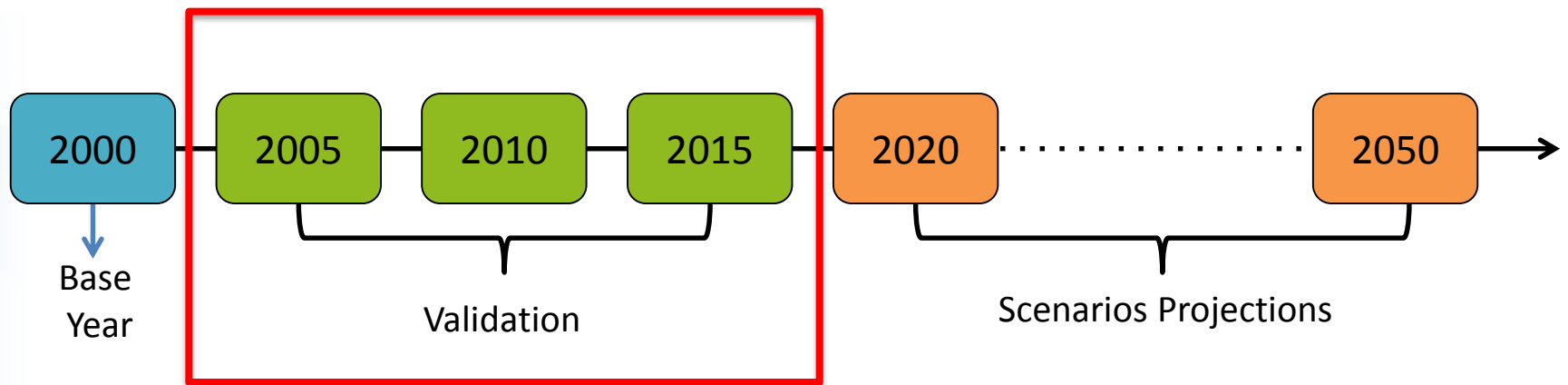


Pulp Biomass

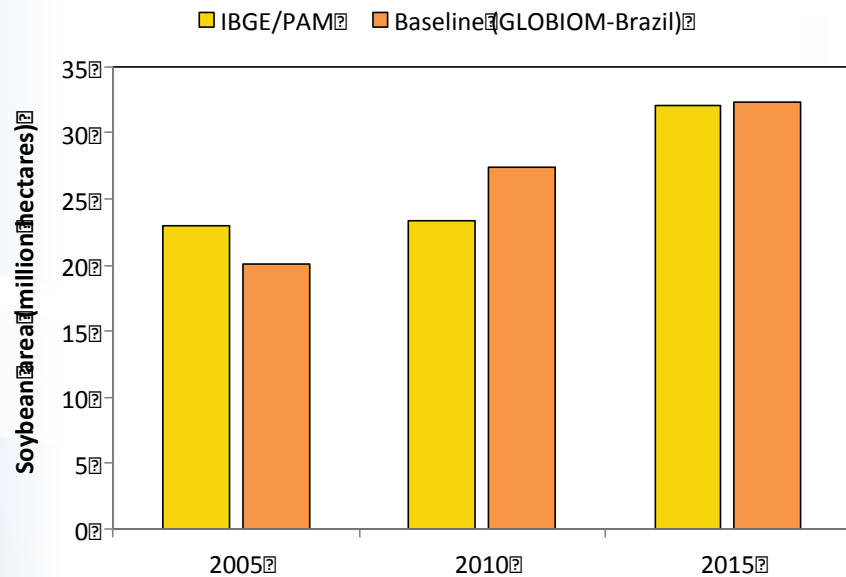


Bovine Meat

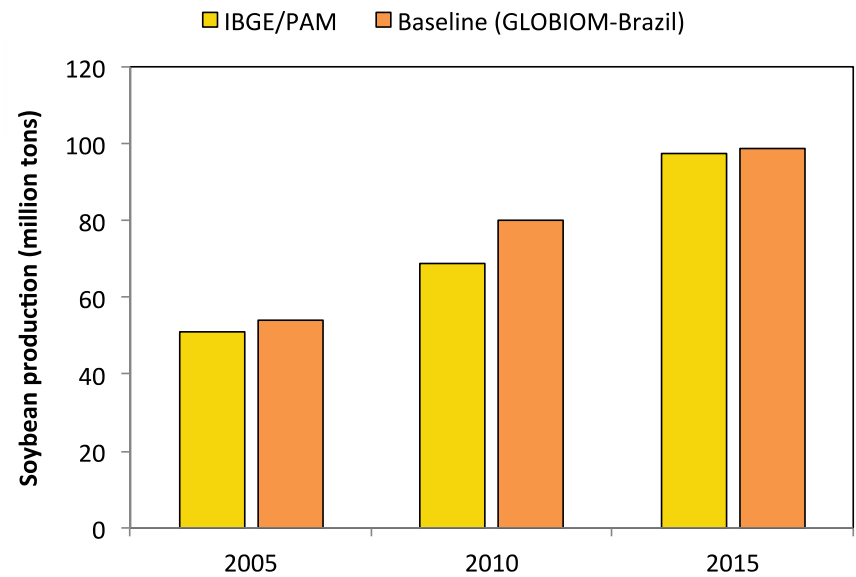
Model steps



Soybean harvested area and production



(a) Soybean harvested area

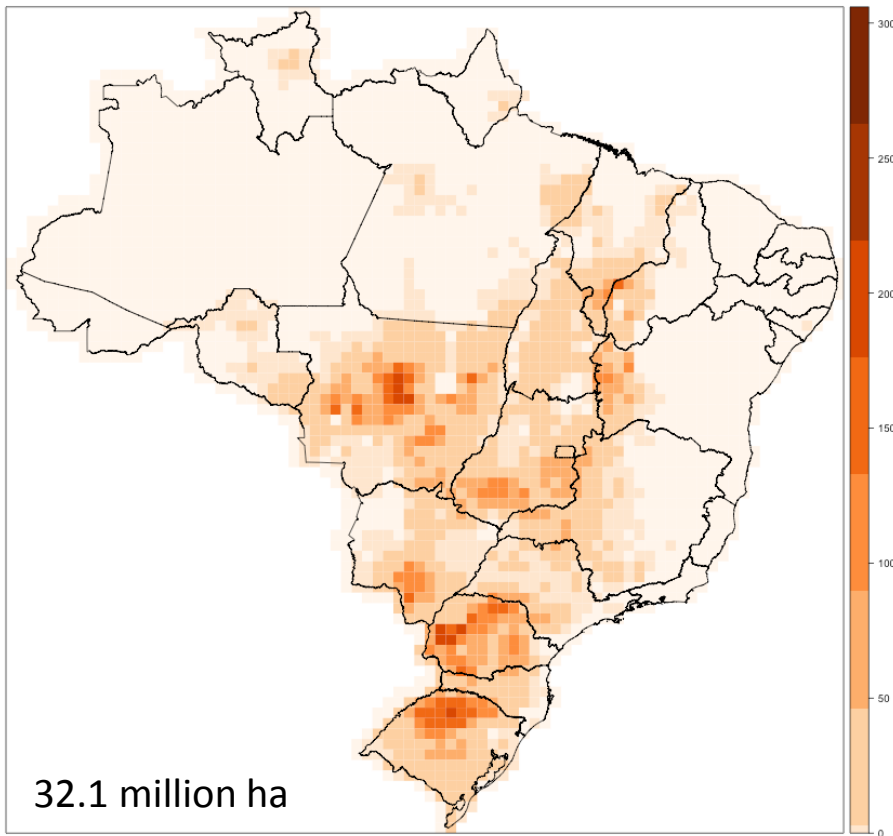


(b) Soybean production

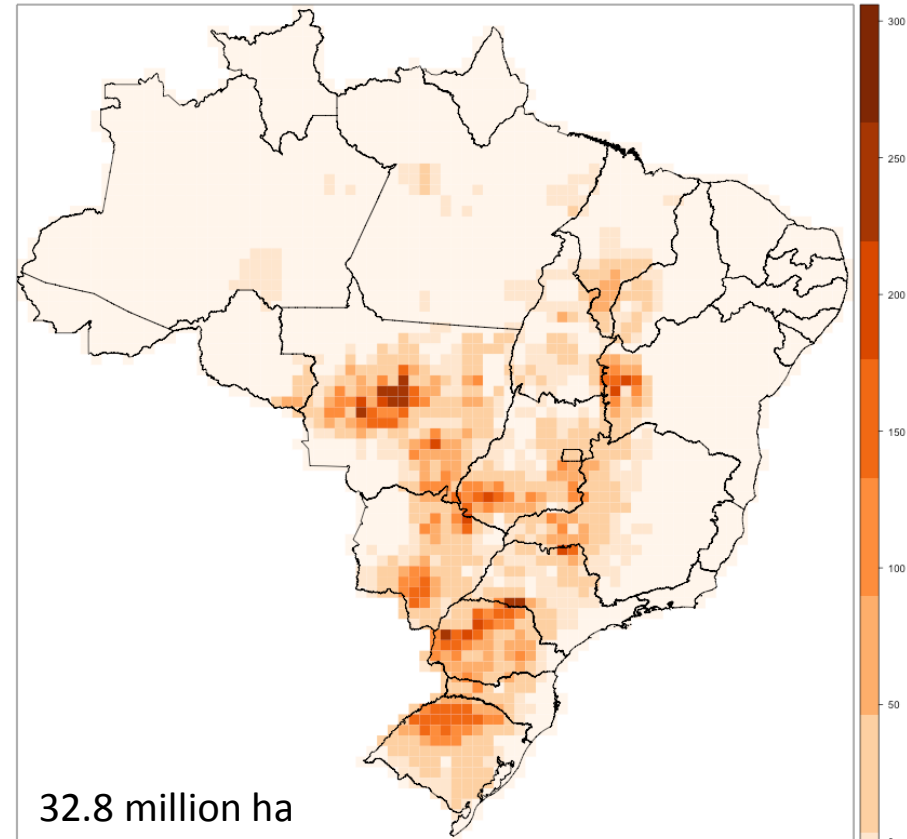
Brazil's aggregated numbers of (a) soybean harvested area and (b) soybean production for the years 2005, 2010 and 2015 according to IBGE/PAM and as projected by the baseline scenario of GLOBIOM-Brazil. The differences between IBGE/PAM and GLOBIOM-Brazil for the year 2015 are less than 2% for either area or production.

Soybean harvested area in 2015

IBGE/PAM



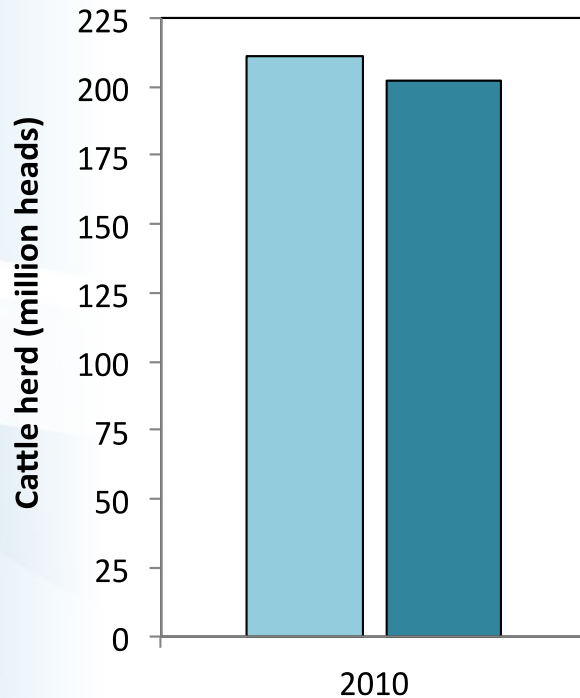
Baseline (GLOBIOM-Brazil)



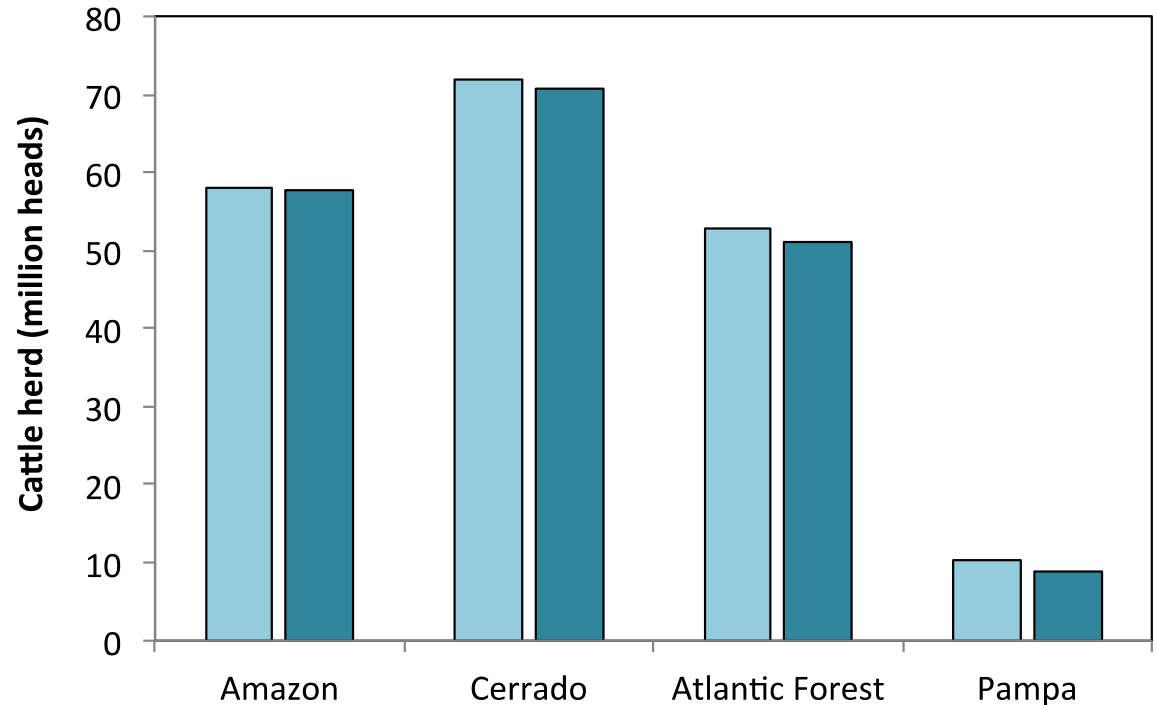
Spatial distribution of the soybean harvested area in 2015 according to IBGE/PAM (left) and the baseline scenario of GLOBIOM-Brazil (right). Color bar values are expressed in thousands of hectare per cell.

Cattle herd in Brazil in 2010

■ IBGE/PPM ■ GLOBIOM-Brazil

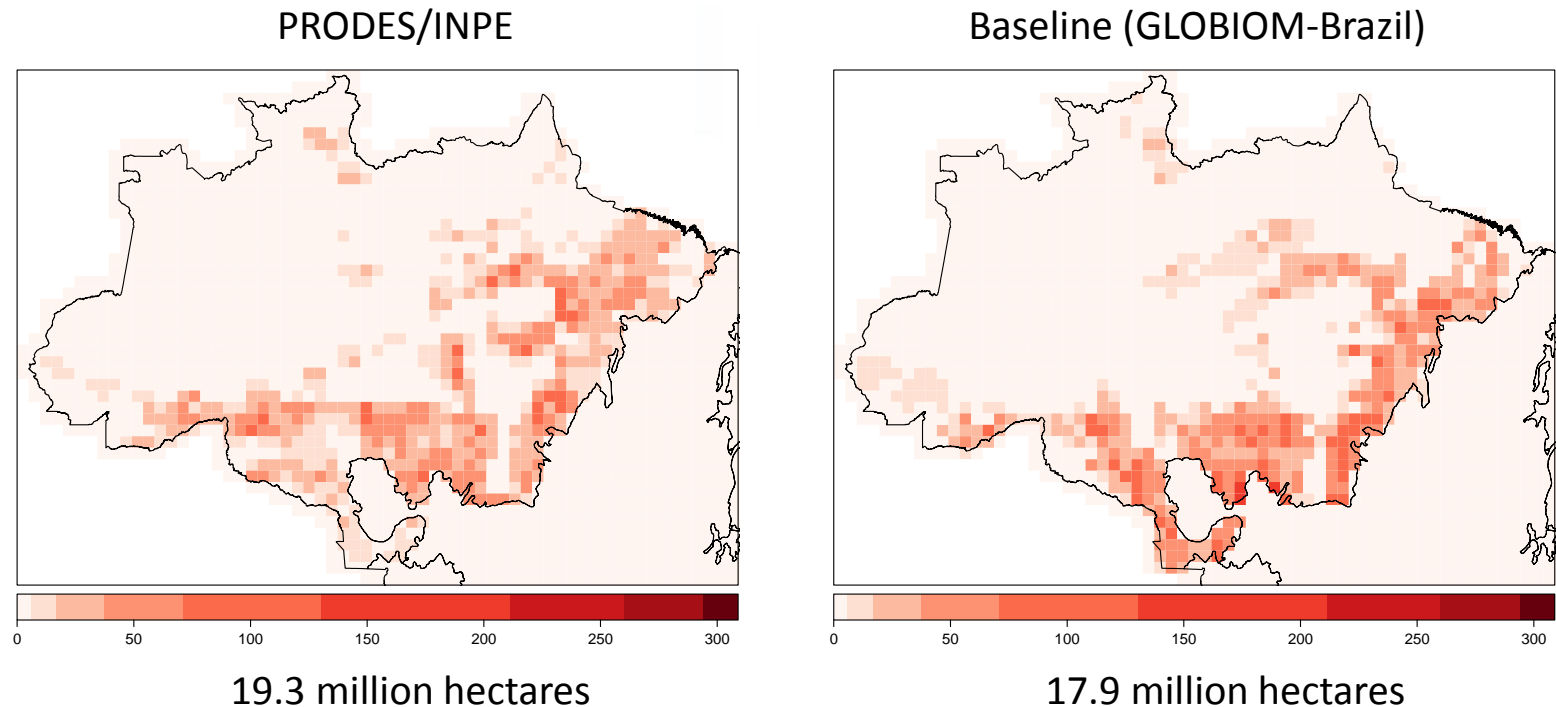


■ IBGE/PPM ■ GLOBIOM-Brazil



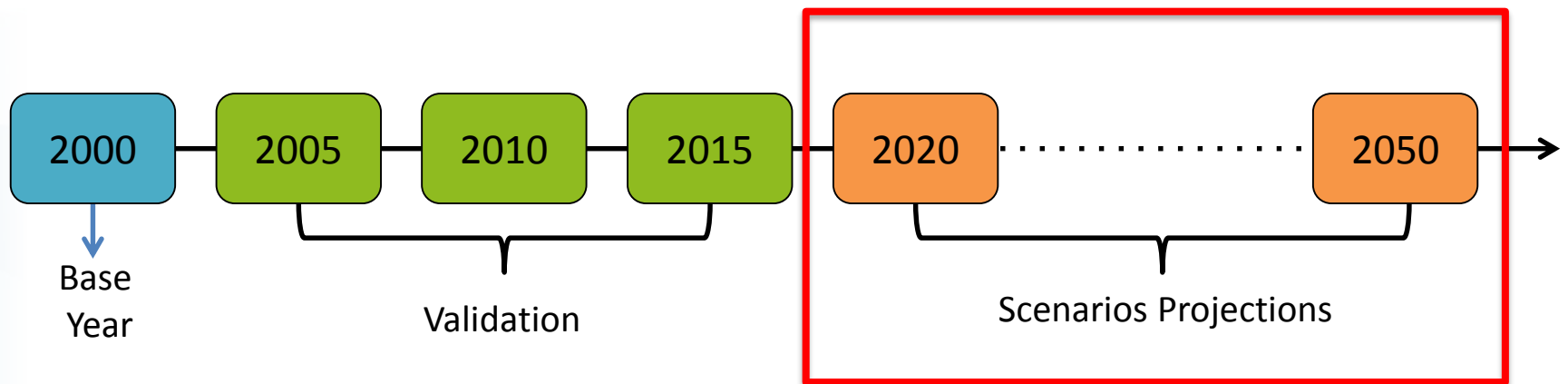
Cattle herd in Brazil and major biomes in million heads for the year 2010 according to IBGE/PPM and as projected by the baseline scenario of GLOBIOM-Brazil. The difference between IBGE/PPM and GLOBIOM-Brazil at national level in 2010 is smaller than 2%.

Accumulated deforestation (2001-2015)

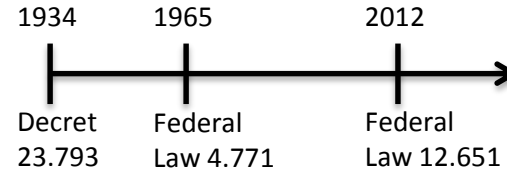


Spatial distribution of accumulated deforestation in the Amazon biome from 2001 to 2015 given by PRODES/INPE (left) and as projected by the baseline scenario of GLOBIOM-Brazil (right). The difference between PRODES/INPE and GLOBIOM-Brazil is around 7%. Color bar values are expressed in thousands of hectares per cell.

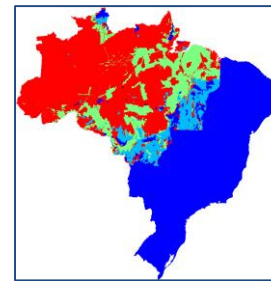
Model steps



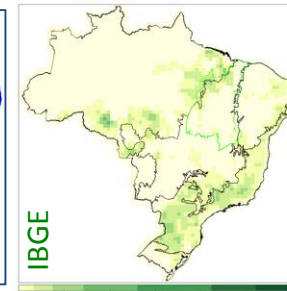
Impacts of Brazil's Forest Code



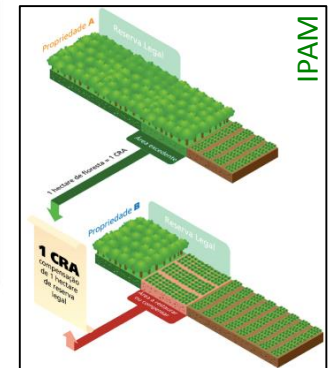
Soares-Filho et al (2014)



Legal Reserve Requirement




Amnesty of Small Farms



CRA

LETTER • OPEN ACCESS • FEATURED ARTICLE

Future environmental and agricultural impacts of Brazil's Forest Code

Aline C Soterroni^{1,2} , Aline Mosnier¹, Alexandre X Y Carvalho³, Gilberto Câmara², Michael Obersteiner¹, Pedro R Andrade², Ricardo C Souza², Rebecca Brock⁴, Johannes Pirker¹, Florian Kraxner¹

[+ Show full author list](#)

Published 5 July 2018 • © 2018 The Author(s). Published by IOP Publishing Ltd

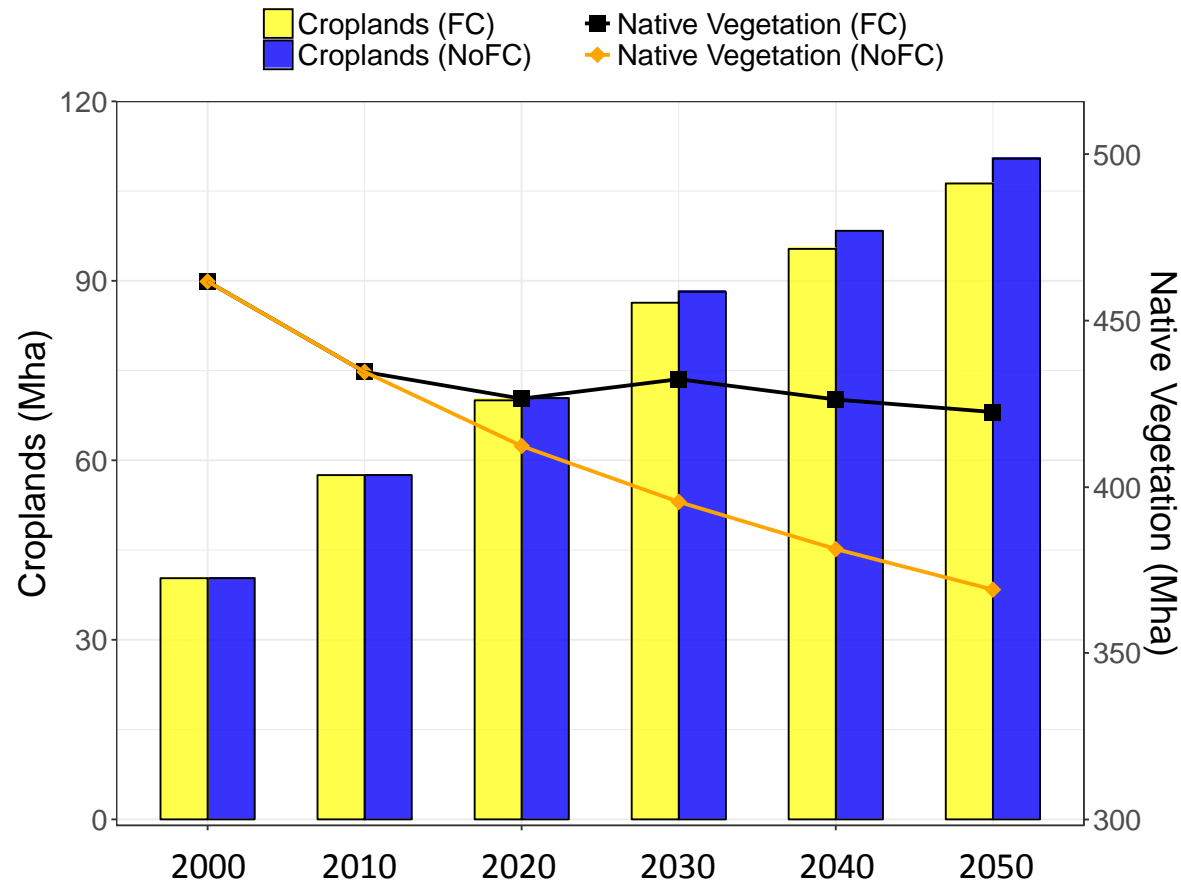
[Environmental Research Letters](#), Volume 13, Number 7

Scenarios

Measures of the Forest Code	No enforcement of the Forest Code NoFC	Full enforcement of the Forest Code FC
Illegal deforestation control	no	yes
Small farms amnesty (SFA)	no	yes
Environmental Reserve Quota (CRA)	no	yes
Forest regrowth	no	yes

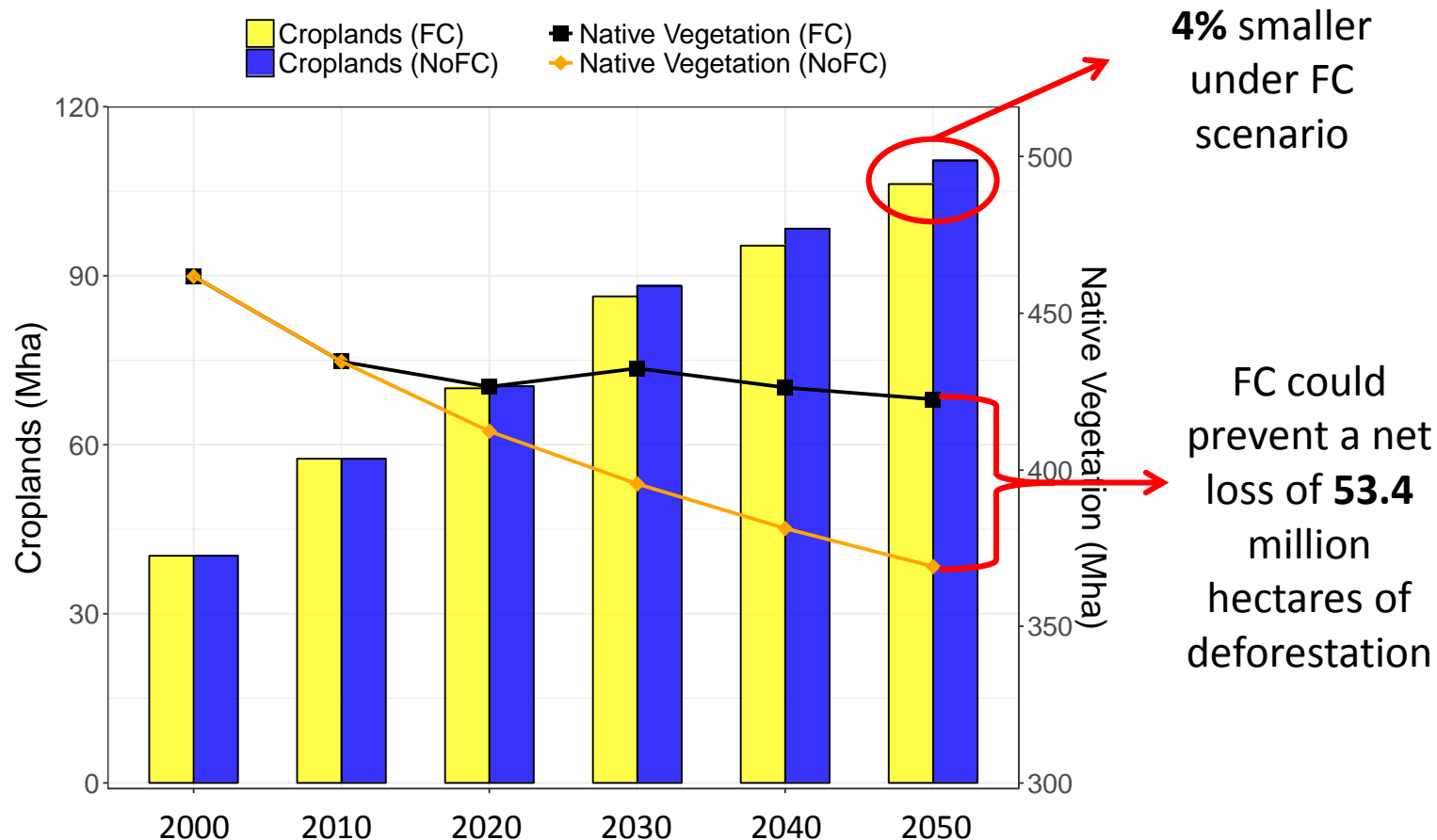
↑
Counterfactual
Scenario

Cropland expansion x Forest stabilization



Cropland expansion (bar charts) and native vegetation area evolution (line charts) as projected by the FC and NoFC scenarios

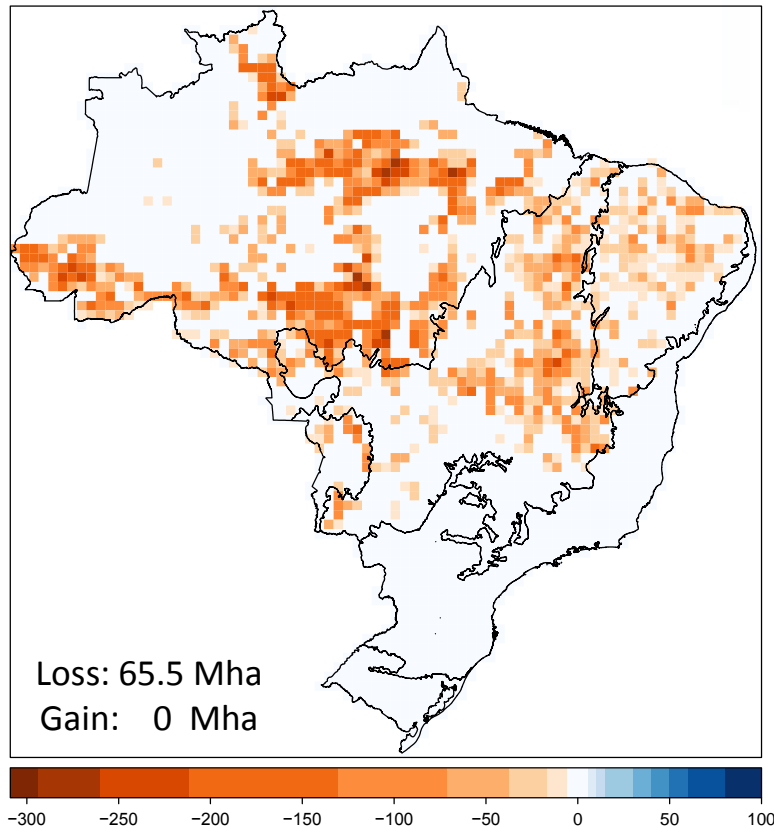
Cropland expansion x Forest stabilization



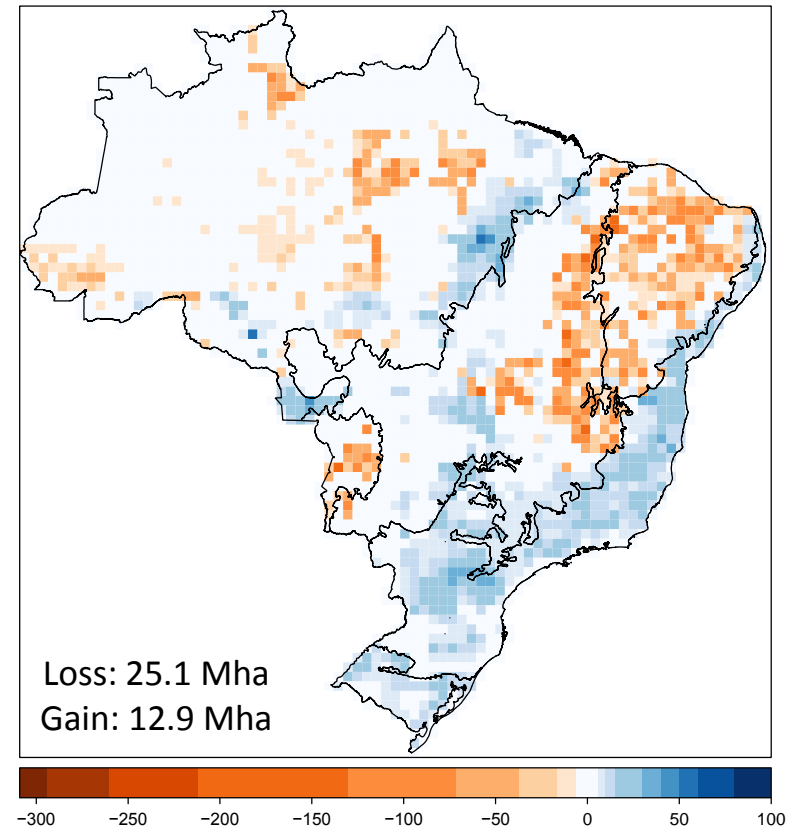
Cropland expansion (bar charts) and native vegetation area evolution (line charts) as projected by the FC and NoFC scenarios

Forest loss (orange) or gain (blue)

No Forest Code



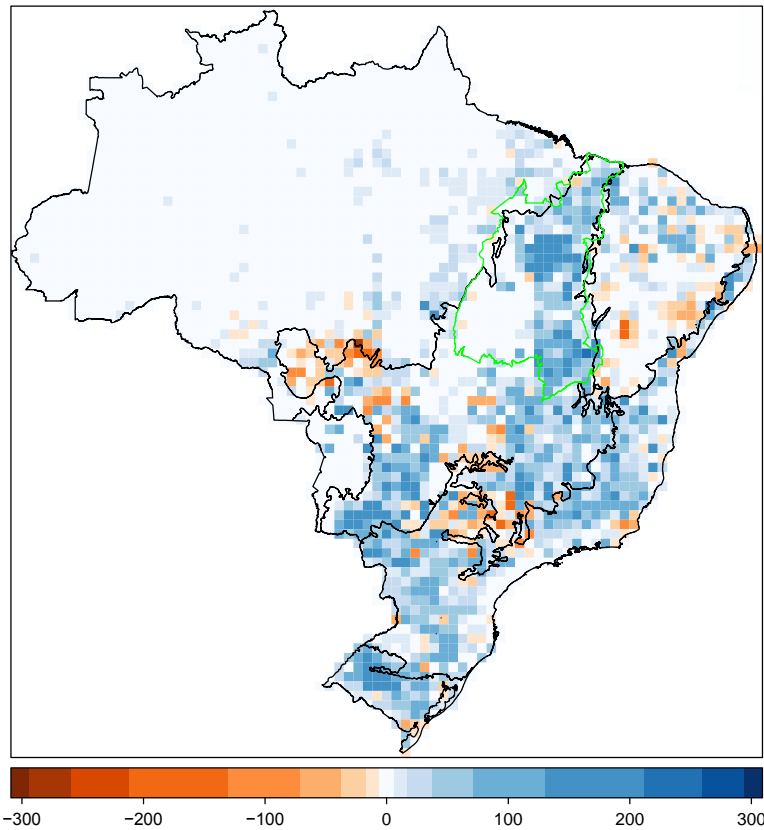
Forest Code



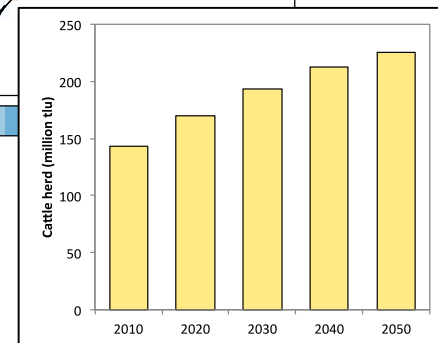
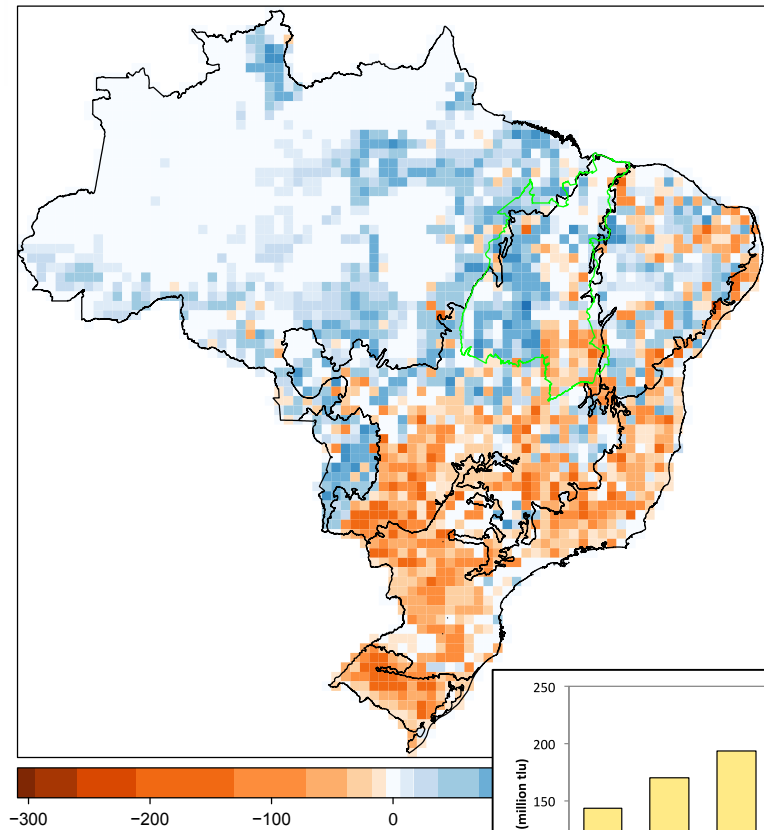
Spatial distribution of cumulative loss (orange) or gain (blue) of native vegetation for the scenarios NoFC (left) and FC (right) between 2010 and 2050.

Cropland and pasture loss/gain Forest Code Scenario (2010 – 2050)

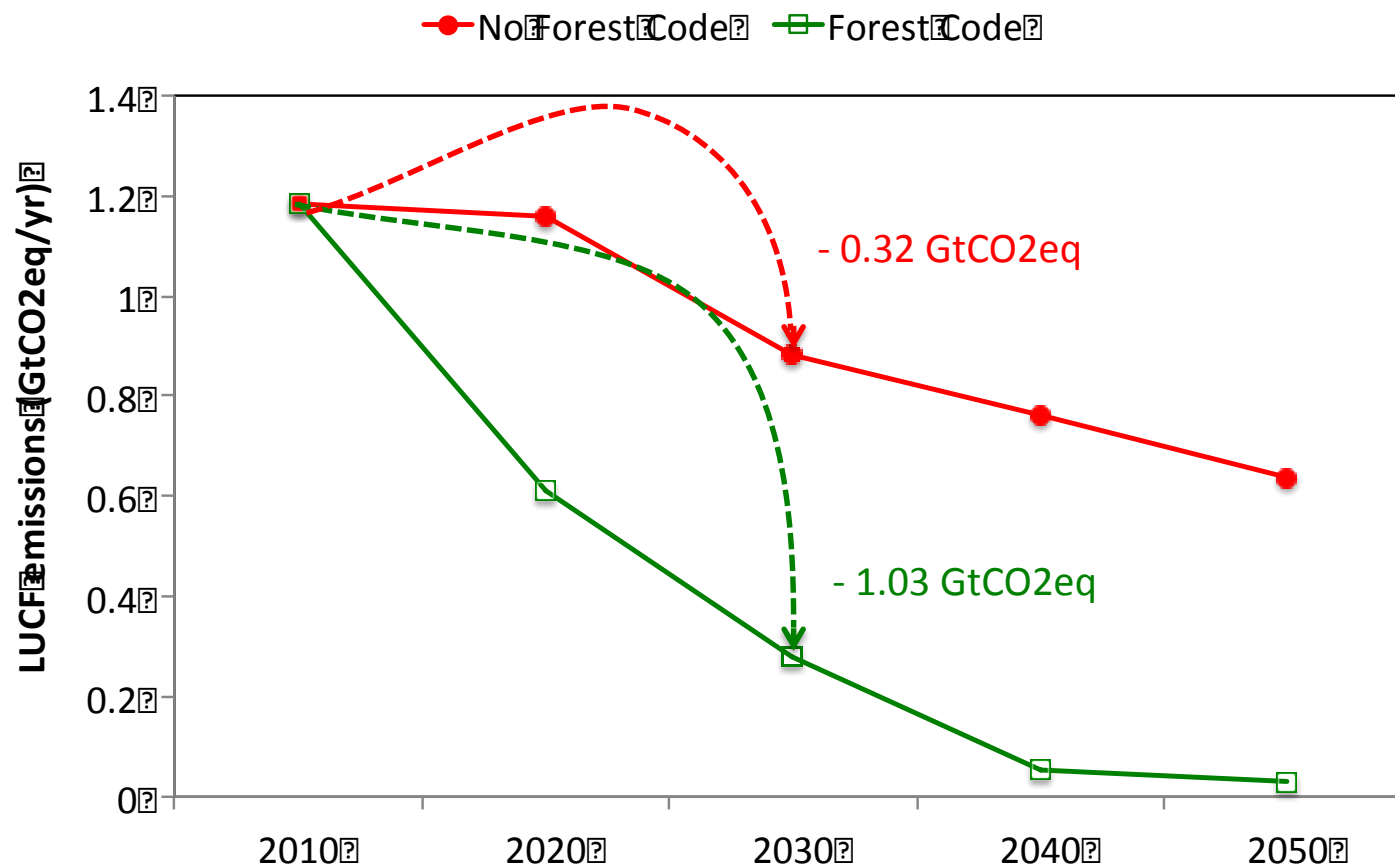
Cropland loss/gain



Pasture loss/gain



Emissions from land-use change and forestry

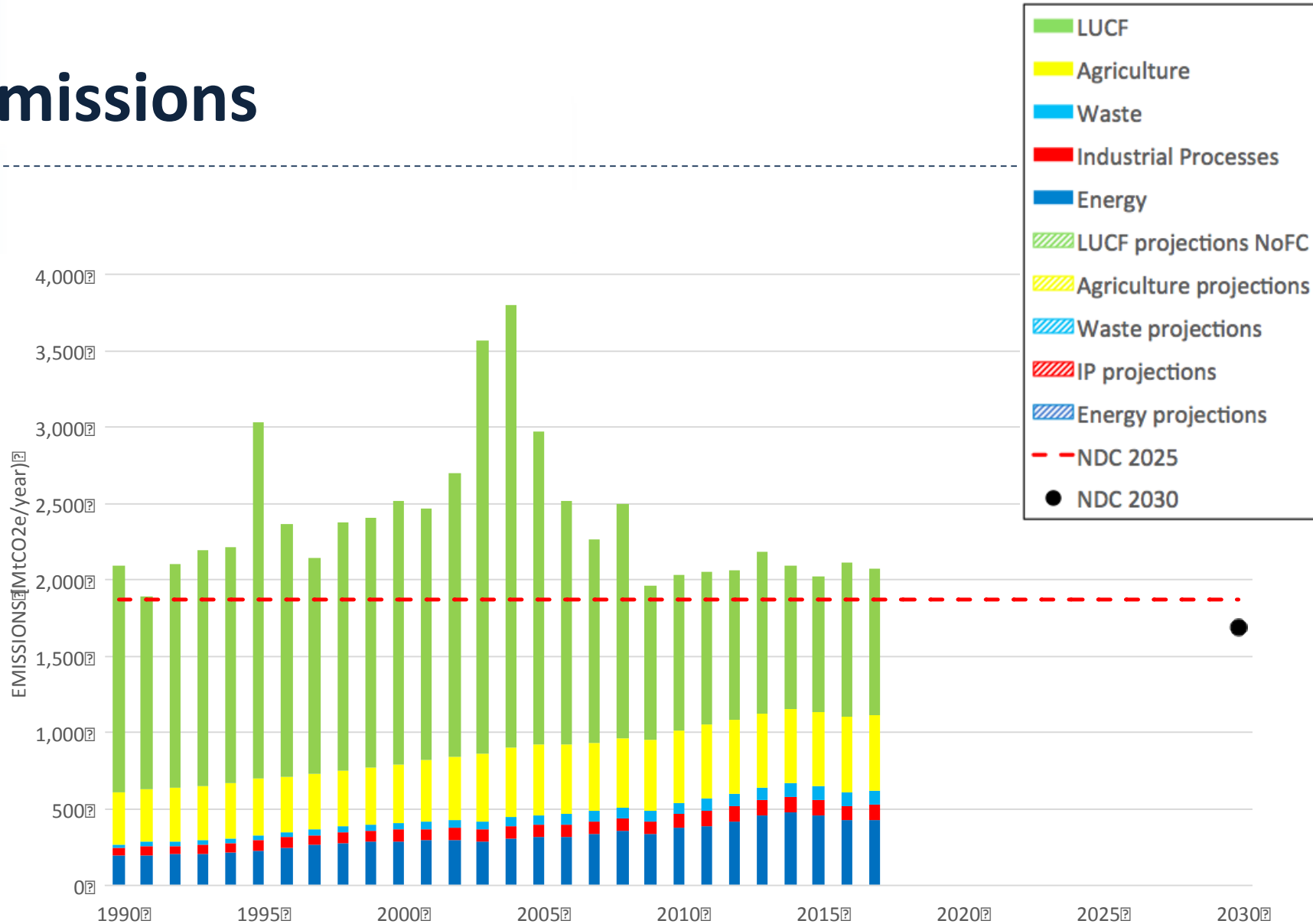


Brazil's NDC commitment: reduction of 1.2 GtCO₂eq (from 2.8 GtCO₂eq to 1.6 GtCO₂eq)

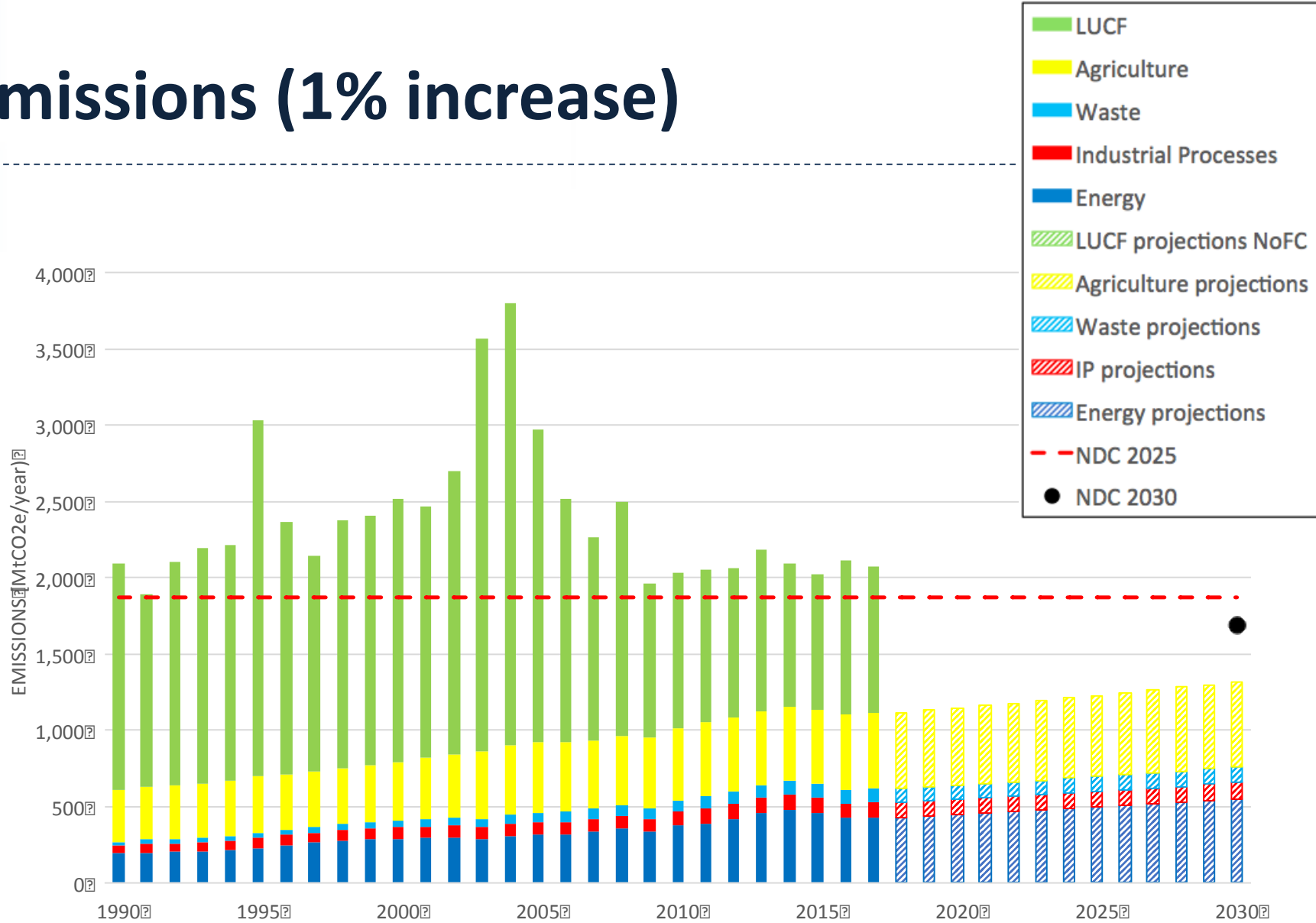


43% below 2005 levels

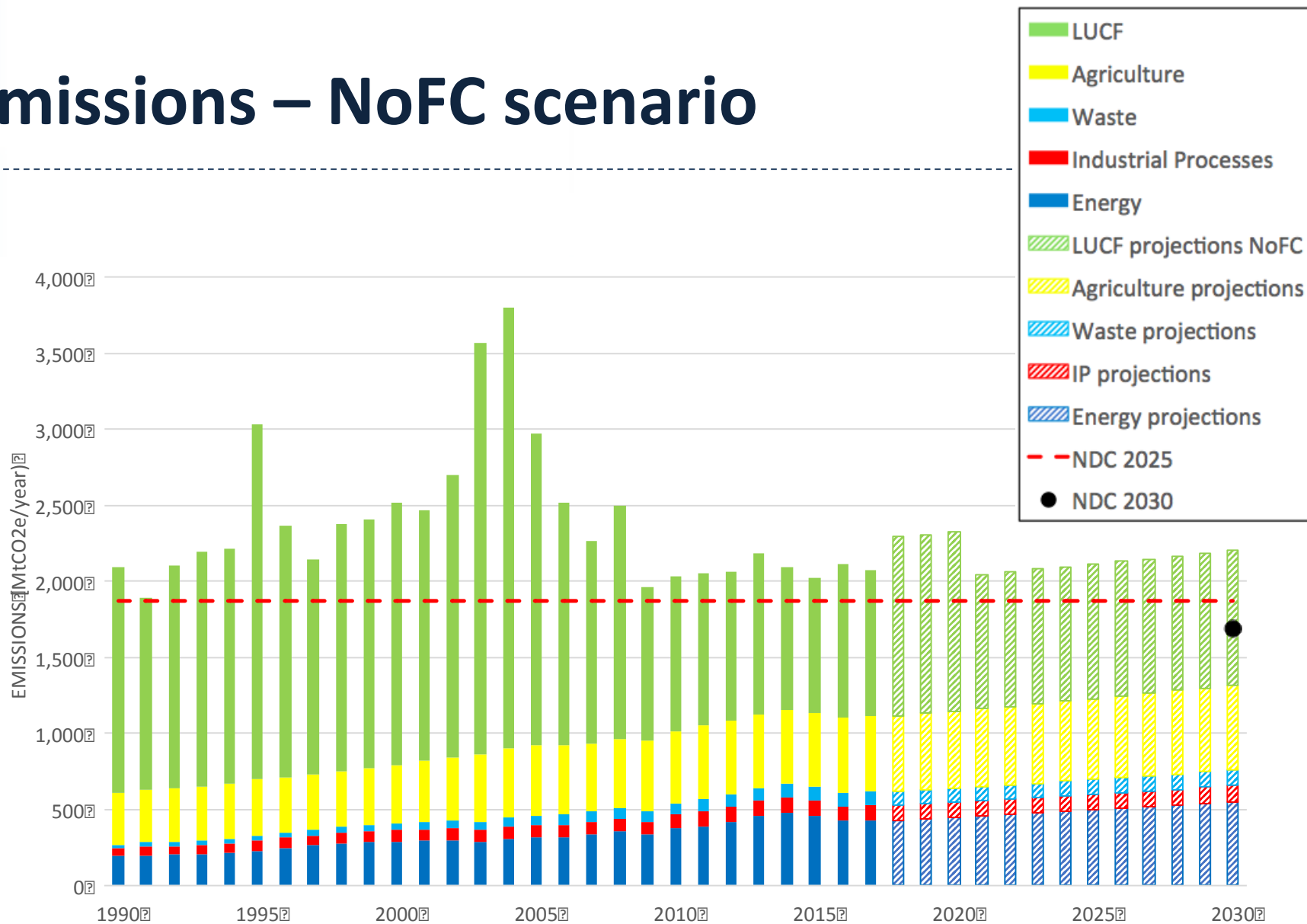
Emissions



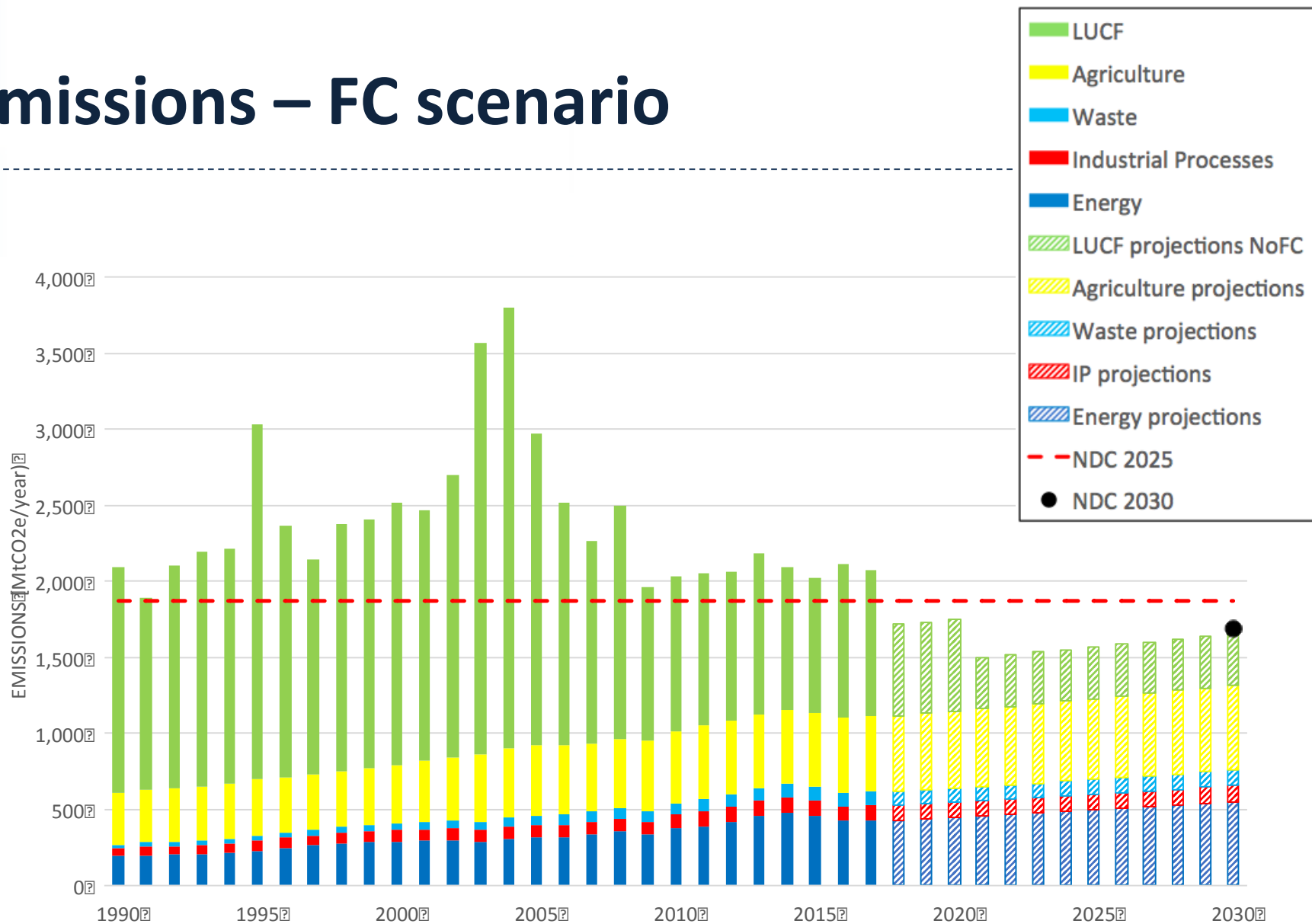
Emissions (1% increase)



Emissions – NoFC scenario



Emissions – FC scenario



Brazil's NDC

► Land Use Change and Forests

- **Zero illegal deforestation** in the Amazon biome by 2030
- Restoring and reforesting **12 million hectares (Mha) of forests** by 2030
- Enhancing sustainable native forest management system
- Enforcing the implementation of the **Forest Code**



GLOBIOM-Brazil model and the Brazil's INDC

*“The Brazilian Government has benefited from the cooperation between **IIASA** and leading Brazilian public institutions **INPE** and **IPEA**. The results of the **GLOBIOM-Brazil model** were quite informative and have provided **science-based evidence** that has contributed to **Brazil's INDC**.”*

Dr. José Domingos Miguez

Dr. José Domingos Miguez was the Director of the Department of Environmental Evaluation in the Ministry of the Environment, Brazil, and one of the Brazil's leading climate negotiators.



ENVIRONMENTAL STUDIES

Expanding the Soy Moratorium to Brazil's Cerrado

Aline C. Soterroni^{1,2*†}, Fernando M. Ramos^{2*}, Aline Mosnier^{1,3}, Joseph Fargione⁴,
Pedro R. Andrade², Leandro Baumgarten⁵, Johannes Pirker^{1,6}, Michael Obersteiner¹,
Florian Kraxner¹, Gilberto Câmara², Alexandre X. Y. Carvalho^{7,8}, Stephen Polasky^{9†}

Example of policy evaluation with GLOBIOM-Brazil

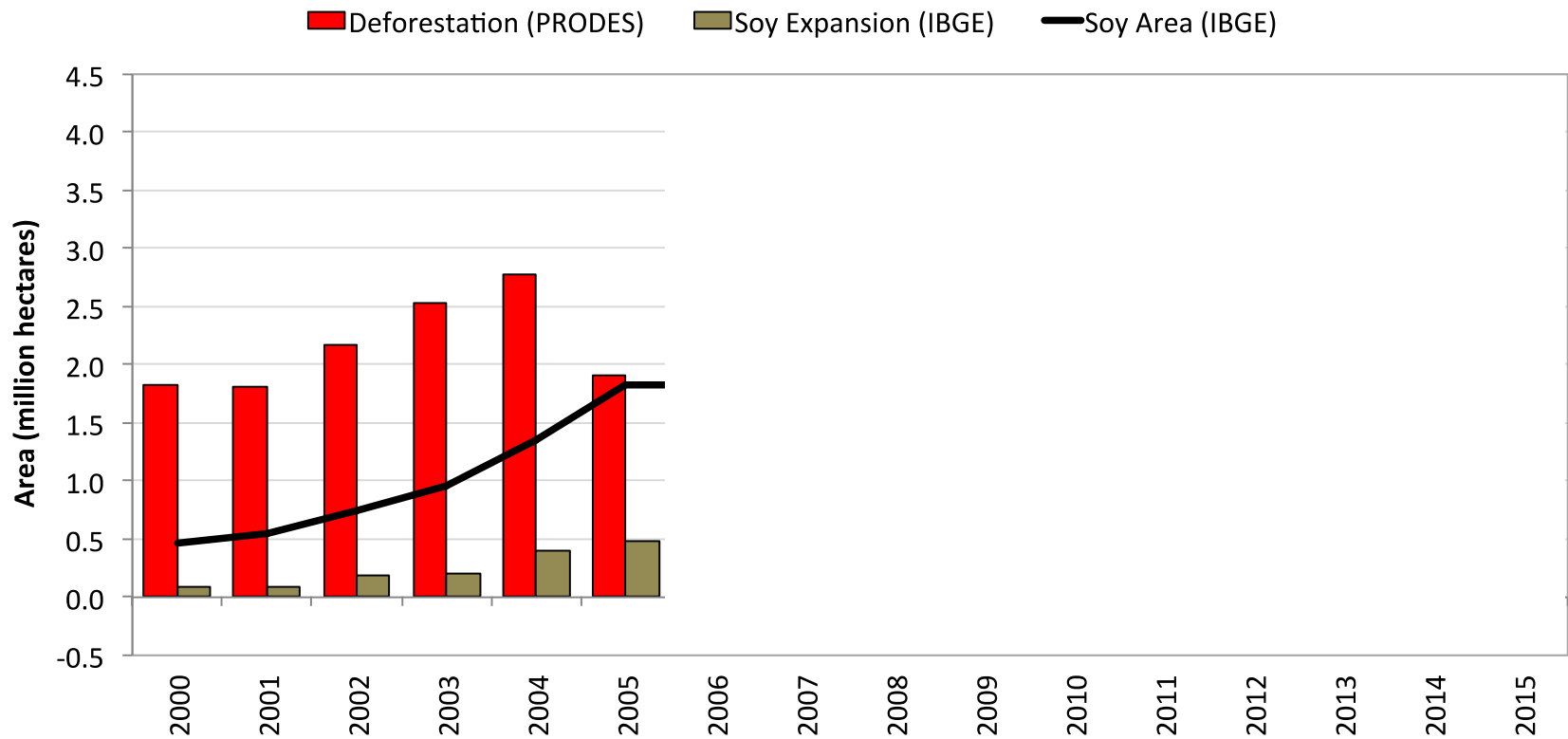


Brazil is a major producer of soybeans



Soy is a well-known commodity-driven deforestation

Deforestation x Soy Expansion in the Amazon



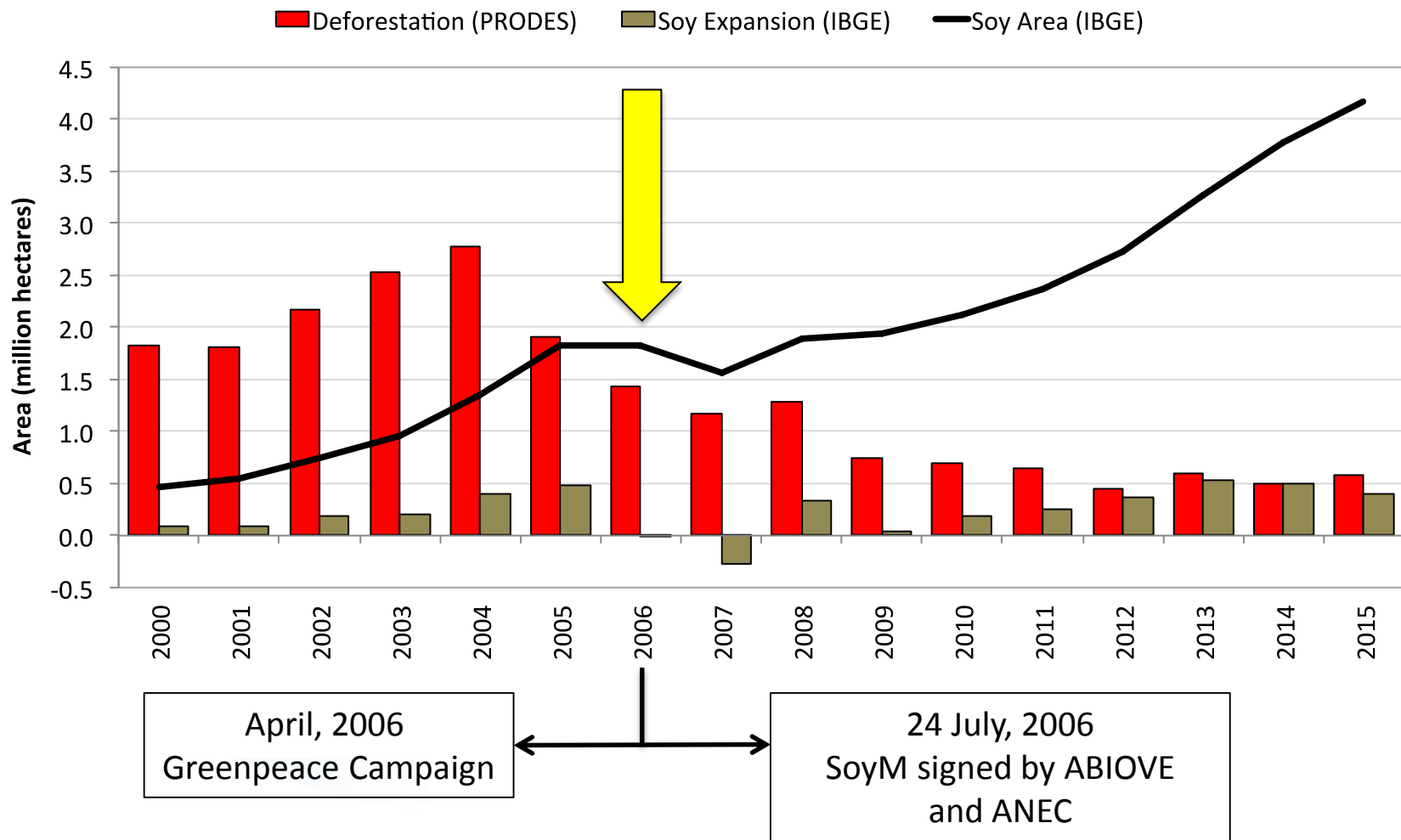
Deforestation x Soy Expansion in the Amazon

Soy Moratorium (SoyM) → First zero-deforestation agreement signed in the tropics

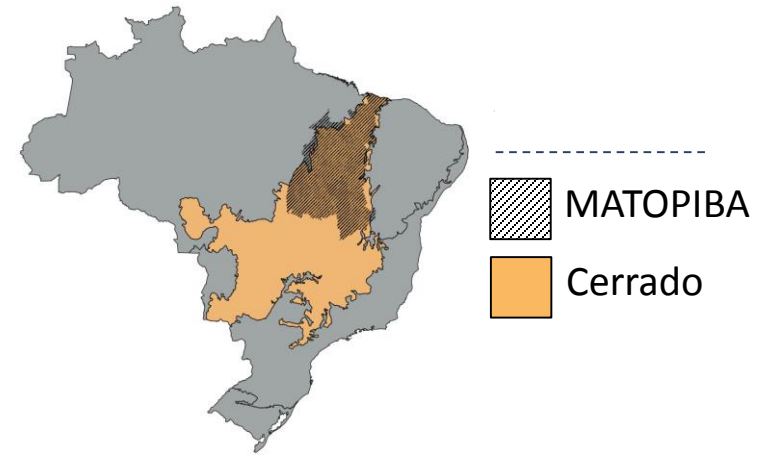


Deforestation x Soy Expansion in the Amazon

Soy Moratorium (SoyM) → First zero-deforestation agreement signed in the tropics

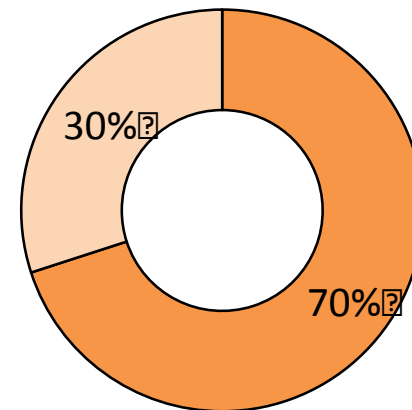
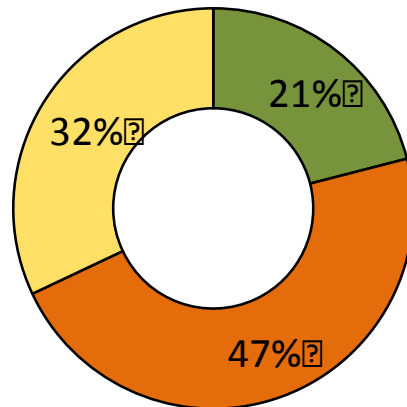


Where do the soybeans grow in Brazil?



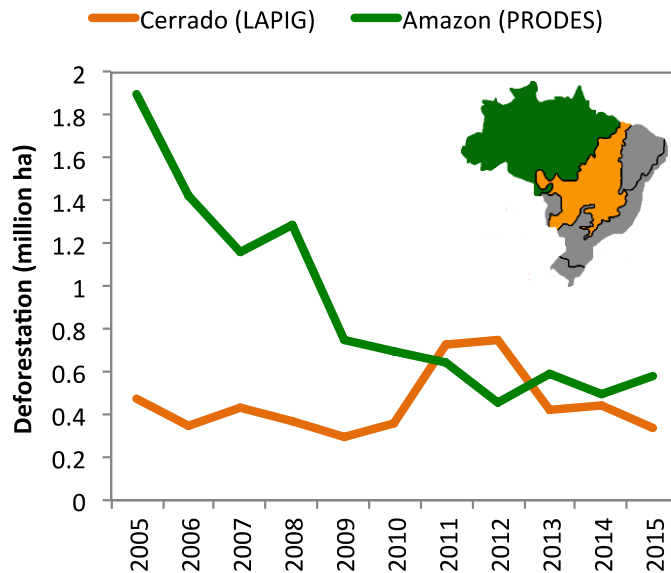
Soy expansion between 2000 and 2016

■ Amazon ■ Cerrado ■ Others ■ Matopiba ■ Outside Matopiba



Source: IBGE/PAM

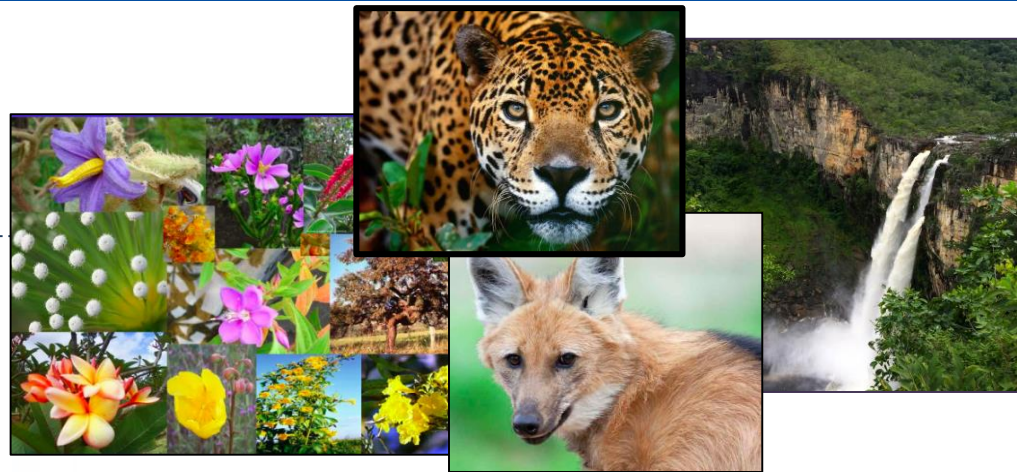
Cerrado context



**Between 2000 and 2014,
around 30% of the soy
expansion in the Cerrado**

occurred in native vegetation

Source: Carneiro-Filho & Costa, K
Agroicone, INPUT 2016



**19.8% of undisturbed remnants
8% of Cerrado is under protection
4,800 endemic species under threat**

Strassburg et al (2017), Nature Ecology & Evolution



**Brazil's
agricultural
boom**

Cerrado Manifesto

**THE FUTURE OF THE CERRADO IN THE HANDS OF THE MARKET:
DEFORESTATION AND NATIVE VEGETATION CONVERSION MUST BE STOPPED**

The undersigned civil society organizations call for immediate action in defense of the Cerrado by companies that purchase soy and meat from within the biome, as well as by investors active in these sectors. This includes the adoption of effective policies and commitments to eliminate deforestation and conversion of native vegetation and disassociate their supply chains from recently converted areas.

More than 70 companies have signed the Cerrado Manifesto, mostly in the consumer and retail sectors (not the big traders such as Cargill, Bunge and ADM, or entities such as China which buys a third of the Cerrado soybeans)



2020

2030

2040

2050

What would be the impacts of the SoyM
expansion to the Cerrado
in the future?

Scenarios

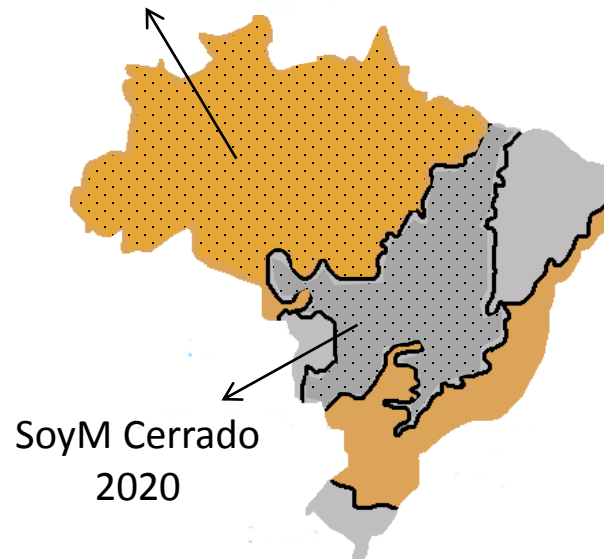
Baseline

SoyM Amazon
2006



SoyMExp

SoyM Amazon
2006



Illegal deforestation control

No deforestation control

Soy Moratorium

Scenarios

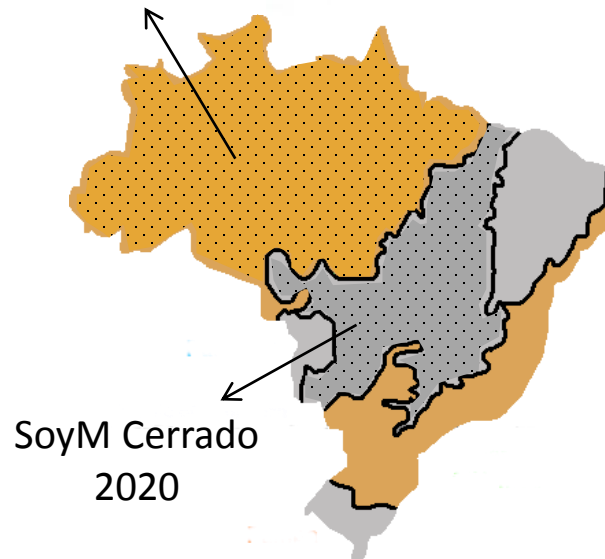
Baseline

SoyM Amazon
2006



SoyMExp




SoyM Amazon
2006



Forest Code

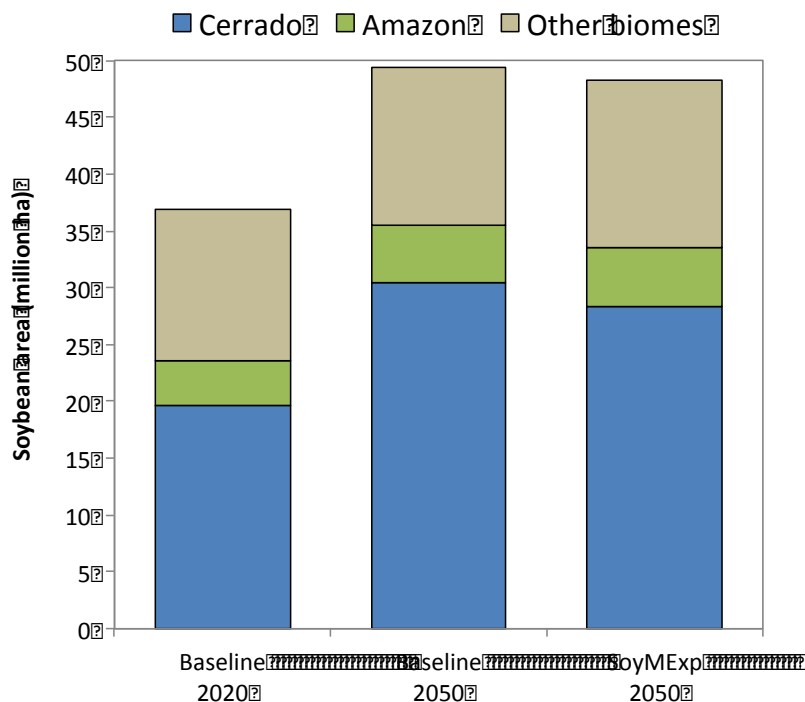
SoyM Amazon
2006



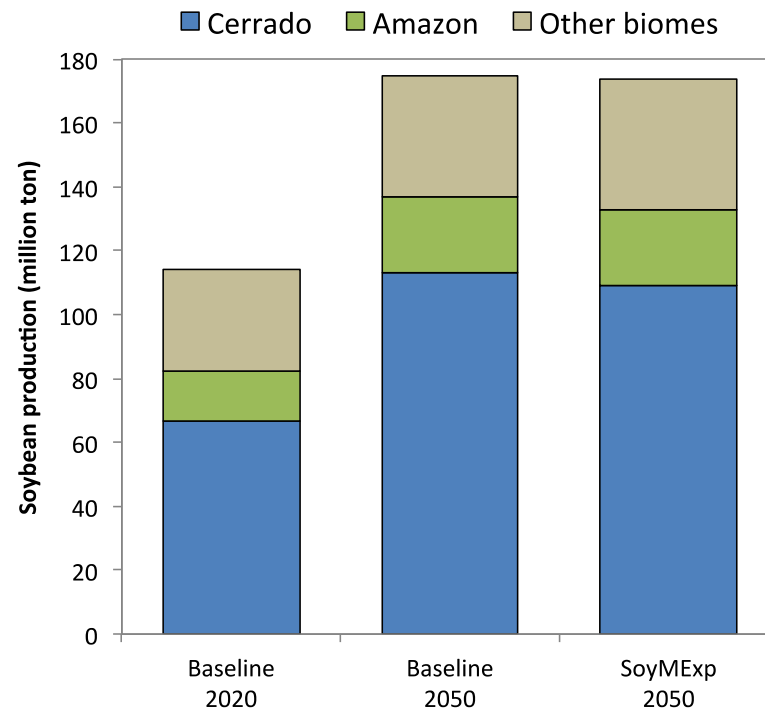
-  Illegal deforestation control
-  No deforestation control
-  Soy Moratorium

Soybeans expansion in Brazil (2021-2050)

Area (million ha)

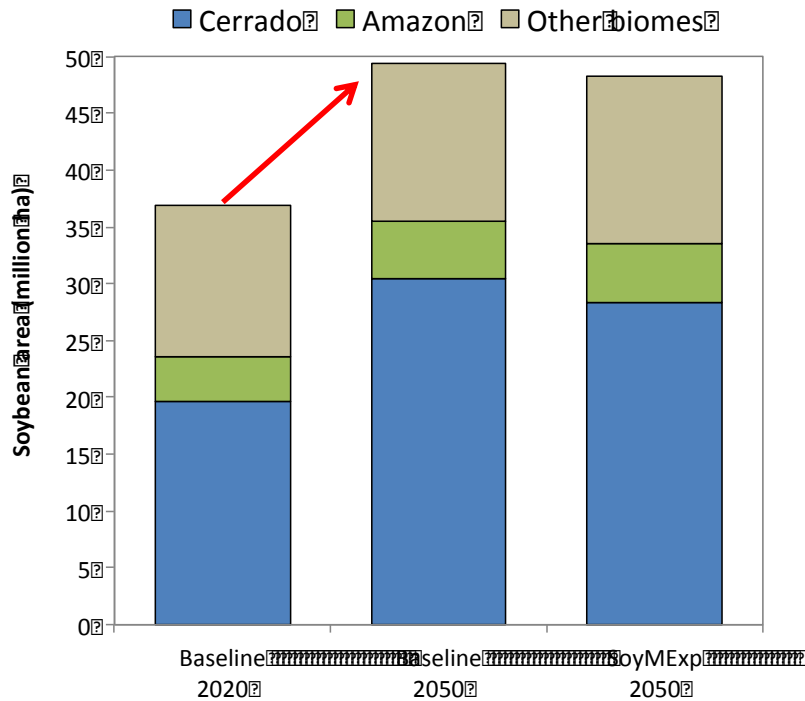


Production (million ton)

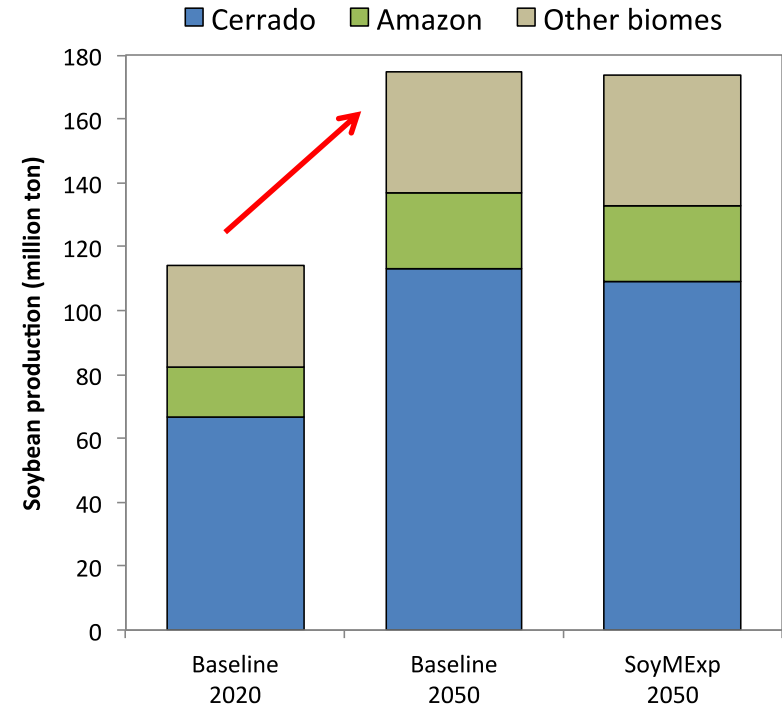


Soybeans expansion in Brazil (2021-2050)

Area (million ha)



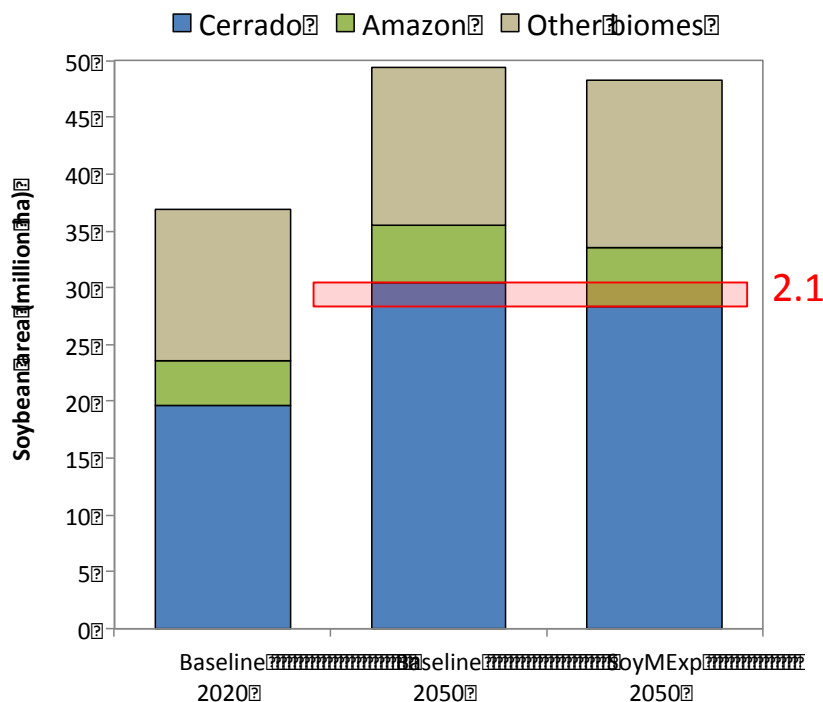
Production (million ton)



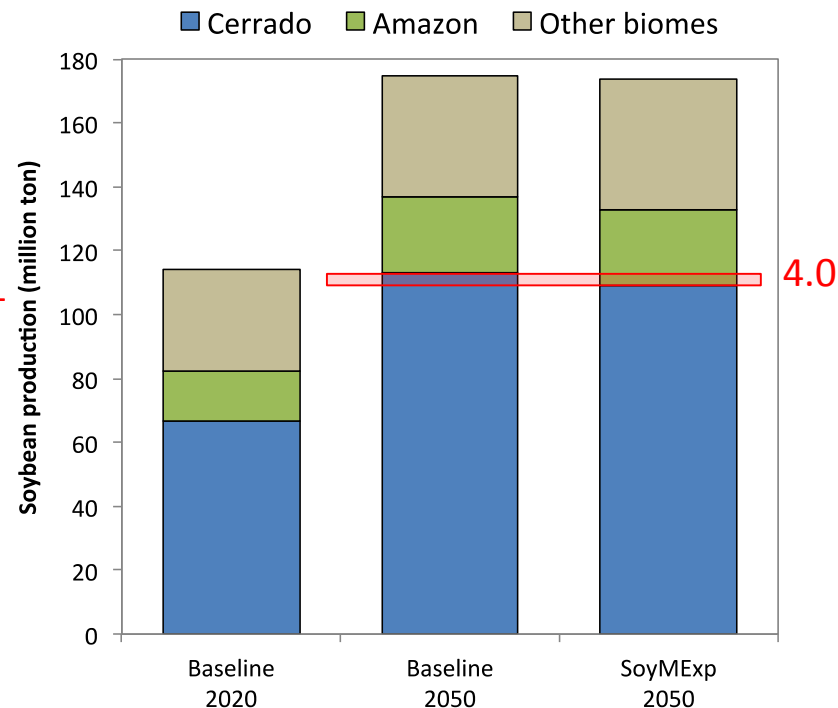
SoyM in the Cerrado would not prevent future soybean expansion

Soybeans expansion in Brazil (2021-2050)

Area (million ha)



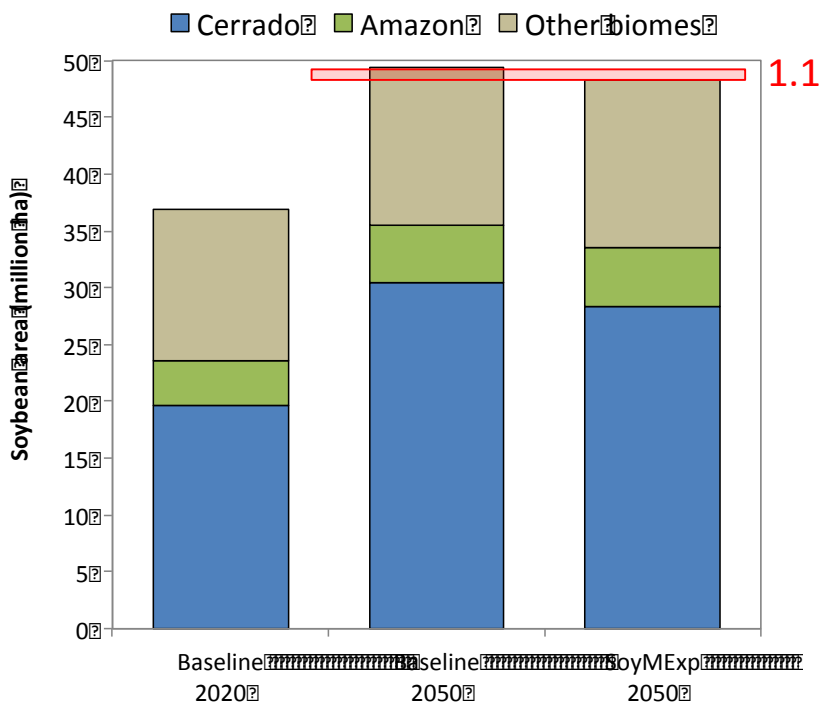
Production (million ton)



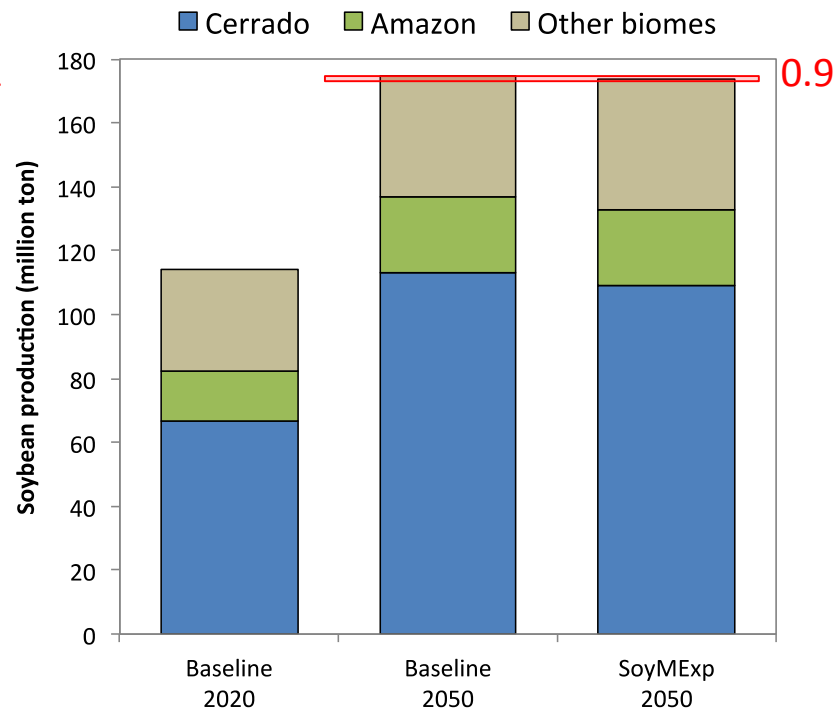
7% of soybean area projected in the Cerrado by 2050

Soybeans expansion in Brazil (2021-2050)

Area (million ha)

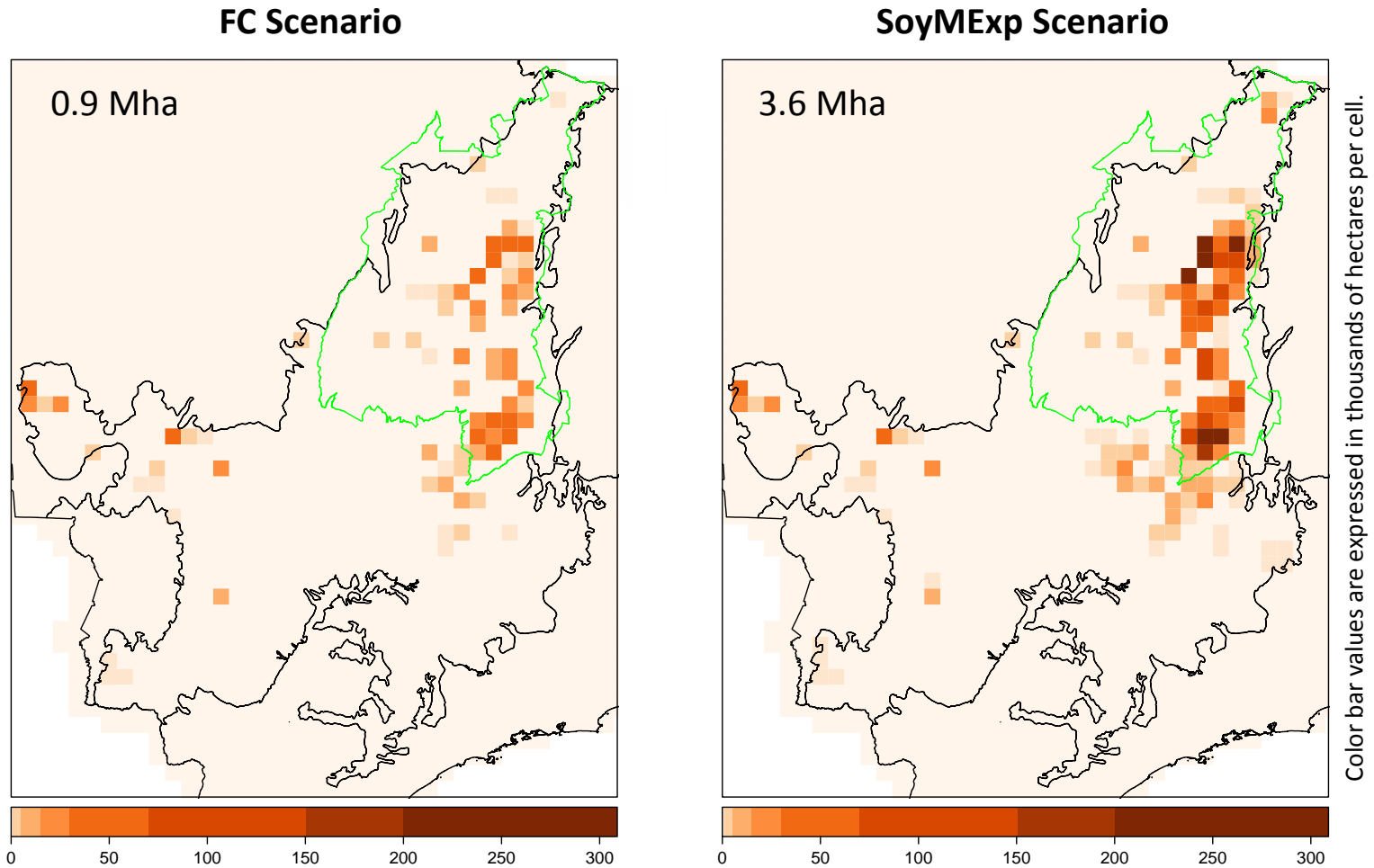


Production (million ton)



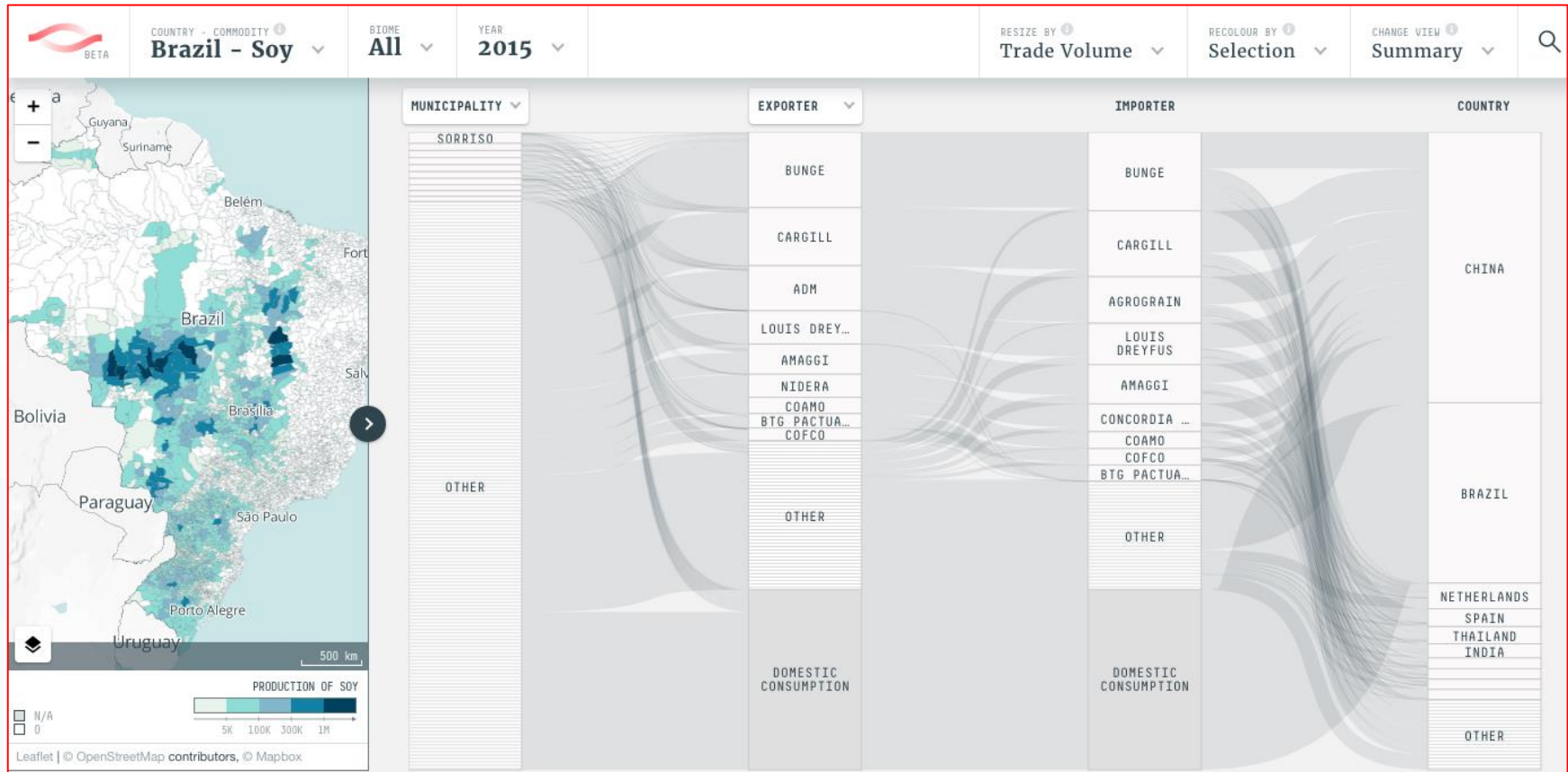
2% of soybean area projected in Brazil by 2050

Avoided (direct) loss due to SoyM (2021–2050)



Spatial distribution of **accumulated** DIRECT avoided deforestation for soybean expansion from 2021 to 2050 due to FC (left) and the full compliance with the SoyM (right)

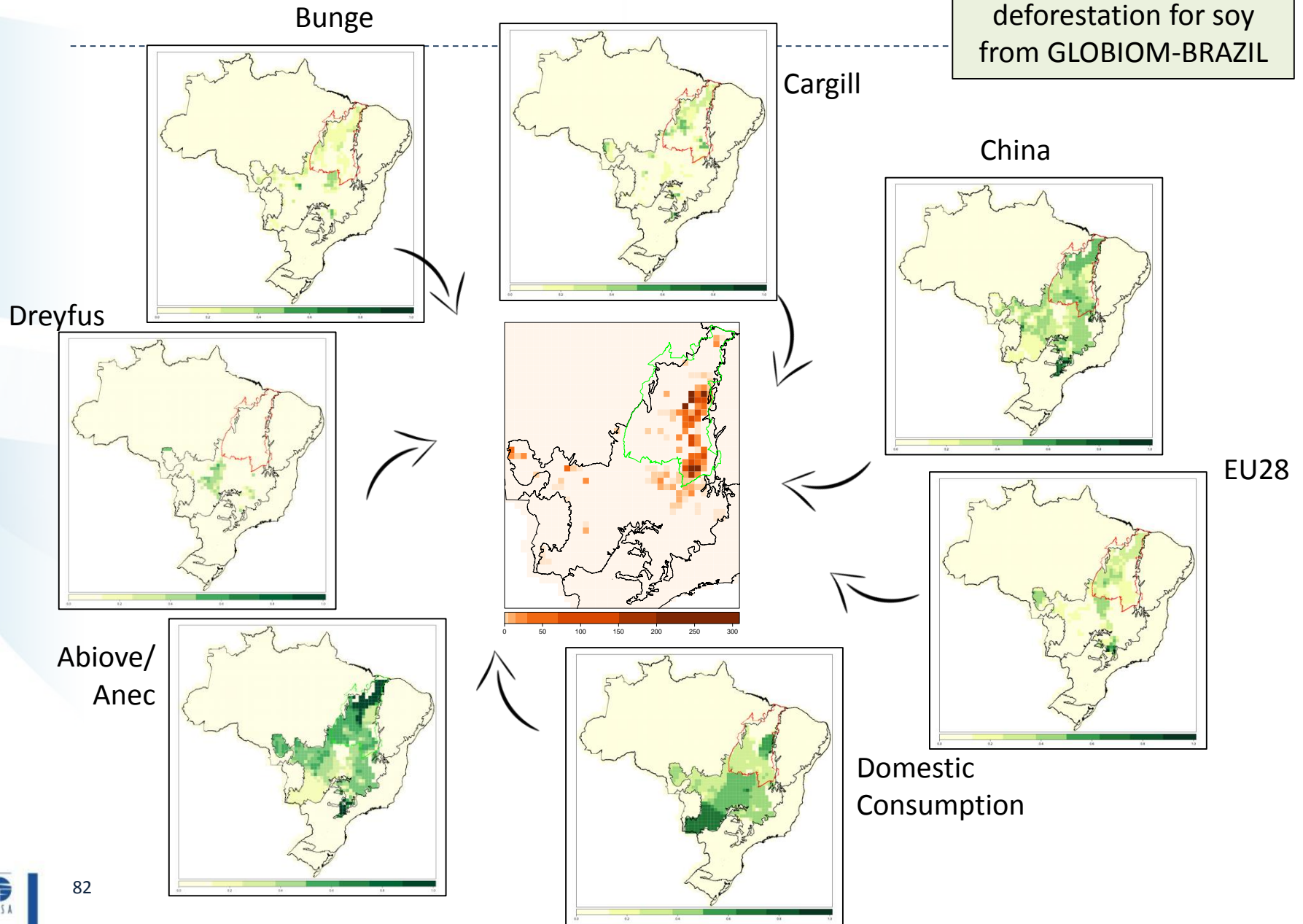
TRASE dataset



TRASE is an internet tool developed jointly by international non-profit organization (NGO) Stockholm Environment Institute (SEI) and Global Canopy to improve transparency in supply chains globally by tracking commodities supply chains in detail from source to market

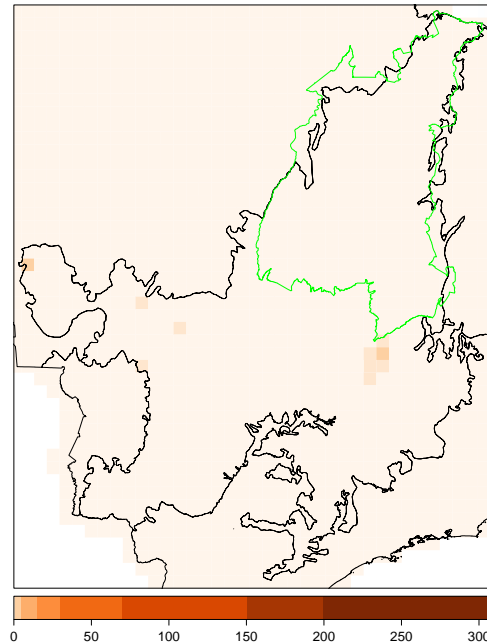
Risk of future deforestation

Market share from
TRASE and future
deforestation for soy
from GLOBIOM-BRAZIL



Risk of future deforestation

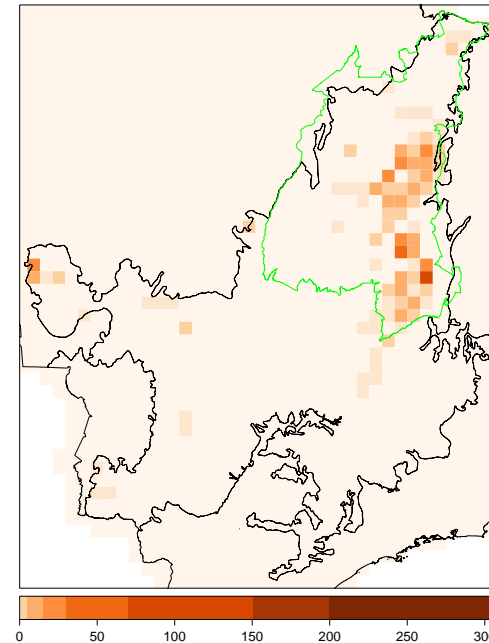
Louis Dreyfus



Soy sourced (2015): 1.8 Mton

Risk of deforestation
0.01 Mha (0.3% of
future deforestation to soy)

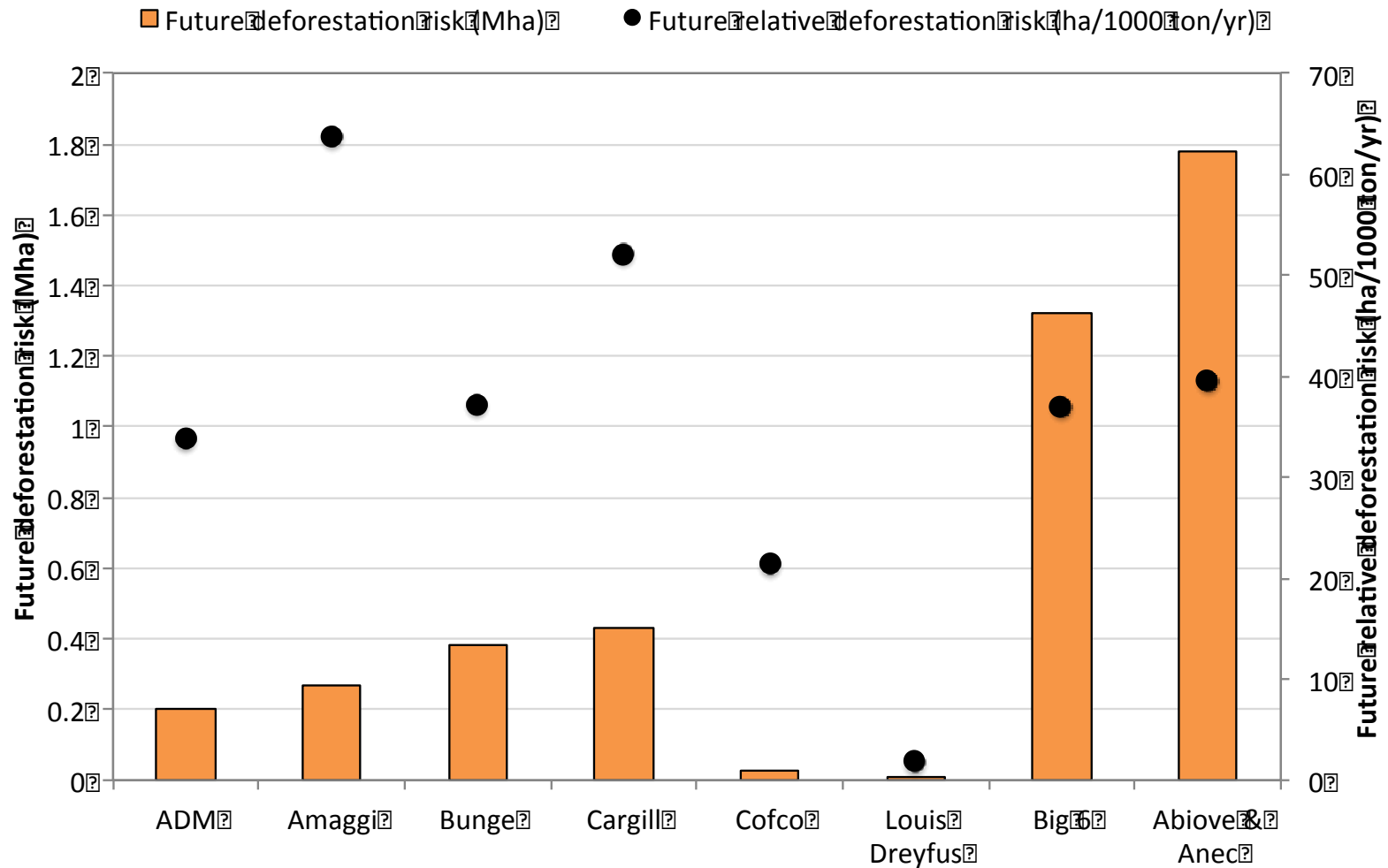
Cargill



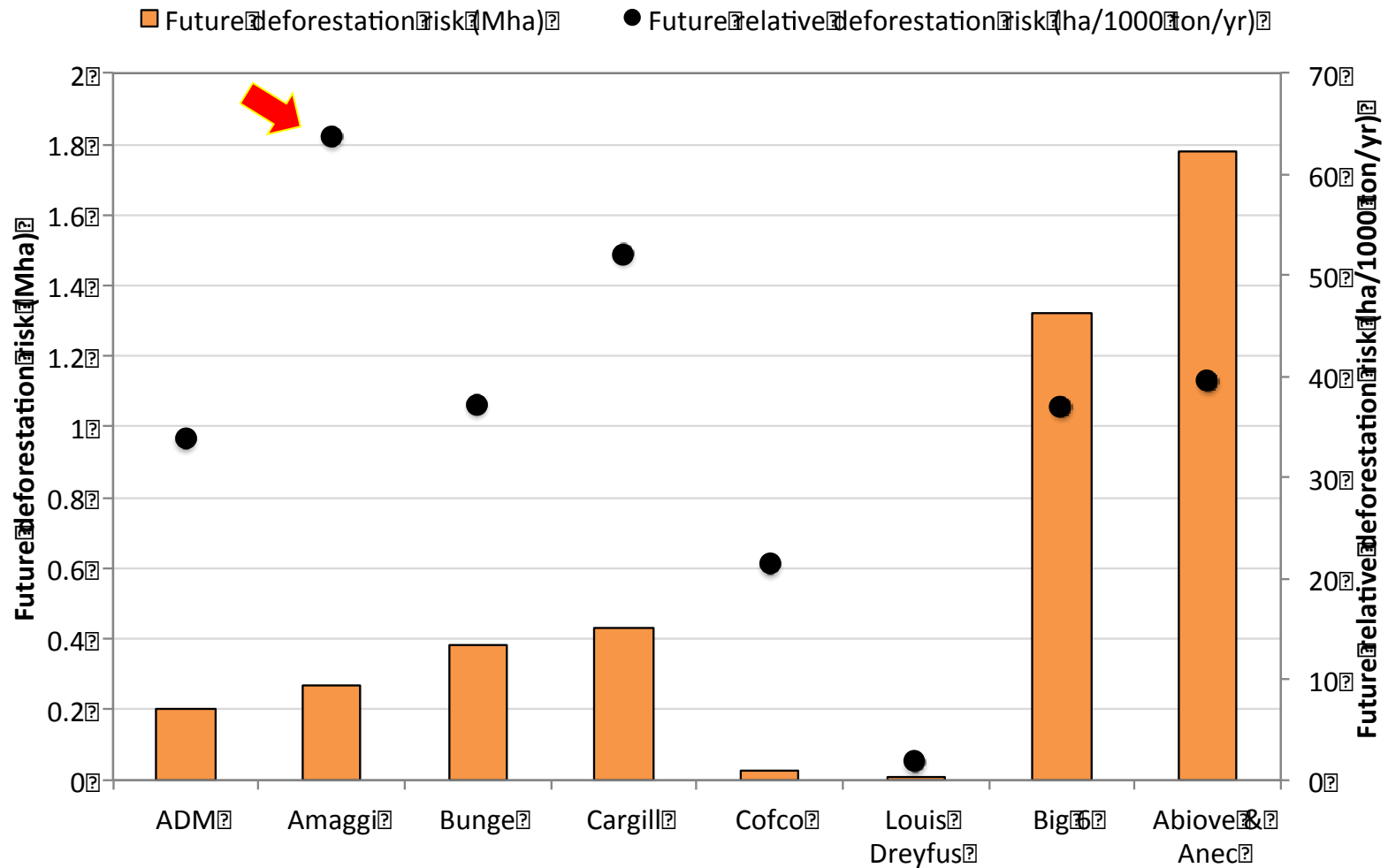
Soy sourced (2015): 3.6 Mton

Risk of deforestation
0.43 Mha (12% of
future deforestation to soy)

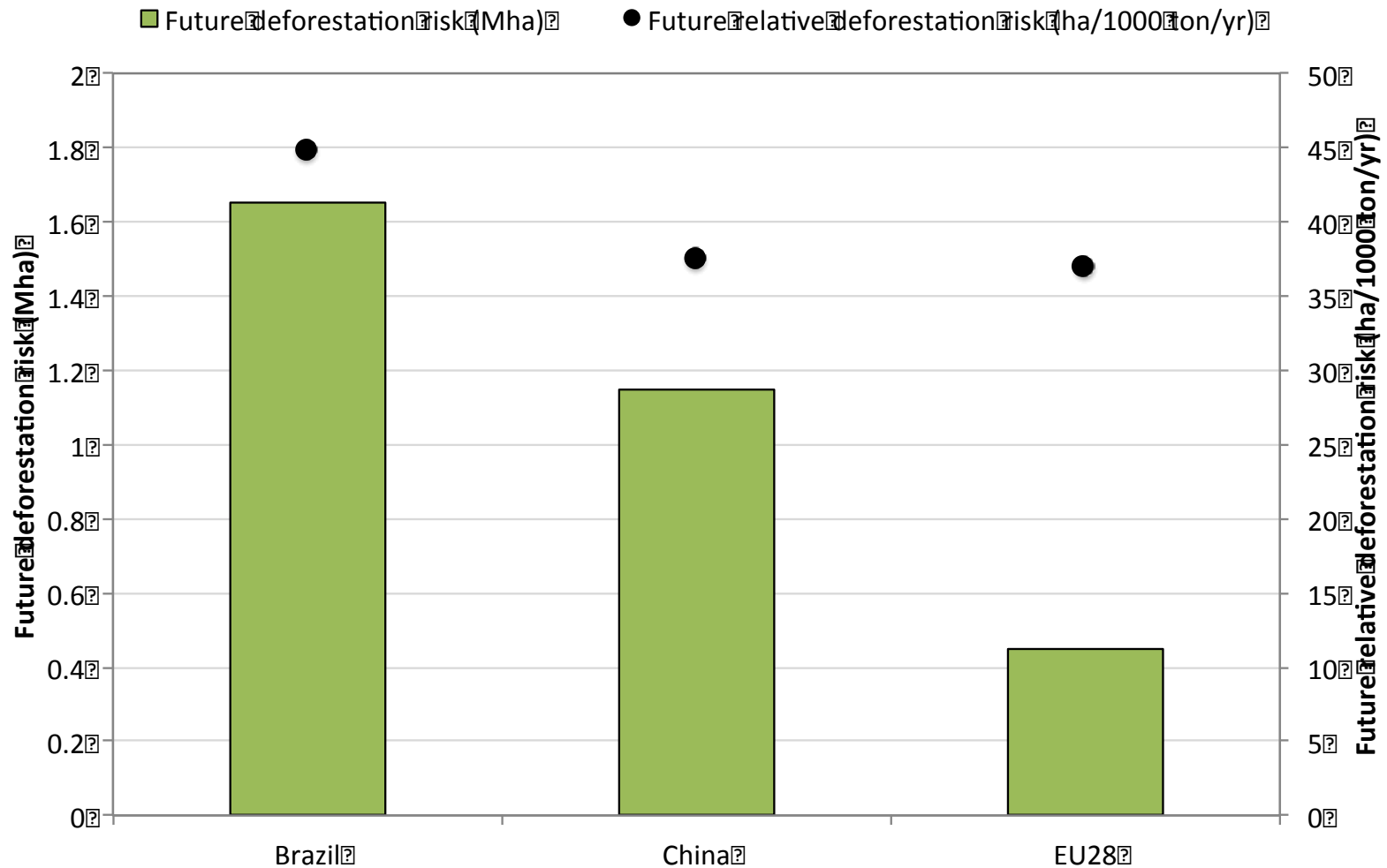
Deforestation risk (absolute and relative)



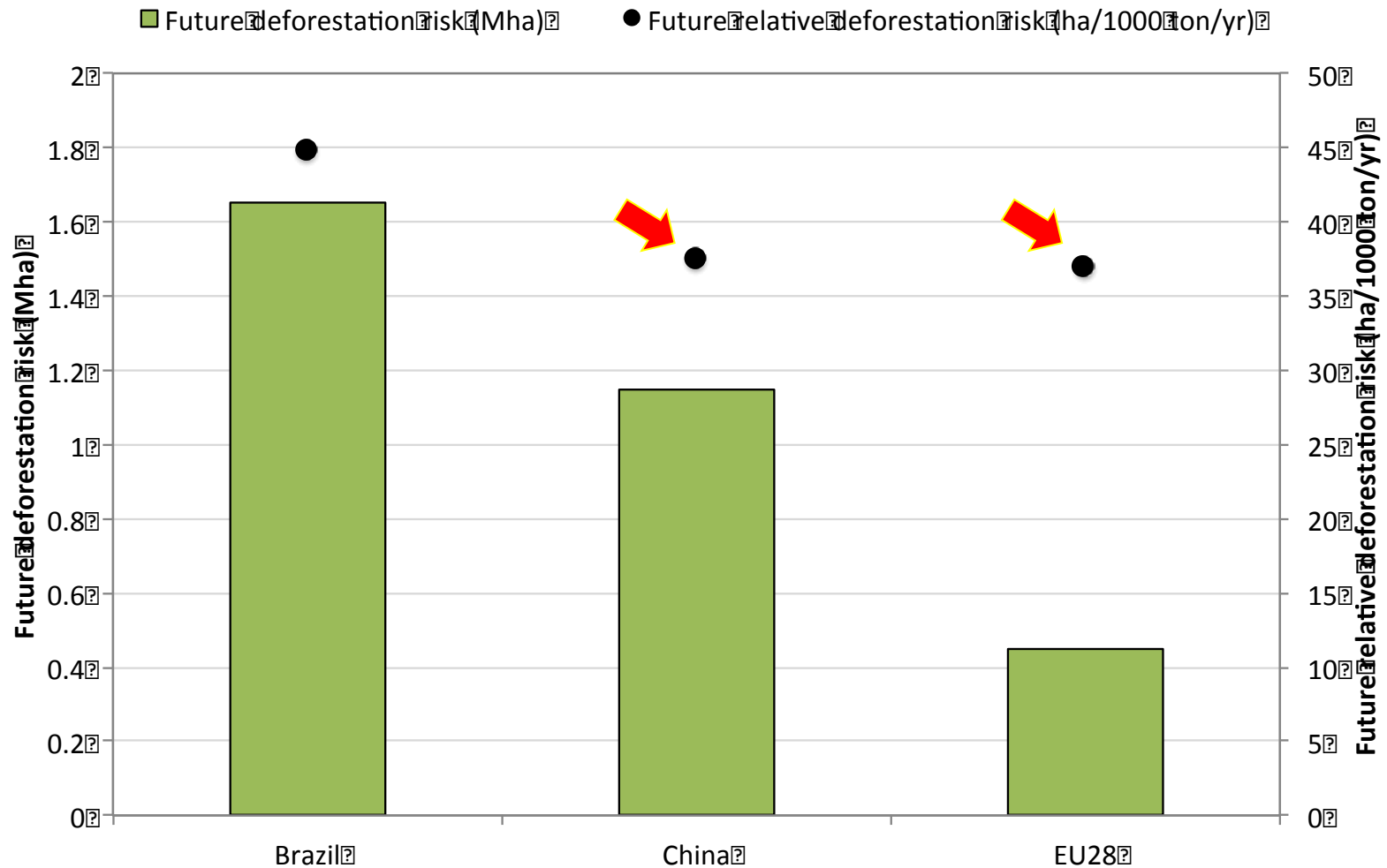
Deforestation risk (absolute and relative)



Deforestation risk (absolute and relative)



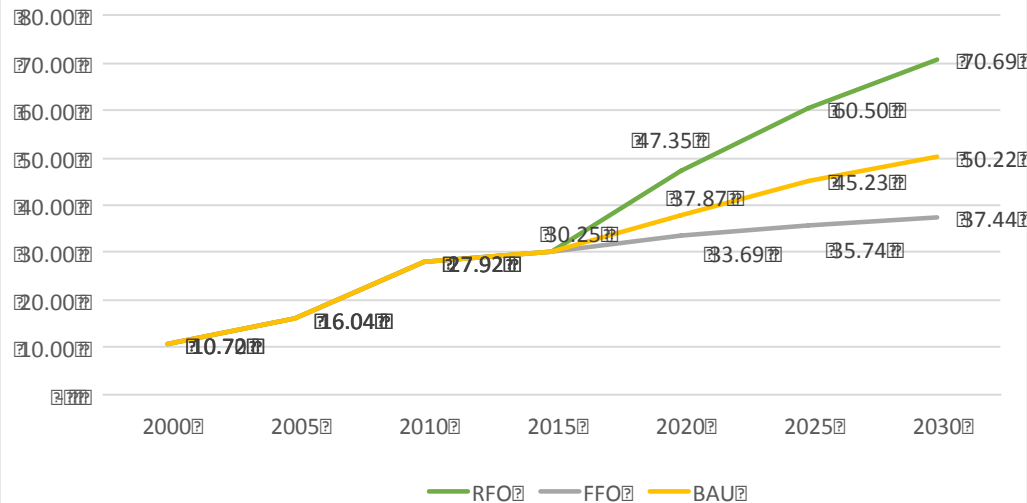
Deforestation risk (absolute and relative)



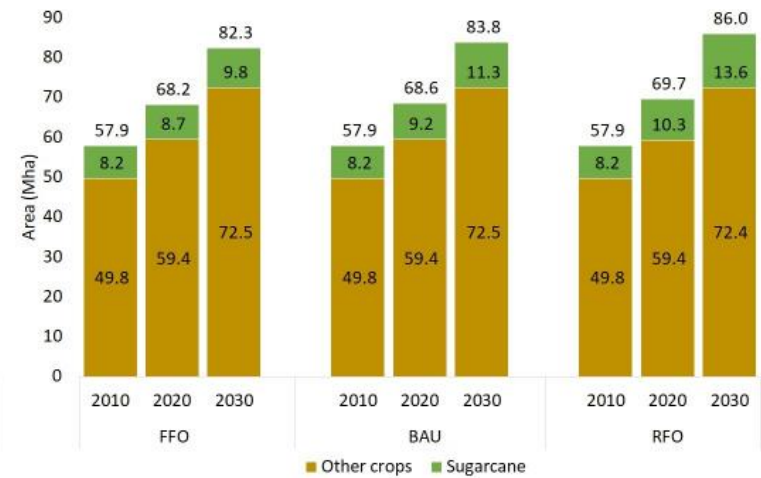
Overview of other policy studies

Biofuels

New scenarios (billion litres)



Cropland area



Energy Policy
Volume 134, November 2019, 110958



Exploring future scenarios of ethanol demand in Brazil and their land-use implications

Milton Aurelio Uba de Andrade Junior ^{a, b} ✉, Hugo Valin ^c, Aline C. Soterroni ^{c, d} ✉, Fernando M. Ramos ^d, Anthony Halog ^a

Climate change impacts

RESTORE+ BRAZIL
MODELING GROUP

Anthropic
Disturbances

GHG Emissions
and RCPs

Radiative forcing and
climatic scenarios

Climatic Impacts

Global Climate Model
– CMIP5/ISIMIP

Global projections of
temperature, precipitation,
moisture

Biophysical Impacts

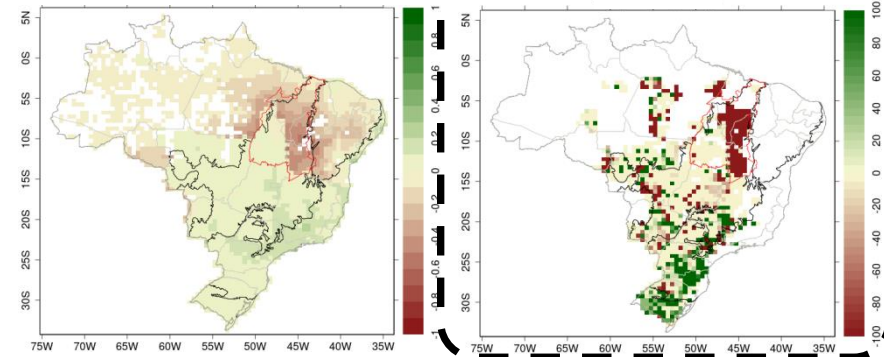
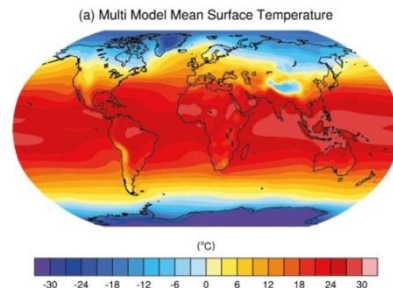
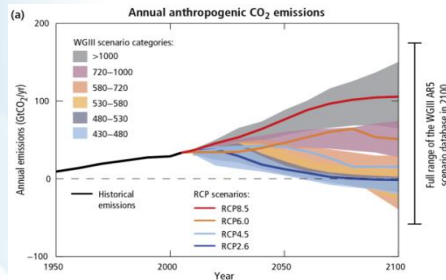
Global Crop Model
– ISIMIP

Global projections of
crop productivity (crops
+ grass)

Economic Impacts

GLOBIOM-Brazil

Global changes in land use,
supply and demand,
bilateral trade



RCP 2.6

RCP 8.5

HadGEM-ES

MIROC-ESM

NorESM1-M

GFDL-ESM2M

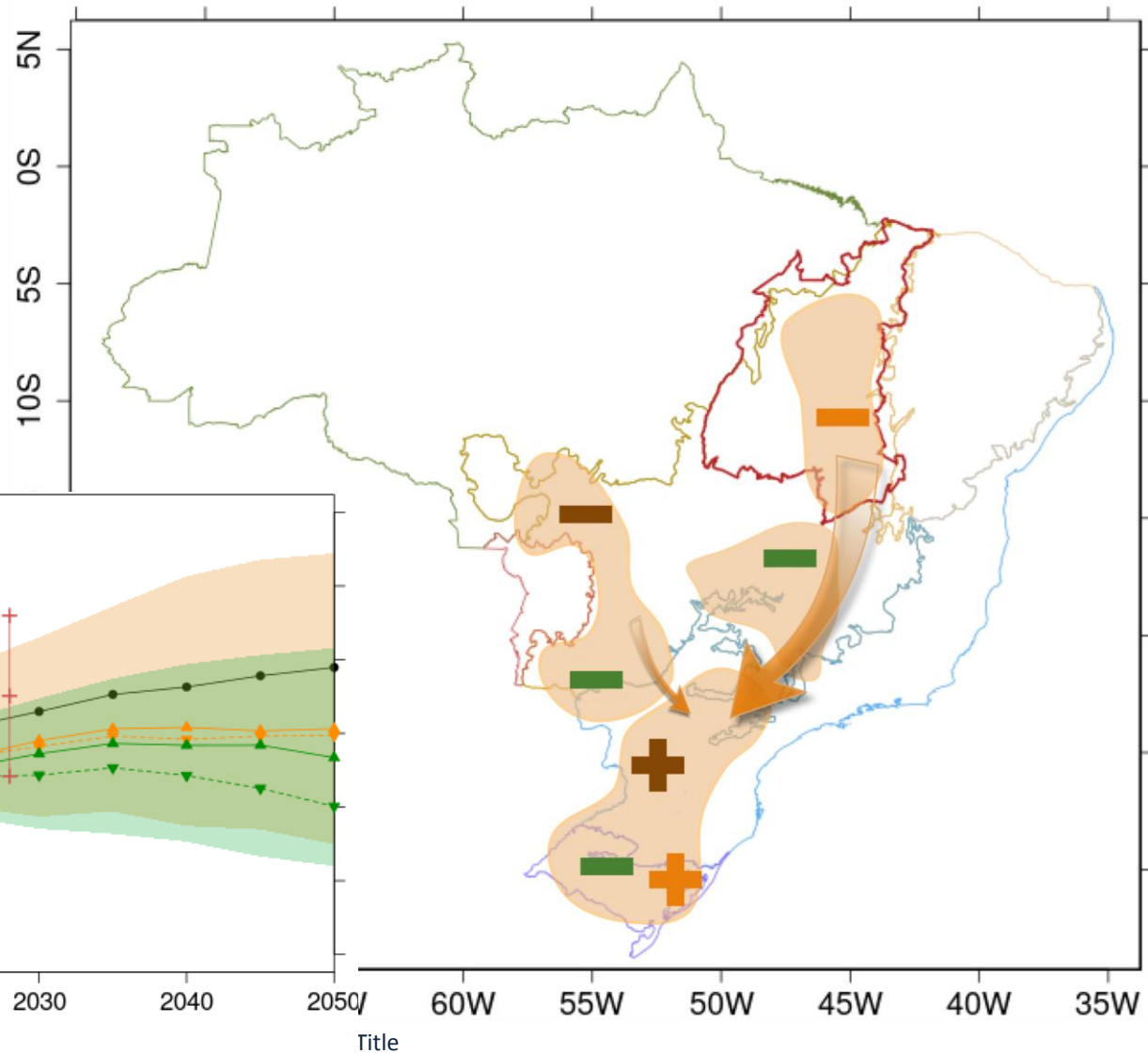
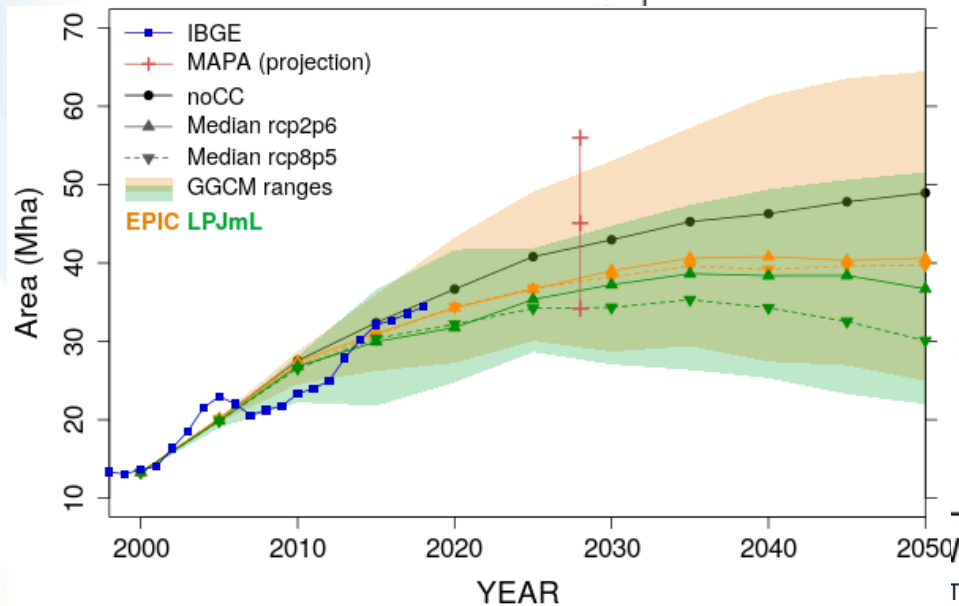
IPSL-CM5A

EPIC

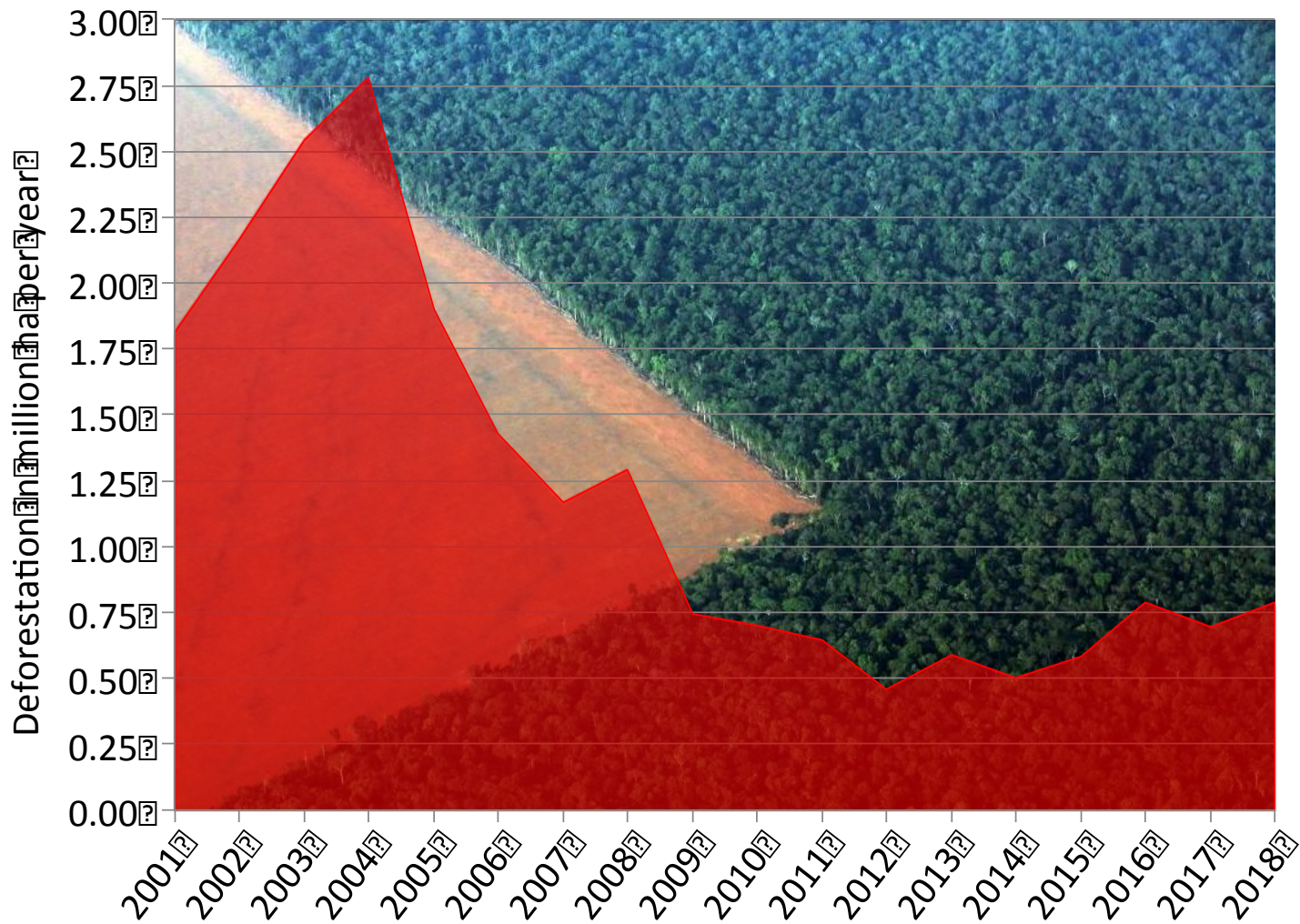
LPJmL

Climate change impacts

Impacts on
soybean area
in Brazil



Fragile Brazil's NDC commitments?



*Deforestation numbers from PRODES

Obrigada! Thank you!

soterr@iiasa.ac.at
aline.soterroni@inpe.br
alinecsoterroni@gmail.com

“Essentially, all models are wrong, but some are useful”
George E.P. Box



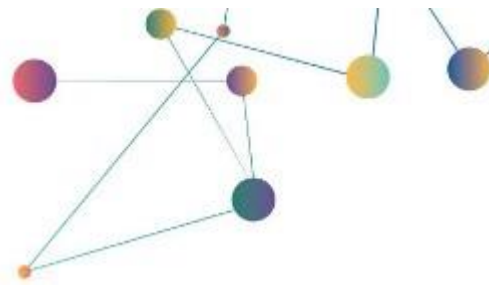
Supported by:



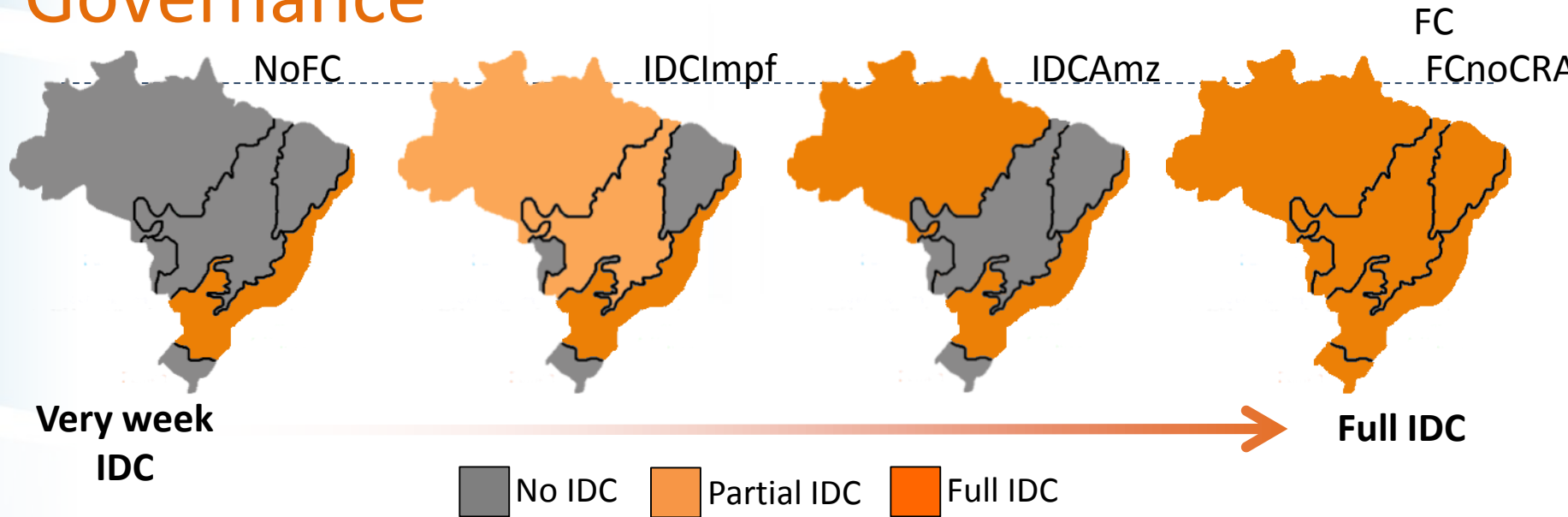
Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

based on a decision of the German Bundestag

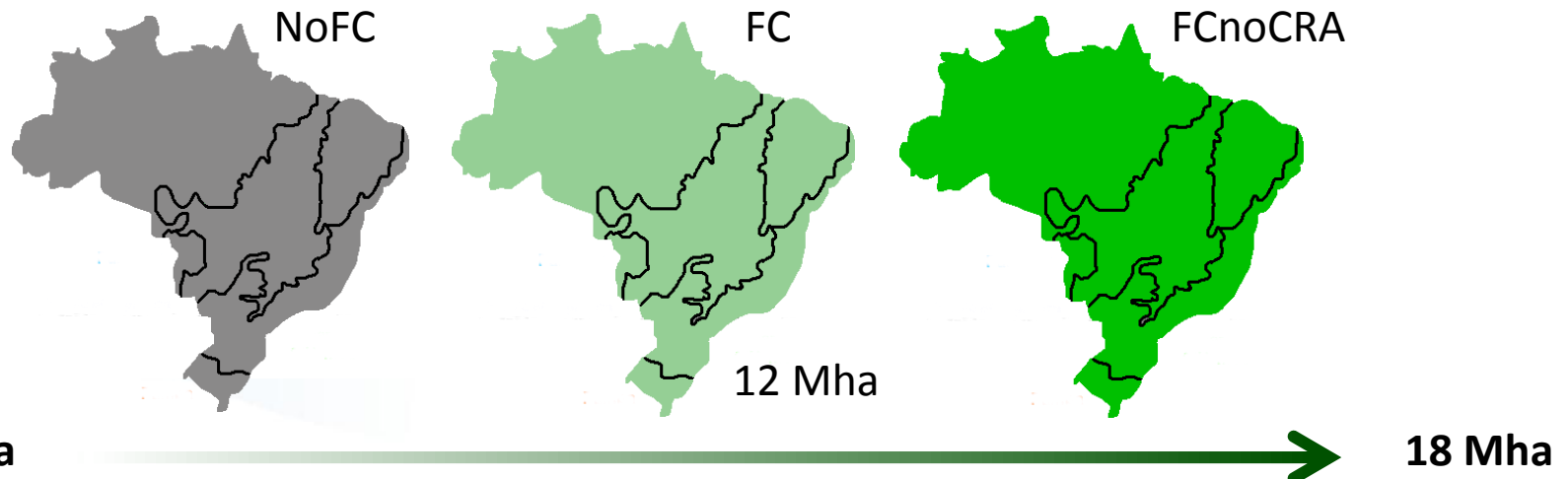
**Systems Analysis
and the Americas**



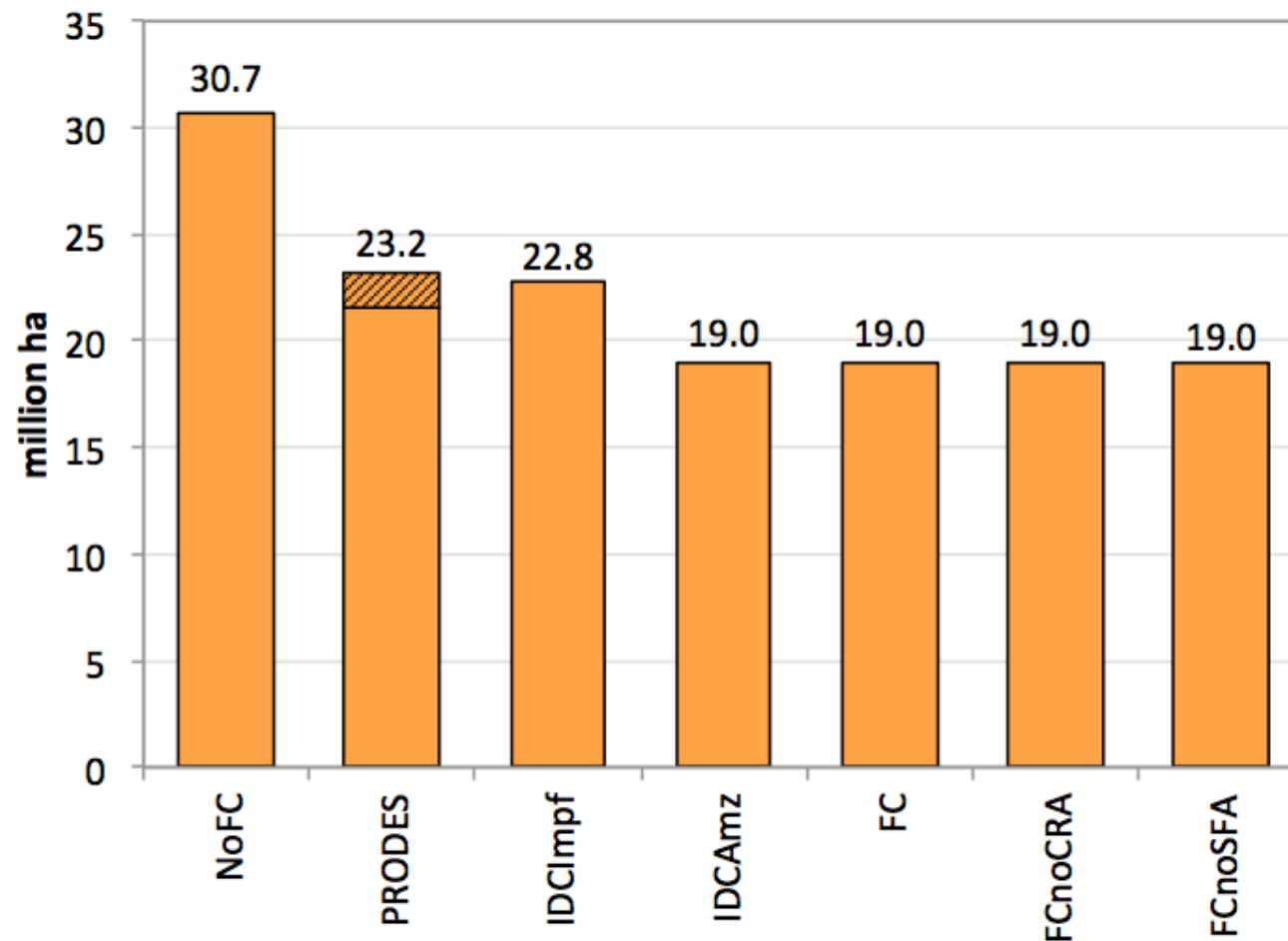
Governance



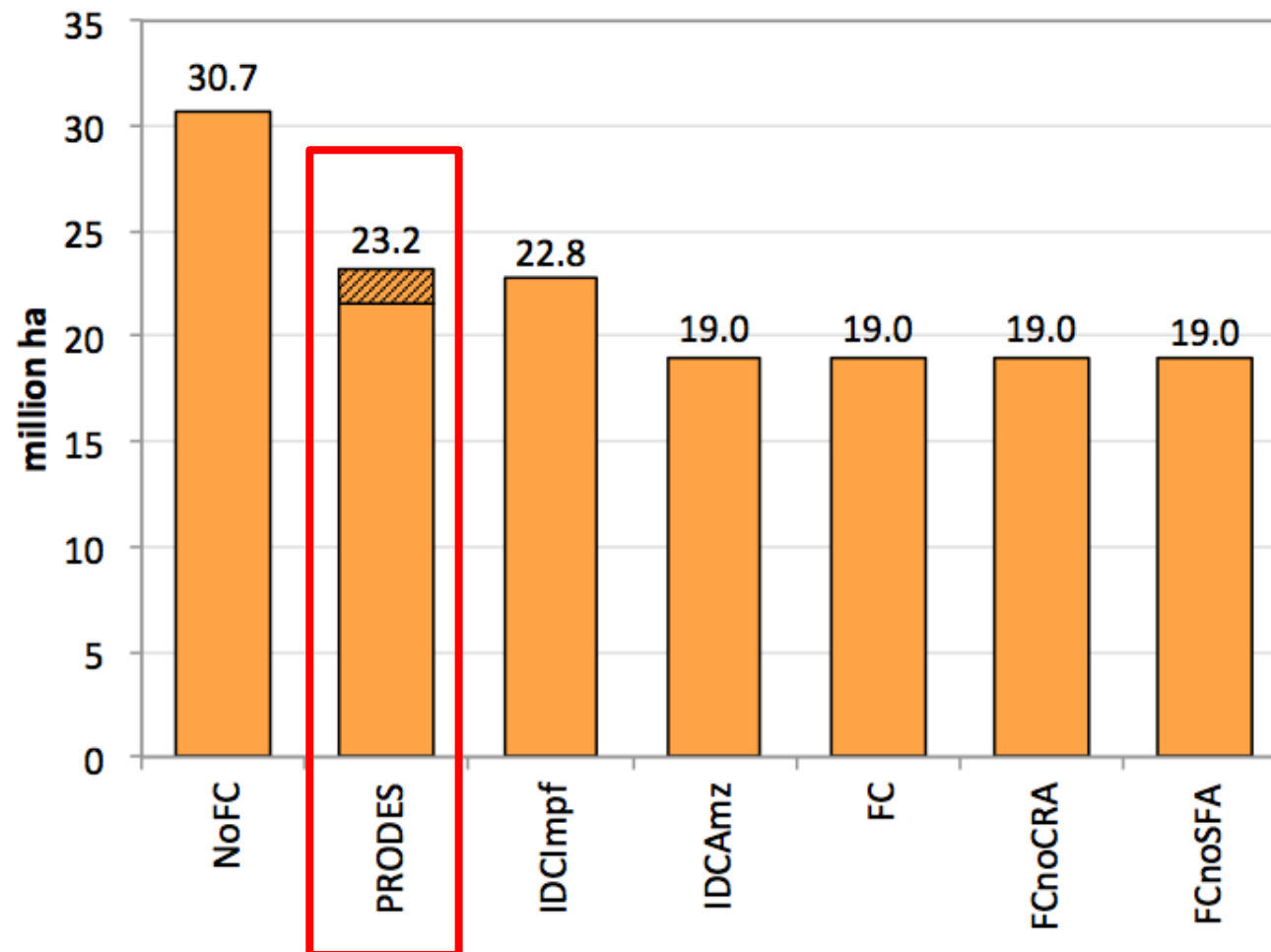
Restoration



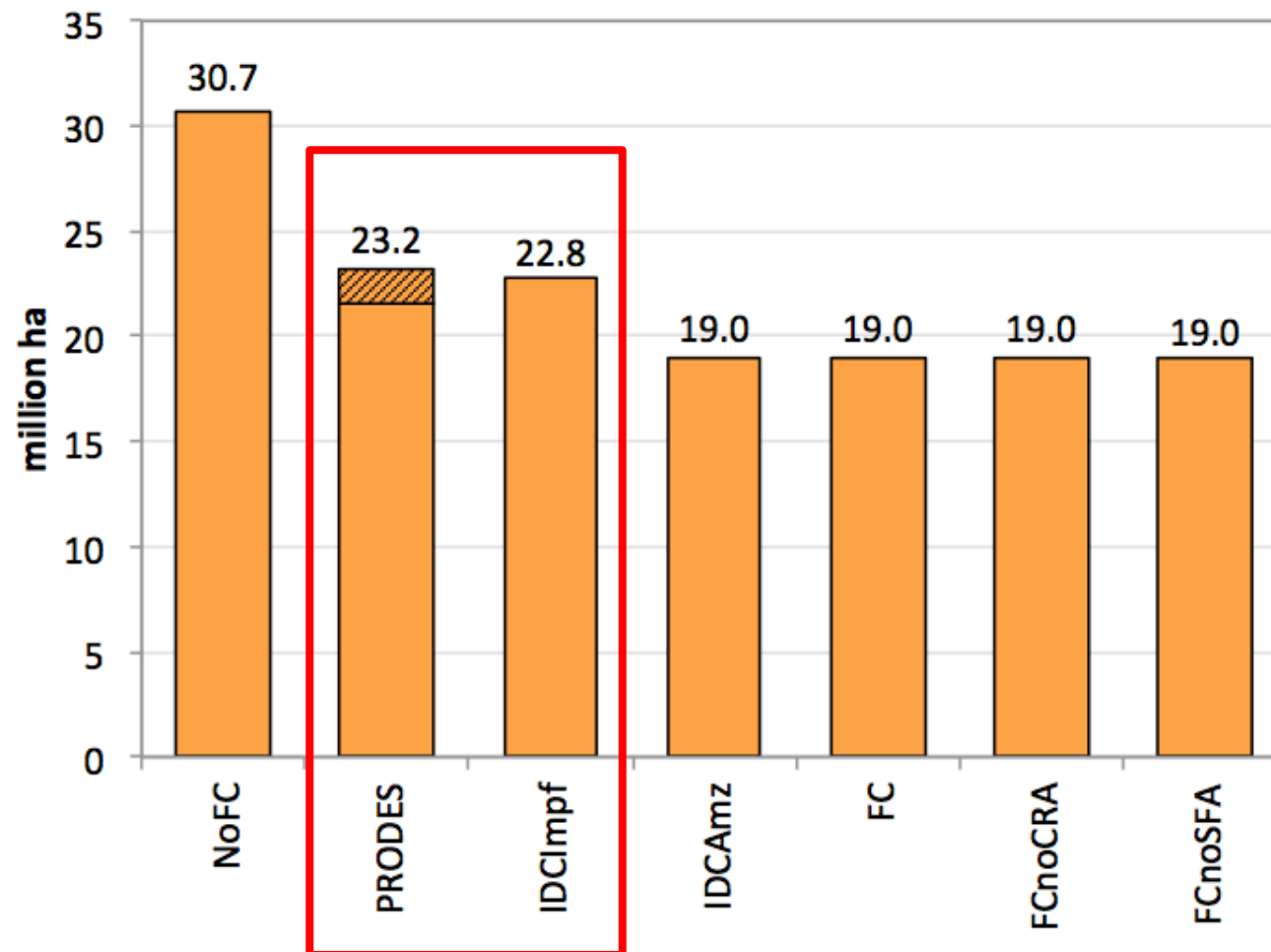
Accumulated deforestation (2001-2020)



Accumulated deforestation (2001-2020)



Accumulated deforestation (2001-2020)



Total emissions – LUCF sector – Brazil

