A Sustainability Analysis of the Brazilian Ethanol

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Statement

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Summary

Executive Summary

Biofuels

Since the turn of the century, **global interest in the production and consumption of biofuels** (essentially ethanol and biodiesel) **has been growing.** This interest has been caused, in part, by environmental concerns, and specifically due to the **need to mitigate greenhouse gas emissions (GHG)**. Other factors include the rise of oil prices, interest in diversifying the energy matrix, security of energy supply and, in some cases, rural development.

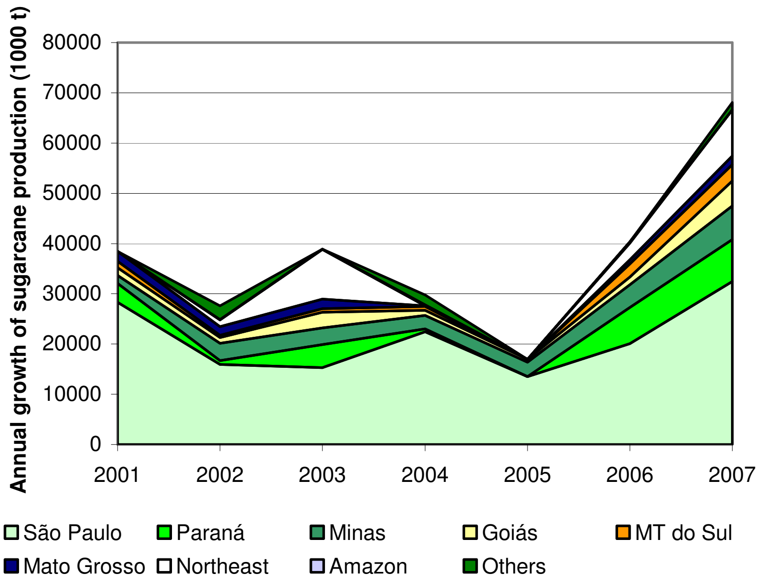
Recently, **doubts have been raised about the actual benefits of biofuels** regarding the mitigation of GHG emissions. **Other questions** have also been raised **about potential environmental, social and economic impacts**, such as disruption of food supply, risks of losing biodiversity, reduction of water quality and water availability, and a lack of direct benefit to those directly affected by biofuels production.

Due to social sector pressure (mainly in Europe), **sustainability criteria** have been proposed in order to promote the effective sustainable production of biofuels. Theoretically, such criteria will **differentiate between** products with similar fuel properties, but with important differences in their supply chain. The adoption of sustainability criteria could result in **certification of biofuels production**. However, **there are also concerns that a certification process could impose new barriers for the international trade in biofuels**.

Ethanol in Brazil

From 2000 to 2007, the production of ethanol in Brazil increased an average of 11.4% per year. In 2007, the domestic market was close to 18 billion litres per annum, with more 3.5 billion litres exported. **Internal consumption has grown continuously since the launch of flex-fuel vehicles** in 2003 and their high domestic take-up. It is estimated that domestic consumption could reach 35 billion litres in 2015 and 50 billion litres in 2020. Future **exports depend on how open the main consumer markets will become,** but it is estimated that 15 billion litres could be exported annually by 2020.

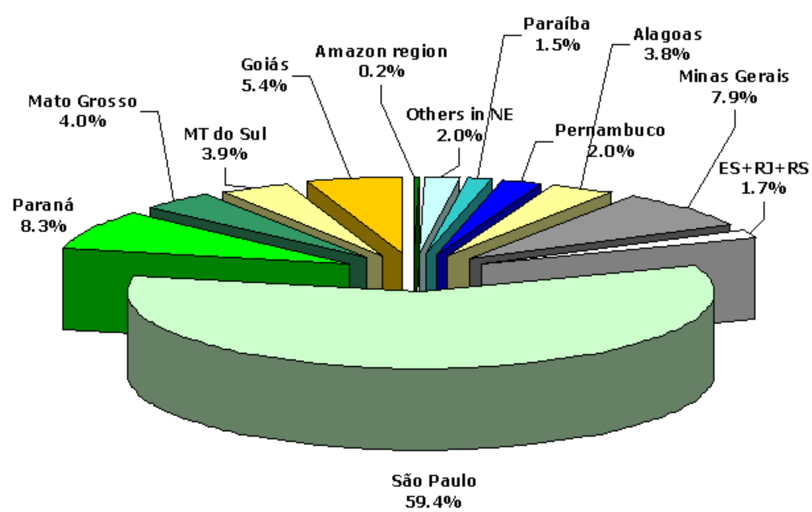
Currently, Brazilian sugarcane is almost equally used to produce sugar and ethanol. The bulk of sugarcane production (ethanol + sugar) is in the Centre-South region (87% in 2007), 60% of total production being in the state of São Paulo. **Only 0.6% of sugarcane is produced in the states of the Amazon region, mainly for sugar manufacturing (0.2% of Brazilian ethanol is produced in the Amazon region)**. Figure 1 shows the growth of sugarcane production (used to produce both sugar and ethanol) between 2001 and 2007 in different states and regions. Figure 2 shows the profile of ethanol production in 2007. In both figures, the concentration of sugarcane and ethanol production in São Paulo, the growing importance of Paraná, Minas and the states of Centre-West region, and the relatively small importance of sugarcane and ethanol production in the Amazon region can be observed.



Source: UNICA (2008)

Note: Growth calculated as difference of production between two consecutive years.

Figure 1. Annual growth of sugarcane production in different states – 2001-2007



Source: UNICA (2008)

Figure 2. Ethanol production in 2007 – % share of States and Regions

Social and Environmental Sustainability

Brazil is and will continue to be a key producer in the global ethanol market over the coming years. **Local conditions for ethanol production are comparatively favourable** taking into account factors such as land availability and climate, long-term experience, existing commercial technology (the so-called "first generation"), and the size of the domestic market. **Nevertheless,**

if the sustainability of Brazilian ethanol production was more widely recognised, these comparative advantages could be reinforced.

The **economic** dimension of **sustainability** is not the focus of this report. It is internationally recognised that **Brazilian ethanol is produced at the lowest cost** and **its feasibility does not depend on subsidies**. However, environmental and social aspects need to be properly addressed, as there are knowledge constraints and controversy about many crucial issues.

The analysis done in this report is based on the international sustainability criteria of biofuels currently under discussion, which prioritises the **reduction of GHG emissions** in comparison to fossil fuels (gasoline and diesel), considering their life cycles. Based on Europe Union initiatives and on policies adopted in the United Kingdom, Germany and the Netherlands which aim to ensure the sustainability of biofuels production, the following aspects were identified as crucial besides the emissions of GHG: a) land use change considering direct and indirect impacts; b) socio-economics benefits and impacts of ethanol production analysis at a regional level; c) potential impacts on water availability and quality; d) impacts of fertilisers and agro-chemical use alongside biomass production; e) soil impacts; and f) loss of biodiversity.

Energy and GHG balances

Ethanol produced from Brazilian sugarcane is the biofuel with the best energy balance. This can be illustrated as **the ratio between renewable products (mainly ethanol) and the energy input as fossil fuel** for Brazilian sugarcane ethanol **is 9.3** (compared with 1.2-1.4 in the case of ethanol produced from American maize, and approximately 2.0 in the case of ethanol produced from European wheat).

The balance of GHG emissions is also the best among all biofuels currently produced. Avoided emissions compared to gasoline are close to 86% given the way ethanol is used in Brazil (and considering a full life-cycle analysis). The consumption of Brazilian ethanol in Europe reduces avoided emissions to approximately 70% due to intercontinental transport and lower efficiency of European engines using ethanol. However, this result is much better than the avoided emissions in case of ethanol from maize and wheat (a maximum of 35%), and would **ensure the criteria that may be applied in the short-term by the European Union or other individual European countries (30%-35% of avoided emissions) are fulfilled**. These results are typical of ethanol production in state of São Paulo and neighbourhoods, as long as no GHG emissions due to land use change occur.

Considering current commercial technologies, mechanical harvesting and enhancement of surplus electricity production from bagasse and sugarcane trash (e.g. leaves of the plant), the energy balance could rise to 11.6 by 2020, while net GHG emissions during in the life-cycle of ethanol production could be reduced by approximately 20%.

Figure 3 shows estimated avoided emissions due to ethanol substitution for gasoline (the emission factor of gasoline was taken as 85 gCO_2eq/MJ) considering the use of current technology. The cases shown correspond to the consumption of ethanol produced from maize (USA), from wheat (Canada and Europe) and from sugarcane (produced in Brazil and consumed in Brazil or in Europe).

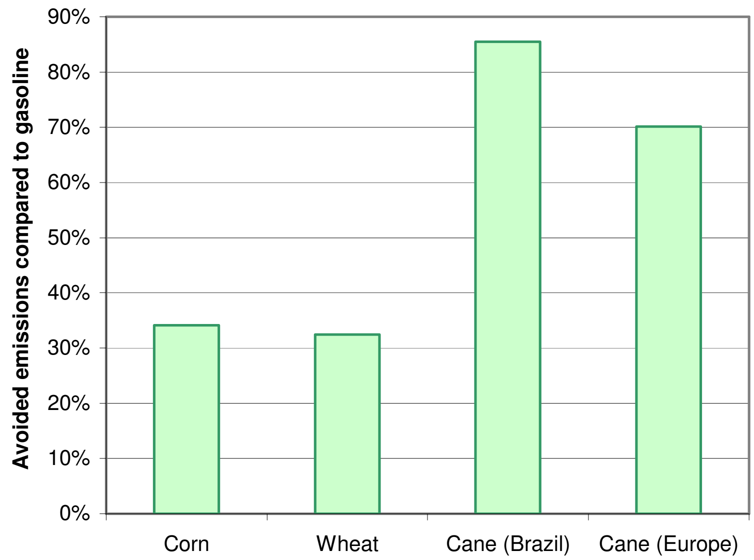


Figure 3. Avoided GHG emissions in comparison with full life-cycle of gasoline

Land use change

In the Centre-South region, the growth of sugarcane production from 2006 to 2007 occurred mainly on former pasturelands (66%) and on land previously used for grain production (e.g. soybean, 18% and corn, 5.3%). The displacement of soybean by sugarcane cultivation in this region represents 1% of total area of soybean production in Brazil. In this region from 1996 to 2006, the intensification of cattle grazing released land, 10% of which was used for sugarcane expansion. The growth of sugarcane areas did not induce the displacement of cattle heads to other regions of Brazil, as cattle's density raised in all where sugarcane expansion took place. **There is no evidence that deforested areas have been used for the enlargement of sugarcane cultivation**, as **in all states where the growth of production was significant** (São Paulo, Minas, Paraná and Goiás, with 1.2 million hectares in the period) **there was a simultaneous growth of forested areas** (3.6 million hectares). On the other hand, during the same period there was deep reduction in forested areas in Mato Grosso and Mato Grosso do Sul (in total 4.7 million hectares) but in these two states the expansion of sugarcane was significantly lower (0.14 million hectares), while soybean cultivation increased by 2.4 million hectares. It is possible to conclude from these figures that **the direct impact of sugarcane expansion in relation to land use change has been insignificant**.

Based on the analysis of the **indirect impact of land use** change carried out, it is possible to conclude that **there is no correlation between the enlargement of sugarcane area from 1996 to 2006 mainly in São Paulo state, and deforestation in Mato Grosso and Pará**. In addition, these results reinforce the hypothesis that between 2000 and 2006, the evolution of livestock farming and the growth of soybean production sped-up deforestation in the Centre-West region and in Pará. Moreover, considering the states in the Centre-South where the expansion of sugarcane production has been significant, the study concludes that a reduction of pastureland does not correlate with a reduction of cattle heads. These rose in most of the states and were kept almost constant in others (e.g. São Paulo and Paraná).

Other environmental and social aspects

Other environmental impacts of the sugarcane sector, **such as water consumption**, **contamination of soils and water shields due to the use of fertilizers and chemicals**, and **loss of biodiversity**, are less important in comparison to other crops. This can be explained by the following: in Brazil sugarcane production mostly occurs without irrigation; the development of sugarcane varieties has occurred over decades (with resulting higher yields and resistance to diseases and plagues); the use of biological control techniques; the use of biological fixers of nitrogen and of residues of production allowing a partial or total reduction of conventional fertilization; and the use of best agricultural practices (e.g. the reduction of erosion).

However, due to the concentration of sugarcane production in some regions and the size of many factories, monitoring all the above mentioned aspects is essential, besides dissemination and wide adoption of best practice (as has already occurred in some producer regions).

Recently, local governments and producers, through their organizations or even by themselves, have developed efforts in order to improve environmental and social results. These actions include definition of targets and establishment of minimum sustainability criteria, as happened in the case of a joint-initiative between Swedish ethanol importers and Brazilian ethanol producers.

Social and economic impacts of sugarcane activity were also analysed. A regional and more detailed approach was adopted based on welfare indicators (e.g. health and education) and on indicators of wealth and wealth distribution. The analysis was carried out comparing municipalities of the same size, with and without sugarcane activity (cropping and industrial conversion to ethanol). The results indicate that in some cases (e.g. in São Paulo) **the municipalities in which sugarcane production is present have better parameters than those where it is absent**. It is not possible to reach the same conclusion comparing municipalities with soybean production and livestock activity. Considering the set of indicators chosen, even the municipalities that receive a large contingent of migrant workers for sugarcane harvesting are not disadvantaged in relation to other municipalities.

Conclusions

The sustainability of biofuels is a challenge that requires, among other actions, enforcement of existing labour and environmental legislation, scientific advances and diffusion of technologies, sharing of best practice, and definition and implementation of adequate public policies. In this regard, policy examples include a degree of control over the expansion of sugarcane production, support of the development of second-generation technologies and support to promote diversification (e.g. the large-scale production of surplus electricity).

Enhancement of environmental and social aspects of ethanol production could be promoted by a co-ordinated national agenda, but in Brazil this has yet to emerge. Taking the international criteria as a reference point is advantageous, since most of the high-priority aspects regarding biofuels sustainability are also issues of concern for Brazil (e.g. land use change, deforestation, impact on hydro resources, improved distribution of economic benefits).

There is a window of opportunity to enlarge ethanol production, ensuring both the supply of the growing domestic and export markets, but this needs to be done without significant environmental impact and with the enhancement of conditions of the social sectors directly involved in ethanol production. The results so far achieved are good, but there are still challenges ahead.

Introduction

This is the report of the project **Analysis of Environmental and Social Impacts of Bio-ethanol Production in Brazil**, funded by UK Embassy, in Brasília, with funds of the **UK's Department for Environment, Food and Rural Affairs (Defra).**

A research team coordinated by Arnaldo Walter, from University of Campinas – Unicamp, has developed the study that concerns the analysis of bio-ethanol production in Brazil. The project was developed from mid March to the mid October of 2008. The research team is mainly composed by researchers from University of Campinas, with participation of Anna Segerstedt, from Hannover University, Germany, and Rocio Diaz-Chavez, from Imperial College, UK.

The main target of the project is the evaluation of ethanol production in Brazil from the point of view of sustainability, considering environmental, social, and economic aspects. It was author's intention to provide a comprehensive analysis of the current situation and also to identify the required actions in order to assure large-scale sustainable production in short- to mid-term. The analysis was based on literature review, in some cases interviews with different stakeholders and, for some aspects, primary research. Primary research was conducted regarding land use change, both concerned to direct and indirect impacts, socio-economics impacts at regional level, and the balance of greenhouse gases (GHG). In order to set the priorities, sustainability principles and criteria currently under discussion in some European countries, mainly UK, and by European Union have been analysed.

The report is organized in ten chapters, including the final chapter with the main conclusions. In the first chapter the current production of ethanol in Brazil and mid-term perspectives are analysed. Chapter two presents sustainability principles and criteria under discussion in Europe. Based on this analysis priorities were defined in order to be analysed in details. The issues considered more relevant were the balance of GHG, land use change, both considering direct and indirect impacts, and socio-economic impacts of ethanol production at regional level. These three aspects were first analysed based on literature, and further primary research was conducted. The results and conclusions are presented in Chapters 3 to 6.

Other important environmental issues are analysed at Chapter 7, only based on literature review. The aspects that were considered are water consumption and impacts over availability and quality, soil impacts, and the use agrochemicals and fertilizers.

Initiatives so far taken regarding certification of ethanol production are analysed at Chapter 8. The analysis is done regarding the principles and criteria under discussion in different countries and the conclusions of the authors of this project regarding the level of knowledge and quality of information available in Brazil.

Chapter 9 summarises the author's opinion about the further required research and recommendations for future bilateral collaboration/projects. Chapter 10 presents the main conclusions of the research.

Complimentary information is presented in a set annexes.

Chapter 1

Current Ethanol Production in Brazil and Perspectives

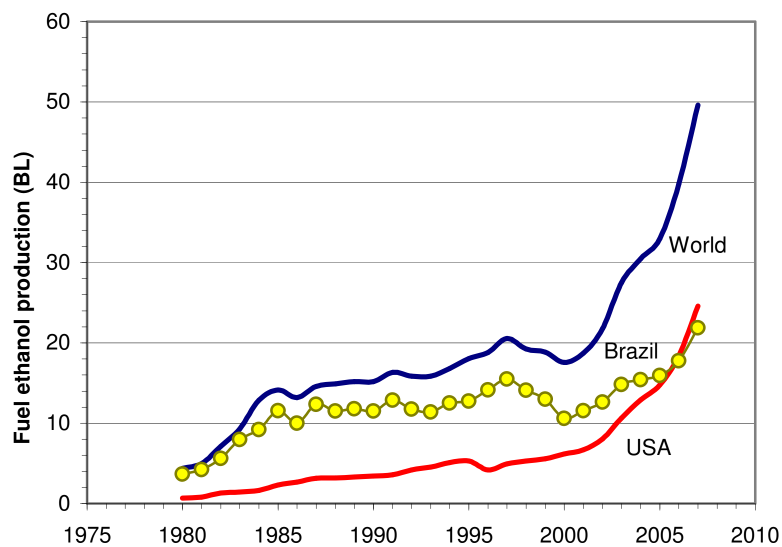
1.1 Fuel ethanol in the world

Worldwide, fuel ethanol consumption in 2007 was estimated as about 50 billion litres, being the increase regarding the previous year of almost 25% (RFA, 2008). Since 2006 US is the main world producer; in 2007 its production was estimated as 24.6 billion litres, while the consumption as fuel was estimated as 26-27 billion litres. In US fuel ethanol production rose three times in the period 2002-2007 and has enlarged five times since 1997 (RFA, 2008).

For more than three decades (from mid-1970s to 2006) Brazil was the world's largest producer and consumer of fuel ethanol. In 2007 its production reached 21.9 billion litres, while the domestic consumption as fuel was close to 18 billion litres (EPE, 2008). Estimates are that fuel ethanol production shall surpass 26 billion litres in 2008, being the domestic consumption estimated as about 20 billion litres (MAPA, 2008). In the period 2002-2007, fuel ethanol production in Brazil raised at annual average rates of 12%.

Besides US and Brazil, other important producers of fuel ethanol are China, Canada, France, Germany, Spain and Poland that altogether produced more than 4 billion litres in 2007 (RFA, 2008; EBIO, 2008). Fuel ethanol production in EU was estimated as 1,731 million litres in 2007 (EBIO, 2008). The production in EU is still small in comparison with the production in US and Brazil, but it is estimated that the installed capacity will surpass 8 billion litres in few years.

Figure 1.1 shows the world fuel ethanol production from 1982 to 2007. Due to the inconsistencies of statistical information, production figures prior to 2000 are in some cases inaccurate.



Sources: (REN21, 2006) for the world, (RFA, 2008) for US and (EPE, 2008) for Brazil

Figure 1.1 World fuel ethanol production – 1980-2007

It is estimated that in 2007 fuel ethanol covered almost 3% of the US automotive fuel demand; ethanol is blended into more than 50% of the gasoline sold, being in most cases consumed as E10 (RFA, 2008). In EU, also in 2007, this figure was smaller than 1% (Walter et al., 2008), being Sweden the most important consumer[1]. Conversely, in Brazil ethanol covered almost 35% of the automotive fuel demand (energy basis) (EPE, 2008), and ethanol surpassed the gasoline consumption (volume basis) is early 2008.

1.2. Fuel ethanol production and consumption in Brazil

Large-scale production of fuel ethanol in Brazil started in 1976 but it has been since 1999, after the complete deregulation of the industry, that the consumption has risen steadily. Since their launch, in early 2003, flex-fuel vehicles (FFVs) have been the main driving force of domestic consumption of fuel ethanol. In Brazil, FFVs can run with any fuel mix between gasohol (E20–E25) and pure hydrated ethanol (E100). The relative low price of ethanol regarding gasoline, and the good technology of FFVs, are the main reasons why currently they are 90% of the new cars in Brazil. It is estimated that FFVs will represent 26% of the fleet of light vehicles in 2008 and possibly 65% by 2015 (Jank, 2008).

Besides the existence of neat ethanol vehicles, all motor gasoline sold in Brazil contains 20-25% ethanol on volume basis (E20–E25). Neat ethanol vehicles use hydrated ethanol, while anhydrous ethanol is blended with gasoline. In Brazil FFVs can be fuelled with hydrated ethanol that is cheaper than anhydrous ethanol.

Since early 1980s all ethanol production in Brazil is based on sugarcane. In addition to the favourable conditions for biofuels production, such as weather, rainfall, land availability and working force availability, Brazil has taken advantage of the long-term experience with sugarcane production. It is also worth to mention that during about 15-20 years (i.e., from 1975 to early 1990s) the Brazilian federal government offered very favourable conditions for fuel ethanol production.

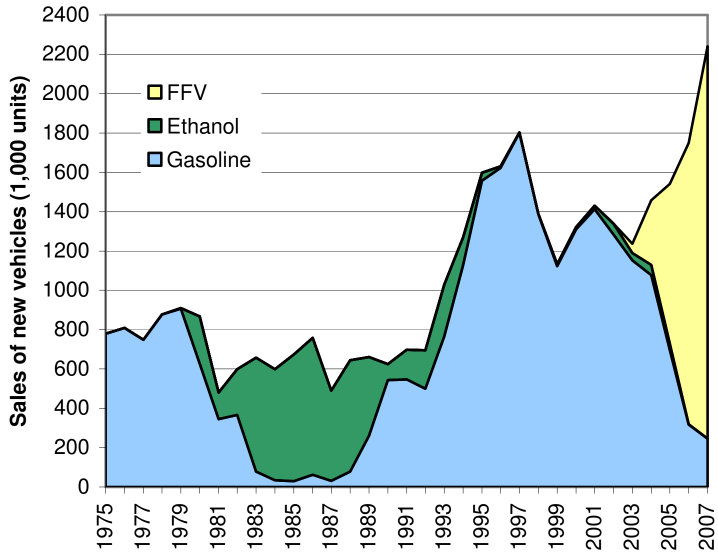
Brazilian experience with ethanol blended to gasoline comes back from the 1930s, but it was in 1975 that the Brazilian Alcohol Program (PROALCOOL) was created aiming at partially displacing gasoline in the individual transport. At that time the country was strongly dependent on imported oil and gasoline was the main oil derivative consumed. In 1979, with the second oil chock, Brazilian Government has decided to enlarge the Program, supporting large-scale production of hydrated ethanol to be used as neat fuel in modified engines.

During the first period of the Program (1975-1979) ethanol production was accomplished by new distilleries annexed to the existing sugar mills, while in the period 1979-1985 many autonomous distilleries were built. It is estimated that at that time about US$ 11-12 billion were invested to create a structure able to produce about 15 billion litres of ethanol per year.

Less support from the government and the lack of a positive attitude by the producers have laid the ethanol market to difficulties during the 1990s, starting with a shortage of ethanol supply in 1989-1990 that lead to a strong drop in sales of neat ethanol cars. For instance, sales of neat ethanol vehicles that have reached 92-96% during the 1980s were continuously reduced until summing up just about 1,000 new vehicles per year in 1997-1998. The reduction of the neat

[1] In Sweden, 5% gasoline blend is consumed nationwide (E5).

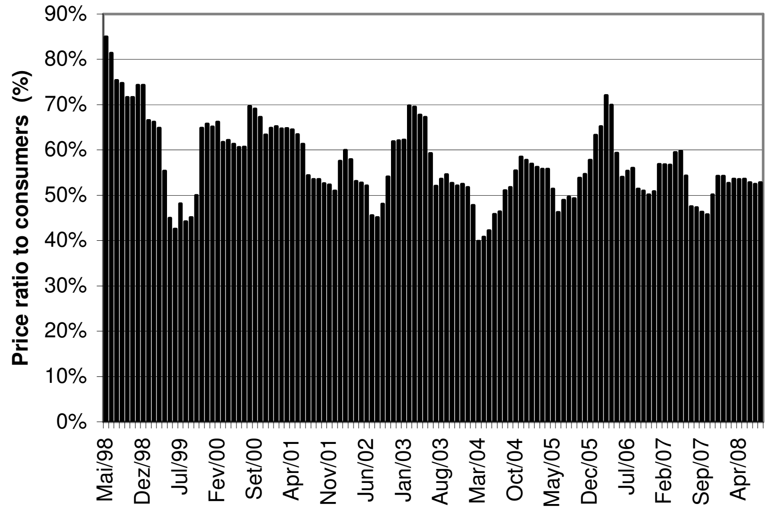
ethanol fleet deeply impacted the consumption of hydrated ethanol during the 1990s and early 2000s. Figure 1.2 shows total sales of new vehicles in the period 1975-2007, according to the fuel option; with the success of FFVs, sales of straight-ethanol vehicles vanished in 2006.



Source: ANFAVEA (2008)

Figure 1.2 Annual sales of new vehicles from 1975 to 2007, according to the fuel option

The PROALCOOL, as initially conceived, has finished during the 1990s as long as the government support has ceased. In fact, main changes started in early 1990s, first with liberalization of fuel prices to consumers and, second, in late 1990s, with full deregulation of sugarcane industry. The positive results started to be noticed in 2001, when sales of neat ethanol cars increased due to a larger price difference between ethanol and gasoline. However, as previously mentioned, since 2003 there is a boom on sales of vehicles able to run powered by ethanol (FFVs). Figure 1.3 shows the evolution of the price ratio to consumers (ethanol/gasoline) in the city of São Paulo, from May 1998 to August 2008. It can be seen that since the full deregulation only in few occasions the price ratio has been close to 70% (prices per litre) (e.g., August-September 2000; February-March 2003; March-April 2006); for most of the models currently available, 70% is understood, on average, as the break-even ratio between ethanol and gasoline prices.



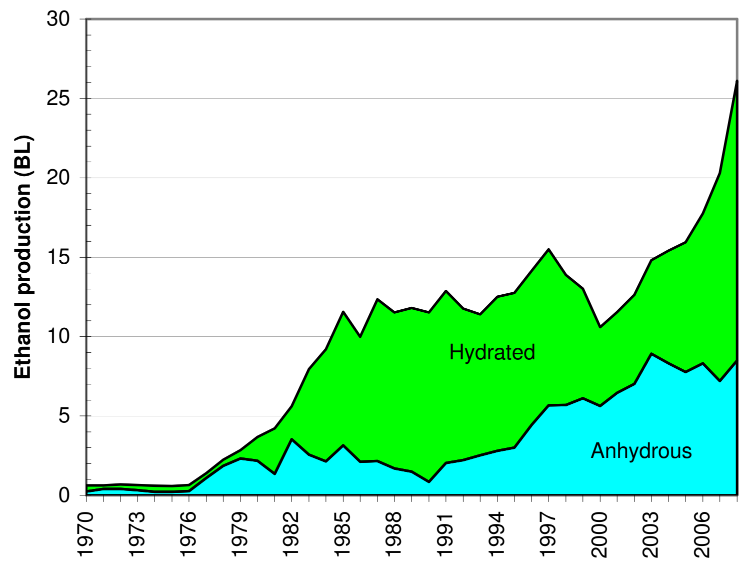
Source: CENEA (2006) (up to 2001) and ANP (2008) (after 2001)

Figure 1.3 Price ratio to consumers (ethanol/gasoline) in the city of São Paulo – March 1998 to August 2008 – current prices per litre

Due to the success of FFVs it is predicted that the domestic market of ethanol shall reach almost 35 billion litres by 2015 and 50 billion litres by 2020. Currently ethanol (hydrated and anhydrous) covers almost 35% of the energy consumption of light-duty vehicles in Brazil. The tendency is that this share will grow in the years to come reaching about 50% (energy basis) in about 10 years.

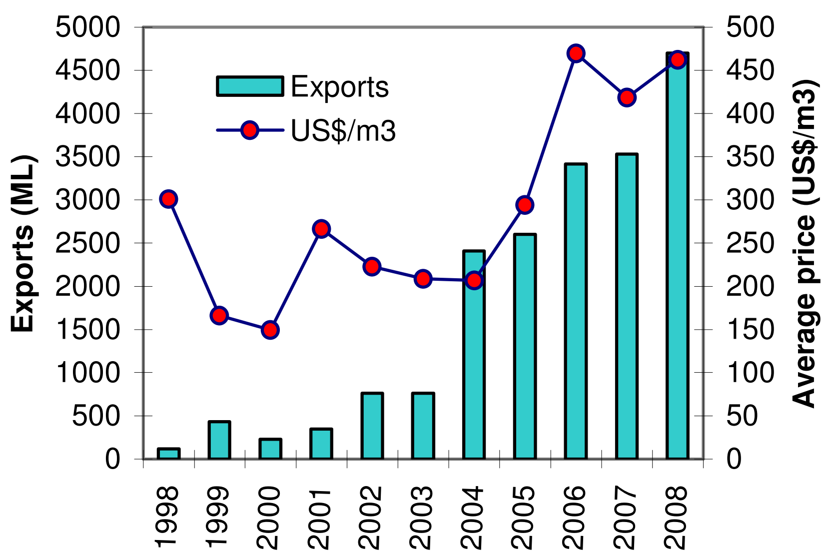
Figure 1.4 shows ethanol production in Brazil from 1970 to 2007, and estimates for 2008. The production in 2007 was 21.6 billion litres, while the domestic consumption grew from about 14 billion litres in 2006 to about 18 billion litres in 2007. It is clear from Figure 1.4 that since 2003 (i.e., after FFVs) the production of hydrated ethanol has increased continuously while the production of anhydrous ethanol (exported and domestically used in fuel blends) has slightly declined.

Brazil exported 3.4 billion litres of fuel ethanol in 2006 and 3.5 billion litres in 2007 (MAPA, 2008). During last years United Stated has been the main market, followed by European Union (e.g., Netherlands and Sweden) and Japan. Figure 1.5 shows ethanol exports since 1998; average prices paid are also shown in the same figure. Estimates for 2008 are based on the average prices paid up to August and on the predicted exports (more than 4.5 billion litres, based on 3,190 million litres exported from January to August, with 33.2% raise regarding the same period of 2007). Abruptly growths on ethanol exports, in 2004 and 2006, were due to relative imbalances between consumption and domestic production in US; as long as the installed capacity of production increased, exports stabilized (i.e., in 2005 and in 2007).



Source: EPE (2007) and MAPA (2008)

Figure 1.4 Ethanol production in Brazil from 1970 to 2007; estimates for 2008



Source: UNICA (2007) and MAPA (2008)

Figure 1.5 Exports of ethanol from 1998 to 2007 (estimates for 2008)

In 2006 there was 370 industrial units and more 100 mills under construction or expected beginning of production between 2009 and 2011[2]. As it is presented in Table 1.1, in 2006 248

[2] There is uncertainty regarding the units under construction as some predicted units could just correspond to projects.

mills were located in the so-called Centre-South region[3]. In four years, from 2005 to 2008, 84 new mills should start operation in Centre-South region, being 40 in the state of São Paulo (Jank and Rodrigues, 2008). It is predicted that only in 2008 32 new mills will start operation; all these mills are located in Centre-South Region, being 13 of them in São Paulo and 10 in Goiás.

Table 1.1 Operating mills and sugarcane crushed in the harvest season 2006-2007

Region	State	Number of mills	Sugarcane processed (Mt)
Centre-South	Minas Gerais	25	29.0
	Espírito Santo	6	2.9
	Rio de Janeiro	8	3.4
	São Paulo	151	264.3
	Paraná	28	32.0
	Rio Grande do Sul	1	91.9
	Mato Grosso	12	13.2
	Mato Grosso Sul	11	11.6
	Goiás	15	16.1
	Sub-total	247	372.8
North-Northeast	Alagoas	24	26.3
	Pernambuco	24	18.4
	Paraíba	8	6.2
	RG Norte	3	2.9
	Bahia	4	2.9
	Maranhão	6	2.9
	Piauí	1	0.7
	Sergipe	4	1.6
	Ceará	3	0.1
	Sub-total	100	52.7
Brazil	Total	347	425.5

Source: CONAB (2007)

In 2007, 273 mills were able to produce both ethanol and sugar, with some degree of flexibility between the two products (general sense, the production varies from 40% to 60% ethanol, and consequently, 60% to 40% sugar), 77 mills were only able to produce ethanol (autonomous distilleries) and 16 mills were able to produce only sugar (MME, 2007). "Brazilian model of ethanol production" refers to the combined production of sugar and ethanol, option that brings some advantages to producers, al least regarding risk reduction[4].

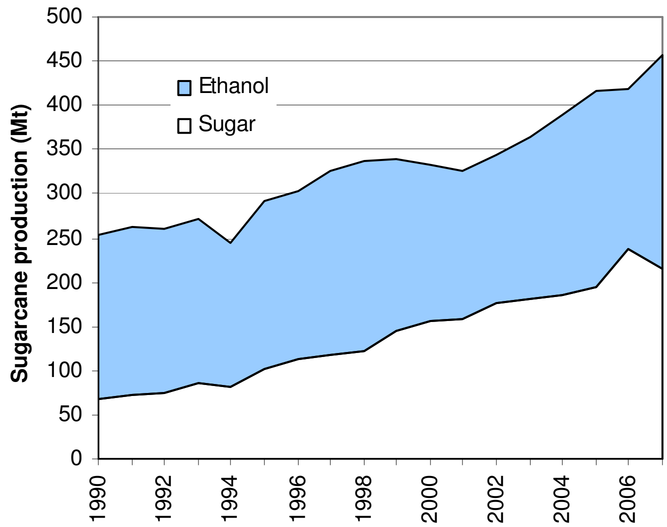
In 2007 the bulk of sugarcane production (87%) occurred in the Centre-South region and a small share in the North-Northeast region (13%, being more than 10% in the Northeast region). In the period 2000-2006 the production of sugarcane in states of the Amazon region was only 0.6% of the total, on average, and this share has not risen along the years. Total sugarcane production (for

[3] In the states of São Paulo, Paraná, Minas Gerais, Goiás, Mato Grosso, Mato Grosso do Sul, Rio de Janeiro, Espírito Santo and Rio Grande do Sul.

[4] By the end of September 2008, there was 414 sugarcane mills officially registered at the Ministry of Agriculture, being 248 mills with annexed distilleries, 151 mills with autonomous distilleries and 15 mills that can only produce sugar (MAPA, 2008).

sugar and ethanol) in the harvest season 2007-2008 was 493 million tonnes (425 in the previous harvest season).

Figure 1.6 shows the growth of sugarcane production for sugar and ethanol from the harvest season 1990-1991 to 2007-2008. Up to early 2000s, there was a growth on the share of sugarcane used for sugar production, with a change of this tendency afterwards. On average, during the five last harvest seasons half of sugarcane was used for sugar and half for ethanol production.



Source: MAPA (2007)

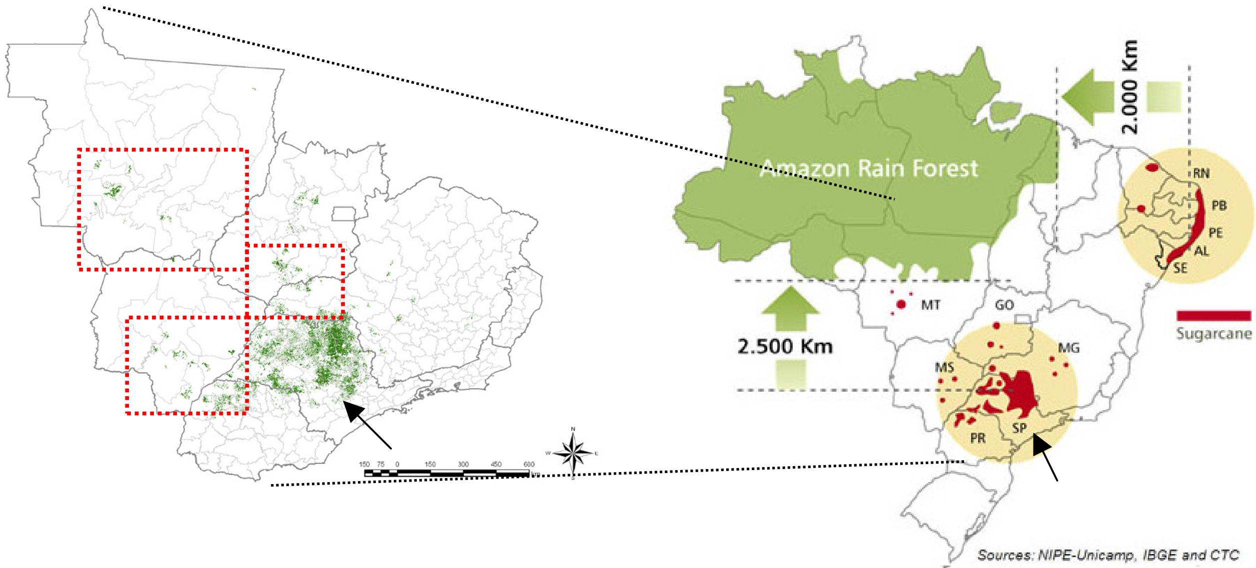
Figure 1.6. Sugarcane used for sugar and ethanol production from harvest season 1990-1991 to 2006-2007 (based on the amount of sucrose used for each product)

State of São Paulo concentrated 60% of the sugarcane production in 2007, having Paraná[5] a production level 8 times lower than São Paulo. Regarding ethanol production, the concentration in the Centre-South region is even larger (90% in 2007), being almost 60% of the total production in state of São Paulo; Minas Gerais and Paraná contributed that year with almost equal shares (8.3%-7.9%) regarding the total national production (UNICA, 2008).

Figure 1.7 (left side) shows the cultivated area with sugarcane in the harvest season 2008-2009 (i.e., the current season) in the Centre-South region. It is estimated that almost 500 million tonnes of sugarcane will be produced in the region and that 58% of the production will be used for ethanol; 24.3 billion litres of ethanol should be produced in the region, with an increase of 19% regarding the previous harvest. As mentioned, in the figure it can be seen that the production is heavily concentrated in São Paulo (SP, indicated by an arrow) and that the planted areas in Paraná (PR, south of São Paulo; see right side of Figure 1.7) and Minas Gerais (MG, north of São Paulo)[6] are in fact very close to São Paulo. Areas of sugarcane production in the Northeast region are highlighted in the circle, in the map at the right side of Figure 1.7.

[5] The second largest producer state.

[6] Second and third most important producer states, respectively.



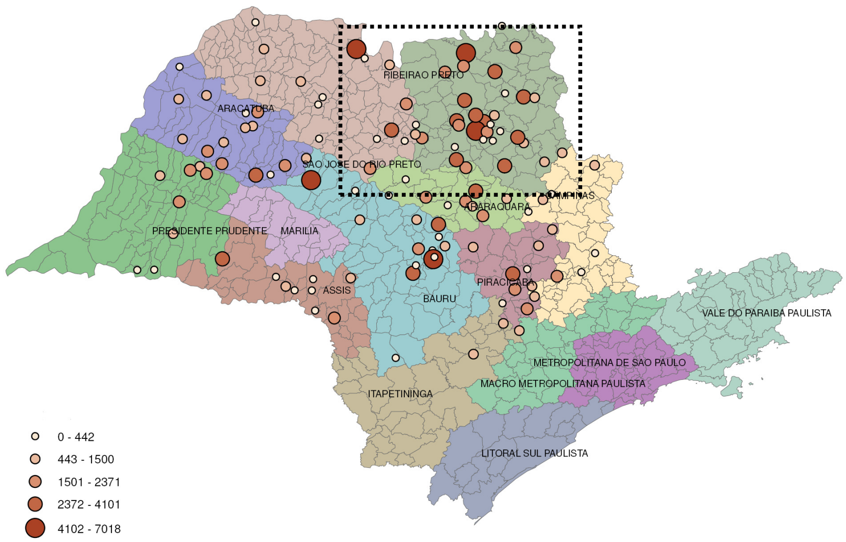
Source: Jank and Rodrigues (2008)

Note: Rio do Grande do Sul and Santa Catarina are not showed in the left side of the figure. The sugarcane production in Rio Grande do Sul is small and there is no production of ethanol in Santa Catarina.

Figure 1.7 Sugarcane areas in the Centre-South region – current harvest (left side) – and sugarcane production areas regarding Amazon rain forest (right side)

In the state of São Paulo, the region with highest concentration of sugarcane mills – Ribeirão Preto, indicated by dotted lines in Figure 1.8 – has the best conditions for this crop, considering soil quality, weather adequacy, rainfall and topography. This region has high concentration of sugarcane areas and land is relatively expensive there (see Chapter 4). In state of São Paulo the tendency is the installation of new producing units in the west side of the state, displacing pasture and, in a smaller extent, other traditional crops (e.g., orange) (see also Chapter 4). Besides the factors mentioned above, the concentration of sugarcane production in São Paulo and neighbourhoods is also due to the best infrastructure available there (including storage facilities, roads, pipelines, harbours, etc.), and the size of the consumer market.

The current capacity of ethanol production is about 30 billion litres and it is growing fast. From 2008 to 2012 about 33 US$ billion should be invested, being 23 US$ billion in new mills (Jank, 2008). It is predicted that the total production of ethanol (domestic market + exports) shall reach 30 billion litres by 2010, 47 billion litres by 2015 and 65 billion litres by 2020 (Jank, 2007). Currently, 7% of the industrial units are controlled by foreign capital, but this share shall increase to at least 12% in five years (Jank, 2008). Some new investors are buying stocks of sugarcane companies as, e.g., BP, that by the end of April 2008 announced that has become investor in a new distillery in Goiás. On the other hand, the largest sugarcane industrial group in Brazil, COSAN, is buying the division Exxon Mobil for distribution of oil products.



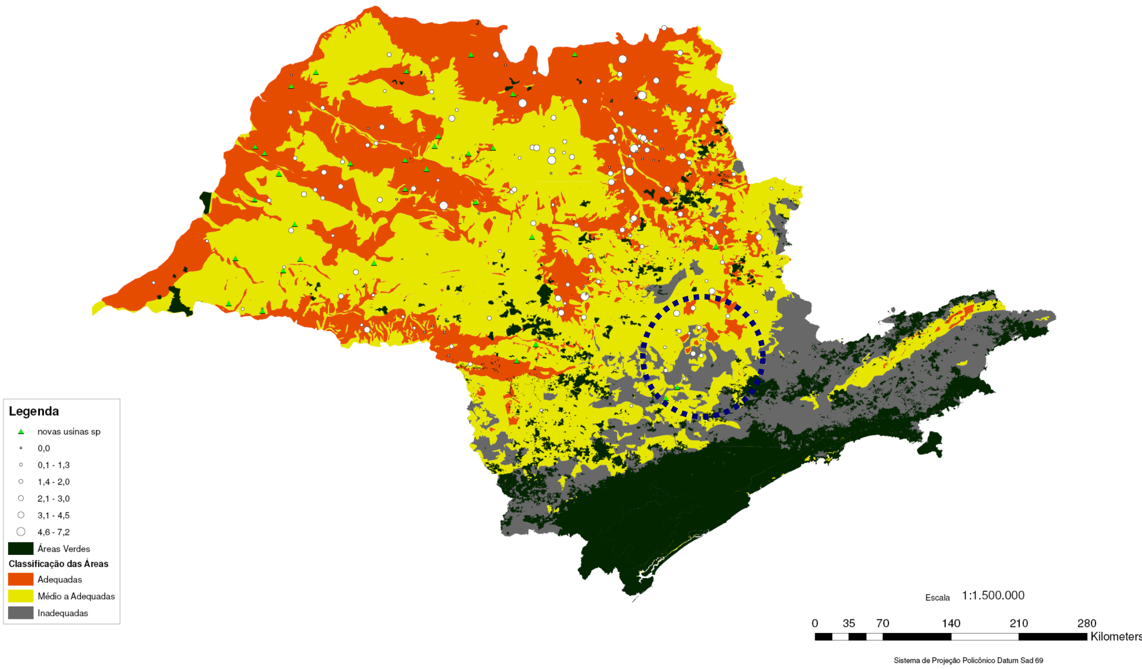
Source: Franco (2008)

Figure 1.8 Regions with sugarcane mills in state of São Paulo, in 2006 (circles represent the amount of sugarcane crushed per year in each mill – thousand tonnes)

In the harvest season 2007-2008 (i.e., the last harvest season) plantations of sugarcane occupied 7.8 Mha in Brazil, allowing the production of 493 million tonnes of sugarcane (in 2007); 550 million tonnes could be produced in 2008. In 2007 56% of the sugarcane was used for ethanol production (the difference for sugar production). Sugarcane occupied 10% of the cultivated land in 2006 (about 77 Mha) (IBGE, 2007); by 2020, it is estimated that about 14 Mha would be occupied with sugarcane, with an average growth on agricultural yield of 0.6% per year (Jank, 2007). About technological development and growth of productivity, see next section.

Due to the raise of land's price in state of São Paulo, the second movement of expansion of sugarcane production has been towards the regions identified by dotted rectangles in Figure 1.7, left side. This tendency should be reinforced in the years to come (see more information in Chapter 4).

Figure 1.9 is an illustration of the areas in state of São Paulo where there are adequate conditions for sugarcane production. Adequacy was defined as function of weather conditions, rainfall, soil quality, erosion risk and topography. It can be seen that most of the mills already installed (white points in the figure) are located in most favourable areas. Some of the new mills are also being built or are planned to be built in these areas. However, considering topography constraints the traditional region of sugarcane production around Piracicaba can be classified as inadequate (identified by the dotted circle in Figure 1.9).



Source: Franco (2008)

Note: More adequate areas are marked orange, medium-adequate areas are marked yellow, while inadequate areas area marked grey. Areas in dark green are area with environmental constraints.

Figure 1.9 Adequacy of areas for sugarcane plantation in state of São Paulo.

Topography imposes important constraints for mechanical harvesting, that is a tendency in state of São Paulo as previous burning of the sugarcane field should be completely phased-out by 2017 (see Chapter 2). Previous burning is still a common practice in Brazil in order to make feasible manual harvesting. Currently, mechanical harvesting is already cheaper than manual harvesting, but the required investments and topography are constraints in this process. In the state of São Paulo, in the last harvest season (i.e., in 2007), 47% of the sugarcane was harvested without previous burning. There are regions is the state (e.g., in Ribeirão Preto) where more than 90% of the sugarcane is harvested without burning (Jank and Rodrigues, 2008).

An important characteristic of ethanol production in Brazil is that there is a high concentration of industrial capacity in large mills. The weighted average capacity in the Centre-South region has been close to 2 million tonnes of sugarcane crushed per year, and new mills tend to be even larger (about 3 million tonnes/year). Table 1.2 presents data about the size of sugarcane mills in the harvest season 2005-2006. The size of the industrial units is one of the factors that have induced cost reductions of ethanol along the years, due to scaling effects (van den Blake, 2006).

On the other hand, there is lower concentration regarding sugarcane production. Mill's proprietors produce part of the sugarcane processed, either using their own land or rented land. This share is referred as own production in Table 1.3. Part of the production is due to suppliers of sugarcane, some of them small farmers, which sell sugarcane to the mills[7]. It can be seen in Table 1.3 that along forty years (1960-2000) the participation of sugarcane suppliers was reduced, but in recent

[7] The payment is according to the sucrose content.

years (after 2000), and probably because of the rise of sugarcane industry, the share of sugarcane production due to the suppliers increased significantly.

Table 1.2 Profile of sugarcane mills in the harvest season 2005-2006

Capacity (per year)	Number of mills (%)	Sugarcane crushed (%)	Sugar production (%)	Ethanol production (%)
< 270 thousand tonnes	47.6	17.2	9.2	23.3
> 270 thousand < 2 million tonnes	40.0	45.4	49.3	41.2
> 2 million tonnes	12.4	37.4	41.6	35.6

From different sources.

Table 1.3 Profile of sugarcane production in Brazil from 1960 to 2005

Season	Sugarcane crushed (thousand tonnes)			From suppliers (%)
	Own production	From suppliers	Total	
1960-1961	18,562	17,985	36,547	49.2
1970-1971	31,125	29,409	60,534	48.6
1980-1981	65,295	58,385	123,680	47.2
1990-1991	133,457	88,971	222,428	40.0
2000-2001	173,559	81,361	254,920	31.9
2004-2005	230,724	150,722	381,446	39.5
2005-2006	232,462	150,019	382,481	39.2

Source: MAPA (2007).

It is estimated that there are about 72,000 suppliers in Brazil (UNICA, 2008), being about 14 thousand in the state of São Paulo. Table 1.4 shows the profile of sugarcane suppliers in São Paulo, during the harvest 2006-2007. It is clear from Table 1.4 that the bulk of the production is due to the larger suppliers but, on the other hand, there are a significant number of small-scale suppliers (77% of them are producing sugarcane in less than 22 hectares).

Table 1.4 Profile of sugarcane suppliers in the state of São Paulo – 2006-2007

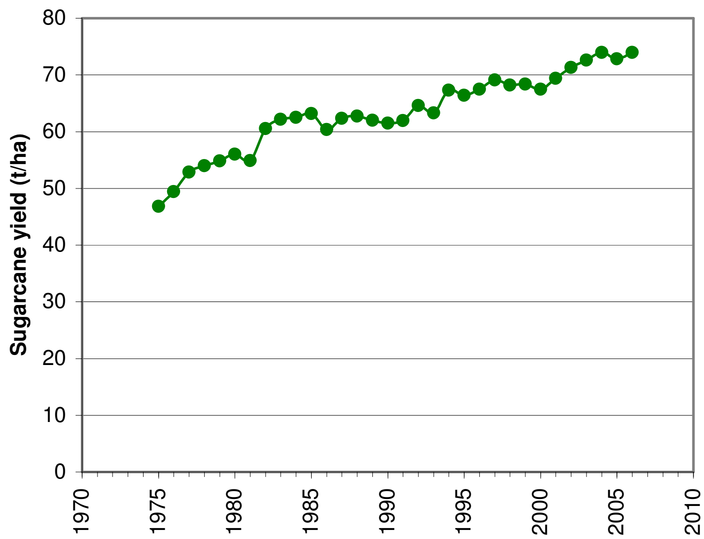
Range of production (t)	Number of producers	% of producers	Average area (ha)	Production (1000 t)	% of production	Average yield (t/ha)
< 200	1,582	11.3	up to1	190.1	0.3	51.2
201 to 800	3,758	26.9	6	1,754.7	2.6	77.8
801 to 4,000	5,455	39.0	22	10,324.4	15.0	86.0
4,000 to 10,000	1,788	12.8	74	11,257.9	16.4	85.1
> 10,000	1,397	10.0	381	45,121.9	65.7	84.8
Total	13,980	100.0	58	68,649.0	100.0	84.7

Source: Orplana (2008)

1.3 Technology development and raise of productivity

Due to the technological developments achieved both on the agriculture and on industry sides, average production yields have grown from 3,000 litres/ha.year (67 GJ/ha/yr) in early 1980s to 6,500 litres/ha.year (145 GJ/ha/yr) in 2005 (UNICA, 2006). Considering these results, for the production of 15.9 billion litres of ethanol in 2005 it was possible to save almost 2.9 million hectares. Production yields based on conventional process can reach 8,000 litres/ha.year (178 GJ/ha/yr) in about 8 years or even 9,000 litres/ha.year (about 200 GJ/ha/yr) in case ethanol production from hydrolysis of sugarcane bagasse would reach a commercial stage.

Figure 1.10 shows the evolution of sugarcane yields in Brazil, from 1975 to 2006. Due to the best conditions, yields are higher in Centre-South region and are particularly higher in state of São Paulo (e.g., at least 82 t/ha in São Paulo, in 2006, vis-à-vis 74 t/ha for the national average). On average, yields grew more than 3% per year from 1975 to 1985 and about 1% per year from 1986 to 2006. Since 1975 yields have grown almost 60% due to the development of new varieties and to the improvement of agricultural practices.



Source: MAPA (2008)

Figure 1.10 Average agricultural yields of sugarcane production in Brazil from 1975 o 2006

The growth on sugarcane yields has been mostly due to the development of cane varieties, effort that also aims to increase the sugar content in the sugarcane (expressed by the total reducing sugars index – TRS). To give an idea of the evolution achieved, in 25 years TRS almost double and best practice figures are close to 15 per cent (Coelho et al., 2006).

Technological development has also occurred in the industrial side, but with lower impact on reduction of ethanol's production costs. A summary of the main technological improvements in the industrial process is presented in Table 1.5.

Table 1.5 Main technological improvements in the industrial process

Process step	Actions	Average and best practice results
Juice extraction	Rise on crushing capacity; Reduction of energy requirements; Rise on the yield of juice extraction.	Extraction yield has improved from 92 up to 97.5 per cent. Average yield around 96 per cent.
Fermentation	Microbiological control; Yeast selection based on genetics and better yeast selection; Large-scale continuous fermentation, better engineering and better control of process	Fermentation yield has improved from 83 to 91.2 per cent (best practice 93 per cent); Production time has decreased from 14.5 to 8.5 hours (best practice 5.0 h); Wine content has improved from 7.5 per cent to 9.0 per cent (best practice 11.0 per cent); Final yeast concentration has improved from 6 to 13 percent (% volume); Reduction of about 8 per cent on ethanol costs due to continuous fermentation and microbiological control.
Ethanol distillation	Improvements on process control	Average yield has risen from 96 per cent in early 1990s to up to 99.5 per cent (result also influenced by higher ethanol wine content).
Cane washing	General improvements	Reduction on water consumption; Reduction on sugar losses (2 per cent down to just 0.2 per cent in some cases).
Industry in general	Instrumentation and automation	Impact on juice extraction, evaporation, fermentation, crystallization and steam generation.

Sources: Finguerut (1997), Macedo and Cortez (2000), Moreira and Goldemberg (1999). Table extracted from Walter (2008).

1.4 Cost reduction

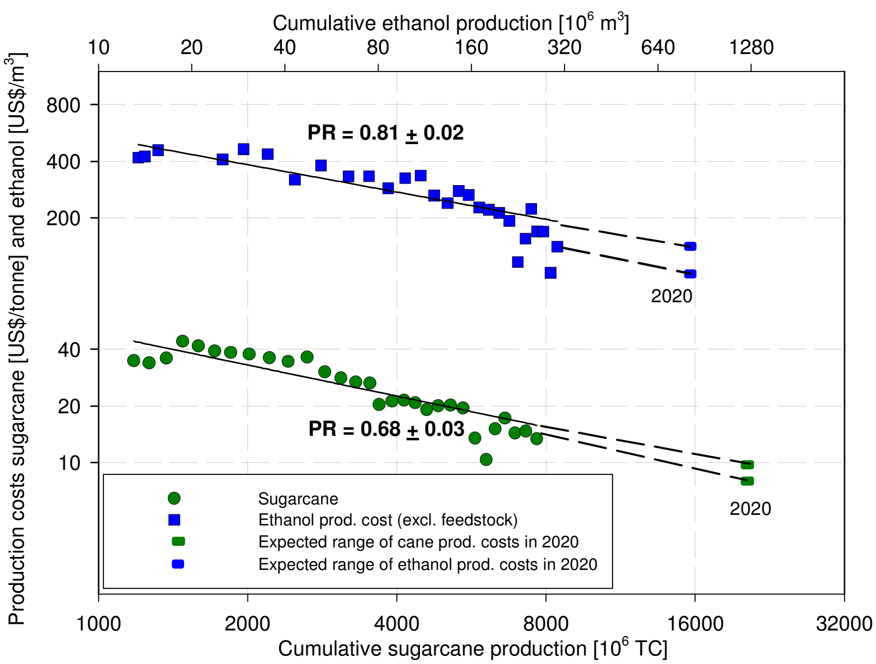
Brazil has the lowest cost of production of ethanol and is so far the only country where biofuels are strictly competitive vis-à-vis oil derivatives. Figures about production costs of ethanol in Brazil vary due to set of mills considered and also according to the exchange ratio that is used.

During 25 years ethanol production costs fell on average 3.2 per cent per year in the Centre-South region since 1975 and about 1.9 per cent per year in the Northeastern region (Carvalho, 2001). In 2001 it was estimated that the production cost of hydrated ethanol in a mill with good performance was around R$ 0.45 (FIPE, 2001), or about US$ 0.18 per litre, considering the exchange rate at that time. In a comparative study published in 2004 (IEA, 2004, *apud* Worldwatch, 2006) it was evaluated that the average production cost of anhydrous ethanol in Brazil at that time was 0.145 Euro per litre, or US$ 0.18-0.19/litre. Production cost of anhydrous ethanol is about 5-10% higher than the cost of hydrated ethanol.

The average production cost of ethanol from corn in USA is more than twice higher than in Brazil, while the production cost of ethanol from wheat in Germany is more than three times higher (Henniges and Zedd, 2004). The same conclusion regarding relative costs was presented by Worldwatch Institute (2006), based on information of International Energy Agency and US-Department of Energy: 14-20 Euro/m^3 of anhydrous ethanol in Brazil, 23-35 Euro/m^3 in USA (production from corn) and 28-46 Euro/m^3 in Europe (from grains).

Also regarding reduction of costs, van den Wall Bake (2006) showed that the experience curve of ethanol production in Brazil is better estimate with a progress ratio of 0.79 over the period 1975-2004, when approximately six cumulative doublings of ethanol production were observed. Industrial processing costs declined more than agricultural costs, but with a lower impact to the overall cost reduction as feedstock represents 60-65% of the total production costs. The largest share of the total feedstock cost reduction was due to the development of new varieties of sugarcane with indirect impacts on costs of soil preparation, planting, stock maintenance and land rents (due to the higher number of the cuts – five to six – and to larger yields). On the other hand, industrial processing costs were reduced more due to economies of scale, with impacts on investments and on operation and maintenance costs.

Based on the calculated progress ratios, and assuming an annual production growth of 5-8 per cent, total ethanol production cost in Brazil is expected to be reduced about 20% up to 2015 (van den Wall Bake, 2006). The prediction presented by Worldwatch Institute (2006) is that after 2010 ethanol production costs in Brazil can be further reduced 10-15% regarding those verified over 2004-2005. Figure 1.11 shows the estimated learning curves and estimated future costs of sugarcane and ethanol production (excluding feedstock costs) assuming 8% annual growth of sugarcane and ethanol production.



Source: Wall-Bake et al. (2008)

Figure 1.10 Learning curves and estimated future costs of sugarcane and ethanol production (excluding feedstock costs) assuming 8% annual growth of sugarcane and ethanol production.

1.5 Electricity production from residual sugarcane biomass

Electricity production from residual sugarcane bagasse is traditional all over the world but what is common is the production of electricity for self-consumption; the technology in use is known as cogeneration[8]. As shown in Figure 1.12 electricity production has increased since late 1980s and, on average, Brazilian mills are producing surplus electricity since 1996 (based on generation index that exceeds 12 kWh per tonne of sugarcane crushed, that is the estimated electricity self-consumption of a typical mill). In fact, some mills are producing surplus electricity since the second half and 1980s.

Considering sugarcane production in 2006 (425 million tonnes), about 3.5 TWh of surplus electricity could be produced and commercialised. However, for the same amount of sugarcane produced, but using both sugarcane bagasse and trash (e.g., leaves of the sugarcane plant) as fuels, the potential would be 5-7 higher than what has been produced. UNICA (2008) estimates that in 2007 the electricity production from sugarcane bagasse contributed with 3% of the total electricity production in Brazil. The installed capacity of electricity production at the sugarcane mills is estimated as about 3,400 MW (ANEEL, 2008), being about 1,800 MW the capacity of surplus electricity production. The potential of surplus electricity production is evaluated by UNICA (2008) as 11,500 MW and 14,400 MW in 2015 and 2020, respectively, that could contribute with 15% of total electricity production. The same organization estimates that in the current breakdown of revenues of sugarcane industry the selling of surplus electricity contributes with only 1%, but this figure could reach 16% in 2015[9].

Sugarcane industry has recognized that diversification of the production is one of the main strategies to enhance the competition of ethanol production from sugarcane and, in this sense, it is important to deploy the existing potential of electricity production from sugarcane residual biomass. In addition, there is a window opportunity due to the enlargement of ethanol production, due to the investments in new mills or due to the retrofit of the existing mills.

However, there are still constraints for fully deploying the existing potential and only a strategy evolving the federal government, the electric sector and the sugarcane sector would allow positive results. Back to Figure 1.12, it is clear that in recent years the potential of electricity generation (expressed as kWh/t sugarcane) has been constrained. Electricity generation in itself has grown at 13.9% per year, on average, since 2000, but this rate has declined to 7.5% per year in the period 2003-2007. This is a clear evidence that investments on electricity generation are not following the same pace as the investments on sugarcane and ethanol production.

1.6 Concluding remarks

Sugarcane production is growing fast in Brazil. Recently, most of this growth has been due to ethanol production, and the main driving force has been the enlargement of the domestic market, induced by the success of FFVs.

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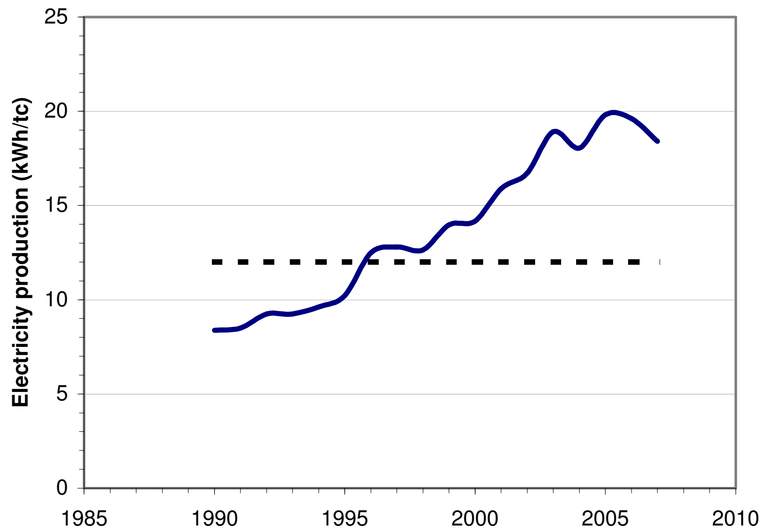
[8] Combined production of heat (in general, steam) and power (in general, electricity) from the same energy source.

[9] In 2006 the revenue of sugarcane industry was estimated as 20 billion US$; the revenue as of 0215 is estimated as 45 billion US$. According to the projections, the revenue from the sales of surplus electricity could be larger than from exports of ethanol (13% of the revenues) and from the domestic market of sugar (10%) (Velasco, 2008).



Source: UNICA (2008) and EPE (2008)

Figure 1.12 Average electricity production (kWh/t of sugarcane crushed) in Brazilian mills – 1990-2007

In Brazil the development of sugarcane industry has occurred since mid-1970s, but it has been during the last 5-6 years that the ethanol market has called attention. There is a clear tendency of modernization (either from technological or managerial point of view) and large groups, some of them with participation of foreign capital, tend to dominate the market. The potential of the domestic market of fuel ethanol is sizeable and only this market would large enough to induce investments and improvements in the industry.

Ethanol production from sugarcane, in Brazil, has many advantages regarding biofuels produced from other raw materials and in other countries. However, developments in this industry are essential, both to keep production costs at a low level and to improve sustainability of ethanol production. Two challenges for the ethanol industry in Brazil are the development of new technologies (e.g., ethanol production through hydrolysis of sugarcane bagasse) and process diversification (e.g., through the development of the biorefinery concept, and with electricity production at a higher extent).

Chapter 2

Sustainability Principles and Criteria – Initiatives and Priorities for the Certification of Biofuels Production

2.1 Introduction

Sustainability of biofuels production has been one of the main focus of the current discussion about biofuels as an option for displacing fossil fuels at a reasonable extent.

The interest regarding biofuels, in general, and ethanol in particular, has been caused by environmental concerns, and specifically due to the need to mitigate greenhouse gas emissions (GHG). Other driving forces include the rise of oil prices, interest in diversifying the energy matrix, security of the energy supply and, in some cases, rural development concerns.

However, doubts have been raised about the actual benefits of biofuels regarding the mitigation of GHG emissions. Other questions have also been raised about potential environmental, social and economic impacts, such as disruption of food supply, risks of losing biodiversity, reduction of water quality and water availability, and lack of real benefits to those directly affected by biofuels production. These questions have been mostly raised in developed countries, and especially in Europe.

As consequence, sustainability criteria have been proposed in order to promote the effective sustainable production of biofuels. Certification of biofuels production is understood by many as the only possible way to assure biofuels sustainability in a broad sense. However, this position is not exempt of strong criticism, mostly in developing countries, as certification could impose additional barriers on trade and reduce comparative advantages of some producer countries[10].

Anyhow, certified production of biofuels seems to be imposed in short-term by some consumer markets. Firstly, traders eager reducing risks on trade and preserving the markets that have been slowly (and hardly) developed. Secondly, growing consciousness of consumers, the diversity of biofuels options and the heterogeneity of biofuels production schemes is a combination that reinforces certification as a necessity. Thirdly, certification would be a way to induce a right movement towards sustainable production. Finally, theoretically countries that have the best production conditions could get benefits as long as certification schemes would give room for market recognition.

This chapter aims at the identification of sustainability principles and criteria currently considered in some European countries and at the European Union. The analysis concerns the main contributions recently presented in UK, Netherlands, Germany and at European Union. In resume, these countries have decided that in case a common procedure could not be adopted at the Europe Union in short-term (e.g., until 2009), specific procedures would be adopted at national level. Initiatives of private companies (e.g., the Swedish SEKAB) and organizations/institutions (e.g., École Polytechnique Féderalé de Laussane – EPFL, through the Roundtable on Sustainable Biofuels) are also analysed in this chapter. The aim of the analysis is the identification of the main issues of concern in order to assure sustainable production of biofuels.

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[10] Both because of constraints that should be imposed and due to the additional costs.

In addition, in the final section of this chapter the main actions so far conducted in Brazil aiming at improving (or assuring) sustainability of ethanol production are presented. This actions have been conducted by Governments (at federal or state level) and private organizations.

2.2 United Kingdom

The Renewable Transport Fuel Obligation (RTFO) is a requirement on transport fuel suppliers to ensure that 5%, by 2010, of all road vehicle fuel is from sustainable renewable sources. RFTO came into force on April 2008. It is predicted that RTFO will be implemented by a certification scheme controlled by the Renewable Fuels Agency (RFA). Fuel suppliers will be oblige to include the required percentage of biofuels (e.g., biodiesel and biogas, besides bioethanol) in their fuel mix or pay a penalty; certifications could be sold in the market.

The focus point of RTFO is on reduction of GHG emissions. In UK, the transport sector is responsible for 25% of emissions and the target is to reduce due to RTFO carbon dioxide emissions by about 2.6-3.0 million tonnes (Department of Transport, 2008a).

RFA should require biofuel suppliers to submit annual, independently verified reports on both the net GHG savings and the sustainability of the biofuels they supply (Department of Transport, 2008b). So far a report on carbon and sustainability is obligatory, but without consequences if poor performance is reported. By April 2010 it is predicted rewarding biofuels according to the amount of carbon savings and by April 2011 rewarding only biofuels that meet all sustainability standards. Table 2.1 presents no-mandatory annual supplier targets recommended by UK Government.

Table 2.1 Annual supplier targets recommended by UK Government

Target	2008-2009	2009-2010	2010-2011
Percentage of feedstock meeting a Qualified Environmental Standard[1] (%)	30	50	80
Annual GHG saving of fuel supplied[2] (%)	40	45	50
Data reporting of renewable fuel characteristics[3] (%)	50	70	70

Notes: [1] Calculated as an overall percentage for all feedstock;
[2] Regarding a pre-defined carbon intensity of gasoline and diesel;
[3] Regarding biofuel feedstock, feedstock origin, standards and land use.
Source: Department of Transport (2008b)

Regarding GHG emissions, the methodology recommended is based on a well-to-wheel procedure including all significant sources of GHG. The recommendation is also to include, when possible, the effects on overall GHG savings of previous land use change.

According to the environmental and social principles, it is recommended that biomass production will not cause impacts such as those listed bellow (Department of Transport, 2008b):

- destruction or damage of above or below ground carbon stocks;
- destruction to high diversity areas;

- soil degradation;
- contamination or depletion of water resources;
- lead to air pollution;
- not adversely affect workers rights and working relationships;
- not adversely affect existing land rights and community relationships.

It is worth to mention that the UK Government recognises that some principles would be difficult to monitor at the fuel supplier level. Land use change arising as indirect result of biomass production and impact of biofuels on commodity prices is explicitly mentioned as an example (Department of Transport, 2008a). Anyhow, the recommendation is that all principles should be monitored ex-post and the RFA report annually the potential effects to the Parliament.

2.3 The Netherlands

In 2006-2007 the so-called Cramer Commission[11] set the Dutch sustainability principles defined by the project group "Sustainable Production of Biomass" (Cramer et al., 2007). In the final report, principles, criteria and indicators were defined for the main issues concerned to the environmental and social sustainability of biomass production (including biofuels).

Due to the possible introduction of EU criteria in short-term, Dutch Government has decided to stall the introduction of Cramer Criteria and currently there is no report obligation.

Six areas of concern were highlighted by Cramer Commission. The principles concerned to these priorities are listed bellow:

- GHG emissions – the use of biofuels should imply reductions of GHG emissions. The comparison should be done regarding the average use of fossil fuels, considering the life cycle of fossil and biofuels (i.e., well-to-wheel basis) and in case of biofuels reduction should be at least 30%. Carbon emissions due to land use change[12] should also be taken into account.
- Impacts over food supply – the production of biomass for energy must not endanger the food supply and other local biomass applications. The analysis should be developed considering possible changes of land use in the region of biomass production.
- Biodiversity – Biomass production must not affect protected or vulnerable biodiversity. The basic criteria are that violation of national laws and regulations are unacceptable.
- Local environmental effects – Principles include (a) soil and soil quality, that must be retained or even improved, (b) ground and surface water supply, that must not be

[11] Leaded by Jacqueline Cramer, Ministry of Environment of The Netherlands.

[12] Both considering above ground carbon sinks (vegetation) and underground carbon sinks (soil). In addition, as principles, (1) the installation of new biomass production units must not take place in areas in which the loss of above ground carbon storage cannot be recovered within a period of ten years of biomass production, and (2) the installation of new biomass production units must not take place in areas with a great risk of significant carbon losses from the soil, such as certain grasslands, peat areas, mangroves and wet areas.

depleted, and water quality, that must be at least maintained, and (c) air quality, that must not be depleted. The basic criteria are that national laws and regulations should be enforced.

- Local economic effects – The production of biomass must contribute towards local prosperity.
- Social well-being – The production of biomass must contribute towards the social well-being of the employees and the local population.

2.4 Germany

By the end of 2006 the Ministry of the Environment and the Federal Environmental Agency launched a project aimed at defining the basis for a certification system of biofuels. The result was the proposed Biomass Sustainability Regulation (BSR). BSR defines sustainability criteria for biofuels, GHG methodology and default values regarding GHG emissions.

Previous to the BSR proposal mandatory quotas of biofuels were defined. In case of ethanol, the quota corresponded to the substitution of a minimum 2.0% (energy basis) of gasoline, 2.8% in 2009 and 3.6% onwards. Sanctions for non-compliance were set as 43 €/GJ of gasoline. Theoretically, with BSR, German policy will change from purely quantitative fuel quota to promoting biofuels with good GHG balance. In addition, BSR could ensure sustainability of biofuels production through minimum requirements for sustainable cultivation of agricultural lands and minimum requirements for the protection of natural habitats (Janssen, 2008) (see more details bellow).

The draft of BSR was released by December 2007 and the proposal is currently under discussion. It is expected that BSR could entry into force in 2009; the requirements on biofuels shall be applied 16 months after entry into force. It is predicted the establishment of a certification system to prove compliance with requirements of sustainability regulation.

The main principles to ensure sustainable cultivation of agricultural lands are the following:

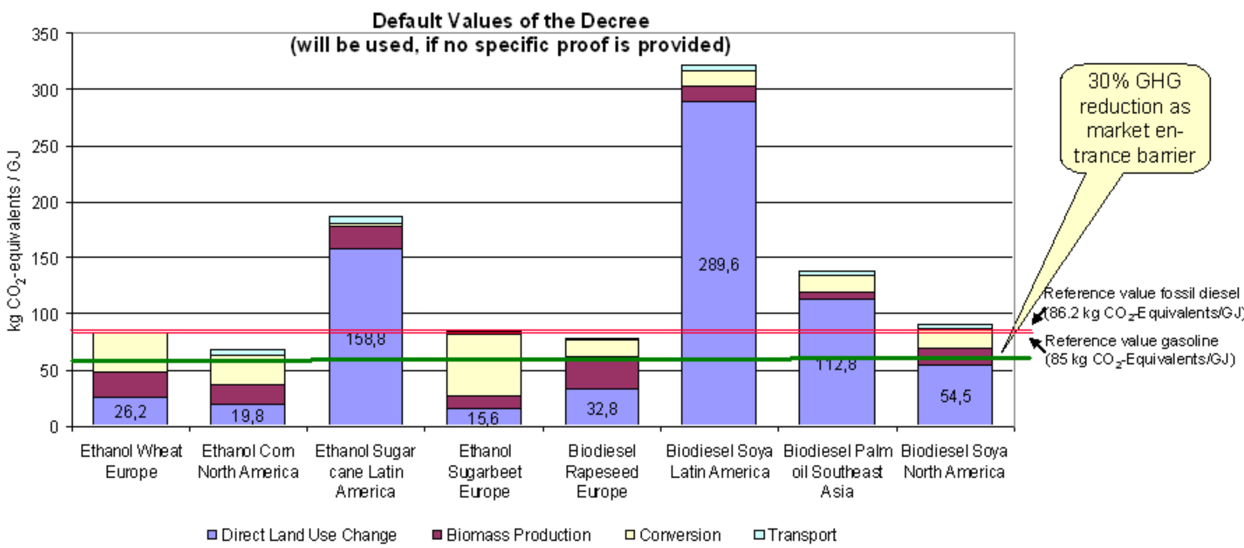
- Biomass has to be produced in accordance with the principles of good practice. The basic criteria is the enforcement of local laws and regulations governing agriculture, forestry and fisheries;
- In the absence of laws, biomass production should be in compliance with (a) no significant increase in emissions of acidic, eutrophic, ozone depleting or toxic substances, (b) no significant deterioration of soil function or soil fertility, (c) no significant deterioration of water quality and water supply, (d) no significant deterioration of species and ecosystem diversity, and (e) environmentally safe use of fertilizers, pesticides and herbicides.

On the other hand, regarding protection of natural habitats the guiding principles are listed bellow:

- biomass shall not be grown in (a) nature reserves or in areas which had been identified as areas of high natural conservation value (as of January 1st, 2005); (b) areas of high natural conservation value; (c) areas which have resources of relevance to biodiversity; (d) areas which lie in globally or regional rare, threatened or endangered ecosystems; and areas which serve fundamental protective functions.

An essential aspect of German BSR is that biofuels must lead a GHG reduction of at least 30% regarding the full life-cycle of fossil fuels, being this value increased to 40% from January 2011. Emissions from direct land use changes must be included in the analysis and co-products should also be considered, being defined that the allocation should be done on energy basis (LHV basis).

Default values of GHG emissions are defined in BSR, and according to these values no biofuel would accomplish the market entrance barrier of 30% GHG minimum reduction. As consequence, all biofuels producers would present a proof that the GHG emissions are lower than the default values. Figure 2.1 shows the default values defined by the German Sustainability Decree, including GHG emissions due to direct land use change, biomass production, biomass conversion to biofuels and transport to the consumers.



Source: Henke and Schmitz (2008), *apud* meó Consulting Team

Figure 2.1. Default values of GHG emissions as defined by the German Sustainability Decree

2.5 Europe Commission

Early 2008 the European Commission published a proposal for a directive on the promotion of the use of energy from renewable sources (CEC, 2008). The proposal aims to establish an overall target of a 20% share of renewable energy sources in energy consumption by 2020 in all Member States, and a 10% binding minimum target for biofuels in transport (energy basis).

The Directive on Renewable Energy defines that a sustainability scheme for biomass, in general, must be developed by the end of 2010, at the latest. Specifically regarding biofuels, the following issues are addressed in the Directive:

- GHG saving regarding full life-cycle of fossil fuels must be at least 35%;

- Biofuels cannot be produced from raw materials from high biodiversity areas, including undisturbed forests, area designated for nature protection, grasslands;
- Biofuels cannot be produced from high carbon stock areas, such as wetlands and forested areas;
- In case of biofuels produced in EU, biomass raw-materials must be cultivated in accordance with European minimum requirement and standards for good agricultural and environmental practice.

Fuel suppliers should provide an adequate standard of independent auditing, that must be verifiable, reliable and fraud-resistant (Abengoa, 2008).

European Parliament should decide about Renewable Energy Directive by Spring 2009. In case of approval, the sustainability scheme for biofuels must be transposed in national legislation of the Member States until March 31st, 2010. It is not certain that the Directive will be approved and many criteria are still under discussion, such as:

- Minimum reduction of 35% regarding GHG emissions should be higher or moving targets should be defined?
- There are doubts regarding the methodology to be applied on GHG balances (e.g., allocation methods).
- What social and local environmental criteria could be included? There are special concerns regarding the legality vis-à-vis Word Trade Organization (WTO) procedures.
- How the food x fuel issue could be addressed?
- Biodiversity sensitive areas should be better defined.

2.6 Roundtable on Sustainable Biofuels

The Roundtable on Sustainable Biofuels is an initiative coordinated by the École Polytechnique Fédérale de Lausanne – EPFL, based in Lausanne, Swiss. By August 2008 it has been launched the so-called "Version Zero" of Global Principles and Criteria for Sustainable Biofuels Production (available at http://EnergyCenter.epfl.ch/Biofuels), that was developed with participation of a considerable number of stakeholders of different countries. "Version Zero" is currently in a public consultation process and it is predicted that by February 2009 a set of workshops will be organized around the world.

The document under consultation presents sustainability principles and criteria, but so far indicators have not been considered in details. Twelve relevant aspects should be considered in order to assure sustainable biofuels production is a broad sense. These aspects are the following (EPFL, 2008):

- All applicable laws of the country in which production of biofuels occur, as well as all international treaties relevant to biofuels' production to which the producer country is a party, should be followed;

- Regarding biofuels projects, all relevant stakeholders should be involved along the main steps of the decision process;
- Significant reduction of GHG emissions should be reached through biofuels use, also considering direct and indirect land use change;
- Biofuel production shall not cause violation of human rights or labour rights (include child and slave labour); working conditions should be decent;
- Biofuel production shall contribute to the social and economic development of local, rural and indigenous peoples and communities;
- Biofuel production shall not impact food security;
- Biofuel production shall avoid negative impacts on biodiversity, ecosystems, and areas of high conservation value;
- Biofuel production shall promote practices that seek to improve soil health and minimize degradation;
- Biofuel production shall optimise surface and groundwater resource use, including minimizing contamination or depletion of these resources;
- The supply chain of biofuel production and use should not cause significant air pollution;
- Biofuels shall be produced in the most cost-effective way;
- Biofuel production shall not violate land rights.

2.7 SEKAB

The Swedish company SEKAB BioFuels and Chemicals announced by mid 2008 that will start offering verified sustainable ethanol. SEKAB delivers about 90% of all ethanol in Sweden. The company has developed together with four Brazilian ethanol producer groups[13] criteria that cover the life-cycle of ethanol from sugarcane on a well-to-wheel basis. It is estimated that 115 million litres of certified ethanol should be traded during the year.

It is stated that regarding GHG emissions savings will be at least 85% compared with gasoline[14] and that the defined requirements have zero tolerance for child and slave labour, as well as for destruction of rain forests. Other requirements concerned to working conditions, labour laws and wages. An independent verification company will audit all production units twice a year (Green Car Congress, 2008)[15]. The sustainability principles and criteria used by SEKAB are summarized in Annex A.

SEKAB (2008) states that the defined procedure could be improved along the years and will be applied until EU regulations or other measures are in place.

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[13] COSAN, NovAmérica, Guarani and Alcoeste.

[14] Following the methodology prescribed by RTFO (UK), previously mentioned. See Chapter 3 for information about this issue.

[15] According to SEKAB (2008), in case of major non-compliance corrective actions need to be taken with two weeks. Major non-compliances will be followed up by an extra audit.

2.8 INMETRO

INMETRO is the National Institute of Metrology, Standardization and Industrial Quality that belongs to the Ministry of Development, Industry and Foreign Trade[16]. Recently the Institute was asked to conduct the so-called Brazilian Program of Biofuels Certification. According to its premises, certification would not be compulsory and the criteria should be in-line with strategies aiming at foster biofuels exports and at reduction of non-technical barriers to trade. A first version of proposed criteria and principles is under public consultation. INMETRO states that once the final version of procedures is approved, a pilot-phase will be developed. The final decision will probably be taken by Brazilian government during the first semester of 2009.

INMETRO has a similar program aiming at certifying forest management (CERFLOR), which is internationally recognised; INMETRO evaluates that this experience is a good start-point for the program with focus on biofuels. Ethanol certification was defined as the main priority. According to the proposal, an ethanol producer could only start the certification process if the following conditions are fulfilled (INMETRO, 2008):

- Sugarcane production should be in accordance with the Agro-Ecologic Zoning, not yet published (see section 2.9.1);
- All environmental licences are required;
- Evidences of water recycling are required;
- Electricity should be generated on-site, from sugarcane residual biomass;
- Evidences of trash deposition over the soil are required (see Chapter 3) that requires mechanical harvesting in a large extent.

Socio-environmental sustainability principles, criteria and indicators proposed by INMETRO are presented in Annex A.

INMETRO is also deeply involved in making compatible biofuels standards at an international level. In this sense, a task force was created early 2007 with participation of the National Institute of Standards and Technology (NIST – US) and the European Committee for Standardization (CEN), besides INMETRO. So far this task force has achieved good results and international ethanol standards are close to be defined (INMETRO, 2007).

2.9 Other initiatives in Brazil

2.9.1 Agro-ecologic zoning (at national level)

Embrapa is the Brazilian Research Centre for Agriculture, linked to the Ministry of Agriculture (MAPA), and that assumed the coordination of the Agro-ecologic zoning for sugarcane at national level. Its release was predicted for August-September of 2008, but the due date has been delayed. The Zoning has been developed by a multidisciplinary group of state

[16] More information is available at www.inmetro.gov.br.

institutes/universities, government organizations and private consultants. The results of the Zoning should be used as guidelines for licensing and credits concession. As mentioned in section 2.8, a sugarcane mill located outside the indicate areas (to be defined) could not claim for certification from INMETRO.

The following aspects are being considered in order to define adequate areas: a) soil and weather adequacy; b) topography[17]; c) water availability and water requirements[18]; d) that sugarcane cannot be planted in areas with sensible ecosystems[19]; e) areas where other crops have been produced.

Based on unofficial information, it is known that 35 to 45 Mha should be identified as adequate for sugarcane cropping. The result to be presented is a matter of controversy and more or less constraints could be imposed. In a more constrained scenario, about 35 Mha should be declared adequate for sugarcane cropping; these areas should be highly concentrated in the states where the bulk of the production already occurs (e.g., São Paulo, Paraná, Minas, Mato Grosso Sul and Goiás).

2.9.2 Agro-environmental protocol (at state of São Paulo)

In the state of São Paulo, in 2008, it was established the Agro-environmental protocol, signed by the state Government and sugarcane sector. In São Paulo, 145 out of 177 ethanol mills have adhered the Protocol, representing 89% of the sugarcane currently processed; the number of sugarcane suppliers that have adhered the Protocol is estimated as 13,000 (Lucon et al., 2008). The Protocol is a voluntary scheme aiming at promote best practices beyond business-as-usual. One the future targets is issuing a Certificate of Conformity. Ten directives were defined as guidelines, as presented bellow (São Paulo, 2008a):

- Anticipation of the due-date for phasing-out of sugarcane burning previous to harvest in areas with declivity lower than 12% (from 2021 to 2014). The percentage of harvesting without sugarcane burning in these areas should be enlarged from 30% to 70% by 2010.[20]
- Anticipation of the due-date for phasing-out of sugarcane burning previous to harvest in areas with declivity higher than 12% (from 2031 to 2017), as well as change of the not-burned sugarcane in these areas, in 2010, from 10% to 30%.
- In areas of sugarcane expansion burning should not be a practice.
- All by-products of sugarcane cannot be burned without a control system.
- Protection of the riparian forest of sugarcane planted areas.[21]

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[17] Maximum declivity 12% is due to the consideration of current technology for mechanization. It is possible to take into account 18% as the maximum, which would enlarge the area. However, the required technology is not yet available.

[18] A minimum level of irrigation has been considered (e.g., the so-called salvation irrigation).

[19] For instance, Amazon and Pantanal were fully excluded as adequate areas.

[20] It is defined by law that the due date for phasing-out of sugarcane burning before harvest is 2021 in areas with declivity lower than 12% and 2031 as the due date for areas with declivity higher than 12%. Through a voluntary agreement, the intention is to anticipate such due dates. In 2007, in São Paulo, almost 47% of the sugarcane was harvested without previous burning.

- Recovery of natural vegetation in order to protect water springs of sugarcane farms.
- Implementation of a technical plan of soil conservation, including erosion control and contention of water runoffs.
- Implementation of a technical plan aiming water resources conservation, including reuse action and a water quality program.
- Adoption of good practices for agrochemicals packaging waste.
- Adoption of good practices aiming at minimize air pollution and optimise recycle of solid wastes.

The counterpart of the state government regarding the Agro-environmental Protocol would be on: a) fostering the research to make feasible the use of sugarcane trash; b) supporting the improvement of logistics aiming at ethanol exports; c) issuing a Certificate of Conformity to the producers according to the results reached; d) supporting mechanical harvesting, specially in the case of sugarcane producers who have up to 150 ha.

2.9.3 Agro-ecologic zoning (at state of São Paulo)

It has been effective in state of São Paulo, since October 2008, the Agro-ecologic Zoning (São Paulob). The information provided by this study is going be considered by the Environment Secretary along the licensing process of new mills. The zoning was defined taken into account the following aspects: a) soil and weather constraints; b) topography; c) water availability at the surface and risks to water shields; d) the existence of protected areas; e) areas that should be preserved considering conservation of biodiversity; and f) air quality.

The cultivated land in São Paulo was estimated in 2006 as 7.9 Mha, and that year 4.3 Mha were already cultivated with sugarcane. According to the Zoning, the adequate areas for sugarcane cropping sum-up 3.9 Mha, (about 16% of the total area), with more 8.6 Mha considered adequate for sugarcane cropping but with some (no-serious) environmental constraints.

2.10 Conclusions

The definition of sustainability principles and criteria regarding biofuels production is a clear tendency and decisions should be taken at State level, in Europe, in less than a year. Certification of biofuels production would be the natural consequence of such policies. Brazilian producers of ethanol used to be against any initiative aiming at defining sustainability principles and minimum criteria, but it is clear that their position has changed. Even Brazilian government has its own certification process under development, despite the fact it is not clear if the procedure proposed by INMETRO will be adopted.

Within the international agenda it is obvious that the most important issue regarding sustainability of biofuels is GHG emissions and the its ability in reducing GHG emissions

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[21] The existing law already defines protection of riparian forest as an obligation, but there are areas in state of São Paulo where the enforcement is weak.

regarding fossil fuels (gasoline and diesel). There is no Brazilian agenda concerned to sustainability of biofuels but all initiatives so far conducted in Brazil include the evaluation of GHG emissions as a priority. Thus, in this report a chapter is deserved to the issue.

Either direct or indirect impacts of land use change are is also issues of concern. The priority is partially due to the potential impact of land use change on GHG emissions, but other aspects have been taken into account, such as loss of biodiversity and disruptions of food supply. The initiatives concerned to Agro-ecological zoning and the decision that some sensible areas should be declared ineligible for sugarcane cropping reflect the importance given to this issue. In this regard, two chapters of this report are devoted to this subject.

Based on the analysis done, other priority aspects considered in this report are: a) socio-economic impacts at regional level; b) impacts of water consumption on water availability and on quality of water bodies, c) contamination of soils and water shields due to the use of fertilizers and chemicals and d) potential impacts on biodiversity.

Chapter 3
Greenhouse Gas Balance

3.1 Introduction

At the international level, the debate regarding sustainability of biofuels has focused on the balance of greenhouse gases (GHG) and to what extent the GHG emissions from fossil fuels burning would be displaced in case of substitution from biofuels. As mentioned in the previous chapter, one of the most recognised driving forces for biofuels is the necessity of reducing GHG emissions.

Due to the priority given to this matter, this chapter is devoted to the analysis of some energy and GHG emission balances regarding ethanol production from sugarcane, considering typical production conditions in Brazil. The final sections of this chapter are devoted to the analysis of uncertainties raised regarding the results published.

3.2 LCA of ethanol from sugarcane – review of studies available

Most of the literature regarding energy balances and balances of GHG emissions along the life-cycle of ethanol produced from sugarcane in Brazil recognizes, the publications by Isaías Macedo and co-authors as the best source of information (e.g., Macedo et al., 2004, and Macedo et al., 2008). One of the constraints of this kind of study is the lack of a good data basis, and the authors have worked with the widest and most reliable set of data in Brazil.

Another publication about the same subject is the paper by De Oliveira et al. (2005) in which ethanol from sugarcane produced in Brazil, and ethanol from corn, produced in USA, were compared. The stages of the whole supply chain considered in that paper are the production of the raw-material, the conversion to ethanol, the fuel distribution and its end-use. Emissions due to land use change were not taken into account by the authors. The data basis correspond to the period 1999-2002 and part of the data was obtained from literature review, while part was from the software Stella. All energy consumption and all GHG emissions were allocated to ethanol (i.e., no co-products were considered), what is in line with the hypothesis of ethanol production in an autonomous distillery. Yield parameters correspond to typical values in the state of São Paulo.

The results presented by the authors where ethanol production from sugarcane was compared with ethanol produced from corn, indicates higher energy efficiency and lower GHG emissions for sugarcane as raw material. The advantage of sugarcane is mostly due to the fact that sugarcane bagasse, a fibrous residue from sugarcane crush, is used as fuel at the mills, producing steam and power. On the contrary, the production from corn requires an external source of fuel, that in general is fossil.

The most quoted publication regarding the energy balances and the GHG balances of ethanol production from sugarcane is Macedo et al. (2004). Recently, these results were updated and a prospective analysis considering different technological scenarios up to 2025 was incorporated (Macedo et al., 2008). In none of the publications, the authors took into account the stages that correspond to the fuel distribution and to its end-use. Neither did they consider the allocation method based on substitution. In both studies the analysis was focused on sugarcane plantations and on mills located in the Centre-South region of Brazil, mainly in the state of São Paulo[22].

Emissions due to land use change were not taken into account as well. The authors justified the simplification stating that during the period under analysis (end of 1990s and early 2000s) the growth of ethanol production was mostly due to the raise of productivity, without significant enlargement of sugarcane planted area for ethanol production. In synthesis, the authors stated that in that period the growth of sugarcane production was only due to the enlargement of sugar production. As mentioned in Chapter 1, this hypothesis is correct regarding what happened in Brazil (and particularly in Centre-South region) during the 1990s and early 2000s, but it cannot be generalised as long as the displacement of ethanol production to less traditional regions is considered.

Recently, Seabra (2008) added the distribution stage to the results of the energy balance presented by Macedo et al. (2008). Thus, the results presented by Seabra corresponded to a so-called well to pump analysis. All other hypothesis used by Seabra (2008) are similar to the Macedo's publication.

The energy balance is here presented as the ratio between renewable energy output (ethanol + electricity + bagasse as fuel) to the fossil energy input in different stages of the supply chain. This is recognised as one of the possible ways to represent the results of an energy balance of biofuels production. The ratio of 9.3 is the result that was highlighted by Macedo et al. (2008), while 8.3 is the ratio when considering production conditions in 2002 (Macedo et al. 2004).

Table 3.1 presents the results of the balances developed by De Oliveira et al. (2005) and Macedo et al. (2008). The main differences between the results can be explained as follows:

- Use of lime, herbicides and pesticides – there are differences between the two studies regarding the amount that is applied: Macedo et al. (2008) consider 1,900 kg/ha, 2.2 kg/ha and 0.16 kg/ha for lime, herbicides and pesticides, respectively, against 616 kg/ha, 3 kg/ha and 0.5 kg/ha, respectively, considered by De Oliveira et al. (2005). There are also differences regarding the energy consumption for producing theses materials: Macedo et al. (2008) present the energy consumption as 0.10, 355.6 and 358.0 MJ/kg of lime, herbicides and pesticides, respectively, while De Oliveira et al. (2005) assumed 1.71 MJ/kg, 266.56 and 284.82 MJ/kg, respectively. Macedo et al. (2008) have used values taken from the softwares GREET[23] and EBAMM[24], i.e., these consumption values are adequate to the US conditions and were used as proxy for Brazil. De Oliveira et al. (2005) state that the values were taken from the literature, and also correspond to the US conditions of production.
- Consumption of fossil fuels in the agricultural stage corresponds to the consumption of diesel in agricultural devices and trucks. De Oliveira et al. (2005) assumed a diesel consumption of 600 litres per ha, while the energy consumption regarding diesel

[22] In recently years, as previously mentioned, state of São Paulo concentrated 60-65% of the national sugarcane and ethanol production.

[23] Version 1.6 of the software that has been developed since 1995 by Michael Wang at the Argonne National Laboratory, USA, (Wang et al., 2007).

[24] Version 1.0 of the software developed by researchers of the Energy and Resources Group and Richard & Rhoda Goldman School of Public Policy, UC Berkeley (EBAMM; 2008. Available at http://rael.berkeley.edu/ebamm/).

production was assumed as 1.078 MJ/MJ. Macedo et al. (2008) assumed a diesel consumption equal to 164 l/ha and an energy consumption equivalent to 1.160 MJ/MJ of diesel.

Table 3.1. Main hypothesis and results regarding energy balances of ethanol production from sugarcane – comparison between previous works

Stages of production	Unit	De Oliveira et al. (2005)[a]	Macedo et al. (2008)[b]
Fertilizer	GJ/m^3	0.75	0.61
Lime, herbicide + pesticide	GJ/m^3	0.31	0.14
Manual operations	GJ/m^3	0.45	-[c]
Seeds	GJ/m^3	0.52	0.07
Consumption of fossil fuels	GJ/m^3	3.59	0.43
Operations at the field	GJ/m^3	-	0.15
Embodied energy	GJ/m^3	-	0.21
Harvest	GJ/m^3	-	0.39
Other activities	GJ/m^3	-	0.45[d]
Agricultural stage	GJ/m^3	5.62	2.44
Distillery	GJ/m^3	0.57	0.27
Industrial stage	GJ/m^3	0.57	0.27
Sub-total (ethanol production) (1)	GJ/m^3	6.19	2.71
Distribution	GJ/m^3	0.44	0.68
Sub-total (ethanol at the pump) (2)	GJ/m^3	6.63	3.39
Credits (3)	GJ/m^3	0.24[e]	3.00
Energy content of ethanol (4)[f]	GJ/m^3	24.31	22.32
Balance (output/input) (4+3)/(1)		3.97	9.34
Balance (output/input) (4+3)/(2)		3.70	7.47
Balance (output/input) (4)/(1)		3.93	8.24

Source: Based on De Oliveira et al. (2005); Macedo et al. (2008) and Seabra (2008).

Notes: [a] De Oliveira et al. (2005) consider the following yields: 80 tonne of cane/ha (tc/ha) and 80 l/tonne of cane;

[b] Macedo et al. (2008) consider the following yields: 87.1 tc/ha and 86.3 l/tc.

[c] Energy consumption due to manual labour is not considered by Macedo et al. (2008). Macedo et al. (2004) mention that in 1984 the consumption was estimated as 7.87 MJ/tc (0.09 GJ/m^3) and this figure has dropped due to mechanical harvesting.

[d] Consumption due to other activities in the agricultural stage without more details (Macedo et al., 2008).

[e] De Oliveira et al. (2005) did not explicitly consider credits of surplus electricity production. The authors referred to credits as the difference between the energy from burning sugarcane at the boilers (5.17 GJ/ha) and the energy consumption at the industrial process (3.63 GJ/ha). The authors did not consider surplus bagasse used as fuel outside the mills as credits, as done by Macedo et al. (2008).

[e] De Oliveira et al. (2005) consider the HHV of anhydrous ethanol, while Macedo et al. (2008) consider the LHV of anhydrous ethanol.

- Industrial stage – the energy consumption presented by Macedo et al. (2008) corresponds to the sum of 19.2 MJ/tc (chemicals and lubricants), 0.5 MJ/tc (embodied energy in buildings) and 3.9 MJ/tc (embodied energy in equipments). De Oliveira et al. (2005) have not detailed the value presented by them.
- Distribution – De Oliveira et al. (2005) took the data from the literature, and the value corresponds to the energy consumption due to distribution of ethanol is US, converted to the units used in the case of ethanol production in Brazil (2.82 GJ/ha). Seabra (2008) considered the specific consumption presented by a large group of mills in the Centre-

South region of Brazil (0.024 l/(m^3.km), besides the average distance between mills and the consumer market (337 km).

As long as GHG emissions are concerned, additional differences between the two papers should be identified. Regarding the emissions due to the application of herbicides and pesticides, Macedo et al. (2008) used values from the softwares GREET and EBAMM – 25 kgCO_2eq/kg and 29 kgCO_2eq/kg of the input, respectively; in the case of lime, the value presented (0.01 kgCO_2eq/kg) was an estimate by the authors. De Oliveira et al. (2005) only considered the emissions of carbon dioxide and presented the values per ha planted with sugarcane: 80.08 kg CO_2/ha, 51.72 kg CO_2/ha and 9.04 kgCO_2/ha, respectively.

De Oliveira et al. (2005) considered methane and nitrous oxide emissions as soil emissions during the agricultural stage; emissions are presented as equivalent to carbon dioxide. Macedo et al. (2008) considered the emissions of methane and nitrous oxide due to sugarcane burning before manual harvesting, the emissions of nitrous oxide due to the use of fertilizers and residues, and the emissions of carbon dioxide due to use of lime and urea.

The emissions due to transport and agricultural operations are emissions caused by diesel combustion in engines. De Oliveira et al. (2005) considered an emission factor of 3.08 kgCO_2/l, while Macedo et al. (2008) presented emission factors that are explained by diesel combustion (20.2 gC/MJ) and by the energy consumption during diesel production (3.87 gC/MJ). Emissions are different in both studies also because of the different hypothesis regarding diesel consumption, as previously mentioned.

Regarding the distribution stage the differences are explained as follows: De Oliveira et al. (2005) considered an emission factor of 227 kg CO_2/ha; despite no detailed explanation in their paper, possibly a mix of modals were considered in the transport of ethanol from the mill to the gas stations. Seabra (2008) considered the transport by trucks and combined the hypothesis of specific consumption, distance and emissions to evaluate the emissions in this stage. Table 3.2 presents the values presented in both references.

Credits considered by Macedo et al. (2008) are due to the substitution of fuel oil for sugarcane bagasse[25] in other industrial branches and also due to the production of surplus electricity. In the case of fuel substitution, the substitution ratio was evaluated considering equal end-use energy (i.e., taken into account the heating value and the efficiencies of conversion: 92% for the oil, and 79% for bagasse, based on fuel's LHV). The avoided emissions due to surplus electricity generation were calculated based on the world average emission factors for power generation in 2005 – 579 tCO_2eq/GWh (Macedo et al., 2008). A sensitive analysis considering different hypothesis for the credits are further presented.

The analysis presented onwards is only based on the results presented by Macedo et al. (2008)[26]. As previously mentioned this reference is well accepted worldwide. A second reason is that, from the point of view of the authors of this report, the study of Macedo et al. (2008) is based on data that are more representative of Brazilian conditions.

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[25] Mainly is the state of São Paulo surplus bagasse is commercialized as fuel. However, this market is constrained to fez regions.

[26] Completed with Seabra (2008) for ethanol distribution.

Table 3.2. Results of GHG balances considering Brazilian conditions of ethanol production from sugarcane.

Stages	Unit	De Oliveira et al. (2005)[a]	Macedo et al. (2008)[b]
Cultivation[c]	gCO_2eq/MJ	2.93[d]	2,79
Burning at the field	gCO_2eq/MJ	-	3,72
Machines	gCO_2eq/MJ	-	0,26
Soil emissions[e]	gCO_2eq/MJ	4.36	6,36
Transport and agricultural operations	gCO_2eq/MJ	12.89[d]	5,22
Agricultural stage	gCO_2eq/MJ	20.19	18,36
Industrial stage	gCO_2eq/MJ	-	1.14
Distribution	gCO_2eq/MJ	1.58[d]	2.28
Credits	gCO_2eq/MJ	-	- 9.41
Total	gCO_2eq/MJ	21.77	12.36

Sources: De Oliveira et al. (2005), Macedo et al. (2008) and Seabra (2008).

Notes: [a] Yields consider by De Oliveira et al. (2005): 80 tc/ha and 80 l/tc.

[b] Yields consider by Macedo et al. (2008): 87.1 tc/ha and 86.3 l/tc.

[c] Emissions due to the use of fossil fuel during the production of agricultural inputs.

[d] Only carbon dioxide emissions were considered (thus, the unit is gCO_2/MJ).

[e] As previously mentioned, De Oliveira et al. (2005) considered emissions during agricultural operations; Macedo et al. (2008) considered emissions due to the use of fertilizers, urea and lime.

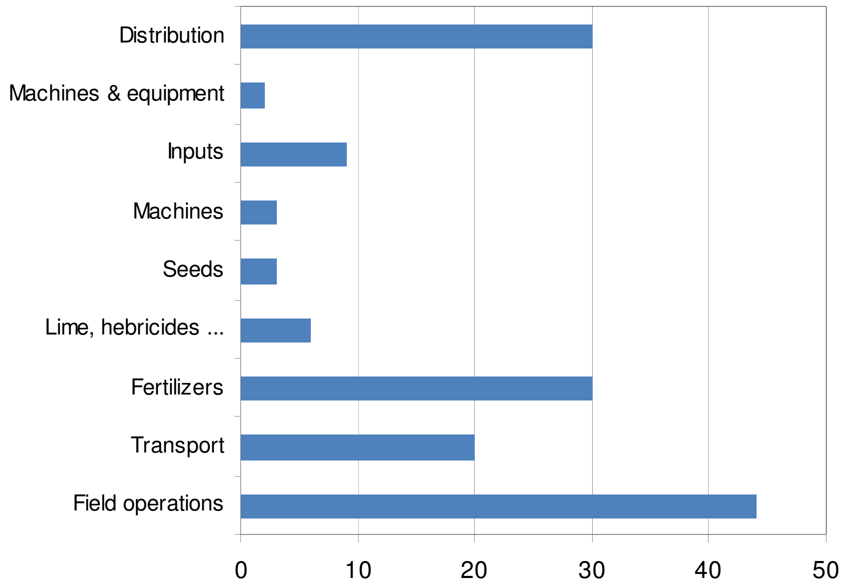
3.3. Energy consumption and GHG emissions due to ethanol production from sugarcane

The consumption of non-renewable energy sources along the life-cycle of the ethanol produced from sugarcane is strongly influenced by diesel consumption, mainly in agricultural machines (e.g. tractors) and trucks. The energy consumption is also impacted by fertilizers use, but it is worth to mention that the results presented by Macedo et al. (2008) could not be a good proxy of the Brazilian case as the required energy for fertilizers production was taken from US sources. Figure 3.1 shows the profile of energy consumption due to the production of ethanol from sugarcane.

Energy consumption due to the fuel distribution is similar to the consumption due to sugarcane transportation from the field to the mill despite the large difference of distances (23 km and 337 km, respectively). The reason is the difference of specific consumptions and autonomies, considered as 2.054 l/tc and 52.4 (tc.km)/l, respectively, in the case of sugarcane transportation (Macedo et al., 2008).

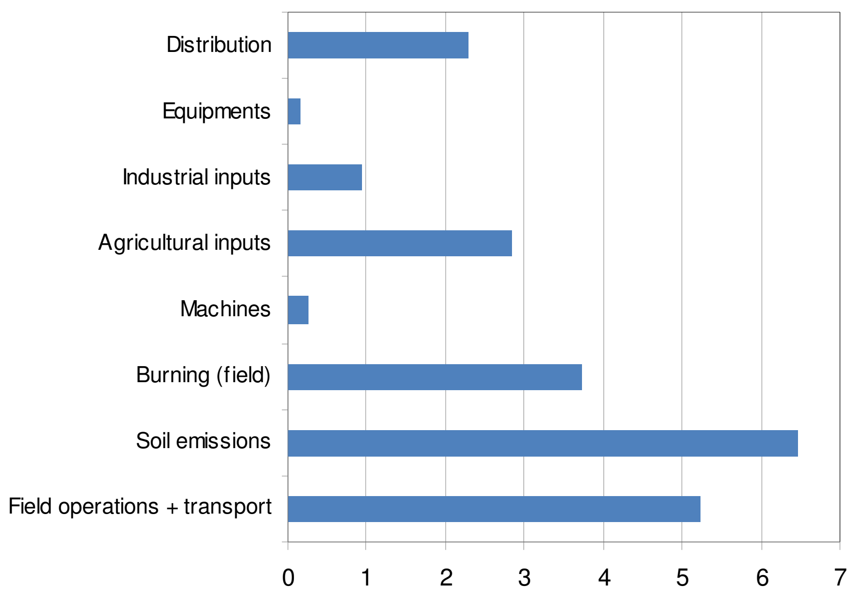
Along the life-cycle of ethanol from sugarcane the most significant GHG emissions are due soil (soil emissions), followed by emissions due field operations (agricultural operations) and transport, burning of the field previous to manual harvesting, agricultural inputs[27] and ethanol distribution. Figure 3.2 shows the profile of GHG emissions along the life-cycle of ethanol production from sugarcane, in Brazil.

[27] Emissions due to the energy consumption during their production.



Source: Macedo et al. (2008)

Figure 3.1. Energy consumption along the life-cycle of ethanol from sugarcane (kJ/MJ of ethanol)



Source: Macedo et al., 2008

Figure 3.2. GHG emission along the life-cycle of ethanol from sugarcane (gCO_2eq/MJ)

3.4 GHG emissions – impacts due to transportation overseas

It seems that the sustainability criteria that could be defined in short-term by Europe Union, or by some European countries, will be based, among other criteria, on avoided GHG emissions considering the whole life-cycle of biofuels use vis-à-vis the emissions of the displaced fossil fuel.

In order to evaluate avoided emissions in any European country it is necessary to take into account the energy use, and consequently the GHG emissions associated, to transport ethanol from Brazil to the end-use place. This analysis was done considering the following hypothesis:

- Firstly, it is necessary to consider the energy consumption to transport ethanol from the mills to the harbour. This was done considering the same methodology used by Seabra (2008) to take into account the distribution stage, previously described, but correcting the average distance that no longer is 377 km, but 510 km, as estimated by Langer (2006). Thus, the emission factor would be (510/337) * (4.4) = 6.7 $kgCO_2eq/t$ of sugarcane, or 3.44 $kgCO_2eq/GJ$ of ethanol.
- Secondly, the energy consumption of transporting the ethanol from Brazil (São Sebastião) to Europe (Rotterdam) by overseas tankers should be evaluated. It was considered that the distance between harbours is 10,000 km and that the cargo capacity (CC) is 300,000 tonnes of ethanol (approximately 380 thousand litres of ethanol). Specific fuel consumption (FC) of shipping was evaluated from Equation (1) (GaiB4, 2005, apud Langer, 2006)

$$FC = (91.1) * (CC)^{-0.4026} \text{ [t fuel/t.km]} \qquad (1)^{28}$$

that leads to 0.568 t fuel/(t.km), or 551 l fuel/(t.km). Consequently, fuel consumption would be approximately 1.7 thousand tonnes of bunker oil for an one-way trip at maximum capacity.

It is considered that bunker oil has the same LHV and the same emission factor as residual fuel oil, i.e., LHV = 40.2 MJ/kg and emission factor = 21.1 tC/TJ (IPCC, 1996). Thus, the energy consumption would be 68.5 TJ/one-way trip, or 0.180 GJ/m^3 of ethanol transported.

GHG emissions were calculated according to the energy consumption per 1000 litres of ethanol transported and using the emission factor of residual fuel oil. GHG emissions due to the transport overseas was estimated as 0.62 $kgCO_2eq/GJ$ of ethanol.

- Finally, emissions due to the transport inside Europe were evaluated considering equivalent distances, the same ways of transport and same emission factors as was reported by MacLean (2008) in the case of ethanol distribution from corn and wheat in US. This emission factor is 1.45 $kgCO_2eq/GJ$ of ethanol.

Thus, it is estimated that the emission factor of ethanol from sugarcane, made in Brazil, at a pump station in Europe, would be, 17.87 $kgCO_2eq/GJ$ of ethanol. being 12.36 $kgCO_2eq/GJ$ of ethanol due to its production (including credits) and 5.51 due to the transport from Brazilian mills to the pump station abroad.

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[28] Equation valid for overseas tankers with cargo capacities between 10,000 t and 300,000 tonnes.

3.5 Avoided GHG emissions

As mentioned in Chapter 2, the European Commission and some European countries tend to define a minimum level of GHG emission savings due to the substitution of fossil fuels for biofuels. In a first moment this minimum level could be set as 30%-35% with tendency of raising up to 50% along the time. Avoided emissions should be estimated along the full life-cycle of fossil fuels and biofuels, i.e., the analysis should be on a well to wheel basis.

In order to evaluate avoided emissions it is necessary to consider two additional parameters: first, the emissions of the full life-cycle of fossil fuels (e.g., gasoline), and second, the substitution factor between fossil fuels and biofuels.

Regarding emissions of the gasoline life cycle there are some divergence depending on the source of information. Macedo et al. (2008) and Seabra (2008) considered 22.3 gC/MJ of fuel, i.e., 81.8 gCO_2/MJ as GHG emissions of the gasoline cycle. This parameter was adopted by IPCC (2006) and takes into account direct emissions (i.e., emissions due to gasoline combustion – 69.3 gCO_2eq/MJ) and emissions in fuel production (i.e., oil extraction, transportation and processing – 12,5 gCO_2eq/MJ). MacLean (2008) considered 86.72 gCO_2eq/MJ to be the total emissions of the gasoline life-cycle, being 64.72 gCO_2eq/MJ the emissions of fuel burning (see Table 3.4). On the other hand, in the German Sustainability Decree 85 gCO_2/MJ was adopted as the reference value for gasoline. In this report, in a first moment, an analysis is presented for all these emission factors; however, the analysis regarding the potential of Brazilian ethanol to fulfil European standards was done considering 85 gCO_2eq/MJ as the reference value.

The second parameter to be considered is the substitution factor between ethanol and gasoline. This factor depends on the heating values of both fuels and also on the efficiency of engines powered with pure gasoline and with a blend gasoline-ethanol. As a result of the almost 30 years of experience with ethanol engines, the substitution factor in Brazil reflects an enlargement of efficiency when ethanol-gasoline blends are used[29].

If there is no change in efficiency when engines are powered with pure gasoline or with a blend gasoline-ethanol, the substitution factor is the ratio of low heating values of both fuel, that leads to 1.42 litre of ethanol per litre of gasoline displaced. In Brazil, the automotive industry recognises that the average substitution factor is 1 litre of ethanol (anhydrous) = 1 litre of gasoline in blends up to E10 (10% ethanol blended with gasoline, volume basis), that reflects an expressive gain on efficiency when fuel blends are used. This hypothesis was recently used by Macedo et al (2008) and Seabra (2008). As curiosity, in case of FFVs the average substitution factor is 1 litre of ethanol (hydrated) = 0.72 litres of E25 (25% ethanol blended with gasoline, volume basis).

Having defined both parameters, avoided emissions can then be calculated from Equation (2):

$$EE = (ET_{etanol}) * (RS/ET_{gas}) \qquad (2)$$

[29] Ethanol has higher octane number than pure gasoline and, as consequence, the engine could be designed for higher compression ratio. An engine with higher compression ration is more efficient.

Where EE = avoided emissions due to the substitution; ET_{etanol} = total GHG emissions along the ethanol life-cycle; RS = is the substitution factor; and $ET_{gás}$ = total GHG emissions along the gasoline life-cycle.

Table 3.3 presents results of avoided emissions considering different hypothesis regarding gasoline emission factors and substitution factors. Considering ethanol use in Brazil it makes sense to take into account the substitution factor 1 L = 1 L and ethanol emission factor 12.36 gCO_2eq/MJ; in case of ethanol use overseas it makes sense to take into account the substitution factor 1.42 L ethanol = 1 L gasoline and ethanol emission factor 17.87 gCO_2eq/MJ due to the transport overseas. It can be seen from Table 3.3 that avoided emissions considering ethanol consumption in Europe would be about 70%, i.e., a much better result than the predicted required limits of 30-50%.

Table 3.3. Avoided emissions (%) considering full life-cycle of gasoline and anhydrous ethanol produced from sugarcane – emission factor in gCO_2eq/MJ

Gasoline emission factor	Ethanol use in Brazil	Ethanol use in Europe
	Substitution factor 1 L ethanol anhydrous= 1 L gasoline	Substitution factor 1.42 L ethanol anhydrous= 1 L gasoline
	Ethanol emission factor 12.36	Ethanol emission factor 17.87
81.8	84.9	69.0
85.0	85.5	70.1
86.7	85.7	70.7

3.6 Comparison with ethanol produced from other feedstocks

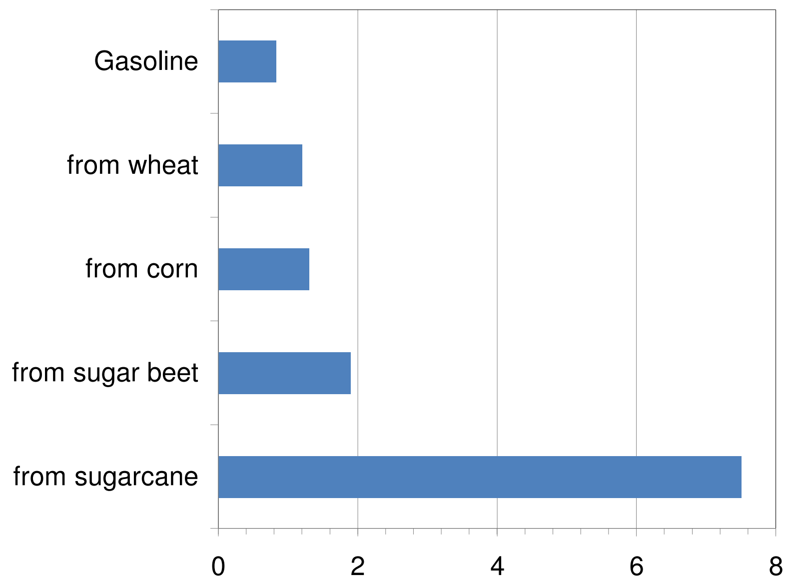
3.6.1 Energy balance

The results of the energy balances developed by David Pimentel regarding ethanol produced from corn in the USA has been controversial; Pimentel stated that in order to produce 1 GJ as ethanol from corn it is necessary to input 1.65 GJ as different sources of energy (Pimentel; 2001 *apud* Urquiaga et al.; 2005). In most of the results presented by Pimentel, the energy that corresponds to human labour was taken into account; however, it is relatively well accepted that the input energy should only correspond to fossil fuels. Other critics of Pimentel's results state that he worked with old data.

Some recent studies about ethanol produced from corn showed that the energy ratio is larger than the unit, i.e., the energy produced as ethanol is larger than the fossil energy used as input. For instance, Shapouri et al. (2002) (*apud* Urquiaga et al., 2005) showed that the energy ratio is 1.23, i.e., the production of 1 GJ as ethanol from corn requires 0.81 GJ as fossil energy sources. Other authors have shown a ratio in the range 1.25-1.32 (Hill et al., 2006; Wu et al., 2006). It is estimated that the energy ratio could be improved from about 1.3 to 2.9 if fossil fuels used in industrial processes are switched to biomass-based fuels, such as wood chips (Wang et al., 2007).

Macedo et al. (2008) showed that the energy balance in the case of ethanol produced from sugarcane in Brazil corresponds to an energy ratio 9.3. Details of this result were presented in previous sections of this chapter.

Figure 3.3. shows the energy ratio of ethanol produced from different feedstocks, compared to the energy ratio of gasoline production. The results presented in Figure 3.3. correspond to the most accepted values of different studies on the same subject.



Source: Macedo et al. (2008) and UNICA (2007)

Figure 3.3. Energy ratio (product/fossil fuels) of ethanol production from different feedstocks

3.6.2. GHG balance

Table 3.4 shows results of GHG emission balances considering the production of ethanol from sugarcane in Brazil and results of ethanol production from corn and wheat, in production conditions similar to those of USA and Canada. MacLean (2008) was chosen as reference of comparison due to the details presented in his report. The results presented by Macedo et al. (2008) were completed with the estimates done by Seabra (2008) regarding the distribution of ethanol.

As can be seen in Table 3.4 the final emission results regarding ethanol produced from corn and wheat have a share due to the combustion of ethanol (2.1 gCO_2eq/MJ), emissions that are not associated with carbon dioxide[30]. Adding the same value to the results presented by Macedo et al. (2008) (and completed with Seabra, 2008), the total GHG emissions of ethanol from sugarcane would be 14.45 gCO_2eq/MJ. Comparing with the emissions of gasoline life-cycle presented by MacLean (2008) and considering a substitution factor 1.42, avoided emissions would be 76% for the ethanol produced from sugarcane. Avoided emissions due to the use of ethanol produced from wheat would be 34% vis-à-vis the full life-cycle of gasoline, while the avoided emissions due to the use of ethanol produced from corn would be 35%. These results are presented in Figure 3.4.

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[30] For instance, emissions of nitrogen oxides and hydrocarbons.

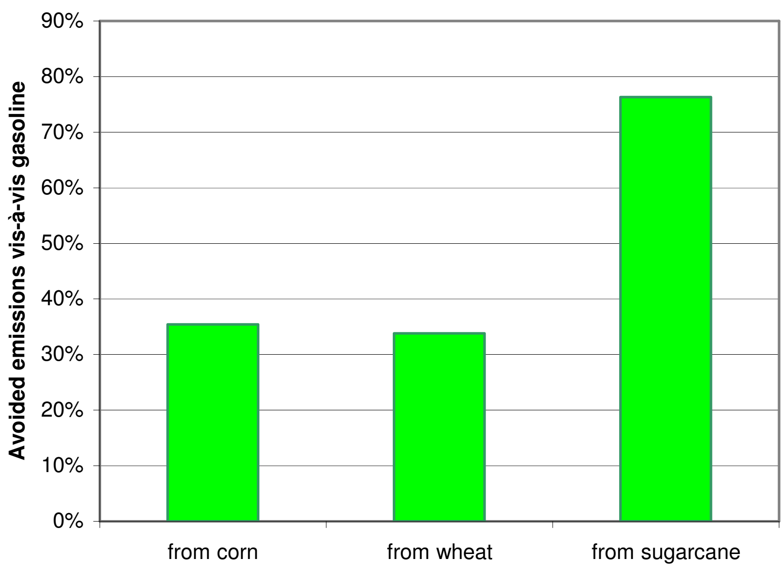
Table 3.4. Emissions factors for ethanol produced from different feedstocks (g CO_2eq/MJ)

	Gasoline	Ethanol from corn	Ethanol from wheat	Ethanol from sugarcane
Agricultural inputs[a]	0.00	5.33	10.70	2.79
Fuel production (industrial stage)	12.28	28.95	31.88	1.14
Avoided emissions	0.00	-17.34	-31.79	-9.41
Emissions due to burning	64.72	2.10	2.10	-
Other emissions[b]	10.15	20.41	27.54	15.56
Emissions due to distribution	0.56	1.45	1.45	2.27
Total	86.72	39.45	40.43	12.35

Sources: Macedo et al. (2008); Seabra (2008); MacLean (2008)

Notes: [a] Regarding ethanol from corn and wheat, emissions are due to the production of fertilizers and insecticides, while in case of ethanol from sugarcane, emissions are due to the production and use of fertilizers.

[b] In case of ethanol from sugarcane, emissions are due burning of sugarcane before manual harvesting, soil emissions and sugarcane transport from the field to the mill. In case of ethanol from corn and wheat, the value corresponds to the sum of emissions in harvesting, transport, distribution and storage of ethanol.



Source: Based on Macedo et al. (2008); MacLean (2008) and Seabra (2008)

Figure 3.4. Avoided GHG emissions due to the substitution of gasoline for ethanol from different feedstocks

In the case or ethanol produced from corn and wheat, the comparison of results above with the directives that could be defined in Europe shows that these biofuel options could match the targets regarding avoided GHG emissions in short-term, but won't be able to match more rigorous targets.

3.7 Allocation between products and co-products

An important methodological issue regarding energy and GHG balances is how to do allocations between products and co-products. There are methodologies based on the energy content of each flow, on mass basis, on market-values and on substitution factors. Methodologies are chosen according to data constraints, in order to avoid large complexity or just because of specific interests.

In case of ethanol production from corn and wheat the credits on avoided emissions[31] (see Table 3.4) are due to the production of DDG, that are used as food and feed. The credits in the wheat-basis route is higher than in the corn-basis route due to the lower starch content of wheat (6-10% lower regarding corn), that implies more DDG production from wheat (12-20% more). Besides that, the protein content in wheat's DDG is higher than in case of corn (MacLean, 2008). The allocation method used is both cases is the substitution one, i.e., based on the energy – and GHG emissions – of producing a similar product from other feedstock.

As previously mentioned, the credits considered in case of ethanol production from sugarcane are due to the use of surplus bagasse as fuel in other industrial branches, substituting fuel oil for raising steam, and due to surplus electricity production that is sold in the electric sector. Avoided GHG emissions were evaluated as those of fuel oil that is displaced in some industrial branches and the avoided emissions of electricity production in thermal power plants.

Macedo et al. (2008) considered that 5-10% of the total bagasse available at the mills site could be sold as fuel. This used to be a common practice for some sugarcane mills in state of São Paulo, but has been reduced as long as industries have other options of fuel supply. In this sense, it is important to consider the impact of the hypothesis used by Macedo et al. (2008) over the final result.

Regarding surplus electricity production, Macedo et al. (2008) and Seabra (2008) considered that on average 10 kWh/t of sugarcane as surplus electricity have been sold to the electric grid. This figure is representative for the current average in the state of São Paulo, and could be significantly enlarged in the years to come (see section 1.5).

The are two concerns about the hypothesis used by the authors: first, it was considered that avoided emissions due to surplus electricity generation could be estimated based on the world average emission factors for power generation in 2005 (579 tCO_2eq/GWh). This is a very controversial hypothesis as surplus electricity production from bagasse would impact the emissions in the Brazilian electric system, and not in the whole world.

In recent years more than 20 Brazilian mills have presented Project Design Documents (PDD) to UNFCC in order to get credits of GHG avoided emissions in the context of Clean Development Mechanism (CDM); avoided emissions would be due to the production of electricity from renewable biomass (sugarcane bagasse). The methodology used for estimating avoided emissions was the former AM0015 (bagasse-based cogeneration connected to an electricity grid) that since

[31] Credits are due to the production of co-products. In case of GHG balances (as well as in cost balances) an allocation method needs to be used in order to distribute values between the main product and co-products.

November 2005 was replaced by the more general methodology ACM6 (grid-connected electricity from biomass residues)[32] (Fennhann, 2006)., Due to the large importance of hydroelectric power plants in Brazil, the calculated avoided emissions are lower than in other countries (e.g., India and China). In the case of most Brazilian CDM projects regarding surplus electricity production from sugarcane bagasse the emission factor was estimated as 268 tCO_2/GWh.

Thus, Macedo et al. (2008) have used an emission factor more than twice the factor generally accepted. As it is shown bellow, the impact on the results of avoided GHG emission due to ethanol production from sugarcane are small because current surplus electricity production is very small regarding the existing potential (see section 1.5 for more details).

Another important issue regarding the hypothesis considered by Macedo et al. (2008) is that it is controversial to regard avoided emissions of electricity production from residual sugarcane biomass as credits of ethanol production. The dispute could be traced back to the fact that some mills have gotten CDM credits from surplus electricity production and the benefit of avoided emissions would be counted twice.

The results presented bellow are based on the following figures of reference: use of ethanol in Europe, considering a substitution factor 1.42/1 (ethanol/gasoline), ethanol emissions 17.87 $kgCO_2eq$/GJ (also considering the emissions of transporting ethanol from Brazil to Europe) and gasoline emission factor 85 $kgCO_2eq$/GJ. The first sensitivity analysis considers a lower amount of surplus bagasse sold as fuel (5%), in comparison to the figure considered by Macedo et al. (2008) (10%). In the limit the benefits of bagasse use as fuel in substitution to fuel oil are not considered (i.e., 0%). In case of surplus electricity production, the sensitivity analysis is defined considering the emission factor as 268 tCO_2/GWh, instead of 579 tCO_2/GWh; in the limit no credits are given to surplus electricity production.

Figures 3.5 and 3.6 show the results of the sensitivity analysis regarding credits due to surplus bagasse sold and to surplus electricity sold, respectively. The impact of bagasse trade as fuel is larger because the emission factor of fuel oil is high (95.7 $kgCO_2eq$/GJ). On the other hand, the impact of not taking into account the credits of surplus electricity production from residual biomass (bagasse) seems to be less significant because surplus electricity production in the reference case is small compared to the existing potential (7-10%)[33].

It is worth to mention that when no credits are taken into account, avoided emissions due to ethanol use in Europe (from sugarcane produced in Brazil) would be reduced from 70.1% to 54.4%. This is a substantial reduction, but even so in condition to match the mid-term target of a

[32] According to the methodology AM0015, the emission factor is calculated as a combined margin consisting of the combination of operating margin (OM) and build margin (BM) factors. The electricity baseline emission factor is calculated through a weighted-average formula, being the weight 50% and 50% for OM and BM. As of 2006, for cogeneration projects in state of Sao Paulo, the OM emission factor was estimated as 0.4310 tCO_2/MWh while the BM emission factor was estimated as 0.1045 tCO_2/MWh. Thus, for default weights, the estimated emission factor would be 0.268 tCO_2/MWh, i.e., about 65-75% of the emission factor of a conventional combined cycle burning natural gas. In comparison with countries that have the bulk of electricity generation with thermal power plants based on coal (emission factor in the 800-1,100 tCO_2/MWh range), this is a clear disadvantage.

[33] In this case considering cogeneration technologies based on steam power cycles, that are commercial. If cogeneration technologies based on biomass gasification and the use of combined cycles are taken into account (technologies that could be commercial only in mid-term) the potential would be 20-25 times higher than the current average figure.

50% reduction regarding the gasoline life-cycle. Based on the parameters previously presented, in the worst case avoided emissions would be reduced to 50.9%; this situation would correspond to add 2.1 $kgCO_2eq/GJ$ due to other emissions during combustion, leading the emission factor to 29.38 $kgCO_2eq/GJ$ (with no credits and consuming ethanol in Europe).

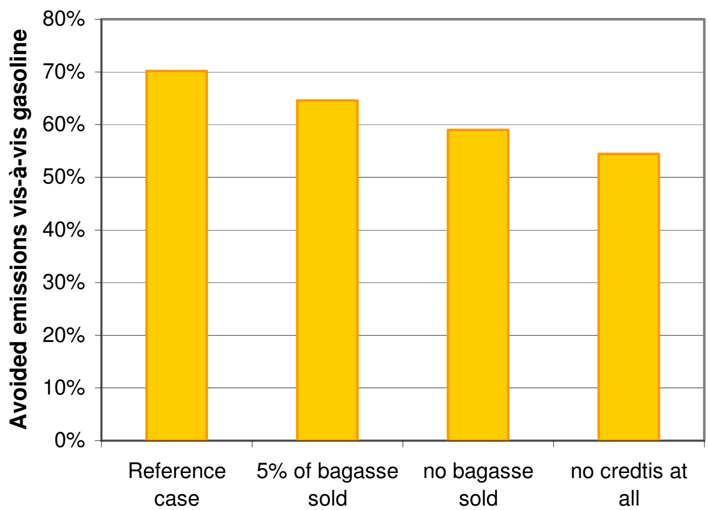


Figure 3.5 Sensitivity analysis regarding the credits of surplus bagasse trade and its use as fuel in other industrial branches

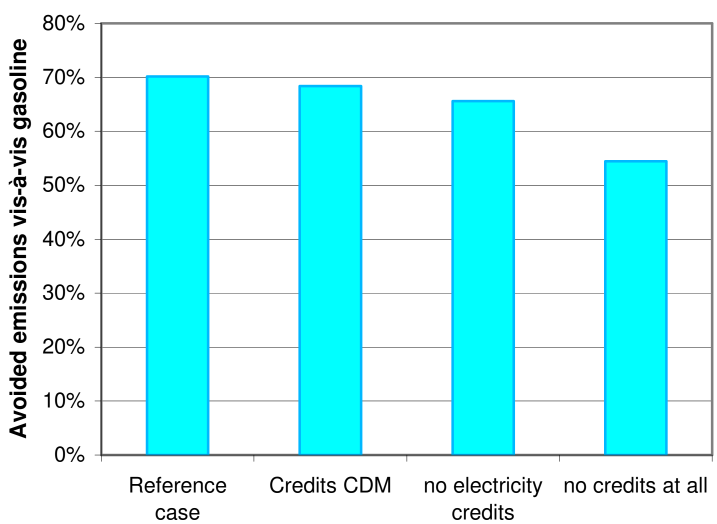


Figure 3.6 Sensitivity analysis regarding the credits of surplus electricity production displacing emissions in other power plants

3.8 GHG emissions to nitrous oxide emissions

The use of fertilizers during the production of sugarcane is important both considering the energy balance and the GHG balance of ethanol from sugarcane. In particular, the emissions that are matter of concern occur as nitrous oxide, that has a very high global warming potential (296)[34]; such emissions derive from the nitrogen applied as fertilizers.

This issue is considered in more details in this section due to the polemic brought by recent papers. In two papers published in 2007 and 2008, Crutzen et al. stated that the emissions as nitrous oxide during the agricultural stage could withdraw the benefits of fossil fuel displacement. In some cases the emissions could be even higher than the avoided emissions. Nitrogen fertilization causes a release of N_2O in agricultural fields that is highly variable. In general it is assumed that the amount released is a percentage of the fixed nitrogen input from mineral fertilizer or biologically fixed N (Crutzen et al., 2008).

In case of ethanol produced from sugarcane the author's conclusion is that the ratio between GHG emissions (in CO_2eq basis) due to nitrous oxide (Meq) and the emissions of carbon dioxide due to gasoline substitution (M) would be in the range 0.5-0.9 (Crutzen et al., 2007 and 2008).

It is also worth to mention that the results presented by Crutzen et al. (2008) regarding ethanol from sugarcane are the best among all biofuels considered. However, the authors developed their analysis based on an information of nitrogen application that corresponds to tests realized in Tanzania (7.3 gN/kg of sugarcane, dry basis) (Isa et al., 2005, apud Crutzen et al., 2008). This parameter should be checked regarding Brazilian practices of fertilization.

Table 3.5 presents an estimate of nitrogen use per kg of sugarcane, according to Macedo et al. (2008). An important aspect of sugarcane production in Brazil is that nitrogen is applied as industrial fertilizer, as vinasse and as filter cake, being vinasse a by-product of ethanol distillation and filter cake a by-product of juice cleaning. Other important aspect is that most of the nitrogen is applied as urea, and in this case the emissions as nitrous oxide would be much lower.

Table 3.5. Typical use of nitrogen in sugarcane – grams of nitrogen per kg of sugarcane (dry basis)

	g/kg
Nitrogen applied as fertilizer	0.80
Nitrogen applied as vinasse	0.58[a]
Nitrogen applied as filter cake	0.72[b]
Total	2.10

Source: Macedo et al. (2008)

Notes: [a] Considering the use of vinasse equal to 140 m^3/ha, that the nitrogen content is 0.36 kg/m^3 of vinasse and an average yield of 87.1 tc/ha (Macedo et al., 2008).

[b] Considering the use per ha of 5 tonnes of filter cake with a nitrogen content of 12.5 kg/tc; the average yield is 87.1 tc/ha (Macedo et al., 2008).

The fertilization under Brazilian conditions was calculated as 7.0-7.5 gN/kg of sugarcane, dry basis[35]. Thus, the impact on the final results could be neglected, but it is important to highlight that the amount of nitrogen that can be converted to nitrous oxide is much lower.

[34] That means, a warming potential 296 times higher than carbon dioxide (mass basis).

[35] Without taking into account the fact that nitrogen is applied most as urea and considering the data presented in Table 3.5.

A polemic assumption of Crutzen et al. (2007 and 2008) refers to the amount of nitrogen released as N_2O. The authors evaluated this parameter as 3%-5%, while the value adopted by IPCC (2006) was 1.325%. Apparently, there is no other reference that is in line with the estimate done by Crutzen et al. (2007 and 2008).

Macedo et al. (2008) have considered the emissions of nitrous oxide both due to the nitrogen not captured by the sugarcane and due to sugarcane burning at the field. In case of nitrous oxide emitted by the plant, the authors considered the amount of nitrogen applied as urea and used the release factor adopted by IPCC (2006). Supposing that Crutzen et al. (2007 and 2008) are correct regarding the emissions of nitrous oxide from the plant, the results of the GHG balance presented by Macedo et al. (2008) would change as follows.

According to Macedo et al. (2008), the emissions of nitrous oxide due to the application of N as fertilizer and residues is equivalent to 8.9 $kgCO_2eq/t$ of sugarcane, i.e., 4.6 gCO_2eq/MJ, or 72% of calculated soil emissions (see Table 3.2). Supposing that the release of nitrous oxide varies from 3% to 5% of the nitrogen applied (and not 1.325%), the emissions of nitrous oxide would grow to 10.4 or 17.4 4.6 gCO_2eq/MJ, respectively. The impact on the final results of the GHG balance would be the following (see Table 3.2): soil emissions would grow to 12.18 or 19.12 gCO_2eq/MJ, respectively, and the total GHG emissions, considering the credits, would be 18.18 or 25.12 gCO_2eq/MJ. Regarding 85 gCO_2eq/MJ as the emissions of the gasoline life-cycle, and considering a substitution factor 1 L = 1 L (ethanol/gasoline; i.e., Brazilian conditions), avoided emissions would drop from 85.5% (see Table 3.3) to 79% or 70%, respectively.

Alternatively, if Crutzen at al. (2007 and 2008) have developed their analysis based on the parameters presented by Macedo et al. (2008), except the percentage of nitrogen released as nitrous oxide, the results of the ratio (Meq)/M would be in the 0.12-0.20 range, and not 0.5-0.9, as published.

Another important aspect is that with the banishment of sugarcane burning previous to manual harvesting, that should be in force in state of São Paulo by 2017, more trash will be let at the field, reducing mineral fertilization. Besides this benefit, emissions due to sugarcane burning (mostly methane and nitrous oxide) would be vanished; these emissions were estimated by Macedo et al. (2008) as 7.2 $kgCO_2eq/t$ of sugarcane, or 3.6 gCO_2eq/MJ.

3.9 GHG emissions due to land use change

A very controversial topic regarding biofuels and its ability to reduce GHG emissions is related to the land use changes that could be imposed due to the enlargement of the area for the feedstock production (sugarcane, in the Brazilian case). Direct impacts would be associated to the change of land use directly induced by the enlargement of sugarcane production, displacing other crops or natural vegetation. The worst case would be native ecosystems conversion (e.g., with deforestation) for the cultivation of sugarcane. On the other hand, indirect impacts would be associated to the enlargement of sugarcane production, causing the displacement of agricultural activities to other regions and inducing there land use change, such deforestation. For instance, the growth of sugarcane production in São Paulo has been blamed for the deforestation in Cerrado and in Amazon region: as sugarcane is displacing pasturelands, a hypothesis is that cattle is moving to state of Pará, for instance, or if sugarcane is displacing soybeans areas, soybeans production could move to pasturelands and cattle, as consequence, could move to the Amazon region, causing deforestation (Cerri, 2007; Fearnside, 2001; and Klink and Machado, 2005)[36]. Land use changes is the subject of Chapter 4 and 5 of this report.

Two papers published early 2008 have heated-up the debate about land use changes. Searchinger et al. (2008) considered the indirect impacts of land use change due to the growth of corn production in US. Fargioni et al. (2008) took into account the direct impacts of land use change considering different ethanol supply chains and different alternative places for feedstock production. In the only case that concerns to ethanol production from sugarcane, in Brazil, Fargioni et al. (2008) supposed a scenario in which sugarcane would cause deforestation of the so-called "Wooded Cerrado", a biome typical of the Central region of Brazil and with relatively high-density of carbon. The authors have considered that all carbon debts should be allocated to the ethanol[37], that the native vegetation would be cleared by fire, with full loss of biomass carbon, and that about 13% of the soil carbon would be lost.

The final result presented by Fargioni et al. (2008) is that it would be necessary to produce ethanol from sugarcane in such conditions during almost 17 years only to repay the carbon debt caused at the beginning. According to the authors, the conversion of native ecosystems to croplands can cause a large and instantaneous release of GHG due to the burning of the existing natural cover, a rapid release of GHG due to the microbial decomposition of organic carbon stored in plants and in soil, and a slow release of GHG due to organic matter decay[38].

Fargioni et al. (2008) call "annual repayment" the avoided emissions of fossil fuel use due to the substitution for biofuels. In case of the ethanol from sugarcane, the estimated "annual repayment" is presented as 9,800 $kgCO_2eq/ha$, that would correspond to 60 gCO_2eq/MJ of avoided emissions[39]. Considering that the emissions of gasoline in its full life-cycle are 85 gCO_2eq/MJ, according to the authors the emissions of ethanol full life-cycle would be 25 gCO_2eq/MJ, almost 40% higher than the estimated emissions of Brazilian ethanol when consumed in Europe (17.87 gCO_2eq/MJ, see section 3.4), and twice higher than the emissions estimated by Seabra (2008) (12.36 gCO_2eq/MJ; see Table 3.2). One reason is the low cane yield considered by Fargioni et al. (2008): 68.7 tonnes/ha. Thus, changing some parameters of analysis the payback estimated as 16.8 years by Fargioni et al. (2008) would be more correctly evaluated as 13.9 or 15 years, depending on the scenario of ethanol use.

On the other hand, if the scenario presented were sugarcane production in the "Grassy Cerrado", yet considering the main hypothesis presented by Fargioni et al. (2008), the initial carbon debt would be reduced from 165 $kgCO_2eq/ha$ to 85 $kgCO_2eq/ha$. Considering the emissions factors of ethanol previously presented in Table 3.2 and in section 3.4 (12.36 and 17.87 gCO_2eq/MJ), the payback would be reduced to 7.2-7.8 years.

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[36] References quoted by Fargioni et al. (2008) in order to support the statement: "*Brazilian Cerrado is being converted to sugarcane and soybeans, and the Brazilian Amazon is being converted to soybeans*".

[37] That means that only ethanol would be produced from sugarcane, in opposite to the traditional way ethanol is currently manufactured in Brazil, together with sugar. However, this hypothesis makes sense in case of large growth of ethanol production, as the sugar market is constrained.

[38] Decay of coarse roots, branches and wood.

[39] Considering the hypothesis presented by Macedo et al. (2008) regarding ethanol production from sugarcane, in Brazil.

In addition, considering that 50% of the sugarcane could be used for sugar production, and not for ethanol, the estimated paybacks would be reduced to 50% of those presented above, reaching 3.6 years

None of these alternative scenarios could be presented as ideal. The only purpose of the exercise done is showing that it is possible to define a more pessimistic or realistic scenario, calling attention for what is more convenient in a certain moment. The authors do not believe that Fargioni et al. (2008) are specifically against ethanol production from sugarcane, in Brazil, but they are clearly raising hypothesis that reduce the appeal of the so-called first generation ethanol.

Regarding the impacts of land use change on the avoided emissions, and more specifically regarding the main conclusions of Fargioni et al. (2008), the authors of this report believe that the following actions are essential:

- it is fundamental to know precisely the actual impacts of land use change in case of scenarios like those presented by Fargioni et al. (2008). In this sense, background scientific information is required;
- it is essential to define more realistic scenarios in order to analyse most probable situations. Some scenarios are ideal to call attention to a certain problem, but could not reflect the mid-term reality;
- it is necessary to define hypothesis that could properly reflect mid-term conditions of production, as the production of sugarcane in the Cerrado biome, if it occurs, will not take place with low productivities;
- and, finally, it is important to take actions in order to avoid problems such those associated to the scenarios supposed by Fargioni et al. (2008). Brazil still has many land available and it is not necessary to convert natural ecosystems to croplands.

3.10. Enhancement perspectives

Along the supply chain of ethanol from sugarcane, the following improvements are predicted in the agricultural side:

- yields of sugarcane have been enlarged since early 1980s and the tendency is that it could continue to happen along the following years (CTC, 2006, apud Seabra, 2008).
- mechanical harvesting is already a reality and in some regions most of the sugarcane is harvested mechanically. It is predicted that mechanical harvesting will be a default technology in less than 10 years, at least in state of São Paulo. Other tendency is tillage, with the reduction of the number of agricultural operations. As consequence, fuel consumption will be higher, but with positive impacts on the energy balance (Macedo et al., 2008);
- due to the phasing-out of sugarcane burning previous to harvesting, the so-called sugarcane trash will be available in large extent. Sugarcane trash could be used as fuel for electricity production and/or as raw material for biofuels production through hydrolysis and/or gasification (Seabra; 2008). The so-called second-generation of biofuels, based on ligno-cellulosic materials are not yet commercially available and it is not clear at this moment which would be the best route of trash use;

Along the industrial side of the supply chain, the best alternatives are concerned to the diversification of the production process, enlarging electricity production and producing materials and chemicals. In this sense, the biorefinery concept should be developed and explored. In order to explore the full potential of a biorefinery, industrial process should be optimised, such as reduction of steam consumption in order to enlarge biomass availability for alternative conversion routes.

Taking into account the GHG balance along the whole ethanol supply chain, an important aspect is concerned to the emissions due to the transport. The bulk of ethanol cannot be transported from the mills the distribution basis, or the harbours, by truck. The best option seems to be transportation through ducts, and investments need to be done in this regard.

3.11 Conclusions

Either the energy balance or the GHG balance of ethanol production from sugarcane, in Brazil, is very favourable. In case of sugarcane cropping without land use change, avoided GHG emissions regarding gasoline life cycle would ensure the criteria that may be applied in the short-term by the European Union or other individual European countries are fulfilled (30%-35% of avoided emissions, or even 40%). These results should be improved in the years to come and, in this sense, process diversification, phasing-out of sugarcane burning, trash recovery and its use as fuel or raw material, and trash deposition in the field, will be essential. Outside to production process, it would be fundamental to reduce fossil fuel consumption along all transportation steps.

Some questions have still been raised about the results of the ethanol GHG balance. There are still doubts about emissions due to land use change, but in a country with about 35-45 Mha available on pasturelands these problems can be avoided with properly regulation and law enforcement.

On the other hand, the potential constrain concerned to the emissions of nitrous oxide still need to be well understood. There is lack scientific knowledge about this issue, and efforts are required in short to mid-term.

Chapter 4

Land Use Change in Brazil due to Ethanol Production – Direct Impacts

4.1 Introduction

Land use change, i.e., how land use changes from a specific use to other, is one the main concerns regarding the sustainability of biofuels production. Abroad, there are concerns if the enlargement of sugarcane production in Brazil has caused deforestation and/or displacement of food crops.

This chapter is devoted to the analysis of the enlargement of sugarcane production in recent years. In the first section the evolution of land use in Brazil is analysed. In the second part the recent growth of sugarcane production is presented, aiming at identifying where the enlargement has occurred. The third section is devoted to the analysis of land use changes in three states where sugarcane growth has been remarkable: São Paulo, Minas Gerais and Goiás. The forth section is a synthesis of similar information for other Brazilian states. Conclusions are presented in the fifth and last section of this chapter.

4.2. Evolution of Land Use in Brazil

Figure 4.1 presents the evolution of land use in Brazil from 1970 to 2006. The figure is based on data of the last six agricultural surveys done by IBGE[40]. The total arable land[41] occupied with crops, pastures and forests in 1970 was 246 Mha (million hectares), i.e., 29% of the total area of the country, and reached 345 Mha (41% of the total area) in 2006. According to IBGE, the group "forests" corresponds to the land occupied with natural vegetation, permanent preserved areas, areas of legal reserve, and reforestation.

In 2006, 76.7 Mha were occupied with different crops (22% of the total arable land), 172.3 Mha with pastures (49%) and almost 100 Mha with forests (29%). According to the IBGE (2008), in 2006 more than 22 Mha were planted with soybeans, about 13 Mha with corn and 6.2 Mha were planted with sugarcane.

As an illustration, Figure 4.2 shows the production of soybeans, corn, sugarcane and rice + beans, from 1990 to 2006; the information is presented as an Index (physical production in 1990 = 100). It can be seen in Figure 4.2 that soybeans production grew more than sugarcane and that there is no reason to suppose that the production of rice + beans could have been impacted by the growth of sugarcane.

Table 4.1 presents changes on land use between two consecutive agricultural surveys. Marked cells in table correspond to land use changes above the average. Traditionally the growth of croplands has been larger than the growth of total arable land, except during the period 1985-1995. The growth of croplands in the period 1995-2006 was remarkable (84%), clearly indicating expansion of agricultural borders in Brazil; in the North region the growth of croplands in a decade was 275.6%.

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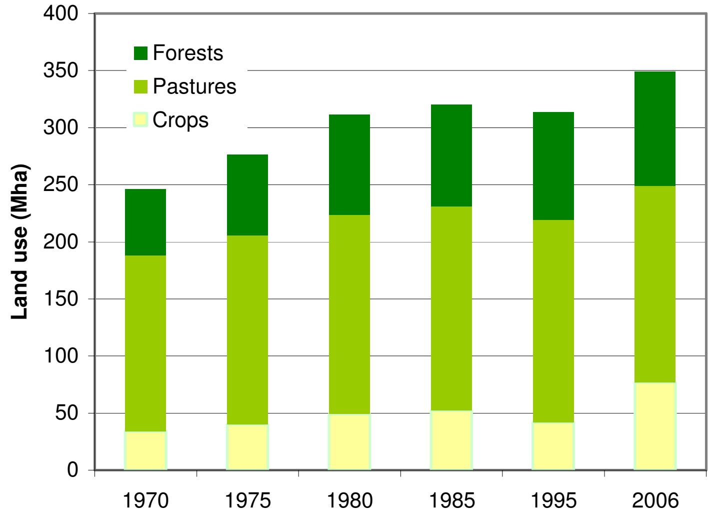
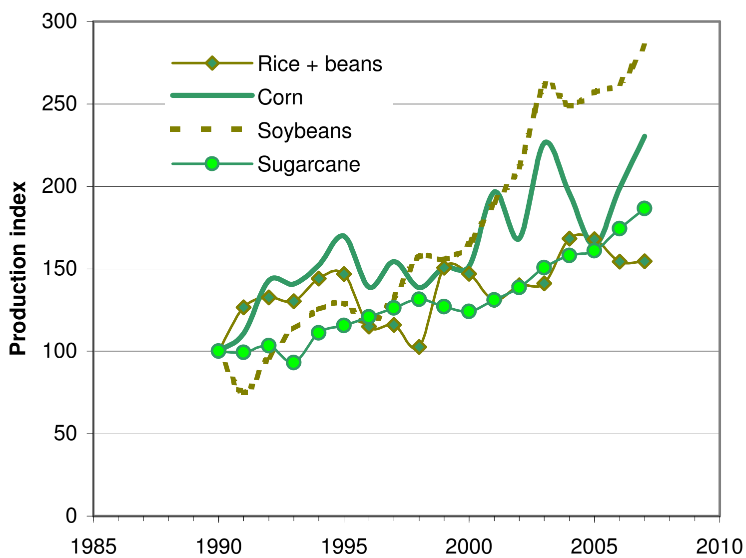
[40] Instituto Brasileiro de Geografia e Estatística.

[41] The area that corresponds to the Amazon Forest, for instance, is not included in this group.



Source: IBGE (Agricultural surveys) (2008)

Figure 4.1 Evolution of land use in Brazil, from 1970 to 2006.



Source: MAPA (2008)

Figure 4.2 Evolution of some crops in Brazil, from 1990 to 2007.

Comparing the total growth of croplands in the period 1995-2006 (from 41.8 Mha to 76.7 Mha), the growth due to sugarcane was less significant (from 4.8 Mha to 7.4 Mha). In 2006 sugarcane occupied less than 10% of the cropland, and about 2% of the total arable land. It is estimated that in 2007 seven million hectares of sugarcane were harvested, while 7.8 Mha were planted.

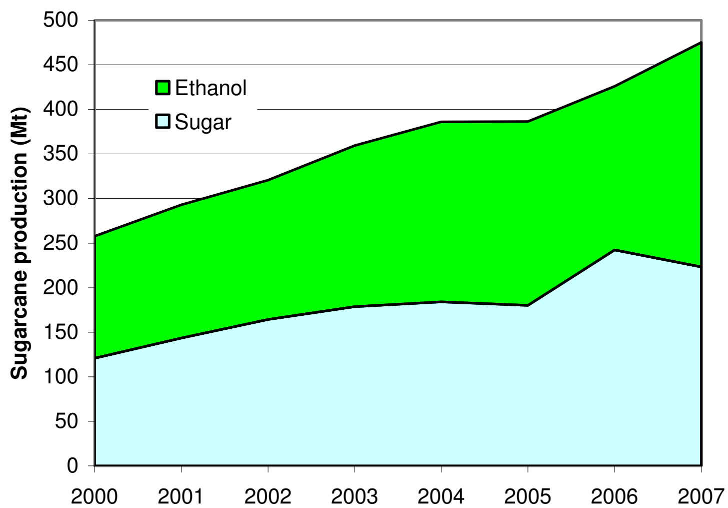
Table 4.1 Land use changes between two consecutive surveys (%)

Land use	1975	1980	1985	1995	2006
Crops	18	23	6	-20	84
Pastures	7	5	3	-1	-3
Forests	22	25	1	6	6
Total	12	13	3	-2	11

Source: IBGE (Agricultural surveys, different years)

4.2. Land use due to sugarcane

Figure 4.3 shows the growth of sugarcane and its use for sugar and ethanol production, from 2000 to 2007. Up to 2004 the production grew mostly due to the enlargement of sugar production, and the opposite hereafter. On average, 51% of the sugarcane was used for ethanol production along the period 2000-2007.



Sources: UNICA (2008) for 2000-2006 and CONAB (2008) for 2007

Figure 4.3 Sugarcane production and its use in Brazil – 2000-2007

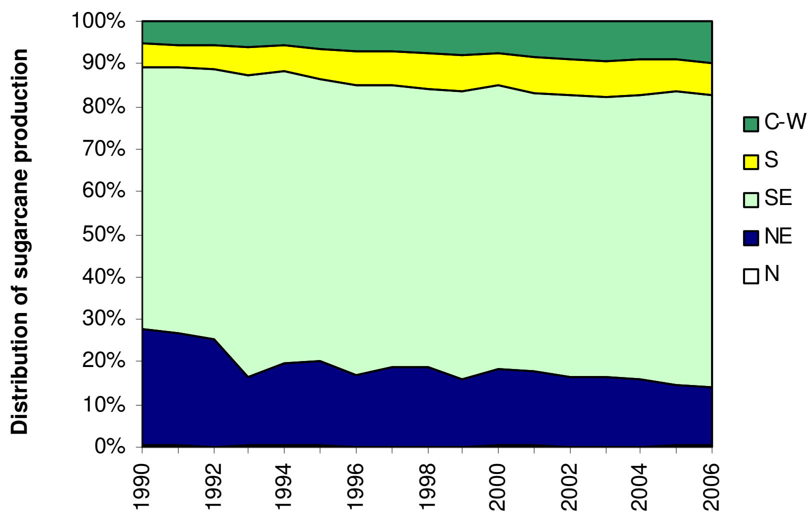
Sugarcane production is deeply concentrated in the Southeast region (SE in Figure 4.4), where 68% of the production took place in 2006. State of São Paulo concentrated 60% of the national production that year, with a reasonable share of the production in Minas Gerais (7.0%)[42]. Sugarcane production is traditional in the Northeast region, but its importance has been reduced

[42] There are (relatively small) differences between the data presented by IBGE and UNICA. IBGE's data refer to the total production of sugarcane while UNICA's data basis refer to the sugarcane that is used for producing ethanol and sugar.

along the years due to inadequate topographic conditions; in 2006 the share of Northeast region (NE in Figure 4.4) over the total production was less than 14%. The production in the NE region is concentrated in Alagoas and Pernambuco (5.1% and 3.8% of total, respectively).

In 2006 almost 10% of the sugarcane production took place in the Centre-West region (C-W), where many investments have occurred. There are concerns regarding the expansion in the C-W region due to the potential risk of environmental impacts in the Cerrado biome. The production in Goiás, Mato Grosso and Mato Grosso do Sul is estimated as 4.2%, 3.0% and 2.6% of the total, respectively. In the South region important sugarcane production occurs only in Paraná; the state concentrates 95% of the regional production (7.8% of the national production by 2006).

North region (N) is where most the Brazilian Amazon is located. The production of sugarcane in this region is insignificant, representing only 0.3% of the national production in 2006. As will be further shown, in absolute terms the growth in the North region is negligible as well. Figure 4.4 shows the distribution of sugarcane production within the five Brazilian regions from 1990 to 2006.



Sources: IBGE (2008)

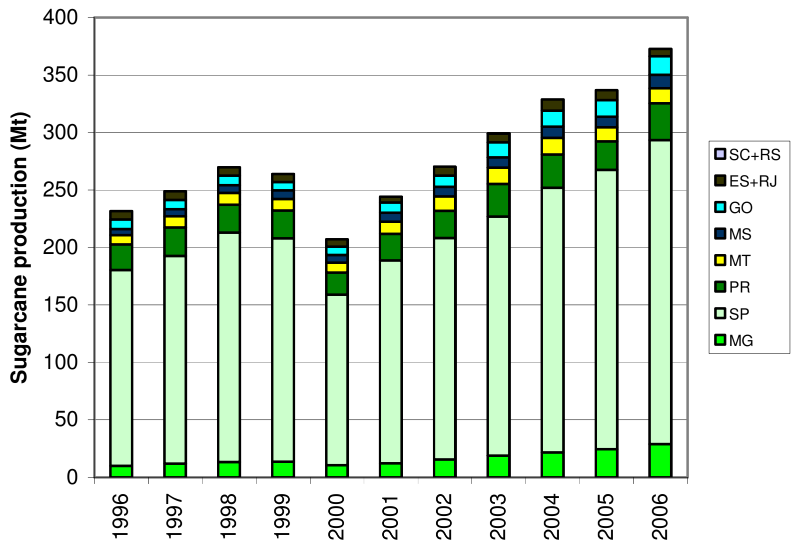
Figure 4.4 Distribution of sugarcane production through regions – 1990-2006

Figure 4.5 shows the growth of sugarcane production in the states of the Centre-West, South and Southeast regions from 1996 to 2006. Altogether, these states covered 87.5% of the national production in 2006. Figure 4.6 shows the same information for the states of Northeast and North regions, where 12.5% of the sugarcane production took place in 2006.

Considering the period 1996-2006, the production of sugarcane in the North-Northeast region was reduced 5%, while the production grew 61% in the Centre-South region[43] in the same period (141 Mt). The largest reduction in the Northeast region was in Pernambuco (almost 4.9 Mt) while the most important growth was in Maranhão (almost 0.95 Mt). In the Centre-South region São

[43] The so-called Centre-South region comprises the geographic regions Centre-West, Southeast and South.

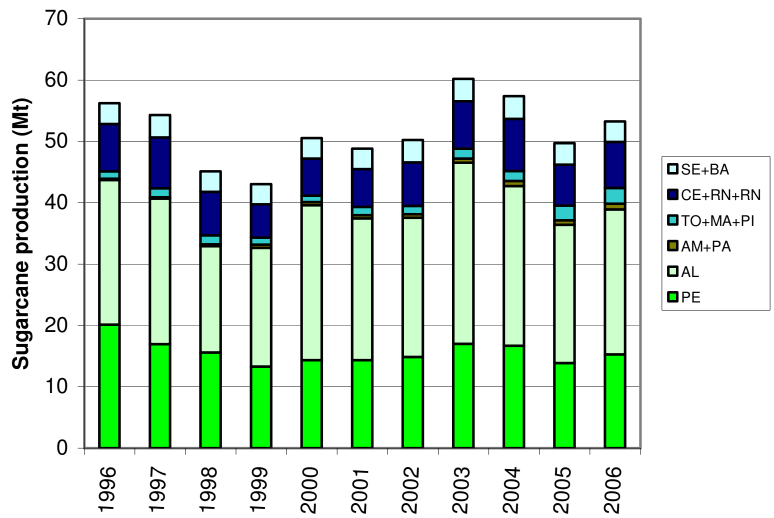
Paulo had the largest growth (94 Mt), with significant changes also in Minas Gerais and Paraná (14% and 7% of the national growth). The central states (Goiás, Mato Grosso do Sul and Mato Grosso) covered altogether 14% of the national growth along the period (more than 19 Mt). Figure 4.7 shows the contributions of the most important states/regions where the expansion of sugarcane took place in the period 1996-2006.



Sources: IBGE (2008)
Notes: MG = Minas Gerais, SP = São Paulo, PR = Paraná, MT = Mato Grosso, MS = Mato Grosso do Sul, GO = Goiás, ES = Espírito Santo, RJ = Rio de Janeiro, SC = Santa Catarina and RS = Rio Grande do Sul

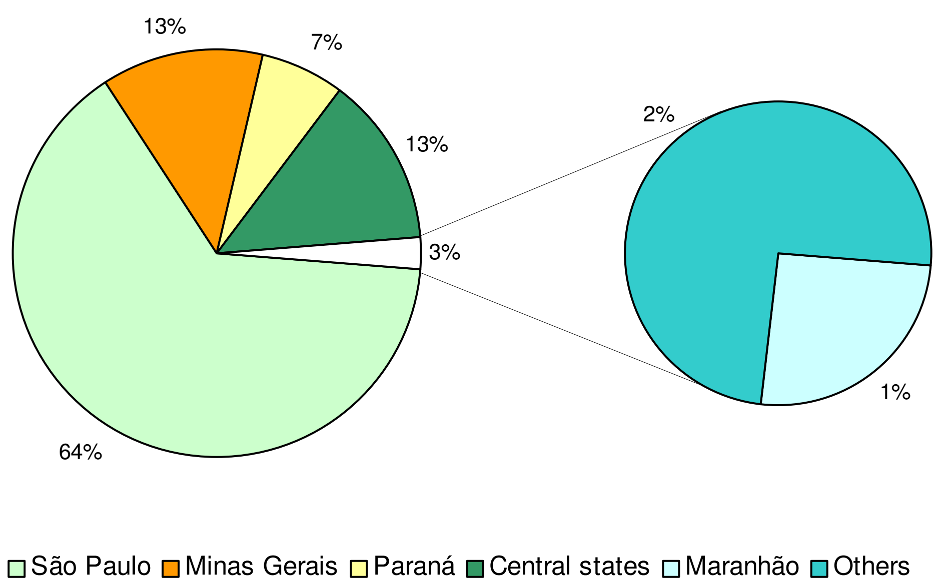
Figure 4.5 Sugarcane production in the Centre, South and Southeast regions – 1996-2006

The information previously presented justifies the choice of São Paulo, Minas Gerais and Goiás in a more detailed analysis regarding land use change; this is done in section 4.3. Information about other states is synthesized in section 4.4.



Sources: IBGE (2008)
Notes: PE = Pernambuco, AL = Alagoas, AM = Amazonas, PA = Pará, TO = Tocantins, MA = Maranhão, PI = Piauí, CE = Ceará, RN = Rio Grande do Norte, PB = Paraíba, SE = Sergipe and BA = Bahia

Figure 4.6 Sugarcane production in the Northeast and North regions – 1996-2006



Source: UNICA (2008)

Figure 4.7 Growth of sugarcane production along the period 1996-2006

4.3. Direct land use change due to sugarcane

The bulk of new sugarcane areas in the Southeast region are in the state of São Paulo and in areas formerly used for pastures in southwest of Minas Gerais. In the South region the growth has been concentrated in the northeast part of Paraná. In the Central region, the enlargement of sugarcane production has occurred in the centre and south regions of Goiás, in the southeast of Mato Grosso and in the southwest and east regions of Mato Grosso do Sul. The areas occupied with sugarcane in the six largest producer states in the Centre-South region are presented in Table 4.2, for the period 1997-2006.

Table 4.2. Sugarcane areas in the main producer states of the Centre-South region (1,000 ha)

States	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
São Paulo	2,446	2,565	2,555	2,485	2,567	2,662	2,818	2,952	3,085	3,285
Minas Gerais	279	279	280	293	295	278	303	335	349	431
Paraná	300	310	338	327	338	359	374	400	405	433
Goiás	115	144	148	139	130	204	168	176	200	238
Mato Grosso do Sul	82	87	94	99	100	112	121	131	137	153
Mato Grosso	134	136	148	135	167	177	197	207	206	202

Source: IBGE (different years for municipal agricultural production)

Higher land prices in state of São Paulo have induced since 2000 the enlargement of sugarcane production in areas close to São Paulo, such as in the states of Paraná, Minas Gerais and Mato Grosso do Sul.

CONAB[44] (2008) evaluated direct land use change due to the enlargement of sugarcane production from 2006 to 2007 based on a survey with all mills in operation by 2007. In the Centre-South region almost 610 thousand hectares were incorporated to sugarcane production in only one year, being 352 thousand ha in the state of São Paulo. Most of the incorporated areas were previously used for cattle ranching (66%), while sugarcane has also displaced soybeans (18%), corn (5.3%) and orange (5%). Less than 9 thousand ha not previously used were incorporated to sugarcane production (1.4% of the enlargment), being 7.9 thousand ha in São Paulo. Table 4.3 presents the main results of this survey.

Table 4.3 Growth of sugarcane areas in Centre-South region – 2006-2007 (1000 ha)

State	Crops displaced due to enlargement of sugarcane (areas)							Total	Share over region (%)
	Corn	Soybeans	Coffee	Orange	Pastures	New	Others		
São Paulo	17.3	42.2	2.3	30.4	242.1	7.9	9.8	352.0	57.7
M Gerais	5.2	26.9	-	-	45.5	-	4.6	82.2	13.5
Paraná	-	6.0	-	-	2.7	0.1	-	8.8	1.4
Goiás	3.7	16.5	-	-	28.2	0.5	2.6	51.5	8.5
MG do Sul	5.4	15.9	0.3	0.3	48.6	0.3	5.3	75.9	12.5
Mato Grosso	0.6	3.1	-	-	35.5	-	-	39.2	6.4
Total	32.2	110.4	2.6	30.7	402.7	8.8	22.2	609.6	100.0
Share (%)	5.3	18.1	0.4	5.0	66.0	1.4	3.6	100	

Source: CONAB (2008) – Perfil do setor de açúcar a álcool no Brasil 2007 (p. 63).

[44] Companhia Nacional de Abastecimento (National Food Supply Company).

A more detailed analysis of land use change is presented bellow, based on the IBGE's Agricultural Surveys for the years 1996 and 2006. The following sections present the results for São Paulo, Minas Gerais and Goiás.

4.3.1 São Paulo

Sugarcane production has been important in the state of São Paulo for at least 50 years. By the end of the 1950s the production of sugarcane in São Paulo surpassed the production in Northeast Brazil, where this crop was introduced centuries ago. Since mid 1980s São Paulo is the largest producer of ethanol in the country, being Ribeirão Preto and Piracicaba the most traditional areas of sugarcane production in the state. Piracicaba doesn't have adequate topographic conditions for mechanical harvesting[45], and the tendency is the stabilization or even reduction of sugarcane production in this region.

A considerable share of enlargement of sugarcane areas has been in the Ribeirão Preto region, despite the high concentration of sugarcane plantations[46] and higher land's price. Both due to the availability of lands and to the adequate topography, most of the expansion of sugarcane in São Paulo has occurred in the regions around Presidente Prudente, Araçatuba and São José do Rio Preto (see Figure 4.8). Figure 4.8 shows the evolution of sugarcane areas in different meso-regions (upper side) and micro-regions (lower side) of São Paulo, from 1996 (left side) to 2006 (right side).

Table 4.4 presents the growth of sugarcane areas in different meso-regions of São Paulo, taken as reference the occupied area in 2002 (% regarding 2002). In São Paulo sugarcane areas grew 21% in only four years, with remarkable expansions in the regions around Presidente Prudente, Assis, São José do Rio Preto and Araçatuba (see notes in Figure 4.7). Also in Table 4.4 it can be seen that the sugarcane area in the Piracicaba region didn't grow in the period 2002-2006, and that the growth in the Ribeirão Preto region was lower than in the state.

Table 4.5 shows the growth of sugarcane areas from 1996-2006 in São Paulo. Despite some degree of concentration, sugarcane is planted in many areas along the state and the enlargement of production has occurred in different regions. A more detailed analysis is presented bellow considering four micro-regions with the most significant growth of sugarcane production in the period 1996-2006. Similar information at a municipal level is presented in Table A.2, at Annex A.

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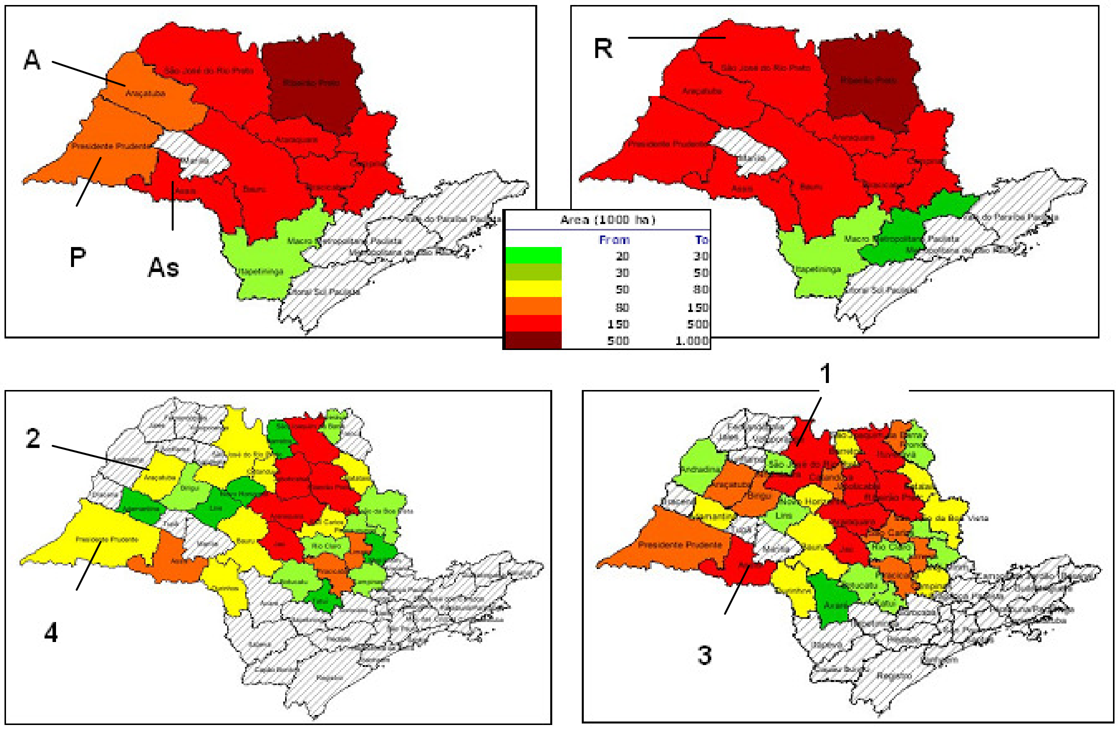
[45] A tendency in São Paulo due to the phasing-out of sugarcane burning previous to the harvest.

[46] More than 40% of the total area of Ribeirão Preto region is occupied with sugarcane plantations. The same happen in the Bauru region.



Notes: Meso-regions – P = Presidente Prudente, As = Assis, A = Araçatuba, R = São José Rio Preto; micro-regions – 1 = São José Rio Preto, 2 = Araçatuba, 3 = Assis, 4 = Presidente Prudente.

Figure 4.8 Evolution of sugarcane areas in state of São Paulo, by meso-regions (upper figures) and micro-regions (lower figures), from 1996 (left side) to 2006 (right side figures).

Table 4.4. Growth of sugarcane areas in different meso-regions of state of São Paulo, 2003-2006 (% regarding the occupied area in 2002)

Regions	2003	2004	2005	2006
São Paulo	6.7	11.2	16.5	21.0
São José Rio Preto	8.4	16.0	28.1	38.2
Ribeirão Preto	6.4	10.0	14.6	14.8
Araçatuba	13.9	22.9	24.9	37.0
Bauru	7.0	7.2	9.1	11.0
Araraquara	12.4	16.5	19.4	20.2
Piracicaba	-1.5	1.2	2.1	-1.3
Campinas	6.7	7.5	11.9	12.7
Presidente Prudente	6.9	24.9	35.4	52.3
Assis	-28.4	2.3	42.4	40.8
Itapetininga	2.5	3.8	11.5	15.2

Source: IBGE - Produção Agrícola Municipal (different years).

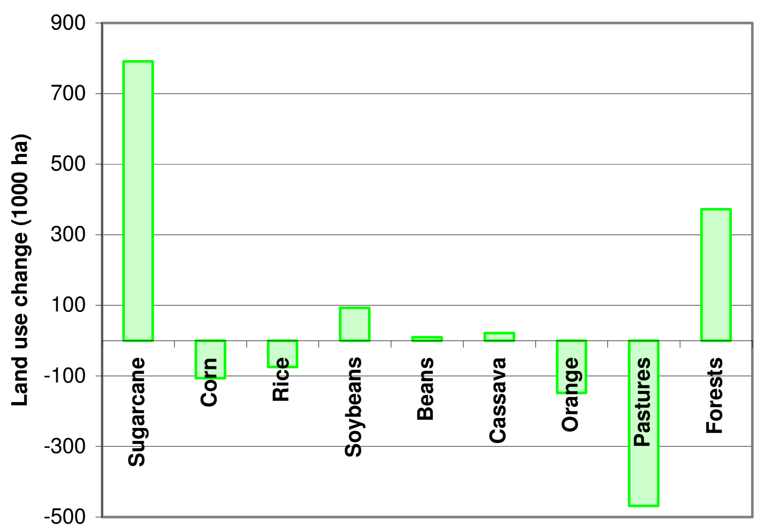
During a decade the growth of sugarcane area in São Paulo was 792 thousand ha, i.e., 31.8% regarding the occupied area in 1996. The largest growth occurred in the São José do Rio Preto micro-region (104 thousand ha in 10 years). Eight up to ten micro-regions presented in Table 4.5 are located in the west bound of São Paulo (except Ituverava and São João Boa Vista).

Table 4.5. Growth of sugarcane areas in micro-regions of the state of São Paulo – 1996-2006

Micro-region	Area growth (1,000 ha)	Area change (%)	(%) regarding São Paulo	Accumulated growth in the state (%)
São José Rio Preto	104.4	141.6	13.2	13.2
Araçatuba	61.2	83.7	7.7	20.9
Assis	60.3	53.3	7.6	28.5
Presidente Prudente	54.2	100.9	6.9	35.4
Barretos	45.9	228.4	5.8	41.2
Birigui	45.0	99.1	5.7	46.9
Adamantina	43.2	167.8	5.5	52.3
Ituverava	40.1	92.2	5.1	57.4
Novo Horizonte	38.4	150.0	4.9	62.3
São João Boa Vista	35.6	89.7	4.5	66.8

Source: IBGE - Produção Agrícola Municipal (different years).

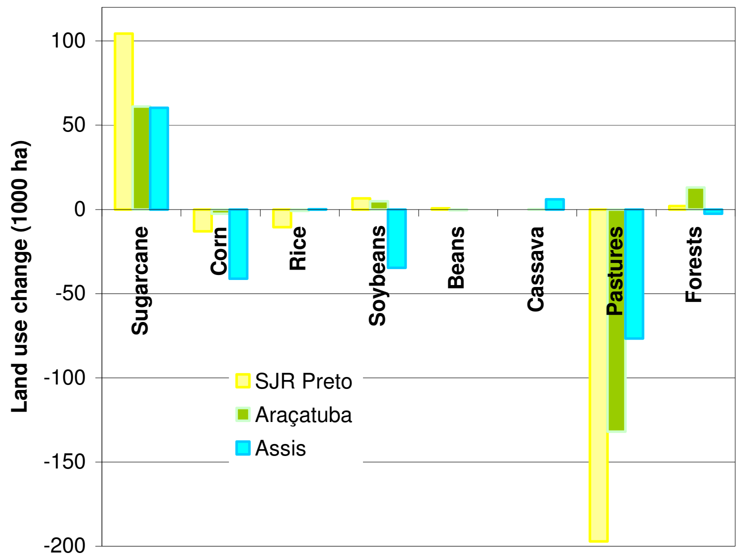
Figure 4.9 indicates land use change in the state of São Paulo from 1996-2006, considering six crops and areas occupied with livestock and forest. In the period the reduction of pasturelands and of areas occupied with orange, corn and rice summed-up 798 thousand ha, while the growth with sugarcane was equal to 792 thousand ha. The enlargement of forest's areas was mainly due to new-planted forests for supplying the pulp and paper industry and, in a lower extent, due to the recovery of degraded forests. Considering land uses listed in Figure 4.9 there is an unbalance of 490 thousand ha, i.e., expansion of 1,288 thousand ha vis-à-vis the reduction of 798 thousand ha.



Source: IBGE (1996 and 2008)

Figure 4.9 Land use changes in state of São Paulo from 1996 to 2006.

Altogether, 28.5% of new sugarcane areas from 1996 to 2006 concentrated in three micro-regions: São José Rio Preto, Araçatuba and Assis (see Table 4.5). As an illustration, Figure 4.10 shows land use change in these three regions.



Source: IBGE (1996 and 2008)

Figure 4.10 Land use change in three micro-regions of state of São Paulo from 1996 to 2006.

In these three regions the growth of sugarcane area was smaller than pasturelands phased-out (46% for São José Rio Preto and 79% for Assis). In the case of São José Rio Preto and Araçatuba, phasing-out of other crops was relatively small and there was also enlargement (small) of forested areas. In the case of Assis, the phasing-out of other crops cannot be neglected as the area made available due to the reduction of grain crops (corn and soybeans) was equivalent to the area made available from pasturelands (76 thousand ha in both cases, approximately). Details of land use change for the ten micro-regions listed in Table 4.5 are presented in Table A.3, in Annex A.

The general tendency in the state of São Paulo was the substitution of pastures for crops, especially for sugarcane, but this conclusion cannot be generalised. First, only based on the data available it is not possible to conclude that the enlargement of sugarcane plantations has occurred in areas previously occupied with pastures. Second, in some regions phasing-out of other crops was at least as important as phasing-out of pastures[47]. Third, in some regions the growth of sugarcane area was larger than the area made available due to phasing-out of pastures[48]. Fourth, in the Presidente Prudente region the area occupied with pastures grew much more than the sugarcane area.

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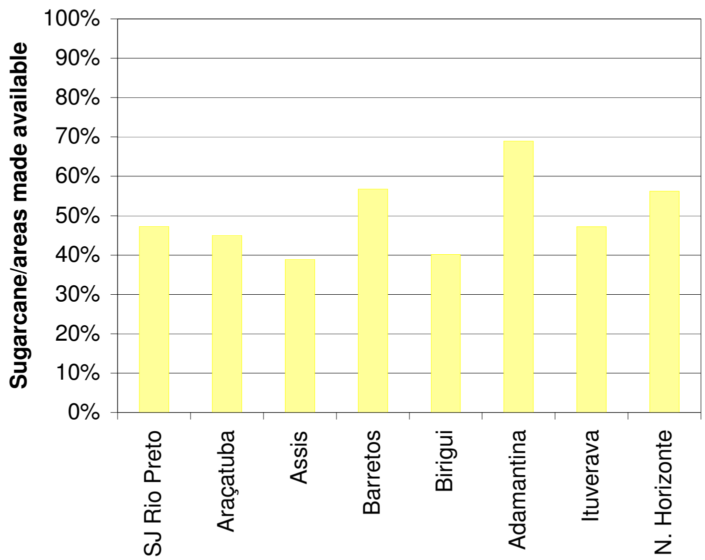
[47] As was the case of Assis and Ituverava.

[48] Again, Ituverava is the example.

Figure 4.11 shows for some regions that the growth of sugarcane areas was lower than the area that became available in the period 1996-2006 (mostly due to phasing-out of pastures). Results are presented for eight up to ten micro-regions listed in Table 4.5[49]. The tendency was different in the regions of Presidente Prudente and São João Boa Vista, not presented in Figure 4.10.



Source: IBGE (1996 and 2008)

Figure 4.11 Growth of sugarcane areas regarding the areas made available due to the phasing-out of other crops (including pastures) – 1996-2006

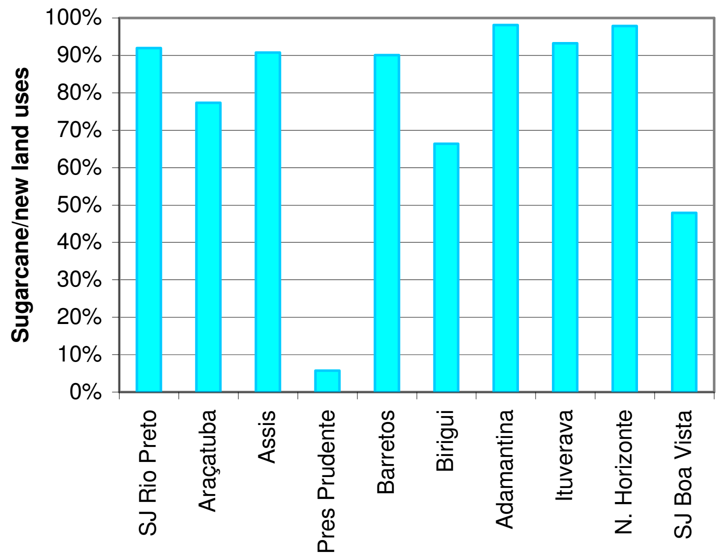
Figure 4.12 shows that where sugarcane growth took place (see Table 4.5) few other new land uses had importance. The clear exception was Presidente Prudente, where the enlargement of pasturelands in the period was almost 15 times higher than the enlargement of sugarcane, besides significant growths of grains and forests[50].

The number of mills under construction confirms the growth of sugarcane production in the west side of state of São Paulo. According to UDOP[51], up to 2010 45 new mills should be in operation in that region, with an enlargement of about 90 Mt of sugarcane production (Jornal da Cana, 2008). A list of the mills under construction at the west of São Paulo is presented at the Table A.5.

[49] Considering cattle ranch and forests, besides cropping of sugarcane, corn, soybeans, rice, beans and cassava.

[50] Along the period 1996-2006, in Birigui there was a considerable growth of soybeans production, while in São João Boa Vista an important expansion of grains (corn and soybeans) and beans.

[51] Usinas e Destilarias do Oeste Paulista, an organization of mills located in the west band of São Paulo.



Source: IBGE (1996 and 2008)

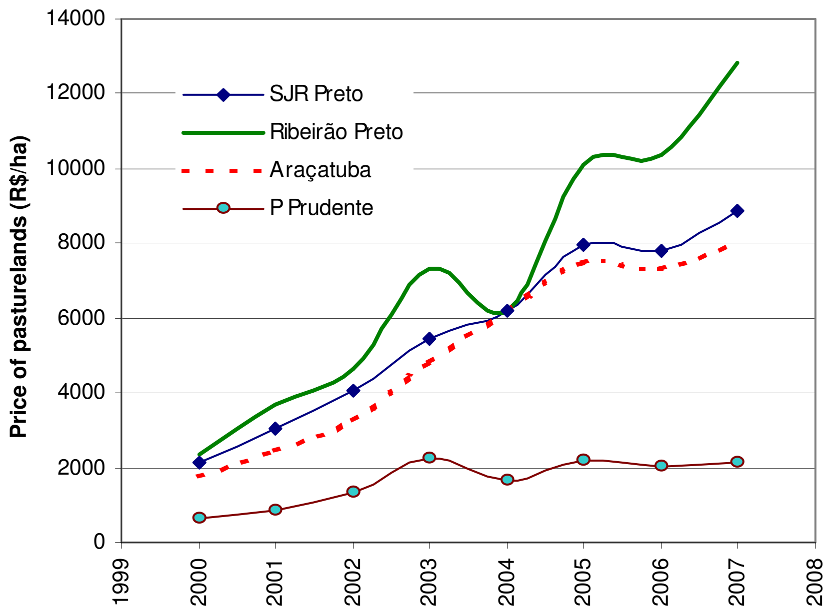
Figure 4.12 Growth of sugarcane areas regarding total enlargements for different crops (including pasturelands) – 1996-2006

It is worth to mention the evolution of the average price of pasturelands in different regions of São Paulo. As can be seen in Figure 4.13, the average price rose significantly in the period 2000-2007 in Ribeirão Preto[52], São José Rio Preto and Araçatuba[53]. The raise of land's price was less remarkable in Presidente Prudente, as in that region there is more land available. More information about average land's price in different regions of São Paulo is presented in Table A.6, Annex A.

According to the last IBGE's Agricultural Survey, in the state of São Paulo there was significant reduction of cattle heads along the period 1996-2006 (from 12.3 million to 10.2 million animals, i.e., reduction of about 17%). According to the same data basis, pasturelands were reduced from about 9 Mha in 1996 to about 8.6 Mha in 2006, i.e., it could be estimated that the density dropped from 1.36 heads/ha in 1996 to 1.19 heads/ha in 2006. This conclusion is not in line with what has been stated recently, i.e., in São Paulo the reduction of pasturelands occurred with raise of the density, and no significant reduction of cattle heads.

[52] As previously mentioned, region with large density of sugarcane plantations and also with important growth of sugarcane areas.

[53] These two regions had significant substitution of pasturelands for sugarcane, as previously mentioned.



Source: IEA (different years)

Figure 4.13 Average prices of pasturelands in regions where significant growth of sugarcane production occurred – São Paulo, 2000-2007

Still based on this data source, and moving down to micro-region level, in some regions where the growth of sugarcane areas was remarkable there was also significant reduction of cattle heads (e.g., São José Rio Preto, Araçatuba and Presidente Prudente; see Table 4.6). Seven up to ten micro-regions listed in Table 4.5 (i.e., regions with significant growth of sugarcane) are also listed in Table 4.6 (i.e., regions with reduction of cattle heads in the same period).

On the other hand, the same IBGE presents another data basis – PAM[54] – with significant differences regarding cattle heads in 2006. This alternative data basis is only partially based on the Surveys and has complementary information from other statistical sources. According to the this alternative data basis, cattle heads in the state of São Paulo remained almost constant in the period 1996-2006, with 12,707.5 thousand animals in 1996 and 12,790.4 thousand animals in 2006. Considering these numbers, the density varied from 1.41 animals/ha to 1.49 animals/ha.

It was not possible to check the reason for these remarkable differences. However, it seems that part of the 2006 Survey is not yet consolidated, in spite of the fact that it was published in mid 2008. In a first moment, the authors of this reports thought adequate to take cattle heads' data from the 2006 Survey because the whole analysis of land use change is based on the Surveys for 1996 and 2006.

[54] Produção Agropecuária Municipal (PAM), for different years.

Table 4.6. Cattle heads in state of São Paulo and in (micro)regions where sugarcane production has been important (thousand animals) – 1996 and 2006

Micro-region	1996	2006	Difference 2006-1996	Change along the period (%)
São Paulo (state)	12,306.8	10,209.2	-2,097.6	-17.1
Presidente Prudente	1,672.0	1,524.3	-147.7	-8.8
São José Rio Preto	725.2	574.9	-150.3	-20.7
Araçatuba	476.5	301.1	-175.4	-36.8
Adamantina	369.9	299.5	-70.4	-19.0
Lins	307.1	247.4	-59.7	-19.4
Assis	361.0	234.1	-126.9	-35.1
São João Boa Vista	250.0	182.0	-68.0	-27.2
Nhandeara	189.8	130.6	-59.2	-31.2
Araraquara	161.0	114.4	-46.6	-28.9
São Carlos	138.7	76.0	-62.7	-45.2
Novo Horizonte	139.0	64.7	-74.3	-53.4
São Joaquim da Barra	102.7	53.8	-48.9	-47.7
Jaboticabal	95.5	51.8	-43.7	-45.8

Source: IBGE (Agricultural Surveys for 1996 and 2006).

There is no deep inconsistency between the two IBGE's data basis regarding 1996, as can be seen in Table 4.7. In case of São Paulo it was possible to compare IBGE's data with the information published by Instituto de Economia Agricola (IEA). According to IEA, cattle heads in São Paulo summed 12,726 thousand animals in 1996 (i.e., equivalent to IBGE's data) and 13,755 thousand in 2006, i.e., a million heads more than the estimate of IBGE-PAM (12,798 thousand). It is accepted that the information provided by Instituto de Economia Agricola (IEA) is more accurate than IBGE's information. Thus, in case of São Paulo the first conclusion is that there was not a reduction of cattle heads, and second, that along a decade (1996-2006) there was an increase of animal's density.

Table 4.7. Cattle heads in the most important states of Centre-South region of Brazil, according to two different data basis of IBGE (1,000 heads)

State	1996		(1)/(2)	2006		(3)/(4)
	Survey (1)	PAM (2)	(%)	Survey (3)	PAM (4)	(%)
São Paulo	12,307	12,798	96.2	10,209	12,790	79.8
Minas Gerais	20,045	20,148	99.5	20,992	22,203	94.5
Paraná	9,901	9,880	100.2	9,154	9,765	93.7
Goiás	16,488	16,955	97.2	16,684	20,647	80.8
Mato Grosso	14,438	15,573	92.7	19,583	26,064	75.1
Mato Grosso do Sul	19,754	20,756	95.2	17,405	23,726	73.4

4.3.2. Minas Gerais

In Minas Gerais, from 1996 to 2006, the growth of sugarcane industry was concentrated in a region that has been traditional for decades as a pole of milk and meat production: the so-called

Triângulo Mineiro region. In recent years it has been observed reduction of pasturelands, and part of this land has been used for sugarcane production. This region is adequate for sugarcane cropping, due to its topography and weather, the land is cheaper and the region is close to the state of São Paulo[55]. In the period 2001-2007 the growth of sugarcane production in Minas Gerais was the largest in the Centre-South region: 218% in Minas, against 61% in São Paulo, for instance, and 74% in the whole Centre-South region. More details can be seen in Table A.7, Annex A.

However, it is worth to notice that in Minas Gerais the growth of sugarcane production was also due to the increase of productivity: in Minas the agricultural yields (i.e., tonnes of sugarcane per hectare) grew 28% in a decade, against an improvement of less than 5% in Centre-South region, on average, and 3.3% in São Paulo.

All micro-regions with significant sugarcane production in state of Minas Gerais are in the Triângulo region[56]. Figure 4.14 shows the sites of existing mills (red circles; 25 in total) and of mills under construction (yellow squares; 7 in total). Most of the mills (existing and new units) are almost at the boarder with São Paulo.

Table 4.8 shows data regarding pasturelands and sugarcane areas in Minas Gerais and in some of its meso and micro-regions, from 1996 to 2006. As can be seen, the reduction of pasturelands was a general tendency; in addition, the growth of sugarcane areas was only a fraction of the lands made available due to the phasing-out of pastures.

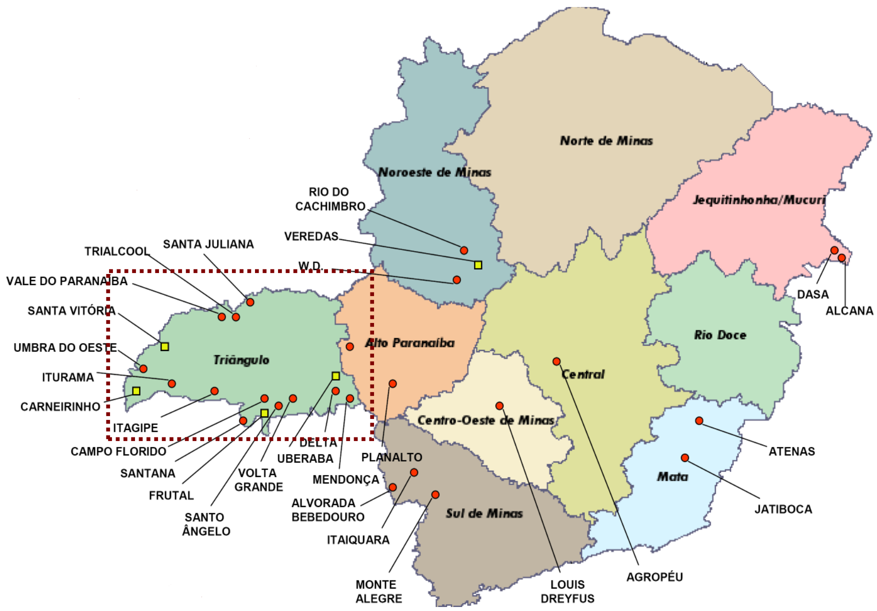
Table 4.8. Reduction of pasturelands and growth of sugarcane areas in Minas Gerais, 1996 and 2006 (1000 ha)

	Pastures			Sugarcane		
	1996	2006	Difference	1996	2006	Difference
Minas Gerais	25,348.6	20,555.0	-4,793.6	279.0	431.3	152.3
Meso-regions						
Noroeste de Minas	2,949.9	2,070.5	-879.4	5.4	12.3	6.9
Triângulo Mineiro	5,258.5	3,975.0	-1,283.5	97.8	251.9	154.1
Central. Mineira	1,495.7	1,155.8	-339.9	30.4	28.9	-1.5
Sul/Sudoeste	2,211.0	1,972.5	-238.5	36.9	40.3	3.4
Micro-regions						
Ituiutaba	600.5	498.3	-102.2	0.6	19.8	19.2
Uberlândia	1,069.5	654.1	-415.4	31.8	41.2	9.4
Frutal	1,130.1	944.8	-185.3	35.2	74.9	39.7
Uberaba	479.3	229.8	-249.5	28.6	107.7	79.1
Araxá	689.2	539.4	-149.8	0.7	7.2	6.5

Source: IBGE (Agricultural surveys, 1996 and 2006).

[55] In principle an advantage regarding logistics, as São Paulo has the largest market and better infra-strucuture.

[56] The bulk of growth occurred in four micro-regions (Ituiutaba, Frutal, Araxá and Uberaba).



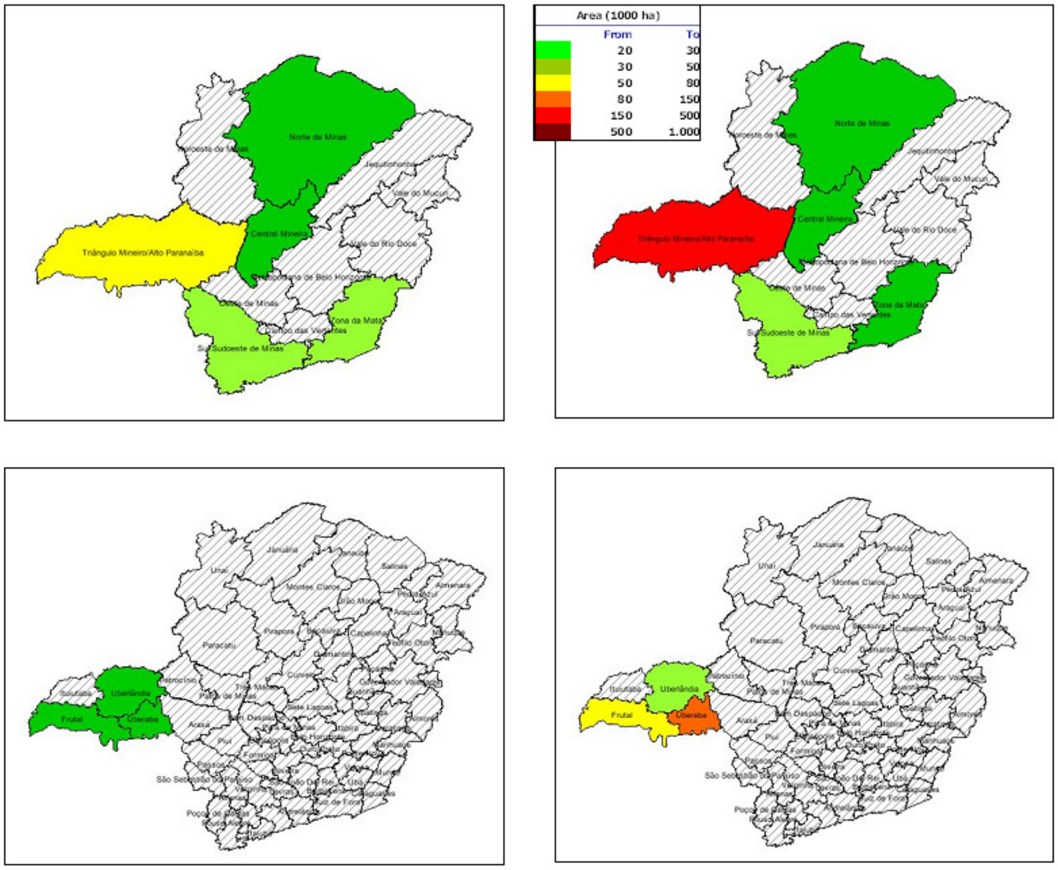
Source: SINDAÇUCAR-MG and SIAMIG.

Figure 4.14 Existing and new sugarcane mills in Minas Gerais, in 2006

Figure 4.15 shows the evolution of sugarcane areas in Minas Gerais from 1996 (left side of the figure) to 2006 (right side), in meso-regions of the state (upper part of the Figure) and in micro-regions (lower part). It is clear from the figure that the growth of sugarcane production occurred mostly in the Triângulo Mineiro region, as mentioned before.

Corn and soybeans cropping are other traditional activities in the Triângulo Mineiro region, and there was no deep reduction of their areas during last years; however, partial substitution between soybeans and sugarcane (and corn) could have occurred in 2005 and 2006 (see Figure 4.16). Figure 4.16 shows the evolution of areas used for cropping sugarcane, corn and soybeans in this region, from 2000 to 2006. On average, along the period the area occupied with corn was twice larger than the area occupied with sugarcane, while in case of soybeans the ratio was about 4 times.

Figures 4.17 and 4.18 indicate tendencies of land use changes in the state of Minas Gerais and in Triângulo Mineiro region, from 1996 to 2006. As can be seen in Figure 4.17, the area made available due to phasing-out of extensive pasture is more than twice the area that has been occupied with different crops and forests, both in the Triângulo region and in the state as whole.



Source: Source: IBGE (1996 and 2008)

Figure 4.15 Sugarcane areas in state of Minas Gerais, by meso-regions (upper figures) and micro-regions (lower figures), from 1996 (left side) to 2006 (right side figures).

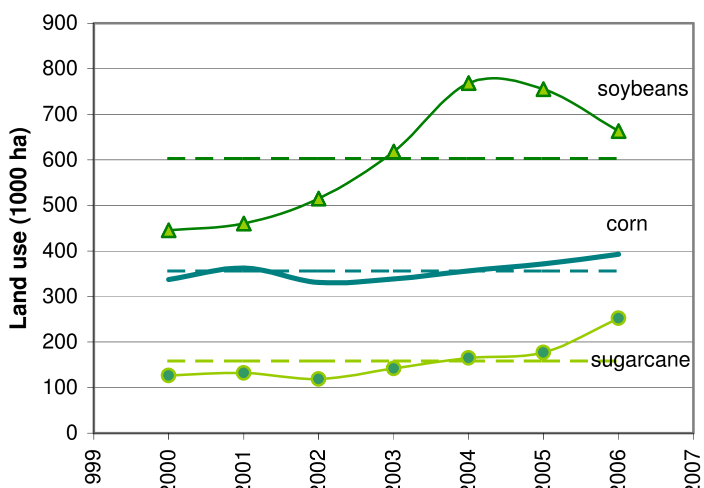
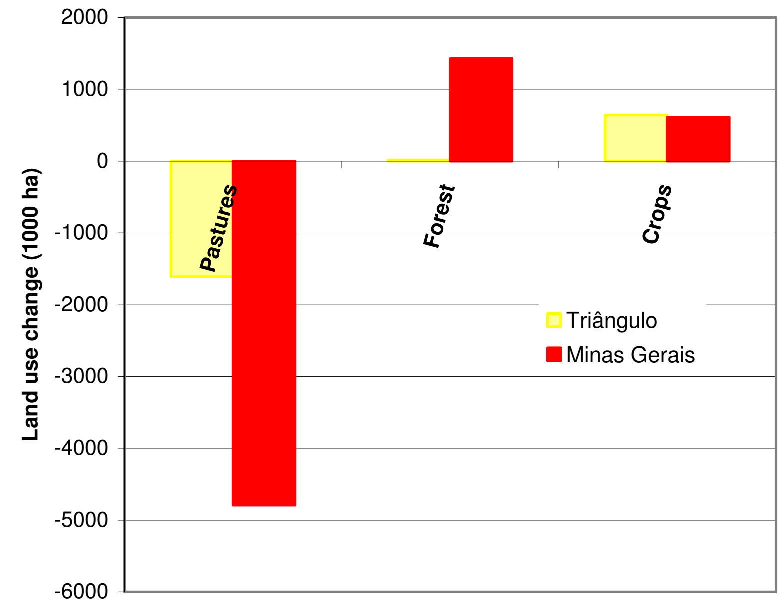
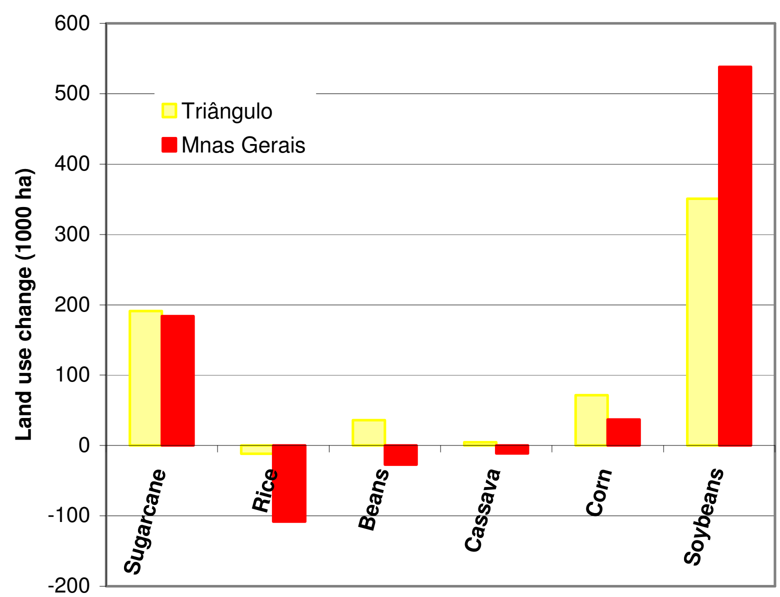


Figure 4.16 Land use for soybeans, corn and sugarcane production in the Triângulo Mineiro region, from 2000 to 2006



Source: Source: IBGE (1996 and 2008)
Note: Crops = sugarcane + rice + beans + beans + cassava + soybeans
Figure 4.17 Changes in land use in Minas Gerais and in the Triângulo region, 1996-2006.



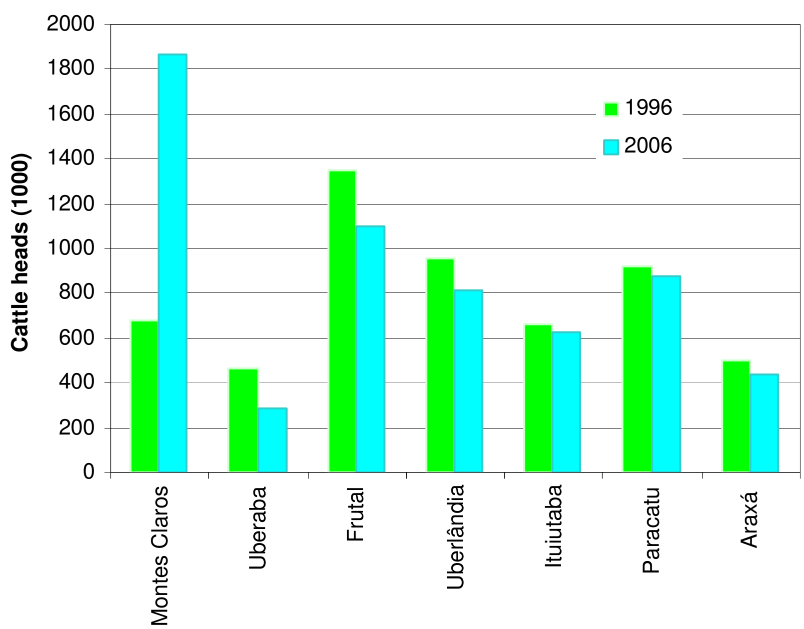
Source: Source: IBGE (1996 and 2008)
Figure 4.18 Changes in land use in Minas Gerais and in the Triângulo region considering some specific crops – 1996-2006.

As can be seen in Figure 4.18, along the period the growth of soybeans areas was larger than sugarcane: almost three times larger in Minas and almost twice in the Triângulo region. In that period almost all enlargement of sugarcane areas occurred in the Triângulo region, with no significant displacement of other crops. In this sense, it can be concluded that the growth of sugarcane in Minas Gerais, from 1996-2006, was not directly responsible for deforestation and displacement of food crops.

According to the 2006 Agricultural Survey of IBGE, from 1996 to 2006 there was a small growth on cattle heads in Minas Gerais, i.e., 4.7% in the period (from about 20 million in 1996 to 20.9 million in 2006). The largest growth was in the north side of Minas Gerais, more specifically in the region of Montes Claros, where cattle heads grew 174% in the period. In all six regions where sugarcane activity grew significantly in the period it was observed reduction of cattle heads, as can be seen in Figure 4.19. In these six (micro)regions cattle heads dropped from 4.8 to 4.1 million, reducing its share in the state from 24% to 20%. However, the reduction of pasturelands was proportionally larger, that induces the conclusion that there was a raise of animal's density both in the Triângulo region and in the whole state.

Alternatively, according to the IBGE-PAM data basis the growth of cattle heads was more significant – about 10% (varying from 20.1 million to 22.2 million animals) (see Table 4.7). Based on these data, there is no doubt about the raise of animal's density.

The general conclusion is that in Minas Gerais the growth of croplands, and more specifically the growth of sugarcane areas, occurred in lands previously occupied with pastures, but without inducing the displacement of cattle heads to other regions of Brazil.



Source: Source: IBGE (1996 and 2008)

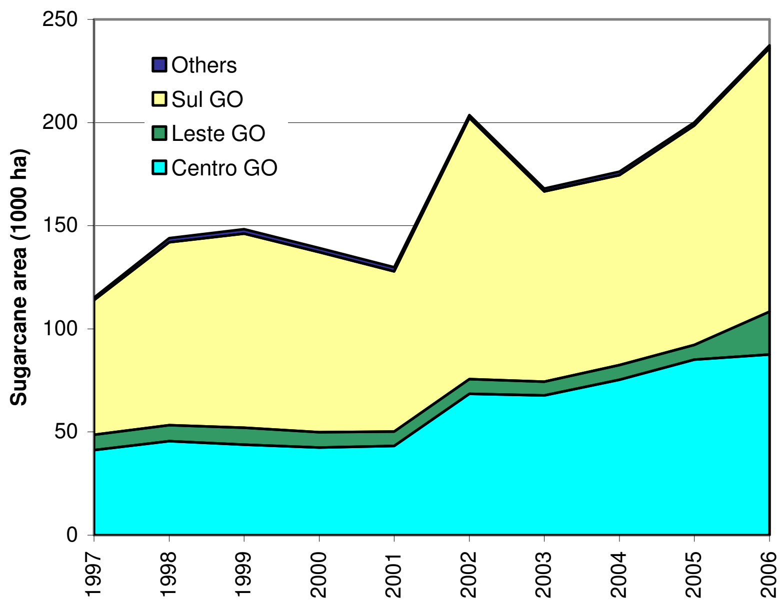
Figure 4.18. Cattle heads in some micro-regions of Minas Gerais – 1996-2006.

4.3.3 Goiás

Between 1997 and 2006 sugarcane areas in Goiás grew more than twice. This growth was more significant in the so-called Planalto Central Goiano, region that has been a large producer of grains and also has had large pasturelands. More specifically, the growth has occurred mainly in the (meso)regions known as Centro (Central) and Sul (South) Goiano.

Figure 4.20 shows sugarcane areas in Goiás, from 1996 to 2006. On average, the growth in South and Central regions summed-up more than 90% of the total growth. More details about the growth of sugarcane areas in meso and micro-regions of Goiás are presented in Table A.9, Annex A.

Moving down to micro-regions, most of the growth of sugarcane production occurred in five regions, three in the south and two in the central part of the state[57]. On average, almost 85% of the enlargement of sugarcane area in Goiás, from 1996 to 2006, occurred in these micro-regions. Figure 4.21 shows the evolution of sugarcane areas in different regions of Goiás, from 1996 (maps at the left side) to 2006 (maps at the right side); meso-regions in the top of the figure and micro-regions in the bottom of the figure.



Source: IBGE - Produção Agrícola Municipal (different years)

Figure 4.20 Sugarcane areas in meso-regions of Goiás – 1996-2006

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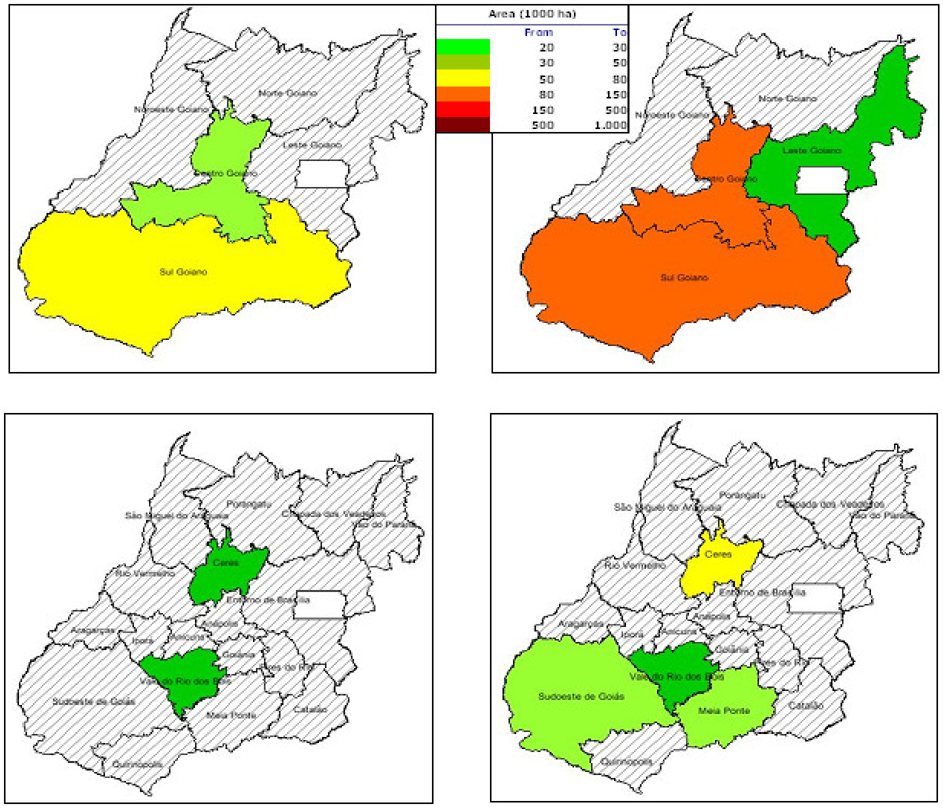
[57] Sudoeste de Goiás, Vale do Rio dos Bois and Meia Ponte, in the South, and Ceres and Anicuns in the Central region.



Source: Source: IBGE (1996 and 2008)

Figure 4.21 Sugarcane areas in Goiás, by meso-regions (upper figures) and micro-regions (lower figures), from 1996 (left side) to 2006 (right side figures).

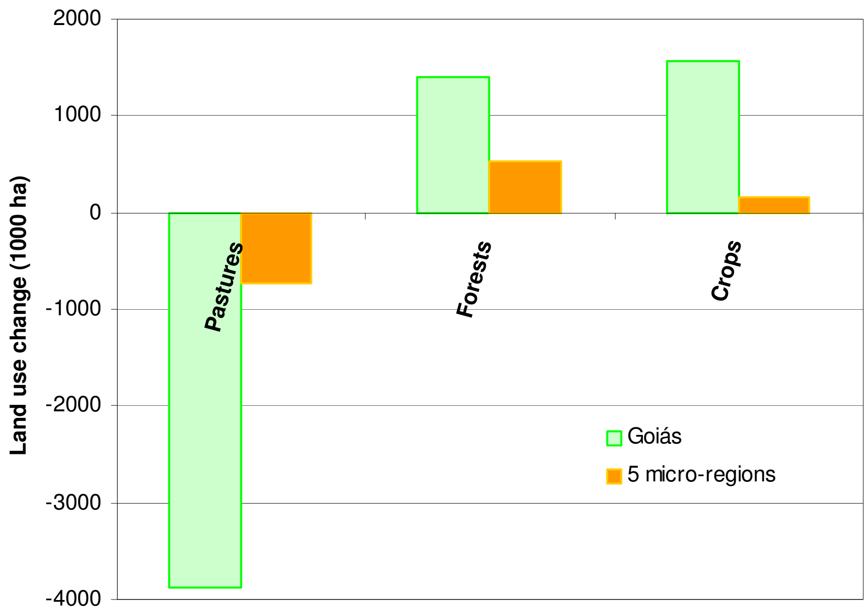
Between 2006 and 2007 the growth of sugarcane areas in Goiás was 51.5 thousand ha (CONAB, 2008) (see Table 4.3), while the average figure from 1996 to 2006 was 13.6 thousand ha (IBGE, different years). It seems that sugarcane production tends to grow in Goiás more than it happened in recent past.

In 2006-2007, the enlargement of sugarcane production has occurred in areas previously used for pastures (54.7%) and also displacing soybeans (32.1%) and corn (14.1%). It is estimated that 6% of the growth of sugarcane occurred in areas previously occupied with other crops, and only 0.5% in new areas (see Table 4.3).

From 1996 to 2006 almost 3.9 million ha of pasturelands were phased-out in Goiás, while the enlargement of sugarcane areas was only 120 thousand ha, i.e., merely 3% of the area made available. In all micro-regions in which the growth of sugarcane was significant, except one, the reduction of pasturelands was at least twice larger[58].

[58] The growth of pasturelands was in the Sudoeste de Goiás region. In this regions there was simultaneous growth of forested areas (300 thousand ha), pasturelands (122 thousand ha), and for cropping soybeans (36 thousand ha) and sugarcane (21 thousand ha). The information available does not allow the conclusion if there was deforestation (i.e., of native forests) in this region. Anyhow, the lower growth in the period 1996-2006 was due to sugarcane.

Figure 4.22 indicates tendencies of land use change in Goiás and in five micro-regions of the state during the period 1996-2006[59]. Pastures and forests are highlighted in the figure, while the group "crops" corresponds to the sum areas deserved to sugarcane, soybeans, corn, rice, beans and cassava production. It can be seen that the reduction of pasturelands was larger than the growth of areas used for forests and crops. For the set of five (micro)regions analysed the conclusion is the same, but in this case the balance is almost nil (i.e., the growth of forested lands and croplands is almost equal to the area made available from former pastures).

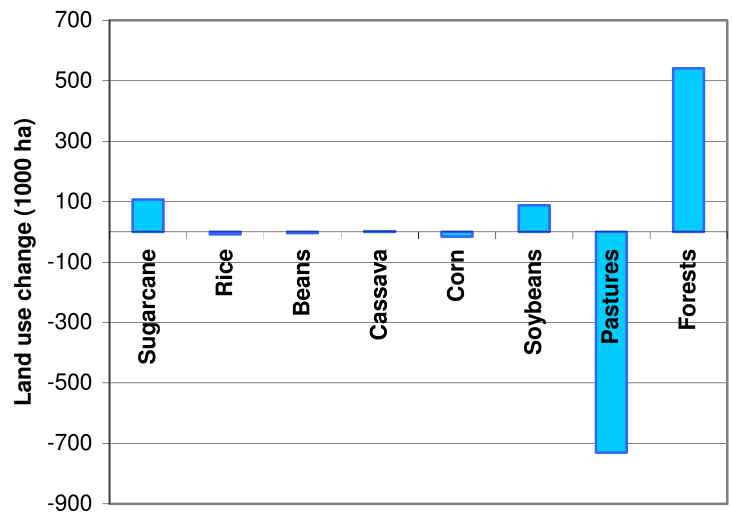


Source: IBGE - Produção Agrícola Municipal (different years)

Figure 4.22 Changes in land use change in Goiás, from 1996 to 2006.

Alternatively, Figure 4.23 shows more details about land use change in the five (micro)regions of Goiás where there was significant growth of sugarcane production. The only significant reduction was for pasturelands, being the area made available almost seven times larger than the growth of sugarcane area. On the other hand, the enlargement of forested areas was more than five times larger than the growth of sugarcane area. It is worth to mention that in these five micro-regions the growth of sugarcane was about 90% of the total observed in the state, but the growth of soybeans was equivalent to only 5% of the total.

[59] Sudoeste de Goiás, and Meia Ponte, in the South, Ceres and Anicuns in the Central region, and Entorno de Brasília, at the east side. The growth of sugarcane area in these five micro-regions was equivalent to 90% of the total in the same period.



Source: IBGE - Produção Agrícola Municipal (different years)

Figure 4.23 Changes in land use in five micro-regions of Goiás, from 1996 to 2006.

According to the Agricultural Surveys of IBGE for 1996 and 2006, despite the deep reduction of pasturelands in Goiás (about 20%, from 19.4 million ha to 15.5 million ha) cattle heads were kept constant (16.4 million animals in 1996 and 16.6 million animals in 2006). Thus, in a decade animal's density grew from 0.85 animals/ha to 1.07 animals/ha. Conversely, in almost all micro-regions in which the growth of sugarcane was significant it was observed a reduction of cattle heads; however, this reduction was proportionally lower than the reduction of pasturelands, which indicates higher density as well. The exception was Anicuns, where there was a growth of cattle heads (see Table 4.9); in this case the density growth was even larger.

Otherwise, considering the IBGE-PAM data basis, the estimated growth of cattle heads would be almost 22%, that implies an increase of animal's density from 0.87 animal/ha in 1996 to 1.33 animal/ha in 2006.

Table 4.9. Cattle ranch activity in some (micro)regions of Goiás – 1996-2006.

Micro-region	Reduction of pasture area (%)	Variation of cattle heads (%)
Ceres	37.3	≈ 0.0
Vale do Rio dos Bois	27.7	-19.3
Sudoeste de Goiás	28.4	-16.8
Meia Ponte	31.8	-13.8
Anicuns	23,1	16.2

Source: Source: IBGE (1996 and 2008)

In case of Goiás the conclusions are similar to those previously presented for Minas Gerais: the enlargement of sugarcane area was a fraction of pasturelands phased-out from 1996 to 2006 and the growth of areas used both for cropping soybeans and forests were larger than the enlargement of sugarcane areas. Moreover, it seems clear that the reduction of pasturelands cannot be correlated with the growth of cattle ranch in the Amazon region, as cattle heads increased in the period.

4.4 Other states

In this section the growth of sugarcane areas in other producer states is concisely analysed. The reported cases are those that concern to Paraná, Mato Grosso do Sul, Mato Grosso and to Northeast region. More detailed information is presented in Annex A.

4.4.1 Paraná

Paraná is the second largest producer state in Brazil and one of those where sugarcane areas have grown mostly during the last years. Between 2000 and 2006 sugarcane areas grew 32%. However, in 2007 the expansion of sugarcane areas was the lowest among all producer states of Centre-South region (see Table 4.3).

Sugarcane areas are located in the north part, close to the boarder with São Paulo (see Figure A.1, in Annex A). The main producer regions are Noroeste Paranaense and Norte Central Paranaense that altogether summed-up 75% of the whole production in 2006. Sugarcane areas have expanded at the same time with other crops, mainly soybeans. Between 1996 and 2006 the (meso)region Noroeste had the largest growth of sugarcane areas, with additional 95 thousand hectares, i.e., almost 70% of the whole expansion in the state. Figure A.2 presents the evolution of sugarcane areas in Paraná, between 1996 and 2006.

In Table 4.10 it can be seen that the growth of soybean areas was larger than the growth of sugarcane areas in Paraná and this also happened in the (micro)regions where the growth of sugarcane was important (except one: Paranavaí). In 2006, soybeans areas were 9 times higher than the sugarcane area while the ratio between corn and sugarcane areas was 5.7. Conversely, the areas cropped with rice and beans were reduced between 1996 and 2006.

Table 4.10 Growth or reduction of pasturelands and of cropland for sugarcane and soybeans, between 1996 and 2006 (ha)

State	Sugarcane	Soybeans	Pastures	Soybeans/Cane	Pastures/Cane
Paraná	132,745	152,784	-942,218	15%	610%
MT do Sul	70,740	811,311	-3,389,280	1,047%	4,691%
Mato Grosso	68,232	1,606,892	1,356,960	2,255%	1,889%

Source: IBGE (Agricultural Surveys 1996 and 2006)

Along the period 1996-2006 there was deep reduction of pasturelands in Paraná, and this reduction was about six times higher than the expansion of sugarcane areas. In Table A.16 it can be seen that the reduction of pasturelands was larger (and in some cases much larger) than the growth of sugarcane areas in all regions where the evolution of sugarcane production was important.

From 1996 to 2006 the reduction of pasturelands was proportionally higher than the changes in cattle heads[60]. As consequence, there was an increase on cattle's density, as can be seen in Table 4.11. In Table A.18 (Annex A) it can be seen that the reduction of cattle heads was larger in all regions where the growth of sugarcane areas was more significant in the period.

Table 4.11 Reduction of pasturelands and evolution of cattle's density between 1996 and 2006

State	Pasturelands (1000 ha)		Cattle's density (heads/ha)			
			IBGE's Surveys		IBGE-PAM	
	1996	2006	1996	2006	1996	2006
Paraná	6,677.3	5,735.1	1.48	1.60	1.48	1.70
MT do Sul	21,810.7	18,421.4	0.91	0.80	1.13	1.29
Mato Grosso	21,453.1	22,809.1	0.67	0.86	0.73	1.14

Source: IBGE (various years)

4.4.2 Mato Grosso do Sul

The Pantanal Mato-Grossense biome occupies most of the west bound of Mato Grosso do Sul, it this is a very important aspect regarding land use and land use change in the state. Agricultural lands are in the east bound of the state and they are used mostly for grains production and, more recently, for sugarcane production. The enlargement of sugarcane areas occurred in the Southwest and in the East regions of Mato Grosso do Sul; more specifically, about 35% of the enlargement of sugarcane areas occurred in the micro region of Dourados (see Figure A.3, in Annex A)[61].

According to the recent study published by CONAB (2008), Mato Grosso do Sul was in 2007 the third largest state regarding expansion of sugarcane areas[62], and most of the enlargement occurred in areas previously used for pastures and grains cropping (soybeans and corn) (see Table 4.3).

In the state, about 50%[63] of sugarcane areas are in the Southwest region, while more than 30% of sugarcane areas are located in the East region. It is worth to mention that in Southeast region soybean areas are much larger than sugarcane areas (13 to 21 times larger, during the 2000s, depending on the year), while in the East region this ratio has been about 5 to 7 times. In the Southwest region the area devoted to corn production is also much larger than sugarcane area (6 to 10 times).

As can be seen in Table 4.10, the growth of soybean areas between 1996 and 2006 was much larger than the growth of sugarcane areas in the state. In the same table it is also possible to see that the phase-out of pasturelands was more than enough to make possible the growth of

[60] There was a small reduction of cattle heads, no matter the data basis considered (see Table 4.7).

[61] Information about the existing mills in Mato Grosso do Sul, by mid 2008, are presented in Table A.19, Annex A.

[62] According to the Jornal da Cana, the state government of Mato Grosso do Sul has offered tax exemptions for about 10 years in order to motivate investments in new ethanol industrial units. According to the information published (Anselmi, 2008, p. 59), it has been relatively easy to get the environment license in Mato Grosso do Sul. In addition, is some cases tax exemptions are also negotiated with the local government (of the municipalities).

[63] Average figure for the period 2000-2006.

soybeans and sugarcane areas, without deforestation. In the regions that had a significant growth of sugarcane areas in the same period, the enlargement of sugarcane areas was also larger than the phase-out of pasturelands (see Table A.22)[64].

In the case of Mato Grosso do Sul, the divergence of IBGE's data regarding cattle heads brings contradictory results about cattle's density: based on data of IBGE's Surveys there was a reduction on cattle heads (see Table 4.7) and the same can be concluded regarding cattle's density (see Table 4.11); on the other hand, based on the IBGE-PAM data basis, the conclusions are exactly the opposite (again, see Table 4.11). In the first situation a possible deduction would be that there was displacement of livestock to other states, but this hypothesis could not be confirmed by the second analysis.

4.4.3 Mato Grosso

During the 1990s, none new sugarcane industry was installed in Mato Grosso[65], what can be explained by two points: first, logistics constraints[66], and second, difficulties to get environmental licenses (Anselmi 2008, p. 60).

However, in recent years sugarcane areas have grown significantly. Sugarcane area grew 50% from 2000 to 2007 (total growth of 67 thousand hectares), and this growth was almost totally concentrated in the Southwest region (42,000 ha) and North region (18,000 hectares) (see Table A.24); more specifically, the bulk of growth happened in the micro regions of Tangará da Serra and Parecis (see also Figure A.4, in Annex A).

Opposing regarding what happened in other regions of the state, in Southwest region sugarcane area is larger than the area used for soybeans and corn cropping; soybeans area raised from 2000 to 2006, but corn areas decreased in the same period.

As can be seen in Table 4.10, between 1996 and 2006 the growth of soybean areas was much larger than the growth of sugarcane areas. Mato Grosso was the only state in the Centre-South region with growth of pasturelands along the period, and this growth was also much larger than the growth of sugarcane areas.

Along the period there was simultaneous expansion of pasturelands and of cattle heads. There was an increase of cattle's density, as can be seen in Table 4.11, but in Mato Grosso the density is the lowest among all states of Centre-South region.

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[64] In the whole state, considering the period 1996-2006, the raise of sugarcane areas was only 2% of the area made available due to the phase-out of pastures. This figure varies from 1.2% to 4.6% in micro regions that had significant growth of sugarcane areas.

[65] Information about existing mills in mid-2008 are presented in Table A.25, Annex A. There was 11 industrial units of ethanol production, being six autonomous distilleries and five annex distilleries.

[66] For instance, the group Brenco (Companhia Brasileira de Energia Renovável) is building ethanol facilities in Goiás and Mato Grosso do Sul and intends to operate a duct since mid 2011 in order to reach the Santos harbour (1,120 km and costs of about US$ 1 billion. With additional investments it would be possible to build more 600 km, and make feasible exports of ethanol produced in Mato Grosso. Entrepreneurs of Mato Grosso are also asking for investments by Transpetro, the logistics division of Petrobras (Anselmi, 2008, p. 60).

4.4.4. Northeast region

In Brazil, during the two last harvest seasons (2006-2007 and 2007-2008) the enlargement of sugarcane areas was estimated as 1.2 million hectares (581,000 ha and 653,000 ha, respectively). Taking into account these figures, the share of the North-Northeast region over the total growth was equivalent to no more than 7% and 5.6%, respectively in 2006-2007 and 2007-2008 (CONAB, 2008, p. 70).

According to CONAB (2008), in the Northeast region almost 37,000 ha of new sugarcane areas were planted during the harvest 2007-2008, being 13,600 ha planted in former pasturelands while 16,000 ha were planted displacing other crops. It is worth to mention that 7,000 ha were planted in new areas, indicating that deforestation has possibly occurred in the states of Maranhão, Rio Grande do Norte and Piauí (see Table 4.12). In five states of the region there was growth of sugarcane areas, being the most significant enlargements in Maranhão and Pernambuco.

Table 4.12 Growth of sugarcane areas in Northeast states during the harvest season 2007-2008, and crops displaced (ha)

State	Former pasturelands	New areas	Other crops displaced	Total growth	Share regarding NE (%)
Alagoas	3,135	-	3,590	6,725	18.4
Pernambuco	2,461	-	5,229	7,690	21.0
Paraíba	874	-	1,044	1,918	5.2
Rio Grande Norte	1,743	2,413	1,054	5,210	14.2
Bahia	3,717		1,000	4,717	12.9
Maranhão	808	2,692	4,230	7,730	21.1
Piauí	-	1,650	-	1,650	4.5
Sergipe	961	-	-	961	2.6
Ceará	-	-	-	-	0.0
Total	13,699	6,755	16,147	36,601	
Share (%)	37.4	18.5	44.1		

Source: CONAB (2008)

On the other hand, from 1996 to 2006 sugarcane area in Northeast region was reduced 6% (from 1.2 million ha to 1.1 million ha), being the most important reduction in Pernambuco (28.2%, or 132,000 ha). Conversely, the largest growth occurred in Maranhão (see Table 4.13).

It is considered that there is reasonable potential for sugarcane enlargement in Maranhão, due to better weather conditions regarding other states in the region, and also due to more than 6 million ha currently occupied with pasturelands.

Figure 4.24 shows information about land use change from 1996 to 2006 in Northeast and Maranhão. In Northeast there was significant growth of areas devoted to the production of corn, cassava and, mainly, soybeans. Conversely, in Maranhão the growth of sugarcane areas was relatively small regarding some crops, and in special regarding soybeans.

Table 4.13 Sugarcane areas in Northeast during harvest seasons 1996-1907 and 2006-2007

States	2006-2007	1996-1997	Variation (ha)	Variation (%)
Maranhão	39,301	17,473	21,828	124.9
Piauí	10,213	8,058	2,155	26.7
Ceará	29,067	25,381	3,686	14.5
Rio Grande do Norte	55,623	55,688	-65	-0.1
Paraíba	116,115	101,655	14,460	14.2
Pernambuco	336,765	469,045	-132,280	-28.2
Alagoas	402,253	432,236	-29,983	-6.9
Sergipe	38,853	22,764	16,089	70.7
Bahia	106,455	76,154	30,301	39.8
Northeast	1,134,645	1,208,454	-73,809	-6.1

Source: IBGE (Produção Agrícola Municipal) (various years)

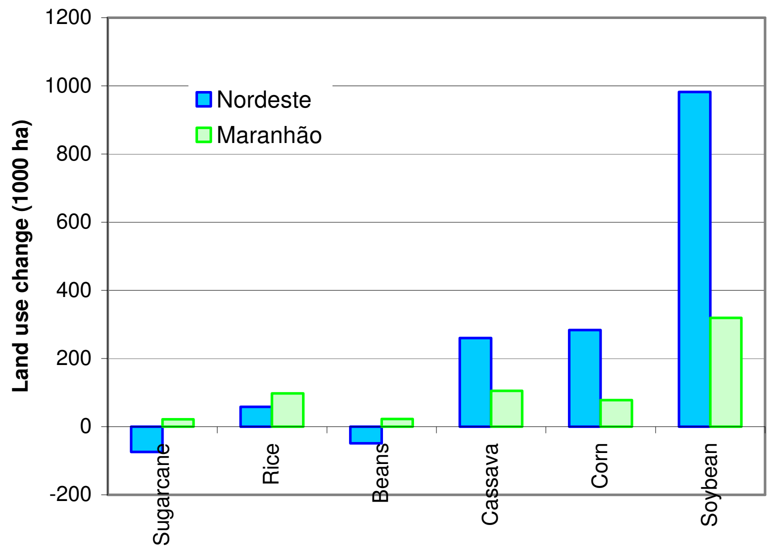

Figure 4.24 Changes in land use in Northeast and Maranhão, from 1996 to 2006

Conversely, Figure 4.25 shows planted areas with different crops in Northeast, from 1996 to 2006. It can be seen that the sugarcane area is relatively small regarding other crops. Along the period there was a remarkable growth of areas devoted to soybeans and beans production.

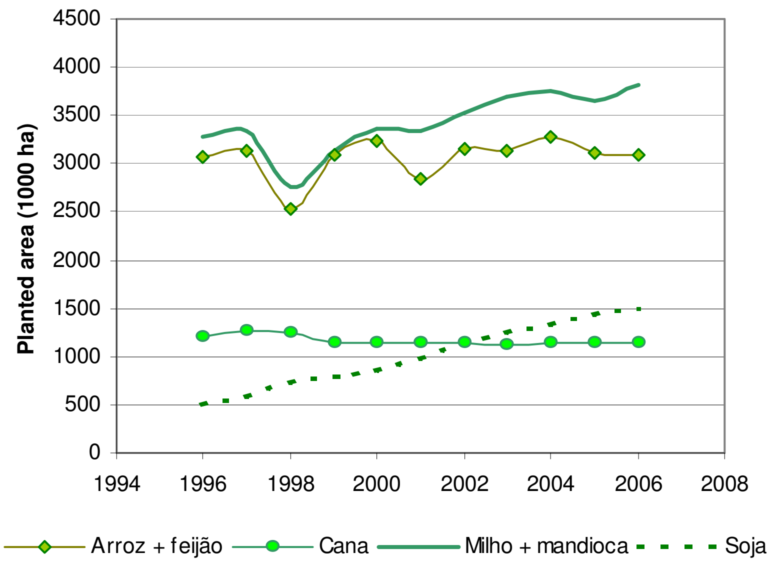

Figure 4.25 Planted areas with different crops in Northeast, from 1996 to 2006.

Along the decade 1996-2006, forested areas in Northeast grew remarkably – 5.8 million ha –, due to the expansion of silviculture for pulp and paper production in Bahia and Maranhão, being 1.8 million ha planted in Maranhão. Also in Maranhão the growth of pasturelands was 852,000 ha in the same period.

In Maranhão, the growth of sugarcane areas has concentrated in four regions (Imperatriz, Coelho Neto, Porto Franco and Chapada das Mangabeiras) that altogether summed-up 91% of the total expansion (20,000 ha). In two of these regions the growth of soybeans production was larger than sugarcane (Chapada das Mangabeiras and Porto Franco) and in two regions the same happened regarding corn (Coelho Neto and Porto Franco).

4.5 Concluding remarks

The growth of sugarcane areas in the Northeast region has been small compared to the expansion in Centre-South region. However, the state of Maranhão seems to be a new producer region of crops, including sugarcane. Due to rapid changes on land use in that state, it is important to follow with attention this tendency and its effects.

Table 4.14 summarises main changes on land use from 1996 and 2006 in the six main producer states of sugarcane in the Centre-South region. Along the period, almost 90% of the enlargement of sugarcane areas was concentrated in four states (São Paulo, Minas, Paraná e Goiás) and in those there was significant phasing-out of pasturelands, and also growth of forested areas. Except São Paulo, both the growth of forested areas and the reduction of pasturelands were larger than the growth of sugarcane areas. Conversely, in two states (Mato Grosso do Sul e Mato Grosso) the reduction of forested lands was remarkable, but in either cases the enlargement of sugarcane areas represented a small fraction of the enlargement of soybean areas.

Table 4.14 Main changes in land use in the six main producer states of sugarcane in the Centre-South region, from 1996 to 2006 (areas in 1000 ha)

State	Sugarcane	Soybeans	Pastures	Forests
São Paulo	792	93	-468	372
Minas	184	538	-4.794	1.428
Paraná	133	153	-942	378
Goiás	120	1.611	-3.880	1.393
Mato Grosso do Sul	71	811	-3.389	-927
Mato Grosso	68	1.607	1.357	-3.785

The general conclusion of this Chapter is that the growth of croplands, and more specifically the growth of sugarcane areas, occurred mainly in lands previously occupied with pastures. Other conclusion is that the growth of sugarcane areas did not induce the displacement of cattle heads to other regions of Brazil, as cattle's density raised in all states considered.

Chapter 5

Land Use Change in Brazil due to Ethanol Production – Indirect Impacts

5.1. Introduction

Different land uses result in different levels of profitability. Physical and geographical variables as well as market and governmental strategies generally determine land uses in a given time interval. It has been observed that, in general, the economic function has been the most strong and most frequent driver for land use change in the world.

As previously mentioned, one the main concerns regarding sustainability of ethanol production in Brazil is related to in what extent the enlargement of sugarcane areas have caused direct and indirect land use changes. Chapter 4 reports the results of the analysis done regarding direct impacts of land use change. In this Chapter the analysis corresponds to the indirect impacts of land use change. The focus point of the analysis is for identifying the economic drivers of land use change in some regions of concern, such as the Amazon region and the Cerrado.

5.2 Land use change and ethanol production: a literature review

This section reports a brief literature review about current (and future) enlargement of ethanol production in Brazil and its consequence over land use and food supply.

The book Sugar Cane's Energy, edited by Macedo (2005), has a chapter devoted to the analysis of soil occupation in Brazil and the potential consequences (if any) of sugarcane expansion[67]. The text highlights that at the time the text was written, agriculture occupied only 7% of Brazilian territory, and the share occupied by sugarcane was even smaller (0.6%); moreover, country's soil was mostly occupied by pastures (around 35%) and forests (55%)[68]. According to the reference, the expansion of sugarcane crops has essentially replaced other agricultural exploitations or cattle breeding. Along the next few years expansion will take place in western of state of São Paulo and its borders (as shown in Chapter 4), in areas that are very far from the current biomes of the Amazon Rain Forest, the Pantanal or the remaining Atlantic Forest. However, and also according to the reference, the occupation of the Cerrado must be planned to protect biodiversity and water resources. Regarding direct impacts of land use change, this is a very important issue despite the fact that it was shown in Chapter 4 that so far most of land use change in the Cerrado region was not due to sugarcane expansion; nevertheless, Cerrado is one of the potential areas for sugarcane expansion and environmental impacts could occur at a large extent.

It has been mentioned, based on an estimate by Embrapa (2006), that about 90 Mha would be available for the enlargement of agricultural activities and, thus, there was no special constrain for sugarcane plantations. These 90 Mha would be mainly located in the "Cerrado" region[69]. As

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[67] Chapter 6 – "Soil occupation: new production areas and biodiversity".

[68] These percentages do not correspond to the current situation, but as previously mentioned in this report croplands still occupy a small share of the territory, while sugarcane areas represent about 2% of the arable land, including sugarcane use for sugar production.

[69] Cerrado has a biome that in some sense is similar to the African savannah.

shown in Chapter 4, Cerrado has been occupied very rapidly, with previous deforestation,[70] due to expansion of soybeans and cattle. Even considering that the land required for the enlargement of sugarcane area would be a fraction of the total area available, environmental organizations would probably claim about non-controlled sugarcane expansion in this region.

On the other hand, the area previous mentioned by Embrapa (90 Mha) is larger than the area that should be indicated by the Agro-ecologic Zoning (see section 2.9.1) as adequate for sugarcane expansion (no more than 45 Mha).

Another very common assertion is regarding the area occupied by the main crops in Brazil. Macedo and Nogueira (2005) comment that in 2004 the area occupied with soybeans plantation was estimated as 21.5 million hectares, while in the same year the area occupied with sugarcane was estimated as 5.6 million hectares. In 2006, according to the IBGE's last Agricultural Survey (IBGE, 2008), the area occupied with soybeans was 22.1 Mha, while the area occupied with sugarcane was almost 6.2 Mha. In the same year the areas planted with corn were 13 Mha and areas planted with beans summed-up 4.2 Mha. There are concerns regarding soybeans and sugarcane due to the high concentration of their production and the tendency of enlargement.

Specifically regarding São Paulo, Scaramucci and Cunha (2004) mentioned that in the state new sugarcane plantations are located in lands previously used for cattle and for orange production. The main reason is that landowners expect larger revenues with sugarcane production and so many have decided to switch from orange. In addition, a significant share of sugarcane (30-35%) has been produced by relatively small farmers, who sell their production to the mills. Other share of about 30-35% of sugarcane is produced in lands rented for the mills owners. In both cases, the short-term revenue perspective induces the decision.

More recently, Zuurbier (2008) has stated that over the past 15 years soybeans have moved North into the Cerrado and up to the Amazon region. The movement has been induced by deforestation that is motivated by timber trade and by land tenure. After deforestation, the faster and cheaper way to occupy these lands is through cattle breeding; cattle owners use to stay about 3 to 4 years in a place, without applying any kind of technology for soil maintenance or recovery. When the soil is useless, cattle owners move to other abandoned areas and soybean farmers come to the areas available, replacing livestock; the investment for fertilizing the area for soybean production is more than compensated by the low land's price. Zuurbier (2008) concludes that sugarcane ethanol production in Centre-South is not pushing cattle and soy farming into the Amazon region; moreover, he states that deforestation induces soybean production near the Amazon, and not the other way around.

In a study mostly focused on state of São Paulo, Smeets et al. (2008) state that additional research is required in order to assess direct and indirect impacts of ethanol production on food security and to develop suitable criteria and indicators[71]. However, as state in section 2.2, land use change arising as indirect result of biomass production would be difficult to monitor, as recently recognised by UK Government (Department of Transport, 2008a).

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[70] For instance, see in Chapter 4 the extension of forested lands that were phased-out from 1996 to 2006, mainly in Mato Grosso.

[71] The authors suggest as possible indicators the food intake, food purchasing power, food prices and land use patterns.

5.3 Exercise on likely drivers on land use change

This section reports the analysis developed aiming at identifying direct drivers acting on deforestation in the states of Pará and Mato Grosso. The methodology is based on the analysis of correlation in an attempt to identify direct and indirect impacts of sugarcane expansion areas on natural land and food production.

Data basis was compiled from different sources (e.g., IBGE, CONAB, CEPEA, IEA, INPE, MAPA, FNP, etc.), for the harvests 1999-2000 to 2005-2006.

5.3.1 Deforestation in the state of Pará

Pará is the state with the largest deforestation rate in the Amazon region. Deforestation in Pará is represented by the deforestation figures in a sample of 30 municipalities that had the highest deforestation areas in 2006. These municipalities were chosen based on INPE (2007); they are listed in Table B.1, Annex B. Following, the set of municipalities were analysed according to different land uses, such as cattle ranching and production of cassava, corn, rice, soybeans and sugarcane. The analysis included timber trade at the end. The sample of 30 municipalities covers 47% of the state area and 58% of the deforested area in Pará, as shown in Table 5.1.

Table 5.1 Sample of 30 municipalities regarding the whole state of Pará – 2006

	Sample	Pará	Sample/Pará (%)
Area (1,000 ha)	59,013	125,318	47
Deforested area (1,000ha)	13,793	23,599	58

Sources: IBGE (2008), INPE (2007)

Based on data of INPE (2007) and IBGE (2008) it was possible to identify new land uses in the set of 30 municipalities with large deforestation in 2006. Results are presented in Table 5.2. It can be seen that from 13.79 Mha deforested up to 2006 in these 30 municipalities, the destination of 8.36 Mha can be identified as due to new areas for expansion of different crops and also for cattle breeding. All crops considered had an insignificant area growth regarding the total accumulated area that was deforested. On the other hand, the enlargements of pasturelands explain the destination of 57% of the area made available through deforestation. The destination of almost 40% of the deforested area cannot be explained by the uses listed in Table 5.2.

It is clear that other agricultural activities could have enlarged, but it is unlikely that small activities could explain the occupation of such large area. The only likely land use able to explain this gap seems to be deforestation for timber activities on native forest, together with charcoal production using non log forest (residues). These areas could have been partially or totally abandoned after the clear cut, either because legal or economic constraints for pasturing or cropping.

Table 5.2 New land uses and their shares regarding deforested areas in 2006 – set of 30 municipalities in state of Pará

Crops/uses	Area (1,000 ha)	Share (%)
Corn	181.1	1.3
Cassava	106.7	0.8
Beans	22.9	0.2
Rice	127.8	0.9
Sugarcane	8.1	0.1
Soybeans	51.6	0.4
Pastures	7,865.3	57.0
Others crops (uses) + timber	5,429.5	39.4

Sources: IBGE (2008), INPE (2007)

Also considering the set of 30 municipalities as representative of recent tendencies in Pará, some correlations were analysed aiming at identifying the main drivers of deforestation. Results are presented in Table 5.3, always taking accumulated deforested area from 2000 to 2006 as the dependent variable. Among the results presented, only the enlargement of pasturelands could be understood as a direct driver of deforestation; in this case the correlation coefficient was estimated as 90.8%.

Cattle prices have a negative strong correlation (-98.9%) regarding deforested areas, suggesting retention of cattle at the field due to price reduction in that period. Deforestation is also strongly correlated with cattle herd (90.3%), reinforcing this hypothesis. Compared to Brazil, the rate of cattle female slaughter in Pará is traditionally lower, and it was even reduced in the period which can be explained by the necessity of retaining cattle at the field, as well as to foster calf production.

Factors such as reduction of world cattle herd, increase in domestic and external demand of cattle meat, and increase in cattle exports, play important role as heaters of the market. The results obtained for the correlation coefficients are in line with this hypothesis.

Based on the hypothesis that timber trade and charcoal production are important drivers of deforestation in Brazil, the following correlations were tested. A good and positive correlation (95.3%) is observed between deforestation in Pará and charcoal domestic demand; the correlation between deforestation in Pará and iron and steel production in Brazil is not good enough (67.1%) but could be considered anyhow[72]. Furthermore, the correlation between deforestation in Pará and sawn wood exports is good enough (82.6) and can be seen as another evidence.

[72] According to Monteiro et al (2005), forest residues from 900,000 ha, plus 82,000 ha of whole forest, are annually used for charcoal production in the Amazon region mostly for ten cast iron industries close to Carajá railway corridor.

Table 5.3 Correlation results – accumulated deforestation in Pará (PA) versus likely drivers (explanatory variables) – 2000 to 2006

Likely drivers	Observation	R (%)	Effect on LUC
Pastureland area (conversion)	in Pará	90.8	Direct
Cattle herd in PA		92.3	Indirect
Cattle female slaughter in PA/BR		-72.1	Indirect
Cattle slaughter in PA/BR		51.2	Indirect
Cattle prices	in Brazil	-98.9	Indirect
Cattle meat, domestic demand	in Brazil	62.5	Indirect
Cattle meat, external demand		93.1	Indirect
World cattle herd		-86.8	Indirect
Cattle meat exports	in Brazil	99.5	Indirect
Sawn wood exports	in Brazil	82.6	Indirect
Charcoal domestic demand (native forests)	in Brazil	95.3	Indirect
Iron/steel domestic production	in Brazil	67.1	Indirect

Notes: It is estimated that the enlargement of pasturelands could directly explain about 57% of the deforestation (see Table 5.2). It is estimated that timber and charcoal production could explain at least about 40% of the deforestation (see Table 5.2).
Sources: IBGE (2008); INPE (2007); CONAB (2008), Agrianual (2008); CEPEA (2008); IEA (2008); MAPA (2008); Anualpec (2007).

In summary, there are strong evidences that deforestation in Pará is highly correlated with enlargement of pasturelands and also with activities such timber trade, charcoal production and sawn wood trade.

5.3.2 Deforestation in Mato Grosso

The state of Mato Grosso has the highest cattle herd and the largest soybean area in Brazil. As presented in Chapter 4, the deforested area in Mato Grosso from 1996 to 2006 was very high, and so the enlargements of the pasturelands and soybean area.

The same procedure described in the previous section, regarding deforestation in Pará, was applied in case of Mato Grosso. A sample of 30 municipalities was defined based on INPE (2007); the list of municipalities and some information about them are presented in Table B.2, Annex B.

Following, based on IBGE (2008) those municipalities were analysed according to different land uses (cattle ranching, and production of cotton, corn, sorghum, rice, soybean and sugarcane). This sample of municipalities covers 41% of the total area in Mato Grosso and 57.5% of the deforested area (see Table 5.4). Deforestation appears as 21% of the overall area and 30% of the sample area. Thus, it is probably inside the limits set for Legal Reserve in this region.

Table 5.4 Sample of 30 municipalities regarding the whole state of Mato Grosso – 2006

	Sample	Mato Grosso	Sample/MT (%)
Area (1,000 ha)	37,141	90,681	41
Deforested area (1,000ha)	10,983	19,095	57.5

Sources: IBGE (2008), INPE (2007)

Once more, following the same procedure described in the previous section, and based on data of INPE (2007) and IBGE (2008), the areas of the most important land used were identified. Results are presented in Table 5.5.

Table 5.5 New land uses and their share regarding deforested areas in 2006 – set of 30 municipalities in state of Mato Grosso

Crops/uses	Area (1,000 ha)	Share (%)
Corn[1]	263.4	2.4
Sorghum[1]	36.5	0.3
Cotton	48.5	0.4
Rice	306.1	2.8
Sugarcane	42.7	0.4
Soybean	1.748.0	15.9
Cattle	8.837.3	80.5

Data sources: IBGE (2008), INPE (2007)

Note: [1] Considered as using the same area than soybean (“safrinha”)

Aiming at identifying the main drivers of deforestation in Mato Grosso, some correlations were adjusted always taking accumulated deforested area from 2000 to 2006 as the dependent variable. Results are presented in Table 5.6. Only the enlargement of pasturelands could be understood as a direct driver of deforestation and, in this case, the correlation coefficient was estimated as 98.1%. Thus, as expected, the correlation is strong and positive.

Accumulated deforestation and cattle price have strong and negative correlation (-98.6%), suggesting retention of cattle at the field due to price reduction in that period. This results is similar to the one obtained in the case of Pará. Comparing the results obtained for Pará (previous section) and these presented here for Mato Grosso, the same conclusions are gotten concerned direct drivers for enlargement of pasturelands (e.g., increase in domestic and external cattle meat demand, and increase in cattle exports).

Charcoal domestic demand, fostered by increase of iron and steel production, is strongly and positively correlated with accumulated deforestation in Mato Grosso. Considering that most municipalities sampled are in the borderline with Para and Amazon states, one possibility is that charcoal could be going the cast iron industries in Pará. A hypothesis is that charcoal production helps to pay deforestation costs. However, further study is required to check how production of charcoal has expanded in Mato Grosso in recent years, and its correlation with deforestation.

Table 5.6 Correlation results – accumulated deforestation in Mato Grosso (MT) versus likely drivers related to pastureland use versus cattle uses and markets (explanatory variables) – 2000 to 2006

Likely drivers	Observation	R (%)	Effect on LUC
Pastureland area in MT (conversion)		98.1	Direct
Cattle herd in MT		99.0	Indirect
Cattle female slaughter in MT/BR		-96.0	Indirect
Cattle slaughter in MT/BR		-69.6	Indirect
Cattle prices	in Brazil	-98.6	Indirect
Cattle meat domestic demand	in Brazil	62.5	Indirect
Cattle meat external demand		93.1	Indirect
World cattle herd		-86.8	Indirect
Cattle meat exports	in Brazil	99.5	Indirect
Charcoal domestic demand (native forests)	in Brazil	95.2	Indirect
Iron/steel domestic production	in Brazil	68.8	Indirect

Notes: It is estimated that the enlargement of pasturelands could directly explain about 80% of the deforestation (see Table 5.5).

Sources: IBGE (2008); INPE (2007); CONAB (2008); Agrianual (2008); CEPEA (2008); IEA (2008); MAPA(2008); Anualpec(2007)

Table 5.7 Correlation results – accumulated deforestation in Mato Grosso (MT) versus likely drivers related to soybeans production and its market (explanatory variables) – 2000 to 2006

Likely drivers	Observation	R (%)	Effects on LUC
Soybean area in MT (conversion)		98.3	Direct
Soybean domestic demand	in Brazil	93.4	Indirect
Soybean external demand		96.5	Indirect
Chicken domestic demand	in Brazil	99.0	Indirect
Chicken slaughter in Centre-West region		98.4	Indirect
Pork slaughter in Centre-West region		96.8	Indirect
Chicken external demand	in Brazil	96.3	Indirect
Pork external demand	in Brazil	88.3	Indirect
Accumulated soybean net revenue in MT		82.7	Indirect
Soybean domestic price in MT	in Brazil	-37.2	Indirect
Soybean external prices		44.7	Indirect
Charcoal domestic demand (native forests)	in Brazil	95.2	Indirect
Iron/steel domestic production	in Brazil	68.8	Indirect

Notes: It is estimated that the enlargement of soybean area could directly explain about 16% of the deforestation (see Table 5.5).

Sources: IBGE (2008); INPE (2007); CONAB (2008); Agrianual (2008); CEPEA (2008); IEA (2008); MAPA (2008); Anualpec (2007)

Soybeans production represents a direct land use conversion; the correlation between soybean area and accumulated deforested areas was calculated as 98.3%, as can be seen in Table 5.7. Various potential indirect drivers for deforestation (i.e., direct drivers for the expansion of soybean area) were tested, and many of them have a good correlation regarding accumulated deforested areas (e.g., soybean demand, both domestic and international; chicken and pork slaughter in the Centre-West region, etc.). According to Marta (2008), soybean-crushing plants were decisive for the development of agro-clusters in Mato Grosso. In addition, the increase in pork and chicken slaughter in the Centre-West region fostered indirectly soybean meal demand and, consequently, soybean production area.

Conversely, soybean domestic prices are in the opposite direction of most analysed drivers (R = -37.2%), which suggests that processed, transformed and exported soybean is responsible for the bulk of area enlargement.

In summary, there are strong evidences that deforestation in Mato Grosso is strongly correlated with expansion of cattle ranching and, in a small extent, with the enlargement of soybean areas.

5.3.3 Growth of sugarcane areas in state of São Paulo

In order to check if the recent expansion of sugarcane in the state of São Paulo has caused indirect impacts in other states the same procedure based on correlation analysis was applied; main results are presented in Table 5.8

It can be seen that the growth of sugarcane area in São Paulo has a relatively strong correlation with the reduction of pasturelands in the state in the period 2000 to 2006 (88.5% and negative, as sugarcane area grows and pasturelands reduces). This issue has been analysed in Chapter 4 and one the main conclusions is that in fact sugarcane expansion is displacing pasturelands. Based on this result, a fast deductive conclusion would be that the expansion of sugarcane in São Paulo could be inducing the reduction of cattle herd in São Paulo[73], consequently creating the opportunity for enlarging livestock in other states, such Mato Grosso and Pará. However, as can be seen in Table 5.8, the growth of sugarcane areas in São Paulo is even better correlated with the reduction of cattle herd in Rio Grande do Sul. Clearly there is no reason to suppose that there is a cause-effect ratio in this regard.

Table 5.8 Correlations between growth of sugarcane area in São Paulo and direct and indirect impacts – 2000 to 2006

Cases analysed	R (%)
Sugarcane area in SP x Pastureland area in SP (conversion)	-88.5
Sugarcane area in SP x Cattle herd in RS	-98.7
Sugarcane area in SP x Bean area in SP (conversion)	-83.8
Sugarcane area in SP x Bean area in RS	-85.1
Deforestation in MT x Cattle herd in SP	-64.3
Deforestation in PA x Cattle herd in SP	-62.7

Sources: IBGE (2008); INPE (2007); CONAB (2008); Agrianual (2008); CEPEA (2008); IEA (2008); MAPA (2008); Anualpec (2007)

The relatively strong correlation between the growth of sugarcane area and the reduction of bean area in São Paulo (83.8%, and negative) could be seen as an evidence of disruptions on food

[73] In section 4.3.1 this issue is analysed and the conclusion is that it is not the case.

supply in the state. However, the result is equivalent regarding bean area in Rio Grande do Sul and, again, there is no reason suppose a cause-effect ratio in this regard.

Finally, deforestation in Mato Grosso and in Pará are weakly and negatively correlated with cattle herd in São Paulo. The weak correlation should be seen as evidence that sugarcane is not causing indirect impacts such as deforestation in other states. However, the two results are influenced by the data basis of 2006 IBGE's Survey regarding cattle herds in São Paulo (see Table 4.7) that indicates reduction in the period

5.4 Conclusions

As previously mentioned, it is difficult to evaluate indirect impacts on land use change, in particular regarding the recent growth of sugarcane. The results presented in this Chapter do not allow any conclusive assertive if indirect impacts exist or not.

There are clear evidences that deforested areas in Amazon and in Cerrado[74] have been used mostly for pasturelands and in less extent to soybean production. However, based on the results presented it is not possible to conclude that cattle ranching and soybean production are drivers of deforestation, or if both activities are just moving towards deforested areas, driven by for example food demands suggested by results shown in the tables 5.6 and 5.7 above.

On the other hand, there is no evidence that the growth of sugarcane is São Paulo has caused deforestation in Centre-West and in North of Brazil. The conclusions presented in this Chapter reinforce the conclusions of Chapter 4.

However, the development of an adequate methodology for analysing indirect impacts of land use change is still essential.

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[74] Analysis done based on deforestation data in Pará and Mato Grosso, respectively.

Chapter 6

Socio-Economic Aspects of Ethanol Production in Brazil

6.1 Introduction

The positive macro-economic results of large-scale ethanol production in Brazil, such as job creation at low cost, reduction of foreign debt, etc., have been highlighted in a number of studies (e.g., see Moreira and Goldemberg, 1999; Macedo, 2005; Goldemberg et al, 2008). However, very little is known about the socio-economic impacts of ethanol production at regional level. The discussion about sustainability criteria in Europe indicates that priority should be given to this issue.

The next section is devoted to summarize the benefits that have been highlighted in previous studies, while section 6.3 summarises updated information about socio-economic aspects of ethanol production in Brazil. Section 6.4 onwards is devoted to the analysis of some socio-economic aspects of ethanol production, specifically at regional level.

6.2 A review on socio-economic aspects

This section is based on literature review. The information is about the following aspects: number of jobs, working conditions and wealth, education level, land tenure and infrastructure in the cities where sugarcane production is concentrated.

6.2.1 Number and quality of jobs

The seasonal pattern of agricultural operations has a strong influence over the number and the quality of jobs created by sugarcane industry (Macedo, 2005)[75][76]. The technology in use determines labour-force requirements during the harvest and in-between harvest cycles. Low technology implies more temporary labour and low salaries.

From 2000 to 2002, the number of direct jobs in the sugarcane industry[77] rose about 18% (642.8 thousand to 764.6 thousand)[78]. In 2002, 62 percent of all formal jobs were offered in the Centre-South region, and the difference in North and Northeast regions (Moraes, 2005).

Also, according to Moraes (2005), the tendency is the reduction of jobs in the agriculture due to advances in mechanization, mainly in São Paulo. From 2000 to 2002 the relative share of agriculture fell from 55.5% to 48.1%.

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[75] Chapter 12 (Socioeconomic impacts of the sugar cane agribusiness) of the book Sugar Cane's Industry, organized by Macedo (2005).

[76] On average, in Brazil the harvest period is constrained to six or seven months per year.

[77] Including sugarcane production, at the field, and sugar and ethanol production at the mills.

[78] In 2000 the index was about 400 tonnes of sugarcane per worker (planted, harvested and processed), and it was almost 420 tonnes of sugarcane per worker in 2002.

The total number of formal employees increased from 53.6% in 1992 to 68.8% in 2003. The level of formal employment in the Centre-South region is much higher than in North-Northeast, particularly in São Paulo where 88.4% of all workers had formal working papers in 2003 Moraes (2005).

Macedo (2005) presents details of people formally employed by the sugarcane industry, in 2002. The group that corresponds to 30-39 year-old people was the largest (29.2% of the total), with the bulk of the employees between 18 and 49 years old (90.4%). The author emphasized the small share (0.3%) of employees less than 17 years old[79].

Regarding the mean education level, the group of workers having not concluded 4th grade prevailed in 2002 (37.6%), followed by those who finished 4th grade (18.6%). A significant fraction of illiterate workers was mentioned (15.3%) (Moraes, 2005). In the North-Northeast region, 39% of all workers are illiterate and 45.8% did not finish 4th grade, summing-up 84.8 percent of the total.

In turn, sugarcane industry has best indicators regarding education in the Centre-South region: the share of illiterates vary from 2.9% (sugar production) to 5.4% (ethanol production) while the share of workers who failed to graduate from 4th grade varies from 24.7% to 38.1% (ethanol and sugarcane production, respectively) Moraes (2005).

Regarding salaries, in 2002 the mean monthly salary for all industries in Brazil was R$ 483.24, while for the sugar industry it was R$ 501.64, and for the ethanol industry R$ 554.83. Salaries were higher in the Centre-South region regarding those paid in North-Northeast region (42% to 82%, depending on activity) (Macedo, 2005).

Hoffmann (2005) compares the income of employees in the sugarcane industry with the income of workers in other crops (rice, soybean, coffee, etc.). The author also compares the income distribution of people engaged in sugarcane industry with the income of workers in other economic sectors (e.g., food and beverage industry, chemical industry, coke, oil refining). In 2003, sugarcane production displayed the lowest wages and the lowest mean education level (2.9 years)[80]. Based on PNAD's data for 2003, Hoffmann (2005) shows that there were 522.9 thousand workers involved with sugarcane production[81].

Hoffmann (2005) also compared the income of workers involved with sugarcane production with workers involved with other crops (e.g., rice, banana, coffee, citrus, cassava, corn and soybean). The author shows that, on average, workers involved with soybean and citrus cropping have higher income, while the lowest income concerns to workers involved with corn and cassava cropping.

Goldemberg et al. (2008) mention that the investment needed for job creation in the sugarcane sector is much lower than in the other industrial sectors. The creation of one job in the ethanol agro industry requires on average US$ 11,000, while a job in the chemical and petrochemical industry costs 20 times more.

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[79] International Labour Organization (ILO) recommends that the minimum age for hard jobs is 18 years. Brazil has signed ILO’s recommendations (Rodrigues and Ortiz, 2006).

[80] Less than 1/3 of the mean education level in the fuel industry (8.9 years) and in chemical industry (9.6 years), and less than half the value corresponding to the sugar (6.5 years), ethanol (7.3 years) or food industry (7.1 years).

[81] Almost 690 tonnes of sugarcane produced per worker, by 2003.

6.2.2 Another point of view regarding working conditions

Ortiz et al. (2007)[82] deals with the problem of manual harvesting, which accounts for over 60% of workers. Payment rules is based on worker's productivity, regime that impels workers to work at the limits of their physical capacity and causes some cases of deaths (about this issue, see also section 6.3)[83].

The issue of sugarcane cutters is also dealt by Novaes (2007), who conducted research at the field and interviewed workers. The author focused on facts occurred in Cosmópolis, in the state of São Paulo, and describes some actions adopted in order to minimize the effects of hard work (including the distribution of hydration liquids to the workers).

The same subject is dealt by Silva (2005), who presents research results about working conditions in the sugarcane production. According to the author, working conditions have deteriorated (e.g., low wages, losing of labour rights, slavery conditions due to debts, use of drugs for enhancing physical activities, and even deaths). Also according to the author, migrant workers are forced to live with bad housing and transporting conditions.

Mendonça (2005) states that the growth of sugarcane production has generated greater exploitation (called "flexibility") of the workforce. According to the author, in state of São Paulo most of sugarcane production is based on migratory workers from the Northeast and from a specific region of Minas Gerais[84]. The organization Pastoral of Migrants estimates that close to 200,000 workers migrate to São Paulo during the harvest periods of sugarcane, orange, and coffee, being 40,000 the estimate number of migrants in the sugarcane industry.

The same author states that besides the deaths occurring in the cane fields there are those that go unregistered. Illnesses and diseases (e.g., cancer, provoked by the use of pesticides) lead to the death of many workers.

6.2.3 Land tenure

As mentioned in Chapter 1, part of the sugarcane required is produced by independent agricultors while mill's owners, leasing land around the mill, produce other important share of the raw material required. Some authors state that the leasing of land involves a complex alteration in the types of agricultural production, job availability, migration to cities, food availability, etc.

A study by Ortiz et al. (2007) in municipalities of the so-called Triângulo Mineiro confirmed changes in land use, including various locations in which pasture has given way to sugarcane. As shown in Chapter 4, this has happened in Minas Gerais along the period 1996-2006. According to the authors, the number of milking cows fell by 12.3% in only two years. Another problem

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[82] "De-polluting Doubts: territorial impacts of the expansion of energy monocultures in Brazil, impacts on land use and food production", developed in the context of the project "International Debates on Bioenergy: raising voices in South America and presenting bad and good practices and policies for biofuels production in Brazil".

[83] According to Goldemberg et al. (2008), in São Paulo 19 cases of workers death were reported during three harvest seasons (2004-2007). The authors state that these can be isolated cases because work conditions in sugarcane crops seem to be better than in other rural sectors.

[84] Vale do Jequitinhonha.

mentioned relates to the expansion of sugarcane plantations in areas surrounding land reform settlements that are dedicated to family farming.

Analysing the issue of land tenure, Mendonça (2005) argues that land monopoly generates poverty, unemployment, and social exclusion. According to the author, land monopoly maintains the power of rural oligarchies.

It is worth to mention that Brazil has one of the two highest levels of agricultural land concentration in the world, where approximately 70,000 properties, representing barely 1.7% of a total 4,238.4 million rural properties, are occupying 43.8% of the total area registered by INCRA (National Institute of Colonization and Agrarian Reform). However, it is clear that concentration of agricultural land is not a problem exclusively caused by sugarcane production.

6.2.4 Impacts on urban infrastructure

The report by Ortiz et al. (2007), previously mentioned, shows that the introduction of the sugarcane agribusiness in small and medium-sized municipalities has altered the entire urban dynamic, creating new demands on public services such as health, security, education, water, sewerage, and housing, etc. The influx of workers puts pressure on existing infrastructure and at the same time demands greater investments by municipal governments. This issue is also dealt in sections 6.8 and 6.9.

6.2.5 Social responsibility and benefits

UNICA[85] argues that sugar and ethanol industries have benefited hundreds of Brazilian municipalities concerned to education, housing, environment and health, thereby contributing to improve the quality of life. According to the organization, the production units maintain more than 600 schools, 200 nursery centres and 300 day-care units (Barbosa, 2005).

A survey conducted in state of São Paulo with 47 sugar and ethanol companies shows that 34 million people live in the 150 municipalities within their direct influence area. The survey indicates what sugarcane mills have provided to the communities, as listed below (Barbosa, 2005):

- 95% of the companies have day-care units/nursery centre;
- 98% of the companies have workers rooms;
- 86% of the companies provide accommodation for workers who come from other locations;
- 84% of the companies already have profit-sharing plans;
- 90% of the workers are duly registered by the companies they work for, and the remaining 10% are outsourced;

[85] The Union of the Sugarcane Agro-industry in São Paulo.

- 58.3% of the companies already employ physically challenged workers at the rates imposed by law[86].

Most of the sugar and ethanol companies based in São Paulo adopted in 2002 the Social Balanced Sheet (IBASE model) concept. In addition, in 2006 UNICA and Ethos Institute signed an agreement targeting the adoption of the so-called Ethos Indicators to all companies that are member of UNICA (Barbosa, 2005).

6.3 Recent information about socio-economic aspects

Either in Brazil or abroad, ethanol production from sugarcane has been strongly criticized due to hard working conditions of cane harvesters. There is a reasonable number of papers and reports highlighting the consequences of such tough working conditions, that is some cases could have resulted in deaths due to exhaustion. As the production conditions are heterogeneous, it is important to know how representative are the most dramatic cases regarding average figures. This section is also based on literature review, but with focus to two recent reports about retirements and deaths of sugarcane workers, and about the income their incomes.

Moraes and Ferro (2008) carried out an analysis based on deaths and retirements of sugarcane workers in São Paulo and in Brazil, and compared the results with similar information regarding other crops. Data basis is RAIS[87] (from 2005), that reflect features of the formal employees in different economic sectors. Table 6.1 summarizes data about deaths of workers at the agriculture, including those related to sugarcane sector.

Table 6.1 Fatalities in the agriculture sector in 2005 – Brazil

	Agriculture, except sugarcane	Share regarding total workers (%)	Sugarcane cropping	Share regarding total workers (%)
Number of workers	2,160,524		414,668	
Number of fatalities	2,901	0.134	453	0.105
Fatalities at work or during commuting	135	0.007	17	0.004
Fatalities according ages (% of total)				
Up to 17 years old		0.3		0.0
18 to 24 years old		8.2		11.3
25 to 29 years old		9.4		11.7
30 to 39 years old		21.8		23.7
40 to 49 years old		22.0		20.9
50 to 64 years old		31.8		29.0
65 years old or older		6.5		3.4

Source: Moraes and Ferro (2008).

Comparing fatalities according ages of the workers, it can be seen that the profile regarding sugarcane production is not remarkably different from other agricultural sub-sectors. Moreover,

[86] Law 8,213/1991.

[87] RAIS (Relação Anual de Informações Sociais, i.e., annual data basis on social information) is a data basis annually provided by the Ministry of Labour.

the proportional of fatalities regarding the total number of workers is even lower in the sugarcane sub-sector regarding other agricultural workers (0.105% vis-à-vis 0.134%).

In 2005, in the state of São Paulo the number of fatalities in the agriculture, except sugarcane, was 634 (working or during commuting) when the total number of formal workers was 507,380, i.e., 0.125%. In the case of sugarcane production, the number of fatalities was 197 while the number of formal workers was 220,157, i.e., 0.089% of the total workers. This proportion is lower regarding the results for Brazil, both in sugarcane cropping and in agriculture as a whole.

Retirements was also an issue of the research recently conducted by Moraes and Ferro (2008). Table 6.2 presents information about retirements in the agricultural sector in Brazil, and similar information regarding sugarcane cropping.

Table 6.2 Retirements in the agriculture in 2005 – Brazil

	Agriculture, except sugarcane	Share regarding total workers (%)	Sugarcane cropping	Share regarding total workers (%)
Number of workers	2,160,524		414,668	
Number of retirements	3,071	0.142	507	0.122
Retirements due to accidents and diseases	519	0.024	29	0.007
Fatalities according ages (% of total)				
Up to 17 years old		0.0		0.0
18 to 24 years old		0.6		0.4
25 to 29 years old		1.2		1.6
30 to 39 years old		4.7		2.2
40 to 49 years old		12.7		12.4
50 to 64 years old		63.9		72.4
65 years old or older		17.0		11.0

Source: Moraes and Ferro (2008).

It is worth to mention the small proportion of retirements regarding the total number of workers, both in sugarcane as well as in other agricultural crops. The reason presented by Moraes and Ferro (2008) is that the data basis (RAIS) only contains information about formal workers. The number of retirements due to accidents and professional diseases is very small regarding the number of workers, and the proportion is even smaller for sugarcane production.

Regarding São Paulo and for the agriculture except sugarcane, the share of retirements regarding the total number of formal workers was 0.125%, being 0.016% the share of retirements due to accidents and professional diseases. Thus, the results in São Paulo were better than in Brazil. In the case of sugarcane, retirements due to accidents or diseases correspond to 0.005% of the total workers, much lower than other agricultural sectors in São Paulo and in Brazil.

The authors conclude that there is no reason to state that the number of deaths and retirements due to tough and dangerous working conditions in sugarcane production is proportionally higher than in other agricultural activities.

Hoffman and Oliveira (2008) carried out an analysis about the average income of workers in the agricultural sector, considering data from 1992 to 2006. They considered the income of people working with the production of sugarcane, banana, coffee, soybean and corn in Brazil, and sugarcane, orange, lemon, coffee and cotton in São Paulo. The data basis was IBGE-PNAD for Brazil and IEA/CATI for São Paulo (IEA, 2008)[88]. Results for Brazil are presented in Table 6.3.

Table 6.3 Average income of people working in different crops – Brazil, 1992 to 2006 (values in Reais of August 2005)

	Sugarcane	Banana	Coffee	Soybean	Corn	Minimum salary
1992	329.0	228.1	240.6	469.2	173.7	285.4
1993	361.8	136.2	222.8	488.8	192.5	253.8
1995	394.7	244.6	321.2	465.7	240.1	226.8
1996	388.8	268.8	352.1	479.5	243.8	225.9
1997	415.1	217.7	321.5	576.8	226.2	232.0
1998	405.3	242.0	334.1	547.8	241.1	243.9
1999	418.5	251.5	310.5	514.7	219.4	239.7
2001	364.6	308.6	294.0	521.9	203.7	276.3
2002	372.7	279.3	296.9	578.6	206.5	279.3
2003	374.1	257.0	293.7	506.5	206.5	279.3
2004	405.9	248.2	303.2	589.0	214.0	293.6
2005	458.9	279.8	338.9	668.6	214.7	322.0
2006	494.3	328.9	400.0	697.8	235.1	365.5

Source: Hoffmann and Oliveira (2008)

The authors show that for all crops there was a raise of the real income during the period. In Brazil sugarcane workers have the second largest income, after soybeans, while in São Paulo the largest income is due to sugarcane production.

On the other hand, based on data of IEA/CATI, Hoffman and Oliveira (2008) show that the payment for specific tasks in the sugarcane sector, in São Paulo, is the second worst among all crops analysed. The authors show that the average yield was close to 7 tonnes of sugarcane harvested, per worker, per day, from 1995 to 1999, but rose since then. Since 2001 there has been a growth of the payment per tonne of sugarcane harvested.

In recent years the average income of sugarcane workers in São Paulo has been larger than the average figure for Brazil. The authors estimate that the income per month was about 35% in 2003, but the ratio continuously reduced to 15% in 2006.

6.4 Comparing municipalities with and without sugarcane production

The results presented in this section correspond to the analysis of indicators of welfare in municipalities with and without sugarcane production in the most important producer states of sugarcane[89]. The analysis is based on indicators taken from the Human Development Atlas of 1991 and 2000, published by IBGE. The indicators considered through the analysis are the following:

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88 PNAD is a survey regularly conducted by IBGE in a sample of house holds. IEA is the Instituto de Economia Agrícola in São Paulo.

89 São Paulo, Paraná, Minas Gerais, Goiás, Mato Grosso and Mato Grosso do Sul in the Centre-South region, and Alagoas and Pernambuco, in the Northeast region.

- Human Development Index at municipal basis – HDI-M;
- Households with electricity service;
- Life expectancy at birth;
- Survival probability up to 60 years;
- Deaths up to 1-year old;
- Share of illiterates older than 15 year old;
- Fraction of illiterates within the whole population;
- Gini Index;
- Share of income of the 20% poorest people;
- Ratio between income share of the 20% richest regarding the 40% poorest;
- Income per capita – month basis.

In each state the municipalities were classified in two groups, according to the amount of sugarcane produced in a certain year. The municipalities in which sugarcane production summed 90% of the total state production defined the group of large sugarcane producers. For this group the population range was defined. The second group has municipalities with no production of sugarcane at all, or municipalities with small production. Only municipalities within the same population range were kept in this group in order to proceed comparison between groups of municipalities with the same size. Considering these the two groups of municipalities average and standard deviation values were calculated for the eleven indicators listed above.

Results for the state of São Paulo are presented in Table 6.4 for 1991 and 2000. Comparison was done considering the procedure known as the paired t-test, taken into account confidence probabilities larger than 95%, between 80% and 95%, and lower than 80%. The criterion was to consider the groups statistically different only when the result of the paired t-test indicated confidence higher than 95%. In Table 6.4 (and onwards) the cells with these results are marked bright green. In case the results of the paired t-test indicated confidence interval between 80% and 95%, it was understood that there are evidences of differences; in tables hereafter, the cells with these results are marked light green. Finally, in case the paired t-test resulted confidence lower than 80%, it was supposed that the groups are not statistically different.

The results presented in Table 6.4 can be interpreted as follows: statistically, the municipalities in which sugarcane production is present have better parameters than those where it is absent. This is the conclusion for all the indicators considered. It is possible to assure that the groups are different with confidence of at least 95%.

Table 6.4 Socio-economic indicators for municipalities with and without significant sugarcane production in state of São Paulo – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	156	499	181	415
Population (1,000)	2.4-435	2.4-435	1.8-504	1.8-504
HDI-M	0.742 ± 0.027	0.714 ± 0.041	0.793 ± 0.025	0.774 ± 0.035
Households with electricity service (%)	98.79 ± 2.15	95.62 ± 7.87	99.63 ± 0.65	98.58 ± 2.89
Life expectancy at birth (years)	69.63 ± 2.07	67.88 ± 2.93	72.58 ± 2.07	71.24 ± 2.69
Survival probability up to 60 years (%)	79.47 ± 3.72	76.26 ± 5.42	84.25 ± 3.54	81.86 ± 4.82
Deaths up to 1-year old (per thousand)	24.16 ± 5.48	29.31 ± 8.97	13.65 ± 3.59	16.27 ± 5.46
Illiterates older than 15 years old (%)	14.52 ± 3.37	17.27 ± 4.24	9.96 ± 2.64	11.41 ± 3.51
Alphabetization index	85.48 ± 3.37	82.73 ± 4.84	90.64 ± 2.64	88.59 ± 3.51
Gini index	0.489 ± 0.047	0.514 ± 0.051	0.516 ± 0.045	0.532 ± 0.046
Income of the 20% poorest people (%)	4.80 ± 0.87	4.24 ± 0.98	4.00 ± 0.85	3.54 ± 1.06
Income ratio (20% richest/40% poorest)	8.36 ± 1.93	9.85 ± 3.19	9.65 ± 2.60	10.90 ± 3.90
Income per capita (R$/hab/month)	258.2 ± 54.2	213.5 ± 72.1	300.0 ± 69.9	268.4 ± 88.1

Unfortunately only two issues of the Human Development Atlas are available. Alternatively, municipal indicators recently published by FIRJAN[90] were used in order to do the comparison for the years 2000 and 2005. Three indicators are available for each municipality in both years (Jobs and Income, Education, and Health). As the year 2000 is common to both data basis (IBGE and FIRJAN), it was possible to check the consistency.

Then, the same procedure previously described was applied, including the paired t-test in order to determine if the groups are statistically different. Results for the state of São Paulo (average values and standard deviation for each group) are presented in Table 6.5. The conclusion is that the municipalities in which sugarcane production is present have better parameters than those where it is absent in 2005. The groups can be seen as different with confidence of at least 95%. In the case of 2000, the same conclusion is correct, except for the indicator Jobs and Income (in this case, the confidence is 78%).

Thus, the conclusions based on the FIRJAN's indicators are nearly similar to the conclusions gotten when the analysis was carried out with IBGE's indicators (Human Development Atlas).

Table 6.5 Socio-economic indicators for municipalities with and without significant sugarcane production in state of São Paulo – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	181	499	206	415
Population (1,000)	2.4-435	2.4-435		
Jobs and Income	0.489 ± 0.105	0.482 ± 0.116	0.573 ± 0.152	0.520 ± 0.172
Education	0.834 ± 0.059	0.803 ± 0.075	0.880 ± 0.047	0.861 ± 0.062
Health	0.803 ± 0.081	0.767 ± 0.091	0.868 ± 0.054	0.842 ± 0.066

[90] Federação das Indústrias do Estados do Rio de Janeiro. The indicators are based on statistics provided by Federal Government; the definition of the three indicators is based on 18 parameters.

The same analysis was carried out other seven producer states of sugarcane. Table 6.6 presents the conclusions for the state of Alagoas, in 1991, where it can be seen that the municipalities in which sugarcane production is present have better parameters than those where it is absent; this the conclusion for all eleven indicators (regarding indicators of education, there are evidences that the municipalities with sugarcane production have an advantage). The advantage of the municipalities with sugarcane production was reduced in 2000, as statistically there is no difference between the groups of municipalities regarding health indicators.

Finally, based on FIRJAN's indicators the only advantage of municipalities with sugarcane production is regarding the indicator "Jobs and Income", both in 2000 and in 2005. These results are presented in Table 6.7.

For all states analysed, except São Paulo, detailed results are presented in Annex C, Tables C.1 to C14.

A comparative analysis for all eight states is presented from Table 6.8 to Table 6.8. It can be seen that based on IBGE's data basis (1991 and 2000), in each year there are only two cases in which the results for the municipalities without significant sugarcane production are better regarding the municipalities in which sugarcane production occurs. Either in 1991 or in 2000, in São Paulo the municipalities with significant sugarcane production have best results for all indicators.

Table 6.6 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Alagoas – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	28	48	31	48
Population (1,000)	7.4-57	7.4-57	7.0-63	7.0-63
HDI-M	0.483 ± 0.043	0.456 ± 0.044	0.589 ± 0.042	0.578 ± 0.039
Households with electricity service (%)	73.90 ± 12.39	53.82 ± 17.15	87.40 ± 7.47	80.98 ± 11.96
Life expectancy at birth (years)	57.62 ± 2.62	55.59 ± 2.67	63.41 ± 3.20	62.92 ± 3.13
Survival probability up to 60 years (%)	60.11 ± 4.59	56.61 ± 4.61	68,10 ± 5.79	67.22 ± 5.67
Deaths up to 1-year old (per thousand)	75.77 ± 13.01	86.55 ± 14.55	50.68 ± 13.28	52.63 ± 13.26
Illiterates older than 15 years old (%)	56.52 ± 8.17	58.97 ± 7.95	42.48 ± 6.40	44.00 ± 6.32
Alphabetization index	43.48 ± 8.17	41.03 ± 7.95	57.73 ± 6.40	56,01 ± 6.32
Gini index	0.471 ± 0.054	0.500 ± 0.058	0.575 ± 0.045	0.606 ± 0.056
Income of the 20% poorest people (%)	4.77 ± 0.89	4.29 ± 1.04	1.76 ± 0.80	1.35 ± 1.34
Income ratio (20% richest/40% poorest)	7.87 ± 2.21	9.36 ± 3.30	14.76 ± 4.64	29.76 ± 40.59
Income per capita (R$/hab/month)	66.4 ± 14.9	57.1 ± 16.6	78.8 ± 18.4	69.8 ± 19.0

Table 6.7 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Alagoas – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	31	48	31	48
Population (1,000)	7.0-63	7.0-63		
Jobs and Income	0.387 ± 0.155	0.275 ± 0.119	0.411 ± 0.153	0.267 ± 0.063
Education	0.358 ± 0.054	0.360 ± 0.053	0.465 ± 0.059	0.453 ± 0.064
Health	0.528 ± 0.076	0.533 ± 0.094	0.662 ± 0.069	0.612 ± 0.080

The worst results for the municipalities with significant sugarcane production are observed in Mato Grosso, especially in 1991. On the other hand, in the case of Alagoas and Pernambuco it can be concluded that, in general, the best results are for the municipalities with significant sugarcane production.

Comparing the results through categories, it can be seen that in 1991 the municipalities with significant sugarcane production had an advantage regarding health and education, except in Mato Grosso (all indicators) and in Paraná (only one indicator). The indicators regarding wealth distribution are better in three states (São Paulo, Paraná and Alagoas). In 2000, results are more even and, in some states, it is clear that the municipalities with significant sugarcane production lost advantage regarding health and education.

Table 6.8 Results of socio-economic indicators for the municipalities with significant sugarcane production – all analysed states, 1991

Indicators	AL	GO	MT	MS	MG	PE	PR	SP
Number of municipalities	28	21	12	7	97	36	56	156
Population range (1,000)	7.4-57	2.4-75	4-30	6-31	1.8-209	11-475	2-240	2.4-435
HDI-M	Better	Better		Better	Better	E.B.	Better	Better
Households with electricity service (%)	Better	Better	Better	Better	Better	Better	Better	Better
Life expectancy at birth (years)	Better	Better	E.W.	Better	Better	E.B.	E.B.	Better
Survival probability up to 60 years (%)	Better	Better	E.W.	Better	Better	E.B.	E.B.	Better
Deaths up to 1-year old (per thousand)	Better	Better	E.W.	Better	Better	E.B.	E.B.	Better
Illiterates older than 15 years old (%)	E.B.	Better	E.W.	E.B.	Better	Better	E.B.	Better
Alphabetization index	E.B.	Better	E.W.	E.B.	Better	Better	E.W.	Better
Gini index	Better				Worst		Better	Better
Income of the 20% poorest people (%)	Better				Better		Better	Better
Income ratio (20% richest/40% poorest)	Better				Worst		Better	Better
Income per capita (R$/hab/month)	Better	Better		Better	Better		Better	Better

Notes: AL = Alagoas; GO = Goiás; MT = Mato Grosso; MS = Mato Grosso do Sul; MG = Minas Gerais; PE = Pernambuco; PR = Paraná; SP = São Paulo.

Better = better parameters regarding municipalities in which sugarcane production is absent; difference between groups attested with confidence of at least 95%;

E.B. = evidence that parameters are better; confidence between 80% and 95%;

E.W. = evidence that parameters are worst; confidence between 80% and 95%;

Worst = worse parameters regarding municipalities in which sugarcane production is absent; confidence of at least 95%;

Blanc = statistically there is no difference between the two groups.

Table 6.9 Results of socio-economic indicators for the municipalities with significant sugarcane production – all analysed states, 2000

Indicators	AL	GO	MT	MS	MG	PE	PR	SP
Number of municipalities	31	22	11	9	122	36	64	181
Population range (1,000)	7-63	3.5-117	4.7-59	6.6-37	2.7-252	11-582	2.2-289	1.8-504
HDI-M	E.B.	E.B.	E.B.	E.B.	E.B.	E.B.	Better	Better
Households with electricity service (%)	Better	Better	E.B.	E.B.	E.B.	Better	Better	Better
Life expectancy at birth (years)				Better	E.B.	E.B.	Better	Better
Survival probability up to 60 years (%)				Better	E.B.	E.B.	Better	Better
Deaths up to 1-year old (per thousand)				Better	E.B.	E.B.	Better	Better
Illiterates older than 15 years old (%)	E.B.			E.B.	E.B.	Better		Better
Alphabetization index	E.B.			E.B.	E.B.	Better		Better
Gini index	Better				Worst	Better	Better	Better
Income of the 20% poorest people (%)	Better	Better		E.B.	E.B.	Better	Better	Better
Income ratio (20% richest/40% poorest)	Better				E.B.	Better	Better	Better
Income per capita (R$/hab/month)	Better	E.B.	E.B.		Better	Worst	Better	Better

Notes: AL = Alagoas; GO = Goiás; MT = Mato Grosso; MS = Mato Grosso do Sul; MG = Minas Gerais; PE = Pernambuco; PR = Paraná; SP = São Paulo.

Better = better parameters regarding municipalities in which sugarcane production is absent; difference between groups attested with confidence of at least 95%;

E.B. = evidence that parameters are better; confidence between 80% and 95%;

E.W. = evidence that parameters are worst; confidence between 80% and 95%;

Worst = worse parameters regarding municipalities in which sugarcane production is absent; confidence of at least 95%;

Blanc = statistically there is no difference between the two groups.

Table 6.10 Results of socio-economic indicators for the municipalities with significant sugarcane production – all analysed states, 2000

Indicators	AL	GO	MT	MS	MG	PE	PR	SP
Number of municipalities	31	22	11	9	122	36	64	181
Population range (1,000)	7-63	3.5-117	4.7-59	6.6-37	2.7-252	11-582	2.2-289	1.8-504
Jobs and Income	Better	E.B.	E.B.	Better	Better	E.B.		
Education		Better			E.B.		Better	Better
Health		E.B.	E.B.			Better	Better	Better

Notes: AL = Alagoas; GO = Goiás; MT = Mato Grosso; MS = Mato Grosso do Sul; MG = Minas Gerais; PE = Pernambuco; PR = Paraná; SP = São Paulo.

Better = better parameters regarding municipalities in which sugarcane production is absent; difference between groups attested with confidence of at least 95%;

E.B. = evidence that parameters are better; confidence between 80% and 95%;

Blanc = statistically there is no difference between the two groups.

The analysis based on FIRJAN's parameters (Tables 6.10 and 6.11) is constrained because the indicators are aggregated. Anyhow, the same relevant conclusions can be gotten, as there is no case in which the municipalities with significant sugarcane production have worst results. In case of São Paulo, once more the best results concern to the group of municipalities with more intensive sugarcane activity.

Table 6.11 Results of socio-economic indicators for the municipalities with significant sugarcane production – all analysed states, 2005

Indicators	AL	GO	MT	MS	MG	PE	PR	SP
Number of municipalities	31	22	11	9	111	36	64	206
Jobs and Income	Better	Better	E.B.		E.B.	Better		Better
Education		Better		E.B.			Better	Better
Health				Better		Better	Better	Better

Notes: AL = Alagoas; GO = Goiás; MT = Mato Grosso; MS = Mato Grosso do Sul; MG = Minas Gerais; PE = Pernambuco; PR = Paraná; SP = São Paulo.

Better = better parameters regarding municipalities in which sugarcane production is absent; difference between groups attested with confidence of at least 95%;

E.B. = evidence that parameters are better; confidence between 80% and 95%;

Blanc = statistically there is no difference between the two groups.

6.5 Comparing municipalities with and without sugarcane mills

Similar analysis was carried out for the state of São Paulo, comparing municipalities with sugarcane production and mills in operation and municipalities with sugarcane production but without mills. The analysis was done for 2000 and 2005 and results are presented in Table 6.12 and 6.13.

The group of municipalities with mills installed have higher Human Development Index and higher Income per capita (month basis) (the confidence level on this assertive is at least 95%). Also for 2000, the indicators regarding health and education are better for the same group of municipalities, but in these cases the level of confidence is between 80% and 95%. Regarding wealth distribution, the only difference is regarding the Gini Index, with small advantage for the municipalities without mills in operation.

Table 6.12 Socio-economic indicators: comparison between groups of municipalities only with sugarcane production and municipalities with sugarcane production and mills – 2000

Indicators	With mills[1]	Without mills
Number of municipalities	94	93
Population (1,000)	2.4-250	2.4-250
HDI-M	0.796 ± 0,025	0.786 ± 0.023
Households with electricity service (%)	99.63 ± 0.76	99.61 ± 0.49
Life expectancy at birth (years)	72.77 ± 2.14	72.28 ± 2.03
Survival probability up to 60 years (%)	15.28 ± 4.23	16.22 ± 4.07
Deaths up to 1-year old (per thousand)	13.34 ± 3.70	14.17 ± 3.56
Illiterates older than 15 years old (%)	9.78 ± 2.38	10.38 ± 2.77
Alphabetization index	90.22 ± 2.38	89.62 ± 2.77
Gini index	0.518 ± 0.046	0.511 ± 0.043
Income of the 20% poorest people (%)	4,00 ± 0.84	4.06 ± 0.88
Income ratio (20% richest/40% poorest)	9.67 ± 2.72	9.43 ± 2.46
Income per capita (R$/hab/month)	306.0 ± 67.1	286.5 ± 65.2

Note: [1] Piracicaba and Ribeirão Preto were excluded of this group as there is no municipality with the same size of population in the other group (municipalities without mills installed).

As for 2000, the group of municipalities with mills installed have a small advantage as long as FIRJAN's indicators are concerned. In 2005, the conclusion that groups are different regarding the indicator "Jobs and Income" is statically (advantage for the group of municipalities with mills).

Table 6.13 Socio-economic indicators: comparison between groups of municipalities only with sugarcane production and municipalities with sugarcane production and mills – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	94	93	92	112
Population (1,000)	2.4-250	2.4-250		
Jobs and Income	0.488 ± 0.103	0.489 ± 0.108	0.618 ± 0.141	0.531 ± 0.147
Education	0.839 ± 0.056	0.827 ± 0.061	0.883 ± 0.047	0.877 ± 0.048
Health	0.803 ± 0.081	0.798 ± 0.082	0.867 ± 0.054	0.868 ± 0.054

This analysis was completed with the stratification of both groups according to the size of population. The first group was defined for municipalities with up to 15,000 inhabitants in 2000, while the second group was defined for municipalities with population between 40,000 and 250,000 inhabitants. Results are presented in Table 6.14. It can be seen that within the group of smaller municipalities there is tiny advantage (confidence between 80% and 95%) for the municipalities with mills installed, mostly regarding indicators of health and education. On the other hand, for the largest municipalities the advantages of municipalities with mills installed are clear regarding health, but the group of municipalities without mills installed has (tiny) advantage regarding education.

Based on the results presented it can be concluded that the municipalities with mills installed have better indicators in comparison with those that only have sugarcane cropping. The advantage is more evident concerned to health and education.

Table 6.14 Socio-economic indicators after stratification: comparison between groups of municipalities with sugarcane production and municipalities with sugarcane production and mills – 2000

Indicators	With mills	Without	With mills	Without
Number of municipalities	32	51	25	19
Average population (1,000)	8,105 ± 3,520	8,163 ± 3,513	86,625 ± 46,045	93,061 ± 56,355
HDI-M	0.781 ± 0.019	0.774 ± 0.019	0.817 ± 0.019	0.812 ± 0.015
Households with electricity service (%)	99.62 ± 0.35	99.54 ± 0.55	99.75 ± 0.33	99.74 ± 0.21
Life expectancy at birth (years)	72.51 ± 2.47	72.35 ± 1.49	73.28 ± 1.84	72.35 ± 1.49
Survival probability up to 60 years (%)	84.09 ± 4.21	83.90 ± 2.60	85.44 ± 3.12	83.90 ± 2.60
Deaths up to 1-year old (per thousand)	13.86 ± 4.26	13.94 ± 2.71	12.43 ± 3.12	13.94 ± 2.71
Illiterates older than 15 years old (%)	11.40 ± 1.85	11.93 ± 2.40	7.67 ± 1.29	7.20 ± 1.18
Alphabetization index	88.61 ± 1.85	88.07 ± 2.20	92.33 ± 1.29	92.80 ± 1.18
Gini index	0.499 ± 0.046	0.495 ± 0.032	0.536 ± 0.039	0.538 ± 0.023
Income of the 20% poorest people (%)	4.55 ± 0.94	4.39 ± 0.92	3.57 ± 0.57	3.49 ± 0.46
Income ratio (20% richest/40% poorest)	8.42 ± 2.81	8.58 ± 2.27	10.76 ± 2.07	10.77 ± 1.37
Income per capita (R$/hab/month)	255.3 ± 35.7	249.1 ± 40.4	368.3 ± 54.3	370.1 ± 51.4

6.6 Comparing municipalities with and without soybeans production and pasture

Similar procedure was applied in order to analyse the socio-economic effects, if any, of soybean production and concentration of cattle ranching. The analysis regarding cattle ranching was carried out for São Paulo and Mato Grosso do Sul, while the analysis regarding soybean was done for Mato Grosso do Sul and Mato Grosso. Cattle herd data were taken from IBGE (PPM).

Due to the large dispersion of cattle ranching is São Paulo, i.e., cattle ranching occurs in many municipalities without large concentration regarding the total activity in the state, the following procedure was adopted: firstly, the group of municipalities with livestock was defined for 20% and 50% of the total cattle herd in São Paulo and for these groups the population range was identified; secondly, for comparison, the group of municipalities without significant cattle ranching activity was defined considering municipalities with the same population range. The same indicators previously described were considered. Results are presented in Tables 6.15 to 6.17, for the 1991, 2000 and 2005, respectively.

From the results presented in these tables it is possible to conclude that livestock doesn't have the same socio-economic impact as sugarcane production. For most of the analysed indicators there is no significant difference between municipalities with (relevant) cattle ranching activity and those without, but when differences raise these indicate advantage of municipalities without significant cattle ranching activity. It is worth to mention that comparatively wealth concentration is higher in municipalities with significant cattle ranching activity.

In the case of Mato Grosso do Sul, the adopted procedure was similar regarding that previously described in the case of sugarcane, i.e., the group "municipalities with significant cattle ranch activity" was defined for the municipalities that sum-up 90% of the total herd in the state. Campo Grande, the capital and the most important city in the state, was excluded in order to avoid distortions. The comparison was done between this group and the group of municipalities without cattle ranch activity (and with the same population range). Results are presented in Tables 6.18 (1991 and 2005) and 6.19 (2005).

Table 6.15 Results of socio-economic indicators for the municipalities with significant cattle ranching activity – São Paulo, 1991

Indicators	With livestock	Without	With livestock	Without
	Herd sums-up 20%		Herd sums-up 50%	
Number of municipalities	23	218	43	240
Population (1,000)	3.5-153	3.5-153	3-278	3-278
HDI-M	0.718 ± 0.046	0.720 ± 0.042	0.717 ± 0.042	0.721 ± 0.042
Households with electricity service (%)	94.08 ± 11.98	96.65 ± 6.11	96.06 ± 7.83	96.68 ± 5.99
Life expectancy at birth (years)	67.89 ± 3.46	68.45 ± 2.57	68.20 ± 3.12	68.29 ± 2.76
Survival probability up to 60 years (%)	76.23 ± 6.40	77.33 ± 4.73	76.83 ± 5.75	77.02 ± 5.09
Deaths up to 1-year old (per thousand)	28.26 ± 10.42	27.32 ± 8.13	28.26 ± 10.42	27.43 ± 8.03
Illiterates older than 15 years old (%)	15.66 ± 3.79	15.91 ± 4.51	16.42 ± 3.82	16.11 ± 4.79
Alphabetization index	82.83 ± 5.89	82.93 ± 5.09	83.12 ± 4.70	83.03 ± 5.04
Gini index	0.546 ± 0.034	0.496 ± 0.058	0.530 ± 0.040	0.494 ± 0.057
Income of the 20% poorest people (%)	3.83 ± 0.53	4.47 ± 1.11	4.10 ± 0.74	4.51 ± 1.12
Income ratio (20% richest/40% poorest)	9.28 ± 2.55	9.32 ± 3.13	9.20 ± 3.00	9.40 ± 3.16
Income per capita (R$/hab/month)	232.3 ± 54.6	240.5 ± 67.9	222.7 ± 60.6	237.0 ± 70.1

Table 6.16 Results of socio-economic indicators for the municipalities with significant cattle ranching activity – São Paulo, 2000

Indicators	With livestock	Without	With livestock	Without
	Herd sums-up 20%		Herd sums-up 50%	
Number of municipalities	28	215	107	245
Population (1,000)	3.7-197	3.7-197	2.7-328	2.7-328
HDI-M	0.785 ± 0.029	0.782 ± 0.032	0.780 ± 0.032	0.780 ± 0.035
Households with electricity service (%)	98.65 ± 1.99	98.67 ± 3.11	99.05 ± 1.38	98.58 ± 3.38
Life expectancy at birth (years)	71.55 ± 2.37	71.61 ± 2.42	71.40 ± 2.54	71.48 ± 2.61
Survival probability up to 60 years (%)	82.44 ± 4.18	82.54 ± 4.30	82.16 ± 4.51	82.30 ± 4.69
Deaths up to 1-year old (per thousand)	15.56 ± 4.46	15.48 ± 4.76	15.90 ± 4.91	15.79 ± 5.36
Illiterates older than 15 years old (%)	10.85 ± 2.82	10.27 ± 3.01	11.16 ± 3.13	10.45 ± 3.27
Alphabetization index	89.15 ± 2.82	89.73 ± 3.01	88.84 ± 3.13	89.55 ± 3.27
Gini index	0.559 ± 0.045	0.523 ± 0.052	0.545 ± 0.038	0.524 ± 0.053
Income of the 20% poorest people (%)	3.23 ± 0.76	3.62 ± 1.08	3.38 ± 0.79	3.59 ± 1.13
Income ratio (20% richest/40% poorest)	12.16 ± 3.12	10.64 ± 4.50	11.36 ± 2.59	10.71 ± 4.55
Income per capita (R$/hab/month)	291.0 ± 73.6	285.0 ± 83.3	281.3 ± 77.7	281.2 ± 86.1

Table 6.17 Results of socio-economic indicators for the municipalities with significant cattle ranching activity – São Paulo, 2005

Indicators	With livestock	Without	With livestock	Without
	Herd sums-up 20%		Herd sums-up 50%	
Number of municipalities	28	214	109	232
Jobs and Income	0.545 ± 0.130	0.583 ± 0.167	0.536 ± 0.154	0.585 ± 0.175
Education	0.883 ± 0.033	0.853 ± 0.065	0.875 ± 0.043	0.851 ± 0.065
Health	0.842 ± 0.052	0.845 ± 0.065	0.845 ± 0.062	0.843 ± 0.066

It can be seen that the results for Mato Grosso do Sul regarding socio-economic impacts of cattle ranching activity are better than those presented for São Paulo, probably because of the lack of other relevant economic activity in the municipalities where cattle ranching have no importance.

Table 6.18 Results of socio-economic indicators for municipalities with significant cattle ranching activity – Mato Grosso do Sul, 1991 and 2000

Indicators	With livestock	Without	With livestock	Without
	1991		2000	
Number of municipalities	50	26	51	24
Population (1,000)	3.7-136	3.7-136	3.6-165	3.6-165
HDI-M	0.674 ± 0.037	0.652 ± 0.032	0.742 ± 0.034	0.736 ± 0.034
Households with electricity service (%)	79.57 ± 10.28	75.26 ± 16.76	92.35 ± 5.50	88.64 ± 11.33
Life expectancy at birth (years)	66.16 ± 1.77	65.48 ± 1.99	69.63 ± 2.07	68.93 ± 2.14
Survival probability up to 60 years (%)	73.94 ± 3.23	72.71 ± 3.66	79.84 ± 3.71	78.56 ± 3.87
Deaths up to 1-year old (per thousand)	36.67 ± 5.88	39.05 ± 6.78	26.91 ± 6.12	29.02 ± 6.51
Illiterates older than 15 years old (%)	22.30 ± 5.54	25.03 ± 4.26	14.74 ± 3.48	18.71 ± 4.38
Alphabetization index	77.70 ± 5.54	74.97 ± 4.26	83.12 ± 4.70	83.03 ± 5.04
Gini index	0.574 ± 0.048	0.550 ± 0.041	0.588 ± 0.062	0.584 ± 0.047
Income of the 20% poorest people (%)	3.49 ± 0.71	3.68 ± 0.79	2.67 ± 0.87	2.93 ± 1.00
Income ratio (20% richest/40% poorest)	12.67 ± 3.09	11.23 ± 2.58	14.03 ± 5.41	14.16 ± 3.88
Income per capita (R$/hab/month)	173.6 ± 53.0	139.9 ± 36.2	223.7 ± 66.2	180.8 ± 42.8

Table 6.19 Results of socio-economic indicators for municipalities with significant cattle ranching activity – Mato Grosso do Sul, 2005

Indicators	With livestock	Without livestock
Number of municipalities	51	26
Jobs and Income	0.454 ± 0.104	0.424 ± 0.077
Education	0.664 ± 0.052	0.654 ± 0.058
Health	0.780 ± 0.068	0.751 ± 0.123

Similar analysis was carried out for Mato Grosso do Sul in order to identify socio-economic impacts of soybean production, if any, at regional level. Results are presented in Tables 6.20 and 6.21. The results for Mato Grosso do Sul regarding socio-economic impacts of soybean production indicate advantages regarding municipalities in which soybean production is absent. However, this conclusion is not valid regarding wealth distribution.

Table 6.20 Results of socio-economic indicators for municipalities with significant soybean production – Mato Grosso do Sul, 1991 and 2000

Indicators	With soybean	Without	With soybean	Without
	1991		2000	
Number of municipalities	18	47	19	47
Population (1,000)	6-136	6-136	5.5-165	5.5-165
HDI-M	0.694 ± 0.031	0.663 ± 0.034	0.746 ± 0.032	0.740 ± 0.033
Households with electricity service (%)	82.18 ± 8.50	78.49 ± 13.88	91.73 ± 6.01	91.47 ± 9.16
Life expectancy at birth (years)	66.92 ± 1.71	65.58 ± 1.77	70.53 ± 1.89	69.11 ± 2.10
Survival probability up to 60 years (%)	75.30 ± 3.08	72.91 ± 3.26	81.44 ± 3.37	78.90 ± 3.80
Deaths up to 1-year old (per thousand)	34.20 ± 5.53	38.61 ± 5.99	24.32 ± 5.47	28.46 ± 6.36
Illiterates older than 15 years old (%)	20.03 ± 5.13	23.39 ± 4.78	13.71 ± 3.57	16.89 ± 4.27
Alphabetization index	79.97 ± 5.13	76.61 ± 4.78	85.27 ± 3.70	83.88 ± 4.37
Gini index	0.582 ± 0.052	0.567 ± 0.045	0.624 ± 0.054	0.578 ± 0.055
Income of the 20% poorest people (%)	3.46 ± 0.79	3.54 ± 0.77	3.07 ± 0.62	2.71 ± 0.94
Income ratio (20% richest/40% poorest)	13.07 ± 3.18	12.27 ± 2.96	15.88 ± 3.42	13.71 ± 5.40
Income per capita (R$/hab/month)	204.8 ± 54.6	155.7 ± 42.3	258.9 ± 78.8	197.7 ± 49.0

Table 6.21 Results of socio-economic indicators for municipalities with significant soybean production – Mato Grosso do Sul, 2005

Indicators	With soybean production	Without soybean production
Number of municipalities	26	43
Jobs and Income	0.475 ± 0.106	0.433 ± 0.075
Education	0.664 ± 0.054	0.654 ± 0.061
Health	0.771 ± 0.094	0.765 ± 0.112

Following the results presented above, an analysis was carried out comparing the socio-economic impacts of sugarcane production regarding those of soybean cropping and cattle ranch activity. The results are presented in Table 6.22 for 1991 and 2000, where it can be seen that the impacts of sugarcane production are more positive regarding those of cattle ranch activity. Comparison regarding soybean cropping indicate advantage of sugarcane activity regarding some indicators, and for two indicators in 2000 (illiterates older than 15 years old and income per habitant) there are evidences that soybean would be advantageous. However, regarding wealth distribution, the results for soybean activity are worse than for sugarcane.

For the state of Mato Grosso, similar analysis was carried out regarding soybean production. The results are presented in Annex C.13 and C.14, where it can be seen that the municipalities in which soybean production is present have better parameters than those where it is absent, except regarding wealth distribution.

Table 6.22 Results of socio-economic indicators: comparison sugarcane versus soybean and sugarcane versus cattle ranch – Mato Grosso do Sul, 1991 and 2000

Indicator	1991		2000	
	Soybean	Livestock	Soybean	Livestock
HDI-M		Evidence of better		Evidence of better
Households with electricity service (%)	Better	Better	Evidence of better	Evidence of better
Life expectancy at birth (years)		Evidence of better		Evidence of better
Survival probability up to 60 years (%)		Evidence of better		Evidence of better
Deaths up to 1-year old (per thousand)		Evidence of better		Evidence of better
Illiterates older than 15 years old (%)		Evidence of better	Evidence of worse	
Alphabetization index		Evidence of better		Evidence of better
Gini index			Better	
Income of the 20% poorest people (%)				Evidence of better
Income ratio (20% richest/40% poorest)			Better	
Income per capita (R$/hab/month)		Evidence of better	Evidence of worse	

Notes: Better = better parameters regarding municipalities with significant soybean production or cattle ranch activity; confidence of at least 95%;

Evidence of better = evidence of better results; confidence between 80% and 95%;

Evidence of worse = evidence of worse results regarding municipalities with significant soybean production or cattle ranch activity; confidence between 80% and 95%;

Blanc = statistically there is no difference between groups.

The comparison between results of the analysis carried out for sugarcane and soybean, in case of Mato Grosso, is presented in Table 6.23. The socio-economic impacts seems to be more positive in the municipalities where soybean production is significant. Nevertheless, particularly regarding wealth distribution there is no advantage induced by the economic activity that corresponds to soybean production.

However, regarding these comparison and the conclusions, two aspects should be highlighted. First, soybean production is a well-established economic activity in Mato Grosso and sugarcane has expanded only recently. Second, from 1991 to 2000 it seems that the difference was reduced between the set of municipalities where soybean and sugarcane are significant.

6.7 Income effects

Considering the set of municipalities with significant sugarcane production, it was observed that the average income per habitant, per month, is the factor that explains in a large extent the differences within the group.

The analysis regarding income effects was developed as follows: the municipalities were classified according to the income/capita/month and then municipalities in first quartil were compared with those in fourth quartil. Results for São Paulo are presented in Table 6.24. It can be seen that the municipalities of the first quartil have better parameters than those of the fourth quartil, except regarding wealth distribution. In all cases it is possible to assure that the groups are different (with confidence of at least 95%). Comparing both quartils, in case of São Paulo the municipalities of the first quartil have larger population, smaller share of rural population and lower intensity of sugarcane production (expressed as tonne per habitant).

Table 6.23 Results of socio-economic indicators: comparison sugarcane versus soybean – Mato Grosso do Sul, 1991 and 2000

Indicator	1991	2000
HDI-M	Better results for soybean	Better results for soybean
Households with electricity service (%)	Evidence of better results - soybean	
Life expectancy at birth (years)	Better results for soybean	Better results for soybean
Survival probability up to 60 years (%)	Better results for soybean	Better results for soybean
Deaths up to 1-year old (per thousand)	Better results for soybean	Better results for soybean
Illiterates older than 15 years old (%)	Better results for soybean	Better results for soybean
Alphabetization index	Better results for soybean	Better results for soybean
Gini index		Evidence of better results for cane
Income of the 20% poorest people (%)		
Income ratio (20% richest/40% poorest)		Evidence of better results for cane
Income per capita (R$/hab/month)	Better results for soybean	Evidence of better results - soybean

Notes: Best = better parameters regarding municipalities with significant sugarcane production; confidence of at least 95%;
Evidence of better results regarding the compared group; confidence between 80% and 95%.

Table 6.24 Socio-economic indicators for set of municipalities: effect of income – São Paulo, 1991 and 2000

Indicators	Quartil 1	Quartil 4	Quartil 1	Quartil 4
	1991		2000	
Number of municipalities	39	39	44	44
HDI-M	0.773 ± 0.016	0.712 ± 0.020	0.820 ± 0.017	0.766 ± 0.015
Households with electricity service (%)	99.62 ± 0.35	97.20 ± 3.58	99.83 ± 0.14	99.40 ± 0.64
Life expectancy at birth (years)	70.41 ± 1.57	68.48 ± 2.40	73.05 ± 1.94	71.92 ± 1.93
Survival probability up to 60 years (%)	80.89 ± 2.78	77.38 ± 4.39	85.05 ± 3.51	83.11 ± 3.31
Deaths up to 1-year old (per thousand)	22.09 ± 3.90	27.38 ± 6.78	12.83 ± 3.35	14.79 ± 3.38
Illiterates older than 15 years old (%)	11.04 ± 2.17	17.43 ± 2.61	7.35 ± 1.63	12.63 ± 2.12
Alphabetization index	88.97 ± 2.17	82.57 ± 2.61	92.65 ± 1.63	87.37 ± 2.12
Gini index	0.506 ± 0.031	0.486 ± 0.054	0.545 ± 0.041	0.487 ± 0.032
Income of the 20% poorest people (%)	4.49 ± 0.61	4.94 ± 1.02	3.53 ± 0.53	4.48 ± 0.94
Income ratio (20% richest/40% poorest)	8.98 ± 1.42	8.18 ± 2.32	11.17 ± 2.22	7.96 ± 1.77
Income per capita (R$/hab/month)	329.7 ± 38.5	194.3 ± 21.4	397.8 ± 45.8	223.1 ± 19.2
Population (1,000 habitants)	81.1 ± 88.2	11.5 ± 7.1	92.4 ± 92.5	10.9 ± 8.4
Share of rural population	0.099 ± 0.048	0.248 ± 0.111	0.068 ± 0.046	0.167 ± 0.113
Sugarcane intensity (t cane/hab)	27.0 ± 25.0	59.8 ± 43.5	19.8 ± 15.0	104.0 ± 76.2
Share of the total area with sugarcane	0.345 ± 0,216	0.206 ± 0.162	0.291 ± 0,193	0.405 ± 0.223
Share of the state sugarcane production (%)	34.6	14.6	27.6	18.2

Similar analysis was carried out considering Minas Gerais and Alagoas, both for 1991 and 2000. Results for Minas Gerais are presented in Table 6.25, while results for Alagoas are presented in Table 6.26.

In case of Minas, the municipalities of the first quartil (i.e., with larger specific income) have the best indicators, including wealth distribution (again, groups are different with confidence of at least 95%). Municipalities of the first quartil have larger total population but smaller rural population, as is in the case of São Paulo. What is important to mention in case of Minas is that sugarcane production is concentrated in few municipalities and, in this sense, the first quartil correspond to a significant share of total sugarcane production. It is also worth to mention that there is significant difference between the first and fourth quartils concerning most of the indicators considered.

Results for Alagoas are qualitative similar the two previous cases. Due to certain degree of concentration, municipalities of the first quartil have a significant share of total sugarcane production. It is also worth to mention that there is significant difference between the first and fourth quartils concerning most of the indicators considered, except those regarding wealth distribution.

Table 6.25 Income effect over socio-economic indicators – Minas Gerais, 1991 and 2000

Indicators	Quartil 1	Quartil 4	Quartil 1	Quartil 4
	1991		2000	
Number of municipalities	24	24	30	30
HDI-M	0.718 ± 0.022	0.581 ± 0.032	0.792 ± 0.019	0.652 ± 0.023
Households with electricity service (%)	95.65 ± 2.52	54.04 ± 13.16	98.90 ± 1.19	76.52 ± 13.31
Life expectancy at birth (years)	68.78 ± 1.56	63.29 ± 1.90	73.06 ± 1.62	66.52 ± 2.68
Survival probability up to 60 years (%)	77.55 ± 2.72	67.87 ± 3.37	84.86 ± 2.69	73.35 ± 4.91
Deaths up to 1-year old (per thousand)	27.54 ± 4.30	44.44 ± 6.51	20.32 ± 4.17	40.90 ± 10.51
Illiterates older than 15 years old (%)	16.32 ± 2.81	34.86 ± 8.45	7.35 ± 1.63	12.63 ± 2.12
Alphabetization index	83.68 ± 2.81	65.14 ± 8.45	92.65 ± 1.63	87.37 ± 2.12
Gini index	0.564 ± 0.051	0.539 ± 0.035	0.560 ± 0.054	0.589 ± 0.054
Income of the 20% poorest people (%)	3.57 ± 0.74	3.92 ± 0.60	3.68 ± 0.65	2.09 ± 1.45
Income ratio (20% richest/40% poorest)	12.49 ± 4.02	10.75 ± 2.32	11.69 ± 3.44	17.16 ± 8.21
Income per capita (R$/hab/month)	210.3 ± 32.8	76.1 ± 11.9	301.2 ± 53.6	98.5 ± 13.7
Population (1,000 habitants)	39.5 ± 43.2	13.9 ± 9.3	36.3 ± 47.7	17.0 ± 10.1
Share of rural population	0.214 ± 0.108	0.583 ± 0.139	0.158 ± 0.092	0.532 ± 0.150
Sugarcane intensity (t cane/hab)	16.4 ± 24.3	5.29 ± 4.67	27.2 ± 50.2	3.04 ± 4.91
Share of the total area with sugarcane	0.049 ± 0.050	0.021 ± 0.029		
Share of the state sugarcane production (%)	41.5	6.6	45.4	4.6

6.8 Analysis considering the share of rural population

The comparative analysis previously described was extend in order to take into account the effects (if any) due to the size of population and due to the share of rural population. This was done only for São Paulo and results are presented for the year 2000.

Table 6.26 Income effect over socio-economic indicators – Alagoas, 1991 and 2000

Indicators	Quartil 1	Quartil 4	Quartil 1	Quartil 4
	1991		2000	
Number of municipalities	7	7	8	8
HDI-M	0.529 ± 0.031	0.442 ± 0.035	0.636 ± 0.032	0.541 ± 0.029
Households with electricity service (%)	83.84 ± 7.73	61.97 ± 10.98	92.29 ± 3.15	81.89 ± 7.15
Life expectancy at birth (years)	58.05 ± 2.26	56.74 ± 2.25	65.44 ± 1.97	60.57 ± 3.28
Survival probability up to 60 years (%)	60.87 ± 3.94	58.58 ± 3.93	71.78 ± 3.56	62.95 ± 5.92
Deaths up to 1-year old (per thousand)	73.36 ± 11.52	80.07 ± 11.63	42.36 ± 7.05	62.72 ± 14.41
Illiterates older than 15 years old (%)	47.39 ± 6.42	63.60 ± 6.71	35.30 ± 5.70	48.77 ± 3.69
Alphabetization index	52.62 ± 6.42	36.40 ± 6.71	64.70 ± 5.70	51.23 ± 3.69
Gini index	0.530 ± 0.039	0.433 ± 0.038	0.581 ± 0.045	0.564 ± 0.047
Income of the 20% poorest people (%)	3.98 ± 0.59	5.20 ± 1.05	2.05 ± 0.45	1.60 ± 1.06
Income ratio (20% richest/40% poorest)	10.16 ± 1.96	6.55 ± 1.31	14.36 ± 3.06	14.97 ± 6.21
Income per capita (R$/hab/month)	86.3 ± 9.7	49.7 ± 4.2	103.7 ± 16.0	60.9 ± 4.60
Population (1,000 habitants)	38.4 ± 17.4	18.0 ± 6.1	45.4 ± 15.6	15.8 ± 6.4
Share of rural population	0.408 ± 0.169	0.555 ± 0.144	0.305 ± 0.155	0.417 ± 0.188
Sugarcane intensity (t cane/hab)	29.8 ± 17.4	27.7 ± 14.6	31.1 ± 21.2	27.6 ± 12.7
Share of the total area with sugarcane	0.545 ± 0.209	0.373 ± 0.171		
Share of the state sugarcane production (%)	36.2	13.6	40.3	11.0

In 2000 the share of rural population in São Paulo was 6.6%. The municipalities with and without significant sugarcane production were divided in two other groups, both defined by the size of their rural population: rural population larger than 6.6%, and smaller than the average figure. Only the municipalities with population in the range 1.8-504 thousand people were considered in the analysis (see section 6.4).

Results are presented in Table 6.27. It can be seen that within the group of municipalities with rural population larger than 6.6%, those with significant sugarcane production have better results regarding those in which sugarcane production is absent. The conclusion is valid for all analysed indicators and the confidence that the groups are different is at least 95%.

Table 6.27 Analysis of socio-economic indicators: comparison regarding the size of rural population (average figure 6.6%) – São Paulo, 2000

Indicator	Larger rural population		Lower rural population	
	With sugarcane	Without	With sugarcane	Without
Number of municipalities	123	334	58	81
HDI-M	Better			
Households with electricity service (%)	Better		Better	
Life expectancy at birth (years)	Better			
Survival probability up to 60 years (%)	Better		Better	
Deaths up to 1-year old (per thousand)	Better		Better	
Illiterates older than 15 years old (%)	Better			Better
Alphabetization index	Better			Better
Gini index	Better		Better	
Income of the 20% poorest people (%)	Better		Better	
Income ratio (20% richest/40% poorest)	Better		Better	
Income per capita (R$/hab/month)	Better			

Notes: Better = better parameters regarding the alternative set of municipalities; confidence of at least 95%;
Blanc = statistically there is no difference between groups.

Regarding the size of municipalities, in 2000 the average population in São Paulo was 36,800 habitants. The same procedure was applied and the comparison was done within groups of municipalities with lower population and larger population vis-à-vis the average figure, in addition to the discrimination regarding the production of sugarcane. The results are presented in Table 6.28.

Among the municipalities with significant sugarcane production, those which are the smallest (considering the population size) have better results regarding those in which sugarcane production is absent. Again, the conclusion is valid for all indicators analysed and the confidence that the groups are different is at least 95%. Comparing municipalities with larger population, there is also advantage for those where sugarcane is produced, but in this case the advantage is less clear.

Table 6.28 Analysis of socio-economic indicators: comparison regarding the size of municipalities (average figure 36,800 habitants) – São Paulo, 2000

Indicator	Lower population		Larger population	
	With sugarcane	Without	With sugarcane	Without
Number of municipalities	134	324	47	91
HDI-M	Better		Better	
Households with electricity service (%)	Better		Better	
Life expectancy at birth (years)	Better			
Survival probability up to 60 years (%)	Better		Better	
Deaths up to 1-year old (per thousand)	Better		Better	
Illiterates older than 15 years old (%)	Better			
Alphabetization index	Better			
Gini index	Better		Evidence/better	
Income of the 20% poorest people (%)	Better		Better	
Income ratio (20% richest/40% poorest)	Better		Better	
Income per capita (R$/hab/month)	Better		Evidence/better	

Notes: Better = better parameters regarding the alternative set of municipalities; groups are different with confidence of at least 95%;

Evidence that is better = parameter is better than the compared one; groups are different with confidence between 80% and 95%.

Blanc = statistically there is no difference between groups.

In summary, it was previously shown that the municipalities in which sugarcane production is significant have better results regarding those in which sugarcane production is absent (see Section 6.4). It was also shown that among the municipalities with significant sugarcane production effects of income are imperative, and the municipalities with larger specific income have better results (see Section 6.7).

Moreover, the main conclusion of the current section is that among municipalities with relatively small population, and larger share of its population living in the countryside, the socio-economic impacts of sugarcane production are more noticeable. This conclusion is accurate for São Paulo and further studies are necessary in order to understand the characteristics of other producer states.

6.9 Analysis for municipalities with large share of migrant workers

The literature review indicates some studies in which the migration of workers to producer regions of sugarcane, in São Paulo, is presented as a socio-economic problem (see section 6.2). Based on a list of municipalities that traditionally receive a large number of workers during the harvest period,[91] an analysis was carried out comparing socio-economic indicators of these municipalities with equivalent municipalities (i.e., with the same population range). The analysis was carried out for the years 1991 and 2000. Results are presented in Table 6.29.

As can be seen, no single result support the conclusion that the municipalities with significant share of migrant workers have worse socio-economic indicators regarding other sugarcane producer cities. On the contrary, mainly regarding indicators of wealth distribution the advantage seems to be for these municipalities.

Due to very often comments about this issue, this result is rather surprising and further analysis is required. The socio-economic indicators considered within this analysis were taken from IBGE, and it is necessary to check if temporary workers are included as residents on the data basis of the municipalities in which they work. Anyhow, even in case of this possible distortion, the results indicate that, except an impact on average income, there is no substantial impact considering the socio-economic indicators analysed in this project.

Table 6.29 Impacts of a significant share of migrant workers over socio-economic indicators – São Paulo, 1991 and 2000

Indicators	With migrants	Others	With migrants	Others
	1991		2000	
Number of municipalities	11	110	11	123
Population (1,000)	7-91	7-91	7.7-105	7.7-105
HDI-M	0.742 ± 0.024	0.746 ± 0.024	0.796 ± 0.024	0.795 ± 0.023
Households with electricity service (%)	99.62 ± 0.28	98.80 ± 2.21	99.82 ± 0.11	99.66 ± 0.69
Life expectancy at birth (years)	70.13 ± 2.10	69.63 ± 2.00	72.93 ± 1.64	72.64 ± 2.13
Survival probability up to 60 years (%)	80.36 ± 3.70	79.48 ± 3.59	84.88 ± 2.80	84.33 ± 3.65
Deaths up to 1-year old (per thousand)	22.92 ± 5.17	24.09 ± 5.25	12.97 ± 2.81	13.57 ± 3.69
Illiterates older than 15 years old (%)	14.77 ± 3.06	14.57 ± 3.06	9.91 ± 2.17	9.71 ± 2.29
Alphabetization index	85.23 ± 3.06	85.43 ± 3.06	90.09 ± 2.71	90.29 ± 2.30
Gini index	0.475 ± 0.043	0.493 ± 0.048	0.500 ± 0.038	0.522 ± 0.047
Income of the 20% poorest people (%)	5.09 ± 0.76	4.72 ± 0.85	4.04 ± 0.66	3.89 ± 0.75
Income ratio (20% richest/40% poorest)	7.70 ± 1.73	8.50 ± 1.88	8.83 ± 1.58	9.98 ± 2.60
Income per capita (R$/hab/month)	262.8 ± 44.6	257.5 ± 47.2	293.5 ± 56.0	305.8 ± 58.6

6.10 Evolution of the indicators – 1991 to 2000 and 2000 to 2005

The analysis was carried out based on the variation of the indicators, between 1991 and 2000 (based on IBGE's parameters) and between 2000 and 2005 (based on FIRJAN's parameters). Then, the municipalities in which sugarcane production have been significant were ordered according to the growth (or reduction) of sugarcane production in each period and, finally, the variation of the indicators (in relative percentage) was compared between the first and the fourth

[91] The municipalities considered were Catanduva, Cosmópolis, Cravinhos, Guariba, Leme, Macatuba, Pradópolis, Serrana, Terra Roxa and Valparaíso.

quartil. This procedure was applied to São Paulo and Alagoas. The results for the period 1991-2000 are presented in Table 6.30, while the results for the period 2000-2005 are presented in Table 6.31.

Table 6.30 Socio-economic indicators: comparison between set of municipalities with growth and with reduction of sugarcane production in the period 1991-2000

Indicators	São Paulo		Alagoas	
	First quartil	Fourth quartil	First quartil	Fourth quartil
Number of municipalities	38	38	8	8
Average change of sugarcane production	$1.5 \cdot 10^6$%	-22%	79%	-11%
HDI-M	Better			Evidence of better
Households with electricity service (%)				Better
Life expectancy at birth (years)	Evidence of better			
Survival probability up to 60 years (%)	Evidence of better			
Deaths up to 1-year old (per thousand)	Evidence of better		Evidence of better	
Illiterates older than 15 years old (%)				
Alphabetization index				Better
Gini index	Better		Better	
Income of the 20% poorest people (%)	Evidence of better			
Income ratio (20% richest/40% poorest)	Evidence of better			
Income per capita (R$/hab/month)				

Notes: Better = better results regarding the alternative quartil; confidence of at least 95%;
Evidence of better = better results regarding the alternative quartil; confidence interval 80%-95%.
Blanc = statistically there is no difference between groups.

Table 6.31 Socio-economic indicators: comparison between set of municipalities with growth and with reduction of sugarcane production in the period 2000-2005

Indicators	São Paulo		Alagoas	
	First quartil	Fourth quartil	First quartil	Fourth quartil
Number of municipalities	44	44	7	7
Average change of sugarcane production	89%	-5%	52%	-43%
Jobs and Income				
Education		Evidence of better		Evidence of better
Health		Better	Evidence of better	

Notes: Better = better results regarding the alternative quartil; confidence of at least 95%;
Evidence of better = better results regarding the alternative quartil; confidence interval 80%-95%.
Blanc = statistically there is no difference between groups.

In case of São Paulo, the growth of sugarcane production within the first quartil was at least 70% from 1991 to 2000[92], and at least 48% from 2000 to 2005. In the fourth quartil the reduction of sugarcane production varies from 3% to 82% along the period, while during the period 2000 to 2005 the change on production varies from 7% (i.e., a small growth) to –51% (i.e., a significant reduction).

In the case of São Paulo, in the period 1991-2000 all indicators improved, except those regarding wealth distribution. For some indicators the difference between first and fourth quartil allows the conclusion that the groups are different, with better results for municipalities within the first

[92] Four municipalities started to produce sugarcane in large-scale along the period, and for them the growth is huge.

quartil (i.e., municipalities with significant growth of sugarcane). The better result regarding the Gini Index is due to its smaller growth. Also in the period 2000-2005 all indicators improved, but conversely, the municipalities within the fourth quartil had better performance in comparison to those of the first quartil. At a first moment it could be concluded that there was advantage of municipalities in which sugarcane production has declined, but it is important to remember that the analysis in the period 2000-2005 is based on more aggregate indicators.

Qualitatively the same can be concluded regarding the results for Alagoas in both periods. What is different regarding São Paulo is that in some cases the improvement of indicators is larger within the group of municipalities in which sugarcane production was reduced. This is possibly related with the lower competitiveness of sugarcane industry in Alagoas in recent years.

In summary, from the point of view of the socio-economic aspects at regional level, in São Paulo the growth of sugarcane production brought more benefits in short-term than its reduction. In case of Alagoas, the results are not conclusive. Anyhow, the analysed period is short and a longer period of time could be necessary to reflect mayor changes.

6.11 Conclusions

This chapter was devoted to the analysis of socio-economic aspects of sugarcane production, with focus on the impacts at a regional level. The analysis was carried out analysing different parameters, in an attempt to identify the welfare in municipalities in which sugarcane production is significant.

The results lead to different conclusions, but in a general sense, considering where the bulk of sugarcane production takes place, and more specifically in the state of São Paulo, there is no reason to suppose that sugarcane production induces deterioration of the welfare. On the contrary, in most of the cases socio-economic indicators are better in municipalities in which sugarcane production is important, regarding equivalent municipalities in which sugarcane production is absent.

Chapter 7
Other Environmental Aspects

7.1 Introduction

In this Chapter other important environmental aspects beyond those previously addressed are commented on. They are grouped in one single chapter not because they are less relevant. Contrarily, they are among the most important issues in studies such as Sustainable biofuels: prospects and challenges, published by The Royal Society in January 2008 (Royal Society, 2008); Cramer Report (Cramer et al., 2007); and Standards for Bioenergy (Fritsche et al., 2006). However, they are not the main focus of this study. In the following sections, the topics biodiversity, water, agricultural patterns and practices (soil, plant protection) are extended.

7.2 Biodiversity

7.2.1 Initial remarks

Royal Society (2008) states: "*Any form of agriculture can pose risks to biodiversity and there are opportunities to improve biodiversity by using specific crops and land management systems. As with any new agro-ecosystem, growing a biofuel crop will alter local habitats and resources in a way that will affect native species distribution and abundance. These effects will depend on the crop, its density, duration and distribution on the landscape, and any regular inputs, including water and agrochemicals. Given the range of potential crops, from trees to dense grasses, impacts to biodiversity will vary*." Towards to these concerns and presenting some other information, it is made an environmental characterization of sugarcane production and the biodiversity in Brazil with an analysis according to production field, local/river basin, which could be helpful for further studies.

7.2.2 Biodiversity into the production field

Biodiversity bellow ground is a key factor for carbon and nutrient cycling. Miranda (2004), based on Giller et al. (1997) and Wardle (1996), mentions that soils are the basis for biodiversity. Quoting Black and Okwakol (1997), the author states that "live" soils help to maintain the environmental equilibrium in the agricultural systems along the time. Physical properties such as structure, porosity, density, and infiltration are highly dependant on the soil organic matter as well as its biodiversity.

On average, sugarcane field is replanted/renewed each 5 years, what means that the soil structure is less disturbed than other annual and seasonal crops soils. Arrigoni, in Macedo (2005), refers that most pests found at sugarcane fields[93] have been controlled by using parasitoids (Tachinid flies), natural predators and the fungus *Metarhizium anisopliae*, instead of using agrochemicals, which also help the life maintenance of the microenvironment at the field.

[93] Such as sugarcane bettle, defoliating caterpillars and spittlebugs.

The input the soil receives annually at the sugarcane field is estimated as about 19 t/ha and 8 t/ha of dry matter, if harvest is mechanized without trash burning or not, respectively (Resende et al., 2001). Residues and trashes contain about 140 GJ/ha and 60 GJ/ha, respectively. It is estimated that 95% of the input is taken during the same year for its decomposition (Resende et al, 2001). This amount of carbon and energy is used for biogeochemical processes. Part of this goes up to the stage of mineralisation, returning thus ashes (nutrients) for the next growing year. It means that it feeds the first levels of the food chain helping biodiversity itself and also the next food chain steps above ground. The use of vinasse and filter cake, as well as the biological nitrogen fixation, make sugarcane almost self sufficient in terms of nutrients. Therefore, small amounts of chemical and mineral fertilizers have to be used to fulfil its overall needs. The impacts that a massive nutrient application could lead to the soil system such as pH, salinity, community disturbance, among others, can thus be highly diminished.

Biodiversity above ground may be specially supported by rich soil attributes. Additionally, integrated pest, weed and disease management techniques must be applied onto the sugarcane field. As it was described above, the alternative control for pests is made using parasitoids and fungus. For diseases it is employed the use of resistant varieties, which is the most common and sustainable method available. For weeds, according to Ricci in Macedo (2005), an integration of mechanical, cultural, biological and chemical methods is the best option for sugarcane. Good weed management thus integrates: preventive mechanical control, selective herbicides applied mostly in post-emerging way and according to the weed pressure on each sub-area, instead of a general and massive pulverization. Practices such as the use of dead cover (also trash) and specially green cover with jack bean, which may act as an inhibitor (allelopathic substances) for nutgrass, can provide different habitats for fauna and flora, improving biodiversity and therefore stabilizing communities variability and population sizes into the own sugarcane field.

7.2.3 Local and river basin biodiversity

Present legal framework set some limits for land use in a given local or river basin. The Forest Code (Law 4.771/1965) determines that any rural land must keep intact part of its area as Legal Reserve (RL). Parameters are 80% in the Amazon region, 35% in the Amazonian Cerrado (savannas) and 20% (25% of the planted area) in all other regions. Furthermore, the Forest Code requires preservation of riparian vegetation according to the water body size or width, slope, and nature of water springs, being these protected areas named as Permanent Protection Areas (APPs).

A survey made by Barbosa, found in Macedo (2005), comprising a sample ranging from 650,000 ha to 780,000, ha mostly in the state of São Paulo, shows a figure of 8.1 % of the sugarcane area as APP. The same survey showed that 0.6% remains as a target to be met trough natural vegetation restoration on sugarcane fields. Another 2.9% are under a process of spontaneous rehabilitation, and 3.4% with natural woods. These figures are peculiar to São Paulo because at the time the new Law of Environmental Crimes (9605/1998) was set to inforce the Forest Code, most arable lands were already opened and RL and APPs standards were previously (partially) met. For new opened lands (e.g., in Minas Gerais, Goiás, Mato Grosso and Mato Grosso do Sul), APPs and RLs are likely to be most in the natural/native state.

Miranda (2008) has surveyed vertebrates at a sugarcane field from 2002 to 2008 at different sites[94]. Results of "Total Richness Value" have shown figures ranging from 137 (restored/improved native forest) to 82 (exotic forests) species, following in decreasing order: enhanced native forests, stand state native forest, wetlands/ponds/riverbanks/riparian forests, drainage channels, spontaneous restoration forests, organic sugarcane fields and exotic forest. The author found about 50% more bird species in this enhanced sites comparing with figures of the macro region in which the survey was undertaken (Miranda, 2004). Results clearly indicate the need for enhancing APPs and RLs notably if they are not in the natural native state they should be. Even being legally accepted, spontaneous restoration produces limited ecological functions during the time its process takes place, including for biodiversity.

Considering that sugarcane in Brazil has presently an area of about 8 Mha, if applied the same proportion mentioned above for São Paulo, the sum of RLs and APPs would to be about 2.8 Mha. It means that for each 100 ha of sugarcane there must be about 35 ha of APPs and RLs located mostly in the same micro river basin or catchment. As, in general, APPs pay the role of wildlife corridors due to their location being along the watercourses, they may provide the appropriate genic flow linking different RLs.

Impacts on fauna of sugarcane plantations were studied by EMBRAPA (2000) and a synthesis of the results is presented in Table 7.1. Scores represents impact levels as follows: 1 – no impact; 2 – low impact; 3 – medium; 4 – high; and 5 – very high impact. Considering that these are average values, and also considering that they were observed before the appliance of several sustainable practices employed presently, some of them described in this section, sugarcane impacts on fauna may be roughly considered low.

Table 7.1 Impacts of sugarcane on fauna in the state of São Paulo analysed from 1984 to 2000

Fauna	Food	Shelter	Reproduction
Mammals	3	2	2
Birds	1	2	2
Reptilians	3	3	3
Amphibious	1	1	1
Invertebrates	2	2	2

Source: EMBRAPA (2000)

7.2.3 Global/national biodiversity

Beyond the Legal Reserves and Areas of Permanent Protection, described above, Brazil has other legal mechanisms for protecting biodiversity, such as UCs – Units of Conservation, TIs – Indigenous Area, and TQs – Quilombo Areas. According to Velasquez (2007), in 2007 TIs account about 109 Mha or 12.8% of the Brazilian territory. There are approximately 850 UCs, 440 from which are Units of Sustainable Use, accounting 99.5 Mha, while the remaining are Units of Integral Protection. The overall UCs lands should be about 14% of the national territory, however there are some overlaps with State units as well as with TIs. Roughly, from the 851 Mha of the total national territory, 228 Mha (or 26.8%) are environmental protection areas.

[94] Located inside an organic production area and neighboured by conventional sugarcane field, RLs and APPs under enhanced and improved methods of restoration, non-assisted ones and also exotic forests.

Table 7.2 presents data in order to characterize the current situation of Brazil, UK, Netherlands and Germany regarding protection areas. Considering the proportion of protected areas in relation to each country's surface, Brazil has the best result, as so regarding the extension of protected areas per habitant.

Table 7.2 Protected areas in Brazil, UK, Netherlands and Germany and their proportion in relation to the own countries overall surfaces and population – 2007

Country	Brazil	The UK	The Netherlands	Germany
Surface (SF) overall (1,000 ha)	851,000 [a]	24,253 [a]	4,055 [b]	35,786 [a]
Protected Areas (PA) (1,000 ha)	228,000 [c]	2,322 [d]	751 [d]	5,289 [d]
Population (PP) (1,000 habitants)	186,400 [a]	59,700 [a]	16,300 [a]	82,700 [a]
PA/SF (2/1) (%)	26.8	9.6	18.5	14.8
PA/PP (2/3) (m^2/habitant)	12,232	389	461	639

Data sources: [a] The Economist (2008); [b] Netherlands Environmental Assessment Agency (2008); [c] Velasquez (2007); [d] European Environment Agency (2007).

7.3 Water

7.3.1 Initial remarks

The impacts of large-scale agricultural activities, particularly sugarcane production, on water availability and on quality of water bodies have been an important issue, both nationally and internationally. This topic would be central in a national sustainability agenda and efforts should be addressed in order to reduce water consumption and the impacts of effluent disposal. The following paragraphs are based on previous research and are divided in agricultural and industrial production phases.

7.3.2 Agricultural phase - sugarcane production

In general, annual rainfall in the Centre-South region is enough for supplying sugarcane needs. According to Sousa (in Macedo et al., 2005), plant requirements range about 1500 to 2500 mm/y, depending on the evapotranspiration (ET)[95]. In the Centre-South region, annual rainfall is similar to plant requirements, i.e., increasing during the summer and decreasing during the winter.

Although sugar has been mostly rain-fed, irrigation is employed always it is technically, economically and hydrologically feasible. Some management practices have been using irrigation in some cases, such as: a) the planting process in dry seasons, assuring survival of stems sprouts; b) ferti-irrigation using industrial residues; and c) complementary irrigation employed for overpass small droughts, as well as to fulfil requirements at the beginning or at the end of its growing cycle.

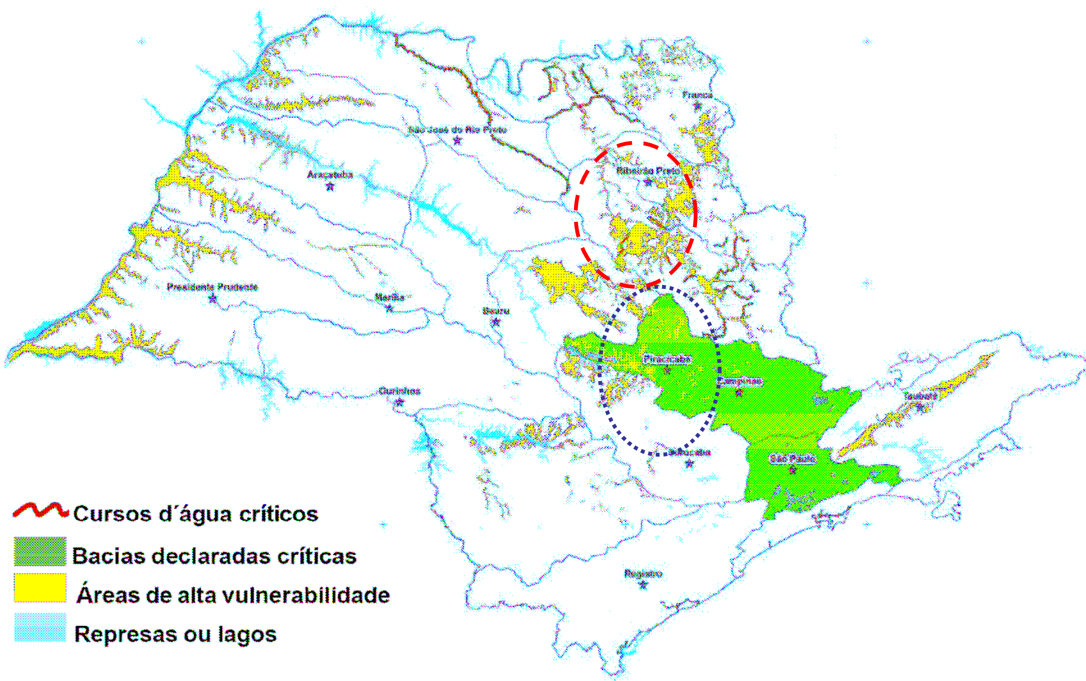
Water balance in some river basins such as the Piracicaba, Capivarí and Jundiaí system (PCJ)[96] deserves special attention because the region is highly populated and due to the fact the region is

[95] ET varies from place to place, and also along the year.

[96] The PCJ water supply system provides water for two dense metropolitan regions: São Paulo and Campinas, apart from many other small municipalities in the countryside with about 20 million inhabitants.

highly surrounded by sugarcane fields. However, the water consumption for sugarcane, measured by the cultural coefficient (KC)[97], is similar to many other crops.

Figure 7.1 shows the result of a recent study carried out by the Environmental Secretariat and the Agriculture Secretariat in state of São Paulo (São Paulo, 2008). The map is subsidiary information of the Agro-ecologic Zoning in São Paulo (see section 2.9.3). It can be seen that the region around Piracicaba, one the most traditional regions of sugarcane production in São Paulo, has a critic status, while the region close to Ribeirão Preto, the largest producer region in the country, has been considered highly vulnerable.



Notes: "Cursos dágua críticos" means critical water flows; "Bacias declaradas críticas" means Basins at a critical situation; "Áreas de alta vulnerabilidade" means Areas under high vulnerability; "Represas ou lagos" means Dams or lakes.

Source: São Paulo (2008)

Figure 7.1 Current status of water resources in state of São Paulo

Regarding ground water, the most important table located at sugarcane producer regions is the Guarani Aquifer, which is for many municipalities the main water supplier for urban demand. One of the main sugarcane poles, the region around Ribeirão Preto, including the region at the Rio Pardo river basin[98], were studied by Cerdeira et al (2007). They stressed the need for adopting best management practices (BMPs) in agriculture due to the sensibility to negative impacts presented by this water table especially in sandy soils. To protect ground water, the state

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[97] KC for sugarcane is estimated as 0.85-1.05. The cultural coefficient (KC) index of water consumption for a given crop has as reference the potential evapo-transpiration (EP), which is measured on a grassy field.

[98] Region shown in Figure 7.1, around Ribeirão Preto.

of São Paulo issued the Law n. 6,134/1988 and the Decree n. 32,955/1991, both treating of its protection and preservation.

The Brazilian Forest Code, Law 4,771/1965, amended by Law 7,803/89 and Provisional Measure 2,166-1967, states the Permanent Protection Areas (APPs) that have a special function of protecting riparian vegetation along water bodies. Forests and other forms of natural vegetation are considered permanent preservation units when located as follows: a) along rivers or any water stream, in a width of 30 m for water stream up to 10 m wide; b) 50 m of vegetation for water streams of 10-50 m; c) 100 m of vegetation for water streams of 50-200 m; d) 200 m for water streams of 200-500 m; e) 500 m for rivers with more than 600 m; f) surrounding lagoons, lakes, natural or man-made reservoirs; g) and in a radius of 50 m around springs and wells (Milaré, 2004).

In São Paulo, as previously mentioned (see section 7.2.3), law enforcement regarding APPs has not been satisfactory. Aiming at filling this gap, an initiative from the Agricultural and Environmental Secretariats of State, called "Green Cane Protocol" (see section 2.9.2) has established an agro-environmental scheme with the sugarcane sector to promote best practices beyond business-as-usual. Its directives "e" and "f" respectively set: "Protect the Riparian Forest of the sugarcane farms due to its relevance for the environment and biodiversity protection, and "Protect the water springs of rural areas of sugarcane farms, recovering its vegetation".

7.3.3 Industrial phase – ethanol production

The ethanol industrial process is traditionally taken as the worse phase of the entire cycle in terms of water quality and quantity, notably in some over industrialized and over populated water basins. However, due to either law enforcement or economic and environmental reasons, it has been experiencing deep improvements through reuse, recycling and returning wastes to the plantation fields.

On average, water intake is 5 m^3/t of cane, while best figures are just 1.23 m^3/t of cane. In fact, water demand may drop to below 1 m^3/t with almost no effluent released (Elia Neto, in Macedo et al., 2005). According to Sugarcane Technological Centre (CTC) the average consumption of water in the state of São Paulo is 1.83 m^3/t of cane.

Output water effluents from sugarcane washing, multijet and barometric condenser, fermentation vats and ethanol condenser cooling, vinasse and other wastewaters may be reused, recycled, technically disposed or applied as fertilizers at the sugarcane field. Special attention must be given to the vinasse, which is produced in large volumes and has a high organic load (11 l/l ethanol with a BOD_5 of 175 g/l) and has a pH of 4-5. Currently vinasse is used as potassium source of nutrients under strict legislation[99] that regulates its disposal and application.

In September 2008, the equipment supplier Dedini, the largest in Brazil concerning equipment and devices for sugarcane mills, states that hereafter it would be possible to vanish water intake in sugarcane mills and, depending on the technology applied, it would even be possible to have surplus of water (0.3 m^3/t of cane, according to the company). Self-consumption of water (i.e., water intake nil) would be possible with dry-cleaning of sugarcane, besides recovery of condensates along the process. Surplus water would be possible with recovery of water from the

[99] CETESB Technical Rule P 4,231/2005.

vinasse, through its thermal concentration (FAPESP, 2008). The advantage in this case would be surplus water availability, but the energy demand in the industrial would be enlarged.

The "Green Cane Protocol", previously described, has respectively in its directive "h" and "j" the following statements: "Implement a Technical Plan of Water Resources Conservation, respecting the hydrological cycle, including a Water Quality Program and Water Reuse Program"; and "Adopt good practices to minimize air pollution from industrial process and optimise the recycling and reuse of industrial process solid waste".

7.4 Soil and plant management

7.4.1 Initial remarks

Some agricultural and environmental aspects of the sugarcane plantations, including good management practices adopted and recommended, are described below. Integrated nutrient, pest, disease, weed and soil carbon management are referred as follows together with some comments on fertilisers and agrochemicals.

7.4.2 Soil protection, nutrient cycling and fertilizers

The adoption of good soil conservation practices on sugarcane production has been reducing erosion rates up to the level of pastures. Beyond some practices, such as contoured seeding/furrowing/ripping and using of absorption terraces, there are two other measures related to straw and tillage even more effective. Figures such as those shown in the table 7.3 confirm the importance of leaving straw and trash as a mulching at the field. Leaving of straw and trash at the field could be a common practice in the years to come, as long as phasing-out of sugarcane burning will be compulsory and it's going to be not feasible to transport all trash to the mills.

No-tillage and minimum tillage may be employed in cane renewal helping to reduce soil and water losses during the most sensible phase. The rotation using crops, such as soybean and jack bean, may be done sowing seeds directly on the mulching layer left by the non-burnt harvest. After that, cane stems may be placed furrowing field in between rows of the previous year with no other mechanical preparation (Demattê, 2004). No-tillage and minimum tillage probably are going to be a common practice in order to reduce costs and soil compactation, with benefits regarding the reduction of diesel consumption (and, consequently, GHG emissions).

Table 7.3 Compared soil and water losses regarding three different straw handling systems under an annual rainfall of 1,300 mm and slopes ranging from 8.5 to 12%

Handling system	Soil loss (Mg/ha)	Water loss (% of rainfall)
Burnt straw	20.2	8.0
Buried straw	13.8	5.8
Straw on the surface	6.5	2.5

Source: Conde and Donzelli (1997) and Gandini et al. (1996), in Macedo (2005)

Either in agronomical or industrial phases, sugarcane management provides more efficient nutrient cycling. Nitrogen extracted from air through biological fixation inserts supplies part of

sugarcane demand at low environmental and economic costs. New technologies are based on returning industrial residues to the sugarcane field, reducing waste material and the consequent input of energy, use of fertilizers and soil regenerators. Straw left at the field would allow recycling nutrients to the plant. Currently, filter cake has been employed as fertilizer, being a whole source of macro and micronutrients, as well as of organic matter. More important, for years vinasse has been used as potassium fertilizer, and since recently, in São Paulo vinasse has been applied according to strict rules (see CETESB Technical Rule P 4.231/2005).
Barbosa (2007) figures suggest that up to two thirds of the macronutrients may return to the field by the use of harvest and industrial residues. As long as good residue management practices are undertaken, apart from biological fixation of nitrogen, lime and chalk, complementary fertilization for the ratoon can be just about 30 kg/ha of nitrogen and 8 kg/ha of phosphorus per year[100]. This, it could be lower than most crops commercially planted in Brazil.

According to Donzelli, in Macedo (2005), in sugarcane crops in Australia 30% more fertilizer in the ratoon and 54% more in the plant cane are used comparing with ordinary nutrition in Brazil. Thus, in Brazil small amounts of chemical and mineral fertilizers have to be used annually which means the likely impacts that a massive nutrient application could lead to the soil system can thus be highly diminished (e.g., pH change, salinity, community disturbance, among others).

7.4.3 Soil carbon stock

Some special functions in soil are attributed to the organic matter, fauna, flora, trashes left on the surface layer, as well as roots and other kinds of biomass constantly decaying. All of them are evaluated through the total soil carbon stocks. Soil density, organic colloids, aggregates, porosity, water carrying capacity, and several other bio-geological functions are dependant on the carbon content in the soil.

Luca, in Cerri et al. (2007), refers that sugarcane soil stocks have increased on average 1.55 Mg of C/ha.yr for non-burnt harvest in the Centre-South region within a 0-40 cm layer. Another study on the same subject was carried out by Jantalia et al. (2006) from 1991 to 2002, in Planaltina-DF, looking at evaluating the effects of pastures and tillage systems on carbon and nitrogen in oxissol (red latossol). In this case, undisturbed Cerrado was converted in different land uses. Results (after more than 10 years) for depth 0-40 cm showed that pasture has reduced total soil carbon in a average rate of 0.18 Mg C /ha.yr, and crops reduced in average of 0.20 Mg C/ha.yr.

According to CONAB (2008), 64.7 % of the sugar cane expansion for the year 2007-2008 all over Brazil was established on pasture lands, 32.9 % on crops + others, and 2.4% on new lands. Therefore, on short term it could be used as the baseline scenario for assessing the impact on soil carbon as a consequence of land use change by conversion to sugarcane fields.

Considering the characteristics of previous land use described above, and values for soil carbon changes referred by authors in the first and second paragraphs, calculations are made and results showed in Table 7.4 below. An exception is the value related to new lands. The value chosen for it is found in Fargione et al (2008), which considered that all new lands for sugarcane conversion

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[100] In Table 3.5 it could be see that current figures of nitrogen use as fertilizer is 0.8 g/kg of plant, that means 64-68 kg/ha/year, considering yields in the range 80-85 t/ha.

are Woody Cerrado. This datum is regarded to be from the worst scenario for new lands, and unlikely to occur as proved in the Chapters 4 and 5. However it is being used as an exercise for analysing the sugar cane performance facing this assumption.

Table 7.4.1 Soil carbon change on land use conversion to sugarcane for the expansion area in Brazil related to the year 2007-08

Item	Soil carbon change (MgC/ha.yr)	Share in the expansion (%)	Share in soil carbon change (MgC /ha.yr)
Land use 2006-07			
Pasturelands (average)	-0.18 [a]	64.7 [d]	-0.12
Croplands + other (average)	-0.20 [a]	32.90 [d]	-0.05
New lands	45.00 [b]	2.40 [d]	1.08
Land use 2007-08 (conversion)			
Sugarcane	1.55 [c]	100	1.55
Net carbon soil change			0.64

Sources: [a] Jantalia et al. (2006); [b] Fargione et al. (2008); [c] Luca, in Cerri et al. (2007); [d] CONAB (2008)

Thus, based on these hypothesis, it is possible to state that expansion occurred in the year 2007-2008 resulted a positive soil carbon change of 0.72 MgC/ha. For the current scenario this value indicates: firstly, that carbon increase is going to help bio-geological functions as described above; secondly, that it must be considered as further mechanism for GHG abatement beyond the avoided emissions provided by the ethanol use in substitution of the fossil fuels.

7.4.4 Plant protection and agrochemicals

Improving biodiversity below and above ground may especially help plant protection. In sequence, integrated pest, weed and disease management techniques must be applied on the sugarcane field looking at avoiding economic losses and maintaining communities' equilibrium.

In section 7.2.2 it was previously mentioned that integrated control is a common practice at sugarcane fields for controlling pests (Arrigoni, in Macedo, 2005). Such techniques, instead of using agrochemicals, indeed preserve natural enemies' population. It was also mentioned that, according to Ricci (in Macedo, 2005), for weeds an integration of mechanical, cultural, biological and chemical methods is the better management available for sugarcane.

For controlling diseases, the use of resistant varieties/hybrids/clones has been employed in Brazil for decades and is the most common and sustainable method available. Diseases such as cane smut, cane rust and yellow leaf virus, are inside those ones researched and protected for plant resistance (Landell and Silva, 2004).

In Brazil the consumption of agrochemicals for sugarcane production is lower than in citric, corn, coffee and soybean cropping. Sugarcane uses more herbicides per hectare than coffee and maize, less than citric crops, and about the same amount as soybeans, as it is showed in the table 7.5 below (Marzabal et al., 2004, *apud* Macedo, 2005).

Table 7.5 Consumption of fungicides, insecticides, acaricides and agricultural defensives – Brazil, 1999 and 2003 (in kg active ingredient/ha/year).

Agrochemical	Year	Coffee	Sugarcane	Citric	Corn	Soybean
Fungicides	1999	1.38	0.00	8.94	0.00	0.00
	2003	0.66	0.00	3.56	0.01	0.16
Insecticides	1999	0.91	0.06	1.06	0.12	0.39
	2003	0.26	0.12	0.72	0.18	0.46
Acaricides	1999	0.00	0.05	16.00	0.00	0.01
	2003	0.07	0.00	10.78	0.00	0.01
Agricultural defensives	1999	0.06	0.03	0.28	0.05	0.52
	2003	0.14	0.04	1.97	0.09	0.51

Source: Macedo (2005)

Most agrochemicals used in sugarcane plantations are herbicides. According to Camargo et al. (2004), in monetary terms sugarcane shared 6.5% of the total demand of agrochemicals in Brazil in 2004. From this amount, 77.1 % were related to herbicides. Equivalent results in 2003 were 8% and, in 2002, 11.5%, therefore decreasing (although this trend has been reverted after 2004, increasing again). Ferreira (2000), quoted by Armas et al. (2005), states that 1997-1999 agrochemical distribution in sugarcane plantations was 10% for insecticides, 84% for herbicides and about 6% for other chemicals.

A study by Armas et al (2005) on the Corumbataí river basin, tributary of the Piracicaba river[101], assessed the use of 24 active ingredients, single or mixed (39 commercial names), from 15 chemical groups. After a period of four years (2000-2003) gliphosate presented 19.9% of the overall products demand, followed by atrazine – 14.5%, ametrine – 14.4%, 2-4D – 10.6%, metribuzin – 9.4%, diurom – 7.9%, and acetochlor – 7.8%.

Trends in herbicide consumption have a reasonable explanation: all products mentioned right above are old chemical groups, presenting low prices per unit (per litre or kg) and high recommended dosage per ha, due to their use on soil instead of on the weeds. Unfortunately, according to Camargo et al. (2004), it is a common practice shifting towards to the old and cheapest chemical products in difficult years forgetting side aspects such as toxicity level as presented by.

For comparing European and Brazilian agrochemical policies, the following regulations can be used: a) Regulation (EC) n^{o} 396/2005 on maximum residue levels of pesticides in food and feed of plant and animal origin; b) British Pesticide Safety Directorate (PSD, 2006) on assessment on agrochemicals use (EFSA, 2007); and c) AGROFIT (2008), from the Brazilian Ministry of Agriculture, which has available a complete data basis containing all agrochemicals registered for sugarcane (64), with their related recommendations (LD 50, and MRL). Thus, it would be possible to compare Brazilian recommendations with the European and British ones.

Checking if water bodies may be contaminated by agrochemicals, in São Paulo CETESB (2008) provides updated Reports on Rivers Water Quality, monitored by the Secretariat of Environment of the state. It has been possible observe directly from the website several parameters and indicators and to compare them with standards established by CONAMA – National Environmental Council (Resolution 357/2005).

[101] In the traditional sugarcane producer region of Piracicaba and Limeira, in the state of São Paulo.

Chapter 8

Further Required Research and Recommendations

The aim of this chapter is to present, from the point of view of the authors of this report, further required research and actions in order to improve the sustainability of Brazilian ethanol.

The results of avoided GHG emissions due to the automotive use of Brazilian ethanol are well recognized as long as its domestic use is concerned. The evaluation done in this report, considering avoided emissions in case of its consumption abroad (e.g., in Europe), is preliminary. The results presented here are reasonably accurate, but this evaluation should be done in more depth.

Also regarding the GHG balance, it is necessary to properly assess nitrous oxide emissions associated to the plant growing cycle. As shown in the Chapter 2, and mostly because of this aspect, there are controversial results attesting both viability and non-viability of biofuels regarding GHG emissions' reduction. In this regard, there is need therefore for a joint scientific effort to evaluate emissions related to the sugarcane growing patterns in its full range. Simultaneously to emission studies, the improvement of fertilization practices must be equally researched, such as the study of alternatives regarding nitrogen plant nutrition as well as for reducing N losses to the atmosphere.

Land use change must be also object of further studies aiming at precisely quantifying the multiple land uses converted to sugarcane. In sequence, the carbon emissions balance has to be carefully done taking into account trends in agricultural practices, including tillage reduction and the use of residues for soil cover, already adopted in large scale. More important, it is imperative that public and private sector assume their responsibilities on carrying for stopping illegal deforestation and land degradation. As presented in this report, sugarcane does not have any relation to deforestation in both direct an indirect ways.

It is necessary to constantly monitor direct land use changes taking into consideration the difficult assessment of the indirect ones, as presented in this report. Further studies are required for defining methodological procedures for Indirect LUC evaluation. Socio-economic impacts must be precisely and seriously evaluated. Although preliminary, results presented in this report, may show that many conclusions brought from other studies have a lot of inaccuracy due to the generalization of results from the use of non-representative figures. Here, methodological procedures are also required as well as the existence of reliable and representative data basis for monitoring and analysing impacts.

Water consumption deserves a special attention targeting efficiency and reduction of relative intakes. In Brazil, some states have issued public policies and effective measures were already implemented for disciplining the use and preserving water resources. However, the first step towards to the protection of water resources is to put in practice which is a legal obligation regarding Permanent Protection Areas (APPs) and areas of Legal Reserve (RLs). From the industrial point of view, water abstraction must be minimized, which is indeed a technological challenge. And from the agricultural point of view, challenges are to produce sugarcane at the new frontiers according to the probably lower rainfall rates and water availability found in some of these expansion areas.

Fertilizers and agrochemicals have to be also object of especial attention. All stakeholders should to be conscious about the importance of this issue and, besides further scientific research, the State should act in order to foster best practices and law enforcement. Anyhow, the experience shows that lower use of fertilizers and chemicals – e.g., due to the use of residues and to the biologic fixation of nitrogen – are not only possible, but also beneficial.

Biodiversity preservation should be a target itself, but good results could be achieved with the use of best practices and technologies besides, obviously, to law enforcement. On the other hand, it is necessary to avoid, mainly through the adoption of appropriated public policies, the exclusive cultivation of sugarcane in large extension areas such as happened in some municipalities found in this study.

Sugarcane and ethanol producers, academy, public and private sectors and society have the duty of discussing and defining a Brazilian agenda for assuring the effective ethanol sustainability here produced. Taking the international criteria as a reference point is advantageous, since most of the high-priority aspects regarding biofuels sustainability are also issues of concern for Brazil (e.g. land use change, deforestation, impact on hydro resources, improved distribution of economic benefits).

Finally, the debate about sustainability of biofuels production should be more democratic and all stakeholders should participate, in special the potential producers. It is comprehensive so many initiatives about this issue, but it is time to join efforts in order to obtain practical results.

Chapter 9

Conclusions

In this Chapter the main conclusions presented along the text are summarized.

It is well known that sugarcane production is growing fast in Brazil. Currently, the main driving force is the enlargement of the domestic market, induced by the success of FFVs. This market is large enough to induce investments, and also improvements in the industry.

The definition of sustainability principles and criteria regarding biofuels production is a clear tendency and decisions should be taken at State level, in Europe, in less than a year. Certification of biofuels production would be the natural consequence of such policies. Within the international agenda it is obvious that the most important issue regarding sustainability of biofuels is GHG emissions and the its ability in reducing emissions regarding fossil fuels (gasoline and diesel). Direct and indirect impacts of land use change are also issues of concern. The priority is partially due to the potential impact of land use change on GHG emissions, but other aspects have been taken into account, such as loss of biodiversity and disruptions of food supply. These issues were prioritised in this report.

The energy balance and the GHG balance of ethanol production from sugarcane, in Brazil, are very favourable. In case of sugarcane cropping without land use change, avoided GHG emissions would ensure that the criteria that may be applied in the short-term by the European Union or other individual European countries are fulfilled (30%-35% of avoided emissions, or even 40%). Both balances could be improved in the years to come and, in this sense, process diversification, phasing-out of sugarcane burning, trash recovery and its use as fuel or raw material, and trash deposition in the field, will be essential. On the other hand, the potential constrain concerned to the emissions of nitrous oxide still need to be well understood. There is lack of scientific knowledge about this issue, and efforts are required in short to mid-term.

Regarding direct impacts of land use change, the main conclusion is that the growth of croplands, and more specifically the growth of sugarcane areas, has mainly occurred in lands previously occupied with pastures. Other conclusion is that the growth of sugarcane areas did not induce the displacement of cattle herds to other regions of Brazil, as have been frequently questioned abroad. Along the period 1996-2006, almost 90% of the enlargement of sugarcane areas was concentrated in four states (São Paulo, Minas, Paraná e Goiás) and in those there was significant phasing-out of pasturelands, besides growth of forested areas. Conversely, in two states (Mato Grosso do Sul e Mato Grosso) the reduction of forested lands was remarkable, but in either cases the enlargement of sugarcane areas represented a small fraction of the enlargement of pasture and soybean areas.

It is difficult to evaluate indirect impacts on land use change, in particular regarding the recent growth of sugarcane. However, there are clear evidences that deforested areas in Amazon and in Cerrado have been used mostly for pasturelands and in a lower extent to soybean production. On the other hand, there is no evidence that the growth of sugarcane is São Paulo has caused deforestation in Centre-West and in North of Brazil.

Regarding socio-economic aspects of sugarcane production, a regional and more detailed approach was adopted based on welfare indicators (e.g. health and education) and on indicators of wealth and wealth distribution. The analysis was carried out comparing municipalities of the same size, with and without sugarcane activity (cropping and industrial conversion to ethanol).

The results indicate that in some cases the municipalities in which sugarcane production is present have better parameters than those where it is absent. It is not possible to reach the same conclusion comparing municipalities with soybean production and livestock activity. Considering the set of indicators chosen, even the municipalities that receive a large contingent of migrant workers for sugarcane harvesting are not disadvantaged in relation to other municipalities.

Other environmental impacts of the sugarcane sector, such as water consumption, contamination of soils and water shields due to the use of fertilizers and chemicals, and loss of biodiversity, are less important in comparison to other crops. This can be explained by the following: in Brazil sugarcane production mostly occurs without irrigation; the development of sugarcane varieties has occurred over decades (with resulting higher yields and resistance to diseases and plagues); the use of biological control techniques; the use of biological fixers of nitrogen and of residues of production allowing a partial or total reduction of conventional fertilization; and the use of best agricultural practices (e.g. the reduction of erosion). However, due to the concentration of sugarcane production in some regions and the size of many factories, monitoring all the above-mentioned aspects is essential, besides dissemination and wide adoption of best practices (as has already occurred in some producer regions).

The sustainability of biofuels is a challenge that requires, among other actions, enforcement of existing labour and environmental legislation, scientific advances and diffusion of technologies, sharing of best practice, and definition and implementation of adequate public policies. In this regard, policy examples include a degree of control over the expansion of sugarcane production, support of the development of second-generation technologies and support to promote diversification (e.g. the large-scale production of surplus electricity).

Enhancement of environmental and social aspects of ethanol production could be promoted by a co-ordinated national agenda, but in Brazil this has yet to emerge. Taking the international criteria as a reference point is advantageous, since most of the high-priority aspects regarding biofuels sustainability are also issues of concern for Brazil (e.g. land use change, deforestation, impact on hydro resources, improved distribution of economic benefits).

There is a window of opportunity to enlarge ethanol production, ensuring both the supply of the growing domestic and export markets, but this needs to be done without significant environmental impact and with the enhancement of conditions of the social sectors directly involved in ethanol production. The results so far achieved are good, but there are still challenges ahead.

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Annex A

Land Use Change in Brazil due to Ethanol Production – Direct Impacts

Complementary material

Table A.1 Areas occupied with sugarcane in different meso-regions of state of São Paulo (1,000 ha), from 1997 to 2006

Regions	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
São Paulo	2,446	2,565	2,555	2,485	2,567	2,662	2,818	2,952	3,085	3,285
SJ Rio Preto	196	225	217	228	251	264	288	312	360	415
Ribeirão Preto	803	835	838	834	872	869	918	958	988	1.002
Araçatuba	142	157	155	157	155	173	204	223	226	264
Bauru	327	320	342	310	327	330	349	351	351	368
Araraquara	232	249	234	233	221	224	261	266	269	273
Piracicaba	250	244	238	240	248	247	244	253	248	248
Campinas	157	179	187	155	162	189	194	197	204	209
Prdt. Prudente	90	96	92	87	78	103	103	123	147	191
Assis	186	204	196	190	201	204	200	203	215	233
Itapetininga	32	31	31	29	28	27	29	36	41	46

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.2 Growth of sugarcane areas in some municipalities of the state of São Paulo – 1996-2006.

Municipality	Area change (1,000 ha)	Area change (%)	Growth regarding São Paulo (%)	Accumulated growth in the state (%)
Valparaíso	25.2	150.0	3.2	3.2
Barretos	25.0	208.1	3.2	6.3
Olímpia	24.6	236.5	3.1	9.4
Novo Horizonte	20.5	228.2	2.6	12.0
Paraguaçu Paulista	20.0	66.7	2.5	14.6
Tambaú	18.1	274.2	2.3	16.9
Promissão	17.2	252.9	2.2	19.0
Guararapes	14.0	93.3	1.8	20.8
Monte Aprazível	13.9	555.2	1.8	22.5
Penápolis	13.6	74.0	1.7	24.3
Flórida Paulista	13.6	199.9	1.7	26.0
Batatais	13.5	54.0	1.7	27.7

Note: In the period the growth of sugarcane areas in São Paulo was 792 thousand ha.
Source: IBGE - Produção Agrícola Municipal (various years)

Table A.3 Land use change in ten micro-regions of state of São Paulo – 1996-2006 (1000 ha)

Micro-region	Sugarcane	Corn	Rice	Soybeans	Beans	Cassava	Pasture	Forests
São José Rio Preto	104.4	-12.9	-10.5	6.6	0.6	-0.1	-197.1	1.9
Araçatuba	61.2	-2.5	-0.9	4.8	-0.5	0.0	-131.9	13.1
Assis	60.3	-41.1	0.1	-34.8	-0.0	6.0	-76.6	-2.5
Presidente Prudente	54.2	20.0	-2.1	47.6	-6.5	0.5	793.6	34.7
Barretos	45.9	-12.2	-0.5	-7.2	-0.1	0.0	-60.9	5.0
Birigui	45.0	-10.6	-0.8	20.4	-1.4	0.3	-99.4	2.1
Adamantina	43.2	-0.4	-1.2	0.5	-2.7	0.3	-55.3	-3.1
Ituverava	40.1	-36.7	-0.8	-18.2	-0.0	-0.0	-29.3	2.9
Novo Horizonte	38.4	-1.8	-2.3	0.9	-1.6	-0.2	-57.1	-5.3
São João Boa Vista	35.6	13.2	-3.8	3.5	11.6	0.1	-1.9	10.4

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.4 Land use change in municipalities with large growth of sugarcane production in the period – 1996-2006 (1000 ha)

Municipalities	Sugarcane	Corn	Rice	Soybeans	Beans	Cassava	Pasture	Forests
Valparaíso	25.2	-0.9	-0.2	-0.5	-0.3	-0.2	-39.6	-5.3
Barretos	25.0	-10.5	-0.4	-0.5	-0.8	0.5	-36.6	2.5
Olímpia	24.6	-0.5	-0.8	0.6	0.0	-6.6	-8.4	-1.2
Novo Horizonte	20.5	-0.9	-1.4	-0.2	-1.1	-0.0	-22.9	-2.9
Paraguaçu Paulista	20.0	2.4	0.0	1.3	0.0	-0.0	-17.7	0.4
Tambaú	18.1	-1.6	-0.4	0.5	0.1	2.2	-10.8	-1.9
Promissão	17.2	-3.3	-0.8	0.0	-0.1	0.0	3.2	1.0
Guararapes	14.0	-4.5	-0.1	1.9	-0.2	0.0	-33.1	1.9
Monte Aprazível	13.9	-0.3	-0.9	0.0	0.0	-1.1	-12.5	1.1
Penápolis	13.6	0.7	-0.0	0.3	0.0	0.0	-20.8	0.1
Flórida Paulista	13.6	-0.2	-0.1	0.1	-0.8	-0.1	-4.5	-0.5
Batatais	13.5	-20.0	-1.4	-6.0	-0.1	-0.2	-6.9	2.1

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.5 Mills under construction in the west band of São Paulo and that should start operation between 2006 and 2010

Mill	Municipality	Owner
Açúcar Guarani III	Pedranópolis	Açúcar Guarani
Albertina III	Pirapozinho	Albertina
Alvorada do Oeste	Santo Anastácio	Grupo José Oswaldo Marques
Aralco II	Buritama	Aralco
Aralco III		Aralco
Catanduva II	José Bonifácio	Catanduva
Cerradinho II	Potirendaba	Cerradinho
CFM	Pontes Gestal	CFM
Clealco II	Queiroz	Clealco
Clealco III	Rinópolis	Clealco
Cocal II	Narandiba	Cocal
Colombo II	Palestina	Colombo
Colombo III	Sta. Albertina	Colombo
Continental	Colômbia	Santa Elisa/Bruno Jacinto
Coplasa	Planalto	Unialco
Damha	Itapura	Grupo Encalso
Destiálcool	Barbosa	Edgar Francisco
Diana-Bartira	Martinópolis	Diana
Dracena	Dracena	Exxel
EMA	Sto. A.Aracanguá	J.Pessoa
Everest	Penápolis	JPessoa/ fornecedores
Furlan II	Avaré	Pedro Furlan
Iacanga	Iacanga	Ipiranga
Ipê	Nova Independência	Da Pedra
Jacarezinho	Valparaíso	Grendene/Brasif/J.Pessoa
Lins	Lins	Usina Batatais
Ouroeste	Ouroeste	Alcoeste/Moema
Paranapanema	Narandiba	Albertina
Petribu II	Tanabi	Petribu
Petribu III	Meridiano	Petribu
Pioneiros II	Ilha Solteira	Pioneiros
Rio Vermelho	Junqueirópolis	Antonio Gariere
Santa Adélia II	Pereira Barreto	Santa Adélia
Santa Isabel II	Mendonça	Santa Isabel
São José da Estiva II	Pongaí	Grupo De Biasi
Usina Monterey	Ubarana	Antonio Ruette
Usina Sopesa	Suzanápolis	Unialco
Virálcool II	Castilho	Toniello

Source: UDOP

Table A.6 Evolution of the average price of land in meso-regions where there was growth of sugarcane production in the years 2000 (R$/ha with pasture)

Meso-region	2000	2001	2002	2003	2004	2005	2006	2007
São José Rio Preto	2,127	3,049	4,050	5,432	6,829	7,945	7,789	8,866
Ribeirão Preto	2,331	3,703	4,660	7,323	8,234	10,098	10,354	12,810
Araçatuba	1,764	2,441	3,284	4,801	6,095	7,460	7,336	8,001
Bauru	1,590	2,172	2,664	4,272	5,105	6,344	6,328	7,883
Campinas	3,649	4,057	4,608	5,960	7,079	8,049	7,932	9,638
Presidente Prudente	621	853	1,353	2,220	2,114	2,201	2,023	2,122

Source: IEA Informações econômicas (various years)

Table A.7 Sugarcane areas in Minas Gerais from 2000 to 2006 (ha)

	2000	2001	2002	2003	2004	2005	2006
Minas Gerais	292,571	295,251	277,977	303,043	334,668	349,112	431,338
Meso-region							
Noroeste de Minas	7,793	9,817	9,830	9,880	8,770	10,865	12,305
Triângulo Mineiro	126,500	132,381	118,636	141,798	165,352	176,791	251,920
Central Mineira	26,571	26,575	23,677	25,176	27,885	27,815	28,862
Sul/Sudoeste	33,973	34,575	32,969	32,184	37,019	39,219	40,304
Micro-region							
Ituiutaba	595	800	1,300	4,076	13,091	14,135	19,814
Uberlândia	38,250	38,300	34,670	36,980	38,310	41,440	41,240
Frutal	42,685	46,670	40,108	46,883	49,614	52,889	74,938
Uberaba	42,900	44,400	40,540	52,006	61,436	63,410	107,740
Araxá	1,195	1,275	1,185	1,095	2,070	3,922	7,194

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.8 Land use change due to the main agricultural activities in micro-regions of Minas Gerais in which the growth of sugarcane production was more important in the period 1996-2006 (ha)

	Sugarcane	Rice	Beans	Cassava	Corn	Soybeans	Pasture	Forest
Minas Gerais	184,048	-107,991	-27,122	-11,208	37,002	538,348	-4,793,542	1,427,618
Uberaba	85,394	-1,934	4,130	736	35,189	100,430	-249,490	6,755
Frutal	50,118	-1,514	-923	-19	-1,466	22,613	-185,369	24,738
Uberlândia	21,127	-1,198	6,630	565	12,888	86,739	-415,413	46,437
Ituiutaba	19,284	-4,034	-261	-279	-10,227	23,383	-102,199	17,700
Paracatu	8,940	-2,023	15,786	3,360	1,130	41,545	-506,095	-69,798
Araxá	6,201	-1,118	10,464	175	33,944	76,205	-149,831	-8,112

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.9 Planted area with sugarcane in Goiás, 1997-2006 (thousand ha)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Goiás	115.2	144.0	148.4	139.2	129.9	203.7	168.0	176.3	200.1	237.5
Meso-regions										
Centro Goiano	41.2	45.6	43.9	42.5	43.2	68.5	67.8	75.3	85.1	87.6
Leste Goiano	7.4	7.7	8.1	7.4	7.0	7.2	6.6	7.1	7.1	20.8
Sul Goiano	65.3	88.7	94.1	87.2	77.6	126.6	92.2	92.1	106.4	127.7
Micro-regions										
Ceres	28.0	26.4	27.0	25.2	25.9	46.8	45.9	53.8	61.5	62.4
Anápolis	6.7	9.3	6.9	7.4	7.7	11.4	11.7	11.9	12.0	12.4
Anicuns	5.3	8.4	9.2	9.2	9.1	9.1	9.1	9.1	10.6	11.7
Sudoeste de Goiás	19.5	27.3	30.3	30.7	34.0	53.1	36.8	36.9	41.2	42.5
Vale do Rio dos Bois	17.1	31.6	34.7	35.7	23.6	45.8	34.3	24.8	27.4	27.7
Meia Ponte	20.4	21.3	21.2	14.3	18.4	24.3	18.8	27.1	34.2	47.7

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.10 Pasturelands and sugarcane areas in meso and micro-regions of Goiás – 1996 e 2006 (thousand ha)

Regions		Pasturelands			Sugarcane		
		1996	2006	Variation (%)	1996	2006	Variation (%)
	Goiás	19.404.7	15.524.7	-20.0	115.2	237.5	106.2
Meso	Centro Goiano	2.828.9	1.996.8	-29.4	41.2	87.6	112.8
	Leste Goiano	2.674.8	1.772.2	-33.7	7.4	20.8	179.2
	Sul Goiano	7.551.5	6.058.2	-19.8	65.3	127.7	95.6
Micro	Ceres	930.1	583.0	-37.3	28.0	62.4	122.8
	Anápolis	546.2	359.9	-34.1	6.7	12.4	84.9
	Anicuns	428.6	329.5	-23.1	5.3	11.7	120.1
	Sudoeste de Goiás	2.845.5	2.038.6	-28.4	19.5	42.5	117.5
	V. R. dos Bois	860.4	622.6	-27.7	17.1	27.7	62.4
	Meia Ponte	1.272.2	867.8	-31.8	20.4	47.7	134.2

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.11 Evolution of sugarcane areas in the main producer regions of Goiás – 1996 to 2006

Region	Area growth (ha)	Area growth (%)	Share regarding GO (%)	Aggregated (%)
Goiás	119.557	101.3		
Ceres	35.641	133.4	29.8	29.8
Meia Ponte	31.155	188.2	26.1	55.9
Sudoeste de Goiás	21.294	100.4	17.8	73.7
Entorno de Brasília	13.019	205.6	10.9	84.6
Anicuns	6.239	114.1	5.2	89.8

Fonte: IBGE - Produção Agrícola Municipal (various years)

Table A.12 Growth or reduction of areas devoted to agricultural activities in important (micro)regions of sugarcane production (1000 ha)

	Sugarcane	Rice	Beans	Cassava	Corn	Soybeans	Pastures	Forests
Goiás	119.6	-49.6	47.4	4.8	-174.2	1.610.8	-3.808.0	1.392.6
Ceres	35.6	0.5	-2.1	0.2	-1.9	6.5	-281.4	25.8
Meia Ponte	31.2	0.5	0.8	0.1	0.5	21.9	-70.2	72.1
Sudoeste de Goiás	21.3	-4.2	-0.7	2.5	-5.8	36.3	122.0	300.1
Entorno de Brasília	13.0	-1.5	2.8	0.2	6.8	14.8	-154.4	97.8
Anicuns	6.2	-3.8	-5.5	-0.4	-15.9	8.8	-347.1	45.5

Source: IBGE - Produção Agrícola Municipal (various years) and IBGE – Agricultural Surveys 1996 and 2006

Table A.13 Growth of main crops in municipalities with significant sugarcane growth - Goiás between 1996 e 2006 (ha)

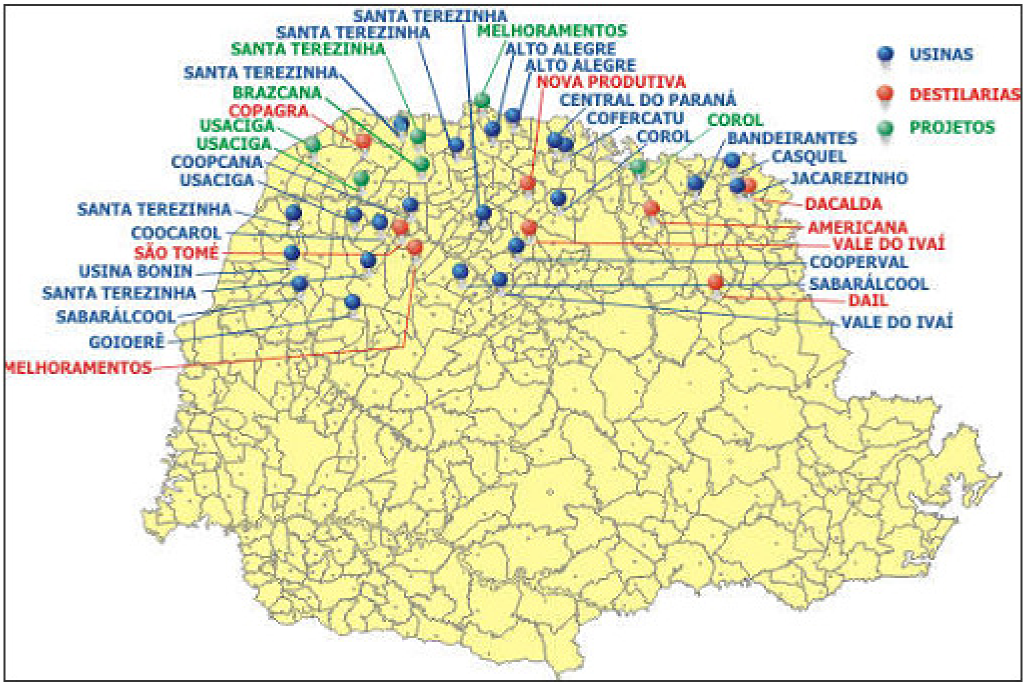
	Sugarcane	Rice	Beans	Cassava	Corn	Soybeans	Pastures	Forest
Vila Propício	18.000	600	0	75	3.200	10.000	-42.368	22.692
Porteirão	14.640	50	0	0	2.500	18.000	-30.992	-2.743
S. H. Goiás	11.708	50	-350	20	-12.746	36.000	-17.344	349
Goiatuba	7.214	-750	-530	-155	-14.950	18.879	-55.595	2.746
Nova Glória	7.150	-680	-210	-80	-1.500	0	-8.532	-1.136
S. L. do Norte	5.605	-790	-360	-5	-930	3.036	-26.709	-2.932
B. J. Goiás	5.270	-500	-37	20	127	28.800	-24.766	7.247
Quirinópolis	5.000	-200	-200	0	-12.420	12.000	-69.501	-11.032
Itaberaí	4.334	2.183	-2.145	141	-1.156	8.910	-35.040	-1.571
Itapaci	4.220	-200	-370	20	-1.700	658	-39.217	-1.951
Maurilândia	3.700	-100	0	-20	300	4.200	-13.357	-1.578

Source: IBGE - Produção Agrícola Municipal e IBGE – Censo Agropecuário

Table A.14 Growth of sugarcane area in regions of Paraná (ha)

Regions		2000	2001	2002	2003	2004	2005	2006	Variation (%)
Meso	Paraná	327.165	338.013	358.874	373.839	399.527	404.520	432.815	32,29
	Noroeste	111.716	115.431	130.739	144.004	156.656	173.211	190.068	70,13
	N. Central	110.771	113.560	117.900	119.611	133.082	122.852	132.908	19,98
	Paranavaí	37.795	39.698	44.315	49.408	53.519	56.792	64.858	71,60
	Umuarama	29.260	27.042	33.025	37.263	41.207	48.933	52.401	79,09
	Cianorte	44.661	48.691	53.399	57.333	61.930	67.486	72.809	63,03
Micro	C. Mourão	14.938	14.290	11.487	12.114	13.527	17.106	17.296	15,79
	Astorga	52.729	54.517	60.620	60.398	69.028	63.621	69.513	31,83
	Porecatu	22.109	22.934	19.899	20.794	23.913	20.958	20.833	-5,77
	C. Procópio	36.150	35.820	34.820	34.660	30.280	20.930	19.700	45,50
	Jacarezinho	30.955	33.120	36.700	36.683	38.503	42.473	43.073	39,15

Source: IBGE - Produção Agrícola Municipal.



Source: ALCOOPAR (Associação dos Produtores de Bioenergia do Paraná)

Figure A.1 Location in 2006 of existing mills (sugar + ethanol production; blues circles) and distilleries (only ethanol production; red circles) in state of Paraná. The location of mills under consideration in 2006 are shown by green circles (6 mills, all of them very close to São Paulo).

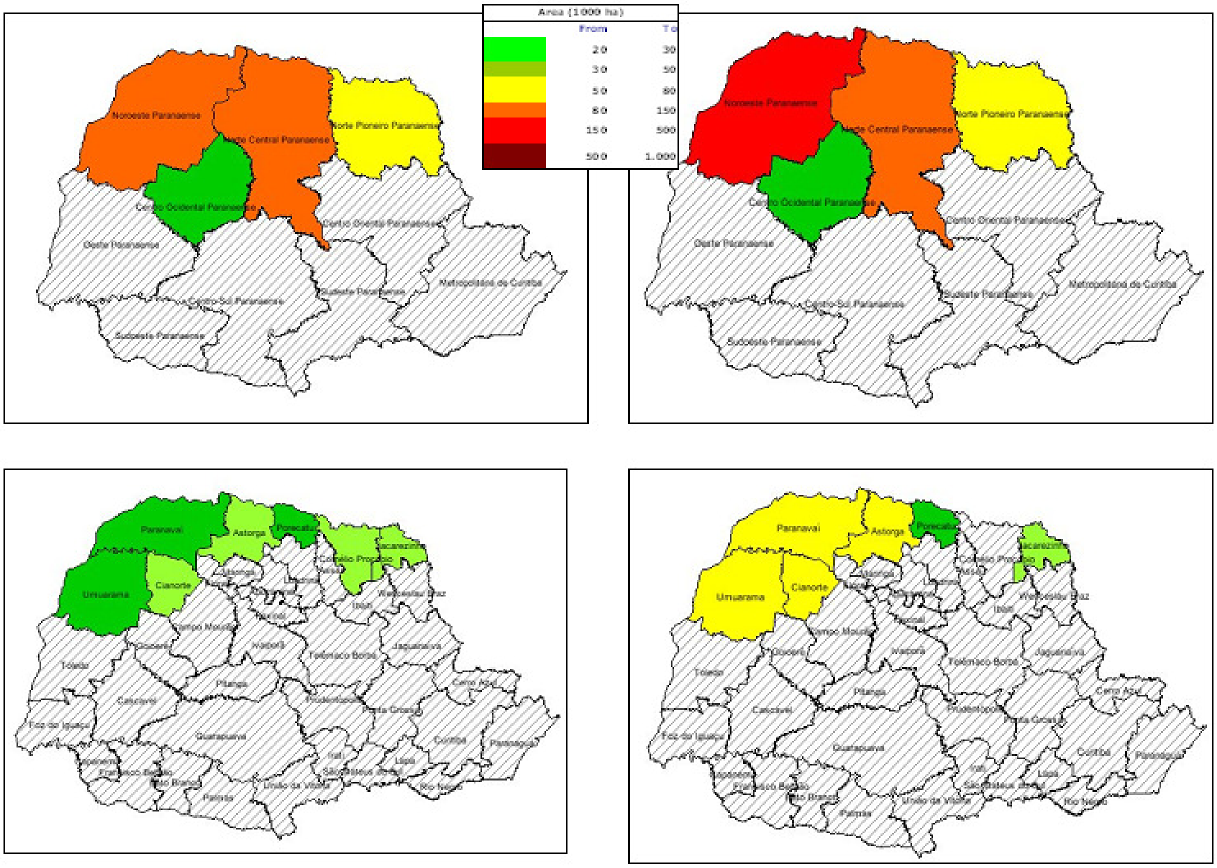


Figure A.2 Evolution of sugarcane areas in state of Paraná, by meso-regions (upper figures) and micro-regions (lower figures), from 1996 (left side) to 2006 (right side figures).

Table A.15 Percentage of planted areas in Paraná, 2000 to 2006 (%)

Region		2000	2001	2002	2003	2004	2005	2006
	Sugarcane	4,17	4,22	4,27	4,03	4,22	4,35	4,78
Paraná	Corn	33,95	35,20	29,46	30,67	26,12	23,31	27,38
	Soybeans	36,39	35,21	39,38	39,32	42,41	44,69	43,42
	Sugarcane	28,57	27,80	29,99	26,16	23,68	26,57	29,77
Noroeste	Corn	19,22	24,64	20,65	24,71	16,42	12,40	15,39
	Soybeans	18,48	18,11	25,19	29,40	35,27	37,34	33,91
	Sugarcane	2,25	2,26	1,84	1,69	1,85	2,46	2,44
Centro Ocidental	Corn	28,03	25,50	22,67	25,94	23,27	16,66	21,27
	Soybeans	47,88	47,54	50,86	51,61	52,54	60,28	55,63
	Sugarcane	8,48	8,05	8,10	7,38	8,14	7,74	8,78
Norte Central	Corn	30,39	32,25	25,77	26,78	24,10	20,81	23,73
	Soybeans	40,13	37,32	41,45	41,34	43,10	46,45	46,55
	Sugarcane	10,30	10,78	10,76	9,24	8,21	7,76	8,78
Norte Pioneiro	Corn	31,48	30,35	18,27	24,63	19,42	18,18	23,99
	Soybeans	31,05	32,30	36,19	33,18	35,09	38,80	40,57

Fonte: IBGE - Produção Agrícola Municipal.

Table A.16 Pasturelands and sugarcane areas in Paraná, 1996 and 2006 (ha)

Regions		Pasture			Sugarcane		
		1996	2006	Difference	1996	2006	Difference
	Paraná	6.677.313	5.735.095	-942.218	300.070	432.815	132.745
Meso	Noroeste	1.663.749	1.420.158	-243.591	94.674	190.068	95.394
	Centro	412.859	285.605	-127.254	21.855	25.329	3.474
	N. Central	1.047.885	1.055.017	7.132	104.408	132.908	28.500
	N. Pioneiro	751.026	674.475	-76.551	75.761	71.213	-4.548
	Oeste	654.312	361.368	-292.944	1.301	7.804	6.503
Micro	Paranavaí	612.357	469.222	-143.135	31.561	64.858	33.297
	Umuarama	729.461	653.003	-76.458	23.181	52.401	29.220
	Cianorte	702.730	649.033	-53.697	39.932	72.809	32.877
	C. Mourão	231.559	118.122	-113.437	6.732	8.033	1.301
	Astorga	238.500	178.889	-59.611	46.803	69.513	22.710
	Porecatu	296.880	324.261	27.381	21.985	20.833	-1.152
	Cor. Procópio	62.516	62.170	-346	5.322	5.280	-42
	Jacarezinho	166.034	127.599	-38.435	5.683	5.830	147

Source: IBGE - Produção Agrícola Municipal.

Table A.17 Variation on croplands in the main sugarcane producer regions –1996 to 2006 (%)

	Sugarcane	Rice	Beans	Cassava	Corn	Soybean
Paraná	44.2	-35.8	-0.9	48.5	0.9	64.7
Cianorte	107.7	-85.5	-37.6	-5.1	72.8	189.7
Paranavaí	135.9	140.3	-37.4	231.0	120.8	732.0
Umuarama	137.1	-3.5	-47.1	423.2	85.6	2.409.6
Astorga	49.2	-79.6	2.4	234.4	79.8	196.6
Jacarezinho	33.1	-37.5	-34.4	195.0	-7.4	38.0
Cascavel	725.5	-53.8	48.7	13.1	9.9	37.8
Ivaiporã	92.4	-67.3	-11.9	-38.1	-55.8	252.9

Source: IBGE (Agricultural Surveys 1996 and 2006)

Table A.18 Cattle herd in the main regions of state of Paraná

	1996	2006	Variation (%)
Paraná	9,900,885	9,153,989	-7.5
Micro-regiões			
Paranavaí	1,122,547	880,043	-21.6
Umuarama	1,095,344	851,795	-22.2
Cianorte	375,517	206,743	-44.9
Campo Mourão	375,205	300,061	-20.0
Astorga	524,724	410,211	-21.8
Porecatu	107,206	61,848	-42.3
Cornélio Procópio	231,226	179,216	-22.5
Jacarezinho	191,358	201,046	5.1

Source: IBGE – Agricultural Surveys (1996 and 2006)

Table A.19 Sugarcane mills in Mato Grosso by June 2008

	Municipality	Production	Region
Alcoolvale S/A - Álcool e Açúcar	Aparecida do Taboado	Mista	East
CBAA - Sidrolândia Cia. Brasileira de Açúcar e Álcool	Sidrolândia	Mista	Southeast
CBAA-Debrasa Cia Brasileira de Açúcar e Álcool	Brasilandia	Álcool	East
Destilaria Centro Oeste Iguatemi Ltda	Iguatemi	Álcool	Southeast
Eldorado Usina Eldorado Ltda	Rio Brilhante	Álcool	Southeast
Unidade Maracaju LDC Bioenergia S/A	Maracaju	Mista	Southeast
Unidade Passa Tempo LDC Bioenergia S/A	Rio Brilhante	Mista	Southeast
Unidade Rio Brilante LDC Bioenergia S/A	Rio Brilhante	Mista	Southeast
Safi Brasil Energia Ltda	Nova Alvorada do Sul	Mista	Southeast
Santa Helena Ltda	Nova Andradina	Álcool	East
Sonora Estância	Sonora	Mista	Centre-North
Usina Naviraí - Açúcar e Álcool	Naviraí	Mista	Southeast

Source: MAPA - Dept. of sugarcane and agroenergy

Table A.20 Area of sugarcane crops in Mato Grosso do Sul, meso and micro regions – (ha)

Region	2000	2001	2002	2003	2004	2005	2006
Mato Grosso do Sul	98,958	99,673	112,100	120,534	130,970	136,803	152,747
Meso-regions							
Centro Norte	22,702	22,527	21,003	22,687	26,970	24,783	23,682
Leste	29,226	26,701	36,529	40,563	45,240	41,271	48,040
Sudoeste	46,406	48,299	53,701	55,556	56,962	69,378	79,645
Micro-regions							
Alto Taquari	12,570	12,610	12,997	12,047	14,031	14,045	13,107
Campo Grande	10,132	9,917	8,006	10,640	12,939	10,738	10,575
Três Lagoas	19,706	16,947	20,470	19,339	19,339	16,095	16,251
Nova Andradina	9,500	9,754	11,659	13,124	13,975	11,500	14,506
Dourados	28,866	30,436	31,771	31,453	32,242	43,628	47,427

Source: IBGE - Produção Agrícola Municipal (various years)

Table A.21 Land use due to the main crops in three meso-regions of Mato Grosso do Sul (%)

	Centro-Norte (Centre-North)			Leste (East)			Sudoeste (Southeast)		
	Sugarcane	Corn	Soybeans	Sugarcane	Corn	Soybeans	Sugarcane	Corn	Soybeans
2000	4.9	22.9	59.8	7.6	16.7	52.6	3.9	28.5	52.6
2001	5.2	18.2	62.6	7.4	23.2	51.1	4.0	31.8	50.5
2002	4.8	16.5	67.5	10.7	15.3	55.7	4.1	27.9	54.4
2003	4.7	19.4	63.5	10.6	17.3	52.4	3.3	32.4	53.4
2004	4.9	12.7	66.4	10.6	13.2	56.1	2.8	24.9	59.8
2005	4.3	11.9	71.2	9.0	11.7	61.4	3.4	21.4	65.1
2006	4.2	17.3	67.1	11.9	13.0	61.6	3.9	24.4	63.2

Source: IBGE - Produção Agrícola Municipal (various years)

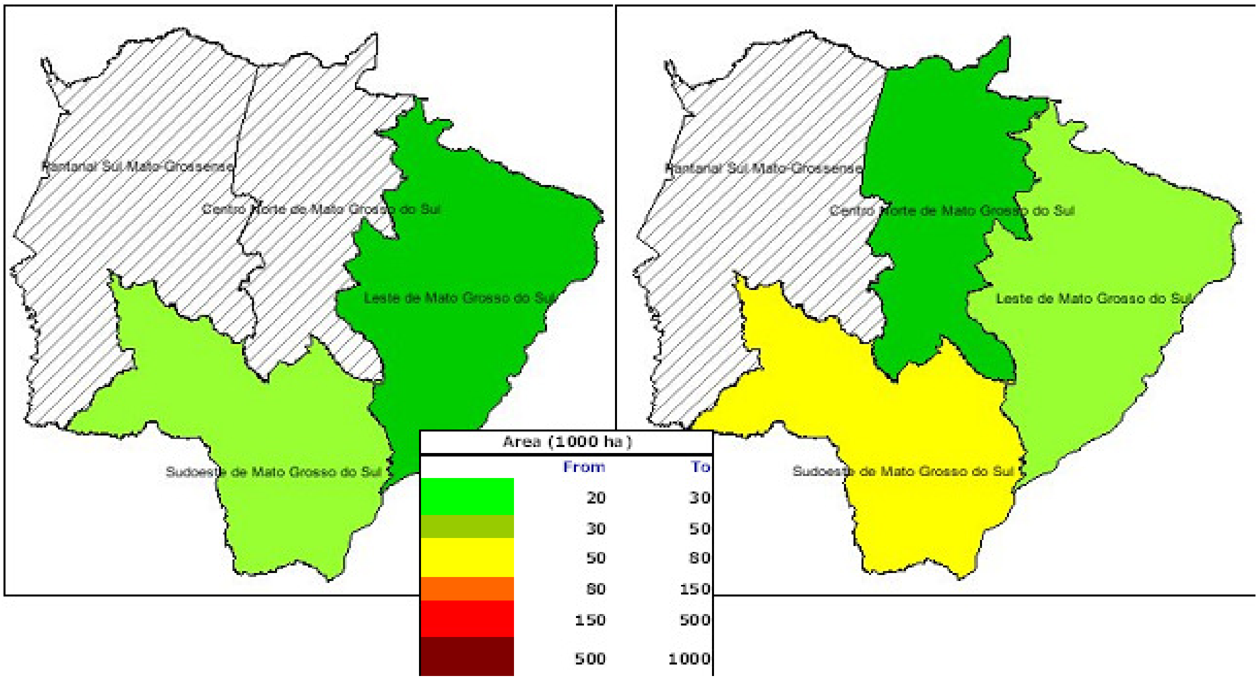


Figure A.3 Evolution of sugarcane areas in state of Mato Grosso do Sul, by meso-regions (upper figures) and micro-regions (lower figures), from 1996 (left side) to 2006 (right side figures).

Table A.22 Pasturelands and sugarcane lands in Mato Grosso do Sul, meso and micro regions – 1996 and 2006 (ha)

Regions	Pastures			Sugarcane		
	1996	2006	Difference	1996	2006	Difference
Mato Grosso do Sul	21,810,707	18,421,427	-3,389,280	82,007	152,747	70,740
Meso-regions						
Centro Norte	4,405,477	3,530,766	-874,711	16,501	23,682	7,181
Leste	6,264,574	5,203,002	-1,061,572	28,054	48,040	19,986
Sudoeste	5,154,990	4,056,853	-1,098,137	37,097	79,645	42,548
Micro-regions						
Alto Taquari	2,658,996	1,999,081	-659,915	10,301	13,107	2,806
Campo Grande	1,746,481	1,531,684	-214,797	6,200	10,575	4,375
Três Lagoas	3,237,678	2,323,578	-914,100	17,664	16,251	-1,413
Nova Andradina	938,632	1,379,194	440,562	9,190	14,506	5,316
Dourados	2,042,418	1,409,459	-632,959	21,987	47,427	25,440
Iguatemi	1,681,706	1,341,530	-374,176	14,722	32,068	17,346

Source: IBGE – Agricultural Survey (1996 and 2006)

Table A.23. Sugarcane mills in Mato Grosso, by June 2008

	Municipality	Production
Alcopan Álcool do Pantanal Ltda.	Poconé	Ethanol
Araguaia Zihuatanejo do Brasil Açúcar e Álcool S/A	Confresa	Ethanol
Usina Barralcool S/A	Barra do Bugres	Ethanol and sugar
Cooperb Cooperativa de Cana Rio Branco Ltda.	Lambari D'Oeste	Ethanol
Cooperb II	Mirassol D Oeste	Ethanol
Coprodia Campo Novo do Parecis Ltda.	Campo Novo do Parecis	Ethanol and sugar
Itamarati Usinas Itamarati S/A	Nova Olímpia	Ethanol and sugar
Jaciara Usina Jaciara S/A	Jaciara	Ethanol and sugar
Libra Destilaria de Álcool Libra Ltda.	São José do Rio Claro	Ethanol
Usina Pantanal de Açúcar e Álcool Ltda.	Jaciara	Ethanol and sugar
USIMAT Destilaria de Álcool Ltda.	Campos de Julio	Ethanol

Source: MAPA - Dept. of sugarcane and agroenergy

Table A.24 Sugarcane areas in Mato Grosso, meso and micro regions, between 2000 and 2006 (ha)

	2000	2001	2002	2003	2004	2005	2006
Mato Grosso	135.0	166.5	176.8	196.7	206.8	206.0	202.2
Meso-regions							
Norte	26.2	31.1	29.4	35.5	42.6	42.0	44.4
Nordeste	5.1	5.6	5.3	5.1	5.4	5.6	5.6
Sudoeste	71.9	97.0	104.8	115.1	115.6	113.7	113.8
Centro	8.9	11.8	12.9	13.9	14.6	15.1	9.4
Sudeste	22.8	21.0	24.5	27.1	28.8	29.5	29.0
Micro-regions							
Parecis	21.8	24.0	23.1	28.5	35.2	34.2	36.4
Tangará da Serra	67.0	91.5	97.6	106.4	105.6	104.7	102.3
Jauru	4.9	5.4	7.1	8.7	9.9	8.9	11.5
Rondonópolis	22.4	20.6	24.0	26.6	28.1	28.9	28.3

Source: IBGE - Produção Agrícola Municipal (various years)

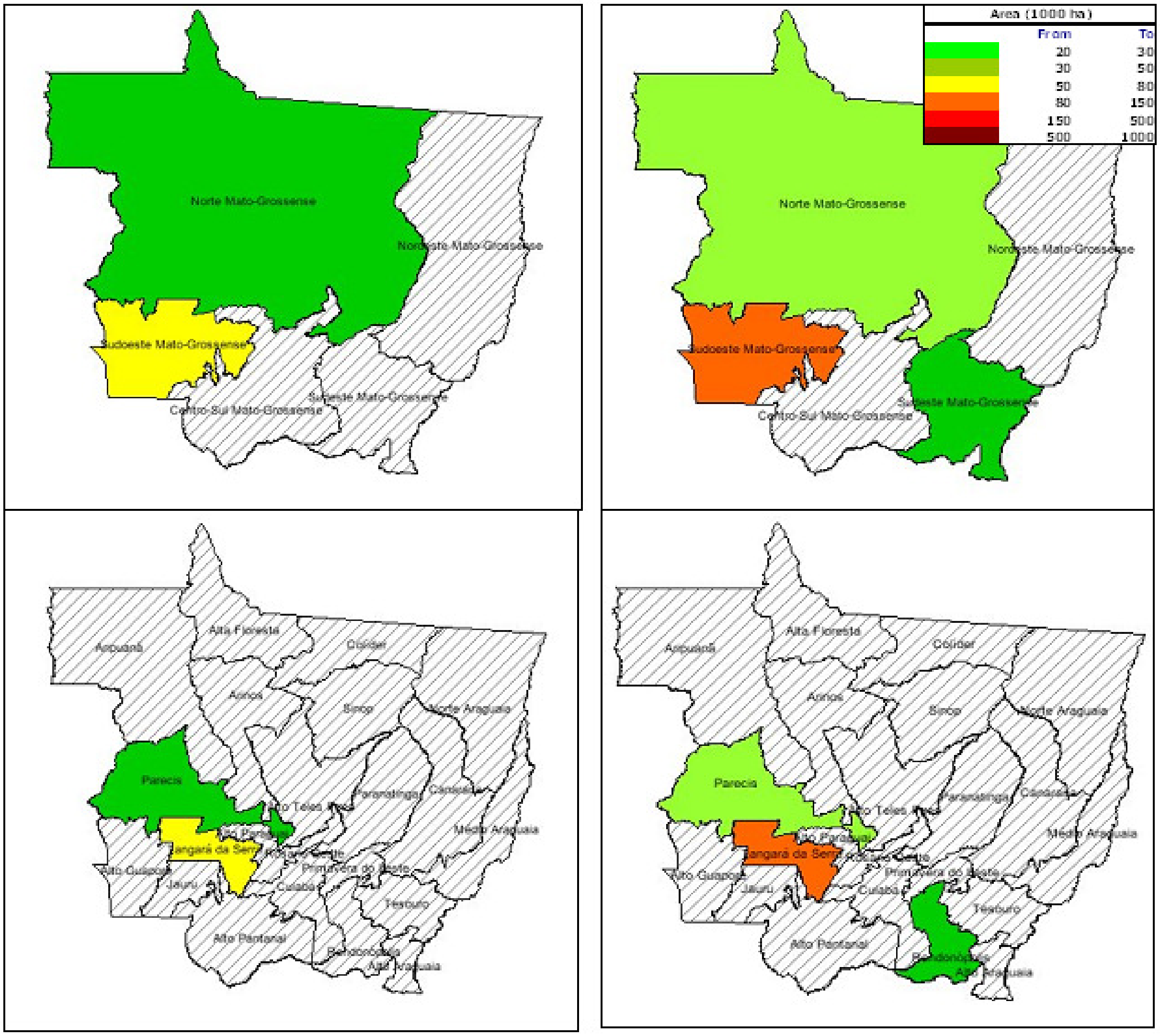


Figure A.4 Evolution of sugarcane areas in state of Mato Grosso, by meso-regions (upper figures) and micro-regions (lower figures), from 1996 (left side) to 2006 (right side figures).

Table A.28 Average yields of sugarcane mills in Northeast – harvest season 2007-2008

Region	State	Yield per tonne of sugarcane		Yield per hectare (planted)	
		Sugar (kg)	Ethanol (l)	Sugar (t)	Ethanol (m^3)
Northeast	Alagoas	131.2	79.8	9,015.4	5,485.0
	Pernambuco	127	77.2	8,140.5	4,952.7
	Paraíba	117.1	71.2	6,859.2	4,173.2
	R. G. Norte	123.8	75.3	7,069.8	4,301.3
	Bahia	125.0	76.1	9,501.1	5,780.5
	Maranhão	131.4	80	9,004.7	5,478.5
	Piauí	127.1	77.3	7,835.9	4,767.4
	Sergipe	123.6	75.2	7,515.9	4,572.7
	Ceará	-	68.1	-	4,740.4
	total	125.775	75.5	8,117.8	4,916.9
Centre-South	total	135.1	82.2	11,380.1	6,923.7
Brazil	Total	134.1	81.6	10,915.5	6,641.0

Source: CONAB (2007)

Table A.29 Growth or reduction of croplands – 1996 to 2006 (%)

	Sugarcane	Rice	Beans	Cassava	Corn	Pastures	Forest
Northeast	-6.1	8.6	-2.0	37.4	11.0	1.8	29.3
Maranhão	124.9	23.8	35.3	98.7	27.1	16.0	61.4
Piauí	26.7	11.9	24.8	38.5	25.0	16.0	21.1
Ceará	14.5	-41.0	33.4	94.6	29.4	11.1	7.4
R. G. do Norte	-0.1	-54.7	-49.2	5.0	-41.3	7.0	2.0
Paraíba	14.2	-51.3	-3.4	-0.3	-18.1	7.9	68.8
Pernambuco	-28.2	-12.6	-22.8	-47.2	-22.9	17.6	16.3
Alagoas	-6.9	-15.8	-40.6	-46.5	-33.5	1.3	26.7
Sergipe	70.7	320.7	-23.4	54.9	47.3	0.8	91.6
Bahia	39.8	-64.7	0.4	56.5	29.0	-11.0	30.3

Source: IBGE (Produção Agrícola Municipal) (different years)

Table A.30 Crescimento da área ocupada com lavouras nas principais microrregiões produtoras cana-de-açúcar do Maranhão - safras 1996/07 a 2006/07 valores em ha

	Sugarcane	Rice	Beans	Cassava	Corn	Soybean
Maranhão	21,828	97,699	22,337	105,353	78,203	319,632
Micro-regions						
Chapada Mangabeiras	13,281	-10,641	1,780	638	905	79,290
Porto Franco	3,280	11	290	-513	4,618	9,620
Coelho Neto	1,770	1,244	112	222	1,787	300
Imperatriz	1,585	-2,977	-93	-830	-6,270	0

Source: IBGE (Agricultural Survey 1996 and 2006)

Table A.31 Occupied land with sugarcane, pastures and forest in the main sugarcane producer regions of Maranhão (ha)

	Sugarcane			Pastures			Forests		
	1996	2006	(%)	1996	2006	(%)	1996	2006	(%)
Maranhão	17,473	39,301	124.9	5,310,553	6,162,692	16.0	2,875,775	4,641,773	61.4
Mangabeiras	6,562	19,843	202.4	293,527	322,402	9.8	272,749	269,376	-1.2
Porto Franco	3,849	7,129	85.2	330,562	344,275	4.1	232,573	292,791	25.9
Coelho Neto	4,323	6,093	40.9	36,187	49,201	36.0	34,993	88,087	151.7
Imperatriz	4	1,589	39625.0	862,641	1,054,776	22.3	362,115	320,055	-11.6

Source: IBGE (Agricultural Survey 1996 and 2006)

Table A.32 Growth or reduction of cropped lands in sugarcane producer regions in Bahia – 1996 to 2006 – (ha)

	Sugarcane	Rice	Beans	Cassava	Corn	Soybean
Bahia	28.5	-183.0	0.4	36.1	22.5	50.3
Porto Seguro	72.1	-600.0	-4.4	58.6	30.3	-
Juazeiro	35.3	-78.7	7.4	23.5	-38.0	-
S. M. Vitória	56.7	27.3	-56.7	8.0	39.8	46.8
Seabra	50.4	-462.2	39.8	63.1	52.0	-
Cotegipe	64.4	-406.0	65.9	7.1	48.1	100.0
Barreiras	58.1	-249.5	-19.3	25.1	42.3	50.8
Catu	-44.9	-	-44.3	-64.5	4.5	-
S. A do Jesus	-35.8	-	-1.6	24.19	-11.6	-

Source: IBGE (Agricultural Survey 1996 and 2006)

Table A.33 Occupied land with sugarcane, pastures and forest in the main sugarcane producer regions of Bahia (ha)

	Cana			Pastagem			Matas		
	1996	2006	(%)	1996	2006	(%)	1996	2006	(%)
Bahia	76,154	106,455	39.8	14,489,768	12,901,698	-11.0	7,136,561	9,301,335	30.3
Porto Seguro	8,933	32,016	258.4	1,154,585	1,049,240	-9.1	221,386	171,860	-22.4
Juazeiro	11,520	17,805	54.6	214,193	431,671	101.5	371,002	529,999	42.9
S. M. Vitória	3,034	7,010	131.1	740,575	796,932	7.6	461,219	1,253,892	171.9
Seabra	2,490	5,020	101.6	447,454	428,275	-4.3	256,611	295,004	15.0
Cotegipe	1,021	2,871	181.2	610,075	460,458	-24.5	465,013	731,935	57.4
Barreiras	879	2,099	138.8	789,882	457,815	-42.0	939,996	1,072,184	14.1
Catu	10,464	6,713	-35.9	189,966	139,825	-26.4	76,950	50,469	-34.4
S. A do Jesus	18,170	10,010	-44.9	81,249	91,721	12.9	56,742	41,660	-26.6

Source: IBGE (Agricultural Survey 1996 and 2006)

Annex B

Land Use Change in Brazil due to Ethanol Production – Indirect Impacts

Complementary material

Table B.1 Accumulated deforestation in a sample of 30 cities in the state of Pará, in 2006

Cities (30 highest deforestation rates)	Total area (ha)	Deforested area (ha)
Água Azul do Norte (PA)	758.600	488.700
Altamira (PA)	15.970.100	546.600
Conceição do Araguaia (PA)	584.800	294.600
Cumaru do Norte (PA)	1.710.600	646.100
Dom Eliseu (PA)	529.600	319.300
Eldorado dos Carajás (PA)	296.700	260.900
Goianésia do Pará (PA)	704.800	354.600
Ipixuna do Pará (PA)	524.500	254.200
Itaituba (PA)	6.209.600	424.200
Itupiranga (PA)	789.900	400.800
Marabá (PA)	1.512.700	744.900
Moju (PA)	913.100	319.700
Monte Alegre (PA)	2.170.100	460.900
Novo Progresso (PA)	3.818.300	435.900
Novo Repartimento (PA)	1.543.300	561.700
Pacajá (PA)	1.185.200	415.800
Paragominas (PA)	1.945.200	858.000
Piçarra (PA)	332.400	283.600
Redenção (PA)	383.000	263.100
Rio Maria (PA)	412.300	331.300
Rondon do Pará (PA)	828.600	518.300
Santa Maria das Barreiras (PA)	1.035.000	546.900
Santana do Araguaia (PA)	1.160.700	655.200
Santarém (PA)	2.287.600	439.400
São Félix do Xingu (PA)	8.424.900	1.449.600
Tomé-Açu (PA)	516.800	270.600
Ulianópolis (PA)	511.500	319.000
Uruará (PA)	1.079.400	259.200
Viseu (PA)	494.300	336.200
Xinguara (PA)	379.400	333.600
Total (ha)	59.013.000	13.792.900

Table B.2 - Accumulated deforestation in a sample of 30 cities in the State of Mato Grosso,in 2006

Cities (30 highest deforestation rates)	Total area (km^2)	Deforested area (km^2)
Alta Floresta (MT)	8955	4809,2
Aripuanã (MT)	25181	3581,5
Barra do Bugres (MT)	7244	3551,4
Bom Jesus do Araguaia (MT)	4282	2670,4
Brasnorte (MT)	16001	4096,4
Castanheira (MT)	3963	2424
Colíder (MT)	3038	2484,1
Colniza (MT)	28134	3043,4
Comodoro (MT)	21849	2891,1
Confresa (MT)	5799	3535,7
Gaúcha do Norte (MT)	16900	3180,4
Juara (MT)	21430	7276,2
Juína (MT)	26358	4172,4
Marcelândia (MT)	12294	3142
Nova Bandeirantes (MT)	9561	2687,5
Nova Canaã do Norte (MT)	5975	2896,4
Nova Maringá (MT)	11528	2999,4
Nova Monte Verde (MT)	6512	2509
Nova Mutum (MT)	9546	2807
Nova Ubiratã (MT)	12690	3985
Peixoto de Azevedo (MT)	14402	3067,8
Pontes e Lacerda (MT)	8465	3663,9
Porto dos Gaúchos (MT)	7016	2867,9
Querência (MT)	17856	4901
São Félix do Araguaia (MT)	16857	4124
São José do Xingu (MT)	7467	4162,7
Sorriso (MT)	9350	3951,2
Tapurah (MT)	11610	5366
Vila Bela da Santíssima Trindade (MT)	13698	4589,8
Vila Rica (MT)	7450	4389,5
Total	371411	109826,3

Annex C

Socio-Economic Aspects of Ethanol Production in Brazil

Complementary material

Table C.1 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Alagoas – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	28	48	31	48
Population (1,000)	7.4-57	7.4-57	7.0-63	7.0-63
HDI-M	0.483 ± 0.043	0.456 ± 0.044	0.589 ± 0.042	0.578 ± 0.039
Households with electricity service (%)	73.90 ± 12.39	53.82 ± 17.15	87.40 ± 7.47	80.98 ± 11.96
Life expectancy at birth (years)	57.62 ± 2.62	55.59 ± 2.67	63.41 ± 3.20	62.92 ± 3.13
Survival probability up to 60 years (%)	60.11 ± 4.59	56.61 ± 4.61	68,10 ± 5.79	67.22 ± 5.67
Deaths up to 1-year old (per thousand)	75.77 ± 13.01	86.55 ± 14.55	50.68 ± 13.28	52.63 ± 13.26
Illiterates older than 15 years old (%)	56.52 ± 8.17	58.97 ± 7.95	42.48 ± 6.40	44.00 ± 6.32
Alphabetization index	43.48 ± 8.17	41.03 ± 7.95	57.73 ± 6.40	56,01 ± 6.32
Gini index	0.471 ± 0.054	0.500 ± 0.058	0.575 ± 0.045	0.606 ± 0.056
Income of the 20% poorest people (%)	4.77 ± 0.89	4.29 ± 1.04	1.76 ± 0.80	1.35 ± 1.34
Income ratio (20% richest/40% poorest)	7.87 ± 2.21	9.36 ± 3.30	14.76 ± 4.64	29.76 ± 40.59
Income per capita (R$/hab/month)	66.4 ± 14.9	57.1 ± 16.6	78.8 ± 18.4	69.8 ± 19.0

Table C.2 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Alagoas – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	31	48	31	48
Population (1,000)	7.0-63	7.0-63		
Jobs and Income	0.387 ± 0.155	0.275 ± 0.119	0.411 ± 0.153	0.267 ± 0.063
Education	0.358 ± 0.054	0.360 ± 0.053	0.465 ± 0.059	0.453 ± 0.064
Health	0.528 ± 0.076	0.533 ± 0.094	0.662 ± 0.069	0.612 ± 0.080

Table C.3 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Goiás – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	21	186	22	155
Population (1,000)	2.4-75	2.4-75	3.5-117	3.5-117
HDI-M	0.668 ± 0.028	0.642 ± 0.044	0.747 ± 0.035	0.735 ± 0.037
Households with electricity service (%)	83.86 ± 9.29	72.21 ± 20.18	96.27 ± 7.17	93.37 ± 10.02
Life expectancy at birth (years)	64.58 ± 2.21	63.53 ± 2.85	69.33 ± 2.32	68.96 ± 2.65
Survival probability up to 60 years (%)	69.27 ± 4.49	67.07 ± 5.86	79,00 ± 4.34	78.28 ± 4.95
Deaths up to 1-year old (per thousand)	30.46 ± 6.40	33.91 ± 8.92	23.45 ± 6.18	24.54 ± 7.08
Illiterates older than 15 years old (%)	22.78 ± 3.87	58.97 ± 7.95	16.84 ± 4.64	17.31 ± 4.73
Alphabetization index	77.22 ± 3.87	73.54 ± 7.31	83.16 ± 4.65	82,69 ± 4.73
Gini index	0.535 ± 0.049	0.536 ± 0.045	0.561 ± 0.047	0.569 ± 0.054
Income of the 20% poorest people (%)	3.84 ± 0.62	3.91 ± 0.77	3.44 ± 0.90	3.01 ± 1.01
Income ratio (20% richest/40% poorest)	10.53 ± 2.90	10.68 ± 3.21	11.77 ± 3.22	14.31 ± 15.95
Income per capita (R$/hab/month)	164.3 ± 40.3	138.7 ± 38.6	220.2 ± 57.0	199.3 ± 57.9

Table C.4 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Goiás – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	22	155	22	155
Population (1,000)	3.5-117	3.5-117		
Jobs and Income	0.373 ± 0.127	0.347 ± 0.116	0.456 ± 0.173	0.389 ± 0.122
Education	0.567 ± 0.073	0.512 ± 0.081	0.735 ± 0.062	0.684 ± 0.084
Health	0.758 ± 0.065	0.741 ± 0.081	0.798 ± 0.059	0.798 ± 0.078

Table C.5 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Mato Grosso – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	12	82	11	84
Population (1,000)	4-30	4-30	4.7-58.8	4.7-58.8
HDI-M	0.636 ± 0.053	0.642 ± 0.051	0.748 ± 0.039	0.735 ± 0.039
Households with electricity service (%)	71.83 ± 16.86	54.28 ± 22.42	87.47 ± 16.26	78.16 ± 15.75
Life expectancy at birth (years)	61.88 ± 13.42	63.61 ± 3.39	68.72 ± 2.21	68.61 ± 2.63
Survival probability up to 60 years (%)	64.38 ± 6.42	67.84 ± 6.28	77,99 ± 3.94	77.76 ± 4.68
Deaths up to 1-year old (per thousand)	41.25 ± 11.40	35.56 ± 9.93	29.36 ± 6.49	29.89 ± 7.83
Illiterates older than 15 years old (%)	28.14 ± 8.53	24.49 ± 8.20	15.99 ± 4.21	16.14 ± 4.94
Alphabetization index	71.86 ± 8.53	75.51 ± 8.20	84.01 ± 4.21	83,86 ± 4.94
Gini index	0.558 ± 0.045	0.557 ± 0.054	0.591 ± 0.055	0.599 ± 0.046
Income of the 20% poorest people (%)	3.30 ± 0.98	3.36 ± 1.07	2.43 ± 0.99	2.25 ± 1.01
Income ratio (20% richest/40% poorest)	12.45 ± 3.11	12.39 ± 4.10	14.74 ± 4.44	15.65 ± 5.37
Income per capita (R$/hab/month)	165.1 ± 51.0	164.7 ± 64.4	250.1 ± 102.9	224.1 ± 78.1

Table C.6 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Mato Grosso – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	11	84	11	84
Population (1,000)	4.7-58.8	4.7-58.8		
Jobs and Income	0.484 ± 0.108	0.450 ± 0.129	0.529 ± 0.165	0.453 ± 0.109
Education	0.504 ± 0.066	0.498 ± 0.083	0.614 ± 0.073	0.605 ± 0.082
Health	0.745 ± 0.092	0.717 ± 0.079	0.773 ± 0.084	0.767 ± 0.083

Table C.7 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Mato Grosso do Sul – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	7	51	9	45
Population (1,000)	6-31	6-31	6.6-36.7	6.6-36.7
HDI-M	0.691 ± 0.024	0.663 ± 0.033	0.754 ± 0.025	0.739 ± 0.034
Households with electricity service (%)	89.61 ± 3.30	76.90 ± 12.82	93.86 ± 4.54	91.55 ± 6.91
Life expectancy at birth (years)	66.97 ± 1.36	65.65 ± 1.85	70.58 ± 1.80	69.28 ± 2.28
Survival probability up to 60 years (%)	75.28 ± 2.37	73.02 ± 3.41	81,51 ± 3.12	79.19 ± 4.11
Deaths up to 1-year old (per thousand)	34.16 ± 4.29	38.41 ± 6.23	24.16 ± 4.82	28.01 ± 6.86
Illiterates older than 15 years old (%)	20.54 ± 3.60	23.50 ± 4.83	14.87 ± 3.20	16.24 ± 3.91
Alphabetization index	79.46 ± 3.60	76.51 ± 4.82	85.13 ± 3.20	83,76 ± 3.91
Gini index	0.567 ± 0.052	0.569 ± 0.048	0.578 ± 0.047	0.593 ± 0.063
Income of the 20% poorest people (%)	3.67 ± 0.85	3.54 ± 0.79	2.74 ± 0.85	3.10 ± 1.12
Income ratio (20% richest/40% poorest)	12.34 ± 3.53	12.33 ± 3.05	13.19 ± 3.87	14.40 ± 5.52
Income per capita (R$/hab/month)	194.2 ± 31.0	160.0 ± 50.8	225.6 ± 43.2	212.4 ± 68.9

Table C.8 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Mato Grosso do Sul – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	9	45	9	45
Population (1,000)	6.6-36.7	6.6-36.7		
Jobs and Income	0.475 ± 0.117	0.394 ± 0.087	0.462 ± 0.132	0.439 ± 0.079
Education	0.593 ± 0.061	0.583 ± 0.066	0.673 ± 0.038	0.654 ± 0.056
Health	0.706 ± 0.046	0.707 ± 0.092	0.808 ± 0.061	0.754 ± 0.087

Table C.9 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Minas Gerais – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	97	733	122	705
Population (1,000)	1.8-209	1.8-209	2.7-252	2.7-252
HDI-M	0.652 ± 0.057	0.628 ± 0.066	0.725 ± 0.057	0.717 ± 0.056
Households with electricity service (%)	79.10 ± 18.20	71.59 ± 22.18	91.08 ± 11.90	91.32 ± 11.55
Life expectancy at birth (years)	65.58 ± 3.27	64.98 ± 3.41	69.54 ± 3.48	69.49 ± 3.40
Survival probability up to 60 years (%)	71.92 ± 15.76	70.86 ± 6.05	78,70 ± 6.17	78.63 ± 6.05
Deaths up to 1-year old (per thousand)	37.39 ± 10.81	39.55 ± 11.75	31.11 ± 11.48	31.21 ± 11.26
Illiterates older than 15 years old (%)	22.83 ± 9.11	26.93 ± 11.90	18.22 ± 7.90	18.37 ± 8.29
Alphabetization index	76.17 ± 9.11	73.07 ± 11.90	81.79 ± 7.90	81,63 ± 8.29
Gini index	0.554 ± 0.049	0.531 ± 0.046	0.567 ± 0.053	0.554 ± 0.049
Income of the 20% poorest people (%)	3.74 ± 0.74	4.06 ± 0.91	3.10 ± 1.21	3.10 ± 1.34
Income ratio (20% richest/40% poorest)	11.76 ± 3.41	10.43 ± 3.21	13.24 ± 5.57	13.37 ± 13.86
Income per capita (R$/hab/month)	137.3 ± 52.7	115.8 ± 48.4	193.8 ± 81.5	174.0 ± 69.4

Table C.10 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Minas Gerais – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	122	705	111	719
Population (1,000)	2.7-252	2.7-252		
Jobs and Income	0.358 ± 0.107	0.330 ± 0.122	0.413 ± 0.140	0.393 ± 0.138
Education	0.637 ± 0.097	0.620 ± 0.102	0.667 ± 0.084	0.665 ± 0.079
Health	0.649 ± 0.117	0.648 ± 0.133	0.738 ± 0.111	0.730 ± 0.105

Table C.11 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Paraná – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	56	338	64	328
Population (1,000)	2-240	2-240	2.2-289	2.2-289
HDI-M	0.675 ± 0.034	0.656 ± 0.044	0.751 ± 0.028	0.737 ± 0.041
Households with electricity service (%)	95.56 ± 3.80	83.56 ± 15.93	99.28 ± 0.89	94.74 ± 8.41
Life expectancy at birth (years)	65.41 ± 2.66	64.88 ± 2.70	69.63 ± 2.33	69.00 ± 3.08
Survival probability up to 60 years (%)	72.26 ± 5.05	71.26 ± 5.14	79,84 ± 4.16	78.61 ± 5.56
Deaths up to 1-year old (per thousand)	39.44 ± 9.89	41.37 ± 10.13	19.83 ± 5.04	21.52 ± 6.89
Illiterates older than 15 years old (%)	21.53 ± 4.16	20.88 ± 6.88	15.19 ± 3.41	14.80 ± 5.30
Alphabetization index	78.47 ± 4.16	79.12 ± 6.88	84.81 ± 3.41	85.20 ± 5.30
Gini index	0.529 ± 0.044	0.544 ± 0.051	0.525 ± 0.041	0.558 ± 0.047
Income of the 20% poorest people (%)	4.28 ± 0.78	3.80 ± 0.97	4.08 ± 0.87	3.01 ± 1.05
Income ratio (20% richest/40% poorest)	10.07 ± 2.57	11.25 ± 3.67	9.77 ± 2.73	12.73 ± 5.11
Income per capita (R$/hab/month)	166.2 ± 42.7	135.0 ± 47.4	222.5 ± 54.7	196.2 ± 55.2

Table C.12 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Paraná – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	64	328	69	322
Population (1,000)	2.2-289	2.2-289		
Jobs and Income	0.400 ± 0.094	0.398 ± 0.104	0.479 ± 0.107	0.469 ± 0.127
Education	0.712 ± 0.066	0.658 ± 0.091	0.755 ± 0.047	0.712 ± 0.071
Health	0.821 ± 0.088	0.763 ± 0.100	0.873 ± 0.058	0.838 ± 0.078

Table C.13 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Pernambuco – 1991 and 2000

Indicators	With	Without	With	Without
	1991		2000	
Number of municipalities	36	114	36	116
Population (1,000)	11-475	11-475	11-582	11-582
HDI-M	0.541 ± 0.057	0.526 ± 0.065	0.636 ± 0.047	0.626 ± 0.056
Households with electricity service (%)	78.72 ± 10.03	60.72 ± 19.53	93.76 ± 3.86	90.90 ± 9.48
Life expectancy at birth (years)	60.31 ± 3.22	59.44 ± 3.96	65.72 ± 3.55	65.10 ± 3.78
Survival probability up to 60 years (%)	64.24 ± 5.25	62.89 ± 6.44	72,64 ± 6.05	71.57 ± 6.44
Deaths up to 1-year old (per thousand)	70.79 ± 15.66	74.97 ± 18.56	55.86 ± 16.27	58.88 ± 17.39
Illiterates older than 15 years old (%)	45.35 ± 9.71	49.52 ± 11.16	32.58 ± 6.68	36.64 ± 9.25
Alphabetization index	54.65 ± 9.71	50.48 ± 11.16	67.43 ± 6.68	63,36 ± 9.25
Gini index	0.535 ± 0.057	0.532 ± 0.053	0.563 ± 0.037	0.598 ± 0.057
Income of the 20% poorest people (%)	3.88 ± 0.79	3.79 ± 0.83	2.07 ± 0.64	1.49 ± 1.07
Income ratio (20% richest/40% poorest)	10.55 ± 3.10	10.80 ± 2.91	13.19 ± 3.03	18.88 ± 9.06
Income per capita (R$/hab/month)	76.4 ± 25.5	77.3 ± 31.1	96.0 ± 31.5	101.4 ± 39.5

Table C.14 Socio-economic indicators for municipalities with and without significant sugarcane production in state of Pernambuco – 2000 and 2005

Indicators	With	Without	With	Without
	2000		2005	
Number of municipalities	36	116	36	116
Population (1,000)	11-582	11-582		
Jobs and Income	0.347 ± 0.177	0.292 ± 0.124	0.404 ± 0.122	0.347 ± 0.116
Education	0.458 ± 0.064	0.458 ± 0.063	0.574 ± 0.069	0.569 ± 0.065
Health	0.605 ± 0.090	0.531 ± 0.063	0.699 ± 0.054	0.621 ± 0.080

Table C.15 Results of socio-economic indicators for municipalities with significant soybean production – Mato Grosso, 1991 and 2000

Indicators	With soybeans	Without	With soybeans	Without
	1991		2000	
Number of municipalities	21	88	22	89
Population (1,000)	3-123	3-123	2.9-150	2.9-150
HDI-M	0.694 ± 0.038	0.632 ± 0.045	0.781 ± 0.032	0.743 ± 0.039
Households with electricity service (%)	77.80 ± 12.81	52.66 ± 21.94	90.83 ± 8.08	82.89 ± 14.04
Life expectancy at birth (years)	65.93 ± 2.15	62.91 ± 3.33	71.42 ± 1.78	68.85 ± 2.65
Survival probability up to 60 years (%)	72.62 ± 4.10	66.27 ± 5.92	82.72 ± 3.06	78.19 ± 4.73
Deaths up to 1-year old (per thousand)	28.12 ± 5.68	37.96 ± 9.66	21.85 ± 4.69	29.18 ± 7.91
Illiterates older than 15 years old (%)	18.33 ± 6.37	26.16 ± 7.76	11.72 ± 4.46	15.61 ± 4.66
Alphabetization index	81.68 ± 6.37	73.84 ± 7.76	88.29 ± 4.46	84.39 ± 4.66
Gini index	0.563 ± 0.046	0.553 ± 0.053	0.620 ± 0.053	0.598 ± 0.048
Income of the 20% poorest people (%)	3.24 ± 0.74	3.43 ± 1.07	2.43 ± 0.92	2.38 ± 1.01
Income ratio (20% richest/40% poorest)	12.40 ± 3.44	12.09 ± 3.88	16.99 ± 6.14	15.34 ± 4.85
Income per capita (R$/hab/month)	209.6 ± 61.4	156.4 ± 56.2	316.9 ± 94.2	238.3 ± 82.0

Table C.16 Results of socio-economic indicators for municipalities with significant soybean production – Mato Grosso, 2005

Indicators	With soybeans	Without
Number of municipalities	39	91
Jobs and Income	0.528 ± 0.097	0.440 ± 0.115
Education	0.661 ± 0.062	0.582 ± 0.080
Health	0.812 ± 0.078	0.753 ± 0.081