Theme # 9 Ethanol Producers Experience

Paper based on Reference Book "Sugar Cane's Energy" (UNICA 2005)

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1. Soil occupation: new production areas and biodiversity

1.1. Introduction

The growth of the sugar-cane culture (and even more that of Brazilian agriculture, taken as a whole) raises questions about the availability and limitations of suitable areas, the areas and locations used over the past few years and trends for the years to come, and the knowledge of the biodiversity in Brazil's main biomes, as the context for possible implications and caution.

In 2004, Brazil's environmental preservation and conservation areas reached 95 M ha, which represents around 11 percent of the Brazilian territory. Brazil's entire crop area corresponded to ~60 M ha.

Biodiversity preservation practices include preserving important samples of biodiversity for the future, prospecting for the unexploited biodiversity in a non-intrusive manner, and fostering an environmentally compliant use of land and natural resources.

The Convention on Biological Diversity proposed in Rio (1992) seeks to ensure the preservation and sustainable use of the biodiversity. In fact, it implies a balance between sustainable exploitation and preservation of biodiversity resources. The setting of very different objetives in this single concept still causes implementation difficulties. Generally speaking, the understanding is that "it is our duty to preserve this asset for the future generations." The Convention provides a legal basis that did not exist in most countries, and remains that way in many. The Convention was never ratified by the United States, for example; also, in many cases, a Biological Inventory is either yet to be prepared or incomplete.

The steps for implementation of the Convention (and Agenda 21, in this topic) to be taken by the countries include the preparation of a biodiversity inventory and monitoring of important biodiversity resources, the creation of reserves, the creation of seed, germoplasm and zoological banks, and the conduct of Environmental Impact Assessments covering activities that could affect the biodiversity. We have witnessed the rise of a biodiversity measurement and preservation "science" over the past few years.[1]

In the following paragraphs we address the use of agricultural soils in Brazil, its evolution, and the position of agriculture; also, with a certain emphasis, the current "agricultural border", i.e. the *Cerrado*, or Savanna. We address the reality of Brazil's plant biodiversity: the present knowledge; the situation in the main biomes; and preservation. In conclusion, we specifically consider the sugar-cane culture in this context, the crop areas, their location, and their recent and expected expansion. The impact of sugar-cane crops on the fauna is not covered for being rather less relevant; an assessment conducted by the EMBRAPA[2] (for sugar-cane) rates almost all impacts on mamals, birds, amphibians and invertebrates as level 2 and 1 (low or no impact), and level 3 (medium impact) on reptiles.

1.2. Use of agricultural soil in Brazil

The Brazilian territory covers an area of 850 M ha, between +5 and -33 degrees of lattitude, -34 and -73 degrees of longitude. The topography is characterized by extensive flat regions and some mountain ranges with altitude of up to 3,000 m. A large portion of the territory has the conditions to economically sustain agricultural production, while huge areas covered by forests with different biomes are preserved.

Brazil's vegetal cover was mapped by the EMBRAPA[3] in 2002, based on daily information provided by the Vegetation sensor of satellite Spot IV. The study was conducted within the scope of the Global Land Cover 2000 program (GLC 2000) through an initiative coordinated by the Institute for Environment and Sustainability (IES). Table 1 shows the distribution of soil use.

Table 1 – Distribution of Brazil's vegetal cover (2002)

Area	**Area (M ha)**	**Distrib.**
Agriculture and pasture	297	35%
Forests	464	55%
Fields and savannas	73	9%
Cities, rivers and others	17	2%
Total	851	100%

According to the IBGE[4] (Brazilian Institute of Geography and Statistics), annual and permanent crop areas have developed regionally as shown in Table 2:

Table 2 – Crop areas in Brazil, million ha

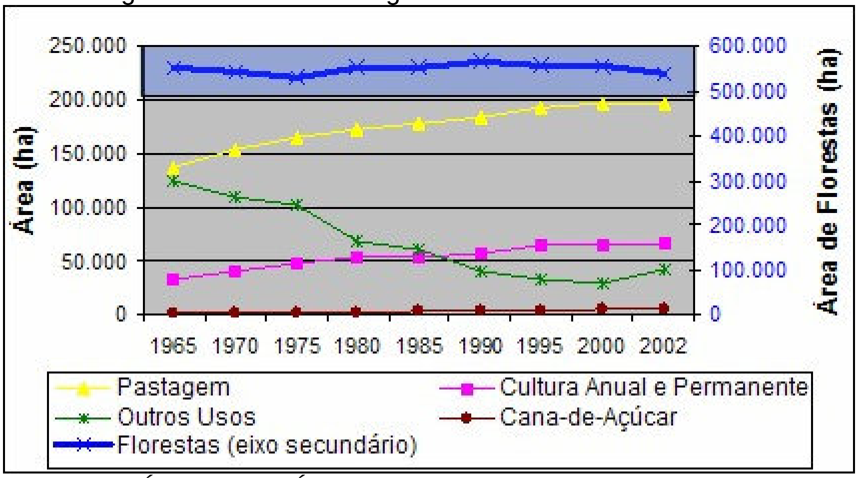
Region	N-NE	S-SE	CO	Brazil
1994	16.0	28.8	8.0	52.8
2004	14.4	30.9	15.1	60.4
Variation	-10.0%	7.3%	88.7%	14.4%

While the crop areas located in the N-NE and S-SE regions showed little variation, it is clear that the agricultural border is in the Center-West region, where the production area has doubled in ten years' time.

Crop areas currently total 60 M ha (around 21 M ha of which with soybean, and 12 M ha with corn). The "pasture" areas correspond to around 227 M ha, including a portion featuring a certain degree of degradation. Forest areas (including those used for forestry) total 464 M ha. An estimation by the EMBRAPA[5] (analyzing the soybean crop expansion situation) indicates that there are still approximately 100 million hectares to support the expansion of cultures of annual-cycle species. In addition, the area to be potentially released as a result of technological development in the livestock business is estimated at 20 million hectars. The Veja[6] magazine, with some help from technicians of the Ministry of Agriculture and the Brazilian Institute of Geography and Statistics (IBGE), shows that around 30 percent of the territory is occupied by crops and livestock, resulting in 106 million hectares, one of the world's largest agricultural reserves, with fertile soils that are almost all located in savanna areas.

A simplified description of the evolution of soil use over the past few decades is shown in Figure 1:

Figure 1 - Evolution of agricultural soil use in Brazil[7]



(Captions. *Área:* Area; *Área de Florestas:* Forest Areas; *Pastagem:* Pasture; *Outros Usos:* Other Uses; *Florestas (eixo secundário):* Forests (secondary axis); *Cultura Anual e Permanente:* Annual and Permanent Culture; *Cana-de-Açúcar:* Sugar-Cane).

This information provided by the FAO (Food and Agriculture Organization of the United Nations) with respect to Brazil indicates that the expansion of the crops and livestock area over the past few years has coincided with the decrease in degraded pasture areas, *campos sujos* (grassland with some shrubs), etc., rather than forest areas. A study recently conducted by the Institute of Applied Economic Research (IPEA[8]) to analyze the rapid growth of soybean crop areas in Brazil confirms that the rise of such culture in areas has basically consisted of occupation of degraded pastures, rather than "virgin areas".

A particularly important case is the use of the *Cerrados*. The three paragraphs below sum up the remarks contained in a report prepared by the EMBRAPA[9] in 2000.

The Cerrado is a Brazilian ecosystem that covers an area of 204 M ha (24% of the territory); it contains the second largest biodiversity in South America (with ~6,500 plant species, three hundred vertebrate species, and one thousand kinds of fungi), and the sources of five major river basins. Virtually ignored until 1960, today it is in a prominent position in the country's crops and livestock. Following the construction of Brasília back in the 1970's, a more technologically advanced crops and livestock economy started to replace the shifting agriculture, extractivism and extensive cattle-breeding. As early as 2000, the Cerrado accounted for 41 percent of the country's cattle and 46 percent of the Brazilian soybean, corn, rice and coffee crops, *and 50 M ha of it were occupied by cultivated pastures, 12 M ha by annual cultures, and 2 M ha by permanent cultures. The activities of Embrapa Cerrados since 1975 have been essential to that development. Today, the Cerrados continue to be the natural agricultural border of the country's South and Southeast regions, with a huge potential for development.*

The Cerrado has a savanna vegetation pervaded by gallery forests, with several "grades" between Campo Limpo (clean grass fields) and Gallery Forests. The soils are highly weathered, deep, and well-drained, but have a low natural fertility and high acidity. However, there is plenty of limestone in the Cerrado regions, and the topography favors mechanization.

In 2000, the main production systems included:
Cattle-breeding (for slaughter), with cultivated pastures (~50 M ha, in 2002, variable stages of degradation);
Agricultural production: grains (rice, beans, corn and soybeans), coffee and manioc are the most important crops, having a considerable share in Brazil's agricultural production. Also reforestation (1970's) and fruit culture growing, currently expanding.

The *Cerrados* are located in extensive, non-continuous areas, which are shown in Figure 2. It is important to consider their location together with the country's main forest biomes (the Amazon Rain Forest, the Atlantic Forest and the *Pantanal* (grasslands and wetlands), as shown in Figure 5, where there are severe environmental restriction on the use of soils, which are considered in the EIA-RIMA analysis for any undertaking.

The expansion of sugar-cane crops in areas that were originally taken up by *cerrados* was small, and in most cases, it seems to have taken place replacing other covers that had subsituted for the *cerrado* already (usually pastures). The current trends seem to be towards continuation of such situtation: expansion of sugar-cane crops in the West of São Paulo, replacing pasture areas. Table 2 shows that the total sugar-cane crop area that was added between 1993 and 2003 in all States where there were extensive *Cerrado* regions (Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais) reached only around 300,000 ha (the expansion of the sugar-cane crop area in the Center-South region represented 1.4 M ha in the same period, and the expansion of the entire crop area in the region between 1994 and 2004 amounted to 7 M ha). However, because sugar-cane may play a role of increasing importance in the agribusiness development within these regions, it will be necessary to consider specific sustainability aspects of sugar-cane growing in these regions; this obviously applies to all other crops considered (some of which, such as soybean, being already used on a large scale) for the *Cerrados* as well. Also, it must be noted that the occupation of *Cerrado* areas or, alternatively, areas orginally covered by the *Cerrados* but currently used as pastures, for example, may have very different consequences (sometimes opposing consequences) to such factors as soil quality, erosion and others.

Analyses are now being conducted of this early occupation stage of the *cerrados*, including the perspective of environmental preservation and the search for profitable and socially fair production systems. A lot more attention shall be given to the combination of irrigated systems with the use of pesticides and fertilizers, improper soil preparation and conservation practices, inefficient use of water, and the effects of the great and rapid urbanization, with deficient waste treatment systems.

Figure 2 – Areas where the *Cerrados* are located[10]

1.3. Plant biodiversity in Brazil: knowledge, situation in the main Biomas; preservation

<u>Brazil, a mega-diverse country</u>

Brazil is regarded as the country that has the world's largest biological diversity for having a large portion of the Amazon Rain Forest, the largest green area on the planet, the Atlantic Forest and the *Cerrado*, which are ecosystems considered to be hotspots because of the threat to, and the wide diversity of, related endemic species.[11] Brazil has one of the world's richest floras, estimated at 50,000 to 60,000 angiosperm species (plants with flowers).

In Brazil the main effort to set biodiversity preservation priorities (hotspots and wilderness areas) was developed within the scope of the "Priority Actions for Preservation of the Biodiversity of Brazilian Biomes" project.[12] The project, coordinated by the Ministry of the Environment, was carried out in conjunction with Conservation International, Funatura, and the Biodiversitas Foundation. In the period between 1995 and 2000, workshops were held in order to discuss and set the preservation priorities for the *Cerrado* and the *Pantanal*, the Coastal and Marine Zone, the Amazon Rain Forest, the Atlantic Forest, the Southern Fields, and the *Caatinga*. Over a thousand experts (in ecology, botanics, zoology and related disciplines) contributed to seeting the preservation priorities for Brazil's main biomes. Base maps were drafted for inclusion of information on natural areas, existing preservation areas, physical and political subdivisions, demographic and economic statistics, and fauna and flora gathered by experts. The setting of priorities was based on the knowledge and opinions of the experts who were consulted. Because the initiative did not take into consideration any future scenarios, including the impact of agricultural expansion and vulnerability to climate changes, it is important to review the preservation priorities by incorporating advances in methodology, aiming at building new impact and vulnerability scenarios.[13]

Present situation of, and threats to, Brazilian Biomes

Of the areas originally taken up by the different biomes in Brazil (Table 3), variable and not always known portions remain, given the imprecision of existing estimations. The areas protected as preservation units are also variable from biome to biome, showing disproportionate efforts in search of representativeness in the National Preservation Units System.

Table 3 – Brazilian biomes: original area, current cover, and percentage contained in preservation units.

Biome	Original coverage (% of the country) (1)	Current cover (% of the original) (2)	Protected areas (% of the original) (3)
Amazon	49.29	85	4.83
Cerrado	23.92	20 (4)	1.71
Atlantic Forest	13.04	7	0.72
Caatinga	9.92	32 (4)	0.69
Southern Fields	2.02	1.98 (4)	0.27
Pantanal	1.76	?	0.57

(1) http://www.ibge.gov.br
(2) http://ebape.fgv.br
(3) http;//www.ibama.gov.br
(4) areas where the ecosystem can be considered untouched.

In addition to the regional differences in preservation conditions, the causes and pace of degradation of Brazil's different biomes have been historically distinct.

The Atlantic Forest was the first biome to be devastated by a slow process of wood exploitation and replacement with agriculture and cattle-breeding throughout the Brazilian seashore. There are now significant remains only on the steep bluffs of *Serra do Mar*, which cover less than 8 percent of the original area. The area currently taken up by sugar-cane crops is almost all located in lands that were originally covered by this biome. The agricultural occupation process in the Atlantic Forest preceded any concerns about preservation, such that no area capable of representing the original biodiversity of the biome was preserved, and even hillside areas and river banks, which are now protected by law, were not spared. For these regions, the current adaptation of soil use for the environmental legislation will necessarily required forest restoration planting.

The *Cerrado* was spared by agricultural occupation until very recent times. Not long ago, extensive cattle-breeding and firewood and coal exploitation were the only major economic activities within the huge territory of the *Cerrado*. Those activites, in spite of having an adverse impact, did not result in a significant reduction of the area covered by the biome. Over the past few decades, however, with the technological advance in crops and livestock, the *cerrado* area has been decreasing at a fast pace, estimated at 3 percent a year, and at least 50 percent of the original *cerrado* has been totally destroyed.[14] Extensive areas have been highly modified by the invading African grass varieties and very frequent fires, and only 20 percent of the original area is untouched.[15] The recent agricultural expansion on the *cerrado* has been taking place without so much as complying with the environmental legislation in force. Since 1965, when the Forest Code took effect, the *cerrado* vegetation should have been preserved in at least 20 percent of the area of each property (50% in the Amazon), not to mention the permanent preservation areas (hilltops, hillsides, and water body banks). Even in the state of São Paulo, where the *cerrado* vegetation currently covers less than 1 percent of the territory, cases of deforestation for the expansion of agriculture and cattle-breeding are reported, and the area covered by the biome in that state has decreased by 26 percent since 1990 (data provided by *Instituto Florestal*).

Unlike the Atlantic Forest, however, for a large portion of the region covered by the *Cerrado* it is still possible to plan the occupation in a sustainable manner, harmonizing the exploitation of crops and livestock with preservation of biodiversity and water resources. Special attention is required to some areas in Goiás (GO), Mato Grosso do Sul (MS) and Mato Grosso (MT) where lie the springs of the rivers that flow to the Pantanal, the agricultural occupation of which may undermine the stability of the entire Pantanal ecosystem if poorly planned. Likewise, the charging areas of the Guarani aquifer, in the Southeast region, which are usually covered by the *cerrado* vegetation, need to be preserved.

The other Brazilian biomes, which are not devastated so fast or intensely, but not less important none the less, have also been the subject of preservation concerns. However, they need no emphasis in the sugar-cane crop expansion context because they are not areas to which such agricultural activity will potentially expand right now.

Building impact and vulnerability scenarios

Harmonizing socio-economic development with environmental preservation is no easy task. The development and implementation of appropriate sustainable development strategies will be increasingly based on knowledge management, upon incorporation of recent developments in information technologies and communications. There is a growing demand for quick answers with a view to solving the problems relating to the occurrence and distribution o biological species, such as impact studies linked with the release of transgenic organisms in the environment and the implementation of invading species and crop pest restraining and controlling measures. Systemic approaches to support an educated decision-making process will depend more and more from access to and integration of information available from information distributing sources and the use of advanced computer-based data analysis and space viewing tools, as well as the building of impact and vulnerability scenarios.

The *Instituto Virtual da Biodiversidade*, (Virtual Institute of Biodiversity), related to the FAPESP Biota Program,[16] incorporates the latest breakthroughs in information technology for biodiversity. That initiative integrates the information from more than 50 research projects (fauna, flora and microbiota) through interoperated information systems, including *Sin*Biota[17] and *species*Link,[18] designed in line with internationally accepted standards and protocols, as well as free software with open protocols. *Sin*Biota supports the integration, summarization and space viewing of data from field observations. *Sin*Biota is a centralized system that dynamically integrates data from projects related to the program with those from external information sources (national and international) via the Internet. The use of the standard data sheet and the geo-coding (lattitude and longitude) for the collection site are compulsory for projects related to the program. The digital map base of the State of São Paulo, with associated environmental layers, including river basins, vegetal cover, highways, city limits and preservation areas, make up the *Atlas Biota*. The *species*Link network integrates primaty data on specimens from distributed biological collection in real time, and uses computer-based tools for correcting and viewing more than 500,000 records of collections related to the system.

Geo-referenced information is of paramount importance to the setting of biodiversity preservation and sustainable use strategies. However, there are still significant gaps in the knowledge of species distribution in the main Brazilian biomes. Computer-based tools to model the distribution of species help directing field research and identification of biologically richer areas, as well as delimitation of areas rich in threatened or endemic species. It also enables identification of species that could be used in environmental recovery efforts and assessment of potential threats posed by invading species or the impact of climate changes on biodiversity. The most commonly used predictive modeling system for species are based on the species ecological niche concept. These methods combine species occurrence data with the environmental characteristics of the occurrence spot, seeking to define places having similar environmental characteristics through algorythms. The niche modeling sets the ecological limitations on the dimensions where the model is developed, thereby allowing the distribution of a given species to be projected in a geographic space with a view to anticipating where the species can or cannot keep viable populations.[19] In order to assess the impact of climate changes on 162 tree species of the Brazilian *Cerrado*, Siqueira & Peterson[20] used predictive modeling methodologies to generate geographic distribution maps for such species based on the ecological niche concept. The analysis shows a loss of the potential distribution area in excess of 50 percent for essentially all of the species under analysis in a period fo 50 years. These results demonstrate the urgent need to put together and apply consistent preservation and sustainable use policies for the *cerrado* biodiversity, while improving handling and monitoring techniques taking into account the impact of climate changes and of the expansion of agriculture and cattle-breeding, as well as the vulnerability of that biodiversity to such changes. If this scenario is confirmed, the tree species diversity hotspots of the *cerrado* that are now located in the country’s central plateau will migrate to the south and overlap degraded landscapes of the *cerrado* vegetation in the state of São Paulo, which are predominantly used for agricultural purposes. It is important to review preservation actions focusing on the Southeast of Minas Gerais, Mato Grosso do Sul and São Paulo, with a view to ensuring the expansion of protected conservation areas and establishing ecological and riverside wood restoration corridors, while integrating high-priority areas.

1.4. Sugar-cane growing expansion areas

Brazil's sugar-cane crops covered an area of 1.0 million hectares in 1955, reaching 1.5 million hectares in 1962.[21] That area remained virtually stable for the ten subsequent years.[22] The period in which the crop area grew more rapidly began in the second half of the seventies, upon implementation of the Proalcool program in 1976. The area stabilized as of the 1987/1988 crop at around 4.2 million hectares (Figure 3). Another growth stage was observed during the period comprised by the 1994/1995 and 1997/1998 crops (motivated by sugar exports), and after a short stabilization period, a new expansion cycle has been going on over the past harvesting seasons, and the areas increased to 5.3 million hectares for the 2003/2004 crop, 4.2 million ha (79%) of which in the Center-South region.

The expansion has occurred in the country's Center-South region for the last 25 years, while the sugar-cane crop area remained practically stable in the Northeast region, covering approximately 1.0 million hectares.

Figure 3 - Evolution of the harvested area in Brazil; Center-South, North-Northeast, and São Paulo

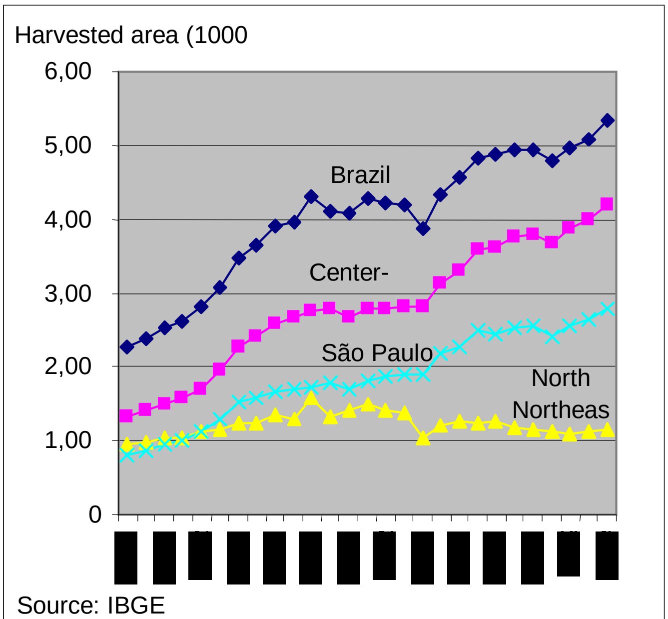
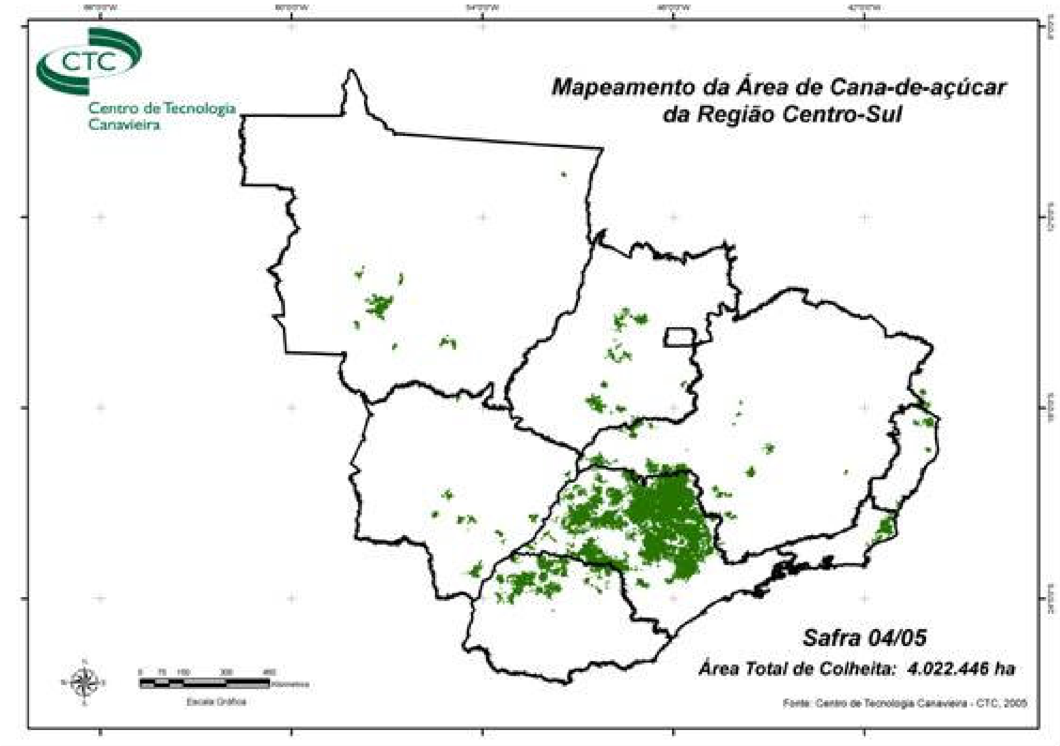


Figure 4 – shows the sugar-cane harvesting area in the Center-South region for the 2004/05 crop, which was mapped through remote sensing by the Copersucar Technology Center (CTC) and the National Institute of Space Research (INPE). Figure 5 shows the same area and the position of Brazil's main biomes (Amazon Rain Forest, Atlantic Forest, and the Pantanal), demonstrating that the areas

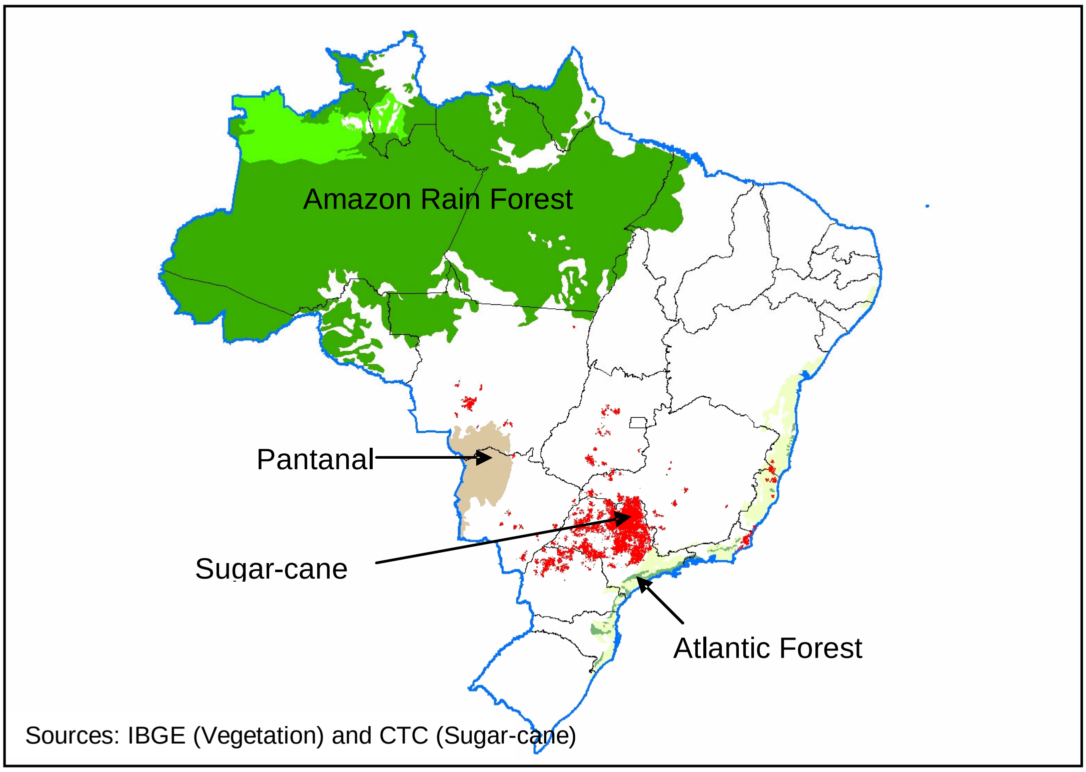
having the highest concentration of sugar-cane crops are far from those vegetation units.

Figure 4 - Sugar-cane map in the Center-South region of Brasil – 2004/05 Crop



(Captions. *Mapeamento da Área de Cana-de-Açúcar da Região Centro-Sul:* Mapping of the Sugar-Cane Area in the Center-South Region; *Safra 04/05:* [20]04/05 Crop; *Área Total de Colheita:* Total Harvesting Area; *Fonte:* Source).

Figure 5 - Sugar-cane areas in the Center-South region and Brazil's main biomes



For the past 10 crop seasons (1993/1994-2003/2004), the sugar-cane crop area in the Center-South region increased by 1.4 million hectares (49%), distributed as shown in Table 4. The State of São Paulo accounts for most of that increase (64% of the total).

With the regional differences in productivity, the Center-South region produced around 85 percent of Brazil's sugar-cane in 2004, distributed among 219 units. It is important to note that the Center-South region's sugar-cane production increased from 176.2 to 281.5 M t (around 60%) from 1992/93 to 2003/04, but the very units already in existence in 1992 account for almost all of that increase (94%), while new units account for only 6 percent of it. Therefore, the great expansion has not actually involved new agricultural borders in a more significant way so far.

Table 4 - Variation of the sugar-cane harvesting area in Center-Southern states for the last 10 crops; ha

State	1993	2003	Variation
São Paulo	1,895,750	2,776,232	64%
Paraná	190,169	369,836	13%
Mato Grosso	69,829	190,391	9%
Goiás	95,981	164,861	5%
Mato Grosso do Sul	62,103	125,002	5%
Minas Gerais	260,685	304,119	3%
Espírito Santo	33,851	58,039	2%
Rio de Janeiro	166,856	161,839	0%
Others	48,607	49,438	0%
Center-South	2,823,831	4,199,757	100%

Source: IBGE[23]

The great importance of São Paulo's production and its growth rate require the context of this growth to be considered with respect to its connection with total agricultural soil occupation. Table 5 is very significant in this respect.

Table 5 – Evolution of crop areas in São Paulo, 1990-2004[4]

Ano	1990	2004
Total crop area	6.27	6.05
Sugar-cane	1.81	2.80
Coffee	0.57	0.22
Orange	0.72	0.58
Other crops	3.17	2.46

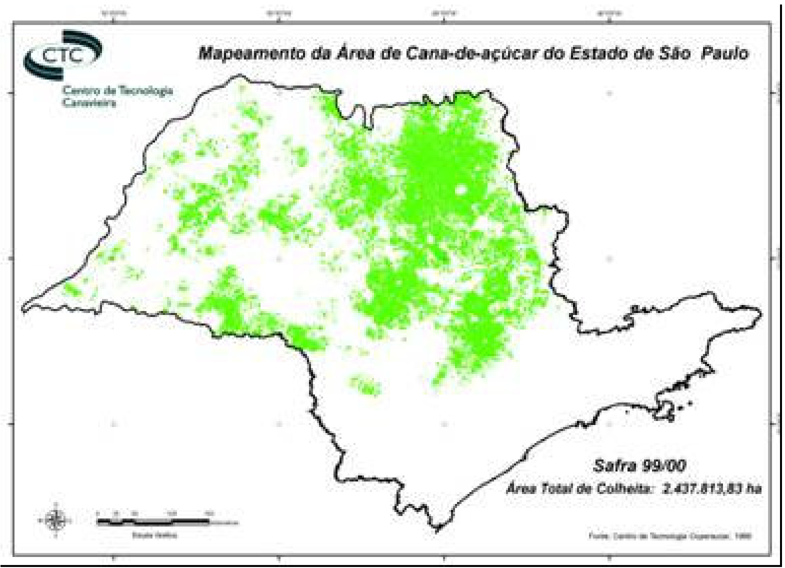
The tables show that the total crop area has been practically constant during a period in which sugar-cane crops have been growing rapidly, since 1990. What has hapened is crop substitution; in this specific case, sugar-cane has mostly been replacing orange and other crops, while also occupying pasture areas. The system, in fact, is known to be very dynamic, responding to prices (international prices in the case of orange and coffee), and the crops are changed (and reversed, in some 4cases) in only a few years.

Accordingly, an analysis of the expansion of sugar-cane crops for the next few years should consider which crops could be replaced in order to assess the impacts of changes in soil occupation. The trends are shown below.

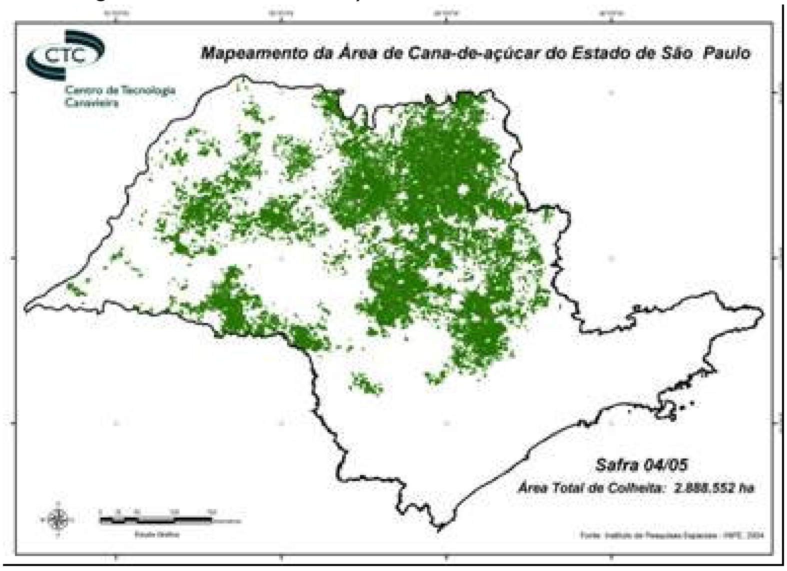
For the state of São Paulo, the Centro de Tecnologia Canavieira has been mapping the growth of the sugar-cane crop area for the past 6 crops (1999-2004) by remote sensing using images provided by the Landsat satellite. Figure 6 shows that mapping, as well as the evolution of the harvesting area during the period. The fastest-growing area is the west of the state, which is a traditional cattle-breeding region where sugar-cane crops started taking up mainly pasture areas.

For the most part, the identified trend is towards increase in the sugar-cane growing area in the Center-South region's current production areas, with an emphasis on western São Paulo, the areas by the borders with Mato Grosso, and some areas in the state of Goiás.

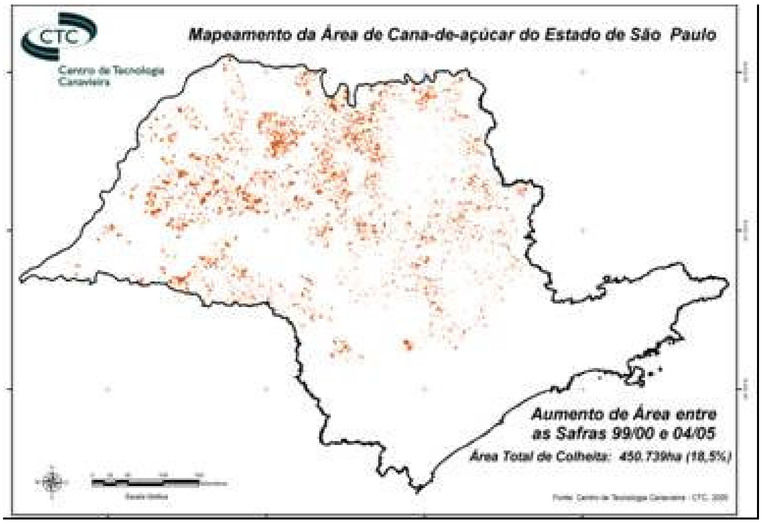
Figure 6 - Mapping of the São Paulo State's sugar-cane areas for the 99/00 and 04/05 crops, and area increase for the period



(Captions. *Mapeamento da Área de Cana-de-Açúcar do Estado de São Paulo:* Mapping of the São Paulo State's Sugar-Cane Crop Area; *Safra 99/00:* [19]99/[20]00 Crop; *Área Total de Colheita:* Total Harvesting Area; *Fonte:* Source).



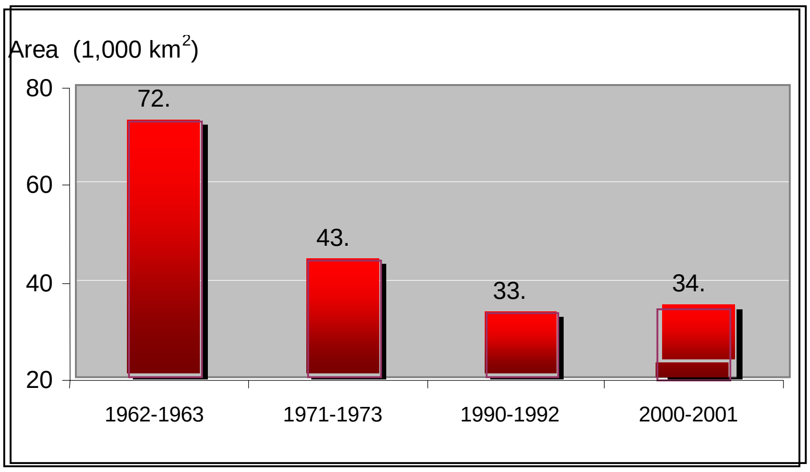
(Captions. *Mapeamento da Área de Cana-de-Açúcar do Estado de São Paulo:* Mapping of the São Paulo State's Sugar-Cane Crop Area; *Safra 04/05:* [20]04/05 Crop; *Área Total de Colheita:* Total Harvesting Area; *Fonte:* Source).



(Captions. *Mapeamento da Área de Cana-de-Açúcar do Estado de São Paulo:* Mapping of the São Paulo State's Sugar-Cane Crop Area; *Aumento de Área entre as Safras 99/00 e 04/05:* Increase in Area from 99/00 to 04/05 Crops; *Área Total de Colheita:* Total Harvesting Area; *Fonte:* Source).

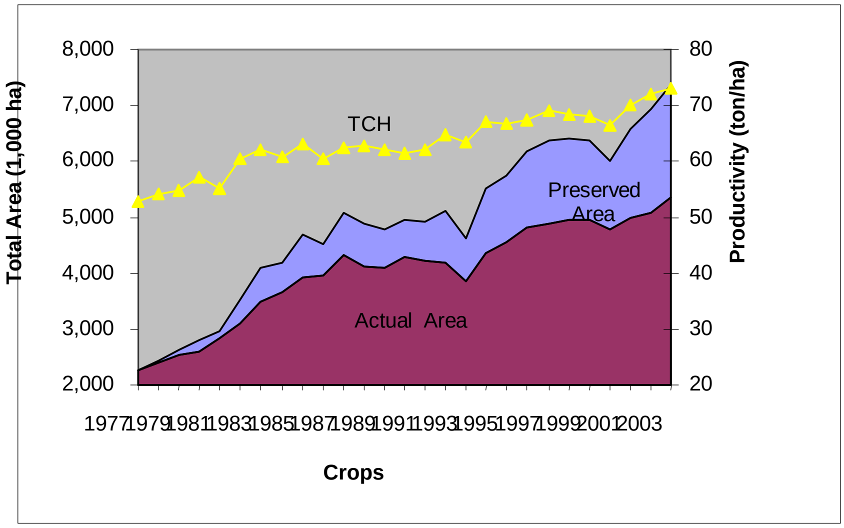
The forest areas once covered 82 percent of the territory of the State of São Paulo back when Brazil was discovered[24]; they have constantly decreased since the beginning of the country's colonization in the 16th century. The evolution of coffee crops was one of the main causes. In the last decade, however, this trend was reversed; that latest forest inventory reported a rise of 3.8 percent in the area with natural vegetation. Figure 7 showns the remaining natural vegetation area of the State, indicating that the recent sugar-cane expansion periods in the state (starting from 1994) coincide with the forest area recovery period. Partly, the restoration of riverside woods has contributed to this process (see item 5.4). This trend may be enhanced.

Figure 7 - Remaining natural vegetation area in the State of São Paulo[25]



The great rise in productivity resulting from technology developments in sugar-cane production has been responsible not only for the industry's increased productivity, but also for the decrease in the crop area that needs to be occupied to support the increase in production. Figure 8 shows that if there was no productivity gain, the area to be used for growing the same amount of sugar-cane would have to be 2.0 million hectares larger than that used for the 2003/2004 crop.

Figura 8 - Actual Production Area and Area Saved by the Introduction of Technology



1.5. Summary and Conclusions

- With 850 M ha, Brazil has a large portion of its territory with the conditions to economically support agricultural production, while preserving vast forest areas with different biomes. Today, agriculture uses only 7 percent (half of which being taken up by soybean and corn crops), pastures use around 35 percent, and forests 55 percent. The expansion of agriculture over the past 40 years took place mostly in degraded pasture areas and *"campos sujos"* (grassland with some shrubs), rather than forest areas. The area currently occupied by sugar-cane crops represents only 0.6 percent of the territory, and the areas currently able to support the expansion of this kind of crop represent at least 12 percent.

- The *Cerrado* (24% of the territory) has been extensively utilized for agriculture and cattle-breeding over the past 40 years. The expansion of sugar-cane crops in areas covered by the *cerrado* vegetation has been very small so far, and has replaced other covers that had previously replaced the *cerrado* (usually pastures).

- The expansion of sugar-cane crops has taken place essentially in Brazil's Center-South region over the past 25 years, in areas that are very far from the current biomes of the Amazon Rain Forest, the Atlantic Forest and the Pantanal. From 1992 until 2003, almost all of the expansion (94%) in the Center-South region occurred in existing units; new agricultural borders were involved very slightly. In São Paulo, the growth has occurred through substition of pastures and other crops.

- For the next few years, there shall be growth in the Center-South region, with emphasis on the west of São Paulo, regions by the borders with Mato Grosso, and in some areas within the state of Goiás.

- Brazil concentrates the world's largest biological diversity (including the Amazon Rain Forest, the Atlantic Forest, and the *Cerrado*), and a flora estimated at 50,000 to 60,000 angiosperm species. The biodiversity preservation priorities were set mainly between 1995 and 2000, with the contribution of hundreds of experts; protected areas were established for the six major biomes in the National Preservation Units System. This important initiative shall undergo some reviews, so as to incorporate methodology advances and to consider the expansion of agriculture and the vulnerability to climate changes.

- Since the discovery of Brazil, the Atlantic Forest was the first biome to be partially replaced with the exploitation of wood, agriculture and cattle-breeding along Brazil's entire seashore; among many others, the sugar-cane culture (Center-South and Northeast) is now in areas originally covered by that biome. The process by far preceded any concern for preservation, and that preservation requires restoration of areas protected by law (riverside woods, hillsides).

- The occupation of the *Cerrado* by agriculture is very recent, and includes areas occupied by cattle-breeding, as well as firewood and coal exploitation. Its growth should be planned taking into consideration the preservation of biodiversity and water resources, especially in sensitive areas (sources of rivers that flow to the Pantanal, and recharge areas of the Guarani aquifer).

- Harmonizing socioeconomic development with environmental preservation requires up-to-date information and appropriate tools for analyzing impact and vulnerability; programs like that of the IVB (São Paulo) and advances in the survey of geo-referenced data (in progress) are highly important in this context.

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2. Erosion in sugar-cane crops: situation and prospects

The erosion process is the leading cause of agricultural soil degradation. The application of soil conservation techniques aims at mitigating soil loss. Any project for the use of land in agriculture should consider the soil type (texture, diagnostic horizon types, water infiltration rate), slope, rainfall pattern, and the crop to be grown. For centuries sugar-cane has been grown in Brazil, often in the same areas, and enough knowledge has been gained for determining the measures to be taken for soil preservation.

Sugar-cane in Brazil is renowned for being a preservationist culture. Bertoni et al.[25] have demonstrated that the loss of soil under soybean is around 62 percent higher than under sugar-cane, and with castor oil plant the loss is around 235 percent higher (Table 6).

Table 6 – Soil and water losses in annual and semi-permanent crops

As an overall average for the handling practices applied, sugar-cane crops in Brazil can be considered to prevent annual erosion of around 74.8 million tons of soil compared to grain production in the same area (grains: mean loss rate of 24.5 t/ha/year).

Annual crop	Losses	
	Soil ton/ha/year	Water % Rain
Castor	41,5	12,0
Beans	38,1	11,2
Manioc	33,9	11,4
Peanut	26,7	9,2
Rice	25,1	11,2
Cotton	24,8	9,7
Soybean	20,1	6,9
English potato	18,4	6,6
Sugar-cane	12,4	4,2
Corn	12,0	5,2
Corn + Bean	10,1	4,6
Sweet potato	6,6	4,2

As an overall average for the handling practices applied, sugar-cane crops in Brazil can be considered to prevent annual erosion of around 74.8 million tons of soil compared to grain production in the same area (grains: mean loss rate of 24.5 t/ha/year[Erro! Indicador não definido.]).

Summary and Conclusions

- Sugar-cane crops have been expanding in areas having poorer soils (especially "highly anthropized *cerrados*," mostly extensive pastures). They contribute to the recovery of those soils by adding organic matter and chemical-organic fertilizers, which also contributes to improving the physicochemical conditions of the soil, thereby incorporating them into Brazil's agricultural area.

- Today, the sugar-cane culture in Brazil is renowned for its relatively small soil erosion loss (compared to soybean and corn, for example). This situation is improving as harvesting without burning expands and reduced preparation techniques are introduced, thereby reducing losses to very low rates that are comparable to those for direct planting in annual cultures.

3. Sugar-Cane use of agrochemicals

- The concern about the impact of pesticides is present in many sections of Agenda 21, which provides for specific control actions. The use of new technologies based on genetically modified plants is promising (reduction of pesticide utilization), but requires additional caution. Ideally, biological controls and, to the extent possible, "organic" agriculture techniques should be used.

- The Brazilian legislation, including rules and controls from production to use and disposal of materials, covers all important aspects.

- Pesticide consumption in sugar-cane crops is lower than in critic, corn, coffee and soybean crops; the use of insecticides is low, and that of fungicides is virtually null.

- Among the main sugar-cane pests, the sugar-cane beetle (the most important pest) and spittlebug are biologically controlled. The sugar-cane beetle is the subject of the country's largest biological control program. Ants, beetles and termites are chemically controlled; it has been possible to substantially reduce the use of pesticides through selective application.

- Sugar-cane diseases are fought against with the selection of disease-resistant varieties in major genetic improvement programs. This procedure has been sufficient to address the occurrences in large proportions, such as the mosaic virus (1920), the sugar-cane smut and rust (1980's), and the SCYLV (1990's), through replacement of varieties.

- Genetic modifications (at field test stage and not permited to production in Brazil) have produced plants resistant to herbicides, smut, the mosaic virus, the SCYLV and the sugar-cane beetle.

- Weed control methods have been frequently changed because of advances in technology (cultural and mechanical or chemical). In Brazil, sugar-cane crops still use more herbicides than coffee and corn crops, less herbicides than citric crops, and the same amounts as soybean crops.

- There is a strong trend towards an increase in the areas where raw sugar-cane is harvested with the trash remaining on the soil. Today it seems impossible to use this to totally eliminate herbicides, as expected, especially because of the rise of pests that were unusual.

- The use of fertilizers in Brazilian agriculture is relatively small, although it has increased over the past thirty years, thereby substantially reducing the need for new areas.

- Among Brazil's large crops (area larger than 1 M ha), sugar-cane uses smaller amounts of fertilizers than cotton, coffee and orange, and is equivalent to soybean crops in this respect. The amount of fertilizers used is also small compared to sugar-cane crops in other countries (48% more is used in Australia).

- The most important factor is the nutrient recycling through application of industrial waste (vinasse and filtercake), considering the limiting topographic, soil and environmental control conditions. Substantial rises in the Potassium content of the soil and productivity have been observed. Nutrient recycling is being optimized, and the use of trash is yet to be implemented. It will be very important in expansion areas.

- A large number of studies in respect of leaching and possibilities of underground water contamination with vinasse indicate that there are generally no damaging impacts for applications of less than 300 m^3/ha. A Technical Standard by the Office of the Secretary of Environment (S. Paulo) regulates all relevant aspects: risk areas (prohibition); permitted doses; and technologies.

4. Sugar-Cane and Water Resources

- Even though Brazil has the greatest availability of water in the world, with 14 percent of the surface waters and the equivalent to the annual flow in underground aquifers, the use of crop irrigation is very small (~3.3 M ha, against 227 M ha in the world).

- Sugar-cane crops are virtually not irrigated in Brazil, except for some small areas (supplementary irrigation). Efficient methods (subsurface dripping and others) are being evaluated.

- The levels of water withdraw and release for industrial use have substantially decreased over the past few years, from around 5 m^3/sugar-cane t collected in 1990 and 1997 to 1.83 m^3/sugar-cane t in 2004 (sampling in São Paulo). The water reuse level is high (the total use was 21 m^3/sugar-cane t in 1997), and the efficiency rate of the treatment for release was in excess of 98 percent.

- It seems possible to reach rates near 1 m^3/sugar-cane ton (collection) and zero (release) by optimizing both the reuse and use of wastewater in ferti-irrigation.

- For the most part, environmental problems relating to water quality, which result from irrigation (dragging of nutrients and pesticides, erosion) and industrial use, are not found in São Paulo. In this respect, the EMBRAPA rates sugar-cane as Level 1 (no impact on water quality).

- The APPs relating to riverside woods have reached 8.1 percent of the sugar-cane crop area in São Paulo, 3.4 percent of which having natural woods, and 0.8 percent having been reforested. The implementation of riverside wood restoration programs, in addition to the protection of water springs and streams, can promote the restoration of plant biodiversity in the long term.

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