RENEWABLE ENERGY TRAINING PROGRAM
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Ethanol and Biodiesel in Brazil

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Aggregating science and technology to traditional agro-industries, biofuels represent a sustainable and competitive alternative for the current and future energy supply.

Outline

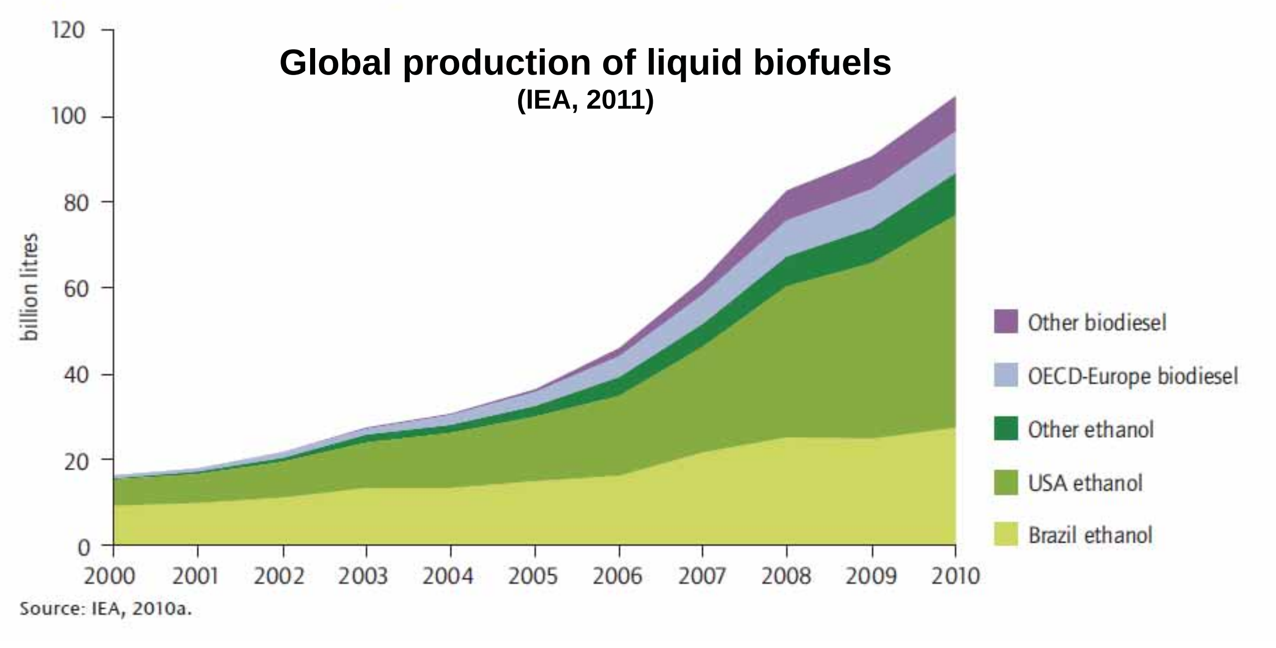
- ✓ ***Context: bioenergy is relevant abroad and in Brazil***
- ✓ ***The evolution of Brazilian bioenergy agro-industry***
- ✓ ***Sustainability of sugarcane bioenergy: some facts***
- ✓ ***Biodiesel evolution and landmarks***
- ✓ ***Final comments***

Bioenergy in the global scenario

More and more, the main drivers towards a global energy transition;

- ✓***concerns on oil dependence and energy costs,***
- ✓***global and local environmental problems,***
- ✓***opportunity for economic activation of agro-industrial sector,***

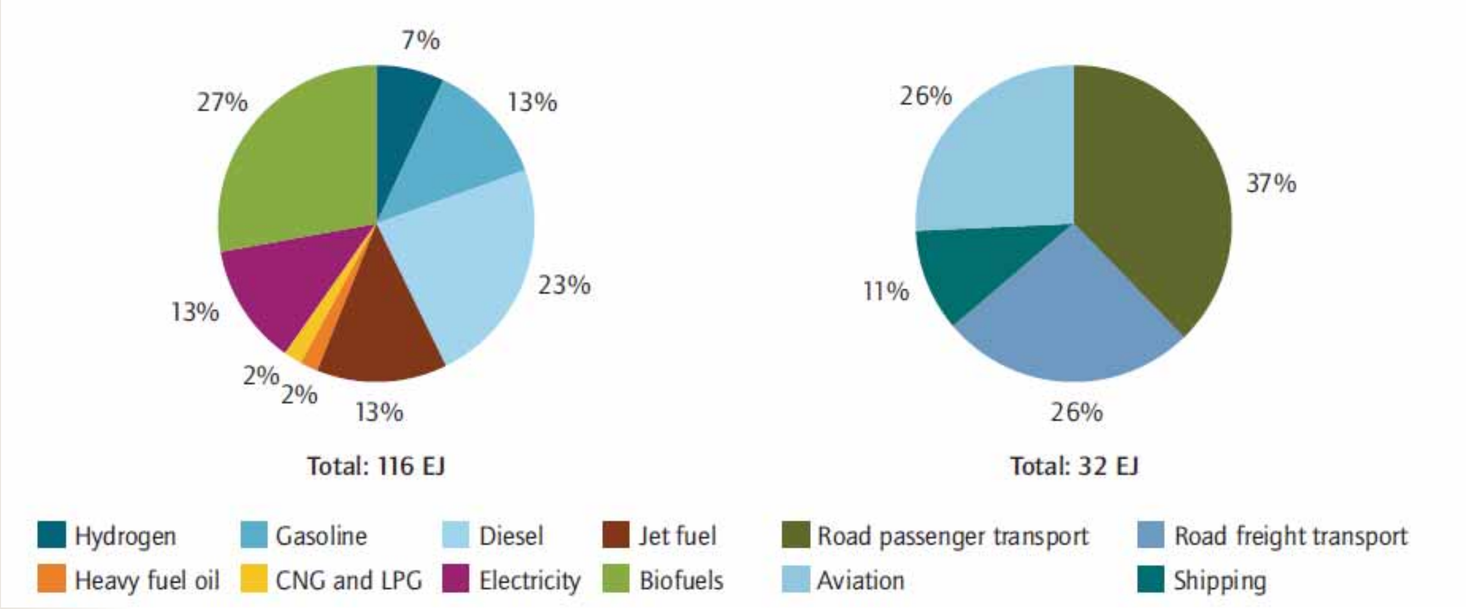
are reinforced and fostered biofuels production and use abroad…



Bioenergy in the global scenario

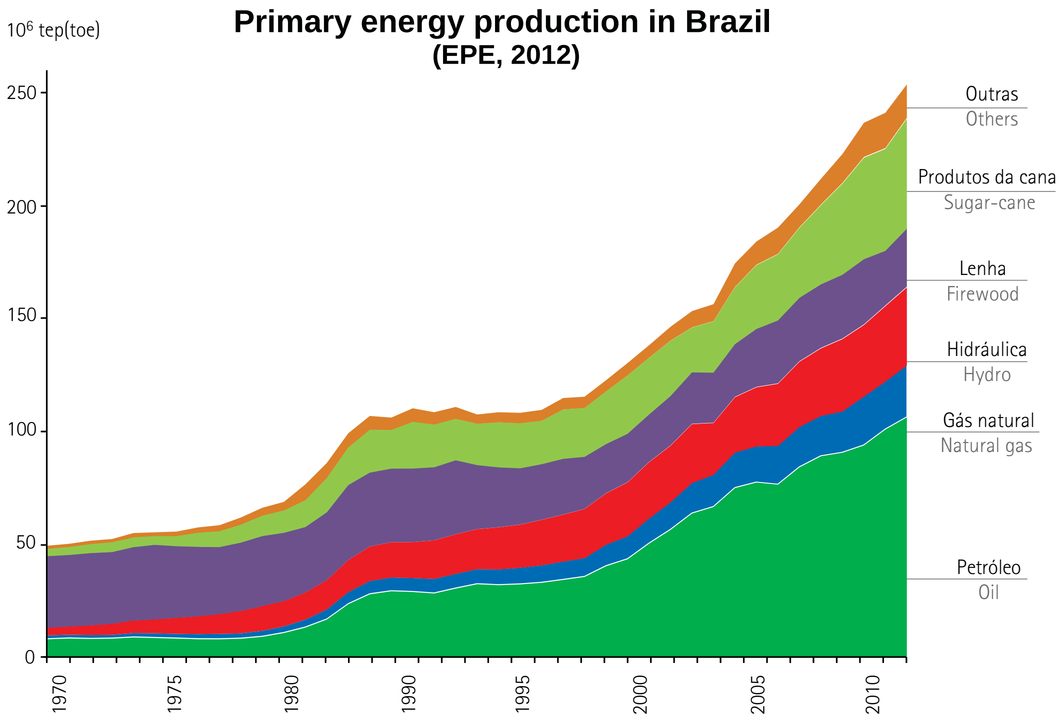
… as well as biofuel demand forecasts are indicating a huge market for bioenergy in the next decades.

Global energy use in the transport sector and use of biofuels in different transport modes in 2050
(BLUE Map Scenario, IEA, 2011)



Bioenergy in Brazil

Biofuels always accounted for a significant share of Brazilian energy matrix. Currently, sugar cane, wood and several waste biomass mean about 1/3 of total domestic energy consumption.



The sugarcane energy in Brazil

Sugarcane energy products (ethanol and electricity) demand in Brazil is equivalent to about 800 thousand barrels of oil per day.

More than 30 million Brazilian cars run using ethanol, either pure (E100) or blended with gasoline (E25-E18).

The area occupied with sugarcane plantation for energy represents a small share of arable land (<1%), with reduced impacts on biodiversity and the production of other agricultural products.

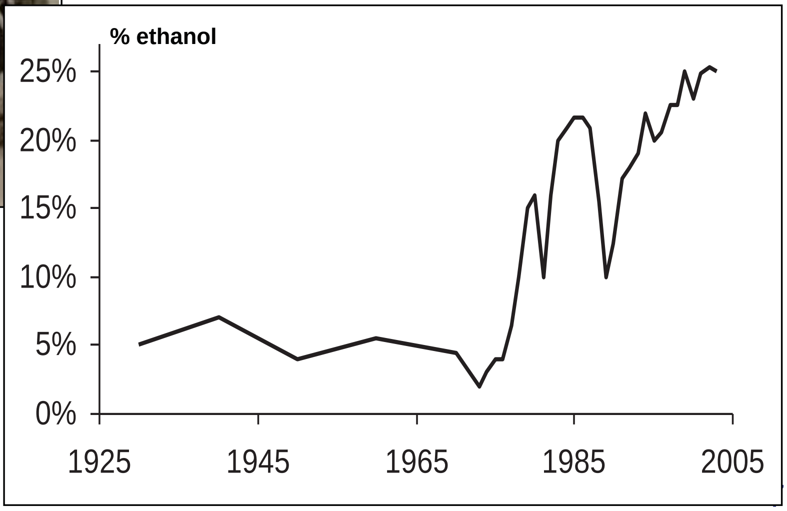
Typical sugarcane mill in the Brazilian Center South region
(BNDES, 2009)

Ethanol use: from the beginning

Gasoline blended with ethanol has been a mandatory practice in Brazil since 1931 (minimum E5, average E7.5), reinforced after the oil crisis during the seventies, when the use of high blends (E25) in all gasoline motors and pure hydrous ethanol in dedicated motors was adopted.

Ford Model T adapted for pure ethanol, used for public demonstrations in the 20's

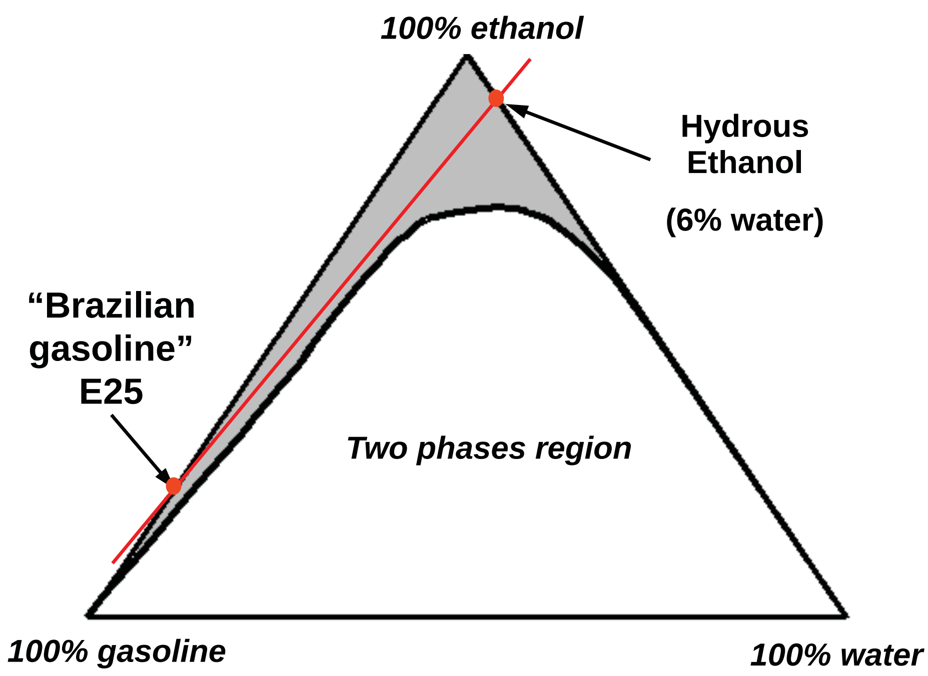
(INT, 2006)



Ethanol content in the Brazilian gasoline
(BNDES, 2008)

Ethanol evolution: flex-fuel motors

Vehicles with motors able to use any blend of pure hydrous ethanol (E100) and gasoline (E25), presenting good performance and accomplishing environmental requirements, were introduced successfully in the Brazilian market and today represents around 90% of new cars in the light vehicles fleet.



Ternary diagram ethanol/gasoline/water
(CTC, 2004)

New frontiers for ethanol use

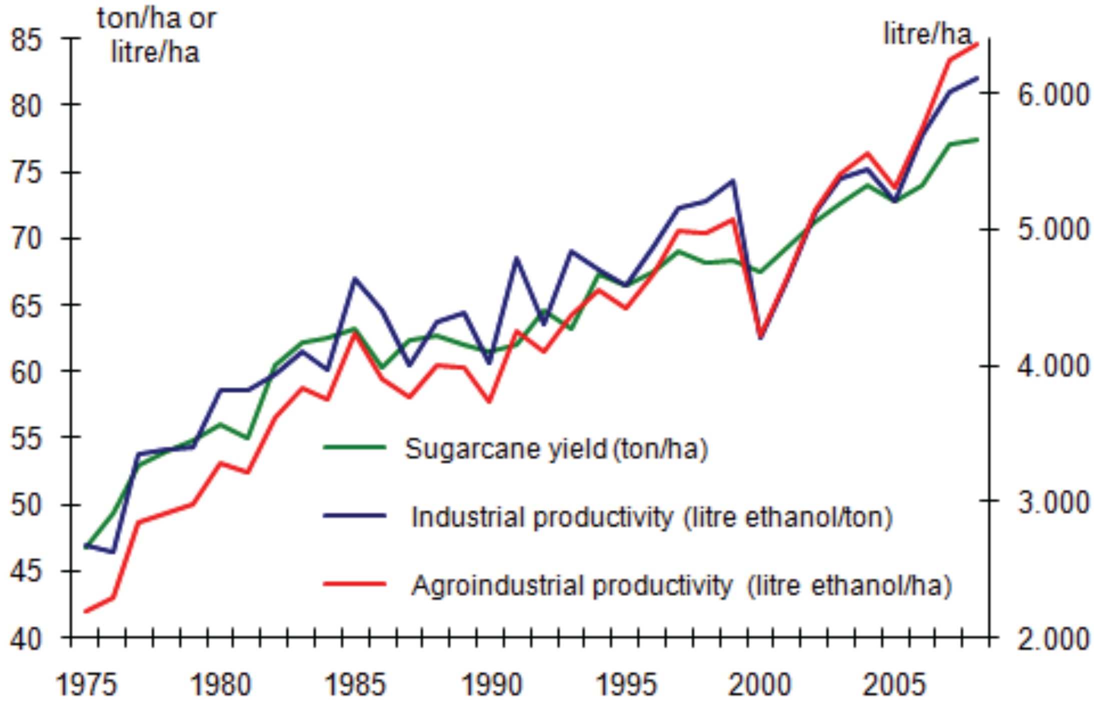
Besides the regular use as pure hydrous ethanol and in blend with gasoline, new interesting opportunities are opening new and promising markets for bioethanol.

Airplane regularly produced to use pure hydrous ethanol
(EMBRAER, 2008)

Bus with Diesel engine able to use hydrous ethanol
(BEST, 20099)

Ethanol evolution: productivity

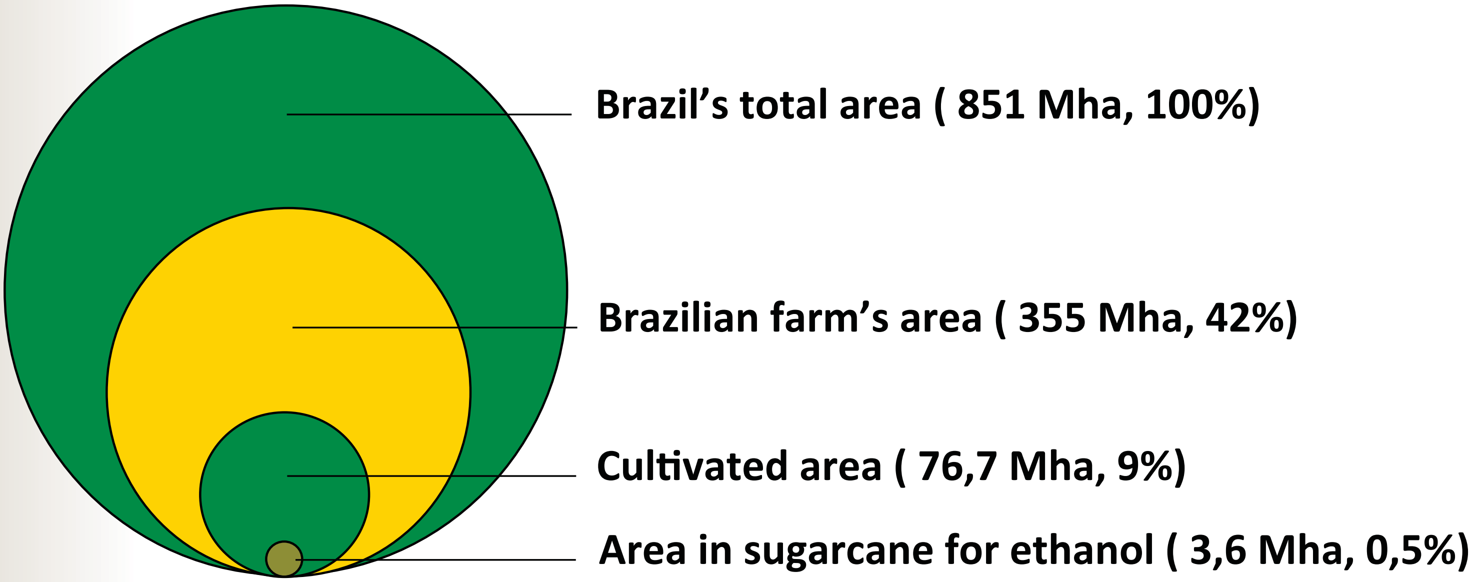
In the last three decades many improvements has been introduced in ethanol production, multiplying the total productivity by 2.6, due to agronomic and industrial gains.



(CONAB/MAPA, 2010)

The sugarcane energy in Brazil

There is a large area for expansion of sugarcane in Brazil, currently occupied by low productivity pastures.

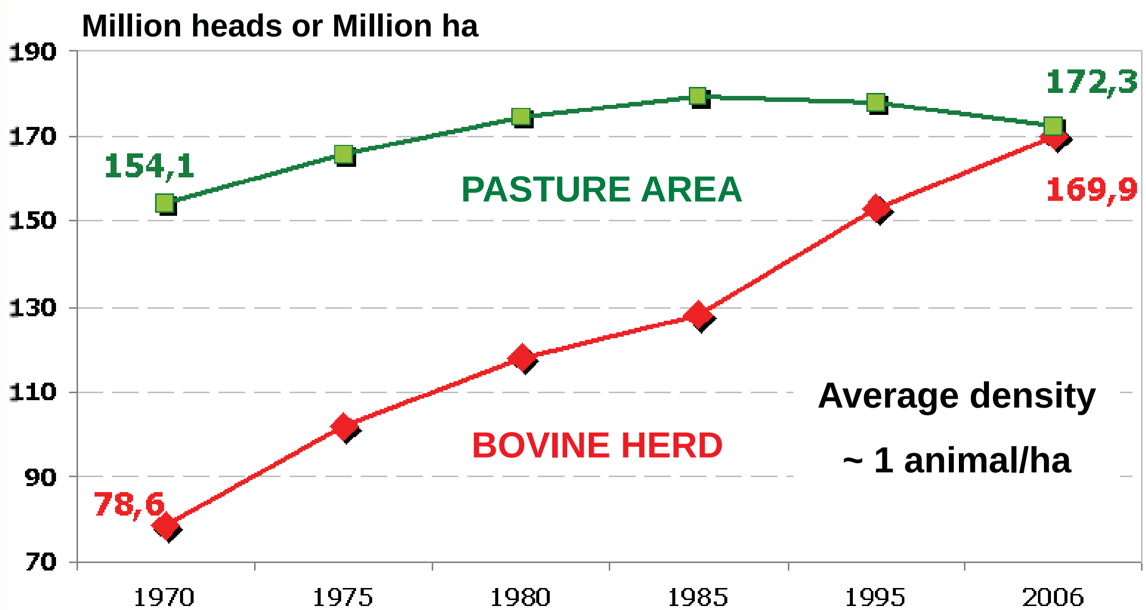


Similar situation is observed in several developing countries.

(IBGE, 2008)

Ethanol evolution: productivity

To reduce the competition for natural resources, efficiency is crucial at any level. For animal protein this aspect is more relevant yet.



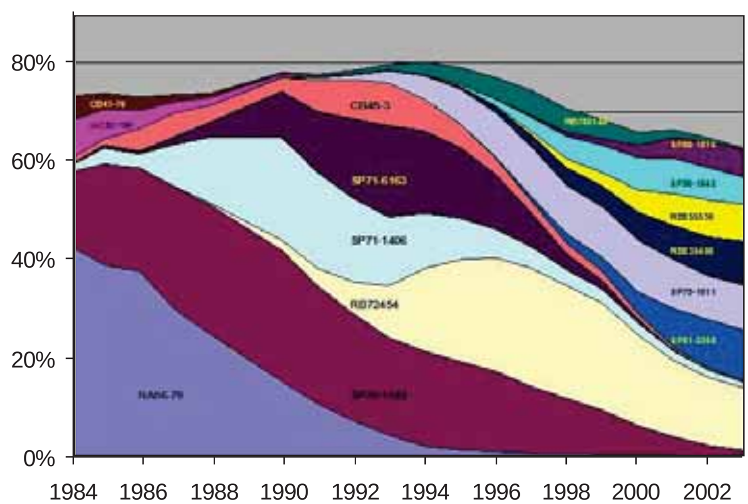
In Brazil, better practices in calf breeding can liberated about 75 M ha.

(FGV, IBGE, 2008)

Sustainability: role of R&D

Innovation has been essential for ethanol development. In agronomic or industrial activities, in logistics or management, new techniques are frequently introduced, cutting costs, diversifying products and reducing environmental impacts of ethanol production.

The use of water, agrochemicals, fossil fuels in sugarcane energy production is reduced in comparison with other systems.



Varietal diversification of sugarcane in Brazil

(Burnquist e Landell, 2005)

Biological control of sugarcane borer (*Diatraea saccharalis*) using a wasp (*Cotesia flavipes*)

(Bento, 2006)

Sugarcane production improvements

Sugarcane breeding
(CTC, 2009)

Use of vinasse as fertilizer
(UNICA, 2008)

Mechanized sugarcane harvesting
(UNICA, 2008)

Efficient feedstock logistics
(Scania, 2007)

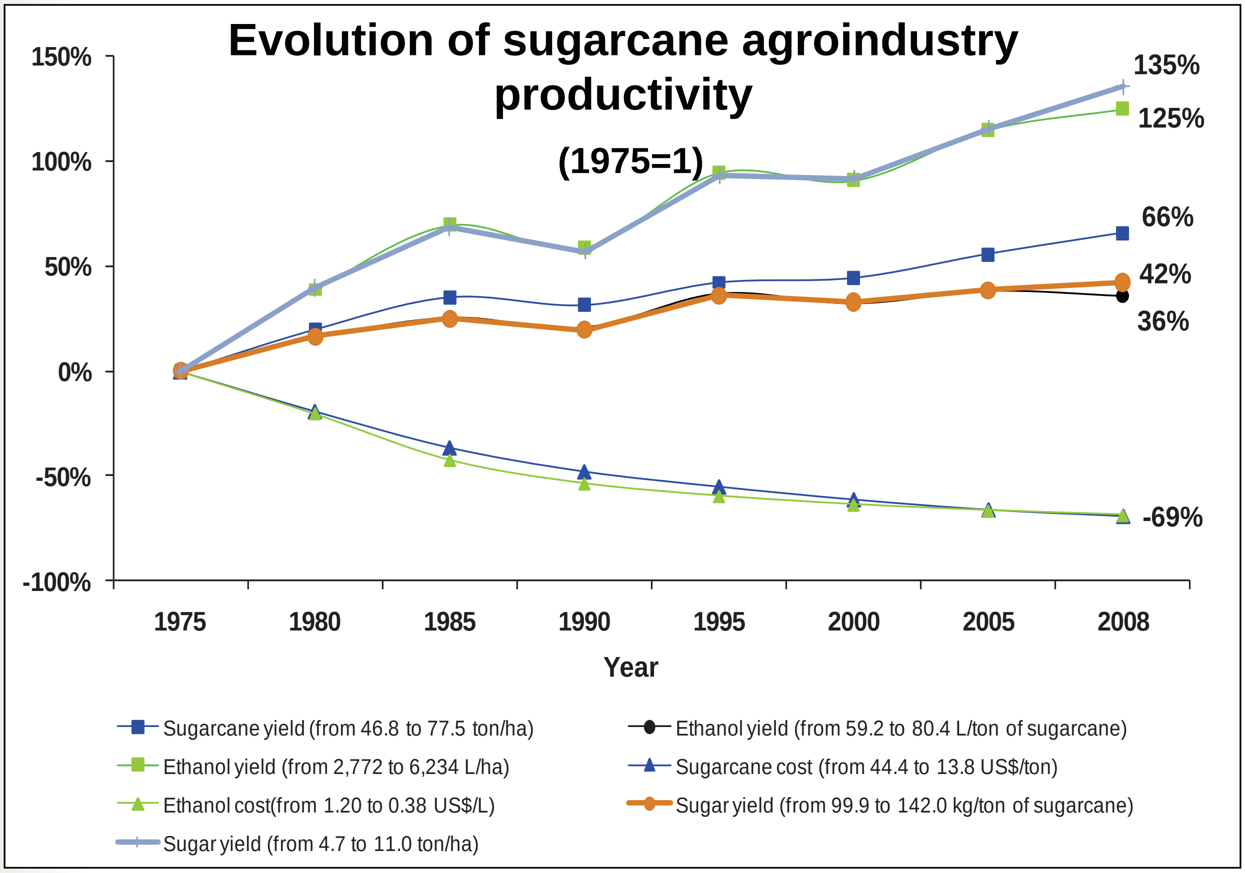
Sustainability: the energy balance

Sugarcane ethanol presents high efficiency in solar energy conversion to chemical energy and consequently fuel energy.

Operation	Energy requirements or production (MJ/ tonne of processed cane)	
	average	best values
Sugar cane production	**202**	**192**
Agricultural operations	38	38
Cane transportation	43	36
Fertilizers	66	63
Lime, herbicides	19	19
Seeds	6	6
Equipment	29	29
Ethanol production	**49**	**40**
Electricity	0	0
Chemicals and lubricants	6	6
Buildings	12	9
Equipment	31	24
Total energy input	**251**	**232**
Energy output	**2089**	**2367**
Ethanol	1921	2051
Bagasse surplus	169	316
Net energy balance (out/in)	**8,3**	**10,2**

(Macedo et al., 2006)

Sustainability: the economic feasibility

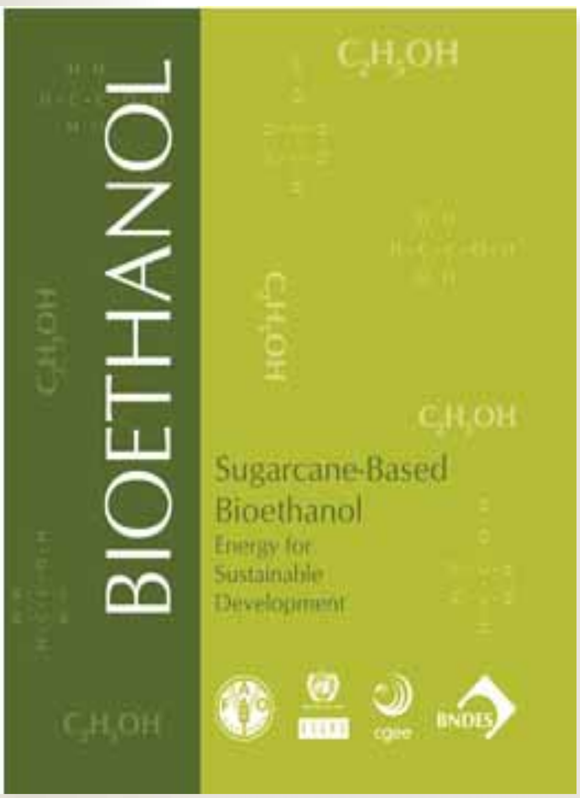


Source: Lago et al., 2010 apud Cortez, 2011.

Sugarcane Ethanol: Energy for Sustainable Development

Available in English, Spanish, French and Portuguese, 300 pg, 2008

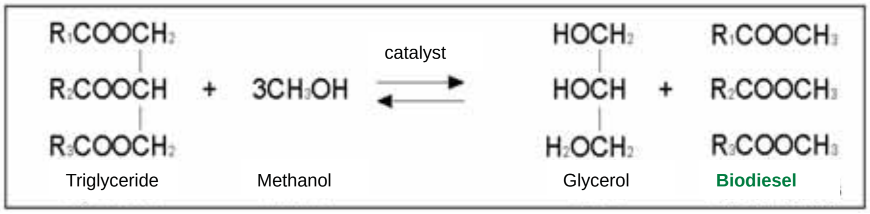
For download: www.sugarcanebioethanol.org

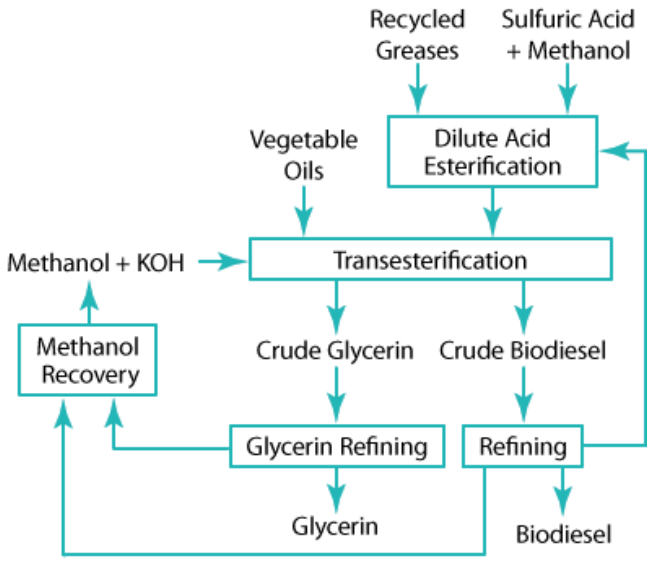


Contents

Biofuels and biodiesel: basic remarks

Biodiesel is produced from fatty feedstock, such as vegetable oils and animal fats, by transesterification processes.





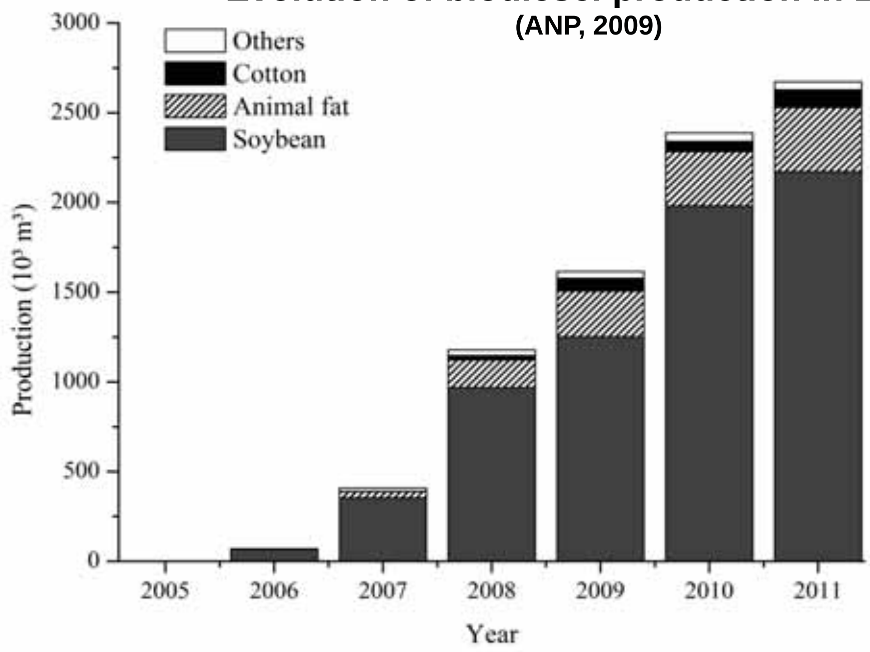
Schematic of biodiesel production path **(DOE, 2008)**

Biodiesel in Brazil

Diesel oil is the most important oil product in Brazil, used to fuel <u>all</u> heavy motors, in trucks, tractors, locomotives and buses. The current annual demand is about 51 billion liters (2011), 20% imported. Transportation represents near to 80% of this diesel consumption.

Evolution of biodiesel production in Brazil

(ANP, 2009)



Biodiesel in Brazil

Since 1920 vegetable oils have been considered as a feedstock for Diesel motors fuel, with limited results. However, some research and development has been done and a biodiesel specification was set, creating the basis for a national biodiesel production.

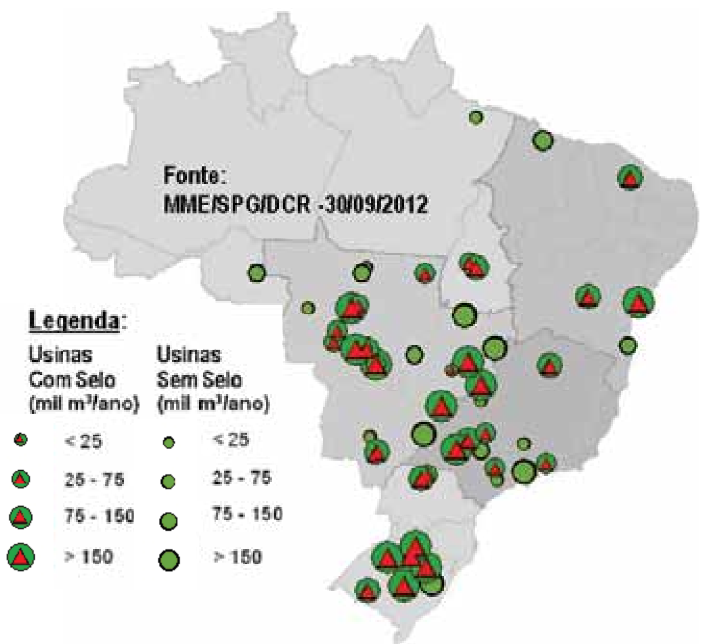
In 2005, the Brazilian Government launched the National Program of Production and Use of Biodiesel, oriented basically towards to encourage small farmers from least developed regions to become involved with biodiesel production.

After a period of authorized blending, up to 2%, a mandatory blending started in 2008. Nowadays, biodiesel represents 3% of diesel oil used in Brazil (B3), about 1,200 million liters per year, basically produced from soybean. A B5 mandatory blend was introduced in December, 2010.

Castor harvest in Brazilian Northeast

Biodiesel in Brazil

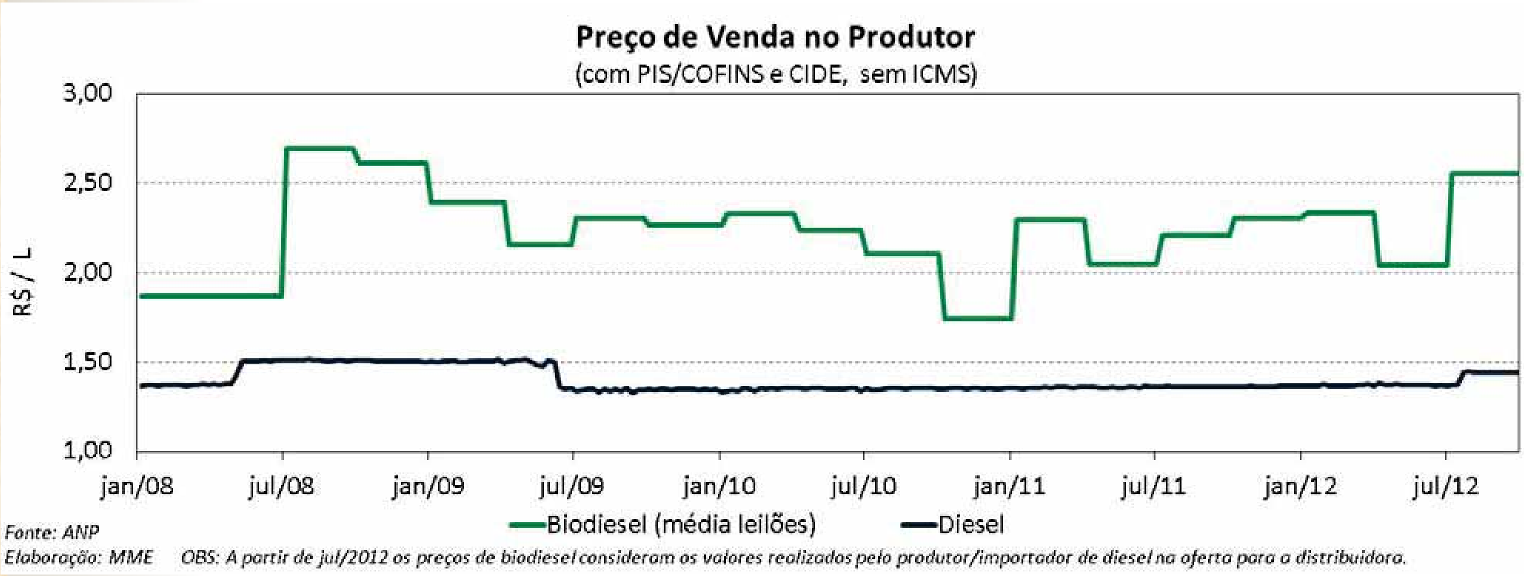
A reduced tax model was implemented in 2004, looking for promoting agriculture in low scale and in less developed regions (North and Northeast). By an additional fiscal alleviation, biodiesel producers are stimulated to buy feedstock produced by small farmers. The conventional technology for biodiesel production is well known in Brazil and equipment suppliers offer biodiesel plants in turn-key basis.



Biodiesel plants in Brazil (operating)
(MME, 2012)

Biodiesel in Brazil

Currently biodiesel production and blending in mineral diesel are developed regularly. Biodiesel prices (about 1.20 US$/liter) have been determined in regular auctions promoted by the Federal Government.



Evolution of biodiesel prIces in Brazil
(MME, 2012)

Sustainability of biodiesel in Brazil

The sustainability of biodiesel production is still to be demonstrated. It is quite far from competitive with fossil diesel international costs and the social benefits are limited, since soybean, produced in plantation schemes is the main feedstock. Castor, initially promoted as the main raw material, in almost no used for biodiesel production.

Thus, after some years of its implementation, it is interesting to explore the foundations of biodiesel feasibility in Brazil, by evaluating the energy balance and GHG emissions for the main productive routes.

An assessment of direct and indirect energy consumption (energy balance) was done, considering fuels and electricity used, as well as the energy required to produce fertilizers and agrochemicals, equipments, buildings, etc. and the energy value of manpower.

Biodiesel feasibility indicators

Four productive systems were studied, covering the most relevant situations existent in Brazil for biodiesel agro-industry:

- *Soybean in large plantation scheme, Center-West region*
- *Oil palm in large plantation scheme, North region*
- *Castor in small agriculture, Northeast region*
- *Tallow as a by-product from beef industry*

Studies conducted in Brazilian actual conditions were used as source of data: for soybean, Gazzoni et al. (2006); for castor, Almeida Neto et al. (2004), for palm, Costa et al. (2006), and for tallow, Lopes (2006). For the energy value of co-products was discounted.

Biodiesel feasibility indicators

There are important differences among productive systems for biodiesel production, specially in the agricultural side.

Aspect	Castor	Palm	Soybean
productive cycle	annual	25-30 years	annual
oil yield	low	high	low
harvest duration	3 months	12 months	3 months
water requirement	low	elevated	medium
soil fertility requirement	low	low	average
possibility of mechanization	low	low	full
availability of by-products	low	average	good
current agro-industry organization	poor	average	excellent

For more details on the energy balance and emissions for biodiesel production in Brazil:

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Does biodiesel make sense?

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A B S T R A C T

In several countries biodiesel blending programs have been implemented looking for reduction in fossil fuel dependence and environmental benefits, including climate change mitigation. The current global biodiesel production, from different fatty raw materials, reaches about 6 billion liters per year and represents 10% of whole biofuel production. Nevertheless, in many cases the actual advantages of biodiesel production and usage are not clearly evaluated. Essentially, the feasibility of biodiesel production can be determined by its efficiency in solar energy conversion, as indicated by agro-industrial productivity and energy balance parameters, which expresses a relative demand of natural resources (land and energy) to produce biofuel. Taking into account the Brazilian conditions, in this paper an assessment of biodiesel production is presented, comparing four different productive systems. According to this evaluation, soybean and castor are limitedly feasible, whereas tallow and palm oil represent more suitable alternatives. The selection of an efficient productive system is crucial for the rationality of biodiesel production.

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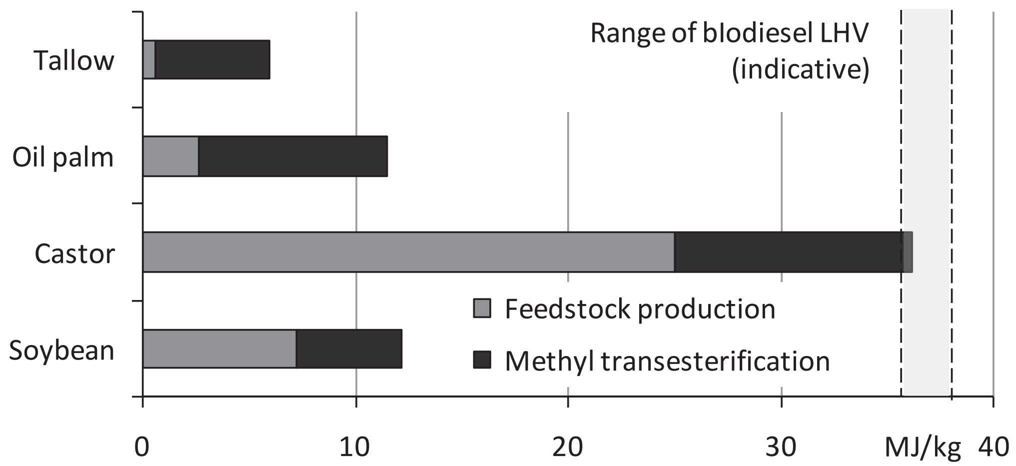
Biodiesel feasibility indicators

Fossil energy consumption in biodiesel production

	Unit	Soybean	Castor	Oil Palm	Tallow
Feedstock production	**MJ/kg oil or tallow**	7.2	25.0	2.6	0.6
Biodiesel production	**MJ/kg biodiesel**	5,0	11,2	8,9	5,4
Total	**MJ/kg biodiesel**	12,1	36,2	11,5	6,0



Total fossil energy requirement for biodiesel production

Biodiesel feasibility indicators

GHG emission in biodiesel production

	Unit	Soybean	Castor	Oil Palm	Tallow
Feedstock production	**g C/kg biodiesel**	186.7	652.5	36.3	14.8
Biodiesel production	**g C/kg biodiesel**	116,1	250,8	200,2	124,7
Total	**g C/kg biodiesel**	302,8	903,3	236,5	139,5

Main results of comparative analysis of biodiesel production from different feedstock

Parameter	Soybean	Castor	Oil Palm	Tallow
Biodiesel yield (kg biodiesel/ha)	880	820	2,730	none
Output/input energy ratio	3.3	1.0	3.5	6.3
Mitigation effect (compared with diesel)	62%	-26%	71%	82%

Biodiesel feasibility indicators

Taking into account agricultural productivity and energy balance, tallow and oil palm arise as the most productive and efficient routes for biodiesel production in Brazil.

As regards to mitigation impacts in GHG emissions, these routes seem to be also the most interesting.

The eventual implementation of ethyl route can improve the energy balance and consequently the mitigation effect on emissions.

These results are preliminary, indicating the most important trends and the necessity of a more detailed evaluation.

Forecast of biodiesel impacts

The impacts of biodiesel production and use depend directly on the feedstock mix and productive route adopted, as can be estimated using the previous figures and similar studies.

As regards the biodiesel production side, again two scenarios were studied:

BAU: mainly based on soybean oil and methyl process, complemented by palm oil and tallow.

Improved: using palm oil (90%) and tallow (10%), processed with ethyl transesterification.

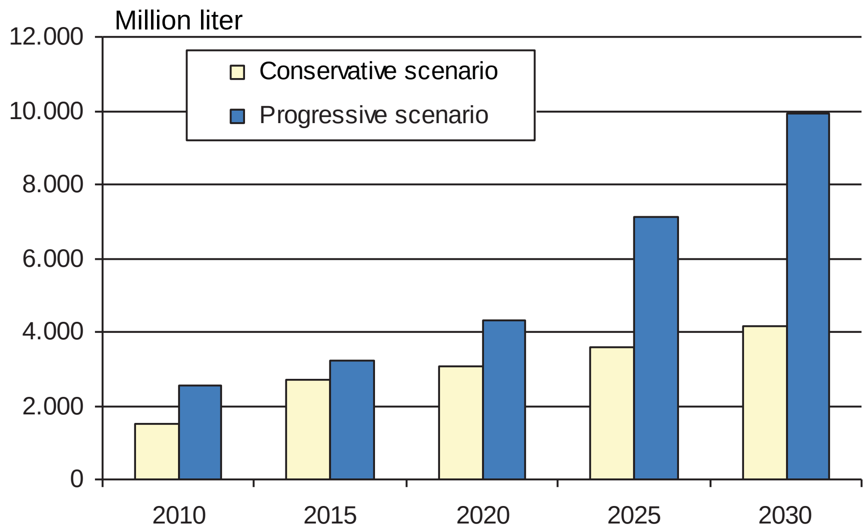
Soybean harvest in Mato Grosso, 2004

Oil palm plantation in Pará, 2005

Forecast of biodiesel impacts

For demand, two scenarios were evaluated, in association to the official estimate for diesel consumption in the near term:

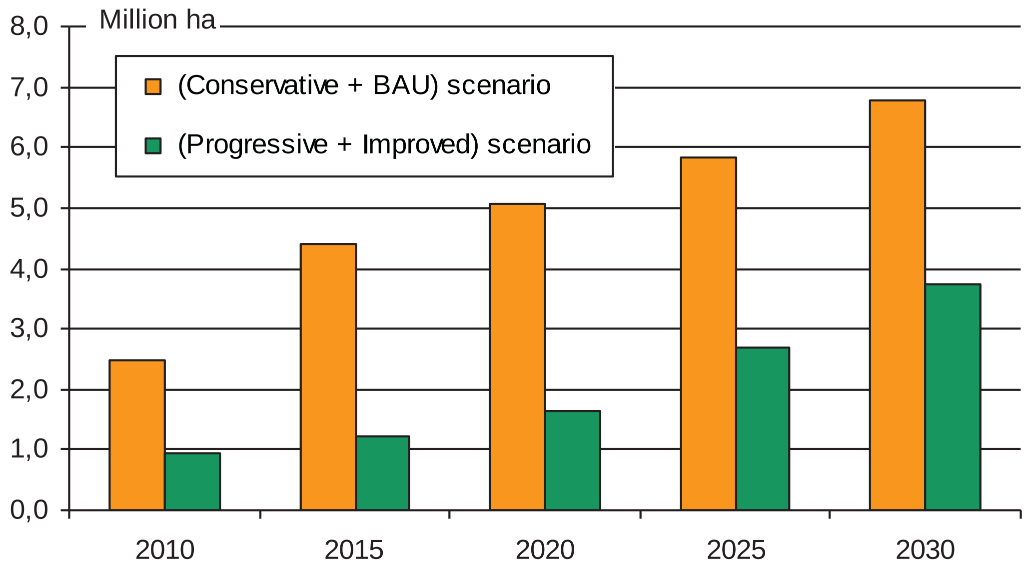
- ***<u>Conservative:</u> B5, mandatory from 2013 according to the current Brazilian legislation.***
- ***<u>Progressive:</u> assuming increasing blending level (up to B12).***



Potential demand of biodiesel in Brazil
(based on EPE, 2007)

Forecast of biodiesel impacts

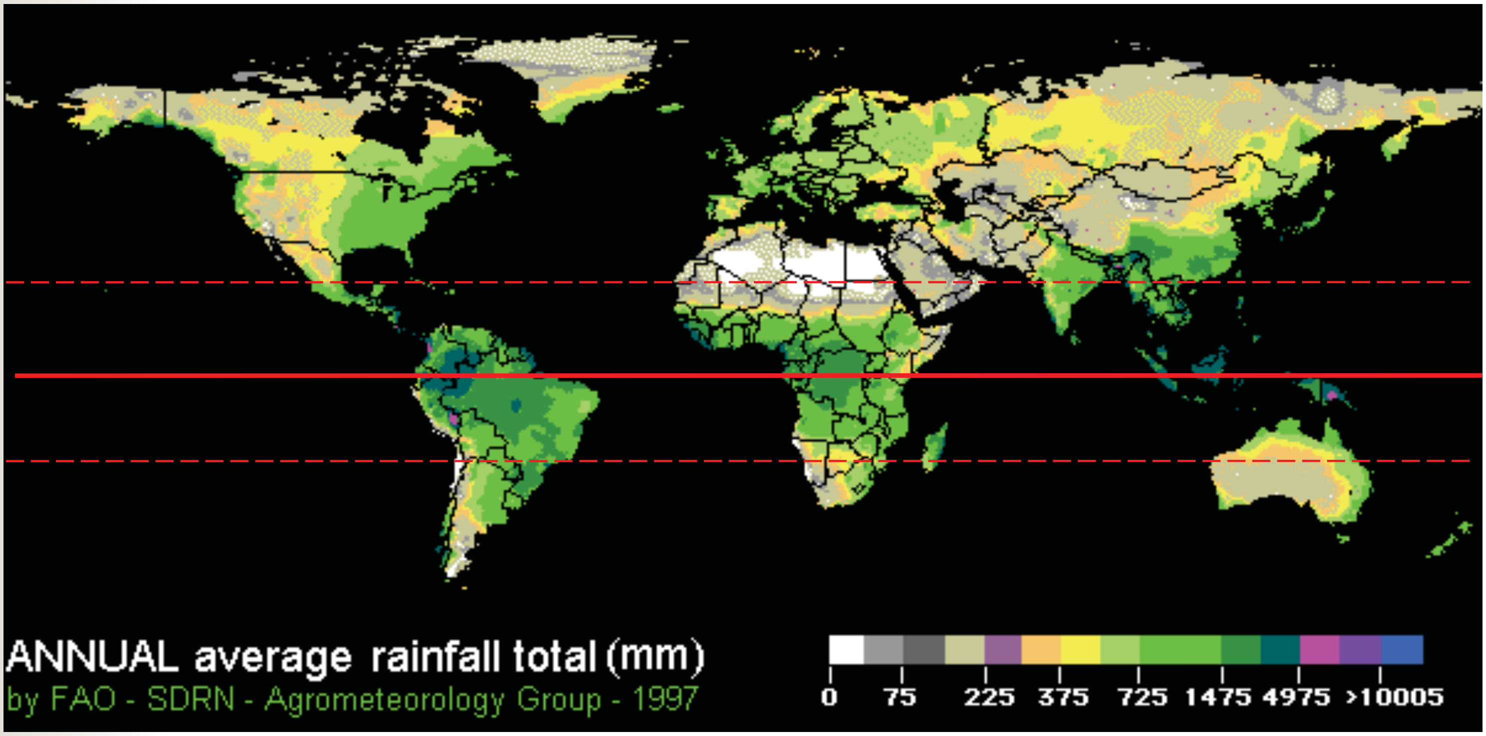
Regarding land-use change and deforestation associated or caused by biodiesel production, it is worth to observe how high yields are able to reduce the impact of higher fuel demand.



Area required for biodiesel production in Brazil
(CCAP, 2008)

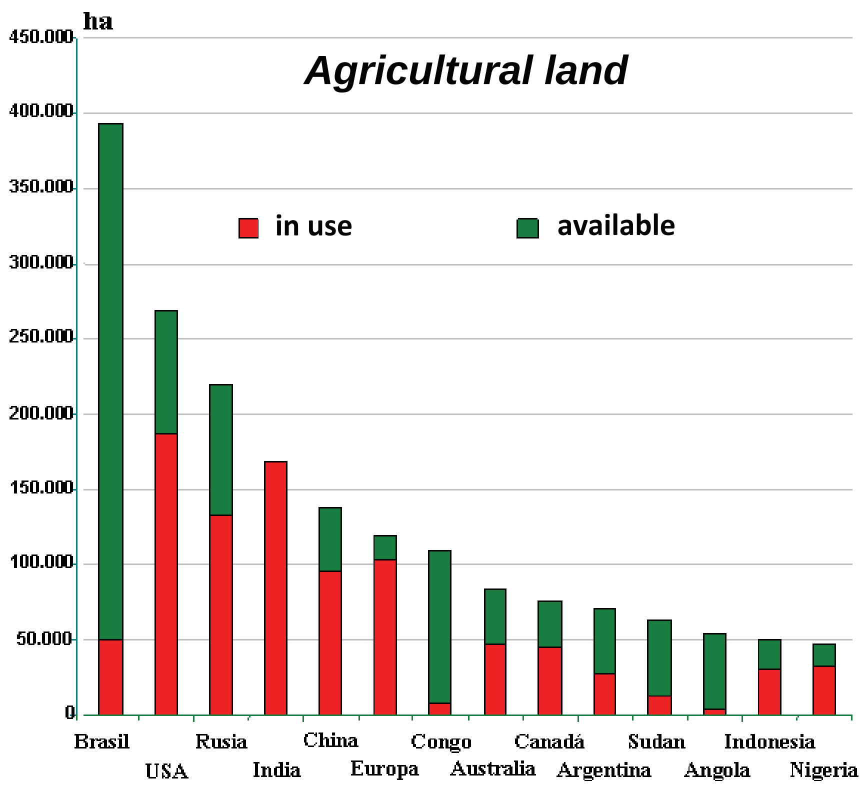
Final comments

To reach new horizons for bioenergy, mainly with regards to liquid biofuels, is crucial to take into account efficiency and sustainability. Biofuels are unlike.



Final comments

The potential impacts of biofuel production on food availability depends strongly of efficiency in using natural resources, such as land, water and energy.



(FAO, 2006)

Final comments

Biofuels offer an effective approach to face the new challenges posed by climate change, energy and food security and socio-economic activation.

The challenge is re-create a new agro-industry, oriented towards energy production.

In this direction, efficiency is name of the game.

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