Bioenergy in Brazil

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Rationale

- GCC: Reducing GHG emissions
- Scarcity of resources
  - Oil is finite
    - (But note that the stone age ended, but this was not because of a lack of stones)
- Energy security (as Food Security)
  - Each nation would like to generate its own energy, or at least most of it, or at least as much as possible of it while not having to pay too much for the rest and having a secure source

The Laws of Thermodynamics
(simplified apud C.P. Snow)

- You cannot win (that is, you cannot get something for nothing, because matter and energy are conserved).
- You cannot break even (you cannot return to the same energy state, because there is always an increase in disorder; entropy always increases).
- You cannot get out of the game (because absolute zero is unattainable).

$$\mathrm{d}U = \delta Q - \delta W$$

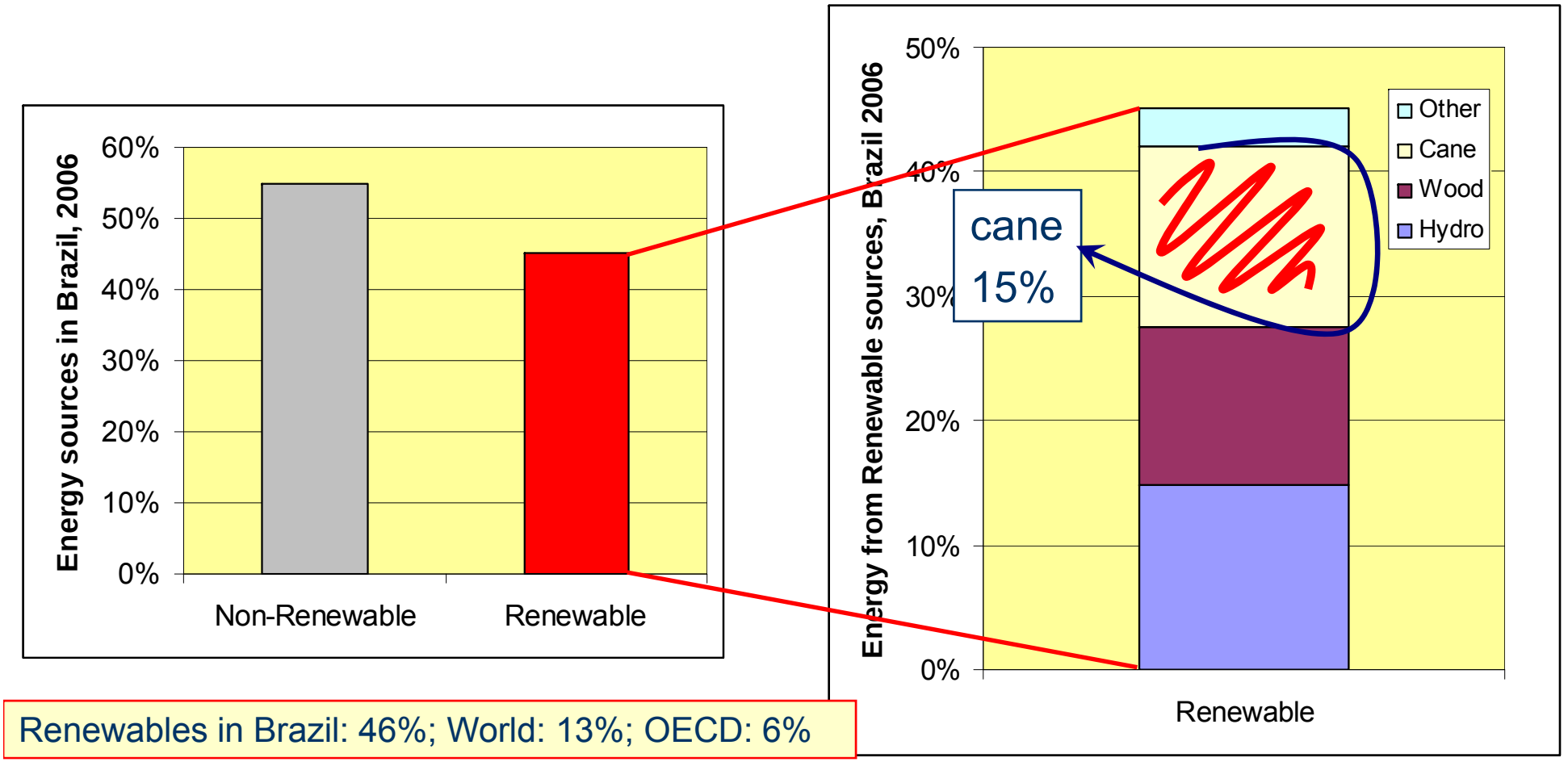
$$\int \frac{\delta Q}{T} \geq 0$$

$$T \Rightarrow 0, S \Rightarrow C$$

Brazil: 180 million people, 9th GNP

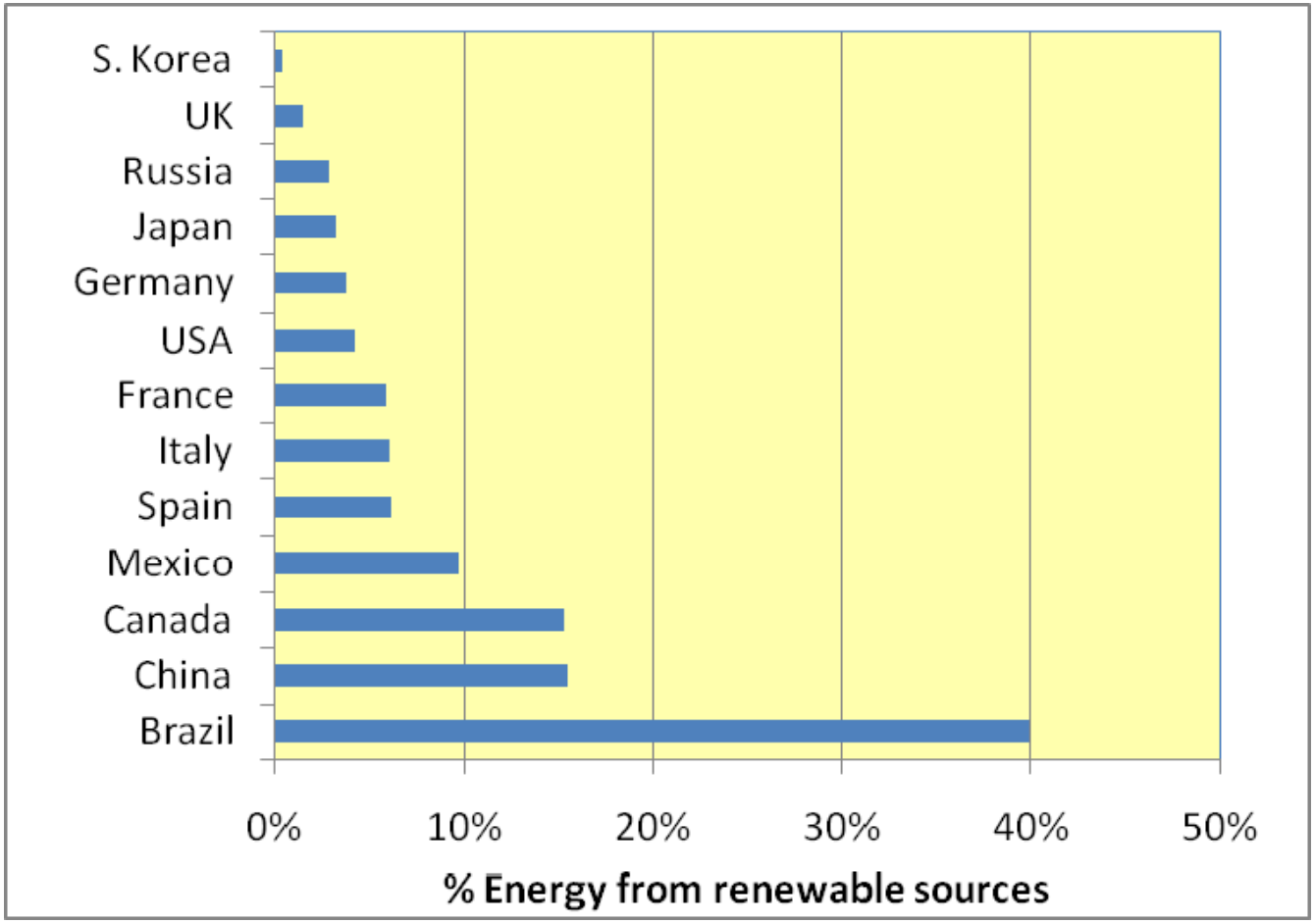
Brazil

Energy sources in Brazil



Renewables in Brazil: 46%; World: 13%; OECD: 6%

Energy from renewable sources
Some industrialized countries

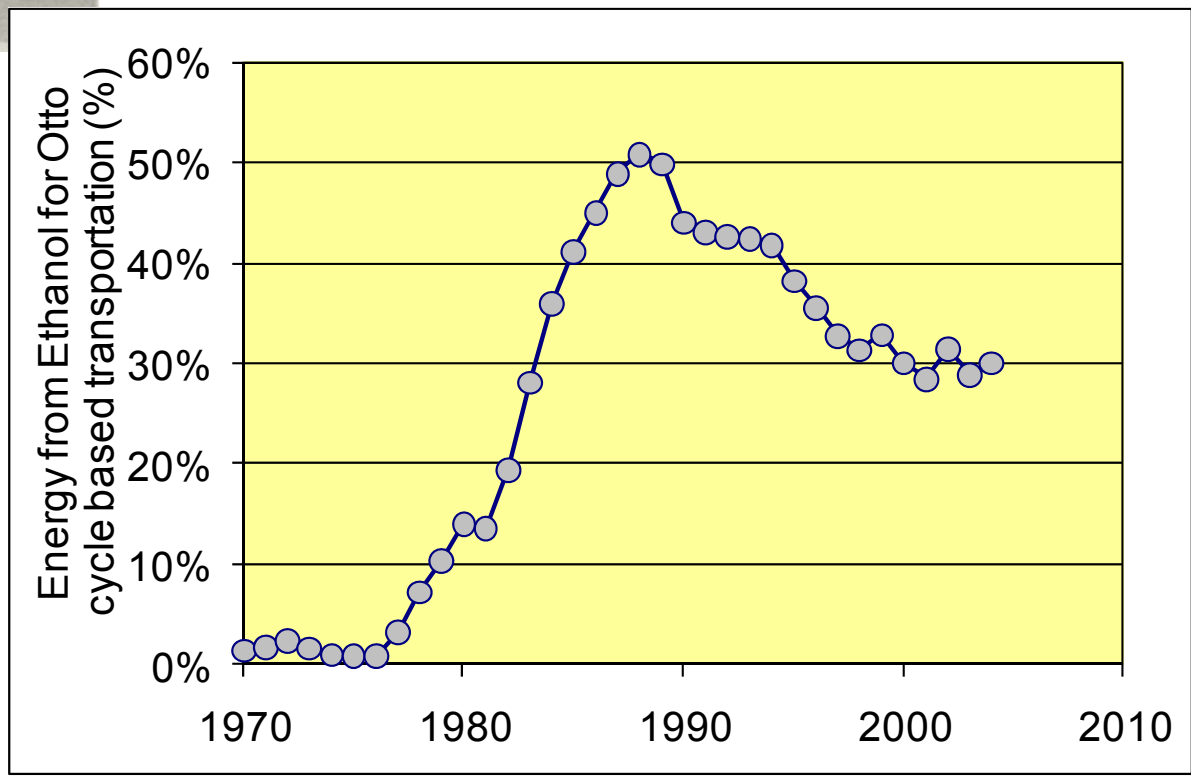


Source: IEA, Renewables Factsheet, 2007

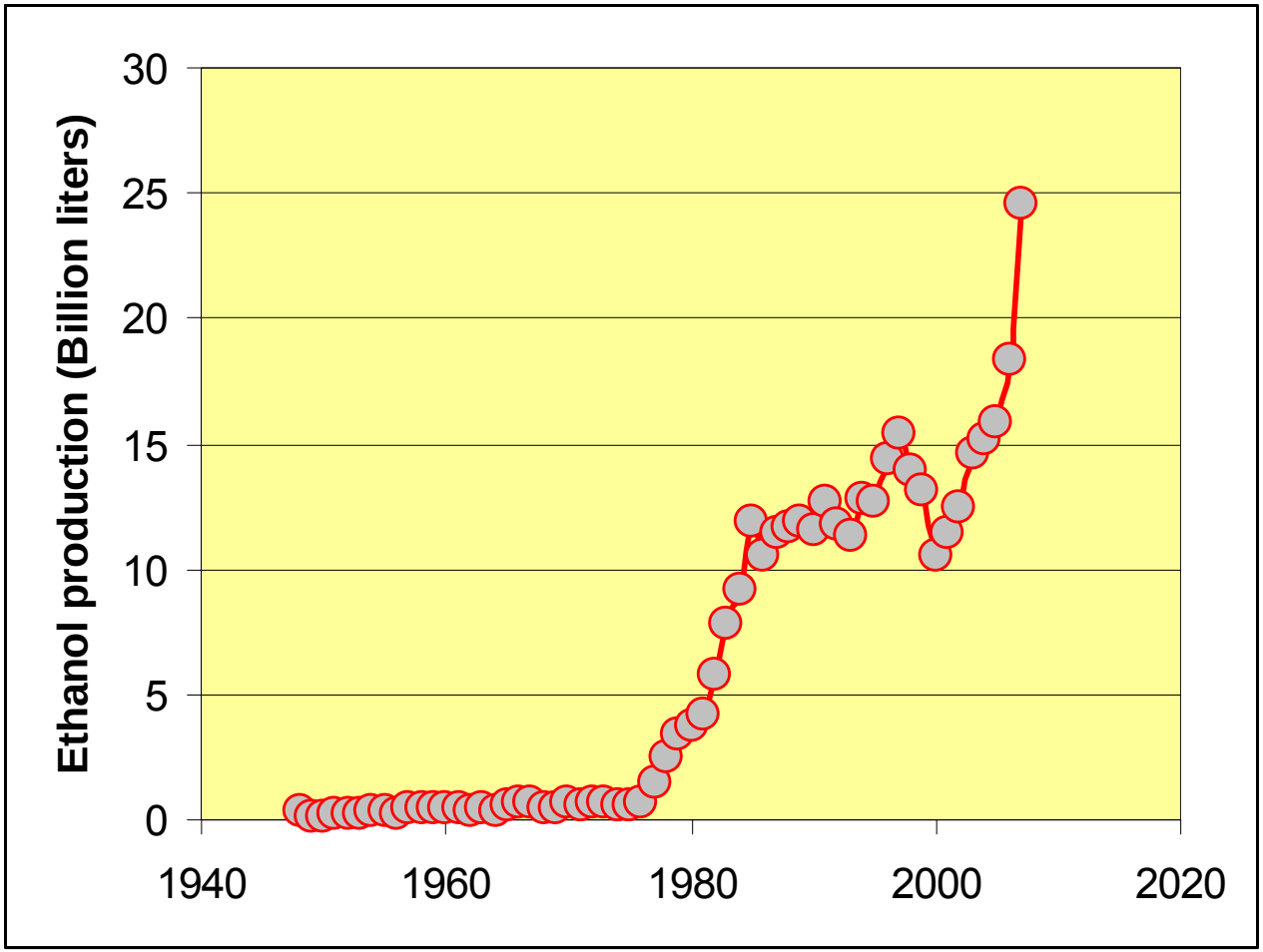
Ethanol in Brazil

Sugarcane in Brazil: 1532

Mandated addition of Ethanol to fuel: 1929



Brazil: Ethanol production 1948-2007



- 1975: Proalcool Program
- 2003: Flex-fuel vehicles
  - 90% of new vehicle sold are Flex
- Gasoline has 25% Ethanol added
  - No pure gasoline in Brazil
- 33,000 gas+ethanol stations (out of 36,000)

Gasoline is the ALTERNATIVE fuel in Brazil

Increase in oil import costs in 1974

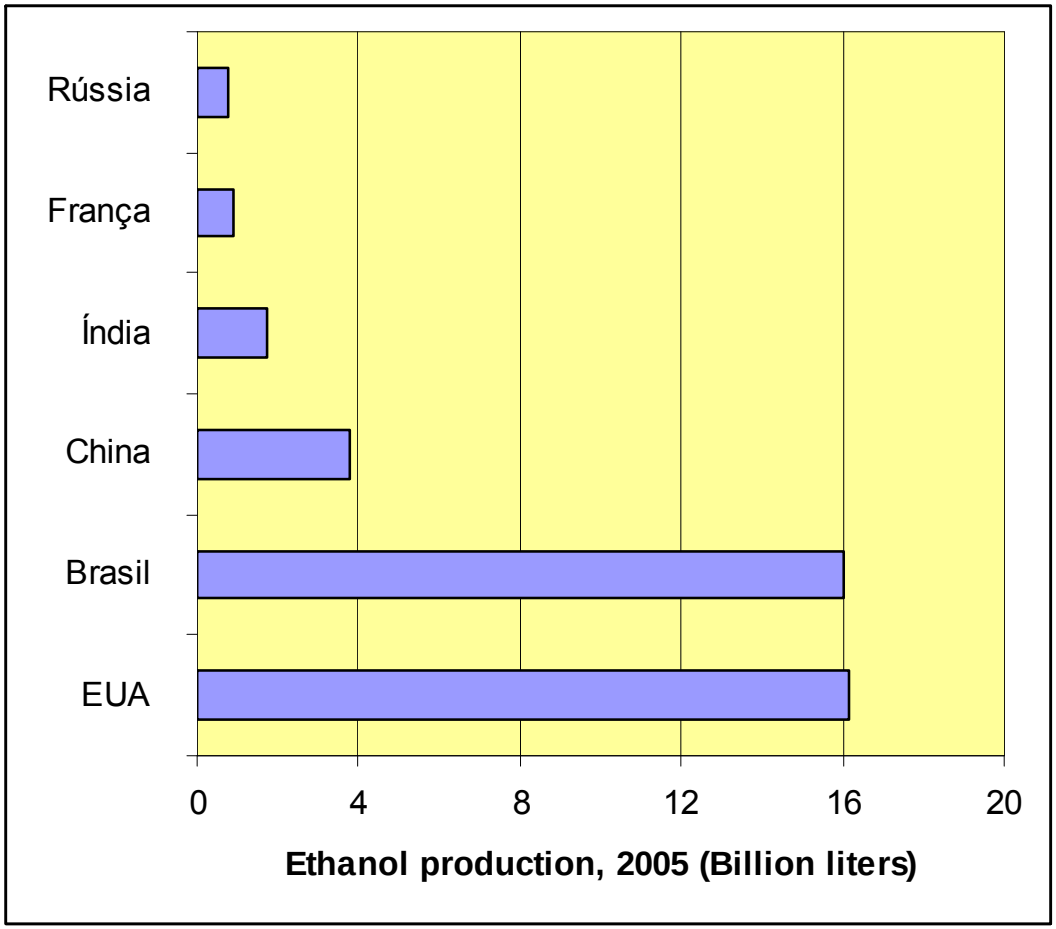
Ano	Quantidade (1.000 t)	Índice de Quantidade	Valor FOB US$ milhões	Índice de valor
1967	11.607	100	153,6	100
1968	14.792	127	204,0	133
1969	15.310	131	203,0	132
1970	17.845	153	236,1	153
1971	21.807	187	326,9	212
1972	25.115	216	408,5	265
1973	36.900	317	750,0	488
1974	42.435	365	4.076,0	2.653

Fontes: Boletim Banco Central e Conjuntura Econômica, citados pos Copersucar, 1974

Source: UNICA, 2008

Ethanol: World Production

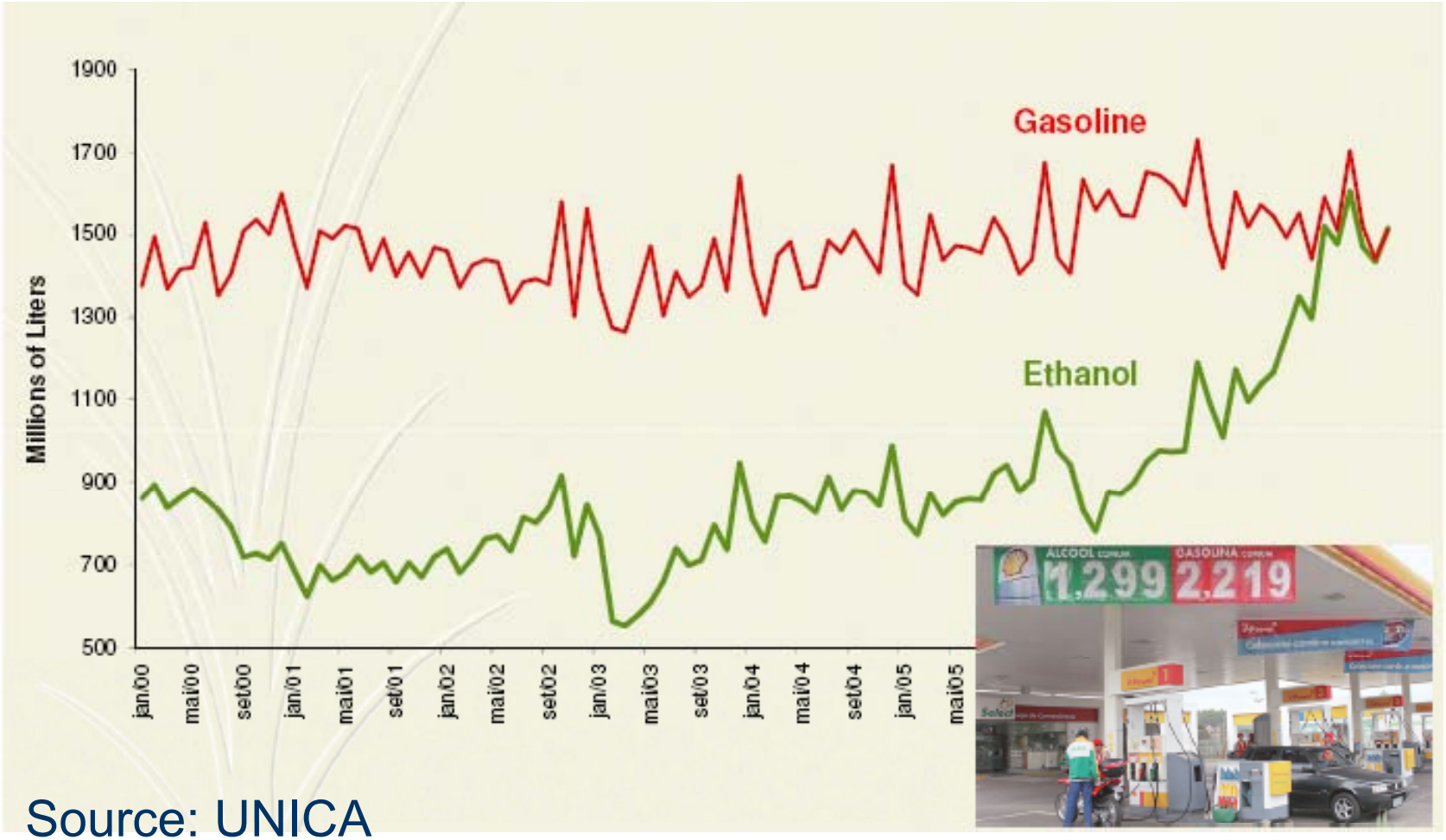
- Brasil is 2nd largest producer
- In 2005:
  - Brazil 35% (cane)
  - USA 35% (corn)
- Brazilian production
  - Sucrose: 1/3 of cane
  - Cellulose used for energy



205 GL of Ethanol will substitute for 10% of the world's gasoline

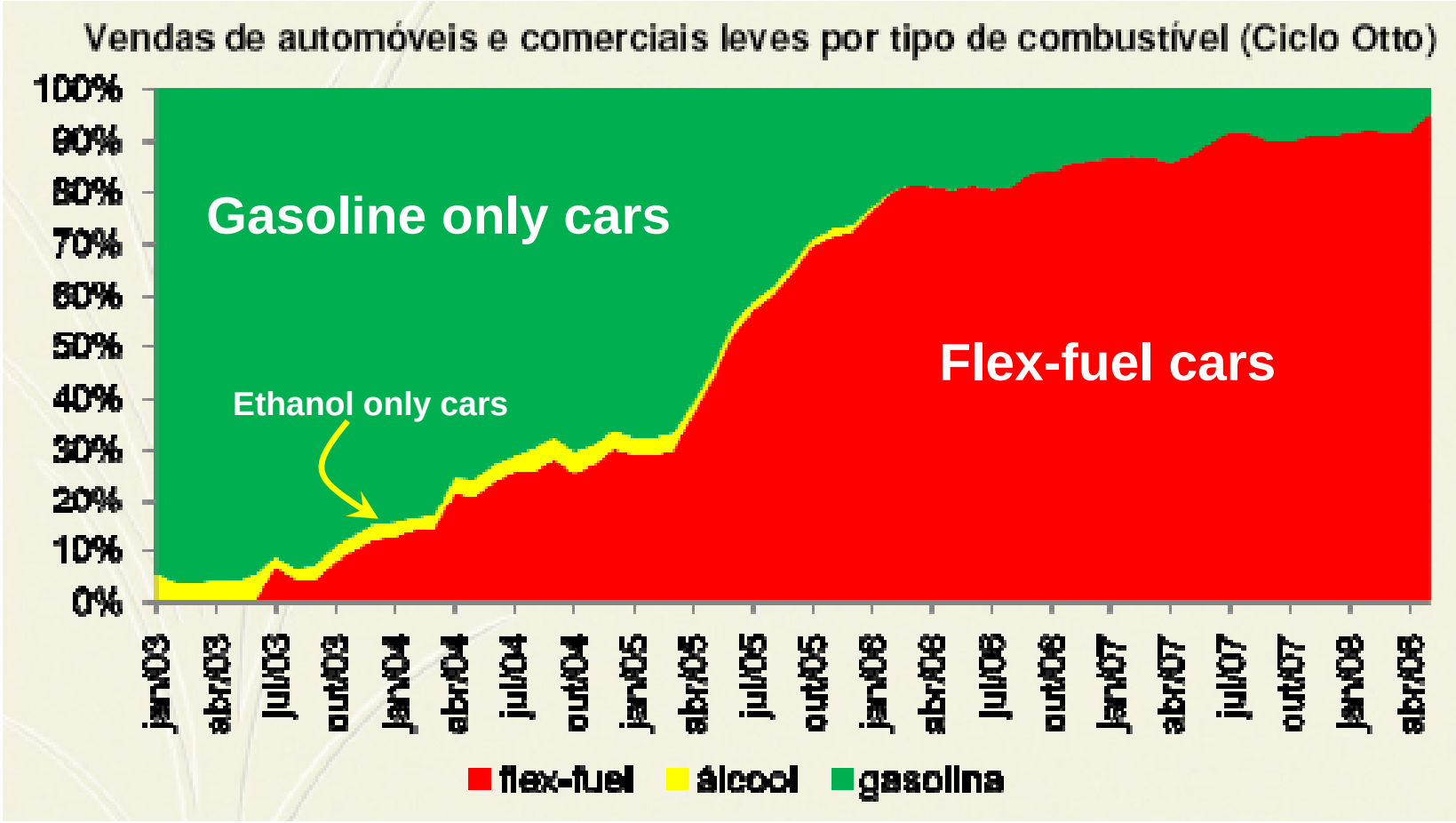
	2004	2025
Gasoline consumption	1,200 GL	1,700 GL
Ethanol consumption	30 GL	
Ethanol substituting 10% gasoline		205 GL

Brazil: Gasoline and Ethanol consumption



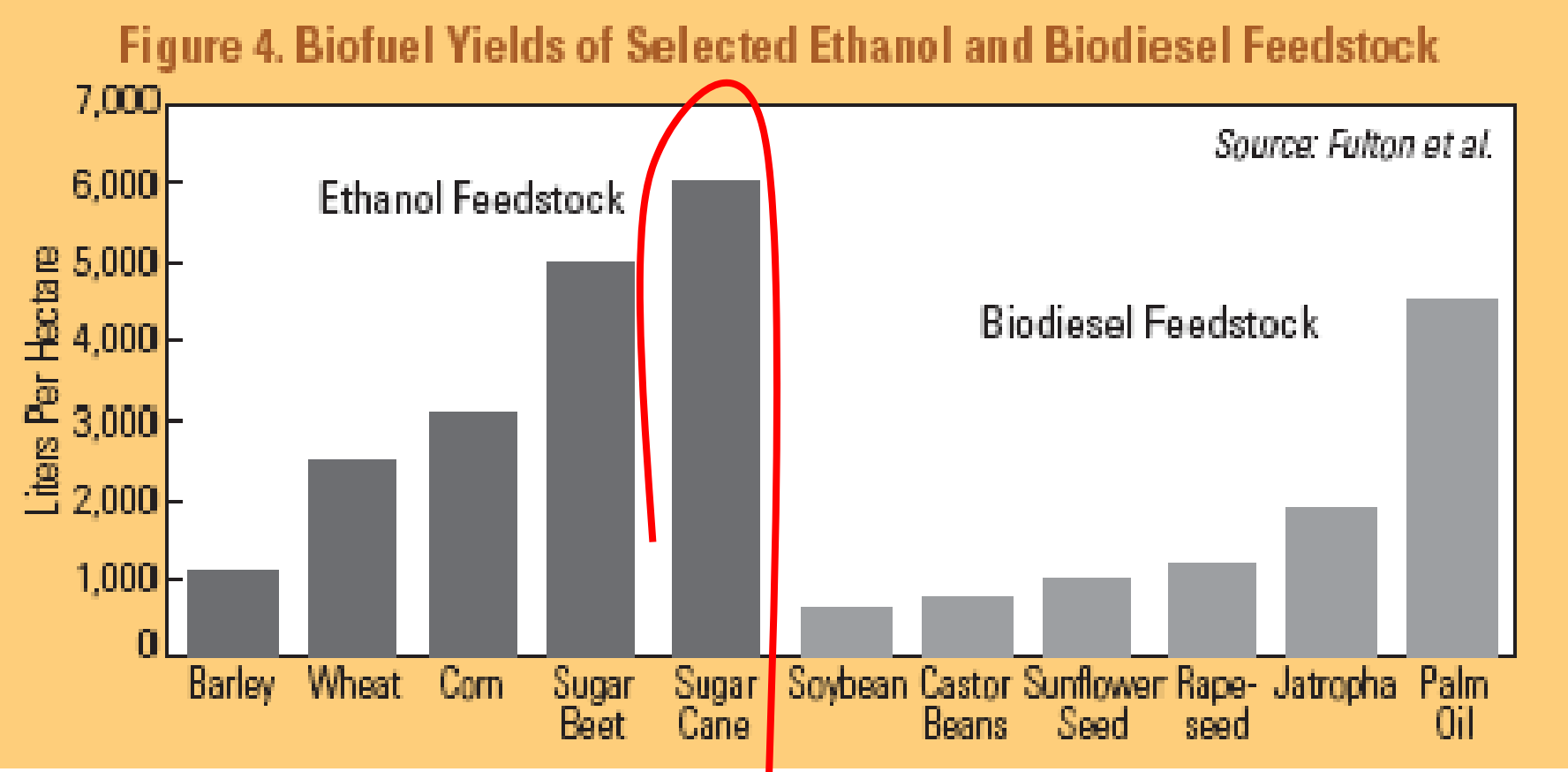
Source: UNICA

90% of cars sold are Flex-Fuel



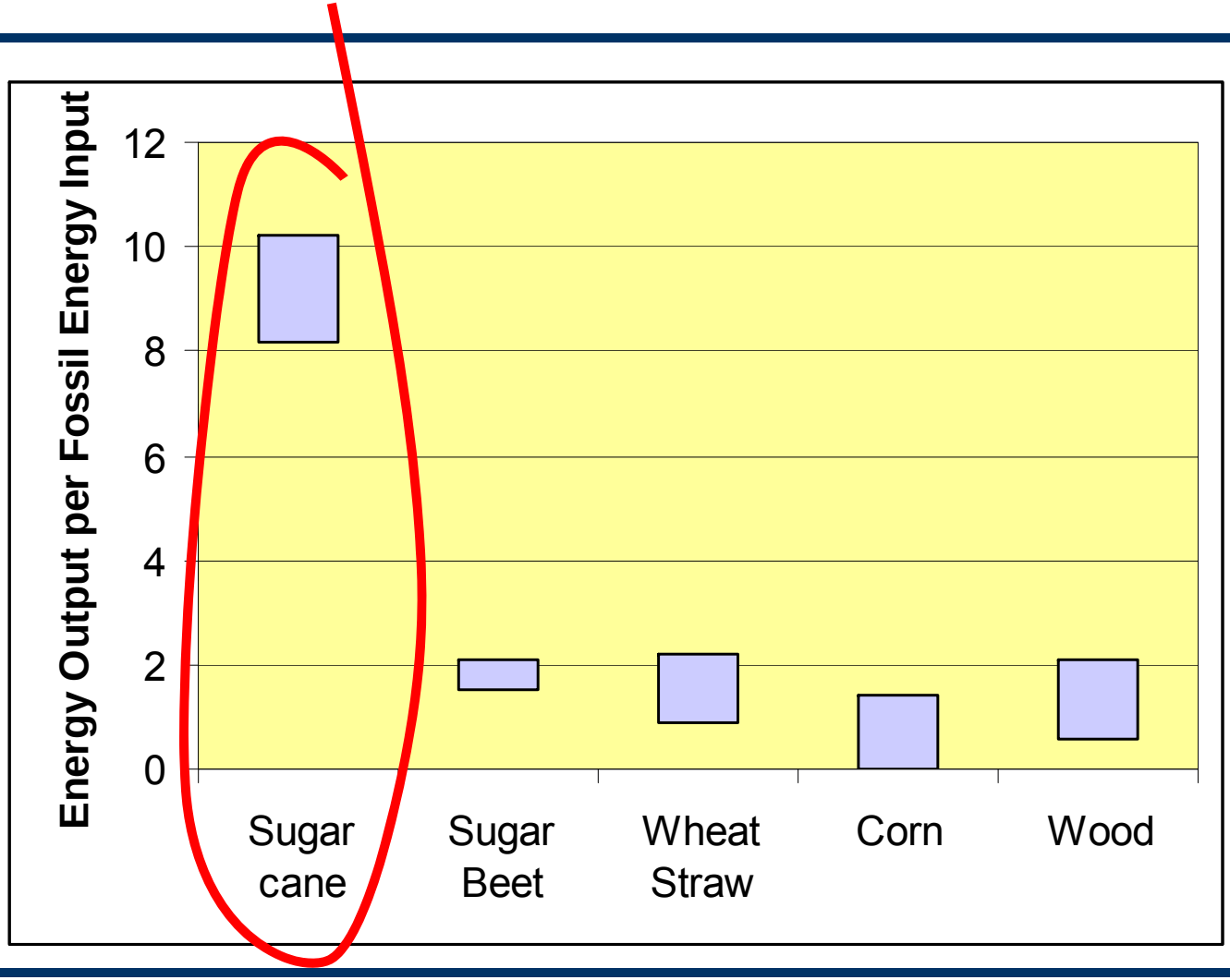
Source: ANFAVEA e UNICA, 2008

Biofuel yield per hectare

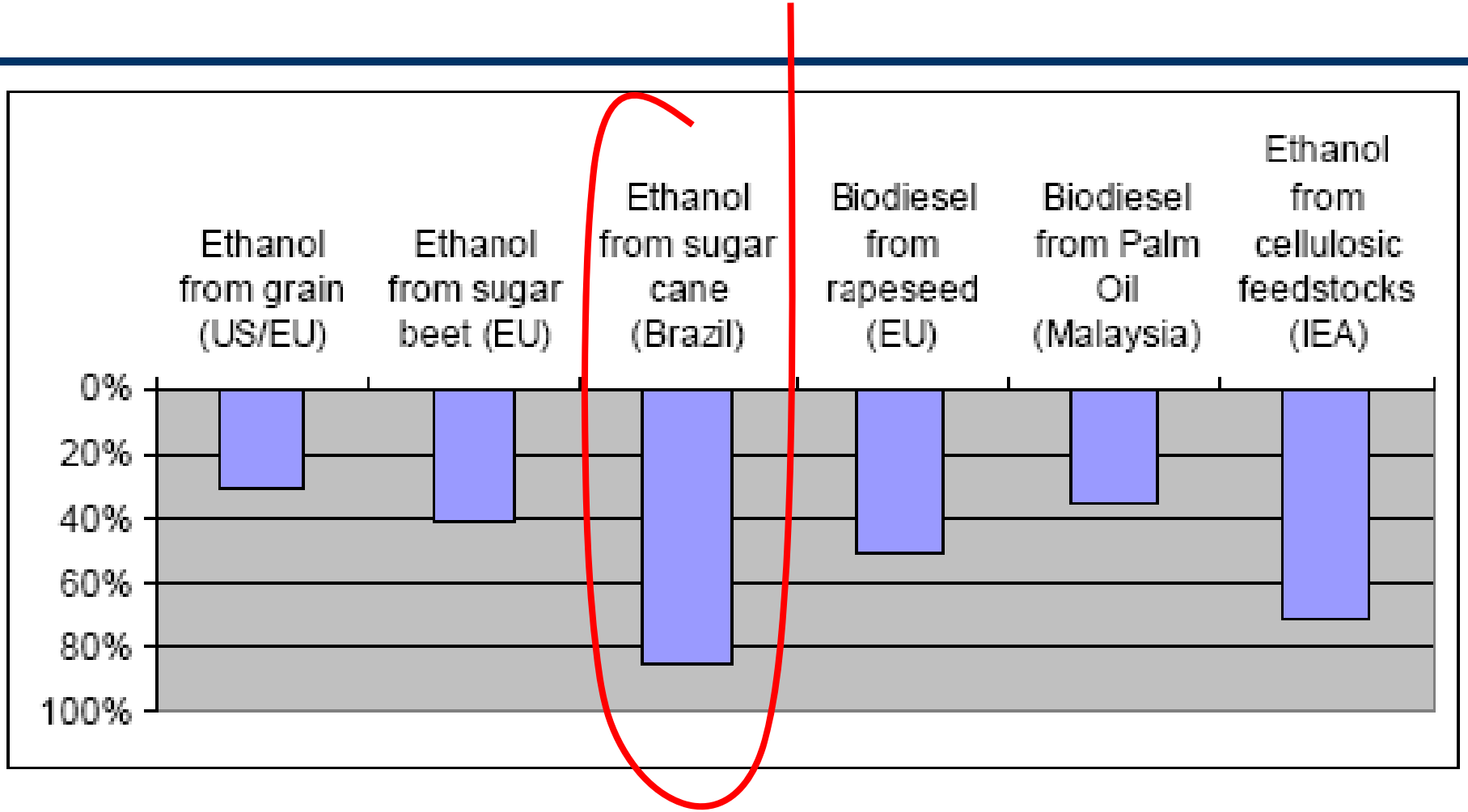


World Watch 2006, http://www.worldwatch.org/system/files/EBF008_1.pdf

Energy balance

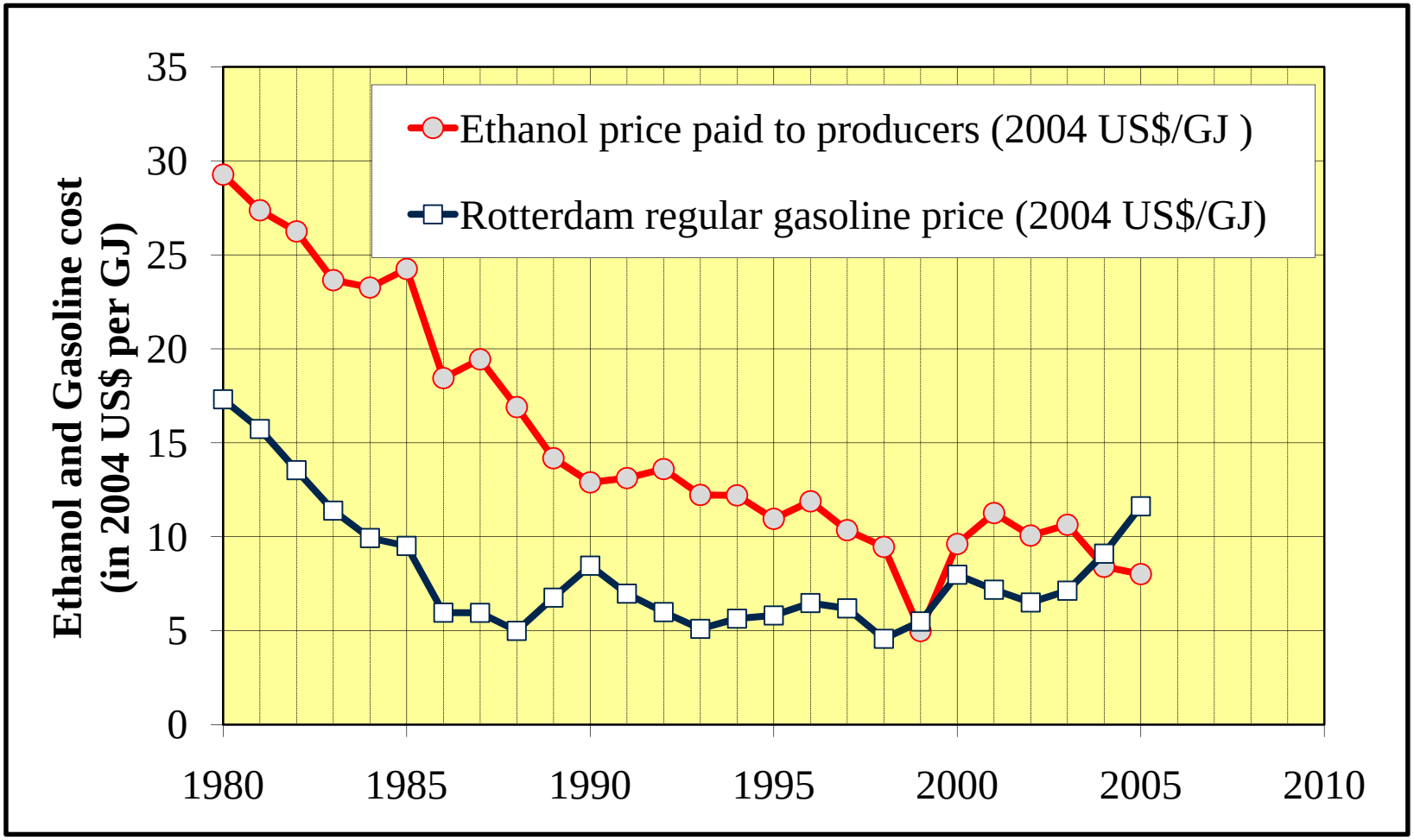


GHG reduction



Doornbosch and Steenblik, OECD 2007

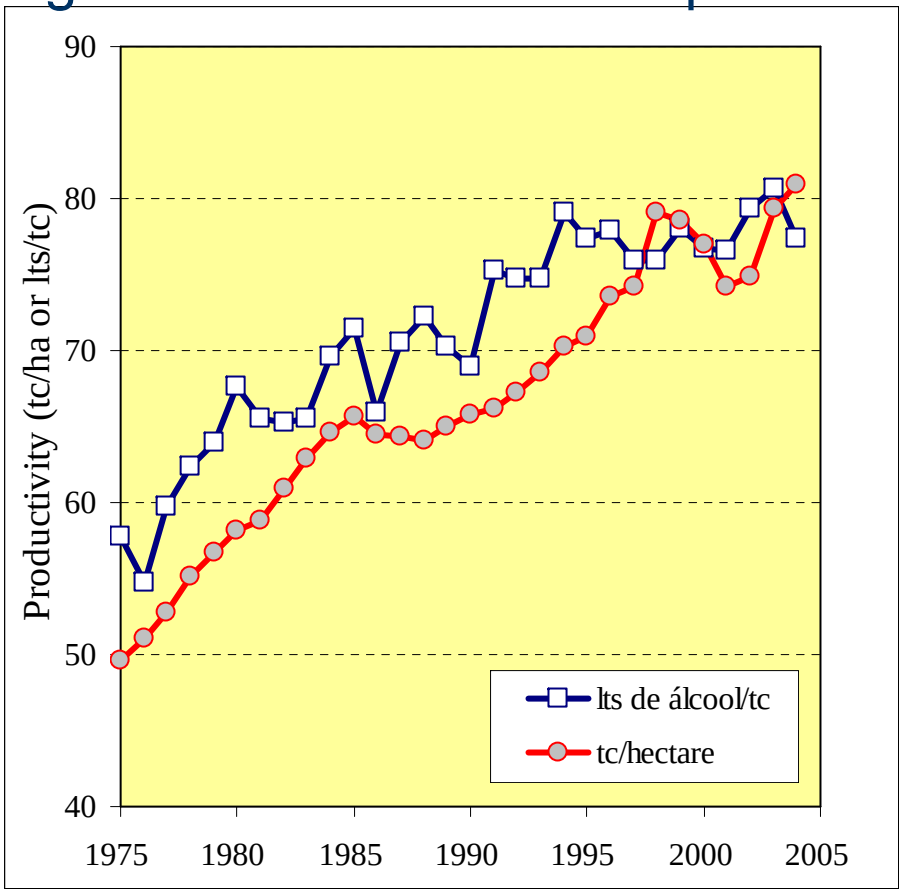
Ethanol costs x Gasoline



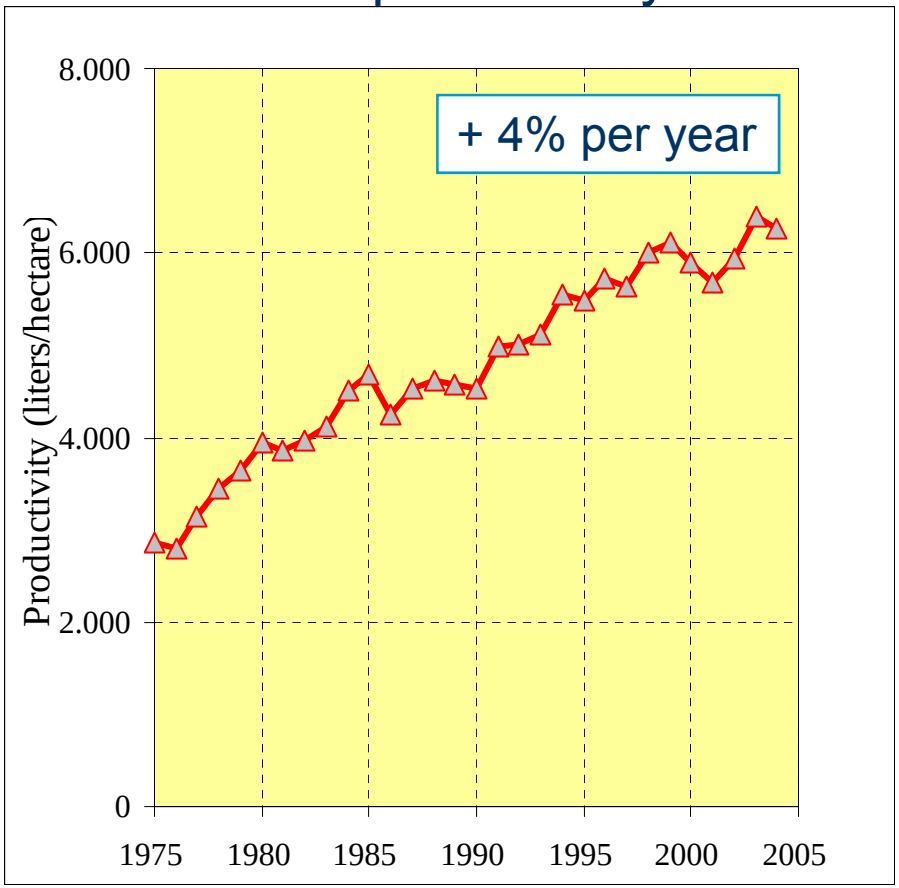
Source: Goldemberg, 2005

Increase in productivity through R&D

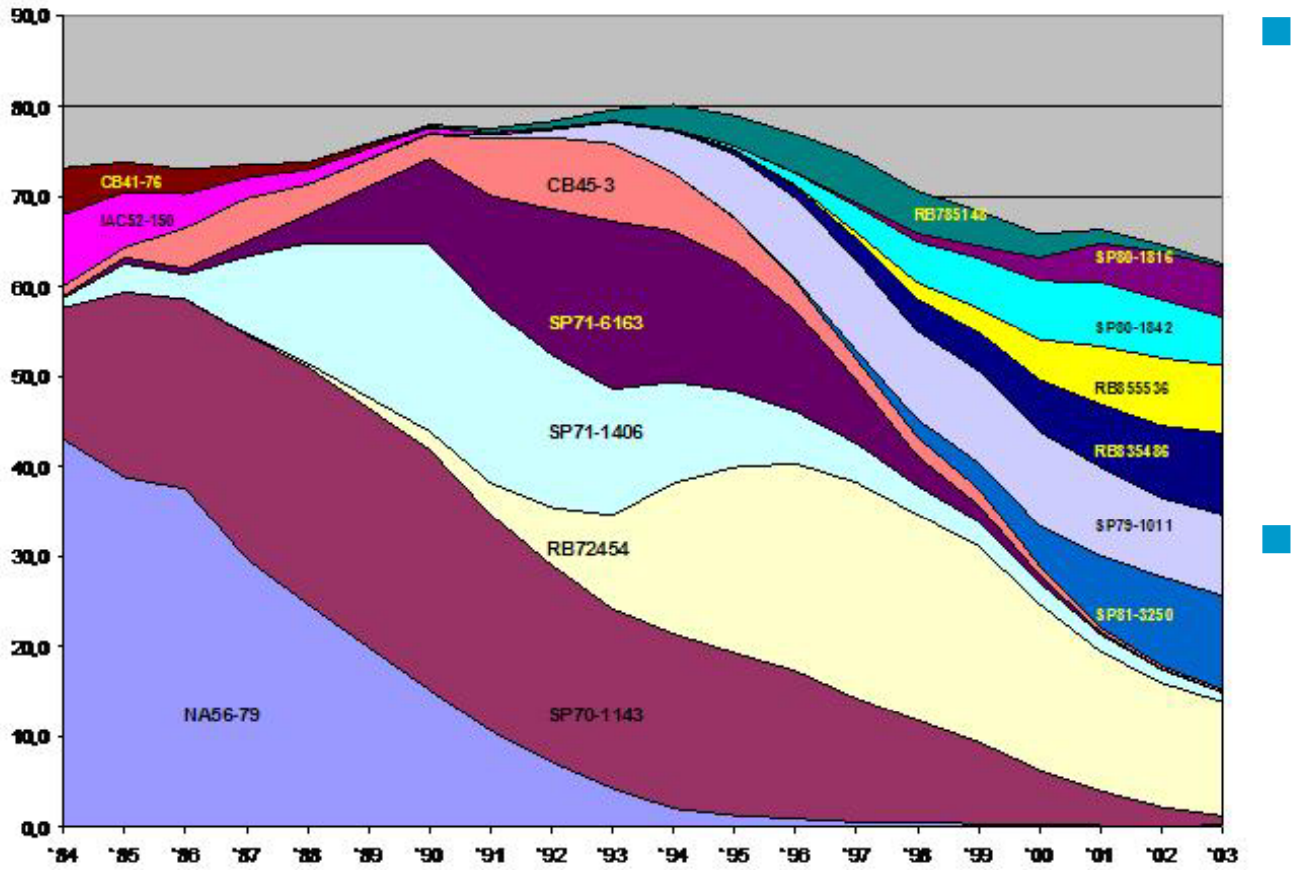
Agricultural and Industrial product.



Total productivity



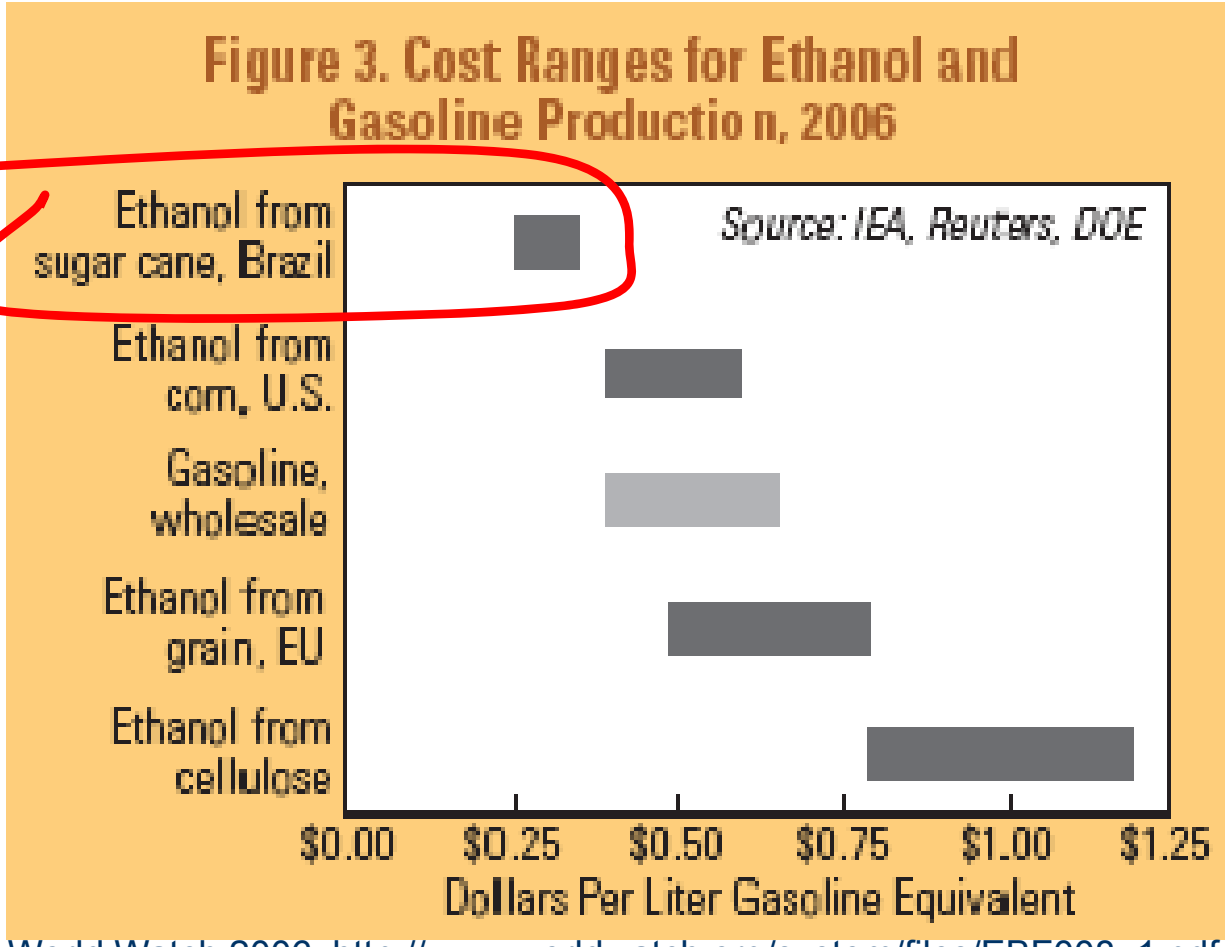
R&D: Increasing number of Sugarcane varieties used in Brazil



- Developed by 3 research organizations
  - CTC
  - Ridesa
  - IAC
- Plus private companies
  - Alellyx
  - Canaviallis

→ Now Monsanto

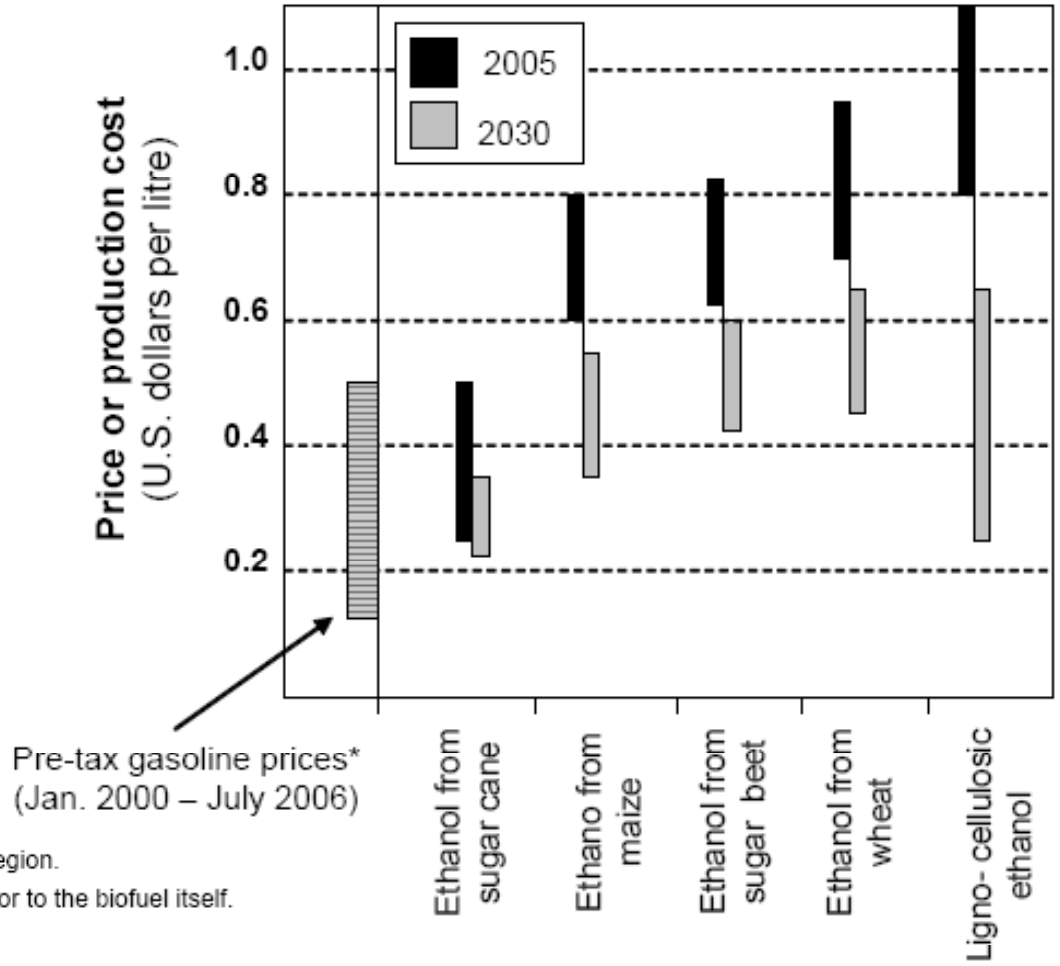
Biofuels costs



World Watch 2006, http://www.worldwatch.org/system/files/EBF008_1.pdf

Present and estimated future costs for Ethanol

From: Steenblik, "Biofuels at what cost", Sep. 2007

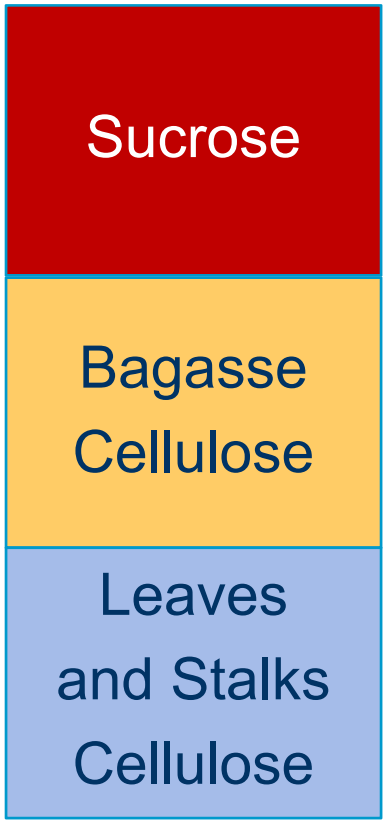


*Based on monthly average import prices for crude oil into the IEA region.

Note: Cost estimates exclude from consideration subsidies to crops or to the biofuel itself.

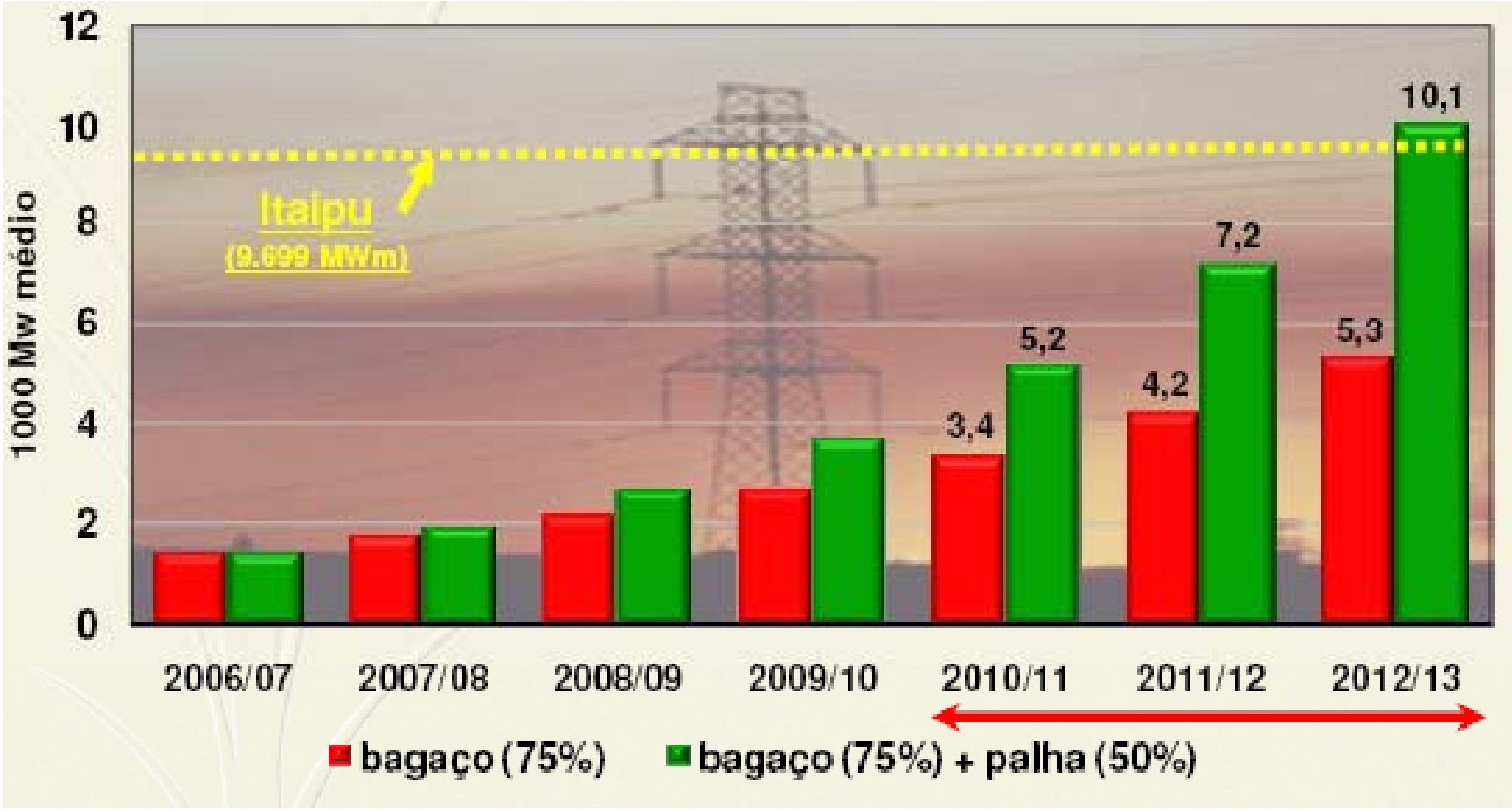
Source: Adapted from IEA (2006), Figure 14.7.

Sugarcane energy content



- 1 Ton of Cane = 1,2 Barrels of Oil
- Today
  - Sucrose → Ethanol
  - Bagasse → burnt for heat for the mill and electricity
  - Leaves and Stalks → burnt on the field (legislation for phasing out)

Sugarcane: Ethanol AND Electricity



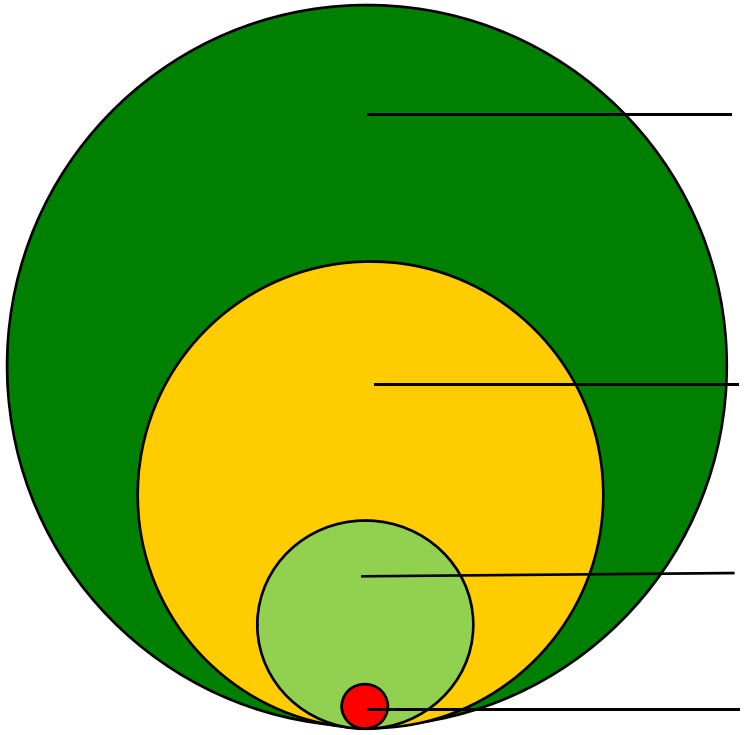
(Source: UNICA)

Brazil: 1% of arable land displaces 30%+ of the gasoline

Millions of Hectares (2007)		% total land	% arable land
BRAZIL	851		
TOTAL ARABLE LAND	354.8		
1. Total Crop Land	76.7	9.0%	21.6%
Soybean	20.6	2.4%	5.8%
Corn	14.0	1.6%	3.9%
Sugarcane	7.8	0.9%	2.2%
Sugarcane for ethanol	3.4	0.4%	1.0%
Orange	0.9	0.1%	0.3%
2. Pastures	172.3	20%	49%
3. Available area Total arable land – (crop land + pastures)	105.8	12%	30%

Source: UNICA

Sugarcane for ethanol uses 0,5% of total area



Small bioenergy footprint

Total country area (851 Mha, 100%)

Rural properties area (355 Mha, 42%)

Area used for agriculture (76,7 Mha, 9%)

Area used for sugarcane for ethanol (3,6 Mha, 0,5%)

Source: Horta Nogueira e Seabra (2008)

2050: Available land for biofuels

(Doornbosch and Steenblik, 2007)

Land (in Gha)	North Am.	South & Centr. Am.	Europe & Russia	Africa	Asia	Oceania	World
Total land surface	2,1	2,0	2,3	3,0	3,1	0,9	13,40
1 Apt for Rainfed cultivation	0,4	0,9	0,5	0,9	0,5	0,1	3,30
2 Apt and Under forest	0,1	0,3	0,1	0,1	0,0	0,0	0,80
3 Apt, already in use	0,2	0,1	0,2	0,2	0,6	0,1	1,50
4 Necessary for food, housing and infrastructure until 2030/50	0,0	0,1	0,0	0,1	0,1	0,0	0,30
5 Available (Gross) [5=1-2-3-4]	0,00	0,25	0,08	0,44	-0,07	0,04	0,74
6 % for grassland	0%	0%	50%	60%	n/a	0%	
7 Additional land potentially available (7)=(5)x(1-% for grassland)	**0,00**	**0,25**	**0,04**	**0,18**	**-0,07**	**0,04**	**0,44**

a. Most studies assume that only a small fraction of additional land is needed to feed the world's growing population — from 6.5 billion people at present to 9 billion people in 2050 — and that most of the increase in food requirements will be met by an increase in agricultural productivity.6 Here it is assumed that 0.2 Gha is needed for additional food production (based on Fisher and Schrattenholzer, 2001 where a yearly increase in agricultural productivity of 1.1% is assumed); the remainder (roughly 0.1 Gha) is needed for additional housing and infrastructure.

b. A negative number is shown here as more land is cultivated than potentially available for rain-fed cultivation because of irrigation. The negative land available has not been rounded to zero because food imports are likely to be needed from other region with implications on their land use.

c. Numbers in this column don't add up because of rounding.

0.25GHa @ 10kL/Ha.yr → 2,500GL /yr (in 2005: 40 GL)

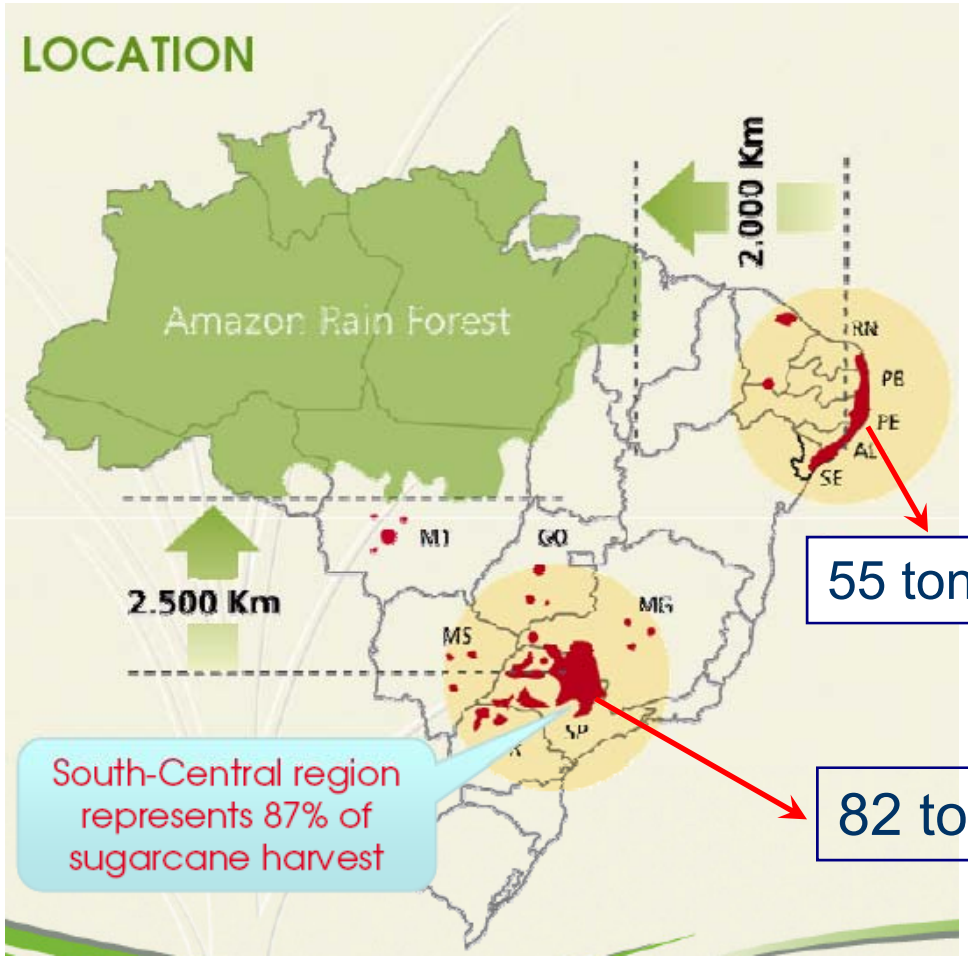
Reference quantities

Area available in Latin America by 2050: 0,25 Gha
Area available in Africa by 2050: 0,18 Gha
(both according to Doornbosch & Steenblik, OECD, 2007)

0.25GHa @ 10kL/Ha.yr $\rightarrow$ 2,500GL /yr (in 2005: 40 GL)

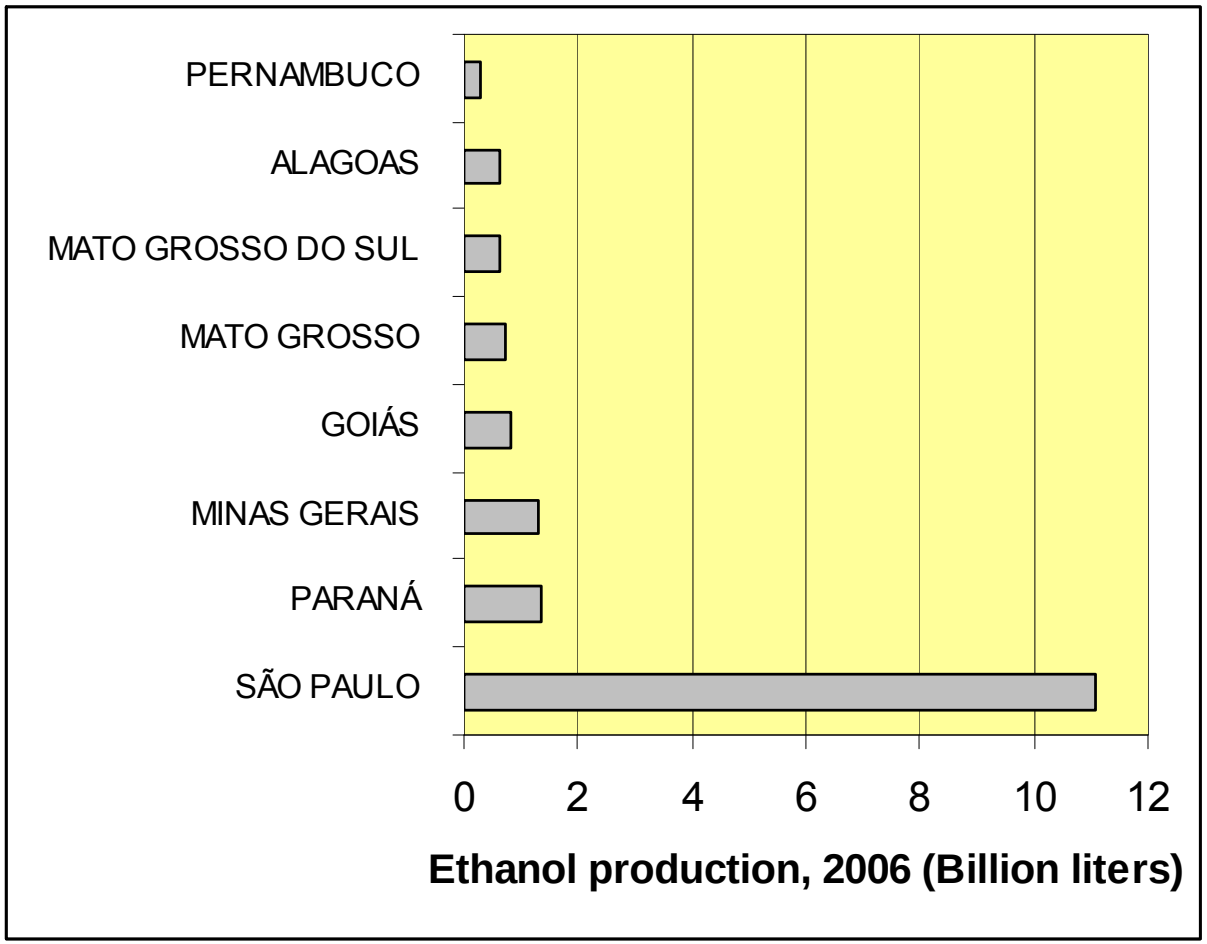
	2004	2025
Gasoline consumption	1,200 GL	1,700 GL
Ethanol consumption	30 GL	
Ethanol substituting 10% gasoline		205 GL

Where does Brazil plant Sugarcane?



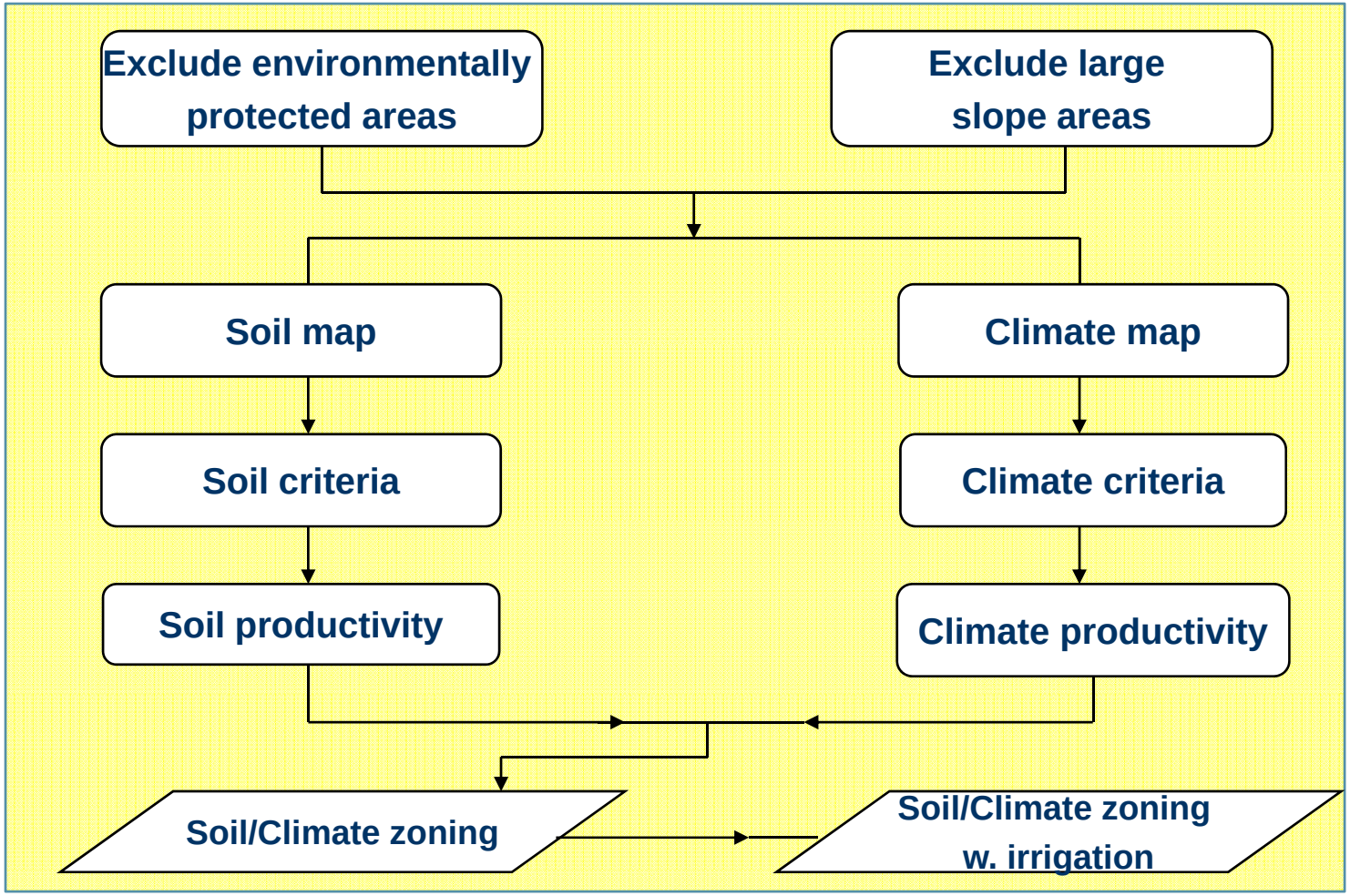
- Not in the Amazon
- Best land for cane:
  - Northeast coast
    - Oldest (XVI century)
  - Southeast
    - highest productivity
  - Centralwest
    - main expansion area

Brazilian Ethanol production, by State

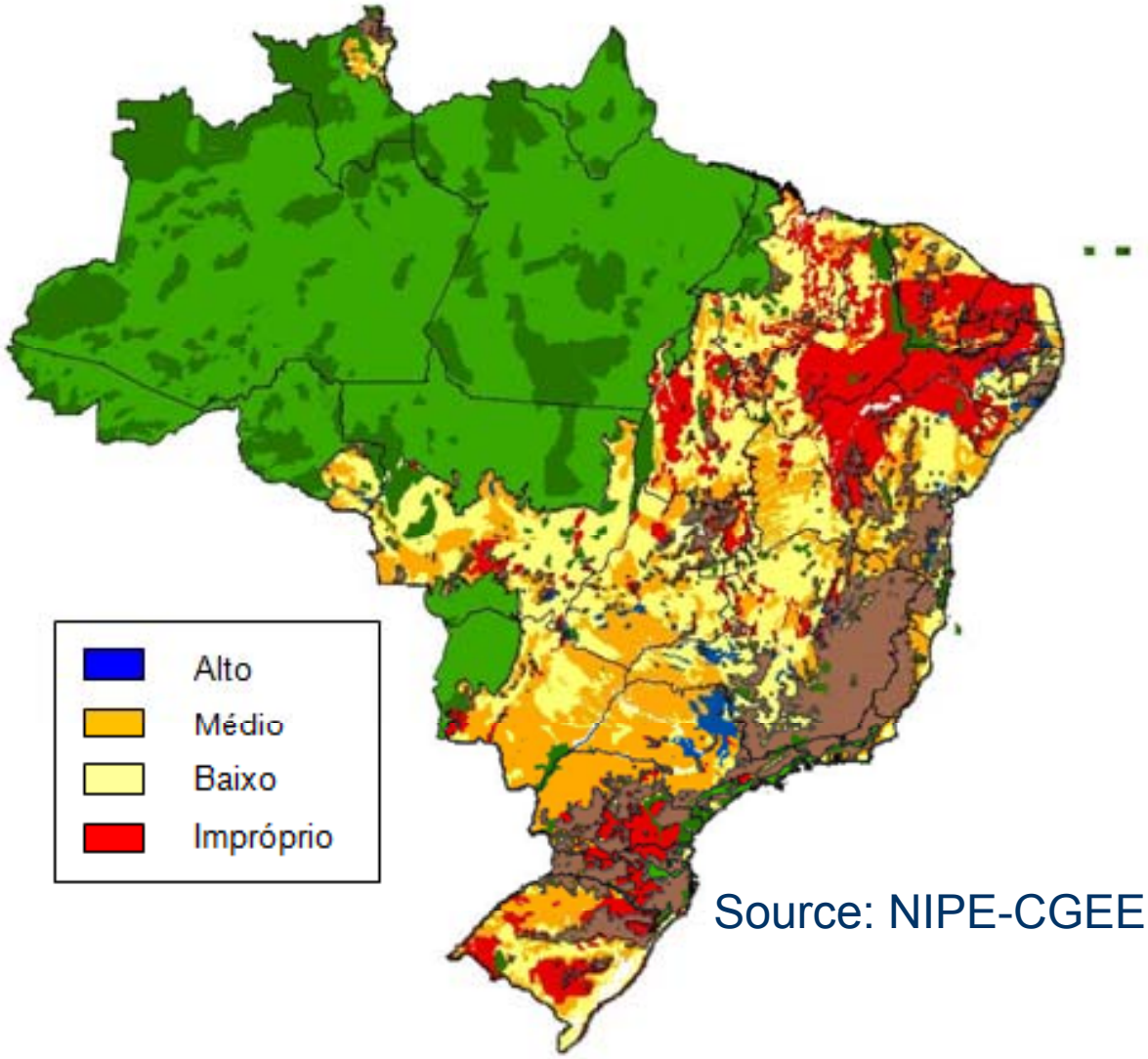


- São Paulo
  - 62% of Brazilian Ethanol
- Makes the State 2nd to the U.S.
- São Paulo hosts most of the R&D in sugarcane and ethanol in Brazil

R&D: Sugarcane expansion assessment *(by NIPE, Unicamp)*

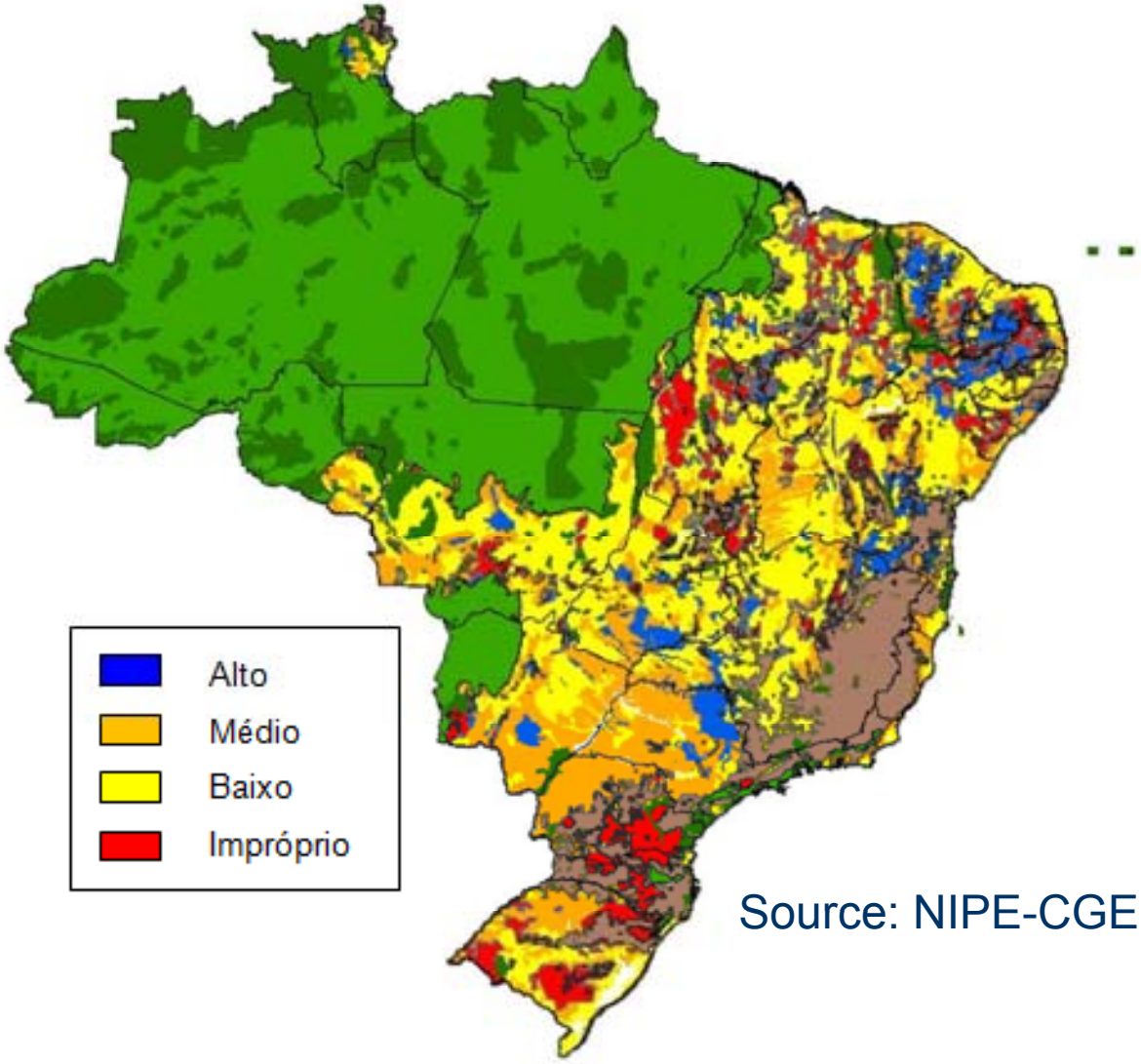


1st step: Potential sugarcane area no irrigation



Source: NIPE-CGEE, Fase I (2005)

1st step: Potential sugarcane area with irrigation



Source: NIPE-CGEE, Fase I (2005)

Potential area classification

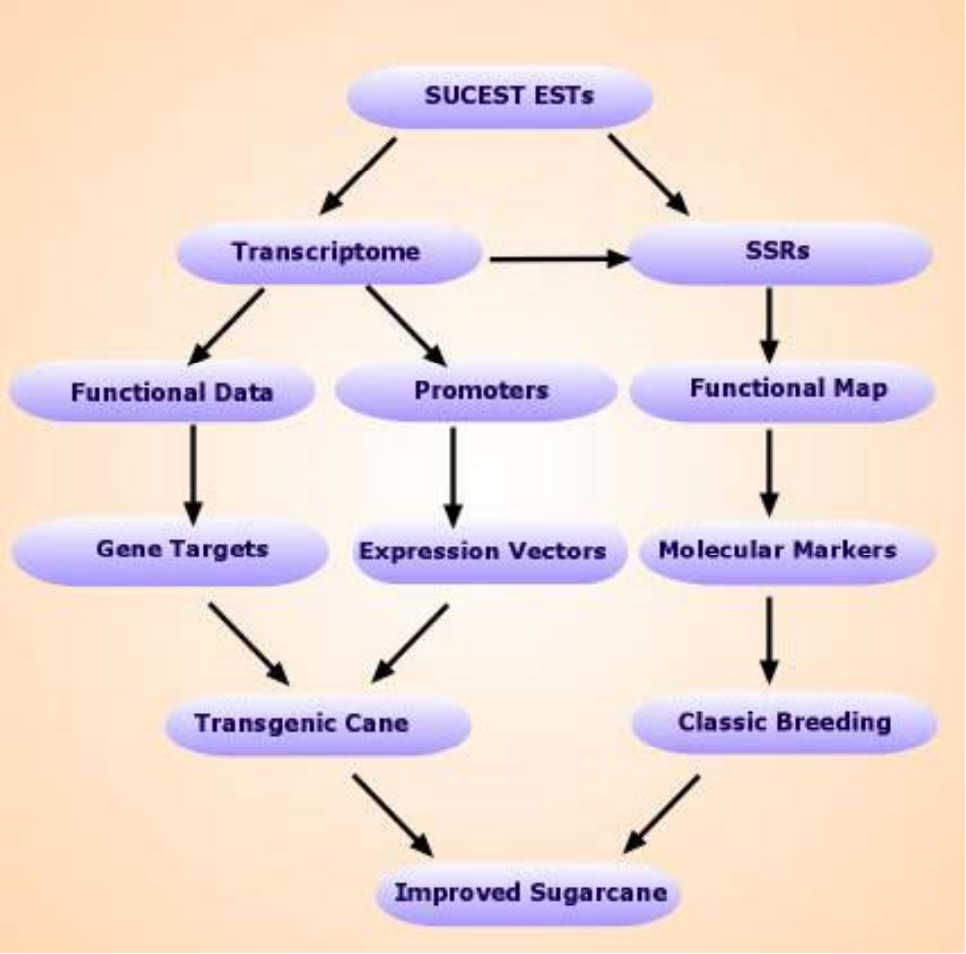
Area classification					
	Productivity	No irrigation		W. irrigation	
Potential	(ton/ha)	MHa	%	MHa	%
High	> 80	7,9	2,2	37,9	10,5
Medium	>73	113,9	31,5	98,0	27,1
Low	> 65	149,2	41,3	167,7	46,4
Inadequate	< 65	90,6	25,1	58,0	16
Total	-	**361,6**	**100**	**361,6**	**100**

122 Mha (as compared to today's 3,6 MHa)

R&D for improving the sugarcane plant

- Traditional genetics and processes
  - 1.3 x in liters/ton
  - 1.6 x in ton/ha
  - Total productivity gain of 2.2 x in 30 years
- Genomics based plant improvement
  - Functional genomics
  - Target: full sugarcane genome

FAPESP (The São Paulo Research Foundation): SUCEST Program, 1999



- Started 1999
- Molecular Biology tools for improving sugarcane
- Science and Technology of sugarcane
  - Articles, thesis and patents
  - Human resources

FAPESP Genome Program
SUCEST
The Sugar Cane EST Project

SUCEST Project
FAPESP, 1999 - 2004

Genome Research

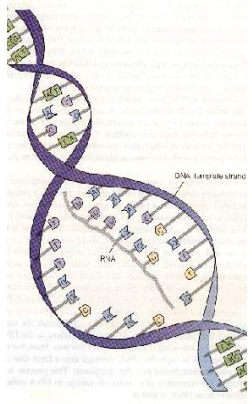
13:2725–2735 ©2003 by Cold Spring Harbor Laboratory Press ISSN 1088-9051/03 $5.00; www.genome.org

Analysis and Functional Annotation of an Expressed Sequence Tag Collection for Tropical Crop Sugarcane

André L. Vettore,[1,24] Felipe R. da Silva,[1,25] Edson L. Kemper,[1,26] Glaucia M. Souza,[3] Aline M. da Silva,[3] Maria Inês T. Ferro,[6] Flavio Henrique-Silva,[8] Éder A. Giglioti,[9] Manoel V.F. Lemos,[7] Luiz L. Coutinho,[10] Marina P. Nobrega,[11] Helaine Carrer,[10] Suzelei C. França,[12] Maurício Bacci Jr.,[13] Maria Helena S. Goldman,[14] Suely L. Gomes,[3] Luiz R. Nunes,[15] Luis E.A. Camargo,[10] Walter J. Siqueira,[16] Marie-Anne Van Sluys,[4] Otavio H. Thiemann,[17] Eiko E. Kuramae,[18] Roberto V. Santelli,[3] Celso L. Marino,[19] Maria L.P.N. Targon,[20] Jesus A. Ferro,[6,27] Henrique C.S. Silveira,[8] Danyelle C. Marini,[9] Eliana G.M. Lemos,[6] Claudia B. Monteiro-Vitorello,[10] José H.M. Tambor,[11] Dirce M. Carraro,[10,24] Patrícia G. Roberto,[12] Vanderlei G. Martins,[21] Gustavo H. Goldman,[22] Regina C. de Oliveira,[15] Daniela Truffi,[10] Carlos A. Colombo,[16] Magdalena Rossi,[4] Paula G. de Araujo,[4] Susana A. Sculaccio,[17] Aline Angella,[18] Marleide M.A. Lima,[18] Vicente E. de Rosa Jr.,[18] Fábio Siviero,[3] Virginia E. Coscrato,[19] Marcos A. Machado,[20] Laurent Grivet,[23] Sonia M.Z. Di Mauro,[6] Francisco G. Nobrega,[11] Carlos F.M. Menck,[5] Marilia D.V. Braga,[2,28] Guilherme P. Telles,[2] Frank A.A. Cara,[2] Guilherme Pedrosa,[2] João Meidanis,[2] and Paulo Arruda[1,27,29]

50 labs

200 researchers



238000 ESTs

43000 Transcripts

SUCEST-FUN Project

BMC Genomics

BioMed Central

Research article

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Signal transduction-related responses to phytohormones and environmental challenges in sugarcane

Flávia R Rocha[1], Flávia S Papini-Terzi[1], Milton Y Nishiyama Jr[1], Ricardo ZN Vêncio[2], Renato Vicentini[3], Rodrigo DC Duarte[3], Vicente E de Rosa Jr[3], Fabiano Vinagre[4], Carla Barsalobres[5], Ane H Medeiros[5], Fabiana A Rodrigues[7], Eugênio C Ulian[6], Sônia M Zingaretti[7], João A Galbiatti[7], Raul S Almeida[8], Antonio VO Figueira[8], Adriana S Hemerly[4], Marcio C Silva-Filho[5], Marcelo Menossi[3] and Gláucia M Souza*[1]

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Sugarcane Functional Genomics: Gene Discovery for Agronomic Trait Development

M. Menossi,[1] M. C. Silva-Filho,[2] M. Vincentz,[1] M.-A. Van-Sluys,[3] and G. M. Souza[4*]

THE SUCEST-FUN PROJECT: IDENTIFYING GENES THAT REGULATE SUCROSE CONTENT IN SUGARCANE PLANTS

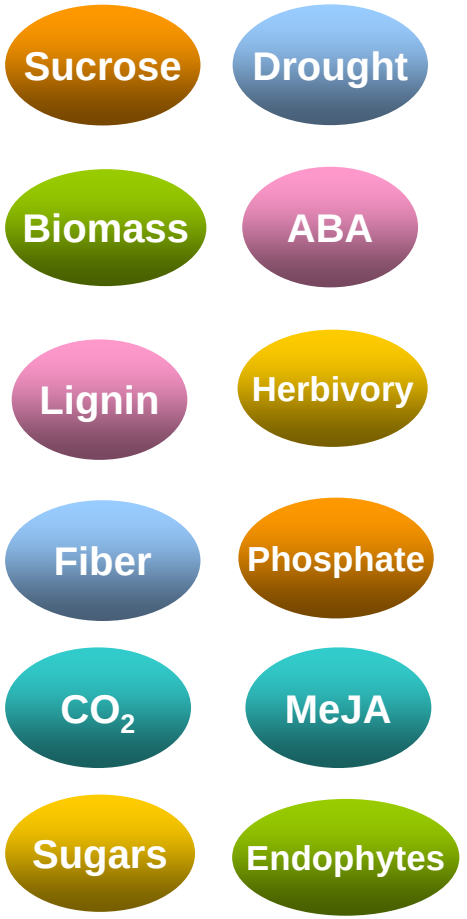
By

F.S. PAPINI-TERZI[1*], J.M. FELIX[2*], F.R. ROCHA[1], A.J. WACLAWOVSKY[1], E.C. ULIAN[3], S. M. CHABREGAS[3], M.C. FALCO[3], M.Y. NISHIYAMA-JR[1], R.Z.N. VÊNCIO[4], R. VICENTINI[2], M. MENOSSI[2] and G.M. SOUZA[1]

DNA Research 12, 27–38 (2005)

Transcription Profiling of Signal Transduction-Related Genes in Sugarcane Tissues

Flávia Stal Papini-Terzi,[1,†] Flávia Riso Rocha,[1,†] Ricardo Zorzetto Nicoliello Vêncio,[2] Kátia Cristina Oliveira,[1] Juliana de Maria Felix,[3,4] Renato Vicentini,[4] Cristiane de Souza Rocha,[4] Ana Carolina Quirino Simões,[1] Eugênio César Ulian,[5] Sônia Marli Zingaretti di Mauro,[6] Aline Maria Da Silva,[1] Carlos Alberto de Bragança Pereira,[2] Marcelo Menossi,[3,4] and Gláucia Mendes Souza[1,*]



Maps and Markers

Mol Breeding (2007) 20:189–208
DOI 10.1007/s11032-007-9082-1

Functional integrated genetic linkage map based on EST-markers for a sugarcane (*Saccharum* spp.) commercial cross

Karine M. Oliveira · Luciana R. Pinto · Thiago G. Marconi · Gabriel R. A. Margarido · Maria Marta Pastina · Laura Helena M. Teixeira · Antônio V. Figueira · Eugênio César Ulian · Antônio Augusto F. Garcia · Anete Pereira Souza

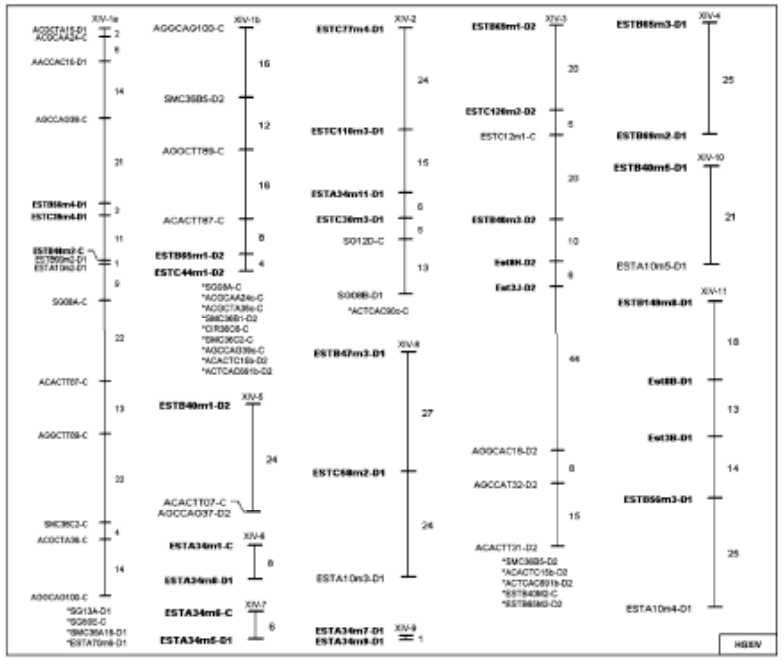
Theor Appl Genet (2006) 112: 298–314
DOI 10.1007/s00122-005-0129-6

ORIGINAL PAPER

A. A. F. Garcia · E. A. Kido · A. N. Meza
H. M. B. Souza · L. R. Pinto · M. M. Pastina
C. S. Leite · J. A. G. da Silva · E. C. Ulian
A. Figueira · A. P. Souza

Development of an integrated genetic map of a sugarcane (*Saccharum* spp.) commercial cross, based on a maximum-likelihood approach for estimation of linkage and linkage phases

Hereditas 144: 78–79 (2007)



OneMap: software for genetic mapping in outcrossing species

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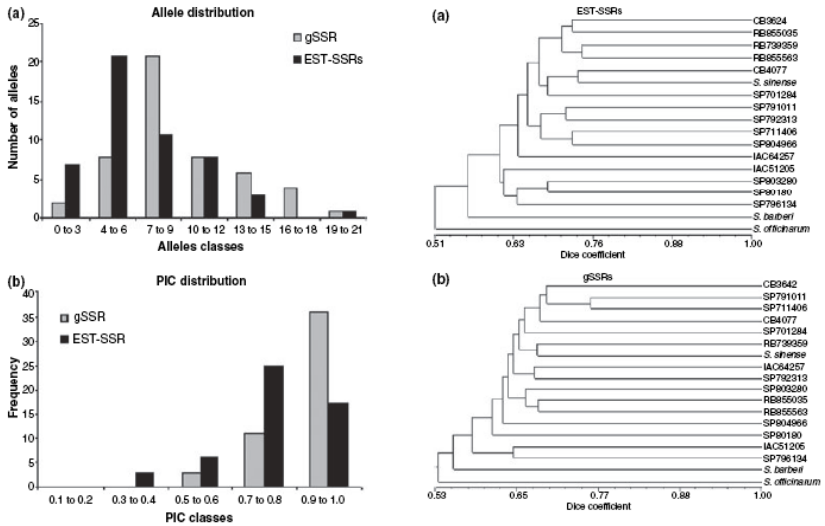
Plant Breeding 125, 378—384 (2006)



Characterization of novel sugarcane expressed sequence tag microsatellites and comparison with genomic SSRs

L. R. PINTO[1], K. M. OLIVEIRA[2], T. MARCONI[2], A. A. F. GARCIA[3], E. C. ULIAN[4] and A. P. DE SOUZA[2]

SUCEST: Gene Discovery and Functional Genomics

- Genes associated to traits of interest
- In association with planters R&D center
  - Sugarcane Transcriptome Project (University of São Paulo, USP)
    - Over 1,000 trait genes (sucrose, herbivory, drought, nutritional responses) identified through genomics tools applied to the study of the Brazilian germplasm (Pat pending USPTO11/716,262)
  - Sugarcane Molecular Marker Development Project (University of Campinas, UNICAMP)
    - A functional map and markers associated to sucrose content developed for breeding populations

Cane Genomics Research Team

Os coordenadores dos laboratórios de seqüenciamento e de *data mining*: equipe avança no estudo das semelhanças biológicas da cana com outros organismos e na pesquisa aplicada, em conjunto com produtores de açúcar e álcool

Biotechnology + Breeding knowledge

- Target genes which migh help in
  - Increasing yield, and
  - Expansion to pasture land (subject to extended drought season)
  - Easing the need for expansion of planted area
- The SUCEST-FUN Database
  - an integrated database for sequences, expression data, markers, germplasm and transgenics characteristics

FAPESP's Research Program on Bioenergy (BIOEN): 5 areas

1. Improvements in the feedstock: building a better cane plant for energy
2. Production of Ethanol and other products: hydrolysis, pyrolisis, gasification, fermentation, distillation
3. New processes in alcohol-chemistry
4. Ethanol based engine and fuel cell developments
5. The Economics of Ethanol, Ethanol production and the environment, Social impacts, the new agriculture of food AND energy

State of São Paulo Bioenergy R&D – BIOEN

- Academic Basic and Applied Research
  - Advancement of knowledge – R$ 48M (2008)
    - Plus R$ 300 M (10 years) for a Statewide Research Center
  - Young Investigator Awards – US$ 6 M (2008)
    - Open to foreign scientists who want to come to Brazil
- Joint industry-university research (5 years)

Company	Subject	Value
Oxiteno	Lignocellulosic materials	R$ 6,000,000
Braskem	Alcohol-chemistry	R$ 50,000,000
Dedini	Processes	R$ 100,000,000