Are Sugarcane Biofuels Worth the Costs in Brazil?

Dr. Solange Filoso

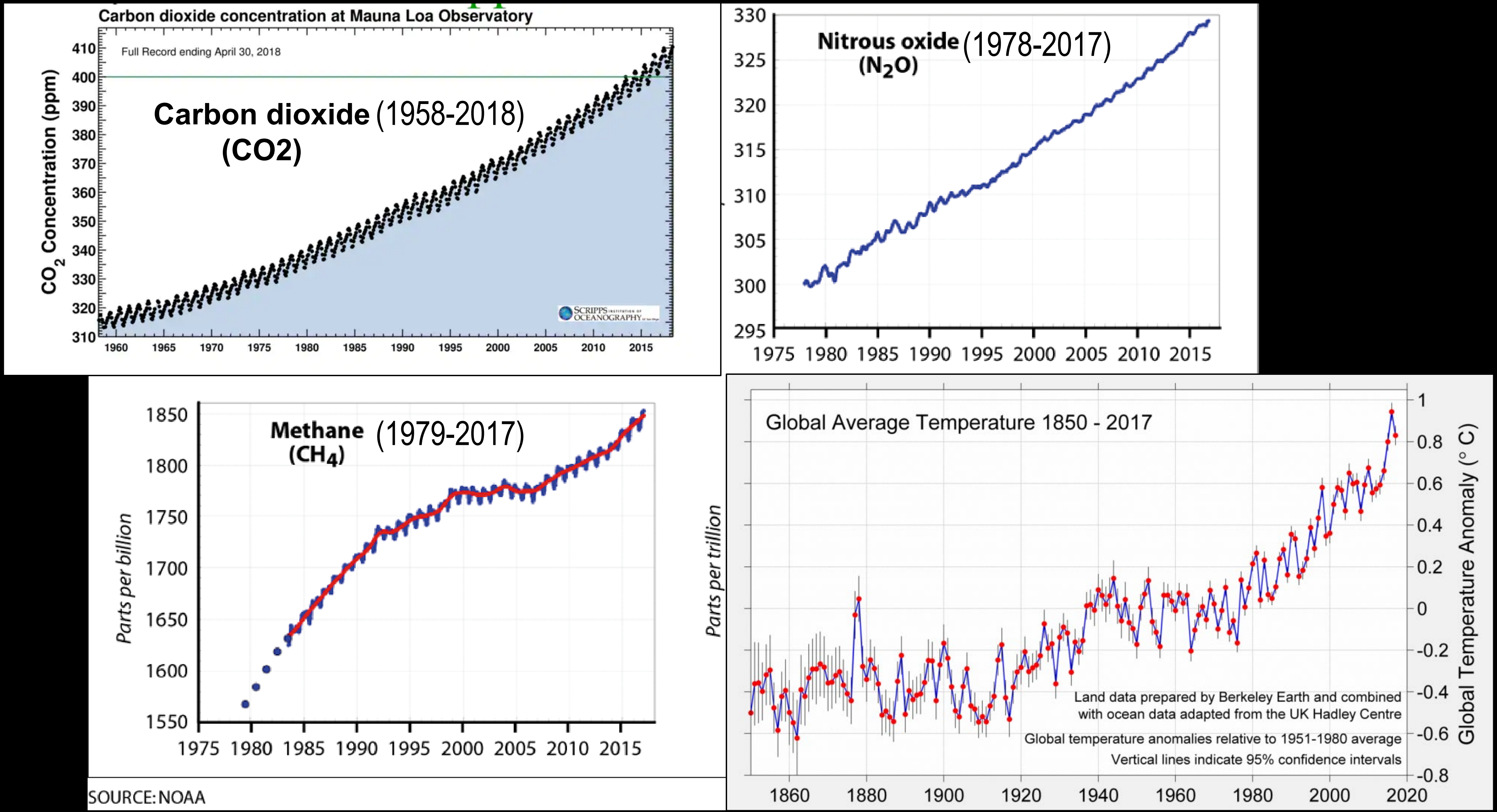
Chesapeake Biological Laboratory

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Outline

- Quick overview: Global warming, greenhouse gases emissions and goals for reductions
- Sugarcane ethanol:
  - How it is produced
  - Advantages and concerns
- Specific environmental issues of sugarcane biofuel production in Brazil
- Possible solutions

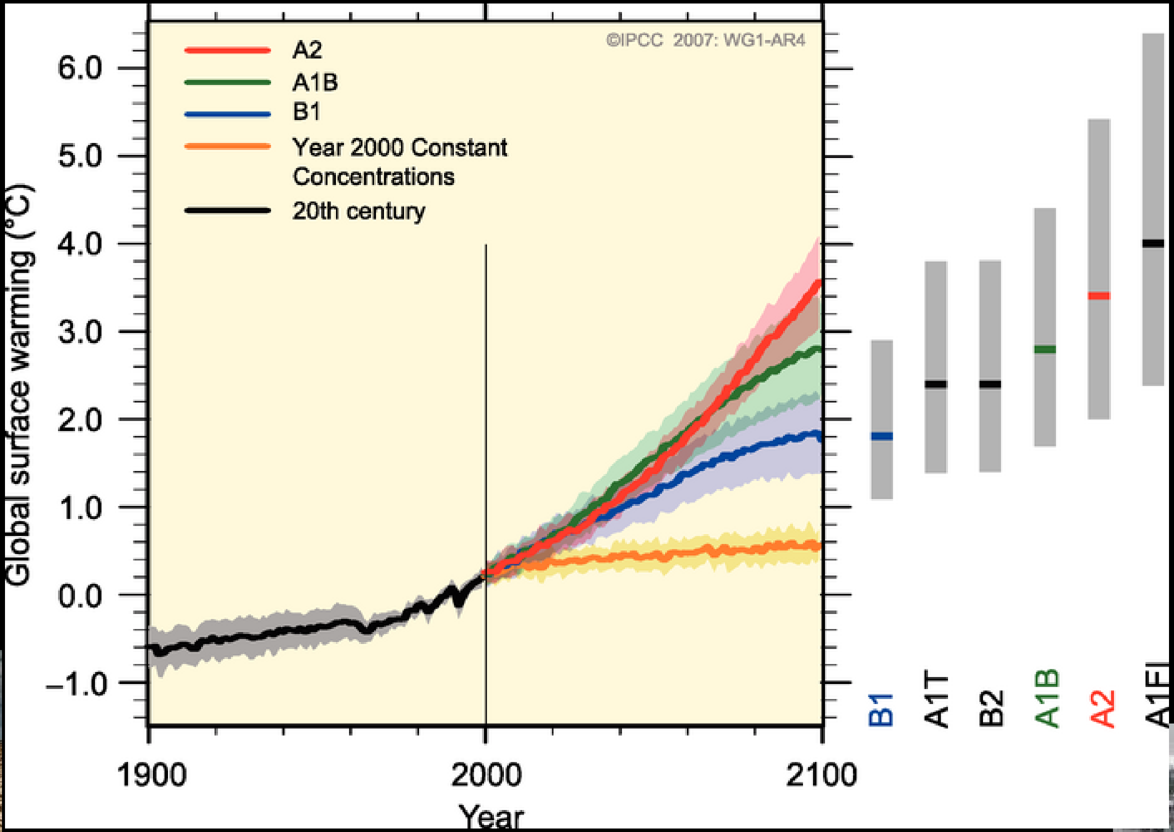
GHG Emissions & Global Warming



Projections of Future Global Temperatures

Artic Meltdown

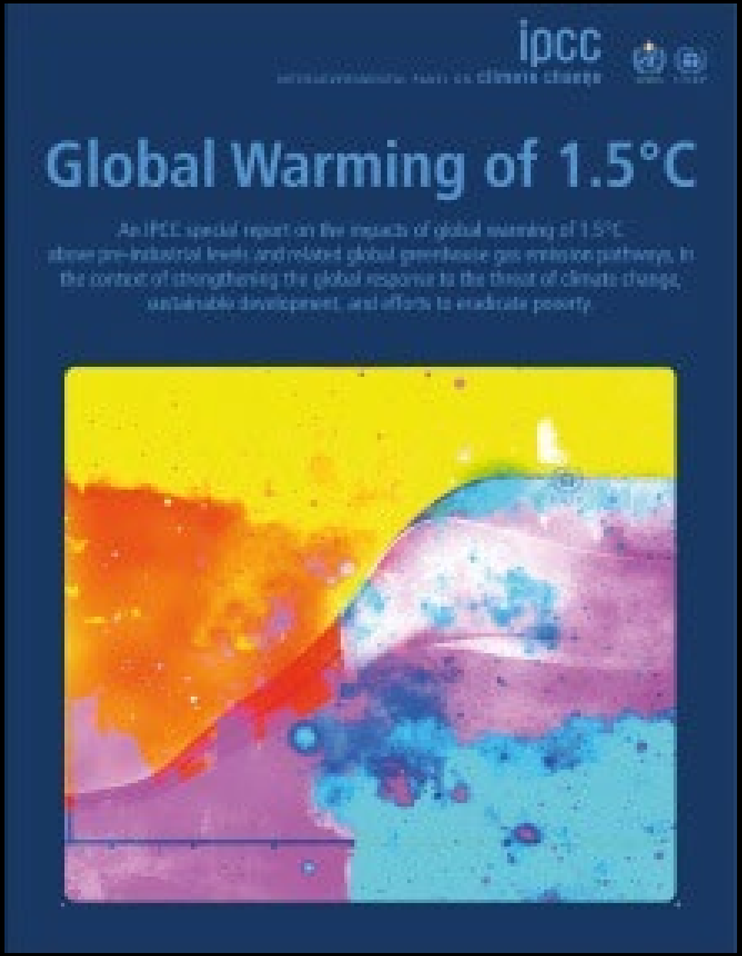
Severe Droughts



Melting Ice Sheets

Sea Level Rise

A special IPCC report came out on Monday!

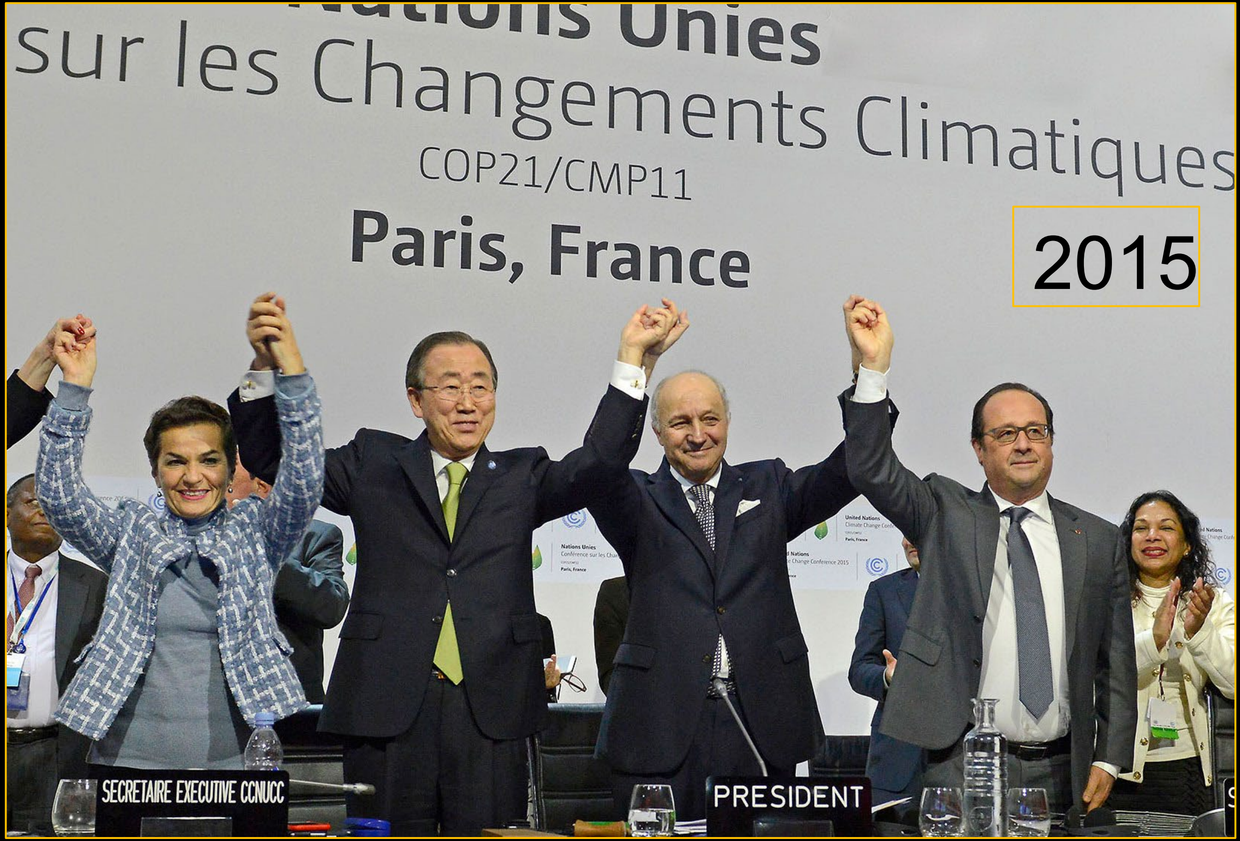


Limiting global warming to 1.5 degrees versus 2 has big benefits, the IPCC says.

From the Earth Summit in Rio de Janeiro to the Paris Agreement

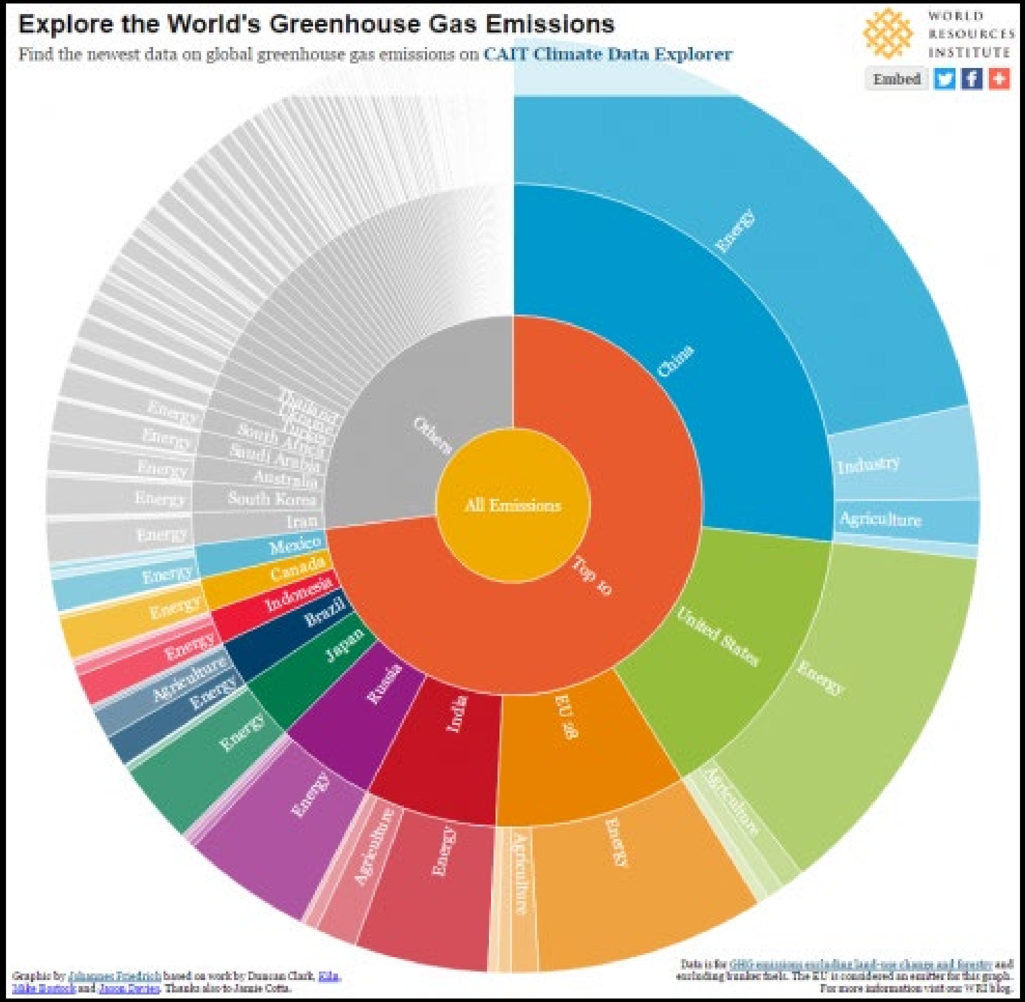
1992

2015



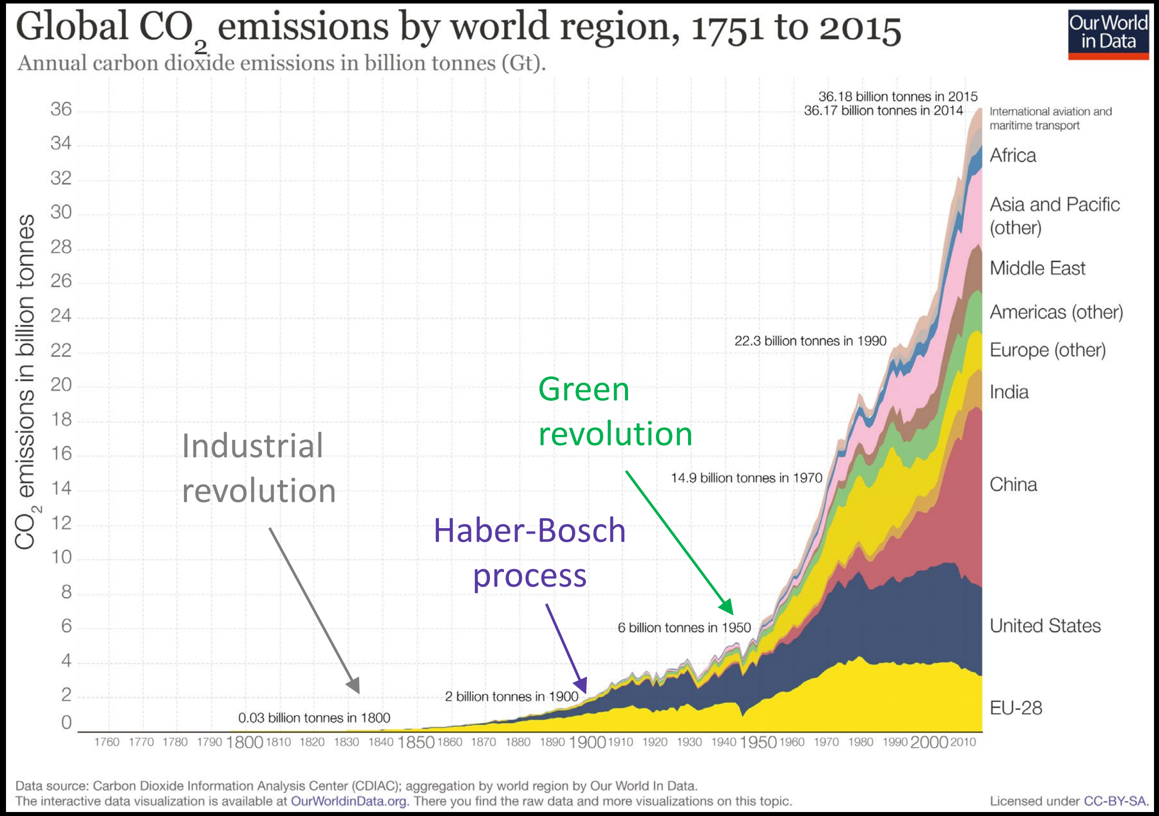
Greenhouse Gas Emissions

Present

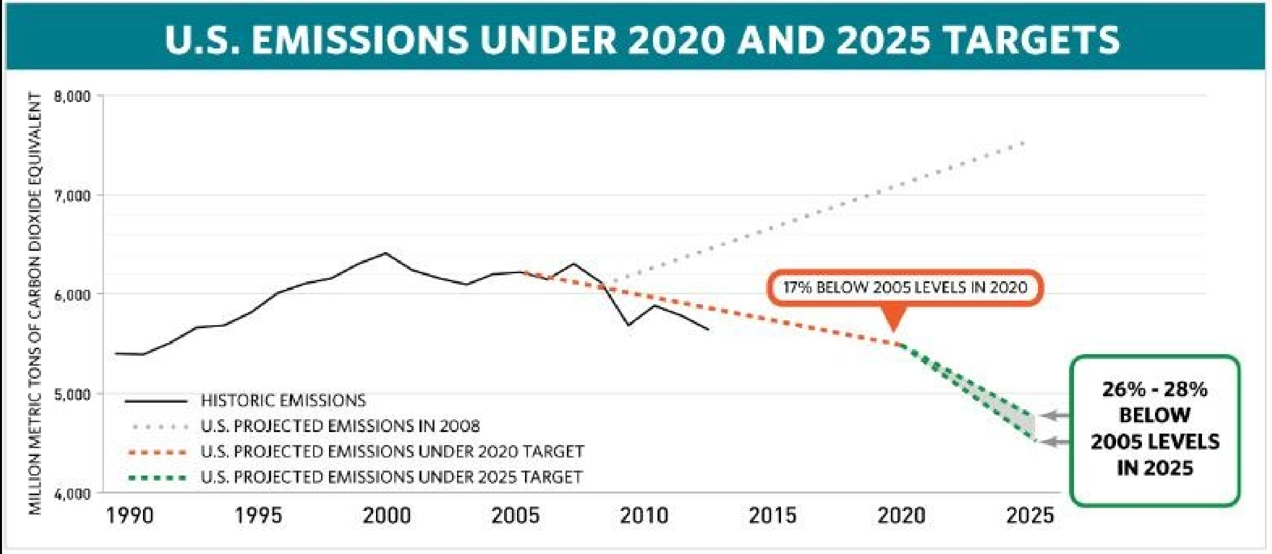


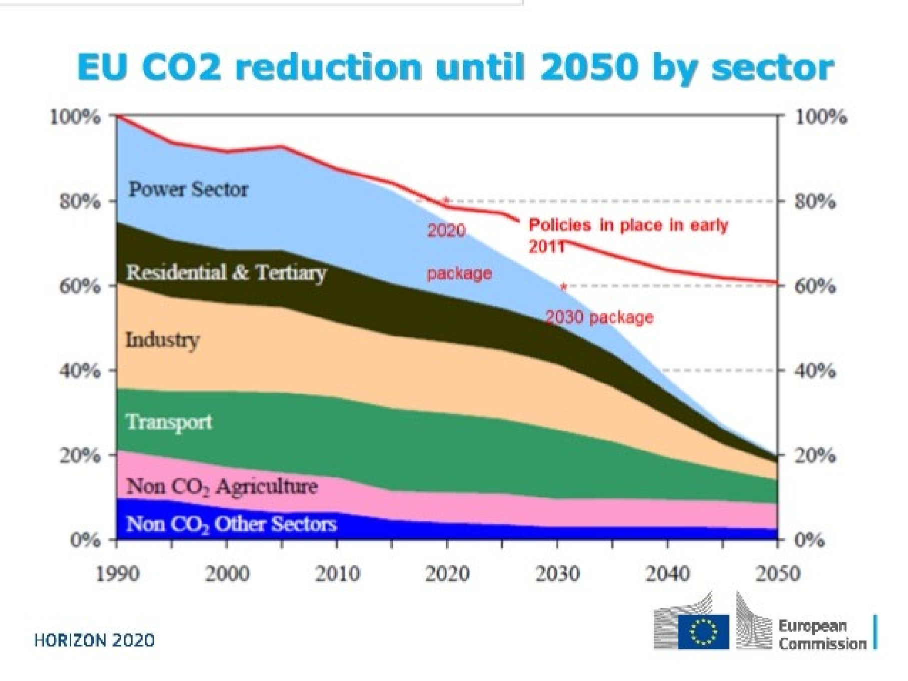
Source: World Resources Institute

~1800 to 2015



Source: EDGAR European Commission

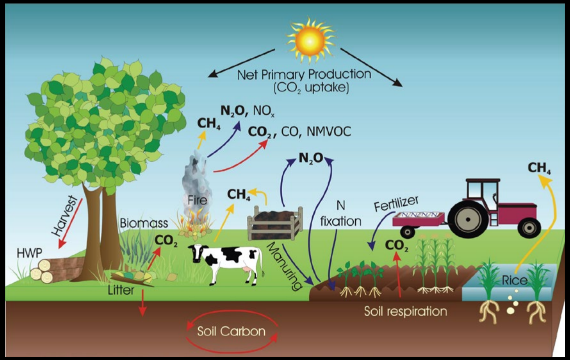

U.S. EMISSIONS UNDER 2020 AND 2025 TARGETS
MILLION METRIC TONS OF CARBON DIOXIDE EQUIVALENT
8,000
7,000
6,000
5,000
4,000
1990
1995
2000
2005
2010
2015
2020
2025
HISTORIC EMISSIONS
U.S. PROJECTED EMISSIONS IN 2008
U.S. PROJECTED EMISSIONS UNDER 2020 TARGET
U.S. PROJECTED EMISSIONS UNDER 2025 TARGET
17% BELOW 2005 LEVELS IN 2020
26% - 28% BELOW 2005 LEVELS IN 2025

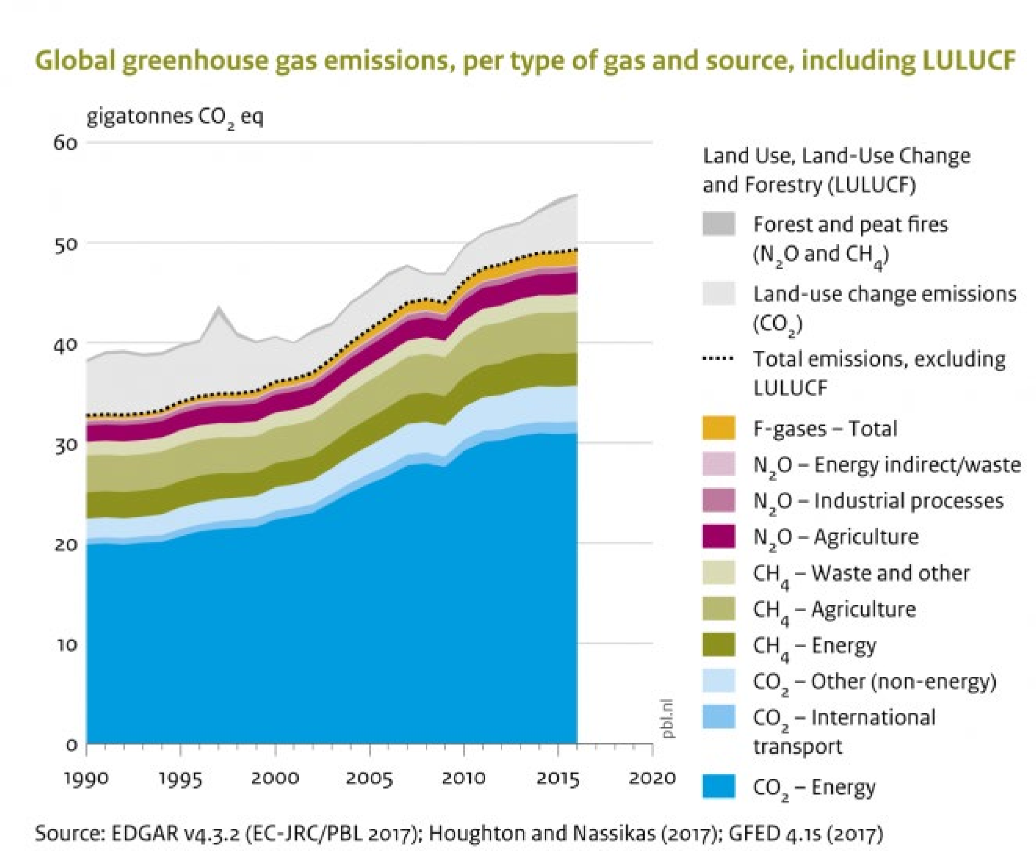

EU CO2 reduction until 2050 by sector
100%
80%
60%
40%
20%
0%
Power Sector
Residential & Tertiary
Industry
Transport
Non CO_2 Agriculture
Non CO_2 Other Sectors
2020 package
2030 package
Policies in place in early 2011
1990
2000
2010
2020
2030
2040
2050
HORIZON 2020
European Commission

Greenhouse Gas Emissions

Energy Generation

Agriculture





Transportation

Land-use Change

Carbon dioxide equivalent (CO_2 eq) is a measure used to compare the **emissions** from various greenhouse gases based upon their global warming potential. ... This **means**that **emissions** of one million metric tons of methane is **equivalent** to **emissions** of 21 million metric tons of **carbon dioxide**

Considered a near-term feasible solution to reduce CO_2 emissions from the transport sector by many countries.

Advantages of Sugarcane Bioethanol

- Highly effective in generating energy
- Highly efficient at converting solar energy into biomass
- Low nitrogen fertilizer requirements
- Sugarcane is a perennial grass
- Low water footprint in agriculture (no irrigation needed)

Brazil’s Sugarcane Agriculture and Ethanol Production

SC harvest area (10^6 ha)

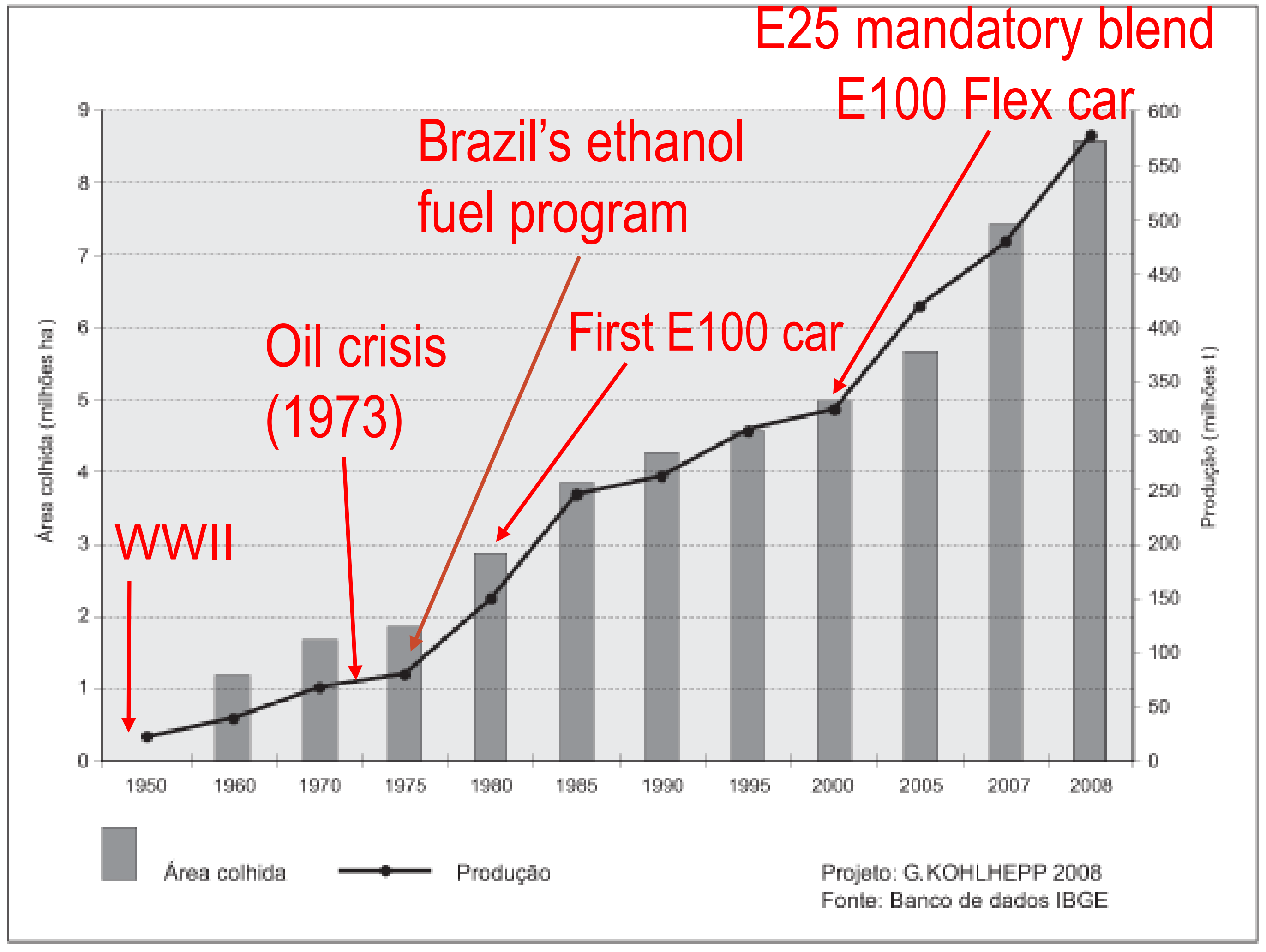


Figura 1 – Área colhida e produção de cana-de-açúcar no Brasil.

SC production (10^6 metric tons)

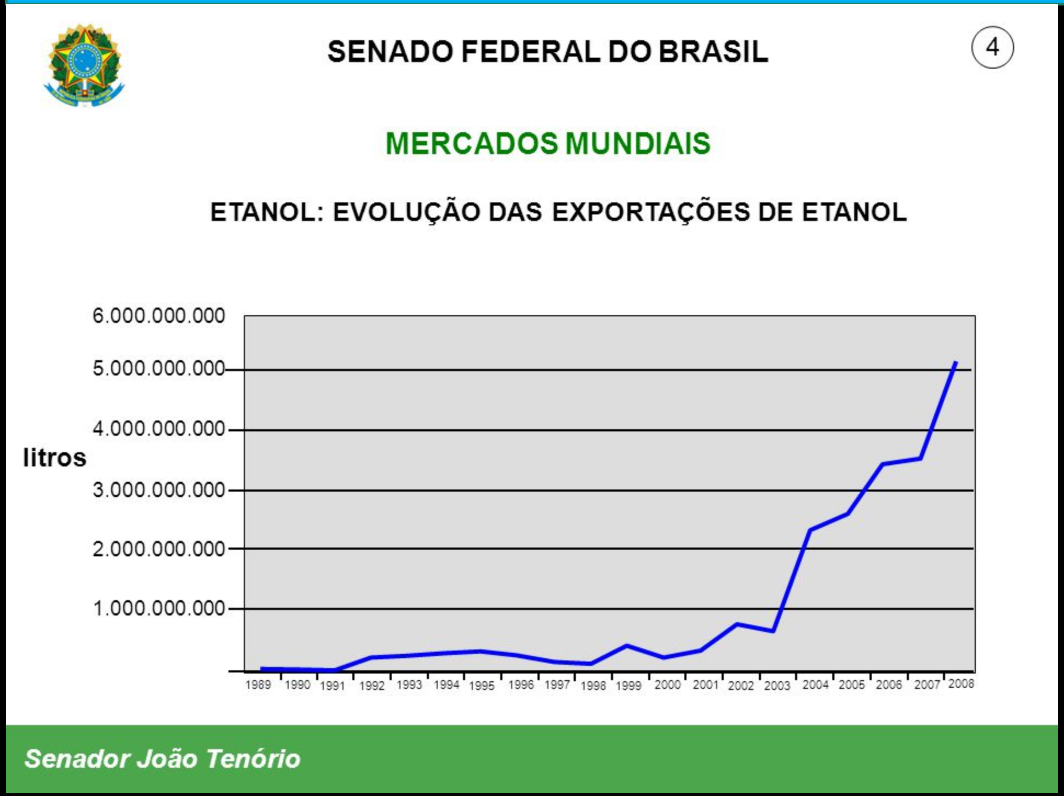
First Brazilian car on 100% ethanol fuel (1979)

First Brazilian E100 flex fuel cars (2003)

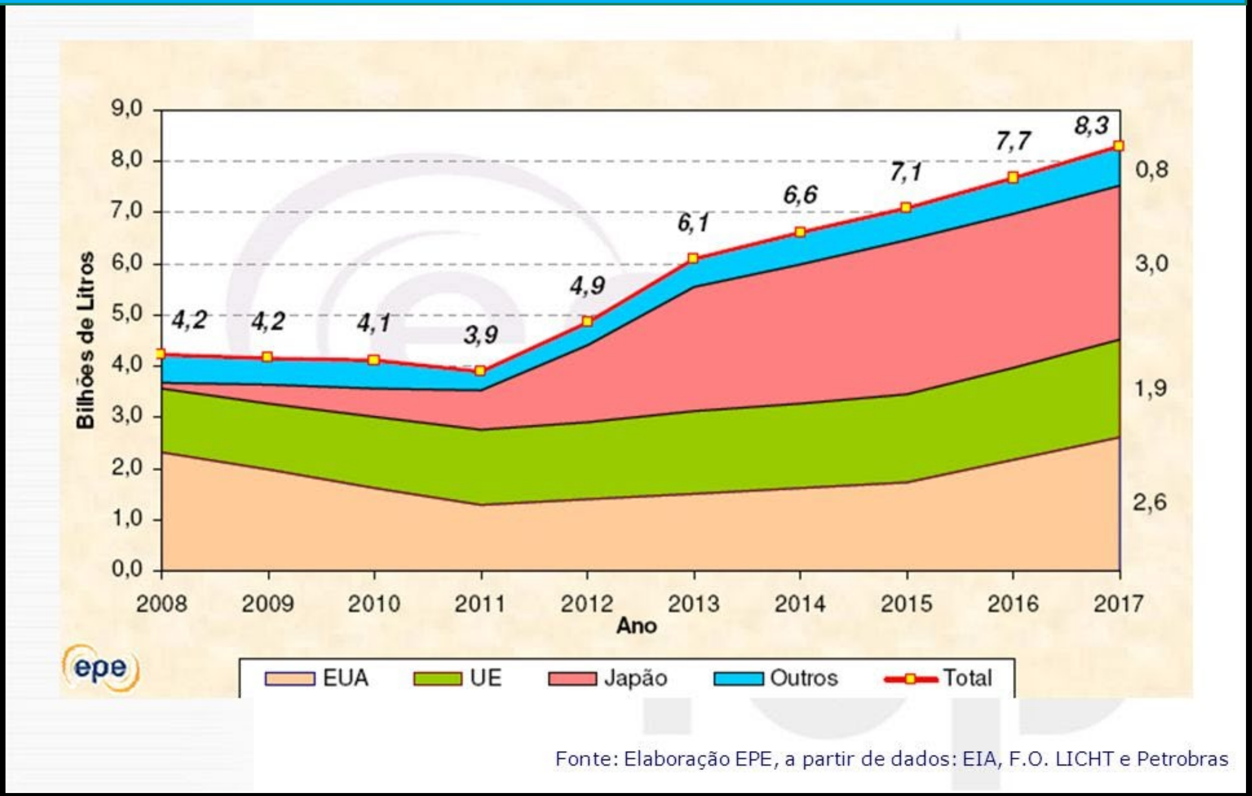
Brazilian Ethanol Export Increases

Brazilian Ethanol Export

1989 - 2008



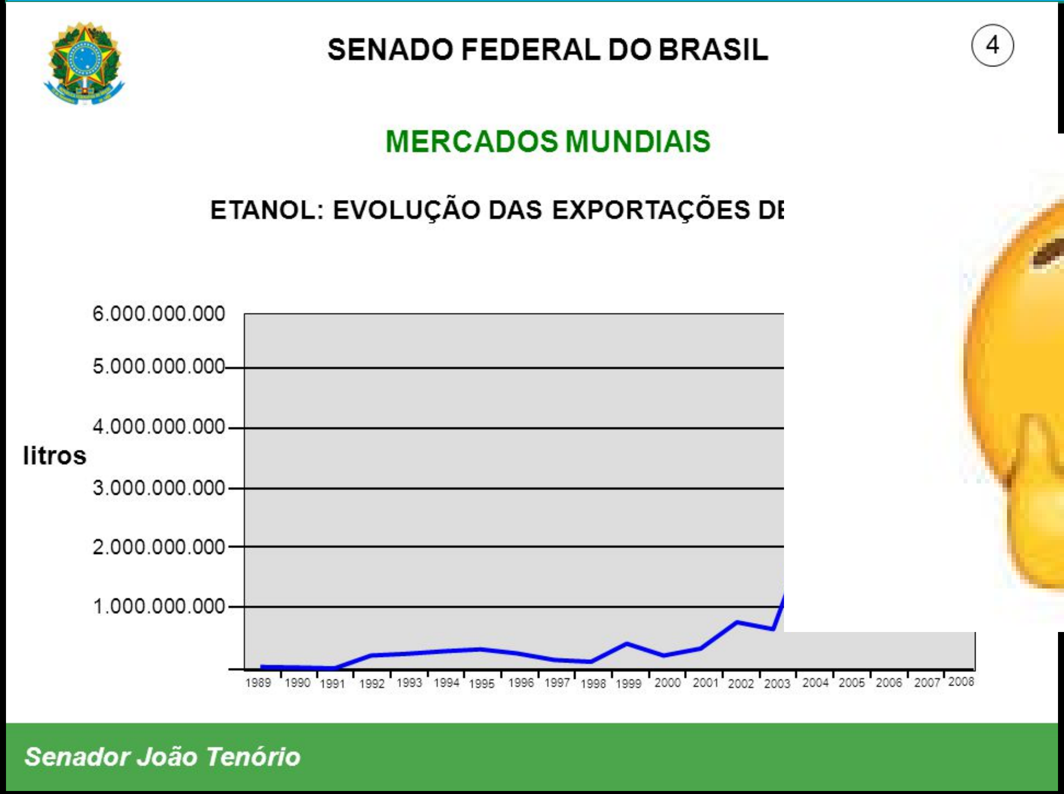
2008 - 2017



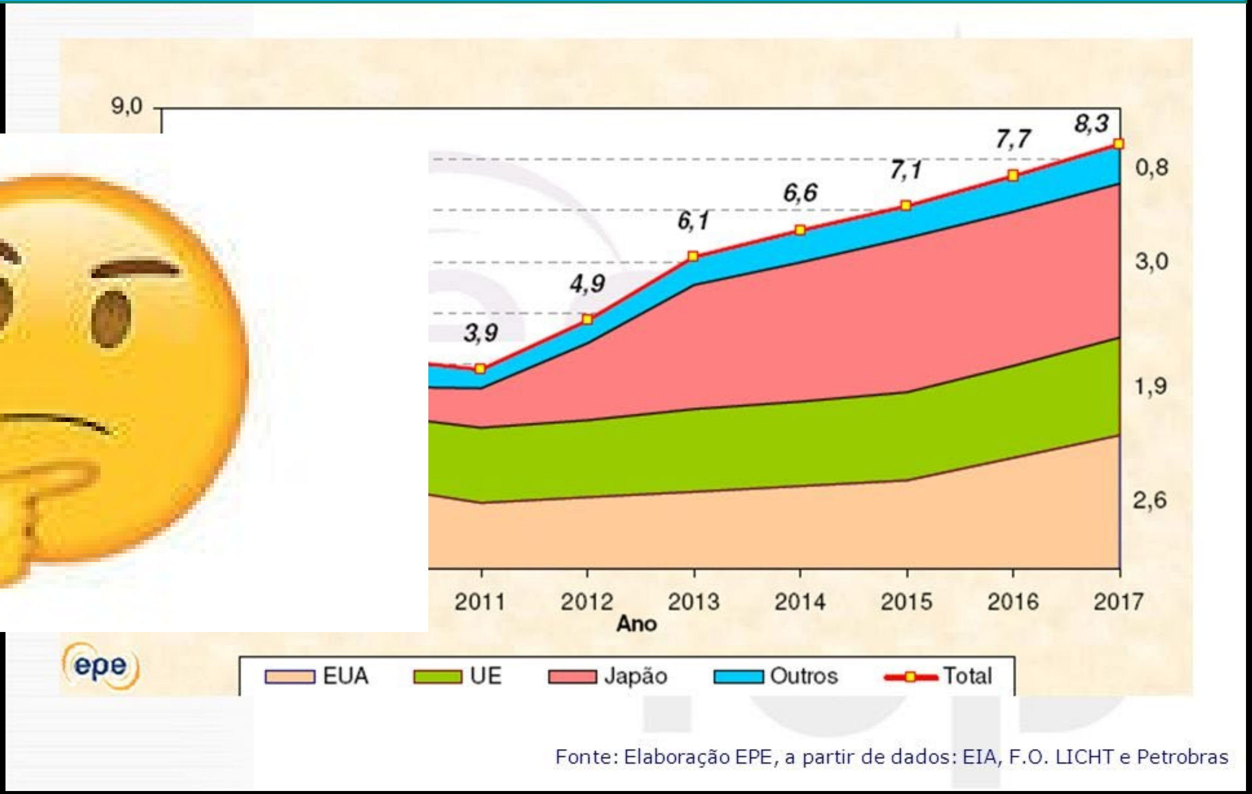
Brazilian Ethanol Export Increases

Brazilian Ethanol Export

1989 - 2008



2008 - 2017



Ecological Applications, 18(4), 2008, pp. 885–898

EXPANSION OF SUGARCANE ETHANOL PRODUCTION IN BRAZIL: ENVIRONMENTAL AND SOCIAL CHALLENGES

Luiz A. Martinelli[1,3] and Solange Filoso[2]

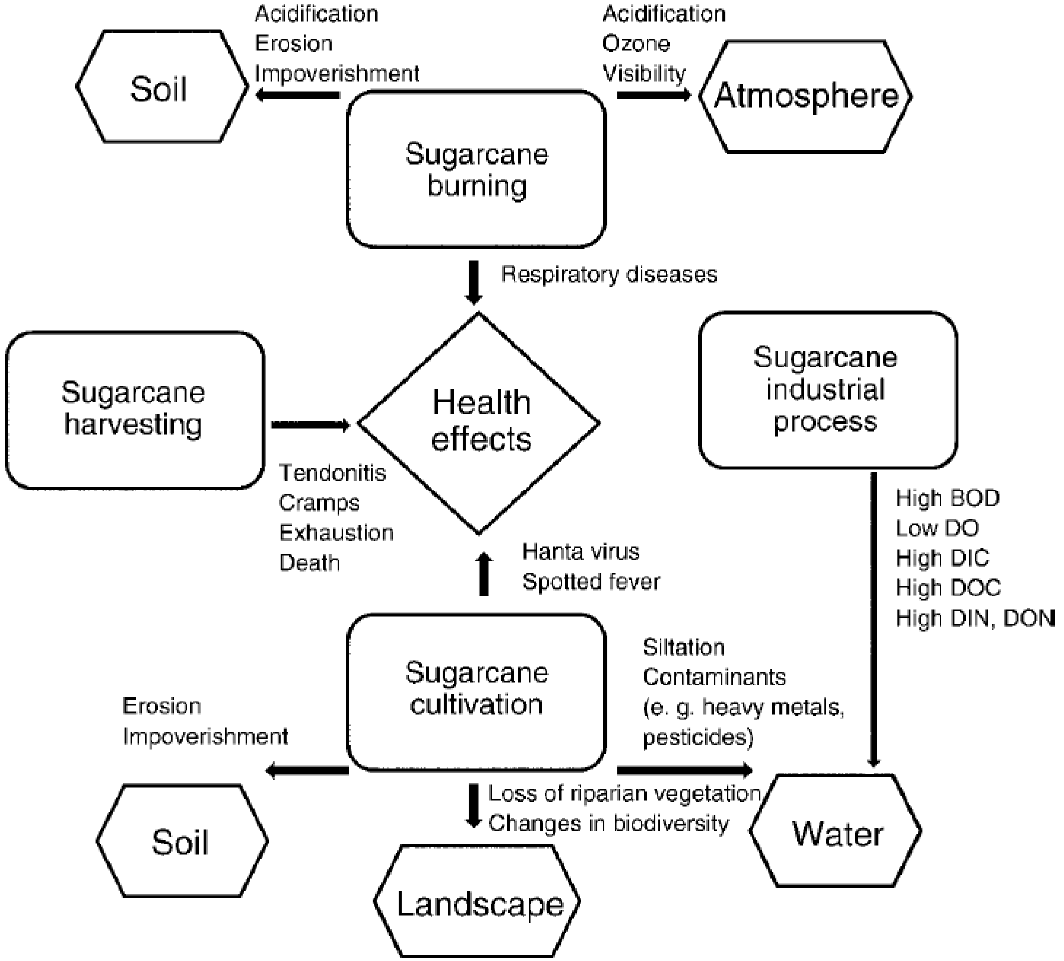


Fig. 5. Diagram showing the main environmental and social impact of the sugar cane agro-industry. For a list of water quality acronyms, see Fig. 4; BOD = biochemical oxygen demand; DO = dissolved oxygen.

Ecological Applications, 18(4), 2008, pp. 885–898

EXPANSION OF SUGARCANE ETHANOL PRODUCTION IN BRAZIL: ENVIRONMENTAL AND SOCIAL CHALLENGES

LUIZ A. MARTINELLI[1,3] AND SOLANGE FILOSO[2]

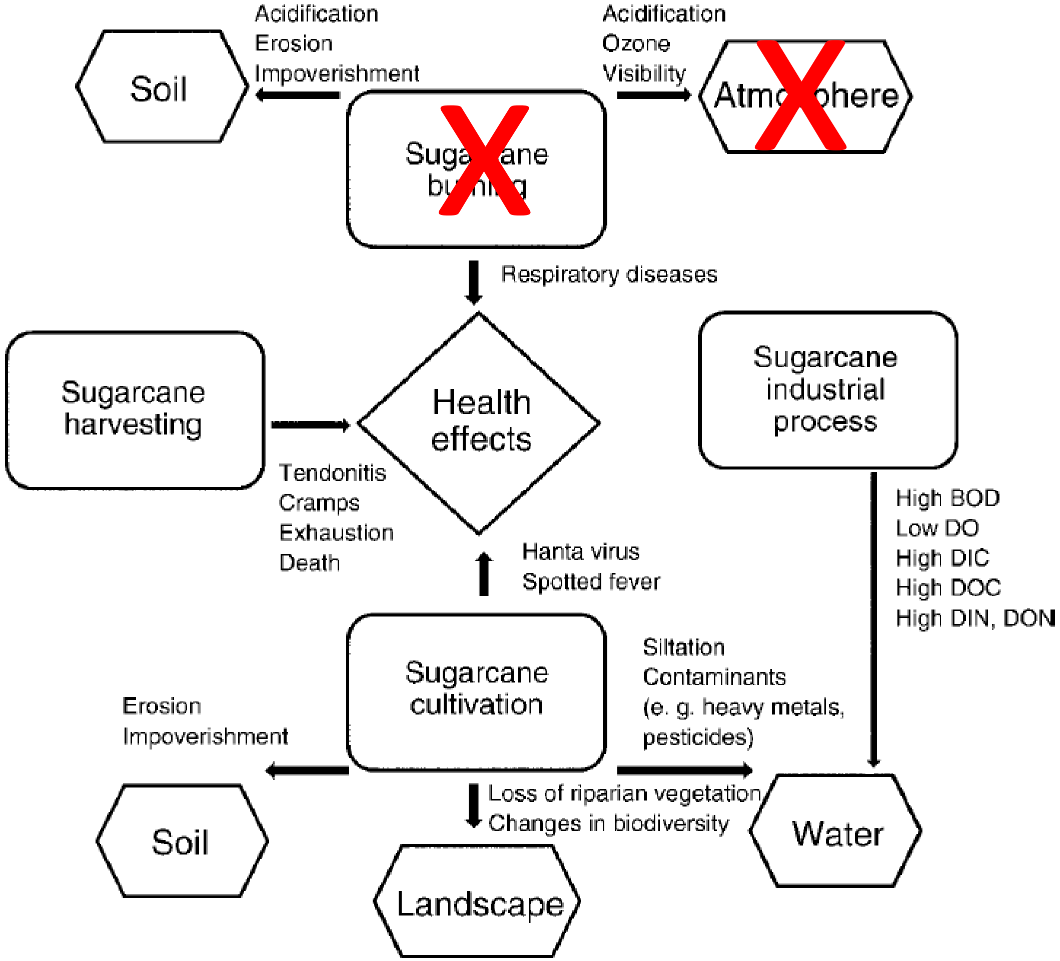
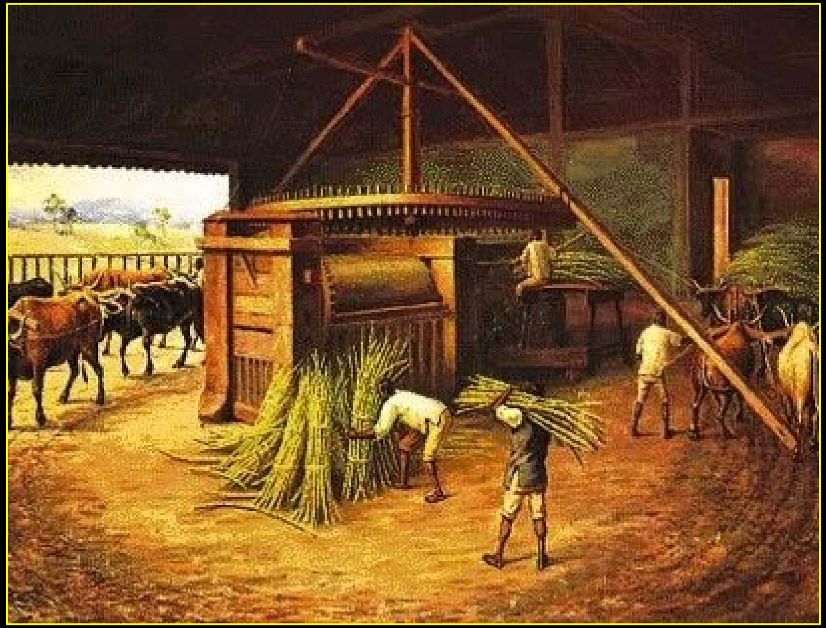


FIG. 5. Diagram showing the main environmental and social impact of the sugar cane agro-industry. For a list of water quality acronyms, see Fig. 4; BOD = biochemical oxygen demand; DO = dissolved oxygen.

Sugarcane is an old agriculture

- Brazil was “discovered” by the Portuguese in 1500
- Sugarcane was introduced in the 1530s



Sugarcane agriculture is intensive

Soil preparation

Land use conversion

Planting every 3-5 yrs

Synthetic fertilizer application
During planting or regrowth

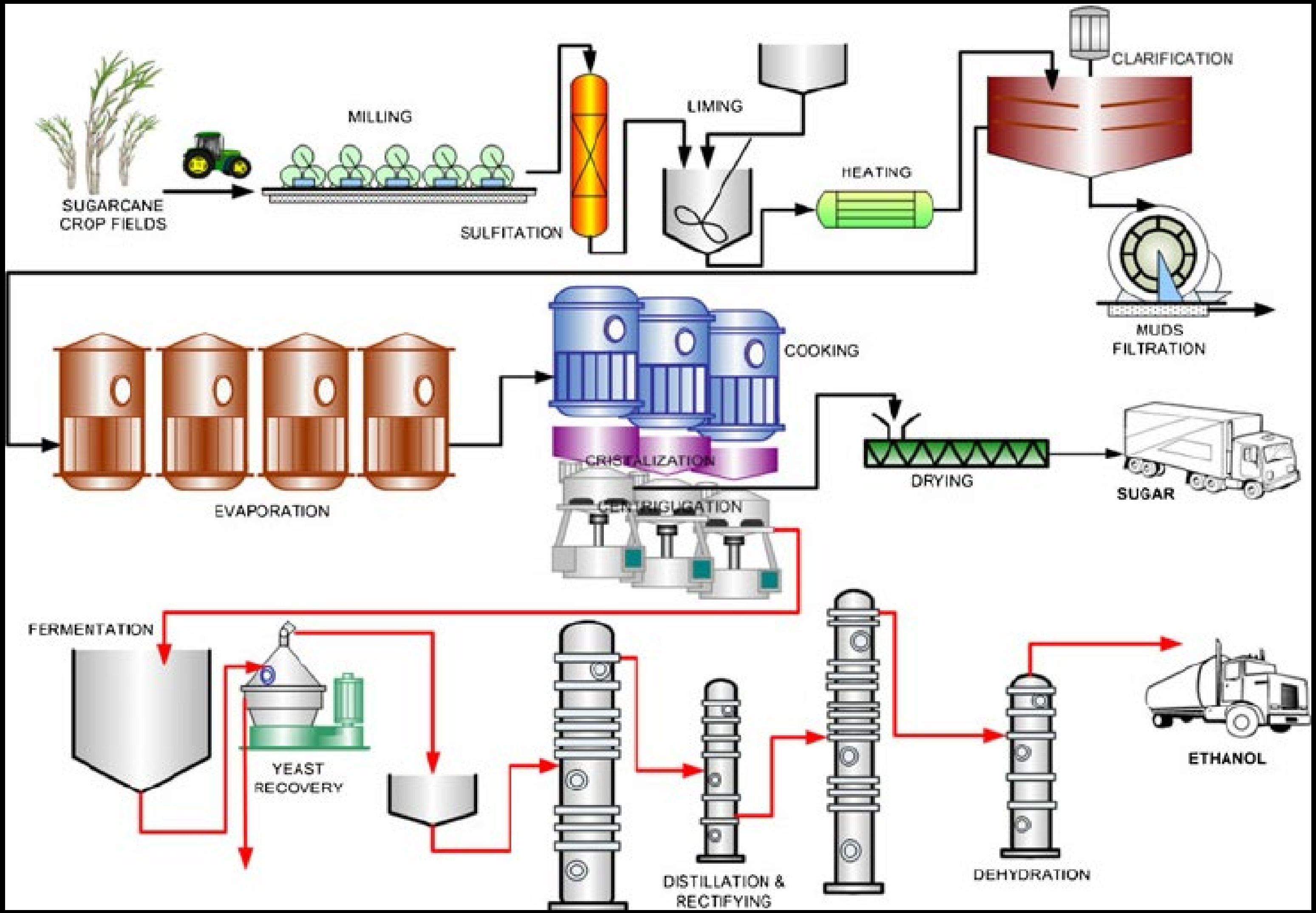
Organic fertilizer application

Pesticide & herbicide application

Harvesting

Transport to mills

Ethanol industrial process is complex

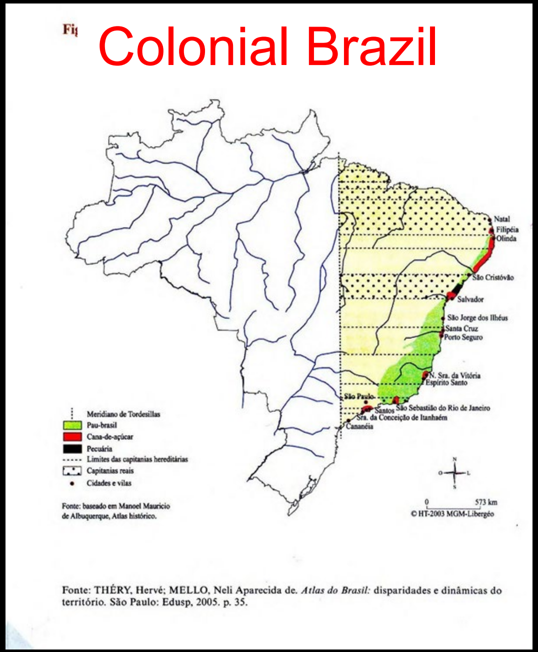


Industrial process produces high volume of waste

Liquid

Solid

Sugarcane agriculture expansion and loss of biodiversity



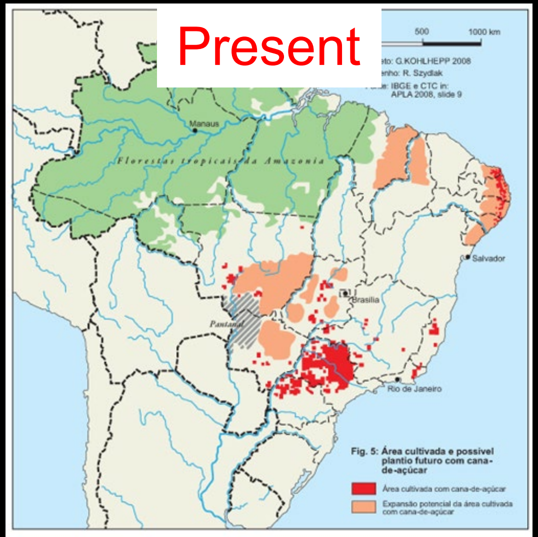


Figura 5 – Área cultivada e possível plantio futuro com cana-de-acúcar.

Future

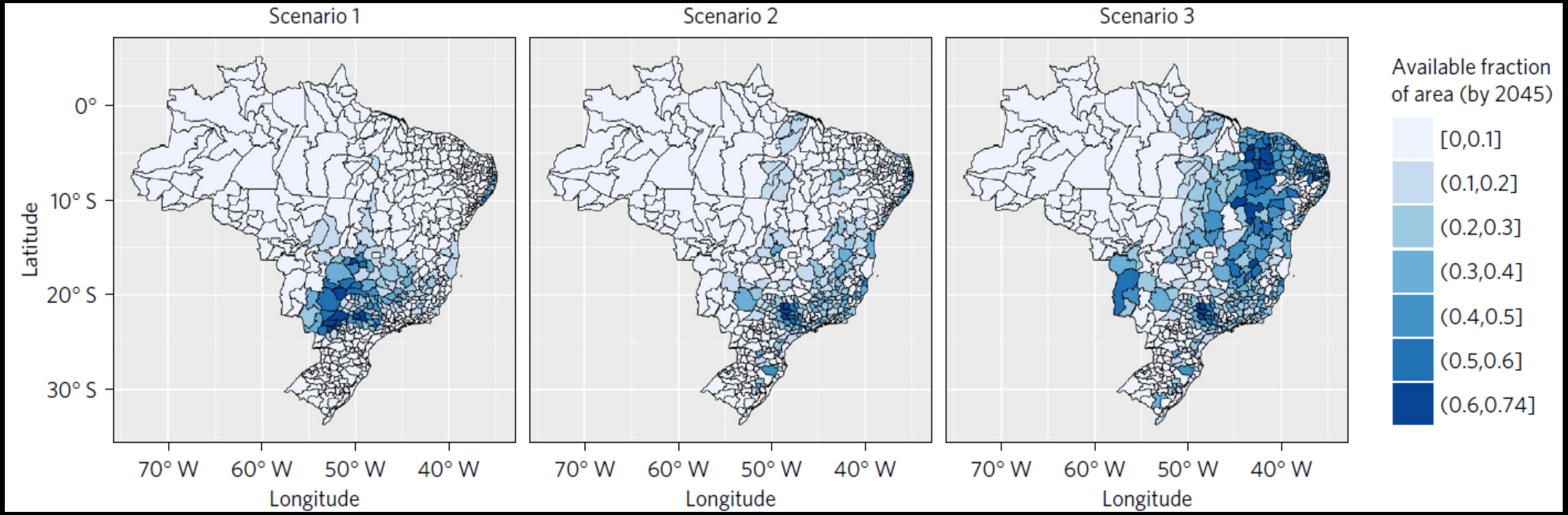


Figure 1 | The fraction of land available for sugarcane expansion by 2045 in each of the legally defined micro-regions of Brazil

NATURE CLIMATE CHANGE | VOL 7 | NOVEMBER 2017 | www.nature.com/natureclimatechange

BRAZIL

Human Population: ~208 million

Specific Concerns

1. What are GHG emissions during bioethanol lifecycle?
    1. Agricultural phase
    2. Industrial phase
    3. Land-use change
2. What are other environmental impacts?
    1. Surface water pollution
    2. Groundwater pollution
    3. Water use
    4. Degradation of aquatic ecosystems
3. Does sugarcane ethanol production compete with food production?
4. What best management practices can help reduce environmental impacts?

Specific Concerns & My Research

- What are GHG emissions during bioethanol lifecycle?
    - Agricultural phase
    - Industrial phase
    - Land-use change
- What are other environmental impacts?
    - Surface water pollution
    - Groundwater pollution
    - Water use
    - Degradation of aquatic ecosystems
- Does sugarcane ethanol production compete with food production?
- What best management practices can help reduce environmental impacts?

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Renewable and Sustainable Energy Reviews

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Reassessing the environmental impacts of sugarcane ethanol production in Brazil to help meet sustainability goals

Solange Filoso [a], Janaina Braga do Carmo [b], Sílvia Fernanda Mardegan [c], Silvia ... rtinelli [c,*]

Biogeochemistry 65: 275–294, 2003.
© 2003 Kluwer Academic Publishers. Printed in the Netherlands.

Land use and nitrogen export in the Piracicaba River basin, Southeast Brazil

SOLANGE FILOSO[1,2,*], LUIZ A. MARTINELLI[2], MICHAEL R. WILLIAMS[1], LUCIENE B. LARA[2], ALEX KRUSCHE[2], MARIA VICTORIA BALLESTER[2], REYNALDO VICTORIA[2] and PLINIO B. DE CAMARGO[2]

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Journal of Environmental Management

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Research article

Impacts of sugarcane agriculture expansion over low-intensity cattle ranch pasture in Brazil on greenhouse gases

Camila Bolfarini Bento [a], Solange Filoso [b], Leonardo Machado Pitombo [c], Heitor Cantarella [d], Raffaella Rossetto [e], Luiz Antonio Martinelli [f], Janaina Braga do Carmo [a,c,*]

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Policy Forums

The Native Vegetation Protection Law of Brazil and the challenge for first-order stream conservation

Ricardo H. Taniwaki [a,e,*], Yuri A. Forte [a], Gabriela O. Silva [b], Pedro H.S. Brancalion [a], Caroline V. Cogueto [c], Solange Filoso [d], Silvio F.B. Ferraz [a]

GLOBAL CHANGE BIOLOGY
BIOENERGY

GCB Bioenergy (2012), doi: 10.1111/j.1757-1707.2012.01199.x

Infield greenhouse gas emissions from sugarcane soils in Brazil: effects from synthetic and organic fertilizer application and crop trash accumulation

JANAINA BRAGA DO CARMO*, SOLANGE FILOSO†, LUCIANA C. ZOTELLI‡§, ERACLITO R. DE SOUSA NETO¶, LEONARDO M. PITOMBO*, PAULO J. DUARTE-NETO‡‡, VITOR P. VARGAS‡, CRISTIANO A. ANDRADE‖, GLAUBER J. C. GAVA**, RAFFAELLA RO...

Balance between food production, biodiversity and ecosystem services in Brazil: a challenge and an ...

Luiz Antonio Martinelli[1,3] & Solange Filoso

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Impacts of converting low-intensity pastureland to high-intensity bioenergy cropland on the water quality of tropical streams in Brazil

Ricardo Hideo Taniwaki [a,*], Carla Cristina Cassiano [a], Solange Filoso [b], Silvio Frosini de Barros Ferraz [a], Plínio Barbosa de Camargo [c], Luiz Antônio Martinelli [c]

Journal of Sustainable Bioenergy Systems, 2013, 3, 135-142
doi:10.4236/jsbs.2013.32019 Published Online June 2013 (http://www.scirp.org/journal/jsbs)

Water Use in Sugar and Ethanol Industry in the State of São Paulo (Southeast Brazil)

Luiz A. Martinelli[1], Solange Filoso[2], Cecilia de Barros Aranha[3], Silvio F. B. Ferraz[4], Tatiana M. B. Andrade[1], Elizabethe de C. Ravagnani[1], Luciana Della Coletta[1], Plinio Barbosa de Camargo[1]

GLOBAL CHANGE BIOLOGY
BIOENERGY

GCB Bioenergy (2010) 2, 152–156, doi: 10.1111/j.1757-1707.2...

Contextualizing ethanol avoided carbon emissions in Brazil

LUIZ A. MARTINELLI*, JEAN PIERRE HENRY BALBAUD OMETTO†, SOLANGE FILOSO‡ and REYNALDO L. VICTORIA*

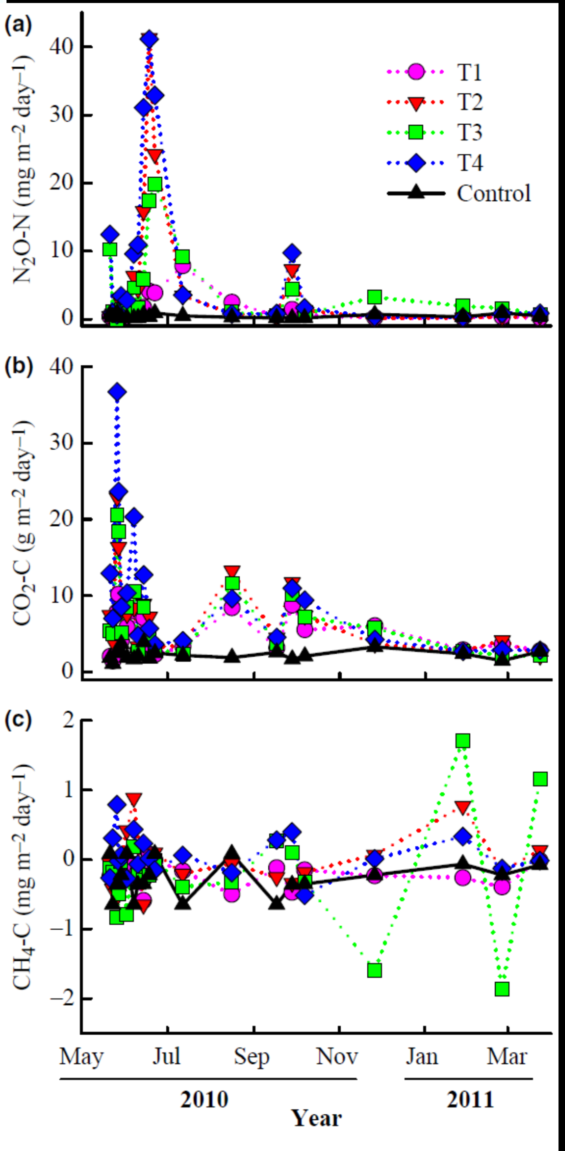
GHG emissions in the sugarcane agricultural phase

Table 4 N fertilizer emission factor and CO_2 equivalent based on the N rates applied during the plant cane cycle in Jaú experiment

Treatment	N source	*Added N (kg ha^{-1})	†Emission factor (%)	‡CO_2 equivalent (kg CO_2 eq ha^{-1} yr^{-1})
Control	None	———	———	———
T1	Urea	60	1.11 ± 0.75	312
T2	Urea + Filter cake	122	1.10 ± 0.54	630
T3	Urea + *Vinasse*	87	2.65 ± 1.13	1375
T4	Urea + Filter cake + *Vinasse*	149	1.56 ± 1.01	1386
MR without *vinasse*	———	———	———	———
§MR with *vinasse*	*Vinasse*	21	2.99 ± 1.1	296

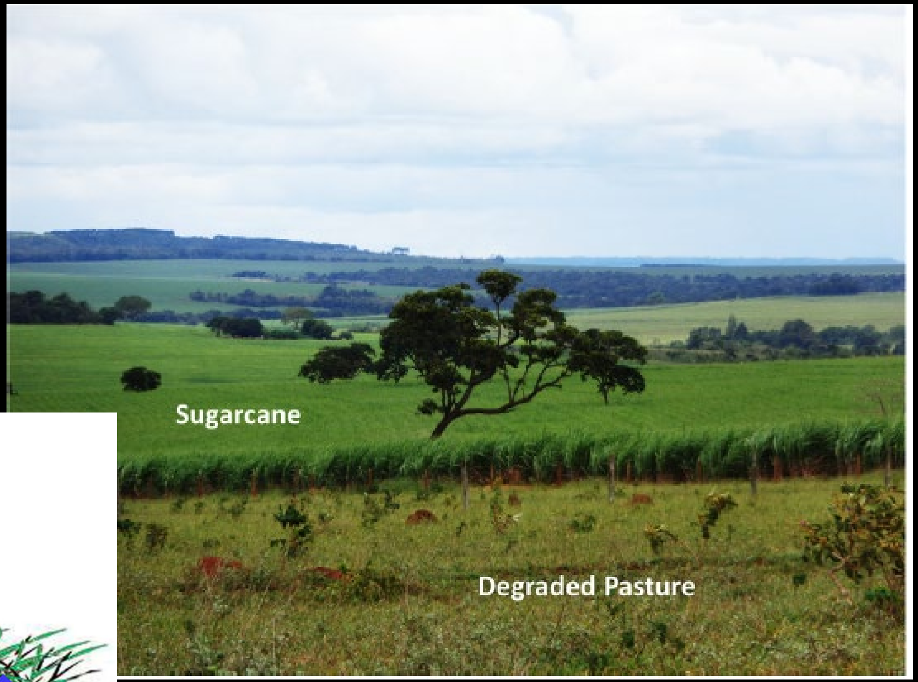
GHG emissions from sugarcane agriculture are relatively low but crop trash accumulation increases rates and offset fossil-fuel savings after N synthetic fertilizer and organic fertilizer (*vinasse*) were applied.

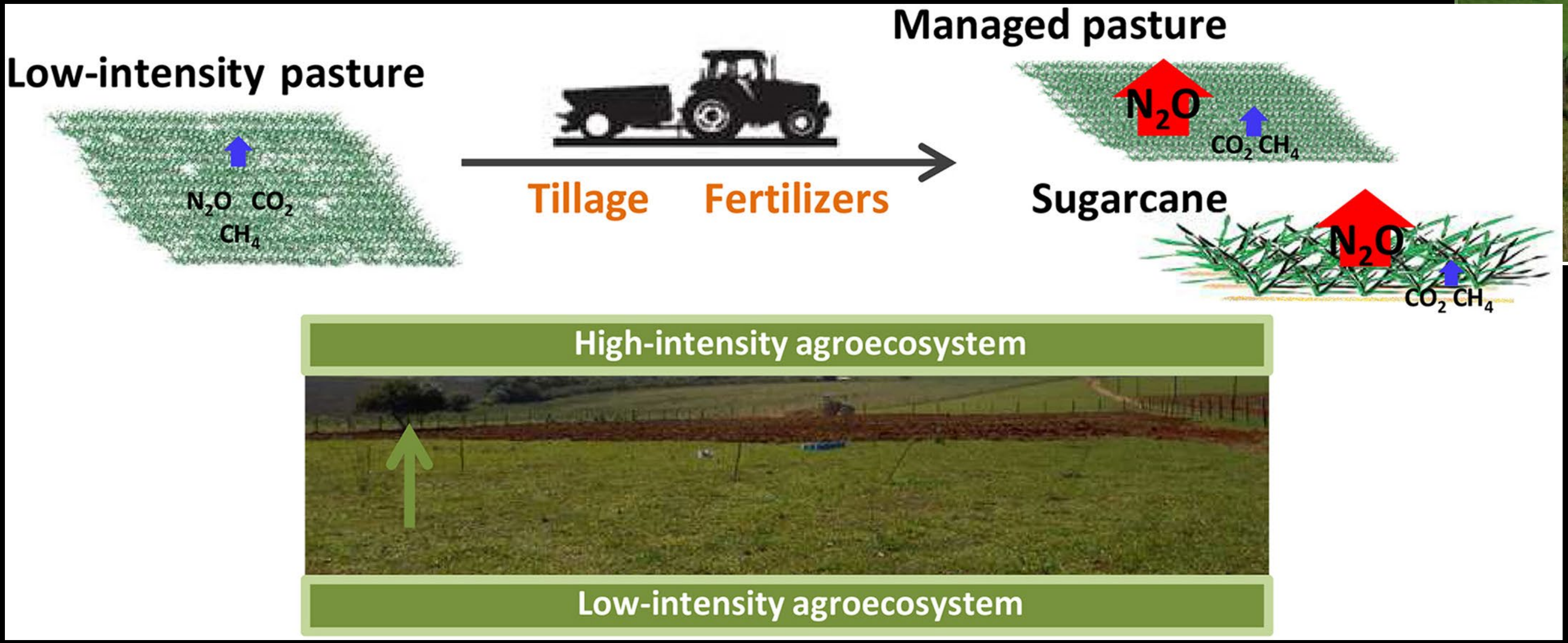
Carmo, Filoso, Pitombo and others. 2012. Global Change Biology Bioenergy



;. 2 Daily mean fluxes of N_2O (a), CO_2 (b) and CH_4 (c) mea-

GHG emissions during land-use change

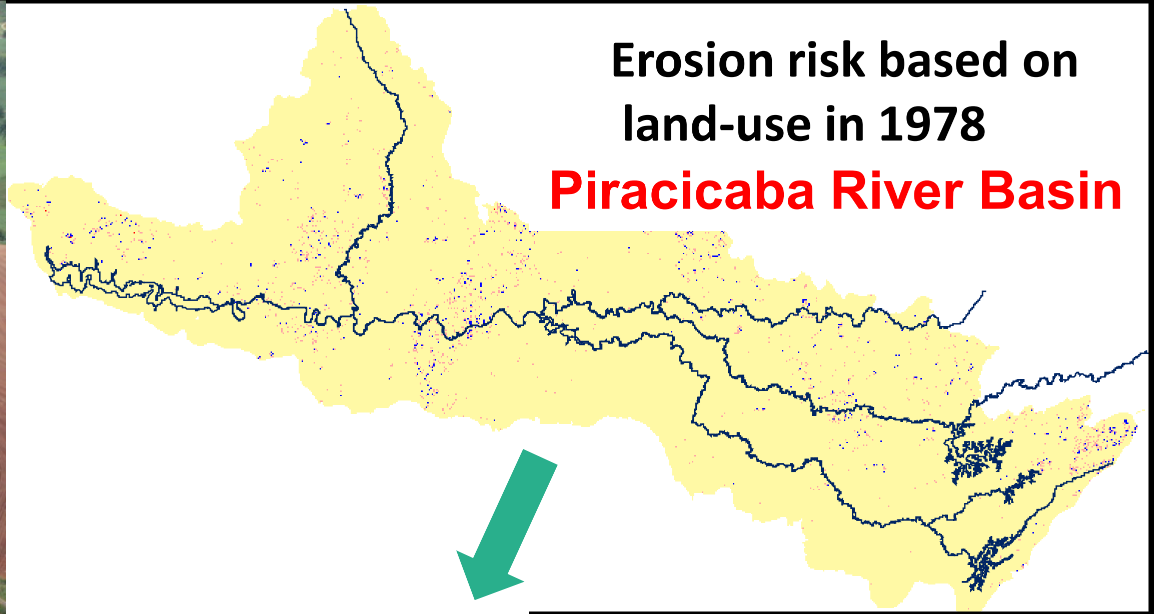


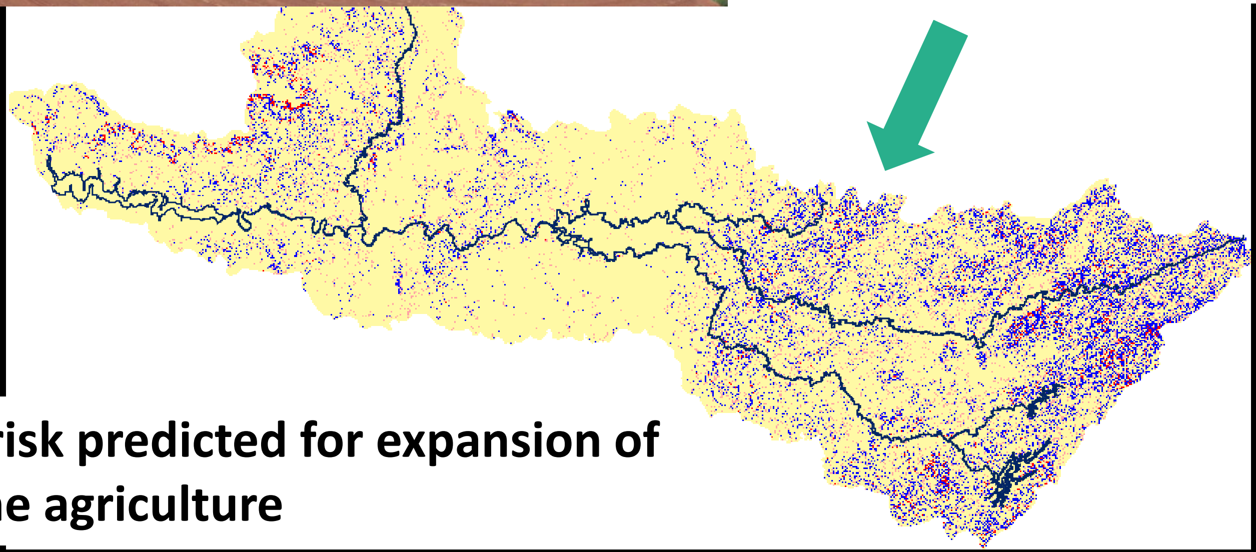


Emissions increase with intensification of pasture management.

Bento, Filoso, Pitombo and others. 2018. JEM

Other environmental impacts: Soil erosion





Sugarcane watersheds have high rates of soil erosion.

Degradation of low-order streams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Policy Forums

The Native Vegetation Protection Law of Brazil and the challenge for first-order stream conservation

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R.H. Taniwaki et al. / Perspectives in Ecology and Conservation 16 (2018) 49–53

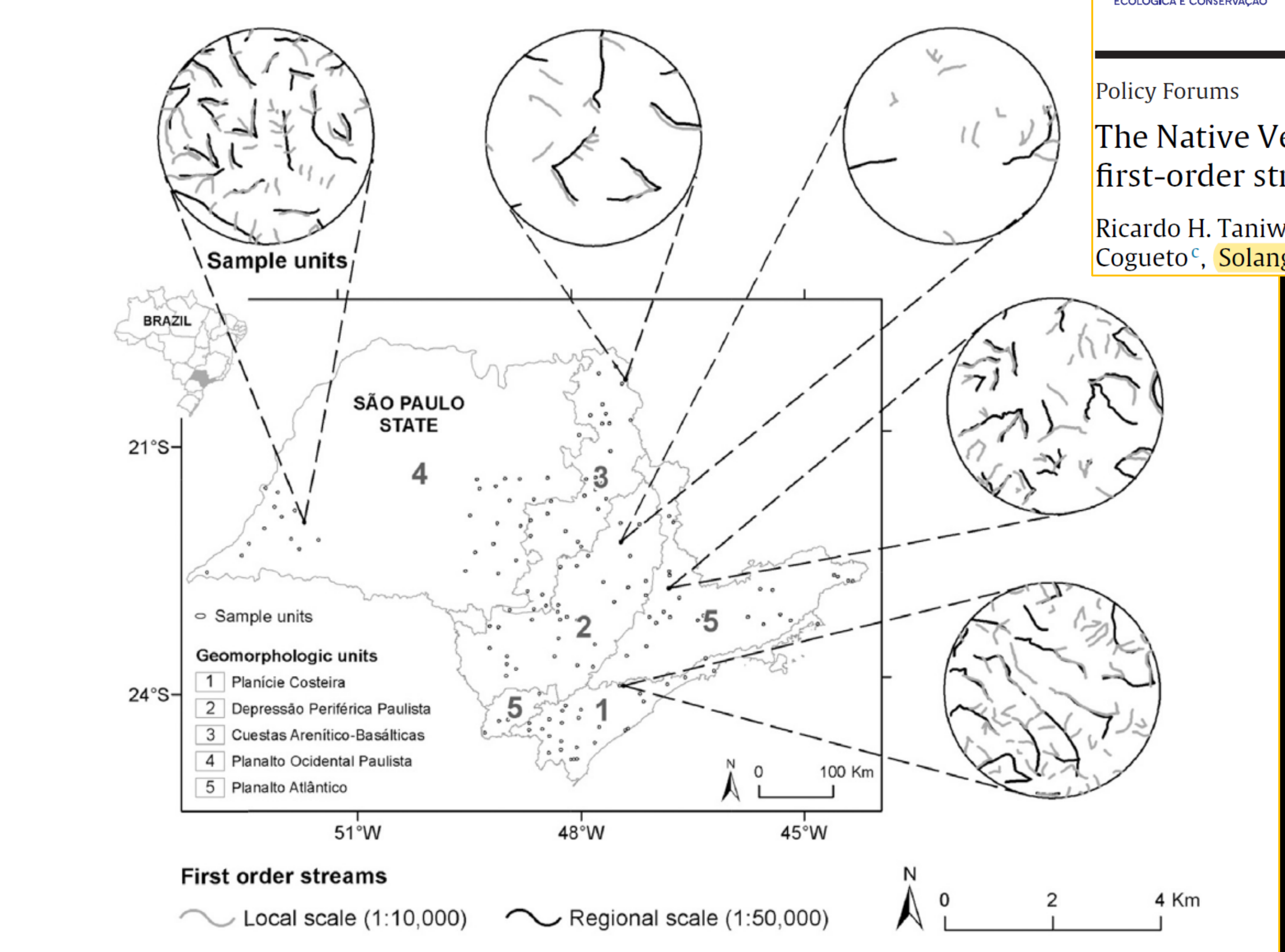
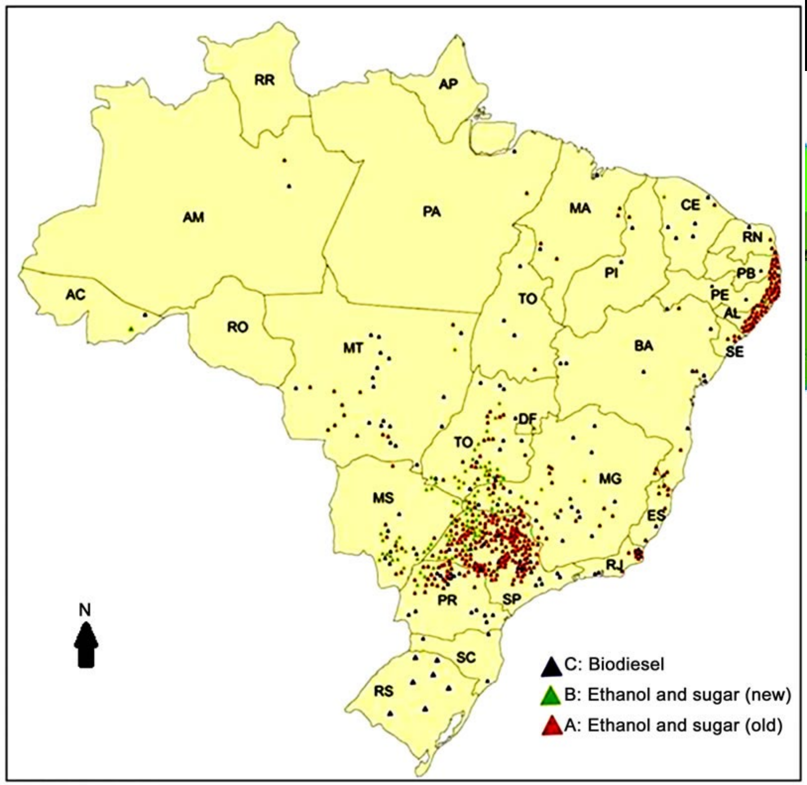


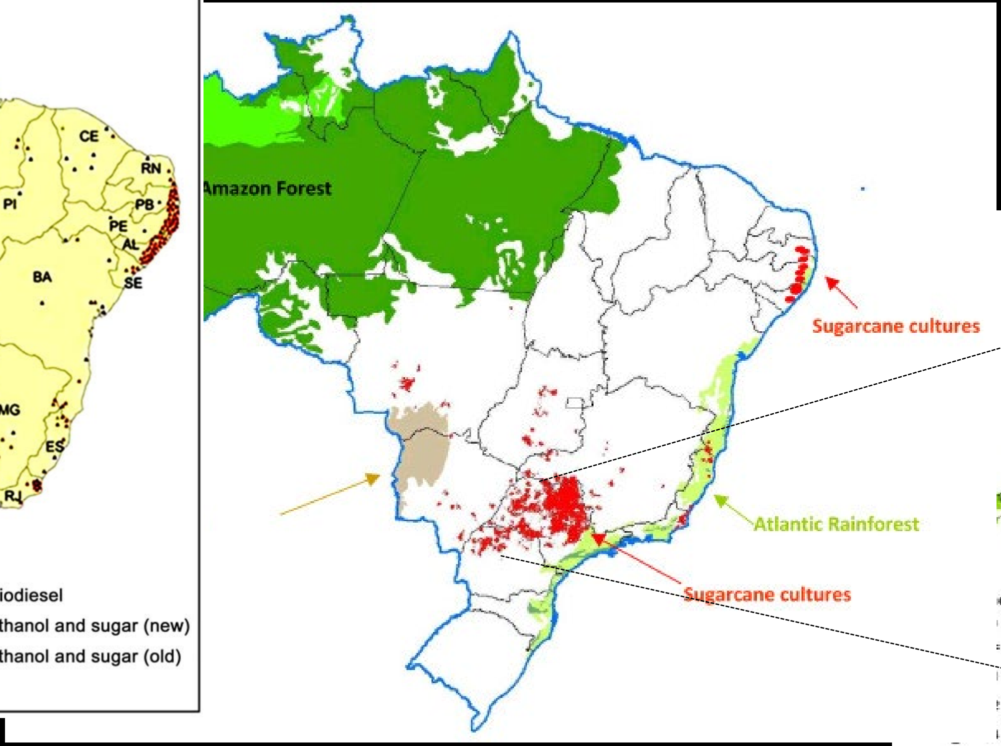
Fig. 1. Spatially explicit distribution of sample units by each geomorphologic region in São Paulo State. In detail, the sample unit shows the overlap of first-order stre
mapped on the local (1:10,000) and regional (1:50,000) scale.

Sugarcane expansion neglects protection of first-order streams.

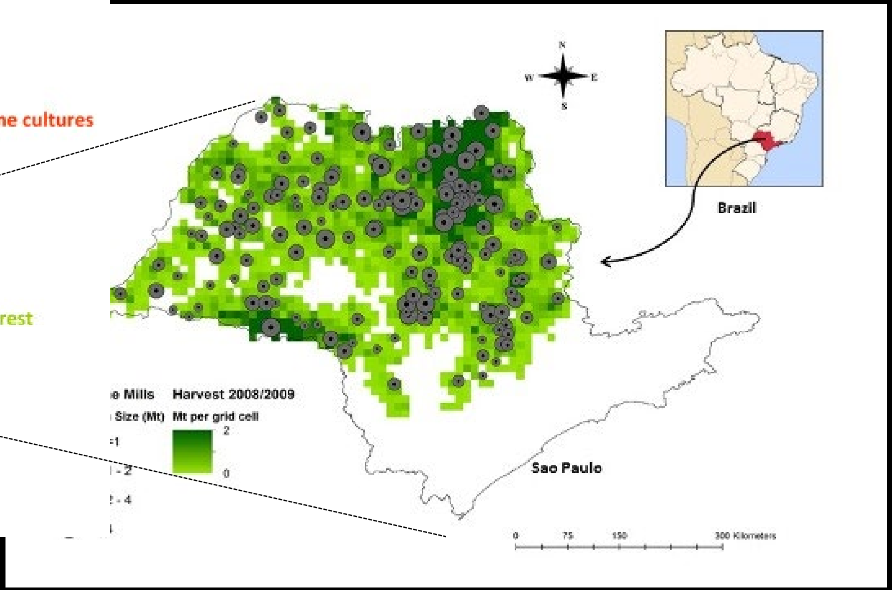
Sugarcane expansion in areas of low water security

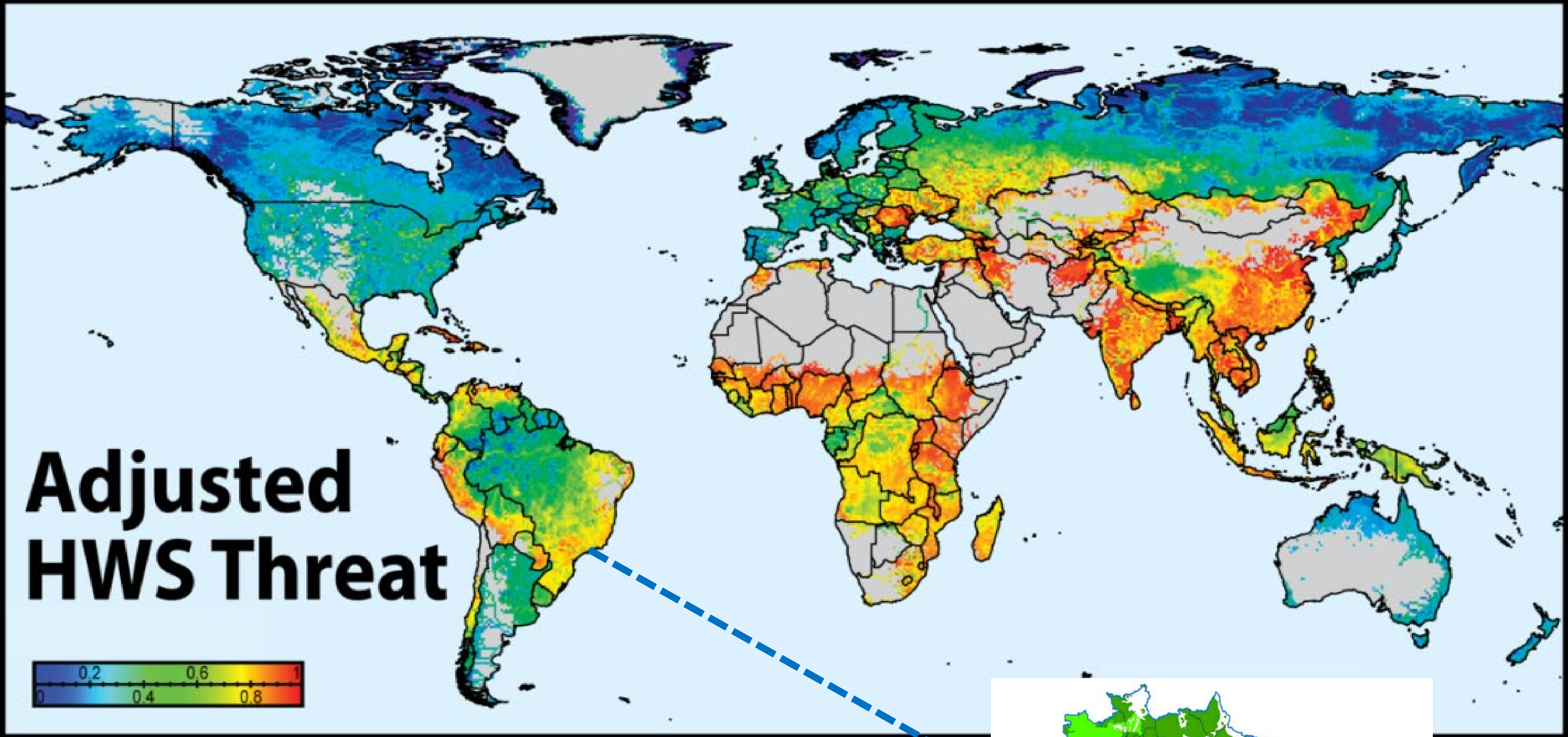
208 million people





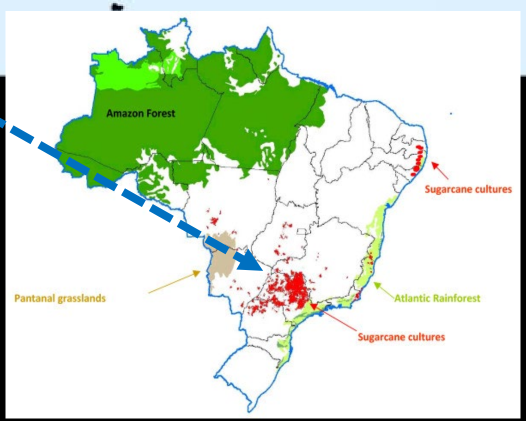
45 million people



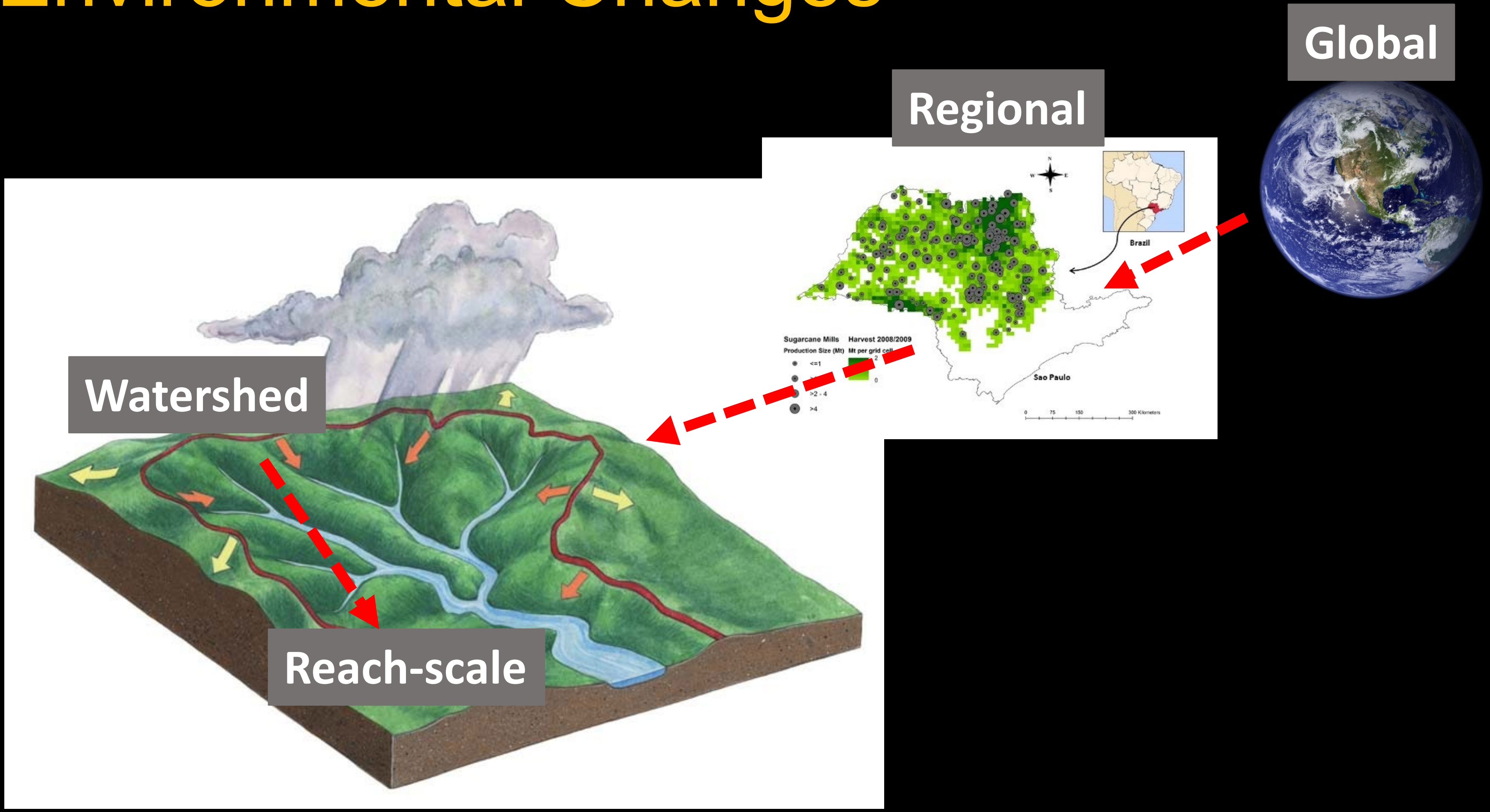


From: Vorosmarty et al., 2010, *Nature 467, 555-561*.

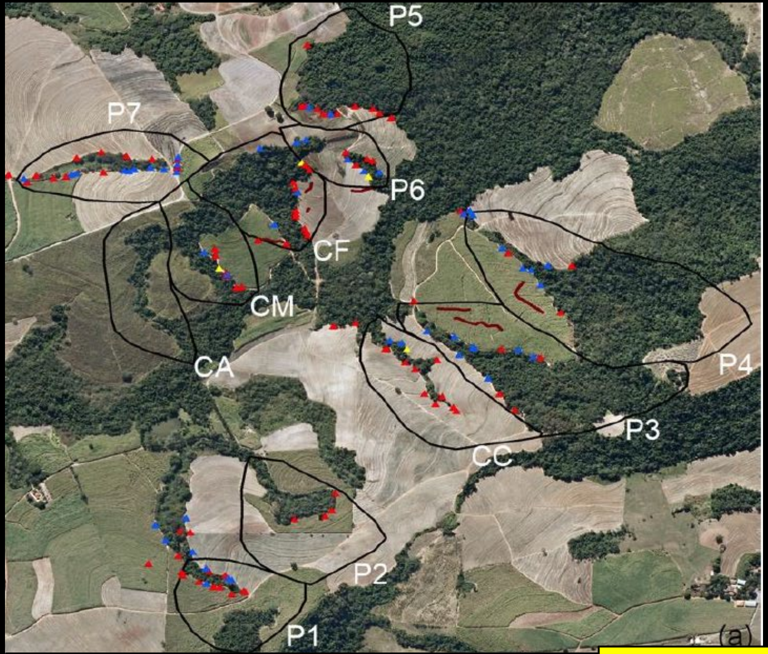
Water quality degradation is the main water security threat in Brazil!

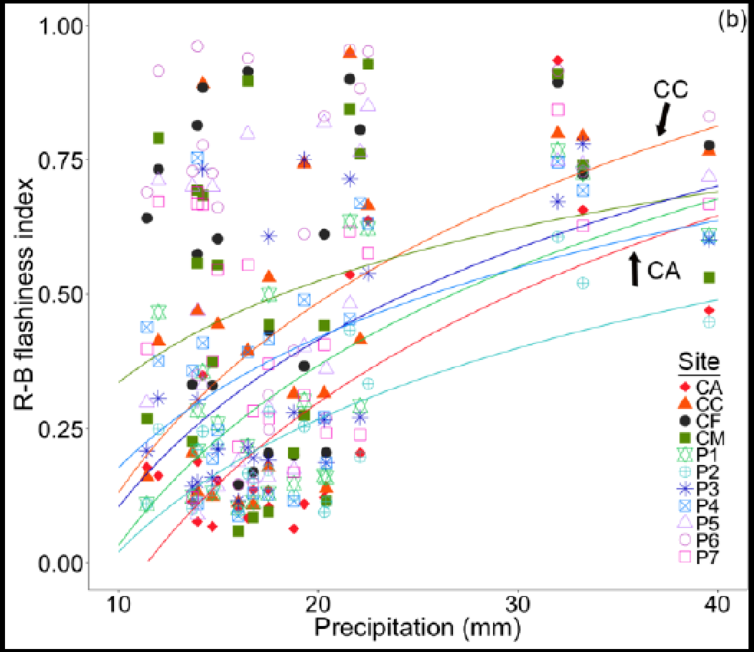


River Ecosystems as Integrators of Environmental Changes

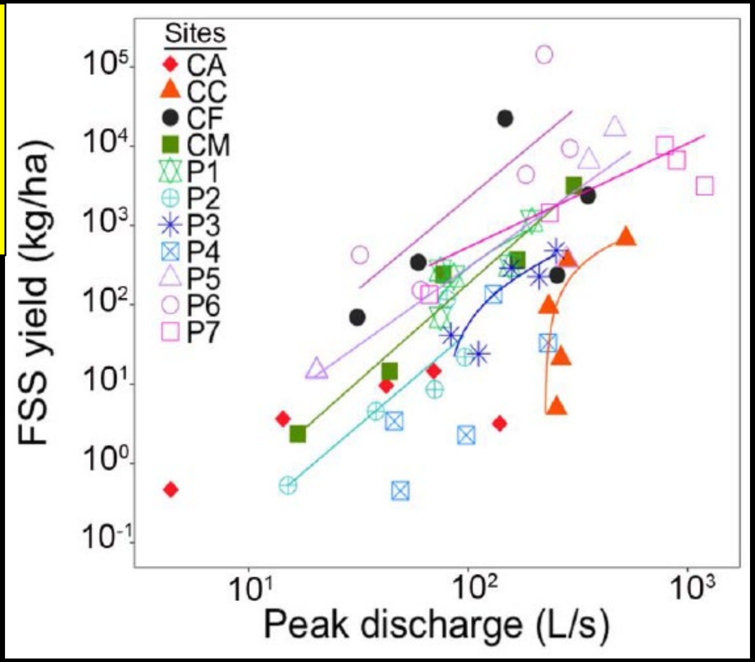


Suspended sediments in streams

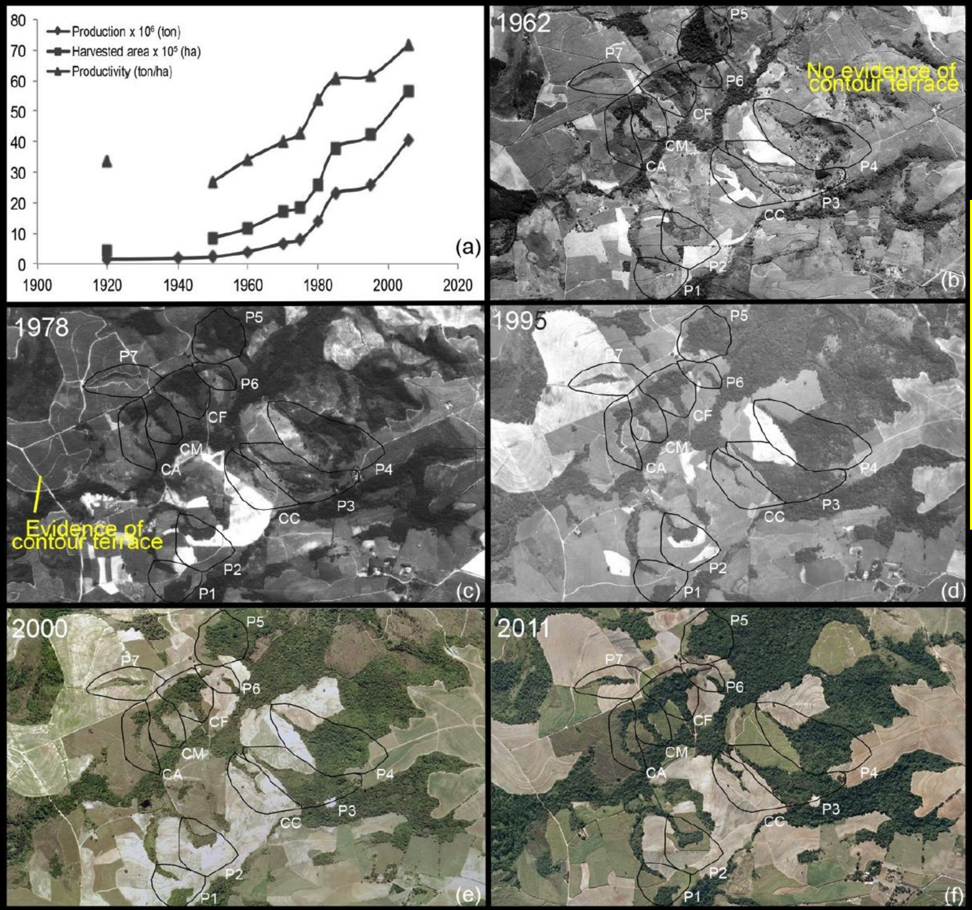




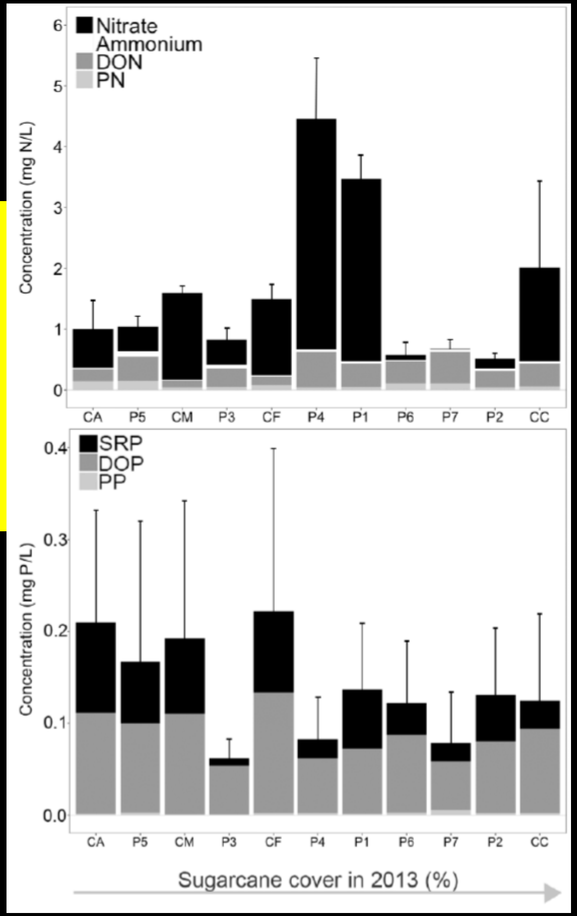
Soil compaction and gully formation increases sediment export in streams



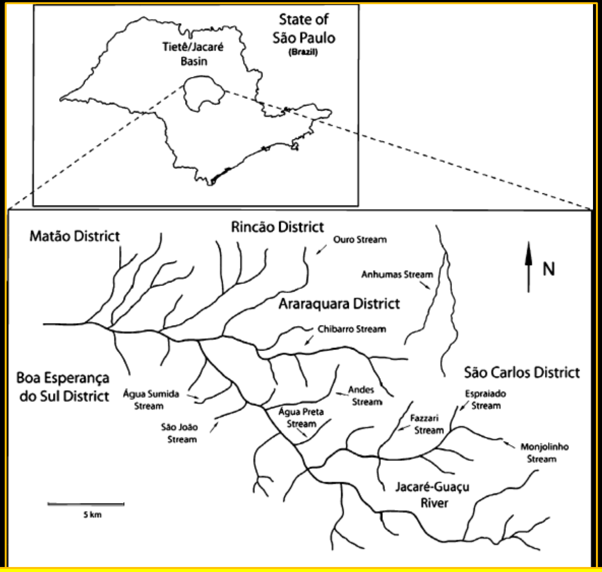
Surface water pollution: Excess nutrients



Years of fertilizer application in sugarcane fields increase N and P concentrations in streams.



Contamination of macroinvertebrates with heavy metals



High concentrations of heavy metals in macroinvertebrates found in streams draining sugarcane fields and w/o riparian buffers

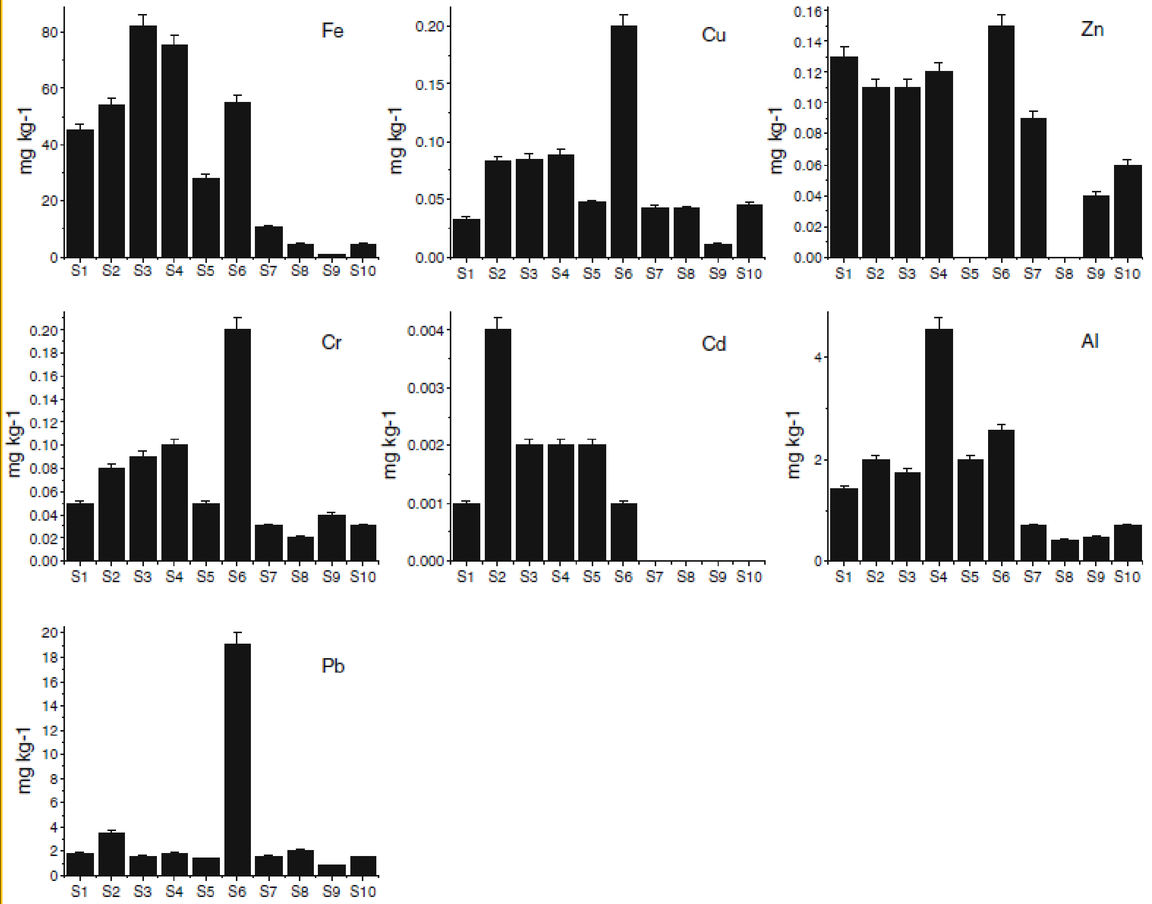
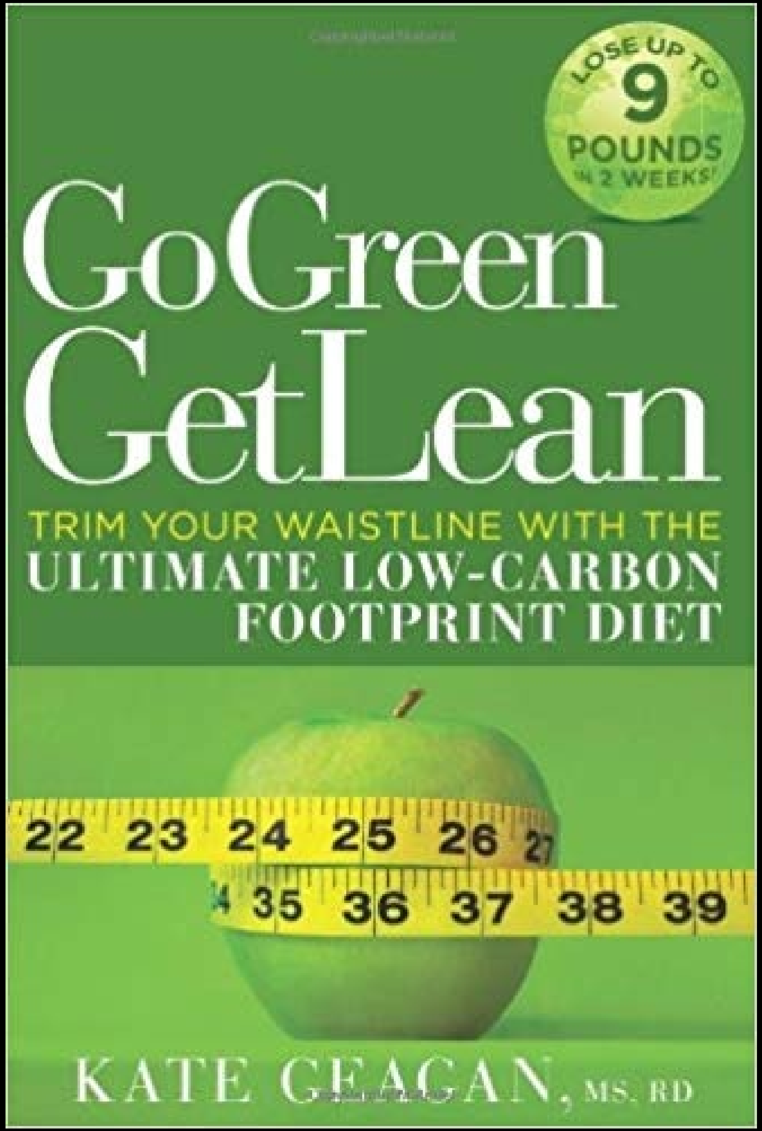


Fig. 4 Mean values and standard deviations of metal concentrations detected in the dragonflies from the ten sampling sites. Legends as Table 1

Corbi et al., 2008. Water Air Soil Pollut.


LOSE UP TO 9 POUNDS IN 2 WEEKS!
Go Green Get Lean
TRIM YOUR WAISTLINE WITH THE ULTIMATE LOW-CARBON FOOTPRINT DIET
KATE GEAGAN, MS, RD


70%
The approximate reduction in emissions when Brazilian ethanol made from sugar-cane is used instead of conventional fuels.

Adoption of Best Management Practices is needed!

No till

Riparian buffer conservation and restoration

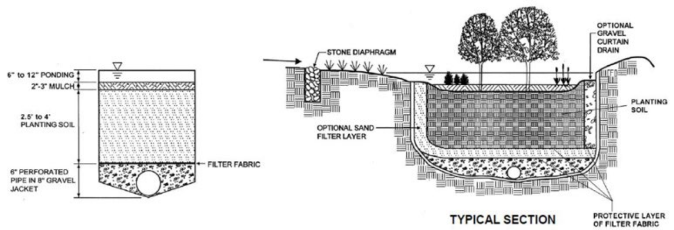
Forest conservation and restoration

Focus of my research in Chesapeake Bay

STREAM RESTORATION

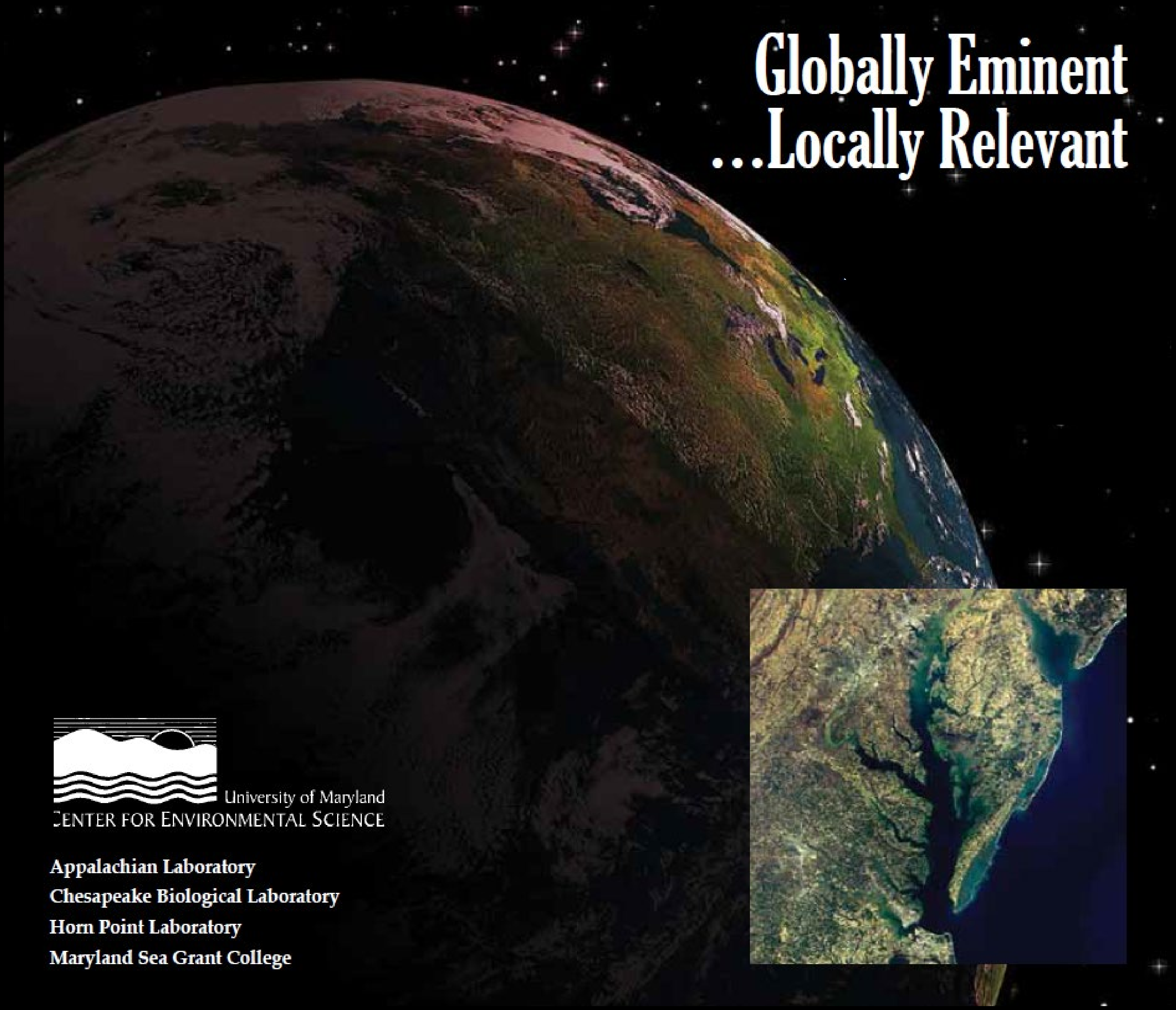
WETLAND RESTORATION

STORMWATER RUNOFF MANAGEMENT



WATERSHED MANAGEMENT MEASURES

Globally Eminent ...Locally Relevant



University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Appalachian Laboratory
Chesapeake Biological Laboratory
Horn Point Laboratory
Maryland Sea Grant College

Conclusions

- Brazilian bioethanol is a good and feasible option for reducing GHG emissions.
- Environmental impacts can be dramatically reduced with the adoption of effective best management practices (BMPs).
- Improving knowledge about BMP effectiveness is essential to increase the sustainability of sugarcane ethanol production in Brazil.

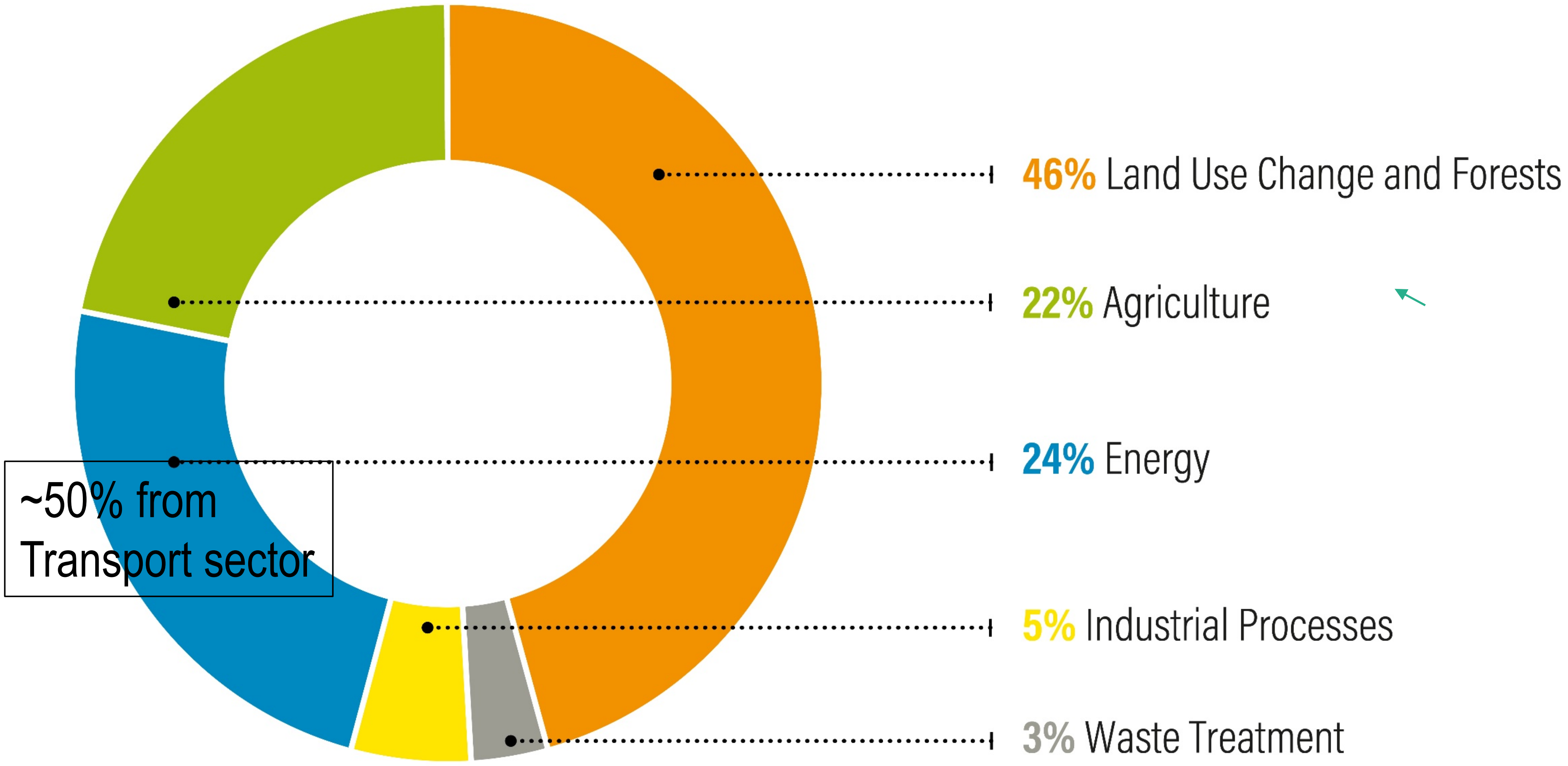

THANKS!

GHG emissions during land-use change

CO_2 emissions from soil carbon losses are minor when pastures and croplands are converted to cane, but larger for native savannahs.

M. Macedo & E. Davidson. 2014. Nature Climate

Estimates of GHG* Net Emissions in Brazil in 2015



* CO_2e GWP
Source: seeg.eco.br

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