SUGAR CANE'S ENERGY

Twelve studies on Brazilian sugar cane agribusiness and its sustainability

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Twelve studies on Brazilian sugar cane agribusiness and its sustainability

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Foreword: Between oil and hydrogen, ethanol is much more than just a transition in this 21st century

Eduardo Pereira de Carvalho
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For a very short period of twenty months, commencing when the first edition of this compilation came out, the global energy base started to go through an intense transformation phase. This is taking place for a simple but strong reason: at last the leaderships in the world's major nations have bowed to the evidences and now acknowledge the decisive impact of carbon emissions from human activities as a primary cause of the global warming. This triumph of the science has finally opened the door to a new era in which the oil civilization will give ground to renewable energy sources, thereby reversing a trend that has ruled unrivalled since the mid 19th century. Bound up for many generations by the consistent, vigorous predominance of prospecting for oil and consuming it, powerful societies, which have for centuries been used to dictate solutions to all others, now suddenly find themselves compelled by internal pressures to recognize concepts and provisions negotiated in a multilateral context. The climate change worries everyone, and the answer to the related fears lies not in the set of palliative measures that had been proposed since the early 1990's. Mankind feels compelled to go deeper in order to solve the problem that it created in the course of its undoubtedly successful history.

For Brazil, that represents an opportunity of a kind that hasn't been seen for a long time: it is now time for renewable energy, and, with it, mankind finds that its future is linked with the properties of fuels recovered from newly harvested plant mass. The list of complements that are now indispensable to oil is extensive; standing out from that list due to both its competitiveness and unmatched environmental performance is an old acquaintance of our social lives: the wholesome sugar-cane.

This turn of events in the energy paradigm is taking place so fast because the disturbance caused by the global warming is becoming palpable. Highly elaborated counter-arguments have ruined before the eyes of billions of people with common sense. In the face of the overwhelming evidence of more and more predictable climate disturbances, the benefit of the doubt turns into irresponsibility. There is time to correct the path of unbridled greenhouse gas emissions, which are a decisive, primary cause of the acceleration of the global warming phenomenon. But action must be taken in a realistic, decisive way to bring on new components for the fuel blend that moves the day-to-day lives of people who depend on oil to eat, dress, work and have fun.

In addition to the traditionally rich part of the planet, there are several billions of new consumers, a vast majority of whom consisting of citizens in emerging countries, who can now for the first time own goods that make their lives less tiresome thanks to the work of engines. In view of this massive pressure on the demand, the human society now bows, in a turn-around that very few people of goodwill would assume to be plausible in such a short period, to the evidence that fossil fuel reserves are finite and even rather limited.

The change in the energy supply scenario in light vehicle transportation is now a definitive fact not only in people's minds, but also on the political plane. This is just why it is opportune to rephrase the title and most of the introductory note to the first edition of this paper that was prepared by Brazilian scientists and researchers invited by UNICA and published in the second half of 2005. The original Twelve Studies, compiled herein from sources that are respectable but not immune nonetheless to the formidable ignorance of sugar cane growing and the manufacturing of ethanol that prevails in the Northern Hemisphere, address challenging issues facing Brazilians who deal with this tropical grass.

The data that have been collected over decades in Brazil on both the environmental impact of the activity and the cost of the fuel that comes from a renewable source and is used without any kind of subsidy by a significant portion of the national fleet of light vehicles are undisputable. Nevertheless, the colonizing wisdom has kept monotonously casting doubts. Hence the careful, substantive tone used at all stages of the paper – using special care in the preparation of the texts. The result, based on experiments, plenty of statistic information and, whenever possible, original research, was intended to speak to people of science, who may be coming from an antagonistic position, but do not hesitate when they acknowledge strengths in the arguments opposing their own. As a matter of fact, this approach was thoroughly maintained in this edition, which gathers together the latest information on the industries under analysis.

It also happens that in the second half of 2005 major multilateral organizations, particularly the World Bank and the International Energy Agency, circulated the conclusions of independent papers on energy from renewable sources. Those papers showed that the primary sources used by developed countries have acknowledged for the first time that sugar-cane ethanol is competitive with oil at very comfortable prices – while recognizing that the Brazilian ethanol program is free of subsidies and that the environmental balance of sugar-cane growing and processing is broadly beneficial to the planet, especially as regards carbon emissions.

Now reviewed and updated in depth, the papers prepared by Brazilian researchers are therefore validated to a rather unusual extent in competitive situations in these globalization times. Brazil no is longer required to claim to high heavens the great quality of a fuel that for three decades has played a role on the streets of its large cities, as well as every corner of the continent-sized country. That doesn't mean that multiplying the supply of that product will be just a cruise over the next few years. There are substantial problems to be examined and solved. However, before considering them, it is worth pointing out the success that has been achieved over time. There is an effective answer to the world's question as to what the complement would be to the overly pollutant oil, and it is now acknowledged that such answer is given by an emerging nation: ours! Therefore, it's time to add ethanol to the list of fuels that transform life in the human society: between oil and hydrogen, which are a revolution of the past and a revolution envisaged for the future, respectively, lies a contemporary revolution in which Brazil plays a major role.

As a matter of fact, the tropical origin of the best-proposed fuel available from a renewable source is quite understandable: it is in low-latitude zones that the sunlight provides the best results for crops that capture solar energy through photosynthesis. However, there is yet another reason for emerging countries to mobilize in search of answers to face the energy challenge. Since 1973, on occasion of the first oil shock, the share of those nations, which are known as developing countries in the world demand for energy, has grown by ten percentage points. The International Energy Agency itself projects that emerging countries will account for 56 percent of the demand by 2030. Therefore, in just two generations' time, the core of the issue will be radically displaced, as the OECD (Organization for Economic Cooperation and Development) nations, which were responsible for 62 percent of the consumption in the early 1970's, will account for just 44 percent of it in 2030.

Now, when one looks towards the future, energy security means a different thing: emerging markets feel compelled to ensure their own supply, irrespective of effectiveness, and seem less prone to make strategic decisions, leaving the environmental emissions theme to the developed world's agenda, where it's in an important position already. In the course of the 21st century, these two realities will certainly converge. The conditions for such convergence now seem well-accepted by most of the analysts and intervening parties: the severity of the problems involved in the prospective depletion of oil reserves; the dangerous geographic concentration of that raw material; the alarming global warming problem; the imperative need to improve the living conditions – and, therefore, the economic development – of most of the world's population; and the very wide range of interests of the oil industry. Due to all of these factors, the issue should not and cannot be left exclusively at the whim of market forces.

The pace of this transition, which began in a hesitating way, now speeds up. Back in the early 1970's, when the fossil fuel-powered locomotion paradigm seemed unshakable, professor Nicholas Georgescu-Roegen was practically banned from the academic community when he published his *The entropy law and the economic process*, which warned about the physical difficulties that he was then the only one to see in the horizon of human evolution, and that would break out soon afterwards with the first oil shock, on November 1973. Disregarded at that time, his conclusions have become more and more of a reference source for the study of economic prospects for the next few decades. It is based on views that sounded notably pessimistic that the knowledge and even the relations between peoples and continents gained dimensions and even a language radically new.

It is in this scenario that Brazil assumes a privileged position to argue about the sustainability of the energy model currently in place, which is underpinned by liquid fossil fuels. Of course, the starting point of such experience was necessity: a country fascinated by the automobile, but which depended on imports and had no access to hard currency. In 1974, the oil bill represented 40 percent of the country's export revenues. No other society would suffer more than Brazil's with the OPEC's gesture, as the limitation on access to fuel stations by rotation, which was considered and even tried at many places, became a stressful situation in the Brazilian's day-to-day lives.

That gave rise to a growing, intensive addition of ethanol to gasoline, as a state program – followed in the early 1980's by the experience with cars running exclusively on ethanol and, starting in 2003, with flex-fuel engines. The successful evolution of this model, along with a tradition of intensive use of hydroelectric power, have placed Brazil in a unique position among nations with an industry base: the share of energy from renewable sources in the country's entire energy base, which was around 41 percent earlier this decade, exceeds by far the world average of around 14 percent.

With these credentials, sugar and ethanol producers based in São Paulo, the world's leading sugar-cane growing and processing center, offer to start showing through UNICA, by means of this paper prepared by experts renowned in their respective fields of expertise, the reasons for the success of a value chain that has tripled in size over the past thirty years and is now going through an investment phase that is expected to add 50 percent to the region's installed capacity by the 2010/11 crop.

This may become a historic moment for the sugar and ethanol industry in view of the convergence between Brazil's and the United States' interests in this renewable energy issue. Together, the two ethanol producers account for three quarters of the world production. If they continue to be truly willing to combine their respective competitive advantages for a common effort towards researching into and encouraging the activity along with other potential producing countries, then the development of biofuels may become a decisive factor for overcoming the climate deadlock. That applies today, but it is also a great opportunity for the future.

There are many possible sources of biomass, just as well as the technological evolution can and should find successors to generate hydrogen at some point in this first half of the 21st century. However, the fact remains that Brazil has a strong scientific base to genetically work with sugar-cane varieties, makes massive investments of private funds to consistently expand the production, is watching a dramatically fast-growing demand for light vehicles equipped with flex-fuel engines, is capable of and has actually succeeded in delivering increasing amounts of ethanol at the world's most distant ports, sustains a subsidy-free agricultural policy that has been recognized as such by the World Trade Organization, seeks to maximize the utilization of sugar-cane waste for energy purposes, and has a strict policy to improve labor relationships and social conditions in the industry.

When major countries like the United States, to begin with, adhere to biomass as a strategic ingredient to reduce emissions without affecting the economic balance of their energy base, they add momentum for the same decision to be made in other centers where the activity is dynamic, such as the European Union and Japan. There is a constellation of other examples in all continents to name: China, India, Sweden, Thailand, Australia, Colombia, Guatemala, Canada, etc. Such diversity attests that the decisive move towards changing energy options has already been made.

Before that this globalized movement took shape and gained strength, the constellation of major light vehicle producers did what they could to move directly from gasoline to hydrogen. In other words, from the fuel that dominates the first century of automobile history to the answer that all scientists consider to be unbeatable in order to insure the primacy of individual transportation for the next one hundred years. However, between the two events, i.e. the fall of oil and the rise of hydrogen, these major industries have been unable to tackle the still insurmountable energy yield challenge, so that it can be stated that there exists a permanent solution for the automotive fuel problem.

It is right now that the ethanol produced from sugar-cane in Brazil can have a huge, positive impact on the energy base of advanced societies that consume energy intensively and are therefore responsible for a greater portion of the cleaning operation that takes shape at the same pace as natural disasters shock public opinion and force governments and business entities to invest in short-term solutions. As can be demonstrated by the data gathered together in this paper, producing ethanol from sugar-cane saves energy while preventing pollution thanks to the intensive use of a fuel that results from the very process, from the harvesting to the fermenting and distillation process, the main energy source of which being combined heat and power generation from the sugar-cane bagasse and straw that are left at the crushing facilities. In addition, sugar-cane ethanol ensures more energy for end use per energy unit that is spend to produce it than any other currently known renewable source.

The pace at which the energy base has been transforming has never stopped surprising since the human society became aware that oil was indeed a finite resource. However, no answer has been more dynamic than that given by Brazil. For example, the introduction of light vehicles equipped with flex-fuel engines sounded like an obscure chimera as recently as 2002. Reliable estimates prepared just two years ago indicated that two thirds of all cars produced would be flex-fuel vehicles in 2007. Reality shows that the actual rate has turned out to be around 90 percent, as consumers realized that they gain great bargaining power by having equipment that can function just as effectively whatever the proportion of the gasoline-ethanol blend.

Reason always prevails in economic decisions of major impact. The events arising out of the heavy pollutant load that the intensive use of fossil fuels has imposed on the world in the last two centuries give place to the efforts to find a competitive and sounder alternative. It is one of those situations that could even trigger spectacular changes in the hierarchy of nations. It is something as big as what our forefathers were able to witness when the United States went ahead and placed all of their economic and strategic chips on the potential of oil. Ironically, Henry Ford, who was then taking the first steps of his lonely adventure that would endow each American home with an unfailing black Ford Model T, originally intended to motorize his cars with ethanol driven engines.

The room available for biomass-derived fuels tends to grow, creating prospects for all countries – particularly those located in the tropical belt or, in other words, the least developed ones. Diversified sources are welcome. Ethanol can be produced not only from sugar-cane, but also from grains and lignocellulosic materials, the latter being a source that is still being tested in laboratories, but with promising results that suggest they will be, within a few decades, in a prominent position among world's most used energy raw materials. It is on societies in need of real opportunities that the efforts towards growing plants that are more suitable for energy purposes should be focused. With intelligent trade rules that actually move forward to free access to currently super-protected markets, humanity will take its most significant step towards achieving the necessary security in energy supply, while contributing to a greater income generation in the least favored parts of the world – thereby creating a both effective and peaceful method to defeat terrorism by redeeming those who are hopeless today.

Acknowledgements

The idea of preparing this report arose from the realization by the Board and Advisors of UNICA of the need for a more solid knowledge of the sugar cane industry's position in the Center-South of Brazil regarding its sustainability in the context of the expansion of its activities. The definitions of scope and coverage must be credited to many people from these groups, particularly Eduardo Carvalho.

The administrative and financial support for some of the studies was provided by UNICA, and it was essential to get the quality work we wanted.

The technical support provided by many advisors of UNICA was consistent and went beyond the preparation of reports in their fields of expertise; we highlight the work performed by Maria Luiza Barbosa in interaction with the mills.

Finally, the power of this study is based on the contributions provided by twenty-three professionals who were selected for their renowned competence. These individuals agreed to go out of their way in order to produce the texts and adapt them to the context, and work with the coordinators on many occasions to improve the whole of the report.

Our thanks to you all.

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Unassigned essays and texts have been written by the Organizer.

Preface

The purpose of this report is to present a unified view of the various aspects of the sugar cane agribusiness' sustainability in the Center-South of Brazil.

The evolution of such industry over the past twenty years and its growth prospects for the next few years demand a much different position from the traditional sugar producer, who should include the role of energy producer and do a lot more business in the world markets. The last twenty years also saw an extraordinary improvement in our knowledge of the consequences of human interaction with the environment, as well as the social consequences of political and economic action in a much more interrelated (globalized) world.

This is the context in which we gathered 23 experts for preparing this report, which also relied on the informal participation of a number of other professionals. The scope of the themes, the complexity and, in some cases, the insufficiency of knowledge indicate that said purpose can only be fulfilled in a limited way, and that the concepts, analyzing methods and, as result, conclusions and recommendations contained herein need permanent reviews.

A very appropriate remark by Dernbach[1] in the much more general context of today's society is that our present actions lead us "stumbling toward sustainability." In the face of Brazil's sugar cane industry, both the current situation reflected in this study and the great opportunities for growth and sustainable development make up very appealing scenarios, thereby allowing researchers, businessmen and governmental players to hope for successful work. We hope this study can help determine the paths for this future.

1 DERNBACH, J.C. (Ed.): *Stumbling toward sustainability*, Washington DC, Environmental Law Institute, 2002

Isaias de Carvalho Macedo

Coordinator

Synthesis

The interaction of the industry's activities with the environment, society and economy is complex; instead of treating it according to activity type (agriculture, industrial process, marketing, end use), we chose to group the topics by type of impact. Accordingly, we considered the *Impacts on the use of material resources* (especially energy and materials); the *Impacts on the environment* (air quality, global climate, water supply, soil occupation, biodiversity, soil preservation, use of pesticides and fertilizers); the *Sustainability of the agricultural production base*, including resistance to pests and diseases; the *Impacts on commercial actions*, covering competitiveness and subsidies; and, in conclusion, some *Socioeconomic impacts*, with great emphasis on the creation of jobs and income. These topics are covered in the following twelve chapters.

I. Impacts on the use of material resources

Even though it is known that there is a need, as well as possibilities, to reduce specific consumption of energy and materials in developed countries without compromising the quality of life, that has not been accomplished. The analysis of *Impacts on the use of material resources* of the sugar cane industry's activities point to a very positive situation (and possibilities): the industry is an energy *supplier*, replacing fossil energy, and may become a supplier of (renewable) materials, such as plastics and chemicals.

The world supply of energy is based on fossil fuels (75%); the scale on which fossil fuels are used quickly leads to depletion of resources, leaving a heavy burden for future generations. Additionally, the use of fossil fuels is responsible for a large amount of local pollution and most of the greenhouse gas emissions. The use of energy should grow as a result of advances in many of the world's developing regions. The current challenge is to seek renewable energy sources and to increase efficiencies in energy generation and use on an unprecedented scale.

Brazil has an intermediate consumption level (1.1 toe / inhab·year), with a deep focus on renewable energy sources (43.8%, compared to 13.8% in the world). Brazil can significantly increase the use of biomass and other resources to improve generation and use efficiencies. In this respect, among other initiatives, Brazil should implement the distributed generation of electrical power (based on combined heat and power), which could reach 10-20 percent of the total within 10-15 years, and establish a fuel policy for the transportation sector.

The sugar cane industry already provides a major contribution (responsive sustainability) to the substitution of fossil fuels, going much further than energy self-sufficiency (electrical and thermal power).

√ It generates 11.3 TWh of electrical and mechanical power (3% of the electrical power generated in the country)
√ It uses bagasse as a fuel: 20.2 Mtoe (equivalent to the sum of all of the natural gas and fuel oil used in the country)
√ It produced nearly 50% of all the gasoline used in the country in 2004

The sugar cane industry's improved energy performance (use of sugar cane trash, and the implementation of efficient co-generation) can lead to an additional 30 TWh of electrical power. Alternatively, the implementation of processes for bagasse and trash conversion to ethanol in the future can increase ethanol production by 40 percent for the same sugar cane production level.

If the expected sugar cane production increases for the next years materialize, for every additional 100 Mt of sugar cane, the industry would supply 3.8 percent of the current electrical power consumption and 4.9 Mm^3 more ethanol (assuming that 58% of the sugar cane are used in ethanol production). The alternative ethanol production from bagasse and trash, when technically possible, would lead to an additional 3.4 Mm^3 of ethanol.

The *per capita* consumption of materials and resources worldwide has continued growing over the past ten years, and so have the resulting environmental impacts. As in the case of energy, governmental policies have not been sufficient to reverse the trends that are aggravated by the advances of large developing areas.

Agriculture (having solar energy as an input) is a field that can lead to a sustainable production of materials in some cases. This perception promotes biological products as "environmentally sound". Ethanol based products (Brazil, 1980's and 1990's) have brought several examples, as have recent advances in sucrose chemistry.

Brazil's sugar cane production corresponded (2006) to a production of 60 Mt of sucrose and 120 Mt (DM) of lignocellulose residue. Sucrose is currently used in sugar and ethanol production, but other important activities are beginning in new products development. Of the residue, 50 percent are used at low efficiency rates in energy generation, and more than 25 percent (trash) are recoverable at costs compatible with energy uses.

The production costs in Brazil and the availability of bagasse energy make sucrose very attractive to dozens of other products. In Brazil, there is commercial production of amino acids, organic acids, sorbitol, and yeast extracts, as well as developments concerning products for large amounts (plastics). Over the next few years, it will be possible to use 1.5 Mt of sucrose in these processes.

In the 1980's and 1990's, more than 30 products were produced from ethanol in Brazil, several of which relied on installed capacities in excess of 100,000 tons / year (via ethylene, acetaldehyde or direct transformations). They became unfeasible in the 1990's because of the national policy for oil derived chemicals and the relative cost of ethanol. The new oil-ethanol cost ratio now leads those processes to be reconsidered.

The large-scale production of renewable materials from sugar cane in Brazil is a possibility, but is still at an early implementation stage. It is growing somewhat rapidly in the use of sucrose, and may grow in alcohol chemistry again, while having a great unrealized potential in terms of residue utilization. It would certainly contribute a lot to the sugar cane agribusiness' "responsive sustainability" position.

II. Impacts on the environment

The *Impacts on the environment* consider the sugar cane culture, industrial processing and end use. They include effects on local air pollution and the global climate, on the use of soil and biodiversity, on soil conservation, on water resources, and the use of agrochemicals and fertilizers. Those impacts may be either positive or negative; in some cases, the sugar cane industry has very important results, such as the decrease in GHG (Greenhouse Gas) emissions and the recovery of agricultural soils. The environmental legislation (including restrictions on soil use) is advanced in Brazil, and efficiently applies to sugar cane crops.

The deterioration of air quality in urban centers is one of the world's most serious environmental problems. For the most part, it is caused by the use of fossil fuels, which also contribute to cross-border pollution, such as acid rain, for example. Mitigating efforts include an increasingly restrictive legislation on fuels and utilization systems.

The sugar cane agribusiness has two very distinct points of connection with the impacts on air quality: ethanol use has been leading to considerable air quality improvements in urban centers; and the sugar cane burning in the field, on a very different scale, causes problems by dispersing particulate matter and because of the risks associated with the smoke.

The main effects of ethanol use (whether straight or as an additive to gasoline) on urban centers were as follows: elimination of lead compounds from gasoline; reduction of carbon monoxide emissions; elimination of sulphur and particulate matter; and less toxic and photochemically reactive emissions of organic compounds.

The burning of sugar cane trash (used in most producing countries to make harvesting easier) was the subject of many papers in the 1980's and 90's (in Brazil and other countries); they were unable to conclude that the emissions are harmful to human health. Such undesirable effects as the risks (electrical systems, railways, forest reserves) and dust (particulate matter) remained. In São Paulo State, legislation was passed which gradually prohibits the burning, with a schedule that considers the technologies available and the expected unemployment, including immediate prohibition in risk areas. That solution is in force, and is an important example given the size of the São Paulo production.

The 30-percent increase in the concentration of greenhouse gases in the atmosphere since pre-industrial times corresponds to an average increase of 0.6 ºC in the surface temperature of the planet. In the 21st century, the mean temperature may increase by more than 3 ºC if the current trend is not changed. The Kyoto Protocol represents one step towards (increasingly consensual) preventing an increase of up to 2 ºC by 2050.

The global climate models, still evolving, always point to temperature rises in Brazil, but the uncertainties about the rainfall are large. The models indicate temperature increases of 1-4 ºC (low emission scenario) or 2-6 ºC (high emission scenario). There is no agreement on the rainfall results, but climate extremes (droughts, severe storms) are expected to occur more often. In the models that indicate a greater amount of rainfall (GFDL, US) the savannah would expand to the Northeast. In the other scenarios (for example, the HADCM3, England), the savannah would expand to parts of the Amazon, and the *caatinga* in the Northeast would become a desert.

A vulnerability assessment of the agricultural sector should consider the simultaneous effects of the temperature (and rains) and the "fertilization" by the increased concentration of CO_2. There are only a few studies for Brazil, and they are focused on coffee and wheat in specific regions.

The evaluation of GHG emissions from Brazil for the 1990-94 period indicates "*Change in the use of land and forests*" as the factor accounting for the most emissions (75%), followed by "*Energy*", with 23 percent.

In the sugar cane industry, the "renewable energy produced to fossil energy used" ratio is 8.9 for ethanol production. *The consequence of this is an extraordinary performance of the industry, which avoids GHG emissions equivalent to 13 percent of the emissions from Brazil's entire energy sector* (reference 1994).

Emissions avoided in 2003:	
With ethanol substituting for gasoline:	27.5 Mt CO2 equivalent
Bagasse in sugar production:	5.7 Mt CO2 equivalent

For every additional 100 Mt of sugar cane, emissions of 12.6 Mt CO_2 equivalent could be avoided over the next few years using ethanol, sugar cane bagasse and the added excess electrical power.

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

Sugar cane crops are virtually non-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 release treatment efficiency was in excess of 98 percent.

It seems possible to reach rates near 1 m^3 / sugar cane t (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 (water run-off, with nutrients and pesticides, erosion) and industrial use, are not found in São Paulo. In this respect, EMBRAPA rates sugar cane as Level 1 (no impact on water quality).

The Permanent Protection Areas (APP, in Portuguese) 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 sources and streams, can promote the restoration of plant biodiversity on the long term scale.

With 850 Mha, Brazil has a large portion of its territory with conditions to economically support agricultural production, while preserving vast forest areas with different biomes. Today, agriculture uses only 7 percent of this territory (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 area currently able to support the expansion of this kind of crop represents 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 already existing sugar fields; new agricultural borders were involved very slightly. In São Paulo, the growth has occurred through substitution of pastures and other crops.

For the next few years, there should be growth in the Center-South region, with an emphasis on western São Paulo, 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 should 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 coast. 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 protected areas (riverside woods, hillsides).

The agricultural occupation of the *cerrado* 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.

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 contribute 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 keeps 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.

The concern about the impact of pesticides is present in many sections of Agenda 21, which provides 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 regulations from production to use and disposal of materials, covers all important aspects.

Pesticide consumption in sugar cane crops is lower than in citric, 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 the *cigarrinha* 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 through 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) 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 technological advances (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 "green" sugar cane harvesting, with the trash remaining on the soil. Today it seems impossible to totally eliminate herbicides as expected, especially because of the rise of unusual pests.

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 Mha), 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 trash utilization is yet to be implemented. It will be very important in expansion areas.

A number of studies in respect to 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 (São Paulo) regulates all relevant aspects: risk areas (prohibition); permitted doses; and technologies.

III. Sustainability of the agricultural production base

The *Sustainability of Brazil's sugar cane production base* requires the ability to respond to pests and diseases and to periodical climate changes, without seriously impairing it.

The production conditions in Brazil, with its diversity of regions and microclimates, have been responding appropriately to periodical climate changes.

Protection from pests and diseases is considered a strength of Brazil's production: it is based much more on a continued supply of disease and pest-resistant sugar cane varieties than on phytosanitary barriers, allowing growers to operate with a great diversification.

There are four operational sugar cane genetic improvement programs in Brazil (the two leading programs are private); they use one quarantine and two hybridization facilities, with germplasm banks. They work with approximately 1.5 million seedlings per year.

More than 500 varieties are grown today (51 have been released over the past ten years). The twenty most important varieties occupy 80 percent of the crop area, but the most widely used occupies just 12.6 percent. The substantial rise in diversification over the past twenty years has provided great safety concerning resistance to exogenous diseases and pests.

Brazil stands out from other producing countries for its sugar cane biotechnology, having had (non-commercial) transgenic varieties since the 1990's. In 2003 the identification of 40,000 sugar cane genes was completed in Brazilian laboratories. There are dozens of groups working on the functional genome, and they are already using the genes in genetic improvement programs (experimental stages). Commercial results may arise over the next five years.

More funds are recommended in order to properly integrate the germplasm banks for all programs and to support specific developments for each expansion area.

The efforts on the legislative front should be carried on in order to facilitate the development of biotechnological research at its final stages.

IV. Impacts of production on commercial actions

The sugar cane ethanol and sugar production in Brazil's Center-South region today have no adverse economic impacts on the external environment; there is no externalization of costs to be paid by other sectors of society. The sugar cane products do not have any price support mechanism under governmental policies, and there are no subsidies to sugar production or trade today.

Ethanol production cost (without taxes) in the Center-South mills, was estimated at R$ 647/m^3, which is highly competitive with international gasoline prices. Ethanol production costs in Brazil are also significantly lower than the costs for corn ethanol in the US or wheat and beet ethanol in Europe.

The ethanol cost reductions in Brazil since the program was introduced have occurred due to advances in technology and management and investments in infrastructure. A broader implementation of existing (commercial) technologies may further reduce costs in the Center-South, but the best prospects relate to new technologies being developed. These include precision agriculture, new sugar cane and trash transportation systems, and genetic modifications of sugar cane.

In addition, the production diversification will contribute to the rise in competitiveness, as it did upon introduction of ethanol. Such diversification includes the increase (in progress) in the use of sucrose and some ethanol-based routes, and the production of excess energy from sugar cane biomass in several ways (also in progress).

The sugar from the Center-South has had the world's lowest production cost for many years now, amounting to R$ 410 / t. The world production cost is currently evaluated at US$ 120 / t, for up to 20 Mt (the production of Brazil's Center-South region); for 20 Mt to 65 Mt, the cost goes up to US$ 200-250 / t; and for 65 Mt to 100 Mt, it rises to US$ 400 / t. The total sugar production and export cost in the Center-South represents 65 percent of the mean cost of other exporters.

The high availability of appropriate land for expansion and the lack of governmental policy-supported prices in Brazil would make the country even more competitive in a trade liberalization scenario (as expected). Analyses of the ethanol and sugar markets point to a demand of 560 Mt of sugar cane / year in Brazil for 2010.

V. Socioeconomic impacts of the sugar cane agribusiness

Brazil has had an unemployment rate of 9 to 10 percent over the past few years. Job quality and income distribution are serious problems; the Gini coefficient was 0.607 (1998) and 0.554 (2003). Notwithstanding the increase in income, social inequalities have not been significantly reduced over the past 20 years. Workers who do not contribute to the social security system are estimated at 55 percent. The rates of child labor (2.4%, 10-14-year-olds) and functional illiteracy (23.9%, less than 3 years at school) have been significantly lowered, but are still high. The *per capita* income in 2002 was US$ (PPP) 7,600.00.

In the consideration of *Socioeconomic impacts of the agribusiness*, the most importance its attached to job and income creation for a very wide range of workforce capacity building programs, with the flexibility to support local characteristics using different technologies. It should also be remembered that the industry fosters substantial foreign currency savings by avoiding oil imports, and the business and technological development of a major equipment industry.

The replacement of gasoline with ethanol between 1976 and 2004 represented savings of US$ 60.7 billion (exchange rate of December 2004), or US$ 121.3 billion, considering the interest rates.

The Brazilian industry supplying equipment for cane, sugar and ethanol production developed into a leading position; the largest manufacturer, alone, produces 726 distilleries (distillation units), 106 full plants, 112 combined cogeneration plants, and 1,200 boilers (including exported units).

Brazil's labor legislation is renowned for being advanced in worker protection; the union organization is developed and plays a key role in employment relationships. For sugar cane, the specific aspects of employment relations in agriculture (specific unions) and industrial operations (unions of the food and chemical industries) are well-defined, including the conclusion of collective agreements, which advanced during the last decade. Compared to the Brazilian 45-percent mean rate of formal jobs, the sugar cane industry's agricultural activities now have a rate of 72.9 percent (from the 53.6% of 1992). In the Center-South, the rate of formal jobs in sugar cane production is 85.8%, reaching 93.8 percent in São Paulo (2005).

The differences in regional development are reflected in the industry's occupational indicators; poorer regions are characterized by lower salaries and a much larger use of labor, consistent with their technological levels (automation, mechanization).

In the early 1990's, there were 800,000 direct jobs; for every 1 Mt of sugar cane produced and processed, there were 2,200 direct jobs (73% in agriculture); in the North-Northeast, three times as much as in the Center-South. In São Paulo, non-specialized workers (sugar cane cutters) were paid US$ 140 / month (US$ at that time), which was higher than the amount paid to 86 percent of agricultural workers in general, and 46 percent of industrial workers. The mean family income of those workers was higher than that of 50 percent of all Brazilian families.

The seasonal index for jobs was 2.2 in São Paulo in the early 1980's, 1.8 in the late 1980's, and 1.3 in the mid 1990's. This decrease was motivated mainly by the mechanical harvesting of sugar cane, which also enabled more training and career planning.

In the late 1990's, with 650,000 direct jobs and 940,000 indirect jobs (plus around 1,800,000 induced jobs), the number of jobs per product unit in the Center-South region was still 3.5 times higher than in the North-Northeast; there is a correlation between the difference in the mean job quality (according to years of education) and salary levels.

The *formal, direct jobs* in the industry are now increasing in number and reached 982,000 in 2005. Of those formally employed, 90.8 percent are aged 18 to 48 (0.2% under the age of 17). Industrial jobs increase more than jobs in agriculture. People having studied for less than 4 years represent 35.2

percent of the workers, 11.3 percent being illiterate (4% in the Center-South).

Considering both formal and informal jobs (2005 PNAD sample), the income of working people in Brazil was as follows: all industries, R$ 801 / month; agriculture, R$ 462 / month; industrial operations, R$ 770 / month; services, R$ 821 / month; sugar cane agricultural jobs: Brazil, 495; N-NE, 316; C-S, 697; São Paulo, 810; Sugar industry: Brazil, 742; N-NE, 600; C-S, 839; São Paulo, 837.

The amounts for ethanol are a higher than those for sugar, reaching 960 for Brazil and 1196 for São Paulo.

In agriculture, the mean education level in the North-Northeast is equivalent to half the level (years at school) of the Center-South.

In the Center-South, the income of people working in sugar cane crops is higher than in coffee and corn crops, equivalent to citrus but lower than in soybean crops (highly mechanized, with more specialized jobs). In the North-Northeast, the income in sugar cane crops is higher than in coffee, rice, banana, manioc and corn crops, equivalent to the income in citrus crops, and lower than in soybean crops.

The income in formal jobs does not include the 13^{th} salary or any benefits. Mills maintain more than 600 schools, 200 daycare units and 300 ambulatory care units. In a sample of 47 São Paulo-based units, more than 90 percent provide health and dental care, transportation and collective life insurance, and over 80 percent provide meals and pharmaceutical care. More than 84 percent have profit-sharing programs, accommodations and daycare units. Social Balance Sheet Indicators for 73 companies (UNICA, SP, 2003) show that funds equivalent to 24.5 percent of the payroll are used for such purposes as profit-sharing programs (6.72%), food (6.54%), healthcare (5.9%), occupational health and safety (5.3%), and education, capacity building and professional development (1.9%).

Introduction

The purpose of this report is to present a unified view of the various aspects of the sugar cane agribusiness' sustainability in the Center-South of Brazil. In this introduction we list some basic sustainable development concepts and the main issues relating to agriculture. Brazil's sugar cane agribusiness is characterized by some production indicators and data. Also a brief description of the production processes is provided for an identification of the interactions of the production system with the environment and society.

Sustainable development

With the end of the Second World War and, particularly, the explosion of atomic bombs in the Japanese cities of Hiroshima and Nagasaki, humanity found itself in the face of a real possibility of undermining its life and survival on the planet through its actions. Over the following years, the exuberant industrial expansion and exponential increase in environmental contamination problems added to that perception.

As a result of those concerns, the First World Environment Conference was held in Stockholm by the United Nations in 1972. In addition to matters pertaining to pollution and problems caused by the ever-more intensive use of natural resources, it became evident thereafter that there is an unbreakable link between the need to fight misery and human exploitation and the need for development and quality of life (and, therefore, the quality of the environment we occupy).

However, outside expert circles, peace and security, economic development and social development, the latter translating as respect for human rights, were understood as basic conditions for "human development" until a little more than ten years ago. In 1992, at the UN Conference on Environment and Development (Rio de Janeiro), the nations around the world agreed to implement an ambitious project to promote a "sustainable development." The principles established in the Rio Declaration, and the resulting actions and responsibilities that were detailed in Agenda 21 in 1992 added environmental protection to the list of basic conditions for human development, as it is considered essential to prevent future generations from being unable to accomplish their development.

Accordingly, the main goals of mankind (freedom, equality, and quality of life) became valid not only in the present, but also for future generations: a development that, by meeting present requirements, would not undermine the future generations' ability to meet their own needs. Rather than development with harm to the environment, or environmental protection with harm to development, a sustainable development would seek both the "traditional" development and environmental protection (or restoration).

Agenda 21, as an action plan, defines the current challenge as overcoming "a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being".[1] Misery and environmental degradation are destabilizing factors. The central idea of Agenda 21 is that each country is responsible for seeking sustainable development, either by itself or in cooperation with other countries.

1 U. N. Conference on Environment and Development, Agenda 21, U. N. Doc. A/CONF. 151.26, 1992

The implementation of these actions has been considerably delayed for reasons that include some governments' disagreement with essential topics. However, it is undeniable that there has been great progress in many fields on the part of governments, and that the decentralizing nature of Agenda 21 has very effectively led to many actions "from the bottom to the top" through municipal and state decisions, NGOs and private sectors of the economies. Such movements are growing in number and influence, and should be expected to eventually determine governmental actions even in more hesitating countries. In fact, the experience over the past few years has shown that even though the environmental legislation plays a key role in the evolution of sustainability, it takes more than just laws and policies: the involvement of many other sectors of society.

The following are some of the basic principles of Agenda 21:

- integrated decision-making process (development and environmental protection)
- the "polluter-payer" principle (not transferring the costs to others)
- seeking sustainable population and consumption levels
- the precautionary principle: in cases of serious risks, the lack of scientific certainty should not delay environmental protection measures
- inter-generation equity
- participation of the population
- common but differentiated responsibilities (among developed and developing countries)

The topics addressed in Agenda 21, which have been detailed since its introduction, cover a wide range of aspects of our civilization, including regional differences. As the main examples, we can point out: population and consumption (demographic policies, consumption of materials and energy); international trade, development financing and support; preservation and management of natural resources (potable water, oceans and estuaries, seashore waters, and sea pollution; air pollution; climate changes; biodiversity; land use, agriculture, forestry); toxic waste and chemical control (agrochemicals, radioactive and non-radioactive waste); education; institutions and infrastructure (transportation, health).

The recent ratification of the Kyoto Protocol is yet another statement of how important sustainable development has become over the past few years.

Agriculture and sustainable development

Agriculture is enormously relevant to human development. Clearly, today's food supply is insufficient for the six billion inhabitants on the planet, and in spite of the efforts set forth in Agenda 21 with respect to rational demographic policies, the world population should reach nine billion within a few decades. Agriculture is a business that will grow together with the global demand. The question that has been asked more and more often is as follows: can agriculture be performed without harm to the ecosystem?

As a matter of fact, according to the concepts of the "green revolution," including the intensive use of materials and water, the sustainability of agriculture is an open question in the best-case scenario; many of the practices are clearly unsustainable. However, we should acknowledge that they have been essential in diminishing hunger around the world over the past few decades. Considering that human development and environmental protection should not be exclusive of each other, what is the proper breakeven point, and how can we evolve into sustainability?

Part of the answer to that question lays in the appropriate use of the production factors: technologies and investment. The stronger emphasis on sustainability is a very recent thing; many of the "modern agriculture" paradigms of twenty years ago are now contested from the emerging standpoint. On the other hand, it is clear that the definitions contained in Agenda 21 are very general, which demand additional efforts towards application to such a diverse sector as agriculture. Agriculture – as well as urban concentrations and most human activities –, in practice, breaks natural ecological functions; there will always be some kind of conflict between it and the "environmental" part of sustainability.

2 DAVIDSON, J.H.: "Agriculture", *in*: DERNBACH, J.C. (Ed.): *Stumbling toward sustainability*, Washington DC, Environmental Law Institute, 2002

Examples that are replicated in many countries are evidence of the distance between the systems in use and the sustainability ideals. A recent analysis[2] of agriculture in the United States shows the origin of the system that somewhat prevails today: strong federal intervention, starting in 1930, combining price and income (subsidies) with a subsidized "conservationist" agriculture. Here, "conservation" is different than "environmental protection": it is about maintaining potential resources, preventing waste and maximizing productivity, focusing on utilization for the population. The following are two important examples:

- Irrigation projects in the western United States (such as that of Yakima Valley), initiated in 1902. There are 46 million acres of irrigated soil in the West (water depth of 0.9 m) with infrastructure paid by the federal government; the water is still strongly subsidized today. The sustainability of that is questioned (water availability limitation, competition for land for other purposes, soil contamination, dragging of fertilizers and pesticides). In the western states, irrigated crops are responsible for 89 percent of the contaminated river sections and more than 40 percent of the pollution in contaminated lakes.
- Drainage projects in grain and cotton-growing areas; drainage was intensively used since 1930, with federal resources, to increase production areas. States like Iowa, Illinois and Minnesota were converted from systems that were rich in water into large dry, arable areas (according to "conservationist" concepts). Such "dry land agriculture" has been very important to the US and the world. But the price to pay is the large volume of polluted waters which the drainage system discharges without soil filtration to rivers and lakes.

This is how Agenda 21 (properly) defines the tough problem of agriculture for the next few years: "*By the year 2025, 83 percent of the expected global population of 8.5 billion will be living in developing countries. Yet the capacity of available resources and technologies to satisfy the demands of this growing population for food and other agricultural commodities remains uncertain. Agriculture has to meet this challenge, mainly by increasing production on land already in use and by avoiding further encroachment on land that is only marginally suitable for cultivation*".

Any intervention in nature and living organisms (even when the purpose is to cure diseases and degenerative processes) implies the choice of options that are selected according to predetermined goals and considering the uncertainties inherent in these choices. The same applies to sustainable development proposals.

In the search for effective alternatives for achieving sustainability in agriculture, and considering the pressures that this activity intrinsically puts on the environment, a suggestion made for the American agriculture[2] seems appropriate: agriculture should be both internally and externally sustainable, while serving as an available resource with which to assist other sectors of the economy and society.

2 see p.42

- Internal sustainability includes the ability to preserve its resources by preventing soil and water degradation, and to respond to pests and diseases of the relevant plants, to climate changes, and to market changes. This should occur without any dependence on direct financial support from the government.
- External sustainability means not imposing costly externalities on the "non-agricultural" society or the local environment.
- Responsive sustainability is the ability to assist other sectors (for example, generating "clean" energy from biomass, restoring degraded soils and riverside woods, producing excess to satisfy the needs arising out of any falls in other locations, and creating jobs and income).

These practical guidelines can be very helpful in planning and assessing sustainability in agricultural sectors. The will be used in the course of this study in respect of Brazil's sugar cane production. Despite not seeking absolute parameters in many cases, these guidelines help by putting the current situations and trends in perspective. The guidance resulting from these observations will contribute to have the steps appropriately oriented towards the industry's sustainability.

The sugar cane agribusiness in Brazil

Sugar cane growing in Brazil covers an area of nearly six million hectares in all geographic regions, reaching a production of approximately 420 million tons in 2006/07, which represents a quarter of the world production. Around 50 percent of that was used in sugar production (30.6 Mt), and 50 percent in ethanol production (17.4 Mm^3), in 320 industrial units. There are around 77 new units in construction or in advanced project stage today, and they are expected to start up within the next six years.

Sugar cane production increased from around 120 to 240 million tons from 1975 until 1985, especially as a result of PNA, and remained stable on that level between 1985 and 1995. Another growth cycle started in 1995, basically motivated by sugar exports. In 1990, sugar exports amounted to 1.2 Mt, and then increased to 19.6 Mt in 2006, demonstrating the Brazilian product's extraordinary increase in competitiveness.

Meeting the domestic and international demand for ethanol and sugar (estimations: see **11.3** and **11.5**) would require a production of around 680 Mt of sugar cane per year by 2012-2013 (an increase of 60% the current production).

The production system comprises mills having very different capacities (from 0.6 to 6.0 Mt of processed sugar cane / year); on average, the mills produce sugar cane on their own land, or on leased land or agricultural partnerships (around 70%), and the remaining 30 percent are supplied by independent growers, which amount to around 45,000, most of whom use less than two agricultural modules. The two producing regions are the Northeast (15%) and the Center-South (85%).

Governmental controls (production and export quotas, prices, and subsidy grants for production and transportation of both sugar and ethanol) have been eliminated by a transition system implemented in the early 1990's and concluded in 1998. Today, the government is present in the regulation of hydrous and anhydrous ethanol specifications and in the determination of the ethanol content of gasoline. The prices are free at all levels of the supply chain, and ethanol is sold in nearly 29,000 fuel stations all over the Brazilian territory.

The pertinent themes of a sustainability analysis of any important sector of human activity entail a number of fields of knowledge if appropriately addressed in the entire life cycle. The interdependence among these fields may cause any such analysis to be "incomplete," allowing for an increase in scope and depth, and the consideration of new points of view. In this study, we try to be critical in a constructive way, relying on many experts and different views. The intention is to apply the formalized sustainability concepts to the sugar cane industry as it is today in the Center-South region of Brazil with greater clarity and depth, and seeking opportunities to strengthen it.

A number of "uncertainties" are facing world agriculture today (including the sugar cane agribusiness), and they affect each country in a slightly different way. For example: uncertainties about the future of transgenic plants and their implications; uncertainty about the magnitude and timing of global climate changes (heating and rainfall); and uncertainty about the world markets, which is deepened by protectionist practices (or elimination thereof).

One of the most important facts demonstrated in this study is that under the present conditions of Brazil's sugar cane agribusiness, there is a very relevant set of responsive sustainability activities in the industry (a part of which being already in progress, and another part appearing as potential) which can make it a promising example in the international context.

Production processes in Brazil

A simplified description of the production processes helps one understand the relations between the sugar cane agribusiness and the environment. There are sugar cane crops in more than 80 countries around the world, with variations concerning growing periods and techniques, depending on local conditions. It is characterized as a very highly photosynthesis-efficient culture (thereby featuring great biomass production per unit area).

In Brazil, sugar cane is grown mainly in large areas in the Northeast and Center-South regions. Five or six harvesting cycles are completed before the sugar cane crop is reformed, and the harvesting period extends for six to seven months. The entire production process is labor-intensive, especially the harvesting, while the expansion of mechanical harvesting has been reducing the number of jobs (per production unit) and also the seasonal index. Sugar cane crops use fertilizers and agrochemicals moderately, and recycle all industrial waste from ethanol and sugar production as crop fertilizers. The use of sugar cane burning before harvesting (removing the leaves to facilitate harvesting) is gradually decreasing by virtue of environmental and safety restrictions in some areas, but still prevails.

Sugar cane transportation to the industry (in fact, the integrated harvesting, loading and transportation operation) has evolved very much to avoid agricultural soil compactation and reduce costs using high-capacity systems within the legal limits of the highways.

The sugar cane crop is used to produce ethanol and sugar; a part of the cane is washed for removing mineral impurities (manually harvested sugar cane only). An extraction system (in Brazil, almost exclusively milling: the sugar cane is chopped, shredded, and goes through a series of milling equipment) separates the juice, which contains sucrose, from the fiber (bagasse). For sugar production, the juice is cleaned (settling and filter-press, whereby the filtercake is removed), concentrated and crystallized. A part of non-crystallized sugars and impurities (molasses) is separated. In Brazil, it is usually much richer in sugar, avoiding the final crystallization stage, and it is used as a fermentation material added to the juice.

Such mixture is taken to the appropriate concentration and fermented with yeasts; most systems are fed-batch type with yeast recycling, but there are continuous processes. The resulting wine is distilled, whereby ethanol is produced (hydrous or anhydrous) and vinasse is left as waste (the sugar cane water and the water added in the milling process, the organic matter and important minerals, such as potassium, which came along with the sugar cane).

The entire energy consumed by the process (electrical power; mechanical energy, for activating some pumps, fans and milling equipment; and thermal energy, for the juice concentration and distillation processes) is supplied by combined heat and power systems that use only the bagasse as the energy source; the mill is self-sufficient and usually has excess energy.

The waste of the industrial processes consists of vinasse, filtercake, and bagasse boiler ashes. There are totally recycled to the crops: vinasse in liquid form, for ferti-irrigation; the filtercake is transported on trucks as a fertilizer. The industrial processes use water (collected from rivers and wells) in several operations; there is intense recycling to reduce both withdraw and the level of treated waste disposal.

I

Impacts on the use of material resources

One of the important contributions provided by the socioeconomic analyses that began to include such parameters as consumption of energy and materials in the 1960's and increasingly in the 1970's was the reaffirmation that beyond certain levels (which are relatively low), human well-being ("quality of life") is independent of the increase in consumption of such items.

However, what has been noted until the present day is an important increase in specific consumptions by the planet's populations, with a greater emphasis on developed countries, especially those which were major consumers already.

In 1997 that situation was well quantified in the argument[1] that it would be possible to double the humanity's well-being while reducing the use of energy and resources by half; the factor 4 could be proposed as a target productivity increase for the use of resources. There are those who propose utilization of a factor 10 for the flow of materials in the OECD countries.

1 WEIZSACKER, E.; LOVINS, A.; LOVINS, H.: "Factor four: doubling wealth, halving resource use", 1997

Energy and raw materials are usually the topics considered in such studies, and fresh water is a theme that increasingly arouses great concern. In the case focused on herein (sugar cane production and processing), these three items will be considered separately, with energy and raw materials in **Chapters 2** and **3**, and water in **Chapter 5**. The use of other agricultural and industrial materials (pesticides, fertilizers, lubricants) is relatively small, and will be approached in the following sections.

In the considerations on energy and raw materials, one of the most important characteristics of this agribusiness is noted: it is essentially an industry that uses the extraordinary efficiency in sugar cane photosynthesis to produce basic materials (lignocellulosic materials and sucrose) from solar energy. Therefore, its role in the impacts on energy and material resources both potentially and actually is not that of a *user*, but rather a *supplier*. In this respect, it is a classic case of "responsive sustainability," as it helps other industries; today this is very important in terms of energy, and is now starting to be explored for other material resources.

Chapter 1:
Share in the use of fossil energy

The production of ethanol from sugar cane in Brazil leads to important savings in fossil energy; for instance, ethanol from corn in the United States needs a ratio between renewable energy production and fuel fossil utilization that is under a fourth of the Brazilian equivalent. This relation can still be improved in Brazil with better use of the bagasse and cane trash for electricity or other energy utilization.

1.1 Introduction; the global context

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Energy is essential to mankind in its search for a healthy and productive life; it is necessary for the production of foods, clothing and other basic goods; for buildings, homes, trade, hospitals and healthcare, education; and the transportation of cargo and people. On the other hand, the production of energy based on fossil fuels (more than ¾ of the world's current total production) has resulted in environmental pollution associated with extraction, local air pollution, regional pollution by acid rain, and global pollution by greenhouse gas emissions. Its utilization on a large scale is clearly leading to the depletion of resources, leaving a heavy burden for future generations.

For the energy sector, sustainable development should consider a more efficient use of fuels based on non-renewable sources, new technologies to significantly reduce the local and global pollution resulting from fossil fuels, and an increased development and implementation of the use of renewable energy sources.

The use of oil over the past fifty years is probably the most spectacular example of depletion of non-renewable resources caused by mankind. As early as 1989 it was possible to foresee, even considering all the possible ways to extend the oil supply (natural gas conversion, non-conventional oil, shale oil, bituminous sands), that the supply peak would take place around 2020 (conventional oil: before 2010). The large-scale use of coal (if at all possible with its environmental limitations) could postpone by ten years that supply peak.[1] More recent evaluations are no longer optimistic, quite the opposite: the Global Hubbert Peak (time when the world supply of conventional or non-conventional oil and liquid natural gas ceases growing, starting to decline year after year) is expected to occur before 2020,[2] and some estimations point to some time before 2010 (for the most part, because of the present instability that may prevent the increase in oil supply from the Middle East).

1 Bookout, J.F.: "Two centuries of fossil fuel energy", Episodes, vol. 12, 1989, pp. 257-262

2 Olson, R.L.: "The end of the oil age: How soon? How real? How critical?", Institute for Alternative Futures, 2004

The world use of energy by resource in 2000 was 77% from fossil sources (half of which of oil, and the rest consisting of natural gas and coal); 15% from hydraulic energy and traditional biomass, 6% nuclear, and 2% from "new" renewable sources.[3] "New" renewable sources include biomass as commercial energy, such as ethanol, whereas "traditional" biomass is essentially firewood and residue, of which the production is neither organized nor sustainable.

3 Sawin, J.L.: "Renewable power: on the brink of an energy revolution", Worldwatch Institute, 2004

Most important (and preoccupying) is the consideration that ten years after the oil supply peak, a substitute will be needed for around a half of the oil that we use today, i.e. a substitute for 10 to 15 billion barrels a year.

A strong restriction that will be imposed on the solutions being sought derives from today's acknowledgement that fossil fuels are responsible for the most anthropogenic GHG (Greenhouse Gas) emissions, and that the increased concentrations of atmospheric CO_2 are responsible for global climate changes. From the pre-industrial concentration level (~250 ppm), we have now reached around 380 ppm; annual emissions increased from 1.9 Gt C per year (1954) to 7.0 Gt C per year in 2003. If the emissions are maintained on that level (7.0 Gt C / year), we may reach over the next decades an equilibrium concentration of ~500 ppm.[4]

4 Sokolow, R.; Pacala, S.; Greenblatt, J.: "Wedges: early mitigation with familiar technology", 7th Int. Conference on Greenhouse Gas Control Technologies, Vancouver, 2004

The magnitude of the problem and the very scarce time to implement solutions (or, in fact, to develop them) have been somewhat "ignored" by a large portion of those responsible, partly based on vague considerations about the coal reserves and new, "cleaner" technologies for its use, and even the return of nuclear energy on large scale. Those who are already convinced of the need for environmental sustainability view renewable energies (sunlight, biomass, wind, water) and all possibilities of energy conservation (including a rationing of the end use) as the natural answer.

Challenges are posed to the implementation of any source as an alternative to oil. For non-renewable sources (natural gas, coal, shale oil), the cost, the need for carbon sequestering, other environmental impacts, and availability (natural gas) are the main challenges. Energy conservation is very important, but it would not be enough. Among renewable sources, hydraulic, biomass and wind are important, but not enough either. Wave, geothermal and solar energy (PV) still feature very high costs. Nuclear (fission) entails radioactive waste treatment and security problems.

The global energy consumption has a strong motivation to grow (rather than stabilize or especially decrease) because of the enormous regional unevenness of its use. Around one third of the world's population today (two billion people) have no commercially available energy to so much as cook food. In 1992, a single country that has 5% of the world's population (the United States) used 24% of all the energy on the planet; ten years later, in 2002, that same country had increased its energy use by 21%. The high growth rates seen in China and India, for example (and their environmental consequences), are indicative of the changes that are already taking place.

In this difficult, complex context, the aim of sustainable development goals concerning energy generation and use is for the activities and sectors of the economy to try to reduce the demand for natural resources (fossil sources), seeking diversification and renewable sources, while trying to diminish the environmental impacts from the use of every source. In general, any progress in this respect can be assessed by three sustainability indicators:

- energy intensity (used energy / GNP)
- the share of renewable energy in the total energy consumption
- the CO_2 emissions resulting from energy production/use (Mt C).

As a reference, the energy intensity the United States[5] dropped from 19.7 to 13.1 (MJ / US$GDP) from 1972 to 2000; the share of renewable energy increased from 6.2 to 6.9 percent in the same period; whereas the total CO_2 emissions from energy use increased from 1,224 Mt C to 1,562 Mt C. Considering a set of 23 industrialized countries (excluding the United States), in 1998 the energy intensity was around 30 percent lower than that of the United States, and the total CO_2 emissions (energy-related) were the same as in that country.

5 PRICE, L.; LEVINE, M.: "Production and consumption of energy", *in:* DERNBACH, J.C. (Ed.): *Stumbling towards sustainability*, Washington DC, Environmental Law Institute, 2002

1.2 Supply and use of electrical power and fuels in Brazil

Brazil's domestic supply of energy in 2004 amounted to 213.4 Mtoe: around 2% of the energy used worldwide for 3% of the world's population (Brazil: 181.6 million inhabitants). The dependence on foreign energy sources was only 15.9%. The end use of energy was 191.1 Mtoe. The final energy consumption per inhabitant (denoted in "toe", or "oil-equivalent t") evolved from 0.7 toe / inhab.·year in 1970 to 1.1 in 2004. The evolution to only 1.1 seems small, but the ratio (OIE)/GDP was greatly influenced by the rate of 0.64 between 1970 and 1980, when there was a major substitution of "traditional" biomass (firewood) with LPG.[6]

For comparison: the United States use 8.1 toe / inhabitant·year.

In 2002 Brazil used more than three times as much energy as in 1970, and the distribution among energy sources changed considerably. Very different from the world profile, such distribution is an important feature of Brazil's energy sector.

6 Ministério das Minas e Energia, BEN-2003 – Balanço Energético Nacional (National Energy Balance), Brasília, 2004

Table 1: Energy sources, Brazil and the World, 1970-2004

Energy source	Brazil, 1970 (%)	Brazil, 2004 (%)	World, 2002 (%)
Oil	37	39.1	34.9
Natural gas	-	8.9	21.1
Coal	3	6.7	23.5
Uranium	-	1.5	6.8
Hydropower	5	14.4	2.3
Biomass	55	29.4	11.5

The two energy sources at the bottom are renewable.

Electrical power (14.4% of the total energy supply) reached 424 TWh (8.8% being imported, and only 8.9% from self-producers), around 75% being produced by hydroelectric power plants. There was an installed power of 90.7 GW, 8% from self-producers.

Oils and derivatives (including LNG), accounting from 39.1% of the supply, corresponded to a production of 1.54 M barrels / day and a net dependence on imports of 10%, especially concerning diesel, LPG and naphtha.

Natural gas corresponded to 18.9% of the supply, with 32% to imports.

The supply of firewood (13.2% of the total supply) was used in the domestic and industrial sectors, as well as for charcoal production.

The sugar cane industry accounted for 13.5% of the total supply, producing 0.23 M barrels / day of ethanol and 6.97 TWh of electricity, 14% of which were sold (surplus production). Bagasse production (102 M t) was used in co-generation for eletricity and heat in the sugar mills

On the other hand, the final consumption of 191.1 Mtoe occurred mainly in the transportation (26.9%) and industrial sectors (37.8%), as well as in the residential sector (11.2%).

Between 1970 and 2004, our share of "renewable energy" dropped from 58.4 to 43.9%. Such reduction corresponded to the coming of LPG and fuel oil as substitutes for firewood, with much more efficiency (for home and industrial use), and also the substitution of charcoal with metallurgical coke in steel works. In the early 1970's, most of the firewood production was not renewed, partly predatory, with energy production as the main use. In the 1980's Brazil's energy production drifted away from the model that still widely predominates in developing countries: extensive use of "traditional" biomass coming essentially from deforestation firewood. A remarkable example is that the commercial availability of energy (LPG in this case) for cooking in Brazil reaches 98% of all homes today, whereas one third of the world's population have no access to it.

The current trend is again towards an increase in biomass energy, but on a sustainable basis; charcoal from planted forests is an example. During this period, there were major increases: in hydropower (5.1 to 14.4%) and sugar cane products (5.4 to 13.5%); the total renewable energy (43.9%) is substantially larger than in the rest of the world (14%). The relative share of natural gas, uranium and charcoal in Brazil is around one third of the world's share (%).

One of the consequences is that Brazil appears in a privileged position, with emissions of 1.62 t CO_2 eq. / toe, against a world average of 2.32. It is very possible that the sugar cane industry may substantially increase ethanol production because that product currently competes with gasoline, and the international demand has been growing. That will have effects on electrical power production as well (combined heat and power in sugar mills).

We can say that the supply of energy for Brazil's growth arouses no concerns as to a lack of options; the country has abundant renewable resources (biomass and hydropower); even on the fossil fuel front, oil and natural gas can meet the foreseeable requirements in the short term. There is room to increase the utilization efficiencies and reduce energy waste.[6]

6 see p. 53

On the other hand, there is, to some extent, a deficiency in a solid, sustained, integrated planning on the energy sector. The following are two critical cases where policies are deficient: in the electrical energy sector, for complementary thermal generation and, generally, for distributed generation; and in the field of transportation fuels (a sector that uses 27% of all the country's energy), where fast variations in the options (fleet "dieselization"; ethanol; NGV, flex-fuel vehicles, etc.) have been causing high losses.

Those two cases are pertinent to the analysis of the sugar cane producers' role in the substitution of fossil energy in Brazil (in the present situation and the prospects for the next few years).

1.3 Distributed generation (and combined heat and power) in Brazil: the need and opportunity in the next twenty years

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The electrical power policies have long given priority to meeting the population's requirements through central generation (CG) systems based on large generators of which the locations are usually far from consumer centers. The idea is that only through large-scale production is it possible to assure moderate costs, despite the inconveniences associated with complex transmission systems where 10-15 percent of the energy production are lost, thereby requiring additional 20-30 percent power at the location of use.

That concept consolidated worldwide over the past century, when electrical power systems were shaped around large monopolies, several of which integrating the generation, transmission and distribution on a vertical basis. After successive oil crises, the search of new alternatives and a real technological revolution increasingly enabled what is called distributed generation (DG): electrical power generation near or next to the load.

Development took place mostly in countries where the supply of distributed natural gas increased, thereby facilitating the use of combined heat and power: a thermoelectric power plant where the heat that would be lost in the CG is used in the processes (production, heating or cooling). Such more efficient solution is typical of DG because the thermal power cannot be transported for long distances; the rejected heat used in DG contains more than half the energy of the fuel used, and that saving compensates for the costs associated with small-scale production. But DG is not limited to this technology, or size or specific source limitations. It can use solar cell panels, energy available from production processes in the form of gases and wastes. Like in the sugar cane industry and in many other sectors.

In Brazil, DG still has a minimal share in the electrical power supply, in spite of its great potential. To name one item, the sugar cane biomass that was processed for the 2004/05 crop had an energy content of 46 million toe[7]; it is being used at low efficiency rates in the sugar and ethanol industry because of the difficulty in exporting electrical power to the power industry. In comparison, the hydropower used in the same year was around 30 million toe, and the country's oil production was 77 million t.

7 Estimation based on the National Energy Balance – BEN 2005, adjusted to include the straw currently burned in the field, ethanol final use was 6.8 M toe.

Even though DG has not been formally prevented, it has been made difficult because it breaks a hundred-year tradition and changes the economic basis of the traditional service. For example, the full use of sugar cane energy recommended at the end of the second stage of the *Proálcool* program was left aside for not adapting to the electrical power industry's traditional culture. The lack of a well-structured policy for natural gas has led to the prioritization of its use in centralized generation, which is an unsuccessful option that contrasts the situation in Portugal, for example. Here NG (natural gas) was preceded by efforts to develop combined heat and power together with consumers, which went as far as to create a secondary market and increase operational flexibility. The development of DG also requires that the inert position of new players be overcome and that the opportunities be noticed. Such process can be accelerated if some of the cultural resistance is removed, provided that there is political will.

By acknowledging DG and removing some of the barriers to distributors, and in spite of some lack of definition concerning operational aspects, the new model of the electrical power sector (Law no. 10,848/04) and its regulation create the conditions for the full realization of that potential. The expansion of DG in Brazil should rely on two complementary facts. On one hand, the traditional electrical power sector has failed to prove itself capable of meeting the growing demand; on the other hand, the country has at least two very important vocations for DG which are going through a maturing process. It is worth detailing these points.

The successive crises in the electrical power sector have been taking place since the late 1990's, and have not been more acute only because the country had an installed overcapacity and the increase in demand over those years was mediocre. The model that would organize the sector on new bases, incorporating a broad privatization process, gave rise to a situation in which investments in new CG units were not made, which led the government to make an intervention, back in 1999, through a thermoelectric power plant (PPT) construction incentive program, which has proved completely wrong. The lack of energy wound up causing the 2001 crisis, which was solved mostly by shrinkage of the market and decisive actions in the conservation context. That was followed by a period of immobility, and the actions for construction of new CG units extended for nearly three years.

The crisis showed how convenient DG was, but in stead of developing the country's potential together with customers having a potential for DG, the country opted for a centralizing and "transitory" solution with the Brazilian Emergency Energy Seller (CBEE). The only successful aspect of the reform was the construction of transmission lines that were considered natural monopolies. Inasmuch the costs of that service were "packed" with other costs, especially those of the generation having already been amortized, they were not felt in their true dimension. However, upon adoption of a more realistic cost policy, transmission prices raised strongly and point to an increase in margins, which is a factor that further values the strengthening of DG.

Today a scenario based exclusively on CG to meet the new demand with private investment is not so likely to occur. On the other hand, the attractive points of DG began to grow again following the announcement in 2003 that important natural gas reserves were found near Brazil's main urban and industrial centers. Considering the problems of its destination to CG in the past, Petrobras has declared its intent to distribute that gas.

Ethanol, whose use as a fuel had been decreasing until the end of last decade, when at some government levels people were already working under the assumption that its use in transportation would substantially decrease, has also gained ground. The current demand for ethanol is going through a boom in both the international market (it is the only "clean" gasoline oxygenizer and has been adopted in several countries as a substitute for MTBE) and the domestic market, where sales of ethanol-powered and bi-fuel vehicles are growing on the back of an attractive price.

The sugar cane industry has been expanding its installed DG capacity even with the crisis, after which the construction of CG units was paralyzed. The incorporation of this new business with no linkage with others can reduce risks, thereby leading to a virtuous cycle of cost reduction for all products. A similar synergy took place upon implementation of the *Proálcool* program, when the industry used the sugar production modernization and intensively benefited from the new stimulus, improving agricultural and industrial productivity while lowering its costs, which are now the lowest in the world. The existence of reliable energy and raw material (sucrose) brings prospects for new products, as in the case of corn processing. This form of DG has several other interesting aspects. These include the greater reliability and quality of the energy, and the broader utilization of labor per energy unit generated. For the mills, it brings an opportunity to recover and modernize energy systems, making them more efficient and producing surplus power.

The energy is competitive, as demonstrated by the existing operations with distributors, and even the recent tender of more than 300 MW for R$ 93 per MWh within the scope of PROINFA (Alternative Electric Power Source Incentive Program), when the projected costs for new hydroelectric and thermoelectric power plants are R$ 105 and R$ 120 per MWh, respectively.

Therefore, a scenario that increasingly emphasizes DG seems to be the most effective way to meet the new demand for electric power, while being attractive to the private enterprise. With the introduction of a large number of new players, the demand would be met more consistently with its growth and with fewer idle investments. DG is the most advisable way of meeting the requirements of some specific consumers, but it indirectly benefits all consumers who are interconnected with the electrical power system. Since only some specific sectors can perform DG competitively, most electrical power consumers will continue to depend on the interconnected system that takes the energy to them regardless of the source, whether CG or GD. Even when they are inactive, DG units increase the power reserves together with the loads, thereby reducing risks of blackouts and dismissing improvised solutions like CBEE. Accordingly, DG does not compete, but it complements and improves both existing and future CG systems.

There is a lot of room for DG development to take place in harmony with, and as a complement to, the existing CG system, as well as that which is yet to be built; little by little, authorities and regulating agencies will consider this a natural scenario, perfecting the rules and guidelines that implicitly presuppose DG, as has occurred in several countries.

Recently the National Energy Plan for 2030 acknowledges the importance of DG, especially the generation derived from the so called alternative sources, forecasting an increase of more than 15,000 MW by 2030. For the sugar cane industry a conservative projection is made for 4,000 MW (till 2030), with 1,100 million t sugar cane being processed annually. Accordingly, the BNDES (National Social and Economic Development Bank) is including in its financing projects specific incentives for the use (by the sugar cane industry) of more efficient technologies for energy production in the sugar mills.

It is difficult to provide a quantitative overview of the role to be played by DG in Brazil. Studies conducted by INEE – National Institute of Energy Efficiency show that it is perfectly possible to account for 10 to 20% of Brazil's requirements within the next ten to fifteen years. Although it seems a small share, since the DG base is currently inexpressive (lower than 5%), an increase could represent a dramatic share of the new potential in an activity that will be turning over a few billion reals a year within the next few years.

1.4 Energy production by the sugar cane industry: fossil fuel substitution

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Brazil's sugar cane production has an important characteristic, among others: the production system has been designed and developed (varieties, agricultural practices) to be independent of irrigation. High levels of photosynthetic conversion (mainly sucrose/hectare) were sought using selected varieties and recycling of all by-products (including crop residue water in ferti-irrigation) for the field. The basic oritentation has never been towards a maximum biomass production. Much higher biomass values could be achieved by using irrigation and/or choosing specific varieties, which, however, would reduce (considering current options) the sucrose/ha values or, ultimately, increase the sucrose cost (in R$ / ton). This option is not being considered (at the moment).

1.4.1 Current energy supply from the industry

For the year 2002, based on a sample of mills located mainly in the Center-South region, the production characteristics were as follows[8]:

- Sugar cane harvest: the estimation for Brazil is 65% manual harvesting, and 35% mechanical harvesting (34% in 2005); 80% of the sugar cane is burnt.
- Sugar and fiber content of the crop residue: the mean values for the period between 1998 and 2002 were 14.53 sucrose % of sugar cane (14.2 in 2005), and 13.46 fiber % of sugar cane (Center-South).[9]
- Agricultural productivity: the mean value for several areas within the Center-South region from 1998 until 2002 was 82.4 t of sugar cane / ha·year (82 in 2005; on the harvest area); the mean age of reform was 5.33 harvests (2001-2002).[9] Considering 5 harvesting periods, the productivity (total area) is 68.7 t of sugar cane / ha·year.
- Brazil's sugar cane production evolved from 80 Mt / year (1970) to 149 Mt / year (1980), 222 Mt / year (1990), 256 Mt / year (2000), and 425 Mt / year (2006). In 2005/06, around 50 percent of the sugar cane was used in ethanol production, and the other half in sugar production. These figures refer to the weight of crop residue ready for industrial processing, excluding the vegetable matter on sugar cane tips and leaves.

8 Seabra, J.E.; Leal. M.R.L.V.; Macedo, I.C.: The energy balance and GHG avoided emissions in the production / use of ethanol from sugar cane in Brazil: the situation today and the expected evolution in the next decade; XVI International Symposium on Alcohol Fuels, Rio de Janeiro, Nov 2006

9 CTC – Centro de Tecnologia Canavieira, Controles Mútuos Agrícolas Anuais – Safras 1998/1999 a 2002/2006

For each t of sugar cane (cane stalks), the biomass and its applications are now as follows:

0,14 t (DM) bagasse	90% for energy at the mill
0,14 t (DM) trash	burning in the field
0,145 t (DM) sucrose	sugar, ethanol, and other products

In the system operation, the mills use a certain amount of fossil fuels (agricultural, industrial and transporting operations, plus the energy embedded in the agricultural and industrial consumables, plus the energy used in equipment production, construction of buildings, etc.). With that (and solar energy), they produce sugar cane in the field (trash, bagasse and sucrose). A part of the bagasse is used to produce energy (combined heat and power for the sugar and ethanol production processes at the mill), and another part is used in outside industries. The trash is not yet used. Around half the sucrose produces ethanol (which substitutes for gasoline), and the remaining portion is used in sugar production. The electrical power produced by the mills today is enough to meet their own requirements, but standard technologies (vapor cycles, mean to high pressures) are starting to be used and produce large energy surpluses, which are then sold.

8 see p. 59

The overall energy balance in the system for ethanol production is summed up in **Table 2** below[8] (sugar production has the same energy "spending", but does not have ethanol as produced energy).

Table 2: Energy balance, sugar cane and ethanol production (MJ/t cane), 2005

Cane production / transportation	182.2
Processing to ethanol	43.1
Fossil Input (total)	**225.4**
Energy in produced ethanol	1,897.4
Energy in surplus bagasse	95.3
Surplus eletricity	19.8
Renewable Output (total)	**2,012.4**
Renewable Output / Fossil Input	
Ethanol + bagasse	**8.8**
Ethanol + bagasse + electricity	**8.9**

The value for surplus electricity is 2.1 kWh / t cane for 2005. Here the fuel needed for a combined cycle Natural Gas fired thermoelectic plant (40% LHV efficiency considered)

The ratio of 8.8 is extremely interesting, indicating the great capacity of the system to save fossil energy; in fact, no other production system gets close to that today (corn ethanol, in the United States, has been reaching 1.4 at best).

For the portion of sugar cane used to produce sugar, the balance is practically zero (which represents a major advantage over the sugar produced from beet or starch hydrolysis, the balance of which is negative).

In sugar cane processing the mills use energy:

- 12 kWh / t sugar cane (electricity)
- 16 kWh / t sugar cane (mechanical energy, drives)
- 330 kWh / t sugar cane (thermal energy for the processes)

The energy contained in the trash and bagasse is much higher than these values.

In addition, since the need for thermal power is much larger than that for electrical and mechanical power, the system can be supplied with power by vapor combined heat and power plants even with very low thermal-mechanical conversion efficiencies; that was the option used in the 1970's, when the abundance of hydro-electric power led to a legislation that virtually prevented the mills' surplus energy to be sold to the system (see 1.3). This situation is changing rapidly, and the technological evolution of the sugar and ethanol mills' electrical power generation systems has been a continued process over the past 20 years. Boilers with higher performance and capacity, and turbo-generators with rated power in excess of 20 MW and efficiencies in excess of 75% are on the market[10]; the systems are for pure combined heat and power, linked with the mill operation.

10 Leal, M.R.L.V; Macedo, I.C.: *Evolução tecnológica dos sistemas de geração de energia nas usinas de açúcar e álcool*, Viçosa, Renabio, 2004

For 372 Mt of sugar cane (2004), comparing the final consumption of the different sugar cane produced energies with the energies they partially substituted for in Brazil, we have the following:

Bagasse:	20.2 Mtoe	Fuel oil:	6.5 Mtoe
Ethanol:	6.9 Mtoe	Gasoline:	13.6 Mtoe
Elect./mechanical energy:	11.3 Twh	El. power.	359 TWh
straw:	currently not used; with a 25% recovery, it is equivalent to 5.1 Mtoe		

Clearly, sugar cane has a very important role to play in the substitution of fossil fuels in Brazil. In 2002, Brazil's net importation of oil and derivatives was 0.274 M barrels / day (and its domestic production was 1.5 M barrels / day). Ethanol substituted for 0.187 M barrels / day of gasoline (equivalent) in 2004. From 1976 until 2004, ethanol substituted for 1440 M barrels of gasoline (around 11.0% of the proven and condensable oil reserves in Brazil). The final consumption of bagasse as a fuel for industrial use was equal to the sum of all final uses of natural gas and fuel oil in the country in 2004, and the electrical and mechanical energy generated (for internal use) corresponded to 3 percent of the electrical energy generated in the country.

1.4.2 Potential increase in supply with the current sugar cane production

The industry's goals generally include an increase in the bagasse use efficiency, and the development of trash recovery and use, as well as new sucrose products (high volume).

Two main alternatives are considered in order to increase the industry's energy production. The most immediate of which (under way) is to increase electrical power generation. The second one, which is dependent on ongoing technological developments, would be the production of ethanol from residues (excess bagasse and recovered trash).

The expected increase in combined heat and power efficiency, the reduction of internal energy consumption, and the recovery of trash for energy purposes have been extensively analyzed and are beginning to be implemented. Trash recovery is related to programs for reducing and controlling trash burning in the field, which are motivated by the need to control local air pollution (see **item 3.3**); the amount of sugar cane that is not burned already represents 24% of the production in São Paulo, and should increase over the next few years.

Estimations of increases in surplus electrical power have been prepared for various technology levels, whether standard or developing ones. The operation with standard high-pressure steam cycles with 40-percent recovered trash, if implemented in 80% of the systems, could lead to around 30 TWh of excess energy (9% of the current electrical power consumption in Brazil) at the present sugar cane production level.

The most promising technology to enable a considerable increase in the mills' generation of excess electrical power for the future (besides the implementation of trash recovery) is biomass gasification integrated with gas turbine combined cycles (BIG/GT). The processes are not yet commercial.

Alternatively, one of the processes that is much sought after is the hydrolysis of lignocellulosic materials (excess bagasse and trash) for ethanol production. These processes arouse great interest because the abundance of raw materials available in practically all regions of the world could turn ethanol into a commodity with a large number of producers. Of the countless developing processes,[11] the highlights are those which seek cellulose and hemicellulose conversion

11 U.S. Department of Energy: www.bioproducts-bioenergy.gov/pdfs/HistoryofOBPandCellulosicEthanol.pdf

using enzyme technology and simultaneous saccharification and fermentation. However, intermediate processes are more likely to be commercially available first. One of them is in development in Brazil for full integration with the sugar mill.[12]

The two main challenges facing these developments today are: for the enzymatic processes, a major reduction of enzyme costs is needed (cellulase) [13]; and for all, biomass costs near US$ 1.0 / GJ are needed so as to make the processes viable against gasoline costs (2002). Brazil's sugar cane industry currently has bagasse and can recover trash in the aforementioned amounts at costs ranging between US$ 0.6 and US$ 1.0 / GJ (amounts updated until 2004, with US$ 1 = R$ 2.7),[14] thereby becoming very attractive as a user of new processes also because of the synergy with current production processes.

Various specific studies and more general reviews of the hydrolysis work conducted over the past twenty years,[15, 16] and the expected results to be attained over the next few years[17] have indicated that considering the wide variety of processes, raw materials and assumptions, it is reasonable to work with around 300 l of ethanol/t of dry matter for the next few years, and that amount could increase (maybe by 15%) within ten years. On that basis, if a given mill should adopt a hydrolysis process to produce ethanol in stead of more surplus electricity, it could use 30% of the excess bagasse (improving the processes) and 50% of the straw to produce around 34 additional liters of ethanol per sugar cane t (all sugar cane: for ethanol or sugar).

1.4.3 Increase in energy supply associated with increased production

Two major increases in Brazil's sugar cane production took place between 1976 and 1983 (from 100 to 200 Mt of sugar cane / crop), and between 1993 and 1998 (from ~215 to 315 Mt of sugar cane / crop), the former having been motivated by the implementation of fuel ethanol, and the latter by sugar exports. The industry is going through a growth cycle again, this time because of the likely increase in demand for both ethanol and sugar.

It is noticeable that for every 100 Mt of additional sugar cane (considering 42% of such addition as the portion to be used in sugar production, as suggested by demand projections), if commercially available technologies were to be used to increase electricity production, we could have the following:

Additional electricity:	12.6 TWh (steam cycle, 40% trash)
Additional ethanol:	4.9 Mm^3

Therefore, for every 100 Mt of sugar cane (42% for sugar), the industry could additionally supply 3.8% of the electrical power currently consumed, while increasing the current ethanol supply by 37%.

12 Olivério, J.L.: "Fabricação nacional de equipamentos para a produção de álcool de cogeração", Seminário BNDES: Álcool – Potencial Gerador de Divisas e Empregos, Rio, 2003

13 U.S. DoE: NREL; www.ott.doe.gov/biofuels.enzyme_sugar_platform.html , 2003

14 Macedo. I.C.: "O uso otimizado da cana-de-açúcar para Geração Distribuída", VI Seminário Internacional de Geração Distribuída, INEE – WADE, Rio, Oct 2003

15 Saddler, J.N. *et al.*: "Techno-economical evaluation of a generic wood to ethanol process: effect of increased cellulose yields and enzyme recycle", Bioresource Technology 63, 1998, pp. 7-12

16 Fulton, L.; Howes, T.: "Biomass for transport fuels: an international perspective", IEA/EET, 2004

17 Wooley, R. *et al.*: "Lignocellulosic biomass to ethanol process design and economy utilizing co-current dilute acid pre-hydrolysis and enzymatic hydrolysis: Current and futuristic scenarios", NREL / DoE, Jul 1999

Alternatively to electricity production, and depending on the time when the hydrolysis technologies will be commercially available, it would be possible to have an additional supply of 3.4 Mm^3 of ethanol, totaling 8.3 Mm^3.

1.5 Summary and conclusions

• Context: the world supply of energy is based on fossil fuels (75%); the utilization scale quickly leads to depletion of resources, thereby leaving a heavy additional load to the future generations. Additionally, the use of fossil fuels is responsible for a large load of local pollution and most of the greenhouse gas emissions. The use of energy should grow as a result of the advance of many of the world's developing regions. The current challenge is to seek renewable energy sources and to increase efficiencies in energy generation and use on an unprecedented scale.

• Brazil has an intermediate consumption level (1.1 toe / inhab·year), with a deep focus on renewable energy sources (43.8%, compared to 13.8% in the world). Brazil can significantly increase the use of biomass and other sources, and improve generation and use efficiencies. In this respect, among other initiatives, Brazil should implement the distributed generation of electrical power (based on combined heat and power), which could reach 10-20 percent of the total within 10-15 years, and set up a policy for the transportation fuel industry.

• The sugar cane industry already provides a major contribution (responsive sustainability) to the substitution of fossil fuels, going much further than energy self-sufficiency (electrical and thermal power).

√ It generates 11.3 TWh of electrical and mechanical energy (3% of the electrical energy generated in the country)

√ It uses bagasse as a fuel: 20.2 Mtoe (equivalent to the sum of all of the NG and fuel oil used in the country)

√ It produced nearly 50% of all the gasoline used in the country in 2004

• The sugar cane industry's improved energy performance (use of trash, DG implementation) can lead to an additional 30 TWh of electrical power. Alternatively, the implementation of processes for bagasse and trash conversion to ethanol in the future can increase ethanol production by 40% for the same sugar cane production level.

• If the expected sugar cane production increases for the next years materialize, for every additional 100 Mton of sugar cane, the industry would supply 3.8% of the current electrical power consumption, and 4.9 Mm^3 more of ethanol (assuming that 58% of the sugar cane are used in ethanol production). The alternative ethanol production from bagasse and trash, when technically possible, would lead to an additional 3.4 Mm^3 of ethanol.

Chapter 2:
Impacts on the use of materials

Agriculture takes sunlight as its basic input and may lead to sustainable production of materials. The low production costs in the cane culture in Brazil and the availability of bagasse as an energy source make sucrose very attractive to dozens of other products; some amino acids, organic acids, sorbitol and yeast extracts are already being produced. Developments in plastics and other large scale products (including ethanol derivatives) are being considered.

2.1 Introduction

Sustainability in the use of materials and resources should be evaluated as to the level of those resources (what the resource utilization rate is relatively to the stocks) and the level of waste released to the environment. Both levels have grown significantly in some regions, and in an "unsustainable" way in many cases. In 1992, each person in the United States was responsible for the extraction and use of 50 kg of materials a day; that amount increased by 10 percent up to 2002.[1] On the other hand, the environmental impacts of the consumption of resources have grown around 15 percent in that period. The figures differ in other regions of the world, but it is clear that the governmental policies have not been appropriate to reverse the trends. It has been proposed that taxes should gradually move from labor and income to materials and energy (as in Norway and Sweden), and that any subsidies which contribute aggravating environmental problems should be eliminated. The actions (and implications) are very different from one country to another, and even regionally within the same country, which hinders a fast implementation; but the necessary direction is clear.

1 DERNBACH, J.C. (Ed.): *Stumbling toward sustainability*; Washington DC, Environmental Law Institute, 2002

Agriculture has a very interesting characteristic in terms of sustainability: a major input is sunlight energy (renewable). If the use of water and consumables (pesticides, fertilizers, fuels) can be limited, then agriculture is a source of "renewable" materials. This has been attained by some but not all production systems. In adequate systems, the use of materials (fertilizers, pesticides, fuels) may be relatively small when the energy production (which already occurs) or the potential production of a wide range of materials (such as sugar cane) is taken into consideration.

Over the past fifteen years, environmental concerns have led to the use of biological products as substitutes for petrochemicals to be considered "environmentally sound and desirable". Several mechanisms have been used to foster new energy technologies. Practically all of them originally sought feasibility through direct subsidies. That occurred with PURPA – Public Utilities Regulatory Policy Act for decentralized generation of electrical power from biomass in the United States, the sugar cane ethanol in Brazil, the corn ethanol in the United States as well, biodiesel programs in the US and Europe, etc. Generally, the main concern was energy production indeed (due to the need of oil substitution), but the possibilities to produce renewable materials began to be explored.

Under an exceptionally successful program, it was possible to remove the initial subsidies to sugar cane ethanol, in Brazil, on the back of the industry's technological and managerial evolution. That program brought along a very interesting non-energy component in the field of products of biological origin, replacing petrochemicals: alcohol chemistry, in the 1980's in Brazil.

A fast-growing bio-products program is based on corn starch glucose in the US. Supported by interesting technological breakthroughs, several products have been introduced in different markets over the past ten years. Genetic engineering technologies should bring more results over the next few years.[2]

Sugar cane sucrose is a natural candidate to become a main raw material in many processes. This is beginning to happen in Brazil.

2 NREL, USA, "Fostering the bioeconomic revolution in biobased products and biotechnology", Biomass Research and Development Board, Interagency Strategic Planning; January 2001

2.2 Sugar cane fiber and sucrose

Between 1998 and 2002, the mean sugar and fiber contents of sugar cane residue (Center-South) were 14.53 sucrose % of sugar cane and 13.46 fiber % of sugar cane. Around 80 percent of the sugar cane were burned (Brazil) before the harvest, thereby eliminating the trash. The total production amounted to 380 Mt of sugar cane (2004), which refers to the sugar cane stalk mass (without the trash).

For each ton of sugar cane stalk (sugar cane ton), the biomass generated is (see **item 1.4.1**) 0.28 t (DM) of bagasse and trash, and 0.145 t (DM) of sucrose. Therefore, the amount of materials produced is very big even when compared to the petrochemical context, for example; about 55 Mt of sucrose, and 100 Mt (MS) of lignocellulosic residue.

Works conducted in Brazil seeking to develop trash collection/transportation technology, including an assessment of its actual availability, have concluded that 50 percent of the trash can be recovered at costs of US$ 0.6-1.0 / GJ, depending on the process.[3] The legislation that gradually restricts the pre-harvest burning should play a positive role in causing the residue to be incorporated into the energy generation system over the next few years. On the other hand, commercially available technologies may (probably) lead to consumption decreases in mill processes, resulting in excess bagasse of up to 45%.

This surplus amount of bagasse and straw are important in the energy context. Their use in energy production (with competition between electrical power and ethanol production by hydrolysis) can be expected to be implemented on large scale over the next few years. The costs of those residues are lower in Brazil (today and in the foreseeable future) than overall energy biomass costs in many other countries.

3 Reports of the project "Biomass power generation: sugar cane bagasse and trash", UNDP-GEF / Copersucar, Centro de Tecnologia Canavieira, 2003

The possibilities offered by new sucrose products are much greater than those currently implemented.

2.3 Sucrose as a raw material for other products

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Sucrose is a very versatile raw material, being a very reactive molecule from the chemical and enzymatic standpoints. With its eight hydroxyl groups, it may act as a base for several "blocks" to build molecules of interest. Additionally, it is produced in more than 80 countries around the world abundantly (nearly 200 million tons a year) and at a high purity degree. Its production cost is relatively low, especially in Brazil (see **Chapter 11**). There are additional advantages: sucrose products may have lower environmental impacts than petrochemicals (as in the biodegradability of some plastics, and the renewability of the energy used in the processes, particularly in the use of sugar cane sucrose).

In the early 1990's around 60 products obtained from direct sugar fermentation could already be listed, some with several natural producing microorganisms. In many cases, secondary products were developed from those primary products by fermentation or enzyme catalysis. Of all those products, a much smaller number are now commercially important, but several have been added to the list over the past ten years,[4] and research in this field is intensive.

Such growing diversification of sucrose applications to produce intermediate and end products (besides ethanol and sugar) is mainly motivated by

4 GODSHALL, M.A.: "Future directions for the sugar industry", SPRI, Int. Sugar Journal, vol. 103, no. 1233, 2001

the low sugar production costs that Brazil has attained. We can consider the production cost of raw crystal sugar from Brazil's Center-South region in 2002 at US$ 0.13 / kg (with sucrose in the juice corresponding to US$ 0.08 / kg, and in the HTM to US$ 0.11 / kg; US$ 1 = R$ 2.7, 2002). In comparison, the corn glucose costs would be US$ 0.13 / kg, beet sucrose or wheat hydrolysate (Germany) at ~0.19 and 0.17 in the juice.[5] There have been cost increases due to higher land costs (with the large expansion since 2005), and labor costs; and for export considerations, the strong appreciation of the Real against the US$ is also important. The production of sugar cane sucrose derivatives can also be totally supplied with energy independently (through the bagasse), as is ethanol today.

5 Based on Henniges, O.; Zeddies, J.: "Fuel ethanol production in the USA and Germany – a cost comparison", F. O. Licht's World Ethanol and Biofuels Report, vol. 1, no. 11. Feb 11 2003

Prospecting works with respect to commercially available products or products at a relatively advanced development stage are under way in several product categories. Sucrose has some exclusive applications, and can substitute for glucose in almost all fermentation cases of interest. The main categories are: sweeteners, polyols, solvents, biodegradable plastics, amino acids and vitamins, polysaccharides, organic acids, enzymes, yeasts, and esters. Some may include products that would use large amounts of sugar (plastics, solvents, some organic acids), while others would correspond high value-added products for smaller amounts.

The "average" mill in Brazil could add (as an annexed production plant) up to ~ 40,000 tons per year of a new product using ⅓ of the sugar cane it processes; some products that are already commercially available reach the scale of 1 Mt / year worldwide. There would be waste water treatment synergies in the annexed plants, and energy independence is possible in all of them. By using the bagasse and standard (commercially available) generation systems already in use, around 2.4 kWh / kg of sucrose (thermal energy) and 0.6 kWh / kg of sucrose (electricity) can be made available for processing.

In Brazil there is today commercial production of citric acid, amino acids like lysine and MSG, yeast extracts and derivatives, and sorbitol. Some plastics (commercial polylactic, abroad; poly-hydroxybutyrate, pre-commercial stage, in Brazil) are being considered for local production here. In addition, some of the ethanol derived products from the 1980's (especially ethylene and derivatives) are being considered again. The world's current (growing) markets in amino acids, some organic acids and polyols already use a few million tons of sugars on a yearly basis; the plastic markets may increase that demand considerably.

2.4 Ethanol derived products

The wide range of ethanol products (chemically processed) that were marketed in the 1980's and then left behind because of the relative costs of ethanol and naphtha have certainly to be reconsidered now. Routes based on ethylene, acetaldehyde and, in several cases, direct transformations have been developed and implemented in Brazil. They are all widely known processes without any major complexities; the country masters dozens of technologies. In the 1980's, the relative prices for naphtha and ethanol and the national oil based chemical industry development policy made alcohol chemistry unfeasible.

In the ethylene route, important products include polyethylene, polyvinyl and ethyl chlorides, ethylene glycol, and acetaldehyde.

In the acetaldehyde route, important products include acetic and chloroacetic acid; ethyl, vinyl, polyvinyl and cellulose acetates, acetic anhydride, and butadiene.

Direct transformations lead to butadiene, acetone, n-Butanol, ethyl ether, and vinyl ethyl acetate, acrylate, chloride and ether.

Alcohol chemistry actually started in Brazil in 1917 [6] from the production of ethyl chloride (Elekeiroz). By the 1960's, several companies (Rhodia, CBE, Eletrocloro, Butil Amil) had introduced intermediates and products like ethylene, polyethylene, acetates, ethyl chloride, and acetic aldehyde. The coming of Coperbo, Oxiteno, Salgema, Cloretil, Stauffer and Cia. Alcoolquímica Nacional marked a period of great development as early as the 1970's and 80's.

The use of ethanol for other products reached 0.494 Mm^3 in 1985. In 1987,[6] the production levels for some key items, using 3.6 percent of Brazil's ethanol production, were as follows:

Dichloroethane	0.300 Mt
Acetic acid	0.125 Mt
Acetic aldehyde	0.100 Mt
Vinyl acetate	0.074 Mt
Ethyl acetate	0.041 Mt

In 1993 there were around 30 ethanol derivatives in production in Brazil. Of these, 14 had installed capacities in excess of 100,000 tons per year. There was an installed capacity in excess of 400,000 tons per year for dichloroethylene (1 M ton / year), LD polyethylene (660,000 tons /

6 BOTO, DANTAS R.: "A alcoolquímica no Brasil", Simpósio Internacional de Avaliação Socioeconômica da Diversificação do Setor Canavieiro, PLANALSUCAR/IAA e PNUD, Águas de S. Pedro, SP, 1988

year), ethyl-benzene (500,000 tons / year), vinyl chloride and HD polyethylene.

In the current assessments, the ability to work on much smaller scales than those of oil based factories, the decentralized production and the ability to get synergies with the mills' traditional production continue to be important.

2.5 Summary and conclusions

• The *per capita* consumption of materials and resources worldwide has kept growing over the past ten years, and so have the resulting environmental impacts. As in the case of energy, governmental policies have not been enough to reverse the trends that are aggravated by the advances of large developing areas in the world.
• Agriculture (having solar energy as an input) is a field that can lead to sustainable production of materials in some cases. This perception promotes biological products as "environmentally sound"; alcohol chemistry (Brazil, 1980's and 1990's) has brought several examples, as have recent advances in sugar chemistry.
• Brazil's sugar cane production corresponded (2004) to 55 Mt of sucrose and 100 Mt (DM) of lignocellulosic residue. Sucrose is currently used in sugar and ethanol production, but other important products are being considered. Fifty percent of the residues are used with low efficiencies in energy generation, and more than 25 percent (trash) are recoverable at costs compatible with energy uses.
• The production costs in Brazil and the availability of bagasse energy make sucrose very attractive to dozens of other products. In Brazil, there is a commercial production of amino acids, organic acids, sorbitol, and yeast extracts, as well as developments concerning products for large amounts (plastics). Over the next few years, it will be possible to use 1.5 Mt of sucrose in these processes.
• In the 1980's and 1990's, more than 30 products were derived from ethanol in Brazil, several with installed capacities in excess of 100,000 tons / year (via ethylene, acetaldehyde or direct transformations). They became unfeasible in the 1990's because of the national policy for oil chemistry and the relative costs of ethanol. The oil-ethanol cost ratio now leads those processes to be reconsidered.
• The large-scale production of renewable materials from sugar cane in Brazil is a possibility, but is still at an early implementation stage; it is

growing somewhat rapidly in the use of sucrose, and may grow in alcohol chemistry again, while having a great unrealized potential in terms of residues. It would certainly contribute considerably to the sugar cane agribusiness' "responsive sustainability" position.

II

Impacts on the environment

The impacts on the environment considered in general agricultural production should be viewed in respect of the sugar cane culture, as should those pertaining to industrial production and end use. They include local air pollution by sugar cane burning and the use of ethanol as a fuel, greenhouse gas emissions throughout the life cycle, and the impacts of the use of new areas, including the biodiversity, as well as the impacts on soil conservation, erosion, the use of water resources, the quality of water, and the use of pesticides and fertilizers.

In assessing the environmental effects of the growth of sugar cane production, it is important to consider that such assessment is always relative, and always refers to alternative uses of land. The impacts (erosion, production base production, biodiversity, use of chemicals, etc.) are much different if sugar cane should substitute (as it has occurred in most cases) for extensive pastures or orange crops, or if it should directly occupy savannah areas of even forests. These considerations are usually made at the time of substitution of soil uses in order to check whether there is any potential degradation or the new use will foster environmental recovery.

The sugar cane production in Brazil today has interesting aspects, environmentally speaking. It uses small amounts of pesticides, it relies on the largest biological pest control implemented in the country, it features the lowest soil erosion rate in Brazilian agriculture, it recycles all of its waste, it does not compromise the quality of water resources, and it actively participates in innovations by having, for example, the country's largest organic production area (as a separate culture).[1]

1 Rossetto, R.: "A cultura da cana, da degradação à conservação", Visão Agrícola, ESALQ-USP, Ano 1, jan 2004

The legal restrictions on soil use aimed at protecting the environment are the subject of extensive legislation in Brazil. An overview of the scope of such legislation is provided below.

Aspects of the environmental legislation for the sugar cane industry

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The considerations about environmental pollution have evolved over the past few decades from case-specific analyses of the most apparent environmental degradation (water and air pollution, deforestation) into a more comprehensive view, including socioeconomic and cultural affairs, and biodiversity, for example. In Brazil, this change appears in the environmental legislation with CONAMA (National Environment Council) resolution no. 01/1986, which requires the conduct of Environmental Impact Studies (EIA) and preparation of the corresponding Environmental Impact Reports (RIMA) before any license can be obtained for activities that may significantly alter the environment. This legislation applies to all undertaking projects in the sugar and ethanol industry,[2, 3] and their main aspects are discussed below.

2 ELIA NETO, A.; NAKAHODO, T.: "Aspectos da análise ambiental no setor industrial sucroalcooleiro - Relatório parcial" - Relatório Técnico n.º 1077-00/01, CTC – Centro de Tecnologia Canavieira, Piracicaba, SP, 2001

3 SALLES, L. da S.: *Elementos para o planejamento ambiental do complexo agroindustrial sucroalcooleiro no Estado de São Paulo: Conceitos, aspectos e métodos* – Dissertação de Mestrado Escola de Engenharia de São Carlos-USP, São Carlos, SP, p. 113, 1993

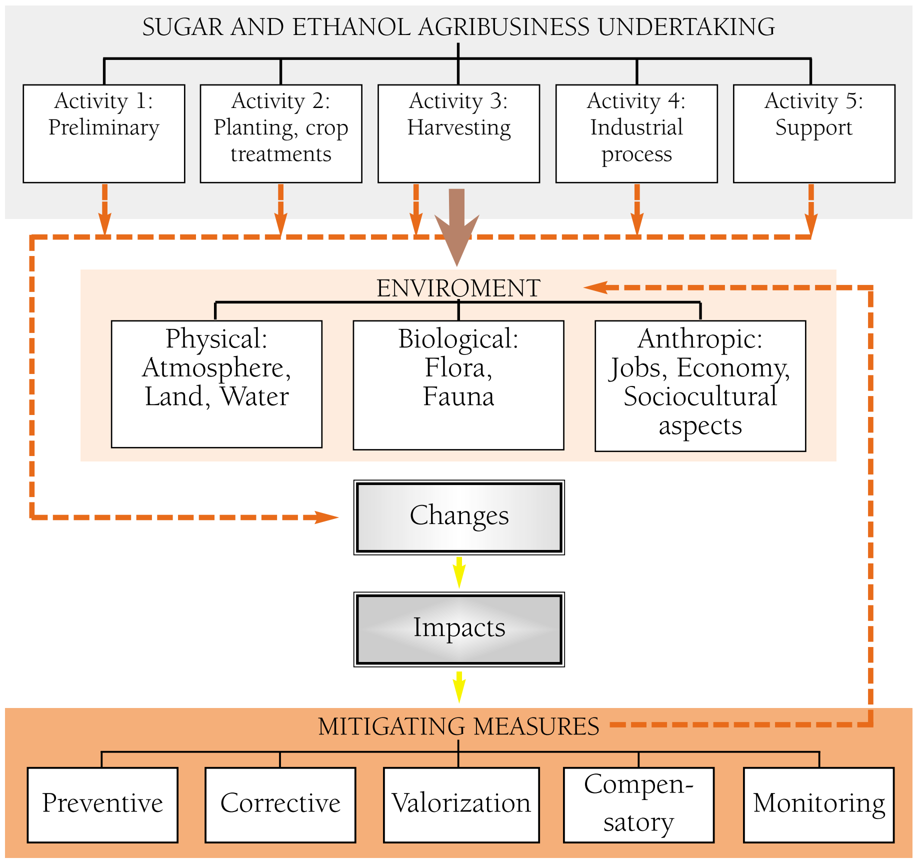
Environmental Impact Study (EIA)

CONAMA resolution no. 01/86, of January 23, 1986 (article 10), defines "impact" as "*any change in the physical, chemical and biological properties of the environment (...) resulting from human activities which may directly or indirectly affect: the population's health, security and well-being; social and economic activities; the biota; the sanitary and aesthetic conditions of the environment; and the quality of environmental resources.*" Article 20 lists the activities that depend on EIA/RIMA to get a permit; these include highways, bridges, industrial and agribusiness units (including ethanol distilleries), and several other activities the dimension and/or location or the environment-altering potential of which "*shall have their impacts identified, and interpreted as to their magnitude or relevance, reversibility degree, cumulative and synergic properties, and distribution of social costs and benefits.*"

Figure 1 shows a diagram of the structure for analyzing the environmental impacts when conducting/preparing EIA/RIMA for the sugar and ethanol industry. The impacts result from the crossing of each of the agribusiness activities considered with possibly affected environments: the physical environment (atmosphere, land and water), the biotic environment (flora and fauna), and the anthropic environment (jobs, economy and sociocultural aspects). Many of the mitigating measures taken in the sugar and ethanol industry have been in use for many years, and are usually incorporated into the agribusiness process.

CONAMA Resolution no. 237, of 1997, provided new criteria for granting environmental permits, including sugar production and refining as an activ-

Figure 1: Environmental analysis structure for EIA/RIMA: sugar cane agribusiness



ity subject to Previous Permit (LP, in Portuguese) and also EIA/RIMA (as it previously occurred in the case of ethanol distillation). Effective periods were provided for the permits: Previous Permit (LP), up to 5 years; Installation Permit (LI, in Portuguese), up to 6 years; and Operating Permit (LO, in Portuguese), effective for 4 to 10 years. In São Paulo State, the LOs must be renewed every 2 to 5 years; every 2 or 3 years for ethanol distilleries or sugar mills, respectively (executive law no. 47397, of 2002).

Preliminary Environmental Report (RAP, in Portuguese)

Still in São Paulo, the SMA (Office of the Secretary of the Environment) Resolution no. 42/94 introduced the Preliminary Environmental Report (RAP) as an initial study to demonstrate the environmental feasibility of undertakings. There is a resolution from the SMA/DAIA (Environmental Impact Analysis of the Office of the Secretary of the Environment) that considers the RAP enough for obtaining the Previous Permit for new mills with capacity of up to 1.5 million tons of sugar cane / year.

Sensitive Areas

There are more sensitive areas from the environmental viewpoint which have received special treatment in respect to the establishment of agribusiness activities: they are the Environmental Protection Areas (APA, in Portuguese),[4] and the Aquifer Recharge Areas[5] (such as the Guarani Aquifer).

The APAs are extensive areas with regionally important ecosystems and whose land arrangement is oriented towards a sustainable use of natural resources, as set forth in a specific law. In practice, environmental preservation and recovery are sought to be placed in harmony with human needs. The environmental permit for undertakings in APAs follows usual procedures that have been set up by the São Paulo State SMA, but the legislation in such areas either is or will be more restrictive using specific agreements to prevent or forbid activities which could lead to environmental degradation.

The Guarani aquifer, covering a total area of approximately 1.2 million km^2 – 839,800 km^2 in the Center-West and South regions of Brazil –, stores around 46,000 km^3 of water. The sustainable extraction considers the demand from 360 million people, with a *per capita* consumption of 300 l / inhab·day. The conserved volume could supply water to Brazil's population for 3,500 years. One of the large recharge areas of that aquifer is located in the north of São Paulo, including an important sugar cane producing center; this leads to further restrictions on these areas and the fertigation rates used.

Trends

The sugar and ethanol industry in Brazil is known today for the environmental benefits of using ethanol in substitution of a fossil fuel, of producing sugar using a renewable fuel exclusively, and of starting to use the potential excess electrical power production.[6, 7] On the other hand, its relationship with the environment, which improves the position of ethanol as a "clean product with clean production," can go further than meeting legal requirements, seeking a continued environmental improvement of the production process. This will be an imposition, especially because of Brazil's position as the most internationally competitive producer.

The normal trend in the environmental legislation is to become increasingly restrictive; important areas where the producers' evolution is already sensitive include control over effluents and rationing of water use, such issues being addressed in specific items below. Brazil's legislation has a strong dynamics, and the Operating Permits must be renewed periodically (every two to three years, in the case of mills or distilleries).

4 SMA – Secretaria de Estado do Meio Ambiente, Áreas de Proteção Ambiental do Estado de São Paulo, site http://www.ambiente.sp.gov.br/apas/apa.htm , (22/02/2005)

5 SMA – Secretaria De Estado do Meio Ambiente, Gestão Ambiental do Aqüífero Guarani, site www.ambiente.sp.gov.br/aquifero/principal_aquifero.htm , acessado em 22/02/2005, GT-Guarani, São Paulo, SP, 2005

6 Elia Neto, A.: "Análise dos impactos ambientais da colheita de cana crua e do aproveitamento energético da palha", Relatório n.º RLT-073, MCT/PNUD Contrato de Serviço n.º 137/97, CTC – Centro de Teconologia Canavieira, Piracicaba, 1999

7 Ometto, J.G.S: *O álcool combustível e o desenvolvimento sustentado*, São Paulo, PIC Editorial, 1998

Chapter 3:
Impacts on air quality: cities and rural area

Ethanol utilization (straight, or blended with gasoline) has led to important improvements in air quality in urban areas, through the elimination of lead compounds in gasoline and sulphur, and the reduction of CO emissions and the reactivity and toxicity of organic compound emissions. Controlling the undesirable effects of cane burning practices (risks to forests, traffic in roads, transmission lines and dirtiness) is being efficiently implanted with the current legislation in São Paulo.

3.1 Introduction

The impacts on air quality from ethanol use in urban centers and sugarcane burning prior to the harvesting in rural areas are highlighted in this chapter.

Air pollution is a major challenge facing sustainable development worldwide. It causes damage to human health and ecosystems in several ways. Carbon monoxide (CO), particulate matter (PM), sulfur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), tropospheric ozone (formed from atmosphere reactions involving mainly VOC and NOx) and lead have all been causing serious problems in many urban centers around the world. Particulate matter (in association with NOx and SOx) have been related with dozens of thousands of premature deaths in the United States[1] and elsewhere; CO is associated with several cardio-respiratory and neurological problems and is a greenhouse gas (GHG); tropospheric ozone, also a GHG, attacks materials, harms agriculture in addition of being an irritant of the respiratory system; NOx and SOx also affect health and contribute the formation of acid rain, which has various undesirable effects such as reduction of agriculture productivity. Last but not least problematic, lead is highly toxic and accumulates in living organisms. Agenda 21 sets the goal of eliminating "unacceptable or unreasonable" risks of air pollution "to the extent economically possible." Agenda 21 also provides for air pollution control actions across the geographic borders. Acid rain, tropospheric ozone, fine PM and GHG certainly deserve undivided attention in this context.

1 Driesen, D. M.; "Air pollution", *in* Dernbach, J.C. (Ed.): *Stumbling toward sustainability*; Washington DC, Environmental Law Institute, 2002

Despite of important advances observed in many countries over the last decades to mitigate air pollution, the challenge for air quality improvement, particularly in developing countries, is enormous. Transport, energy production and industrial processes are the leading sectors that contribute to air pollution worldwide and the vast majority of air pollutants result from the intensive use of fossil fuels. The efforts to prevent and control air pollution have been intensified, with market-derived strategies being associated to increasingly stricter regulations on fuels and utilization systems. Even though such extremely serious cases as the use of lead-based additives in gasoline have been almost entirely eliminated, it is apparent that there is still a lot to do. With this perspective the use of renewable fuels such as ethanol and bagasse, in substitution of fossil fuels, is a step towards an energy matrix in line with sustainable development goals.

3.2 Impacts of the use of ethanol on vehicle emissions in urban areas

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ADS Tecnologia e Desenvolvimento Sustentável

Brazil has been the largest laboratory in the world with regard to the use of ethanol as an automotive fuel. Since 1977, in compliance with the National Alcohol Program requirements, blending of ethanol into gasoline gained nationwide scale and strategic importance. Presently the renewable fuel makes up 20% to 25% of the blend (named gasoline C). Exception made to aviation gasoline, all gasoline sold in the country contains ethanol. Furthermore, since 1979 ethanol has been widely used as a straight fuel (E100); as a result over 5 million dedicated ethanol vehicles have been produced. Flex-fuel vehicles (able to run on gasoline C or E100 or any blend of both) were introduced in the Brazilian market in 2003 and have gained consumers preference very quickly. In December 2006 the market share of new flex-fuel vehicles reached 78.1% with sales totaling 2.7 million units since 2003.[2]

2 ANFAVEA, 2007

Although the National Alcohol Program was not specifically designed to reduce motor vehicle emissions, blending of ethanol to gasoline and use of E100 in dedicated alcohol vehicles resulted in significant emission reductions, contributing therefore to important environmental benefits. The decrease in emissions can be seen in Table 1, which shows the progress of the main pollutants until 1994. Emission levels are compared for straight gasoline, certification grade gasoline C (78% gasoline and 22% anhydrous ethanol) and E100 hydrous ethanol.

Irrespective of the technological upgrades implemented by the automotive industry until 1988 period and the adoption of emission control technologies since 1989, dedicated ethanol vehicles generally showed greater reductions of CO, HC and NOx emissions than those fueled with gasoline C.

Table 1: Mean exhaust gas emission by new vehicles (g/km)[3]

Year-model	Fuel	CO	HC	NOx	R-CHO
Pre-1980	straight gasoline	54.0	4.7	1.2	0.05
1980-1983	gas. C	33.0	3.0	1.4	0.05
	A	18.0	1.6	1.0	0.16
1984-1985	gas. C	28.0	2.4	1.6	0.05
	A	16.9	1.6	1.2	0.18
1986-1987	gas. C	22.0	2.0	1.9	0.04
	A	16.0	1.6	1.8	0.11
1988	gas. C	18.5	1.7	1.8	0.04
	A	13.3	1.6	1.4	0.11
1989	gas. C	15.2	1.6	1.6	0.04
	A	12.8	1.4	1.1	0.11
1990	gas. C	13.3	1.3	1.4	0.04
	A	10.8	1.3	1.2	0.11
1991	gas. C	11.5	1.1	1.3	0.04
	A	8.4	0.6	1.0	0.11
1992	gas. C	6.2	0.6	0.6	0.013
	A	3.6	0.6	0.5	0.035
1993	gas. C	6.3	0.6	0.8	0.022
	A	4.2	0.7	0.6	0.04
1994	gas. C	6.0	0.6	0.7	0.036
	A	4.6	0.7	0.7	0.042

gas. C (C grade gasoline) = 78% gasoline and 22% anhydrous ethanol, in volume
A = 100% hydrous ethanol
R-CHO = aldehydes
Source: CETESB, **Note 3**

3 CETESB, Relatório de Qualidade do Ar no Estado de São Paulo, 2005

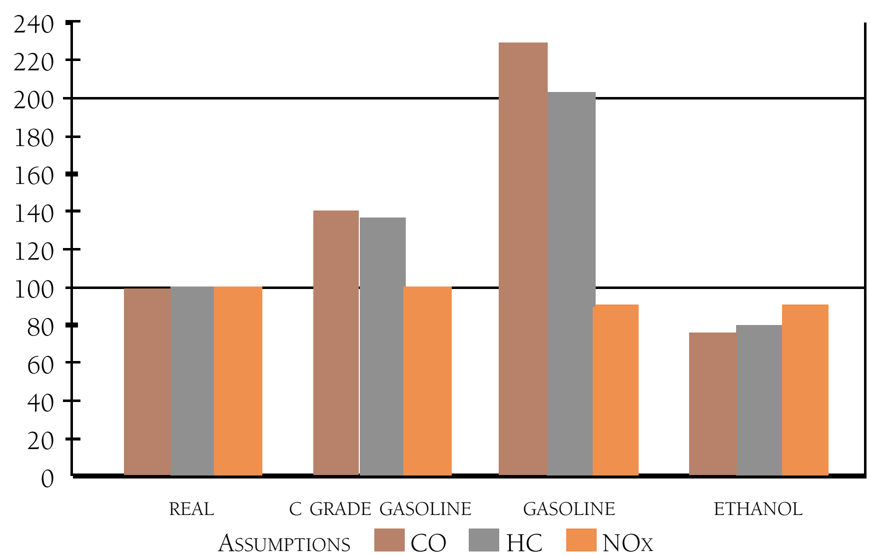
In order to evaluate the environmental importance of ethanol during this period, a study conducted in 1989 for the São Paulo Metropolitan Region (SPMR) compared the emission of pollutants by vehicles fueled with E100, gasoline C, and straight gasoline.[4] The existing light-duty vehicle fleet mix –

4 Confederação Nacional da Indústria, Veículos Automotores: "O Proálcool e a Qualidade do Ar", Rio de Janeiro, 1990

76% of vehicles fueled with gasoline C and 24% with E100 – was adopted for reference. The study shows that if the fleet were to be fueled exclusively with straight gasoline there would be an increase of 130% in CO emissions, 100% in HC emission and a decrease of 10% in NOx compared to the reference scenario. If the fleet were to be fueled only with gasoline C, there would be an increase in CO and HC emissions of 40% and 37% %, respectively, and no change in NOx. Finally, if the exclusive fuel were to be E100 then emissions would decrease 23% for CO, 20% for HC and 10% for NOx.

Accordingly, the study shows the environmental importance of ethanol use, either straight or blended with gasoline, points out that the decision to use the renewable fuel was wise. It can be inferred from the study that the air pollution levels in the SPMR that were quite high at that time, particularly for CO, would have been more critical if no ethanol had been used. Because the beneficial effects of ethanol are not limited to the SPMR, the study highlights the environmental relevance of ethanol to other urban areas in the country.

Figure 1: Emission scenarios for the RMSP



Source: **Note 4**, p. 81

The enforcement of stricter vehicle emission limits in the mid nineties resulted in substantial emission reduction, particularly for gasoline C vehicles. At that time, due to a number of reasons but mainly because of the relative low prices of oil the motor industry reduced its interest (and consequently investments) in the technological development of dedicated ethanol vehicles therefore restraining the evolution of its environmental performance. As a result levels of controlled exhaust emissions became equivalent on a quantitative basis, with some advantage for gasoline C vehicles. However the fundamental conditions that made E100 to be known as "clean" fuel are still in place. When E100 is used in flex-fuel vehicles average CO emission is still lower, VOC have lower toxicity and photochemical reactivity and emission of both PM and SOx is practically nil; not to mention the enormous advantage with regard to carbon dioxide (CO_2) emission, the main GHG.

Aldehyde (R-CHO) emissions need to be analyzed separately because this matter always comes up when environmental impacts of ethanol are discussed.

Although it is true that combustion of ethanol generates aldehydes this is also true to other automotive fuels like gasoline, diesel oil and natural gas, although less recognized. A first fact that needs to be acknowledged in this discussion is that fossil fuels generate a variety of aldehyde species with high toxicity and photochemical reactivity, such as formaldehyde and acrolein, while ethanol combustion generates primarily acetaldehyde, which has lower toxicity and smaller environmental impact. Another relevant fact is that emission of aldehydes from both gasoline C and E100 have been considerably reduced over the years due to advances in emission control technology (**Table 1**). For ethanol vehicles, the average observed with 1992 model-year cars (0.035 g/km) is lower than the level reported for the end of the 1970's for straight gasoline vehicles (0.05 g/km); 2003 model-year ethanol and gasoline C vehicles showed, respectively, a mean emission of 0.020 g/km and 0.004 g/km. With flex-fuels the average emission for 2005 model-year vehicles was further reduced reaching 0.014 g/km with E100 and 0.003 with gasoline C3. These values are substantially lower that the present emission limit for aldehydes (sum of acetaldehyde and formaldehyde must be lower than 0.03 g/km).

For comparison, it is worth mentioning a survey conducted by the CETESB (the São Paulo State environmental protection agency) in 2003 with diesel-powered light commercial vehicles[5] that likewise elsewhere are not subject to aldehyde emission control. The survey showed that depending on

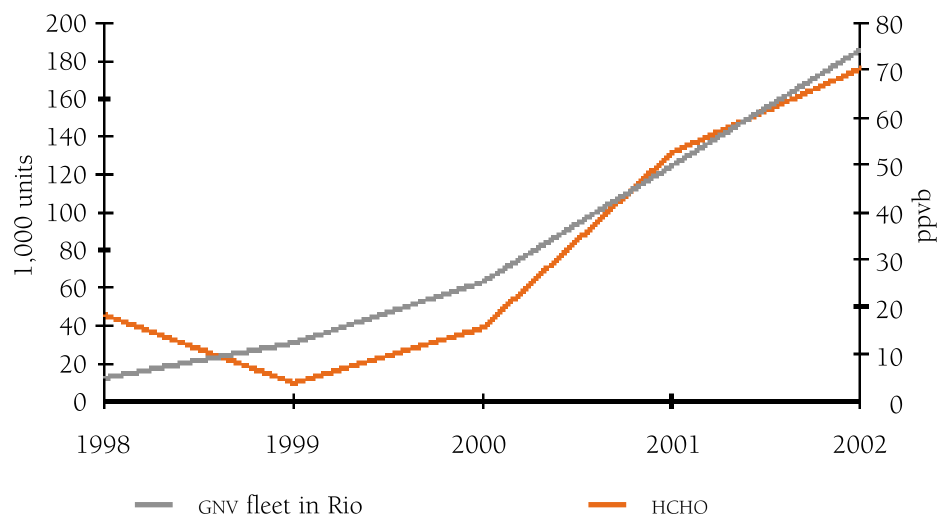
5 Abrantes, R., "A emissão de aldeídos e hidrocarbonetos policíclicos aromáticos de veículos comerciais a diesel", SIMEA, São Paulo, 2003

the vehicle, aldehyde emissions ranged from 0.022 g/km to 0,160 g/km, thereby demystifying the belief that ethanol resulted in higher levels of emissions of that kind. It is also important to note a study conducted by the Rio de Janeiro State University that shows in Figure 2 a very close relationship between the growth of the fleet of vehicles converted to natural gas and the increase of the ambient concentration of formaldehyde.[6]

6 Corrêa, S. M., UERJ, Rio de Janeiro, 2003

Moreover various studies carried out by CETESB in the São Paulo Metropolitan Region have shown that the large scale of ethanol use has not resulted in ambient aldehyde concentrations that might bring significant risks to the population.

Figure 2: Evolution of formaldehyde emissions and growth of the NGV fleet in the city of Rio de Janeiro



Because of its high octane rating, ethanol has brought the additional benefit of significantly reducing the use of lead-based additives in gasoline, thereby enabling the ban on these products from the domestic market on 1990. That way, the concentrations of toxic lead compounds in the atmosphere were reduced by around 75 percent in the RMSP.[7] The use of high levels of ethanol in gasoline has also made it unnecessary to produce gasoline with high contents of aromatic hydrocarbons such as benzene, toluene and xylene

7 CETESB, *Relatório de qualidade do Ar no Estado de São Paulo*, 1989

to substitute lead-based additives. Because these substances are known to be toxic and have high photochemical reactivity its content is being reduced in gasoline used in the most developed countries.

A point of paramount importance to this discussion is the impact of vehicle emissions on public health. Numerous research studies have demonstrated that there is a connection between air pollution, respiratory and cardiovascular diseases and premature deaths. An example is the relationship between asthma and air pollution in the vicinity of busy roadways. The literature on this subject is abundant and identifies SOx, PM and tropospheric ozone, pollutants strongly associated with fossil fuels combustion, as the main trigger of asthma attacks.[8] Data gathered by the Canadian organization Victoria Transport Policy Institute, shows that the average environmental cost due to the use of gasoline and diesel oil in automobiles is within US$ 0.6 – 5 cents/km.[9] A study conducted in Europe by the World Health Organization[10] shows that the social costs (diseases and premature deaths) related to fine PM pollution can be up to 190 billion Euro/year. The study emphasizes the contribution of diesel vehicles to the problem, which respond for about one third of the fine PM in the region.

8. Environmental Defense, www.environmentaldefense.org/documents/2655_MotorAirPollutionAsthma.pdf

9 Victoria Transport Policy Institute, Transportation Costs and Benefit Analysis – Air Pollution Costs, Canadá, 2006

10 World Health Organization, www.euro.who.int/mediacentre/PR/2005/20050414_1

Taking into consideration the earlier comments as well as the confirmation by the University of São Paulo's Experimental Air Pollution Laboratory that vapor and gases resulting from ethanol combustion are less toxic than those resulting from gasoline combustion, which was reported in several published works, it can be said that ethanol is a clean fuel and as such should be increasingly used.

3.3 Emissions by sugar cane burning; control

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Sugar Cane Technology Center

The burning of sugar cane straw is a usual practice in almost all of the 97 countries where sugar cane is produced. That burning aims to improve the workers' safety and the harvesting yield by eliminating the straw and dry leaves.

3.3.1 Human health

In the 1980's and 1990's, several works were conducted in Brazil and other countries in order the clarify whether the emissions from sugar cane burning were harmful to health. Papers prepared by the Ribeirão Preto Medical School associate sugar cane burning with the increase in respiratory diseases, but fail to analyze other regions where there is no sugar cane burning at the same season (winter) to use it as a reference.

The local effect was considered in the paper for a research[11] jointly conducted by EMBRAPA (Brazilian Crops and Livestock Company), USP (University of São Paulo), UNICAMP (University of Campinas) and Ecoforça in order to assess the occurrence of chronic respiratory diseases in some regions of São Paulo State (Atibaia, Ribeirão Preto, São José dos Campos and Campinas). Taking Atibaia as a reference, it concludes that the risk increases by around 40 percent in São José dos Campos, gets close to 80 percent in Campinas, and is unchanged in Ribeirão Preto. The conclusion, therefore, is that Ribeirão Preto, Brazil's leading sugar and ethanol production park, has the same disease occurrence risk as a Atibaia, a municipality considered a climatic zone where there is no sugar cane production.

In Hawaii, during the 1988-89 period, NIOSH – US National Institute for Occupational Safety and Health conducted an investigation into the chronic effects of exposure to sugar cane burning soot (which contains biogenic silica fibers – BSF) on the health of workers in the sugar cane agribusiness. The occurrence of respiratory diseases and mesothelioma (lung cancer) were not associated with BSF exposure.[12]

Although several papers show no direct relationship between burning and damage to health, it should undoubtedly be noted that any kind of burning has some sort of effect on the environment, especially when performed incompletely, which is the case of sugar cane burning. In addition, sugar cane burning brings the discomfort caused by the emission of particulate matter (known as "*carvãozinho*") and some risk to areas having electrical networks and highways.

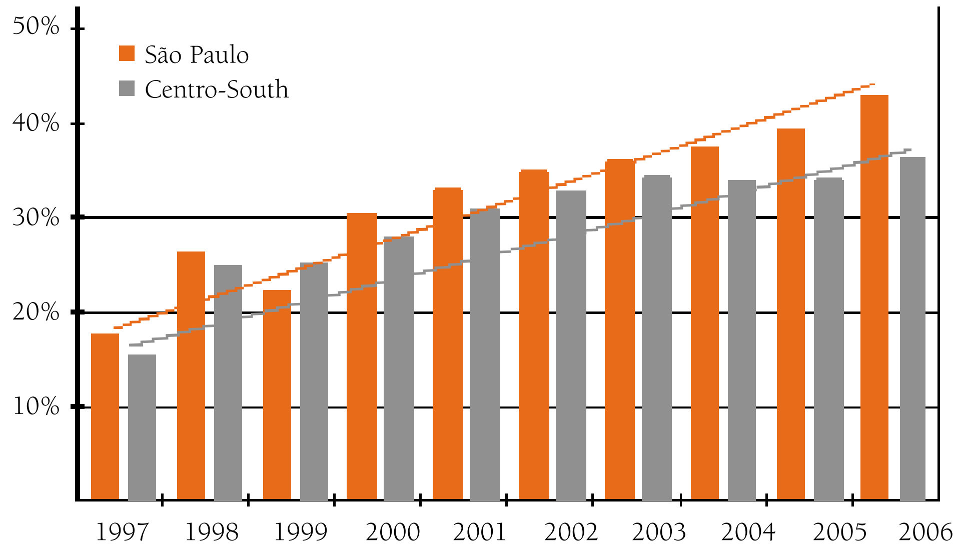
11 MIRANDA, E.E.; DORADO, A.J.; ASSUNÇÃO, J.V: *Doenças respiratórias crônicas em quatro municípios paulistas*, USP/UNICAMP/Ecoforça, 1994

12 SINKS, T.H.; HARTLE, R.W.; BOENIGER, M.F.; MANNINO, D.M.: "Health hazard evaluation: Report", Hawaiian Commercial & Sugar Company/Hamakua Sugar Plantation (Health Hazard Evaluation HETA Report 88-119-2345), ago 1993, p. 44

3.3.2 Technologies and evolution

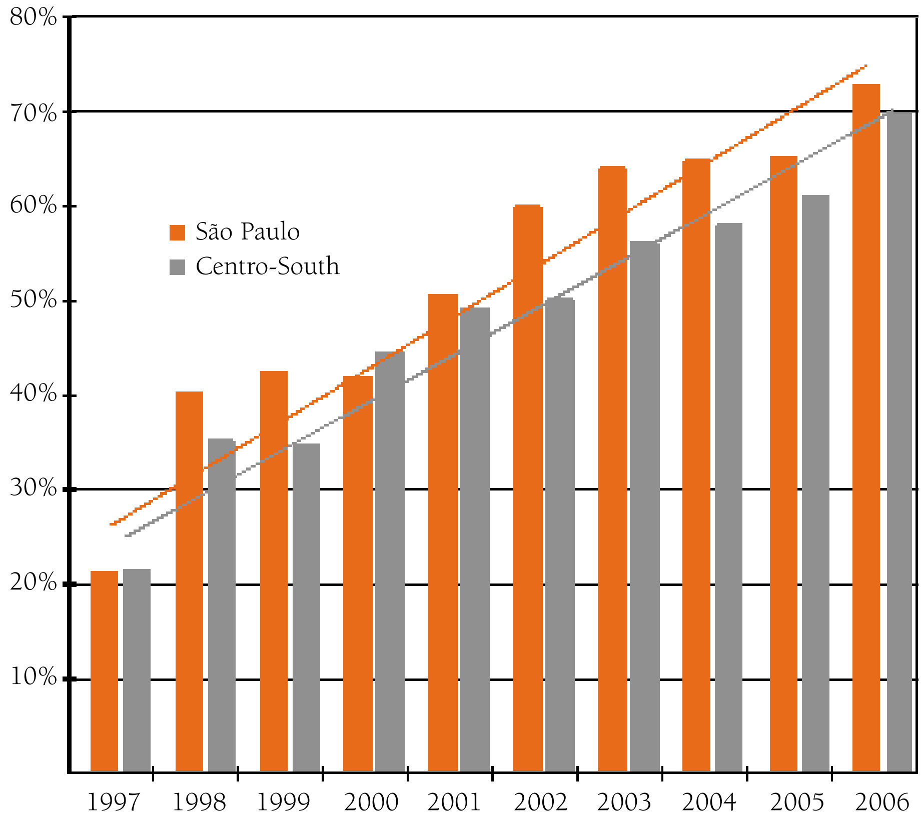
The introduction of mechanical harvesting of sugar cane in Brazil actually took place in the 1980's and has been growing over the years. The increase in the mechanical harvesting area is due to the need for mills to meet their schedules at times when the workforce became extremely scarce (*Cruzado* Plan, etc.), to cost reductions, and to the environmental pressure for harvesting sugar cane without burning it. **Figure 3** shows the evolution of mechanical harvesting in the leading producing state (São Paulo) and the Center-South region of Brazil, which accounts for more than 80 percent of the country's sugar cane production. Approximately 10 percent of the crop areas in the Northeast region have mechanical harvesting.

Figure 3: Evolution of mechanical harvesting in Brazil's Center-South region



Sources: 1997-2002: IDEA (Note **13**); 2003-2004: CTC (Note **14**)

Figure 4: Raw sugar cane share in mechanical harvesting



Sources: 1997-2002: IDEA (Note **13**); 2003-2004: CTC (Note **14**)

13 IDEA, "Indicadores de Desempenho da Agroindústria Canavieira – Safra 2002/03"

14 CTC: "Programa de acompanhamento mensal de performance agrícola", Technical report, Piracicaba, 2004

The technological evolution of production equipment and processes, the environmental pressures and the legislation in force have motivated the increase in mechanical harvesting of sugar cane without burning. **Figure 4** shows the share of raw sugar cane in the mechanical sugar cane harvest. Today, in the country's main producing regions, approximately 70 percent of the mechanically harvested sugar cane don't use fire to remove the straws.

3.3.3 Legislation on sugar cane burning

The gradual prohibition of sugar cane burning in Brazil was originally provided for in an executive law passed by the São Paulo State government on April 16, 1997. Today, the legislation on the matter consists of Law no. 11,241, of September 19, 2002 (São Paulo State), and decree no. 2,661 passed by the Federal Government in July 08, 1998. Both of them provide for a burning elimination schedule and specify prohibition areas as protection ranges near urban perimeters, highways, railways, airports, forest reserves and preservation units, among other areas. **Table 2** shows the sugar cane burning reduction schedule set forth by the federal and state legislation.

Table 2: Burning reduction schedule

State Decree (São Paulo) 2002			Federal Law 1998		
Year	Area where mechanical harvesting is possible[1]	Area where mechanical harvesting is not possible[2]	Year	Area where mechanical harvesting is possible[1]	Area where mechanical harvesting is not possible[2]
2002	20%	-			
2006 (5th year)	30%	-	2003 (5th year)	25%	-
2011 (10th year)	50%	10%	2008 (10th year)	50%	-
2016 (15th year)	80%	20%	2013 (15th year)	75%	-
2021 (20th year)	100%	30%	2018 (20th year)	100%	-
2026 (25th year)		50%			
2031 (30th year)		100%			

1 Area where mechanical harvesting is possible: tilt <12%
2 Area where mechanical harvesting is not possible: tilt >12%

In order to comply with the legislation, the introduction of mechanical harvesting shall extend to 100 percent of the crop areas where the soil tilt is compatible with such practice within the next 13 years (2018).

For crop areas where the soils are on sharper tilt, the federal decree does not prohibit burning, while the state decree provides that the burning should terminate within 30 years, i.e. in 2031. Since those areas do not allow mechanical harvesting and the cost of manual harvesting of sugar cane without burning would reduce their competitiveness, the producing areas can be reasonably expected to migrate to regions featuring better topographic characteristics. Attempts to increase production in areas where mechanical harvesting is possible by incorporating new technologies into the production process are also likely to occur.

3.3.4 Burning reduction and impacts on employment levels

Brazil's sugar cane agribusiness plays an important role in job creation, an the number of people it directly employs is estimated at around one million (see **Chapter 12**), approximately 80 percent in the agricultural area. Sugar cane is one of the leading job-creating cultures per crop area unit. In São Paulo State, it employs around 35 percent of the agricultural workforce, totaling 250,000 workers.[15] The demand for labor in sugar cane production should be reduced by the increased introduction of mechanical harvesting and planting (reduction), and that reduction will be only partly compensated for by the likely introduction in the field of the straw collection process for energy generation, as discussed in **Chapter 12**.

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3.4 Summary and conclusions

- The deterioration of air quality in urban centers is one of the world's most serious environmental problems. For the most part, it is caused by the use fossil fuels, which also contribute to cross-border pollution, such as acid rain, for example. Mitigating efforts include an increasingly restrictive legislation on fuels and utilization systems.
- The sugar cane agribusiness has two very distinct points of connection with the impacts on air quality: the use of ethanol has been leading to considerable air quality improvements in urban centers; and the sugar cane burning in the field, on a very different scale, cause problems by dispersing particulate matter and because of the risks associated with the smoke.

• The main effects of ethanol use (whether straight or as an additive to gasoline) on urban centers were as follows: elimination of lead compounds from gasoline; reduction of CO emissions; elimination of S and particulate matter; and less toxic and photochemically reactive emissions of organic compounds.
• The burning of sugar cane straw (used in most producing countries to make harvesting easier) was the subject of many papers in the 1980's and 1990's (in Brazil and other countries) that were unable to conclude that the emissions are harmful to human health. Such undesirable effects as the risks (electrical systems, railways, forest reserves) and dust (particulate matter) remained. In São Paulo State, legislation was passed which gradually prohibits the burning, with a schedule that considers the technologies available and the expected unemployment, including immediate prohibition in risk areas. That solution is in force, and is an important example given the size of the São Paulo production.

Chapter 4: Impacts on global climate: greenhouse gas emissions

Brazil, as most other countries in the world, is considering its vulnerability to the effects of increased GHG concentration in the atmosphere. Ethanol utilization in Brazil today leads to avoiding 13% of the GHG emissions of the whole energy sector. For every additional 100 Mt of sugar cane, emissions of 12.6 Mt CO_2 equivalent / year could be avoided withethanol, sugar cane bagasse and the added excess electricity.

4.1 Introduction; concepts and the world context

In the 1990's, fossil fuel emissions were responsible for 82 percent of the heating power of greenhouse gas emissions in the United States. Developed countries have contributed 84 percent of total GHG (greenhouse gas) emission worldwide since 1800.[1] Irrespective of the level set as the limit (under discussion) on annual emissions, developed countries shall reduce their current emissions to accommodate the growth of developing ones; the differences in total emissions (and also in *per capita* emissions) are huge. In 1996, the *per capita* carbon emissions in the United States amounted to 5.37 tons; in most of Asia and Latin America, 0.5 to 1.0 ton; and in Japan and Western Europe, 2 to 3 tons.

1 Brown, D.A.: "Climate change", *in*: Dernbach, J. C. (Ed.): *Stumbling toward sustainability*, Washington DC, Environmental Law Institute, 2002

Of all partial solutions being considered, including those involving energy preservation, carbon uptake, and utilization of the set of "renewable" energies, the use of biomass in substitution of fossil fuels appears to be a great opportunity. The efforts to develop and implement technologies in this area are vast. The use of sugar cane ethanol, associated with the bagasse, has become the first experience to bring positive results on a large scale.

The following topics describe the current knowledge of the climate changes arising from the concentration of greenhouse gases in the atmosphere, the impact of the agricultural production system and its vulnerability to changes, the greenhouse gas emissions in Brazil, as well as the emissions avoided by the sugar cane agribusiness in Brazil.

The conditions for sugar cane and ethanol production in Brazil have led to extremely positive results in terms of decreasing emissions, and have put ethanol in the spotlight as a fuel for the world.

4.2 Global climate changes: current knowledge

Luiz Gylvan Meira Filho
IEA-USP (Institute of Advanced Studies, University of São Paulo)

The climate change addressed by the United Nations Framework Convention on Climate Change and its Kyoto Protocol focuses on global change caused by the man-induced gradual increase in the amount or concentration of carbon dioxide and other gases.

The concentration of carbon dioxide in the atmosphere 200 years ago has increased from 280 ppmv (parts per million in volume) to 370 ppmv, and continues to grow.

Even though the amount is very small compared to those of nitrogen and oxygen, which jointly correspond to around 99 percent of our atmosphere, carbon dioxide and other gases known as greenhouse gases are responsible for preventing the surface from naturally cooling down due to infrared radiation. Those who live in cold areas know that cloudless winter nights are very cold exactly because of such radiation cooling. By preventing natural cooling, the greenhouse effect causes an increase in the surface temperature, in addition to other climate changes in general.

The greenhouse effect is a natural phenomenon. Without it, the mean temperature on the surface of the planet would be more than 30 degrees Celsius lower than it is today. What happens is that as the concentration of carbon dioxide in the atmosphere increases, the greenhouse of our planet becomes more efficient. Since the pre-industrial period, the mean global surface temperature has increased by around 0.6 ºC. According to the forecasts of the United Nations Intergovernmental Panel on Climate Change (www.ipcc.ch), the temperature will have increased by around 3 degrees Celsius by the year 2010, if we fail to take action in order to mitigate the increase of greenhouse gas concentration in the atmosphere.

In addition to carbon dioxide, methane and nitrous oxide resulting from human activities, as well as other greenhouse gases having a lesser effect, are increasing in the atmosphere and contributing to the climate change.

In the face of this problem, there are only three possible options:

i. inactivity, which means accepting the climate change and the damage that will be caused as it reaches its peak many years after the emission of gases to the atmosphere (around 20 years of delay, for methane, 40 years, for carbon dioxide, and 50 years, for nitrous oxide).

ii. mitigation of the climate change by reducing greenhouse gas emissions or, in the case of carbon dioxide, removing it from the atmosphere through the process called "carbon uptake". The removal of carbon dioxide from the atmosphere can be temporary, through its fixation to the biosphere by planting trees, for example. It can also be a longer-term action, in the case of what is known as geological sequestration, through carbon dioxide injection into oil wells, etc.

iii. adapting to the climate change through measures designed to mitigate the damage resulting from that change. In a very schematic way, raising the level of ocean restraining dams to diminish the damage resulting from a rise in sea levels, and more generally, actions designed to build-up resistance to climate changes that will tend to increase in extent and frequency as the climate changes, are adaptation measures. In many cases, however, adaptation is simply not possible. The best examples of this are the melting of the Arctic ice cap and, in Brazil, the "savannization" trend on the edges of the Amazon Forest as result of changes in the wet weather flow as part of the climate change.

In 1990, the United Nations General Assembly passed a resolution requiring global action for protecting the climate from changes. They decided to negotiate a convention in order to address this theme. The task was performed in two years, and in 1992, the United Nations Framework Convention on Climate Change was opened in Rio de Janeiro. The Convention was subscribed to and ratified by essentially all of the countries.

According to the Convention, countries must undertake a stabilization of the concentration of greenhouse gases in the atmosphere at such levels as capable of allowing the dangerous human interference with the climate system (atmosphere, oceans and biosphere) to be prevented. No exclusive answer exists to the question as to what greenhouse gas concentration level in the atmosphere should be considered dangerous and should not be exceeded. This is due to the fact that the harmful effects of the climate change are distinct in different regions and in different fields of human activity.

It is also plausible to admit that, initially, a small increase in temperature may even have beneficial effects by improving climatic conditions for agriculture in regions where the weather is very cold. For the most part, however, there is a growing consensus that we should not let the mean global temperature increase by any more than around 2 degrees Celsius by the year 2050. Such is the opinion of European countries, in particular. This theme was the subject of a scientific debate at a recent international science conference held in Great Britain.[2]

2 www.stabilisation.com

As a first step towards fulfilling the goal of the Convention, 1997 saw the adoption of the Convention's Kyoto Protocol. It took effect in February 2005 with the remarkable absence of the United States and Australia, who indicated that they intended to pursue the said goal by other means. The Kyoto Protocol has the noteworthy characteristic of providing for mechanisms to compensate for the reduction of emissions among projects and countries. The reason for this, is to reduce the global cost of decreasing emissions. With this in mind, the compensation mechanisms release market forces that tend to make the decreases take place only in those sectors where the costs are lower.

In the Brazilian case, experience has shown that there are favorable conditions, especially concerning the use of biomass as an energy source. In particular, the substitution of gasoline with ethanol in the transportation sector, and steel works coke with charcoal in the production of pig iron (and steel directly, in some cases).

It is interesting to note that the irreversible world trend towards limiting greenhouse gas emissions, especially those of carbon dioxide, have the immediate effect of valuing the use of renewable fuels. As a result, the consideration of such a factor shall value either those fuels or, in the case of charcoal steel works, the product itself. This, whether due to market requirements or the use of the Clean Development Mechanism to provide an economic margin that is essential to making the activities viable in some cases.

As the Kyoto Protocol takes effect, international attentions turn to the definition of the international system on climate change that shall be adopted following 2012. The participation of the sectors concerned is essential to ensuring that Brazil's competitive edge will be taken into account in future.

4.3 Vulnerability, impacts, and adaptation to the climate change; the present knowledge

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CPTEC/INPE (National Institute of Space Research)

4.3.1. Introduction

In 2004, the CGEE – Center for Management and Strategic Studies conducted a study (Prospective Activity in Climate Change)[3] in order to assess the vulnerability conditions, and the impacts of climate changes arising from increased GHG concentrations in the atmosphere on Brazil and the country's adaptation thereto. The study also focused on the international negotiations concerning the mitigation of such changes. The study had a broad coverage, considering the vulnerability of and impacts on forests, livestock, soils and biodiversity, regional aspects like coastal and subarid areas, social vulnerability aspects, and water resources. As it happens in a large portion of developing countries, there still is little information on these issues. This summary brings some of the results that are interesting to Brazil's agricultural activities.

3 "Atividade prospectiva em mudança do clima", Brasília, CGEE – Centro de Gestão e Estudos Estratégicos, Agosto 2004

The discussions about climate change, vulnerability, impacts and adaptation have particular connotations. Here, *vulnerability* refers to a certain system's level of reaction to a specific climate change. *Impacts* (climatic) refer to the consequences of the climate change to natural and human systems. *Adaptation* describes adjustments in ecological or socioeconomic systems in response to current or projected climate changes resulting from structural practices, processes, measures or changes.

The assessments conducted by the IPCC indicate that developing countries are among the most vulnerable to climate changes. In Brazil, for example, adverse impacts of natural climate changes are droughts, overflows and floods, and hillside landslips.

Adaptation and/or mitigation strategies depend on the existence of credible climate change scenarios on a regional time scale of decades. Present knowledge does not yet allow such scenarios to be established with great confidence. Notwithstanding that all projections point to a temperature increase, it is essential for a tropical country like Brazil to advance in order to get reliable scenarios of likely changes in the water cycle, as many of the impacts are primarily associated with water. Even though some centers in Brazil are building up capacity to set up regional scenarios by downscaling scenarios from global models, the uncertainty inherent in global climate models remains. The main difficulty in analyzing potential sectoral impacts is precisely that which results from the uncertainty about the future behavior of the rainfall intensity and distribution. These impacts still require a wide range of possible scenarios to be considered.

The mean overall temperature on the surface of the planet has increased by 0.6 °C over the past 100 years, and that increase has been sharper since the 1960-70's. The three hottest years in the past 1,000 years of the recent geological history have all occurred in the past decade. Today, by analyzing the systematic analyses conducted by the IPCC, a reasonable consensus can be reached that the global heating over the past 100 years is probably explained mainly by the man-induced emissions of greenhouse gases (GHG), rather than any natural climate variability.[4] Until the beginning of the Industrial Revolution in the late 18th century, the concentrations of carbon dioxide (CO_2) in the atmosphere had ranged from 180 parts per million in volume (ppmv) to 200 ppmv of the total atmospheric mass (which characterized it as a minority gas) for at least 700,000 years, but possibly for more than 5 million years. Over the past few years the concentration of that gas has exceeded 375 ppmv and keeps on growing, as 8 to 9 million tons of carbon (in the form of CO_2) are released every year by the burning of fossil fuels and man-induced changes in land use, especially deforestation in rain forests. The concentration of other important greenhouse gases (CH_4, N_2O) in the atmosphere has been increasing at rates that are even higher than those of CO_2.

4 Houghton, R.A. *et al.*: *Climate change 2001: The scientific basis*, Cambridge, Cambridge University Press, 2001

4.3.2 Climate change scenarios for South America in the 2090-2100 decade

In order to project probable climate change scenarios for the future, mathematical models of the global climate system are used which take into consideration the behavior of climate components (atmosphere, oceans, cryosphere, soil-vegetation, etc.) and their interactions. These models allow climate evolution scenarios to be simulated for several GHG emission scenarios. Given the uncertainties about future GHG emissions, as well as uncertainties arising from imperfections of the very models, several models and scenarios are used.

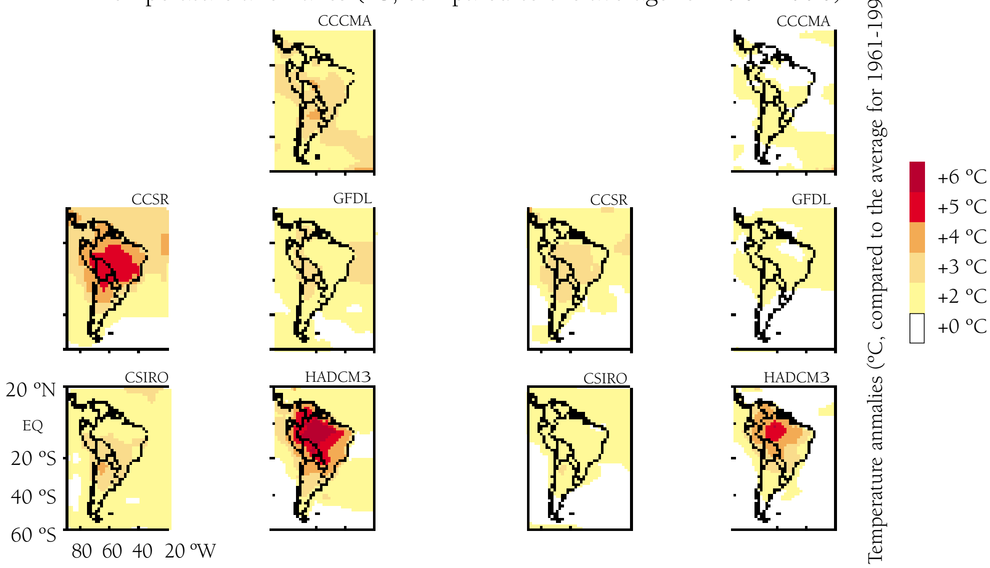
Figures 1 and 2 show climate scenarios for South America in the 2091-2100 decade for five different global climate models and two GHG emission scenarios from the Intergovernmental Panel on Climate Change.[5] A2 is a scenario consisting of a high level of GHG emissions, i.e. maintaining the GHG emission standards observed for the past few decades. The level shown here indicates that by 2100 we would have CO_2 concentrations in the atmosphere of 850 ppmv. B2 is a lower emission scenario considering a stabilization of GHG emissions and a concentration of 550 ppmv at the end of this century.

5 Nakicenovic, N.; Swart, R. (Eds.): *Emissions scenarios 2000: Special report of the Intergovernmental Panel on Climate Change*, Cambrigde, Cambridge University, 2000

Figure 1: Projected surface temperature changes for 2091-2100, computed according to five global climate models,[6] IPCC Data Distribution Center

A2: High gas emission scenario B2: Low gas emission scenario

Temperature anomalies (ºC, compared to the average for 1961-1990)

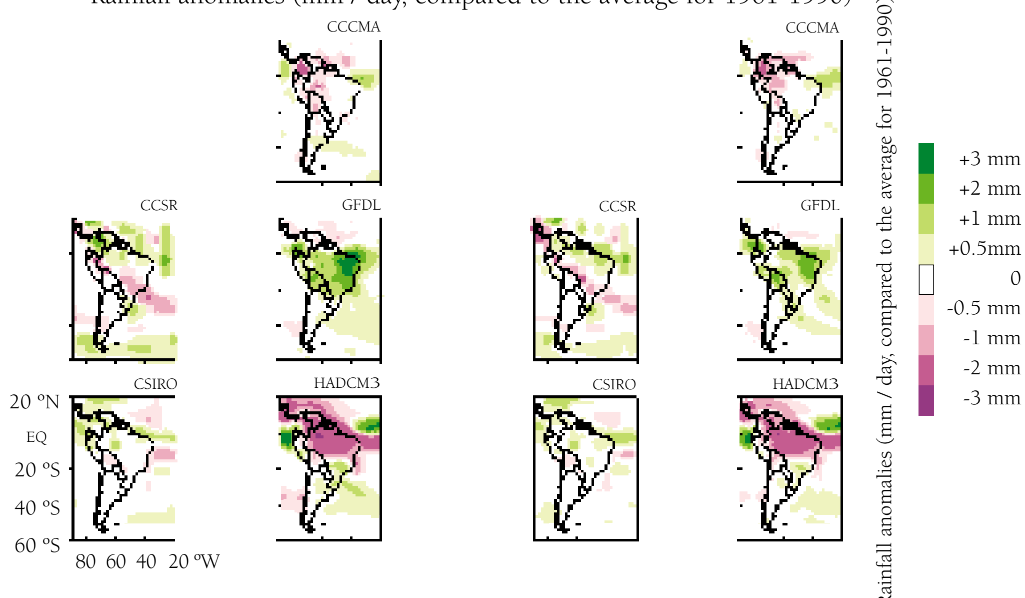


6 RUOSTEENOJA, K. *et al.*, IPCC Data Distribution Center, 2003

Figure 2: Projected rainfall changes for 2091-2100, computed according to five global climate models[6]

A2: High gas emission scenario B2: Low gas emission scenario

Rainfall anomalies (mm / day, compared to the average for 1961-1990)



An analysis of these scenarios shows a greater fluctuation of temperature and rainfall anomalies between different climate models than between the high emission scenario (A2) and the low emission scenario (B2). For temperature, a fluctuation range is projected at 1-4 °C for the B2 scenario, and as much as 2-6 °C for the A2 scenario: a substantially hotter weather for any of the scenarios and climate models considered. For the projected rainfall changes (where all projections point to heating), different climate models show significant differences in rainfall patterns, sometimes with radically opposing projections. For example, the GFDL model (US) points to an increase in rainfall in the tropical South America, whereas other climate models point to a decrease (such as the HADCM3, of Great Britain) or little change. Therefore, current methods do not allow the setting of reliable scenarios of changes in the rainfall distribution and intensity, on a regional scale, so as to subsidize active governmental policies to mitigate vulnerabilities and/or seek a potential adaptation to climate changes. Advances in the scientific knowledge may diminish the uncertainties inherent in such projections, perhaps within fewer than 10 years. Nevertheless, there is an indication of a more frequent occurrence of climate extremes and intense events (droughts, short summers, windstorms, severe storms) on a hotter planet.

The possible increase in climate extremes turns our attention to the problem relating to the vulnerability of populations and ecosystems to those changes. With hotter weather, there will be more water vapor in the atmosphere and an acceleration of the water cycle. This is one of the projected climate changes considered to be of high reliability. Such acceleration would result in an increased frequency of severe, intense storms, with consequences we can evaluate.

4.3.3 Impacts of climate changes on ecosystems and agroecosystems

The possible changes in Brazil's major natural biomes as a response to the climate change scenarios illustrated in **Figures 1** and **2** were evaluated by the CPTEC-INPE.[7] We remind that natural ecosystems are unable to migrate or adapt to the projected climate changes on the time scale in which they are taking place, i.e. decades. Therefore, we should expect significant rearrangements of the ecosystems and biomes.

Most of the differences in projections of the future distribution of biomes again lie in the comparison between the GFDL and the HADCM3 models, and are attributable to differences in rainfall patterns. Since rainfall increases in the tropical South America in the first model, there would be no sensible change in distribution in the Amazon Rain Forest, but there the savannah would expand to the northeast, thereby replacing the *caatinga* biome in the northeastern subarid area. For the other scenarios, there is a trend towards "savannization" of parts of the

7 Nobre, C.A.; Oyama, M.D.; Oliveira, G.S.; Marengo, J.A.; Salati, E.: "Impact of climate change scenarios for 2100 on the biomes of South America", First International CLIVAR Conference, Baltimore, USA, 21-25 June 2004. http://www.clivar2004.org

8 Cox, P.M.; Betts, R.A.; Jones, C.D.; Spall, S.A.; Totterdell, I.J.: "Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model", London, Nature, vol .408, 2000, pp. 184-187

9 Siqueira, O.J.W.: "Efeitos potenciais das mudanças climáticas na agricultura brasileira e estratégias adaptativas para algumas culturas", *in*: Lima, M.A. de; Cabral, O.M.R.; Miguez, J.D.G. (Eds.): *Mudanças climáticas globais e a agropecuária brasileira*, Jaguariúna, SP, EMBRAPA Meio Ambiente, 2001, pp. 65-96

10 Siqueira, O.J.W.; Farias, J.R.B. de; Sans, L.M.L.: "Potential effects of global climate change for Brazilian agriculture and adaptative strategies for wheat, maize and soybean", Revista Brasileira de Agrometeorologia, 2, 1994, pp. 115-129

Amazon (i.e. expansion of the *cerrado*, or savannah to the north) and even towards the *caatinga* of part of the subarid area becoming a semi-desert. Generally, there is a projected expansion of savannah areas in the tropical South America and a decrease in the *caatinga* area. Four of the five scenarios point to a decrease in the area covered by the Amazon Rain Forest. In particular, the HADCM3 model is the one providing the most extreme scenario for the Amazon, going as far as to speculate about a possible complete disappearance of the Amazon Rain Forest.[8]

An analogous reasoning could be used in respect to the impact of such projected climate changes on the agroecosystems. For the most part, except for the GFDL, there is a trend towards decreased availability of water in parts of the Amazon, the Northeast and the Center-West, which could adversely affect agriculture, especially in the Northeast and the Center-West. In the South and Southeast, those projections point to much smaller changes in the water system. However, in order to project the impacts on agriculture and, as a result, evaluate the vulnerability, the effects of the temperature and the concentration of carbon dioxide (CO_2 "fertilization"), should be considered. A sharp increase in the mean temperature is usually harmful to the crops if outside the optimum range, but in the other way around, an increase in CO_2 concentration usually results in higher productivity for the crops.

There are only a few studies dealing with the impacts of climate changes on the Brazilian agriculture. Some of the studies used future climate change scenarios based on global climate models. These studies sought to calculate the negative and positive effects on the productivity of wheat, corn and soybean crops[9, 10, 11] or the impact of climate changes in the occurrence of pests in wheat crops in the south of Brazil.[12] Other studies analyzed the agroclimatic risk to coffee crops at climate extremes.[13, 14] In São Paulo State, for example, it was calculated that with an increase of 3 ºC in the mean temperature and 15% in rainfall, only 15% of the state's area would be favorable to the Arabic coffee culture (compared to today's 40%), even considering that there would be no risk of frosts in these scenarios.

For the most part, the studies of the impacts on the agricultural productivity of corn, wheat and soybean crops do not allow the conclusion to be safely reached that the effect of temperature rises contributes to productivity decreases, even including the possibility of the greater occurrence of pests. To some extent, this can be compensated for by the increased concentration of carbon dioxide. Effects on soil (new physicochemical and biological balances, influencing fertility) also need evaluation. It is noted that all studies have used mathematical models to estimate the impacts on agriculture, but their results lack further validation by field experiments.

8 see p. 98

9 see p. 98

10 see p. 98

11 Travasso, M. *et al.*: "Expected impacts of climate change on crop yields in the Pampas region of Argentina, Brazil and Uruguay" (AIACC Project No. LA27), Second AIACC Regional Workshop for Latin America and the Caribbean, Buenos Aires, Argentina, 24-27 August 2004

12 Fernandes, J.M. *et al.*: "Expected impacts of climate change on the incidence of crop disease in the Pampas region of Argentina, Brazil and Uruguay: Modeling fusarium head blight in wheat under climate change using linked process-based model" (AIACC Project No. LA27), Second AIACC Regional Workshop for Latin America and the Caribbean

13 Marengo, J.A.: "Impactos das condições climáticas e da variabilidade e mudanças do clima sobre a produção e os preços agrícolas: ondas de frio e seu impacto sobre a cafeicultura nas regiões Sul e Sudeste do Brasil", *in*: Lima, M.A.; Cabral, O.M.R.; Miguez, J.D.G. (Eds.): *Mudanças climáticas globais e a agropecuária brasileira*, Jaguariúna, SP, EMBRAPA Meio Ambiente, 2001, pp. 97-123

14 Pinto H.S.; Assad, E.D.; Zullo Jr.; Brunini, O.: "O aquecimento global e a agricultura", Revista Eletrônica do Jornalismo Científico, COMCIENCIA - SBPC, vol. 35, 2002, pp. 1-6

Considering the possibility of more frequent, more severe rainfall and temperature extremes, the important effects on agriculture would be increased soil erosion (more intense rainfall), and the effects of hail and high-speed, high-turbulence winds.

4.4 Greenhouse gas emissions in Brazil

In late 2004, Brazil submitted its initial national communication to the UN Framework Convention on Climate Change, as expected. The first part provides an overview of the country, its priorities, and its complexity. The second part provides the first national inventory in respect to greenhouse gas emissions for the 1990-94 period. The third part shows some of the steps the country has already taken towards reducing emissions.

Some difficulties with the computation methodology are highlighted. Most of them are due to the fact that the IPCC methodology is based on the experience of developed countries, where most of the emissions result from the *use of fossil fuels*. In Brazil, the *change in the use of land and forests* is more relevant. This required an adjustment to the proposed methodology. Several initiatives taken in the country, especially in the field of "renewable energy", particularly involving the sugar cane ethanol, are listed in the last part. Even though current information concerning the implementation of that Convention in Brazil was reflected in the report until the year 2000, several pieces of information for as late as 2002 were added.

Some of the results of the national greenhouse gas inventory are shown in **Table 1**. Although the inventory includes other gases (HFC, PFC, SF_6, and those having indirect effects: CO, NOx, NMVOCs), we have listed only the most important ones: CO_2, CH_4 and N_2O.

Table 1: Estimations of GHG emissions in Brazil, 1994

Sectors	Energy (Mt)	Industry (Mt)	Crops and live-stock (Mt)	Change in use of land & forests (Mt)	Waste treatment (Mt)	TOTAL (Mt)	Variation 1994/90 (%)
CO_2	237	17	-	776	-	1030	5
CH_4	0.4	-	10.1	1.8	0.8	13.2	7
N_2O	-	-	0.5	-	-	0.5	12

Source: Brazilian National Report to IPCC, Ministry of Science and Technology, Brasília, 2004

As demonstrated in **Table 1**, CO_2 emissions in 1994 were caused by *changes in the use of land and forests* (75%), followed by *energy* (23%). Methane emissions originated mainly from *crops and livestock* (77%, most of which from enteric fermentation by ruminants), which also accounted for 92 percent of the N_2O emissions. We point out that the "global warming power" of methane is 29 times as large as that of CO_2, while that of N_2O is 296 times as large as that of CO_2.

The figures above serve as a reference for comparison with GHG emissions from sugar cane production and processing, and with the emissions prevented by using ethanol and bagasse as fuels, as quantified in **item 4.5**.

4.5 GHG emissions by the sugar and ethanol industry in Brazil: current and expected values

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The energy products of sugar cane, i.e. ethanol and bagasse, have largely contributed to the reduction of the emissions of greenhouse gases (GHG) in Brazil, by substituting for fossil fuels, i.e. gasoline and fuel oil, respectively. Not only does the bagasse supply energy (thermal and electrical) for ethanol production, it is also used in sugar production (substituting for the fossil fuel that would be used in the alternative production from sugar beets, or starch) and other industrial sectors (such as orange processing).

Fossil fuels are consumed in sugar cane planting, harvesting, transportation and processing and emit GHG. Also, there are processes that have no connection with fuels, but generate emissions that are not compensated for by photosynthetic re-absorption as the sugar cane grows (non CO_2 gases in trash burning, fertilizer decomposition, etc.). A complete balance sheet of energy and emissions (in the life cycle) for evaluating the net results in ethanol production from sugar cane and its utilization as a fuel in transportation sector has been prepared and recently updated in Brazil.[15] In 2006 a new update included also some forecasts for the evolution (based on technical improvements) for the next years.[16]

The energy analysis is summed up in **item 1.4.1**, resulting in a mean ratio between the production of renewable energy and consumption of fossil energy of 8.9. For comparison, the energy ratio in the case of ethanol and corn in the United States was evaluated at 1.34 in 2002.

15 MACEDO, I.C.; LEAL, M.R.L.V.; SILVA, J.E.A.: "Emissões de gases de efeito estufa (GEE) na produção e uso de etanol no Brasil: situação atual (2002)", SMA – Secretaria do Meio Ambiente de São Paulo, São Paulo, 2004

16 SEABRA, J.E.; LEAL. M.R.L.V.; MACEDO, I.C.: The energy balance and GHG avoided emissions in the production / use of ethanol from sugar cane in Brazil: the situation today and the expected evolution in the next decade; XVI International Symposium on Alcohol Fuels, Rio de Janeiro, Nov 2006

For greenhouse gases, emissions from the use of fossil energy were evaluated at 0.20 kgCO_2 eq./m^3 ethanol anhydrous (on average), and emissions from other sources (non CO_2 gases from trash burning, fertilizer decomposition, etc.) 0.18 kgCO_2 eq./m^3 ethanol anhydrous. As a net result, the emissions avoided by the substitution of ethanol for gasoline, and of surplus bagasse for fuel oil, minus the foregoing values amount to 2.86 t CO_2eq. / m^3 of anhydrous ethanol and 2.16 t CO_2eq. / m^3 of hydrous ethanol, for the mean values. For the mills featuring the best performance, the values can be around 4 percent higher. These values consider anhydrous ethanol as an additive (added up to 24%) and hydrous ethanol for E100 cars.

These are very relevant results. Under these conditions, which reflect the current situation in Brazil, ethanol production from sugar cane is much superior compared to any other technology to produce biomass fuels worldwide. This is because of the "renewable energy obtained/fossil energy used" ratio and the very high rate of decrease in the emissions of GHG. For the Brazilian consumption of ethanol in 2003, i.e. 11.6 million m^3 per year (6.1 Mm^3 of which consisting of hydrous ethanol), ethanol was responsible for a reduction of around 27.5 million t CO_2 equivalent.

The emission of GHG from beet sugar production (energy based on coal or natural gas) is much larger than that from cane-sugar production. Although that difference cannot be used in CDM projects due to baseline definitions, it should nonetheless be pointed out. At the moment, beet processing takes less energy (on average) than sugar cane processing (the availability of bagasse has made sugar mills less energy-efficient). Modern beet sugar mills operate today with around 1.1 Gcal / sugar t (on average); using natural gas, the CO_2 emissions would amount to 0.26 ton CO_2 / sugar t. This is a conservative result. Compared to the emissions from beet-based sugar mills, the Brazilian mills have avoided emissions of 5.7 million tons CO_2 equivalent in 2003.

An analysis of the expected situation concerning emissions for the next few years[17] considers:

- Increased mechanical harvesting of sugar cane (increasing the consumption of fossil fuels), and reduced sugar cane burning (reducing some methane and nitrous oxide emissions
- Equivalences between ethanol and gasoline, for the various applications, being changed to include new compositions with the use of flex-fuel engines

17 MACEDO, I.C.: "Estimativa da redução adicional de emissões de gases de efeito estufa (GEE) com o aumento da produção de cana e derivados no Brasil; 2010", Internal report, UNICA, São Paulo, 2004

• Future production (2010-): 34 Mt of sugar, 17.3 Mm^3 of ethanol (11.2 Mm^3 of hydrated ethanol), 535 Mt of sugar cane / crop.

In these cases, the emissions avoided by the use of ethanol would amount (possibly in 2010) to 46.7 Mt CO_2 equivalent. Therefore, the additional decrease in emissions thanks to ethanol use would amount to 19.2 Mt CO_2 equivalent.

The increase in sugar production through 2003 would lead to an additional decrease of 3.2 million tons CO_2 equivalent in emissions.

On the other hand, Brazilian mills are essentially independent in terms of electrical power, notwithstanding the purchase at the period between harvesting seasons (some energy is sold during the crop season). For the sugar cane production increase over the next years, and considering that 50 percent of it, on average, would be introducing C-E high-pressure generation systems (commercially available), with a 20-percent reduction of the specific steam consumption in the processes (over the current amount) and utilization of 10 percent of the trash, a surplus power of ~75 kWh / sugar cane t would be reached. The total surplus power would amount (for only half of the additional 217 million tons of sugar cane) to 8,140 GWh.

If this energy were to replace that generated by natural gas-based thermo-electrical power plants (a criterion not accepted by the CDM; an energy mix would be required), we would avoid emissions of 440-500 kg CO_2 eq. / MWh. The additional generation would lead us to avoid emissions of 4.1 Mt CO_2 eq., compared to natural gas-based thermo-electric power generation.

In short: every increase of 100 Mt of sugar cane / crop season, under the foregoing conditions, could lead to additional reductions in the emissions of of GHG equivalent to:

9.1 Mt CO_2 eq	(through ethanol use)
2.0 Mt CO_2 eq	(added electricity in 50% of the cases)
1.5 Mt CO_2 eq	(sugar cane sugar compared to beet sugar)

4.6 Summary and conclusions

• The 30-percent increase in the concentration of greenhouse gases in the atmosphere since pre-industrial times corresponds to an average increase of 0.6 °C in the surface temperature of the planet. In the 21st century, the mean temperature may increase by more than 3 °C if the current trend is not changed. The Kyoto Protocol represents one step towards (increasingly consensual) preventing an increase of up to 2 ºC by 2050.

• The still evolving global climate models all point to temperature rises for Brazil, but the uncertainties about the hydrology are substantial. The models indicate temperature increases of 1-4 ºC (low emission scenario) or 2-6 ºC (high emission scenario). There is no agreement on the results for rainfall, but climate extremes (droughts, severe storms) are expected to occur more often.

• In the models that indicate a greater amount of rainfall (GFDL, US) the savannah would expand to the Northeast. In the other scenarios (for example, the HADCM3, England), the savannah would expand to parts of the Amazon, and the *caatinga* biome in the Northeast would become a semi-desert.

• A vulnerability assessment of the agricultural sector should consider the simultaneous effects of the temperature (and rains) and the "fertilization" by the increased concentration of CO_2. There are only a few studies for Brazil, and they are only focused on coffee and wheat in specific regions.

• The evaluation of the emission of GHG from Brazil for the 1990-94 period indicates *change in the use of land and forests* as the factor accounting for the most emissions (75%), followed by *energy*, with 23%.

• In the sugar cane industry, the "renewable energy produced/fossil energy used" ratio is 8.9 for ethanol production. This is due to an extraordinary performance in the industry, which avoids the emission of GHG equivalent to 13 percent of the emissions from Brazil's entire energy sector (reference 1994).

Emissions avoided in 2003:	
With ethanol substituting for gasoline:	27.5 Mt CO_2 equivalent
Bagasse in sugar production:	5.7 Mt CO_2

• For every additional 100 Mt of sugar cane, emissions of 12.6 Mt CO_2 equivalent could be avoided over the next few years using ethanol, sugar cane bagasse and the added excess electricity.

Chapter 5:
Impacts on the water supply

Brazil has the greatest availability of water in the world, and the use of crop irrigation is relatively small. Sugar cane crops are virtually not irrigated. The levels of water withdraw and release for industrial use have substantially decreased in the last years, with larger water reuse. Water treatment before discharge in São Paulo is adequate. The protection of areas around waterways and lagoons has advanced and may constitute an important factor also for the protection of biodiversity.

5.1 Introduction

The use of water for irrigation is considered an essential factor to agriculture worldwide. For a harvested crop surface (2000)[1] of 1,500 Mha, around 275 Mha are irrigated. There are around 190 Mha that allow agricultural use by agricultural drainage systems. The crop surface under dry farming, covering around 1,225 Mha (approximately 82% of the total), accounts for 58 percent of the production, which clearly demonstrates the importance of irrigation. The water used in agricultural production worldwide (2,595 km^3 in 2000) corresponded to an average of 9,436 m^3 / ha·year. It is estimated that this average can be reduced to 8,100 m^3 / ha·year by 2025.

The conflicts surrounding the uses of water have become more and more important around the world, with crop irrigation as one of its major issues. Likewise, the water sources and streams must be protected in order to prevent aggradations.

The impacts of the sugar cane culture on the water supply today (volumes and quality) are small under the conditions found in São Paulo. The main reasons for this are non-utilization of irrigation; an important reduction of water withdraw for industrial purposes that has been attained over the past few years thanks to internal reuse in the processes; and the practice of returning the water to the crops in the ferti-irrigation systems.

On the other hand, the forest protection legislation and its specific application to environmental protection areas (APP, in Portuguese) consisting of riverside woods have been releasing those areas from planting. This may lead to a major advance, creating corridors for biodiversity restoration, as proposed by the Office of the Secretary of Environment (São Paulo).

1 Estimations (2005) for 2003, Christofidis, D.; complementing Min. Integração Nacional /SIH/ DDH (1999); also Christofidis, D.: “Irrigação, a fronteira hídrica na produção de alimentos”, Item, vol. 2., no. 54, 2002, pp. 46-55

Availability and use of water in Brazil; irrigation

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Fresh water is distributed[2] around the world as follows: 76.7 percent in glaciers and ice tables; 22.1 percent in water tables; and 1.2 percent in surface waters. Brazil stands out for its great abundance of water resources both on the surface and in water tables. Table 1 compares the figures of Brazil to the world average supply (mean runoff of basins) and consumption of surface water. Brazil has 50,000 km² of its surface covered by fresh water (rivers, lakes).

2 Freitas, M.A.V.: "Hidroeletricidade no Brasil: Perspectivas de desenvolvimento e sustentabilidade", Seminário Sustentabilidade na Geração e Uso de Energia no Brasil: Os próximos vinte anos, UNICAMP / ABC, 2002

Table 1: Surface water supply and consumption, Brazil and the world

	Supply[1]		Consumption[2]	
	km³ / year	m³ / inhab·year	km³ / year	m³ / inhab·year
Brazil	5,740	34,000	55	359
World	41,281	6,960	3,414	648

1 Mean runoff, 2000

2 Consumption as evaluated in 1990

As to water tables, the Guarani Aquifer covers a total area of approximately 1.2 million km² – 839,800 km² of which in Brazil's Center-West and South regions. It stores around 40,000 km³ of water (which is equivalent to the world's total annual runoff). Because of both its huge availability and its low *per capita* use of water, Brazil is in a privileged position to plan the multiple uses of water in a sustainable way. As a matter of fact, Brazil is viewed as an important reserve for the world.

The space distribution of surface water resources and population causes only a few regions to appear as "critical" (supply below 1,500 m³ / inhab·year). According to a preliminary analysis conducted by the National Water Agency,[2] the main utilization conflicts (with different regional emphases) should consider: electricity generation; irrigation in agriculture; waterways development; human supply; leisure; and special cases of borders, floods and droughts. If well-grounded, the billing for use of water that starts being implemented in some regions of the country may favor the adoption of appropriate handling practices for the various applications, particularly the use in irrigation projects.

Although water does not seem to be a limiting factor today, the use of irrigation in agriculture is very small in Brazil. In most of the Brazilian territory, the agriculture used is dry farming: crops are grown depending exclusively on natural rainfall. In some regions, especially the *cerrados*, or savannahs, the total rainfall in the rainy season is enough for the development of agriculture. This is in spite of the frequent occurrence of successive dry days during the rainy season, which affects the development of crops and the final productivity.

Irrigation in Brazil's crop areas took up only 2.9 Mha in 2002.[3] More recent estimations point to 3.3 M ha, including all systems (drainage control on the surface, or using standard sprinkling, central swivel systems or localized irrigation). This corresponds to only 1.2 percent of the world's irrigated areas (277 Mha). Some studies[3] indicate that additional areas considered to be fit for a "sustainable irrigation" (fit soils with assured water) worldwide have reached 195 Mha. Around 15 percent of those areas are in Brazil (30 Mha), two thirds of which being located in the North and Center-West regions.

3 FAO, Data Base: Faostat, 2004

Even though the use of water for irrigation is very little in Brazil, it should be pointed out that the use efficiency (relation between the water coming to the crops and the water withdrawn from sources) is low: 61 percent on average. This results from the use of surface irrigation for 50 percent of the total water in Brazil. The future should consider the re-conversion of those systems: with equipment easier to control, adequate handling of surface irrigation systems, more uniform water application systems (by sprinkling), and spot irrigation (dripping and microsprinkling).

The use of irrigation is being investigated in Brazil for sugar cane, on a very small scale. The uses being tested correspond to very conservative technologies with a minimum use of water. Taking full advantage of the natural climatic conditions while implementing irrigation systems – for full, supplementary or salvage irrigation – may lead to interesting cost-benefit ratios in some cases.

Irrigation in sugar cane production is more widespread in the Northeast.[4] It also displays gradual growth in the Center-West and some areas in the Southeast, especially in Rio de Janeiro, Espírito Santo and west of São Paulo. "Salvage irrigation" is used after the planting of sugar cane in order to ensure sprouting in long periods without rain. "Supplementary irrigation" with different blades at the most critical of development stages is used in order to mitigate any shortages of water; and irrigation is used throughout the cycle, in relatively small areas.

4 Anselmi, R.: "Irrigar é preciso", JornalCana, ed. 124, Apr. 2004, pp. 36-40

Practically all of the sugar cane produced in São Paulo State is grown without irrigation,[5] based on economic analyses that were conducted considering full irrigation and productivity gains. However, experiments conducted by the Sugar Cane Technology Center have demonstrated the economic feasibility of subsurface sprinkling in the Ribeirão Preto region. The sugar cane harvesting season and the increase in longevity of the sugar cane crop, among other factors, have an influence of the feasibility of irrigation.

5 MATIOLI, C.S.: *Irrigação suplementar de cana-de-açúcar: modelo de análise de decisão para o Estado de São Paulo*, Piracicaba, SP, Doctor's thesis – Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, 1998

Although it is usual to associate sugar cane productivity with water availability (a 8.0-12.0 mm ratio of water evapotranspired for each t of sugar cane produced is widely used), that ratio varies according to many factors.[6] However, it is important to keep a suitable humidity level throughout the growing process in order to get high yields. Depending on the weather, the water required by sugar cane crops amounts to 1,500 to 2,500 mm, uniformly distributed across the cycle. The growing demand for the incorporation of new sugar cane areas in the Center-South region of Brazil has lead to the exploitation of regions having higher water deficits. In these cases, irrigation can be economically feasible, especially using more efficient methods.

6 DOORENBOS, J.; KASSAM, A.H.: *Yield response to water* (Irrigation and Drainage Paper, 33), Rome, FAO, 1979

For the most part, it can be said that some of the environmental problems arising from irrigation, and found in many sugar cane and beet crops around the world, do not exist in Brazil. An evaluation provided by EMBRAPA[7] now rates the impacts of sugar cane crops on water quality as level 1 (no impact).

7 ROSSETTO, R.: "A cultura da cana, da degradação à conservação", Visão Agrícola, ESALQ-USP, Ano 1, Jan 2004

5.3 Water withdraw and use in sugar cane processing

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The sugar cane culture in Brazil has traditionally not used irrigation. This is highly important in the reduction of environmental impacts (not only because of the little use of water, but also to avoid the dragging of nutrients and agrochemical residues, loss of soil, etc.). The water goes into the mills with the sugar cane (around 70% of the crop stalks weight) and it is also withdrawn from sources to be used in the industry. The collected water is used in several processes, at different reuse levels. Part of it is returned to the water streams after the necessary treatments, and another part is used in ferti-irrigation together with the vinasse. The difference between withdrawn and released water, is the water consumed internally (processes and distribution in the field).

5.3.1 The São Paulo context

The levels of water collection and release have been decreasing in a sensible way over the past ten years. In fact, this has been occurring in the industry in general, and is the result of a greater awareness of the need to save water and the indications of future legal actions in this respect. In the 1990's, the sugar cane industry's share of water withdraw was around 13 percent of the demand in the state, and around 40 percent of entire industrial sector, according to the São Paulo State Plan on Water Resources (PERH-1994/95).[8] Table 2 briefly shows the water availability and demand data of the forementioned plan and the PERH-2004/07.[9]

8 Conselho Estadual de Recursos Hídricos, Plano Estadual de Recursos Hídricos – Primeiro Plano do Estado de São Paulo – 1990 – Síntese, CRH, CORHI, GTP, São Paulo, 1994

9 Conselho Estadual de Recursos Hídricos, Plano Estadual de Recursos Hídricos 2004/2007 Relatório 1: Síntese dos Planos de Bacia, CHR, CORHI, Consórcio JMR Engecorps, São Paulo, junho 2004

Table 2: Surface water availability and demand, São Paulo

Availability and demand			PERH - 1990 [1]				PERH - 2004-07 [2]	
			1990		2010 (Pessimistic)		2003	
			m^3/s	%	m^3/s	%	m^3/s	%
Availability	$Q_{reference}$		2,105				2,020	
	$Q_{7,10}$		888				893	
Demand	Urban		97	24	200	23	151	39
	Irrigation		154	44	490	55	102	26
	Industrial	Total	112	32	190	22	137	35
		Mills	47	13				
	Total		353	100	880	100	390	100

1 State Plan on Water Resources – 1994/95 (1st Plan of São Paulo State – 1990 – Summary)
2 State Plan on Water Resources – 2004/2007 (Brief, 2004)

The pessimistic value of 880 m^3 / s estimated for 2010, which dangerously puts the demand on the minimum available flow level ($Q_{7,10}$) is unlikely to be reached, as shown by the values for 2003. The demand in the state increased by only 11 percent, to 389 m^3 / s. Of this, urban demand accounted for most of the increase (74%), followed by a 22-percent increase in industrial demand, and a 34-percent decrease in the demand for irrigation purposes. Part of these changes can be attributed to the reviews of concepts in the new PERH. A piece of relevant information is that irrigation does not have the weight that was previously attributed to it; the leading user of water is the urban sector, with around 39 percent of the state's surface water.

In the industrial sector (including the sugar cane agribusiness), the demand for water increased by only 22 percent in that period. This is partly because of the rationalization of water use that has been encouraged by the implementation of the new legislation, which provides for billing for the use of water (yet to be regulated).

Some partial estimations and measurements have been concluded for the sugar cane industry regarding water withdraw, use and release. Previously, the water release figures and the polluting load were always more important to the sector than the collection. Based on the estimated demand for 6 cropping months, and the total milling of sugar cane in 1990 in São Paulo State,[10] the water collection rate at the time was estimated at 5.6 m^3 / t of sugar cane. The specific release flow rate (32.3 m^3 / s, according to the PERH-1990) was estimated at 3.8 m^3/t of sugar cane, leading to consumption of 1.8 m^3 / t of sugar cane.

10 FERNANDES, A.C.: "Desempenho da agro-indústria da cana-de-açúcar no Brasil (1970 a 1995)", Piracicaba, SP, CTC – Centro de Tecnologia Canavieira, July 1996

For the 2004/05 crop, 207.8 Mt of sugar cane milled in São Paulo,[11] represent a growth of 58.5 percent since 1990, which has outpaced the increase in demand for water without a doubt.

11 UNICA, "Resumo da produção da região Centro-Sul", site www.portalunica.com.br/referencia/estatisticas.jsp accessed in Feb 03 2005

5.3.2 Legislation on the use of water resources

The billing for use of water is based upon the "user-payer" and "pollutant-payer" principles: based on the amount and quality of the water collected and released by the user. All uses that require consent are subject to billing, such as collection, derivation, disposal dilution, energy production, navigation and others.

The costs affecting the industrial sector correspond to water withdraw, consumption and disposal. Billing for the use of water in São Paulo has been implemented for two geographic basins, the PCJ (Piracicaba, Jundiaí e Capivari) and the Paraiba do Sul. Both have established federal and state committees, and the water in rivers crossing state borders are already being billed for urban, industrial and rural utilization. For the state rivers (within a single state) and for underground water billing will be effective in 2007 (Decrees 51449 and 51450, from 2006, for the PCJ and Paraiba do Sul). The majority of the remaining 18 basin committees (in São Paulo) will start the billing in 2008; in São Paulo the billing of water for irrigation was postponed till 2010. The main legal mechanisms to bill for use of water at the federal and state levels for São Paulo State are as follows:

- The São Paulo Constitution, 1988: it provides that the use of water resources shall be billed, and the proceeds shall be used to maintain the quality and quantity of water.
- State Law (SP) no. 7,663, 1991: it introduces the State Policy for Water Resources and the Integrated Water Resources Management System; provided for the Water Resources Management Hydrographic Units (UGRHI), the basis for billing water collection and use; the apportionment of multi-use works costs, and the granting of rights to use by the state. It also sets the priorities for uses, to be effective for as long as the plan for a certain basin is not established.
- Federal Law no. 9,433, 1997: it provides for the National Policy for Water Resources and creates the National Water Resources Management System, which is based on principles of decentralized management, multiple uses of water, and priorities.
- CEIVAP Decision no. 08, 2001: whereby the Committee for Integration of the Paraíba do Sul River Basin (CEIVAP) provides for the implementation of billing for the use of water resources from the basin, effective as of 2002. The billing considers the collection, consumption, the treated effluents-total effluents ration, and the BOD (Biochemical Oxygen Demand) reduction level of the treated effluent.
- CEIVAP Resolution 65/2006, establishing new mechanisms to consolidate the billing of water in the Paraiba do Sul with the State regulations
- CNRH Resolution 52 (2005) approving the methodology and values for the billing in the PCJ (federal) rivers for 2006
- Law 2183 (2005) establishes the methodology, limits and values for the billing in State rivers
- State Decree 50667 (2006), including the procedures for determination of the final prices
- CRH (State Water Resources Council), in Dec 2006, approved the propositions for the billing in State areas
- State Decrees (S Paulo) 51449 and 51450 (Dec 29, 2006) determine the billing in the PCJ and Paraiba do Sul basins.

5.3.3 Water withdraw for industrial use in the sugar cane agribusiness

Table 3 sums up the specific water use ranges and averages for industrial processing of sugar cane. It considers that the sugar cane is used in the production of sugar and ethanol on a 50/50 basis.[12]

The estimated mean end use of 21 m^3 / sugar cane t corresponds to much lower levels of water collection, consumption and release due to water reuse. Note that about 87 percent of the uses take place in four processes:

12 Elia Neto, A.: “Workshop sobre cobrança pelo uso da água” – Convênio AIAA Comitê da Bacia Hidrográfica dos Rios Piracicabas, Capivari e Jundiaí (CBH-PCJ), Piracicaba, 1996

Table 3: Water uses (mean values) in mills having an annexed distillery

Sector	Process	Mean use (total m^3 / sugar cane t)	Distribution (%)
Feeding	Sugar cane washing	5.33	25.4
Extraction (grinding)	Imbibition	0.25	1.2
	Bearing cooling	0.15	0.7
Juice treatment	Preparation of lime mixture	0.01	0.1
	Cooling at sulphiting [1]	0.05	0.2
	Filter imbibition	0.04	0.2
	Filter condensers	0.30	1.4
Juice concentration	Condensers/multijets evaporation [1]	2.00	9.5
	Condensers/multijets heaters [1]	4.00	19.0
	Molasses dilution	0.03	0.1
	Crystallizer cooling [1]	0.05	0.2
	Sugar washing [1]	0.01	0.0
Electrical power generation	Steam production	0.50	2.4
	Turbo-generator cooling	0.20	1.0
Fermentation	Juice cooling [2]	1.00	4.8
	Fermentation cooling [2]	3.00	14.3
Distillery	Condenser cooling [2]	4.00	19.0
Other	Floor & equipment cleaning	0.05	0.2
	Drinking	0.03	0.1
Total		21.00	100.0

1 in sugar production only
2 in ethanol production only

sugar cane washing; condenser/multijet in evaporation and vacuum; fermentation cooling; and alcohol condenser cooling.

With the rationing of water consumption (reuses and circuit closing, as well as some process changes, such as the reduction of sugar cane washing), water collection has been decreasing. A preliminary, limited survey conducted in 1995[13] in mills owned by the Copersucar Group pointed to a mean collection rate of 2.9 m^3 / sugar cane ton. A more comprehensive review released in 1997 indicated that the collection was actually at 5 m^3 / sugar cane t. Such a rate is equivalent to that estimated for 1990, based on the total demand in São Paulo, which was 5.6 m^3 / sugar cane t.

The results for water withdraw, consumption and release are shown in Table 4.

Table 4: Water withdraw, consumption and release: 1990 and 1997

Specific volume (m^3 / sugar cane t)	1990 [1]	1997 [2]
Collection	5.6	5.07
Consumption	1.8	0.92
Release	3.8	4.15

1 State Plan on Water Resources – 1994/95 (1st Plan of São Paulo State, 1990 – Summary)

2 Survey (review) conducted in 1997 by the CTC with 34 mills owned by Copersucar

Over the past few years, there has been more action concerning the rationalization of water consumptions and reuse, and the reduction of release levels at São Paulo-based mills. In order to examine the extent of the changes, a survey was conducted through questionnaires and interviews with a large number of mills, accounting for a total sugar cane milling of 695,000 tons per day (around 50% of the Center-South production).[14] The result was 1.83 m^3 of water / t of sugar cane, and excluding the mills having the highest specific consumption, the mean rate for the mills that account for 92 percent of the total milling is 1.23 m^3 of water / t of sugar cane.

These figures indicate an extraordinary advance in water handling during the period.

5.3.4 Main effluents, organic load and treatment

With regard to the effluents and their organic load, the survey conducted in 1995 with 34 mills[13] pointed to a remaining organic load of 0.199 kg BOD_5 / sugar cane t. This represented an efficiency level of 98.40 percent compared with the estimations of the pollutant potential for that same

13 Elia Neto, A.: "Tratamento de efluentes na agroindústria sucro-alcooleira", presented at FEBRAL/95 – Brazil-Germany Fair, São Paulo, SP, 1995

14 Internal report (reserved), UNICA, 2005. Survey on water collection by sugar cane industry, M. Luiza Barbosa, assisted by Centro de Tecnologia Canavieira

period. Note that ferti-irrigation of sugar cane crops is the major disposal channel for that organic matter, with environmental and economic benefits.

The main effluents and their treatment systems are as follows:

• Sugar cane washing water: 180-500mg / l of BOD_5 and high concentration of solids. Treated with settling and stabilization ponds for the case of release to water bodies. For reuse, the treatment consists of settling and pH correction of 9-10.

• Multijet and barometric condenser waters: low pollutant potential (10-40 mg / BOD_5) and high temperature (~50ºC). Treatment with sprinkler tanks or cooling towers, with recirculation or release.

• Fermentation vats and ethanol condenser cooling waters: high temperature (~50ºC). Treatment with cooling towers or sprinkler tanks for return or release.

• Vinasse and wastewaters: large volume and organic load (10.85 / l of ethanol, with around 175 g BOD_5 / l of alcohol).[15] Vinasse is used in sugar cane crops together with wastewaters (floor washing, closed-circuit purging, condensate remainders), promoting ferti-irrigation using the nutrients.

15 Elia Neto, A.; Nakahodo, T.: "Caracterização físico-química da vinhaça", Project no. 9500278, CTC – Centro de Tecnologia Canavieira, Piracicaba, SP, 1995

5.3.5 Prospects for the industry

Since 1995, the industry (especially the Sugar Cane Technology Center) has been assessing techniques for a rational use of water and reuse of waste. The possibility of reaching a water collection rate of 1 m^3 / sugar cane t and an effluent release rate of zero in the mid term has been considered. The organic load would be treated by using waste in crop ferti-irrigation together with the vinasse. Water consumption (difference between the amount of collected water and released water) would be near the collection value, i.e. 1 m^3 / sugar cane t. We noted that sugar cane itself carries 70 percent of water, which does not represent utilization of water resources.

These basic guidelines imply a management of water, including a decrease in collection and a maximum reuse of effluents. This has already occurred partially, and may be accelerated by the incorporation of new technologies, including dry cleaning of sugar cane (eliminating sugar cane washing). Treatments like biodigestion of vinasse might reduce the organic load, thereby allowing recirculation upon tertiary treatment.

The results of the latest assessment indicate that there has been an evolution to these goals over the past few years. Even when the particularities of mills are taken into account, which will certainly imply different results, the withdraw averages may continue to decrease. An optimization of reuse shall be the subject of studies over the next few years, aiming at reducing the costs of disposal.

5.4 Protection of water sources and streams

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The preservation and recovery of riverside woods, combined with appropriate soil preservation and handling, are essential to ensuring one of the main natural resources, water. Riverside woods are essential plant systems for environmental equilibrium. Their functions include controlling erosion on banks of water streams, thereby avoiding fountainhead aggradations, minimizing the effects of floods, maintaining the amount and quality of the waters, filtering any possible waste resulting from the chemicals used as pesticides and fertilizers, and helping to preserve biodiversity and the genetic inheritance of the flora and fauna.

5.4.1 Legal aspects; forest legislation

The main legal aspects of riverside woods and their preservation and restoration are distributed among several rules at the state and federal levels.[16] The subject is addressed by several pieces of the environmental legislation, such as the Forest Code, the Environmental Crime Law, rules on permits and licenses and recovery projects, as well as the tax legislation on rural properties. In addition to the specific legislation on the subject, the legislation on Preservation Units is also relevant.

Brazil's main legislation on forests[17] is the Forest Code (Law no. 4,771/65, as amended by Law no. 7,803/89 and Provisional Measure no. 2,166-67), which contain the following items applicable to riverside woods:

Article 2nd - For the purposes of this law, forests and other forms of natural vegetation are considered permanent preservation units when located as follows:

a) along rivers or any water streams, from their highest level, in a marginal width range of at least:

1) 30 m, for less than 10 m wide water streams;
2) 50 m, for 10-50 m wide water streams;
3) 100 m, for 50-200 m wide water streams;
4) 200 m, for 200-500 m wide water streams;
5) 500 m, for more than 600 m wide water streams;

b) around lagoons, lakes, or natural or artificial water reservoirs;

c) at springs, yet intermittent, and at "water holes", whatever the topographic situation, within a radius of at least 50 m.

16 Estado de São Paulo, Secretaria de Estado do Meio Ambiente: "Projeto de recuperação de matas ciliares no Estado de São Paulo: proposta o GEF", Documento de avaliação ambiental, São Paulo, 2003, site www.ambiente.sp.gov.br accessed in Feb. 1 2005

17 Ventura, V.J.; Rambell, A.M.: *Legislação federal sobre o meio ambiente*, Vana Editora, 3rd ed., 1999

These principles and limits extend to urban areas.

Riverside woods are the main example of Permanent Preservation Areas (APP, in Portuguese), as defined in the Forest Code (Law no. 4,771/65) and its regulation (particularly CONAMA Resolution 303/02). In addition, the São Paulo State Constitution, article 197, defines springs, fountainheads and riverside woods as permanent protection areas.

Under the federal legislation, riverside woods are protected from cutting. However, their restoration, if no environmental infringement is characterized, is not mandatory, except for springs (Law no. 7,754, of 04/14/1989). The riverside strips, if duly covered by woods or other natural vegetation, are excluded from the taxable area of the property, as set forth in the specific legislation on the Rural Property Tax (ITR, Law no. 9,393/96).

Formally, there is no explicit determination in the federal legislation that riverside woods should be recovered if previously degraded. There is no clear definition of acceptable uses in the law either, and such uses as public utility and/or social interest are often mentioned for suppression of vegetation (articles 2nd and 3rd of the Forest Code). In São Paulo State, Law no. 9,989, of May 22, 1998 requires riverside woods to be recovered by owners of rural property. This, however, was not regulated within the expected period.

It is an environmental crime to damage a forest or cut trees in APPs. The punishments and fines are set forth in the Environmental Crime Law (Law no. 9,605/97). There are also punishments for "*preventing or hindering the natural regeneration of forests and other forms of vegetation*" (Forest Code, Law no. 4,771/65).

5.4.2 Provision of seeds and seedlings

Obtaining seeds and seedlings of native species in an adequate manner, considering such factors as quality and intra- and inter-specific diversity, is a critical aspect of forest recovery actions. In this case, Preservation Units (UCs, in Portuguese) and State Parks may represent an important, if not the only source of such genetic material. In São Paulo State, those units, under Law no. 9,985, of July 18, 2000, and Decree no. 25,341, of June 04, 1986 (Regulation of São Paulo State Parks), have restrictions on the collection of plant specimens and seeds. For the sake of recovering degraded areas, such restrictions should be reviewed.

Law no. 10,711, of 2003, on the National Seed and Seedling System (SNSM, in Portuguese), regulates the production of and trade in seeds of forest, native or exotic species. Decree no. 5,153, of 2004, provides for the forest species seed and seedling production and certification process.

5.4.3 SMA initiatives – São Paulo State

Only 13.7 percent of São Paulo State is covered by the remaining native vegetation (8% of which being part of the original Atlantic Forest). The area of degraded riverside woods that need restoring is estimated at around 1 million hectares, representing 120,000 km along the banks of unprotected water streams.[16] The SMA (Office of the Secretary of Environment) is carrying out a long-term project for recovering riverside woods within the state. In addition to local environmental benefits, the program aims at creating alternative jobs and contributing to the reduction of greenhouse gas emissions. The carbon dioxide fixation by the vegetation could use resources from the CDM (Clean Development Mechanism).

16 see p. 115

5.4.4 Possibilities in the sugar cane culture

In most sugar cane culture cases, places considered permanent preservation areas (APPs) have been left for natural, spontaneous recovery. This has been happening especially over the past few years. The recovery of degraded riverside woods by reforestation activities is still limited to only a portion of the total area.

In order to evaluate the dimensions and situation of the permanent preservation areas corresponding to old riverside woods, a survey was concluded in 2005 involving a large number of mills in São Paulo.[18] The areas comprise owned and leased land, and in many cases, land owned by sugar cane suppliers. The main results, denoted in % of the sugar cane crop area, are shown below. For the first item (total permanent protection area, corresponding to riverside woods), the sample consists of 781,000 ha; for the other items, between 650,000 and 780,000 ha.

18 Survey by Maria Luiza Barbosa for UNICA, questions prepared by CTC – Centro de Tecnologia Canavieira, Jan 2005

Total APP (banks, springs, lagoons)	8.1 % of the sugar cane area
APP with natural woods	3.4%
APP with reforestation	0.8%
Abandoned APP	2.9%
APP with sugar cane	0.6%

Those estimations allow the total APPs relative to riverside woods for the sugar cane crops alone in São Paulo, to be evaluated at around 200,000 ha. The portion having natural woods is important, and the reforested area has grown over the past few years. The importance of implementing programs like that of the São Paulo SMA, besides the necessary protection of water streams, has to do with the ability to foster a restoration of the plant biodiversity in the region if the programs follow appropriate criteria.

5.5 Summary and conclusions

• 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 Mha, compared to 227 Mha 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 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, 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.

Chapter 6: Soil occupation: new production areas and biodiversity

Agriculture uses only 7% of Brazilian territory (0.7% for sugar cane): most of the country's soil is occupied by pastures (around 35%) and forests (55%). The expansion of sugar cane crops has essentially replaced other agricultural exploitations or cattle-breeding. In the next few years expansion will take place in western São Paulo State and its borders, in areas that are very far from the currrent biomes of the Amazon Rain Forest, the Pantanal or the remaining Atlantic Forest. Occupation of the cerrado must be planned to protect biodiversity and water resources.

6.1 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. It also raises questions about areas and locations used over the past few years and trends for the years to come, as well as 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 Mha, which represents around 11 percent of the Brazilian territory. Brazil's entire crop area corresponded to ~60 Mha.

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 has provided a legal basis that did not exist in most countries, and still does not exist in many. The Convention was never ratified by the United States, for example; and, in many cases, a Biological Inventory has either yet to be prepared or remains incomplete.

Steps for the implementation of this 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]

1 TARLOCK, D.: "Biodiversity and endangered species", *in*: DERNBACH, J.C. (Ed.): *Stumbling toward sustainability*, Washington DC, Environmental Law Institute, 2002

In the following paragraphs we will address the use of agricultural soil in Brazil, its evolution, and the position of agriculture; including a certain emphasis on the current "agricultural border", i.e. the *cerrado*, or savannah. We will also address the reality of Brazil's plant biodiversity: the present knowledge; the situation in the main biomes; and preservation. In conclusion, we will 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 will not be covered being less relevant. An assessment conducted by 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.

2 "Agroecologia da cana-de-açúcar", EMBRAPA, 2003; www.cana.cnpm.embrapa.br (Nov 2003)

6.2 Use of agricultural soil in Brazil

The Brazilian territory covers an area of 850 Mha, between 5 ºN and 33 ºS of lattitude, 34 ºW and 73 ºW 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 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 IES – Institute for Environment and Sustainability. Table 1 shows the distribution of soil use.

3 EMBRAPA, "Mapa da cobertura vegetal do Brasil", www.cobveget.cnpm.embrapa.br/resulta

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

Area	Area (Mha)	Distribution
Agriculture and pasture	297	35%
Forests	464	55%
Fields and savannahs	73	9%
Cities, rivers and others	17	2%
Total	851	100%

According to 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	CW	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 within ten years' time.

Crop areas currently total 60 Mha (around 21 Mha of which with soybean, and 12 Mha with corn). The "pasture" areas correspond to around 227 Mha, including a portion featuring a certain degree of degradation. Forest areas (including those used for forestry) total 464 Mha. An estimation by 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. Veja Magazine,[6] with some help from technicians of the Ministry of Agriculture and IBGE – Brazilian Institute of Geography and Statistics, reports that around 30 percent of this territory is occupied by crops and livestock, resulting in 106 million hectares, one of the world's largest agricultural reserves, with fertile soil that is almost all located in savannah areas.

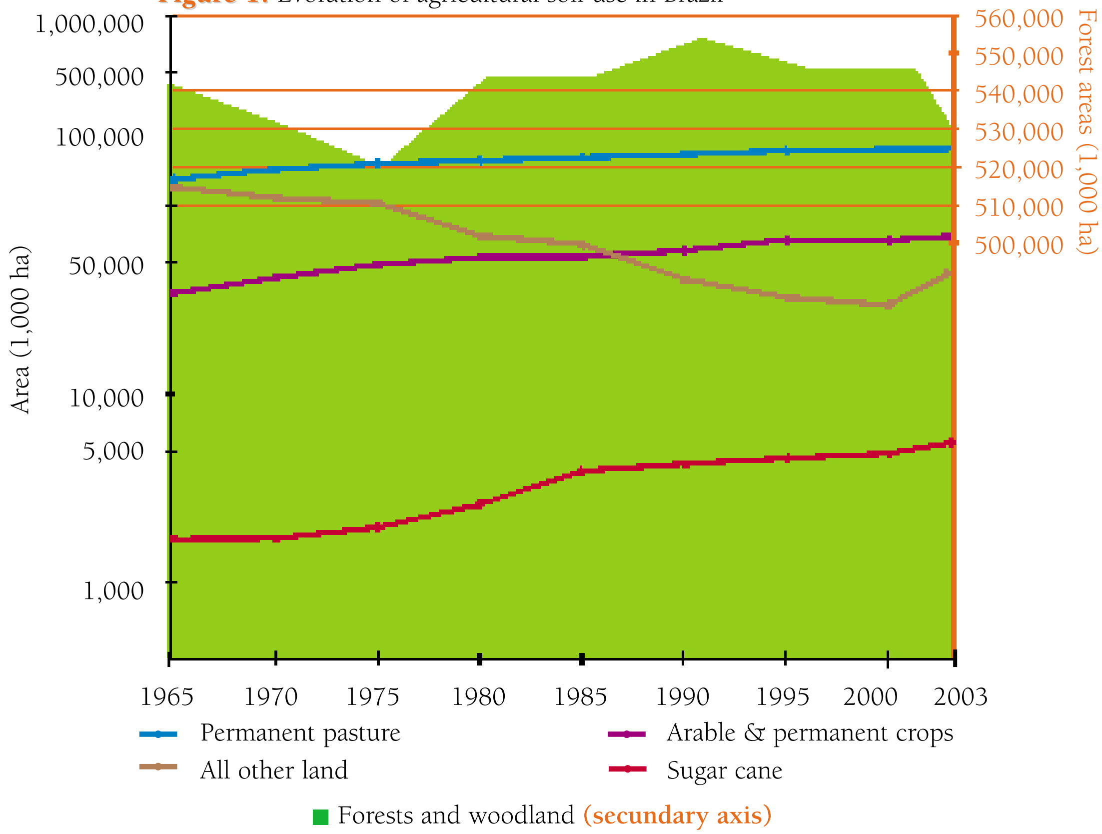
A simplified description of the evolution of soil use over the past few decades is shown in **Figure 1**:

4 IBGE: "Levantamento sistemático da produção agrícola para 2003-2004", site www.sidra.ibge.gov.br (June 2004)

5 CASTIGLIONI, V.B.R.: *Avaliação da expansão da produção de etanol no Brasil*, Brasilia, EMBRAPA, CGEE-NAE, 2004

6 Revista Veja, "Agricultura – O tamanho do Brasil que põe a mesa", Edition 1843, March 3 2004

Figure 1: Evolution of agricultural soil use in Brazil



Source: FAO - Food and Agriculture Organization of The United Nations, http://faostat.fao.org/faostat

This information provided by the FAO – Food and Agriculture Organization of the United Nations with respect to Brazil, indicates that the expansion of crops and livestock area over the past few years has coincided with the decrease in degraded pasture areas and grassland with some shrubs, rather than forest areas. A study conducted by IPEA – Institute of Applied Economic Research[7] 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 *cerrado*. The three paragraphs below sum up the remarks contained in a report prepared by EMBRAPA[8] in 2000.

The cerrado is a Brazilian ecosystem that covers an area of 204 Mha (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 genera of fungi), and the sources of five major river basins. Virtually ignored until 1960, today it is in a prominent position for 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

7 O Estado de São Paulo Newspaper, Caderno Economia, January 11 2005, p. 4

8 Information provided by Bressan, A.,M.: "Agriculture", from EMBRAPA reports, 2000

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. Fifty Mha of it was occupied by cultivated pastures, 12 Mha by annual cultures, and 2 Mha by permanent cultures. The activities of* EMBRAPA Cerrados *since 1975 have been essential to that development. Today, the* cerrado *continue to be the natural agricutural border of the country's South and Southeast regions, with a huge potential for development.*

The cerrado *has a savannah vegetation pervaded by gallery forests, with several "grades" between* campo limpo *(clean grass fields) and gallery forests. The soil is highly weathered, deep, and well-drained, but has a low natural fertility and high acidity. However, there is plenty of limestone in the* cerrado*, and the topography favors mechanization.*

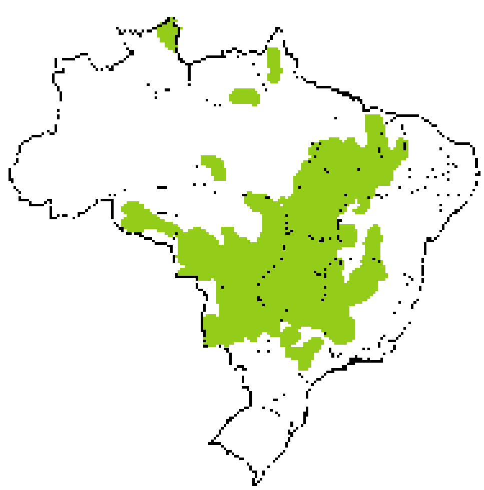
In 2000, the main production systems included:

Cattle-breeding (for slaughter), with cultivated pastures (~50 Mha, 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 restrictions on the use of soil, which is considered in the EIA/RIMA analysis for any undertaking.

Figure 2: Areas where the cerrados are located



Source: EMPRABA information (2004)

The expansion of sugar cane crops in areas that were originally taken up by *cerrados* has been relatively small. In most cases, it seems to have taken place by replacing other covers that had already subsituted for the *cerrado* (usually pastures). The current trends seem to be towards the continuation of such a situation: 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 Mha in the same period, and the expansion of the entire crop area in the region between 1994 and 2004 amounted to 7 Mha). 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 region. 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 on 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.

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

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Brazil, a mega-diverse country

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*. These are ecosystems considered to be hotspots because of the threat to, and the wide diversity of, related endemic species.[9] Brazil has one of the world's richest floras, estimated at 50,000 to 60,000 angiosperm species (plants with flowers).

9 Mittermeyer, R.A.; Myers, N.; Mittermeyer, C.G: "Hotspots Earth's biologically richest and most endangered terrestrial ecoregions", New York, cemex, Conservation International, 1999

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.[10] This 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 setting the preservation priorities for Brazil's main biomes. Base maps were drafted for the 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.[11]

10 www.mma.gov.br/biodiversidade/probio/sub.html

11 Canhos, V.P.C; Siqueira, M.F.: "D.A.L. 2004 – Mudanças climáticas globais: conseqüências para a biodiversidade", Nota Técnica elaborada para o Núcleo de Assuntos Estratégicos da Presidência da República, Centro de Gestão e Estudos Estratégicos, Contrato no. 083/2004

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 (2005), 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 Rain Forest	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
Campos Sulinos	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 areas capable of representing the original biodiversity of the biome were preserved. 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. At least 50 percent of the original *Cerrado* has been totally destroyed.[12] 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.[13] 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 São Paulo State, where the *Cerrado* vegetation currently covers less than 1 percent of the territory, cases of deforestation for the expansion of agriculture and cattle-breeding have been 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 in 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*. If poorly planned, the agricultural occupation of these areas undermine the stability of the entire Pantanal ecosystem. Likewise, the charging areas of the Guarani aquifer, in the Southeast region, which are usually covered by the *Cerrado* vegetation, need to be preserved.

Building impact and vulnerability scenarios

Harmonizing socioeconomic development with environmental preservation is no easy task. The development and implementation of appropriate sustainable development strategies will be increasingly based on knowledge management, and the 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 of 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 on access to and integration of information available from information distributing sources. They will also depend on the use of advanced computer-based data analysis and space viewing tools, as well as the building of impact and vulnerability scenarios.

12 Felfili, J.M.; Haridasan, M.; Mendonça, R.C.; Filgueiras, T.S.; Silva Junior, M.C.: "Projeto Biogeografia do bioma cerrado: vegetação e solos", Cadernos de Geociências, 12, Rio de Janeiro, 1994, pp. 75-165

13 www.ibama.gov.br/

The *Instituto Virtual da Biodiversidade*, (Virtual Institute of Biodiversity), related to the FAPESP Biota Program,[14] 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[15] and *species*Link.[16] These systems have been 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 São Paulo State, 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 one million records of collections related to system (data obtained in Nov 10, 2006).

14 www.biota.org.br

15 http://sinbiota.cria.org.br/atlas

16 http://splink.cria.org.br

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 the direction field research and the identification of biologically richer areas, as well as the delimitation of potentialy rich in threatened or endemic species. It also helps identifying species that could be used in environmental recovery efforts, assessing potential threats posed by invading species and evaluating the possible 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 use a sub-set of conditions for the ecological niche, combining species occurrence data with the environmental characteristics of the occurrence spot, seeking to define places having similar environmental characteristics through algorithms. The niche modeling sets the enviromental 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.[17] In order to assess the impact of climate changes on 162 tree species of the Brazilian *Cerrado*, Siqueira &

17 PETERSON, A.T.: "Predicting species' geographic distributions based on ecological niche modeling", Condor 103, 2001, pp.599-605

Peterson[18] used modeling methodologies to generate potential geographic distribution maps for such species based on the fundamental 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 within a period of 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. It must also take 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 may migrate to the south and overlap degraded landscapes of the *Cerrado* vegetation in São Paulo State, 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.

18 Siqueira, M.F.; Peterson, A.T.: "Consequences of global climate change for geographic distributions of cerrado tree species", Biota Neotropica 3(2), 2003, www.biotaneotropica.org.br/v3n2/pt/download?article+BN00803022003+item

6.4 Sugar cane growing expansion areas

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Brazil's sugar cane crops covered an area of 1.0 million hectares in 1955, reaching 1.5 million hectares in 1962.[19] That area remained virtually stable for the ten subsequent years.[20] 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 between the 1994/1995 and 1997/1998 crops (motivated by sugar exports). After a short stabilization period, a new expansion cycle has begun. The areas increased to 5.9 million hectares for the 2005/2006 crop, 4.7 million ha (80%) of which in the Center-South region.

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

19 Junqueira, A.A.B.; Dantas, B.: "A cana-de-açúcar no Brasil", *in*: *Cultura e adubação da cana-de-açúcar*, Ed. Instit. Brasil. de Potassa, 27-60, 1964

20 Fernandes, A.C.: "Produção e produtividades da cana-de-açúcar no Brasil", Centro de Tecnologia Canavieira, internal report

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

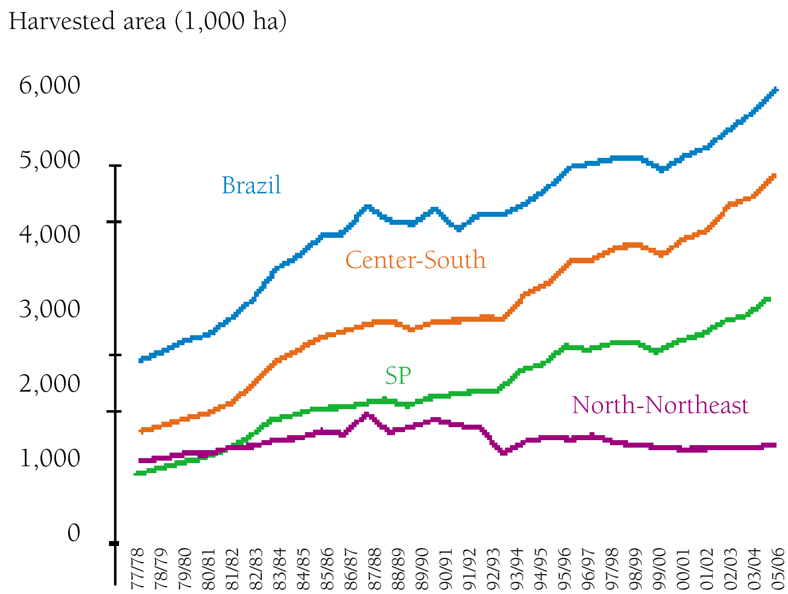
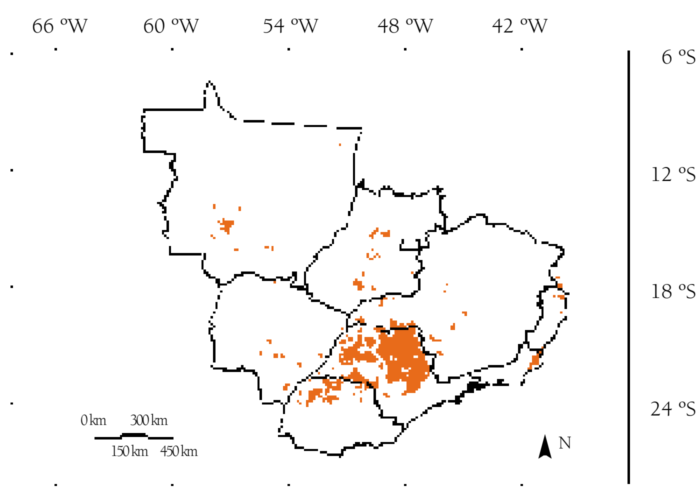


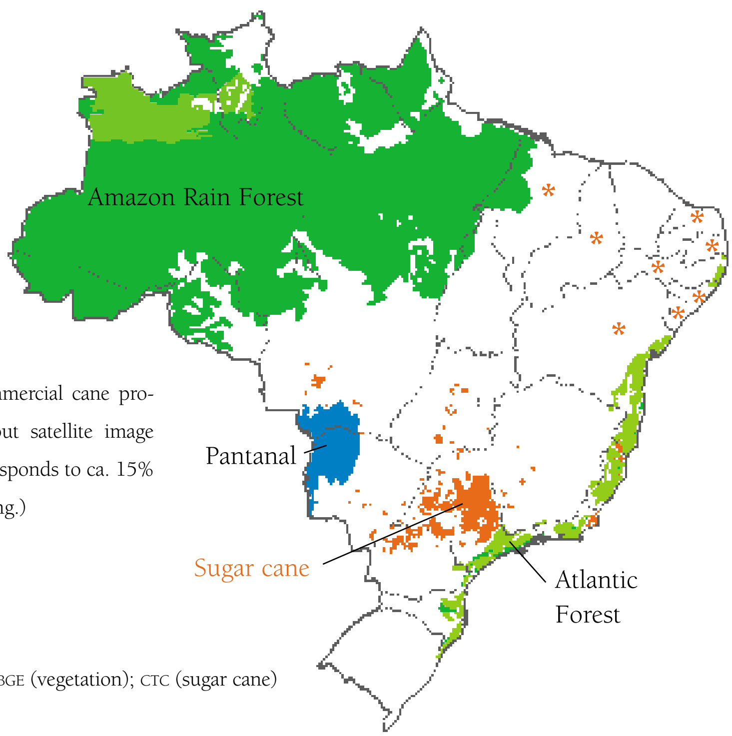
Figure 4: Sugar cane map in the Center-South region of Brazil, 2004/05 Crop



2004/05 Crop
Source: CTC, 2006

Figure 4 shows the sugar cane harvesting area in the Center-South region for the 2005/06 crop, which was mapped through remote sensing by the Sugar Cane 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 5: Sugar cane areas in the Center-South region and Brazil's main biomes



*: States with commercial cane production, but without satellite image survey. (N-NE corresponds to ca. 15% of national harvesting.)

Sources: IBGE (vegetation); CTC (sugar cane)

For the past 10 crop seasons (1991/92-2005/06), the sugar cane crop area in the Center-South region increased by 1.9 million hectares (69%), distributed as shown in **Table 4**. São Paulo State accounts for most of that increase (70% of the total).

With the regional differences in productivity, the Center-South region produced around 85 percent of Brazil's sugar cane in 2005, distributed among 238 units. It is important to note that the Center-South region's sugar cane production increased from 176.2 to 281.5 Mt (53%, or 5% per year) from 1992/93 to 2002/03. However, the very units already in existence in 1992 accounted for almost all of that increase with some reduction in the number of producing units in the period (from 248 to 216). Actually, the great expansion at new agricultural frontiers occurs only in the last crop seasons, with average growth of 10% per year from 2003/04 to 2005/06.

Table 4: Variation of the sugar cane harvesting area in Center-Southern states for the last 15 crops; ha

State	1993	2003	Variation
São Paulo	1,852,400	3,141,777	70%
Paraná	172,296	406,989	136%
Mato Grosso	51,293	206,849	303%
Goiás	101,919	196,586	93%
Mato Grosso do Sul	65,358	135,427	107%
Minas Gerais	275,709	349,394	27%
Espírito Santo	34,157	64,373	88%
Rio de Janeiro	195,352	169,139	-13%
Others	75,347	49,153	-35%
Center-South	2,823,831	4,719,687	67%

Source: IBGE – Anuários Estatísticos

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, Mha

	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

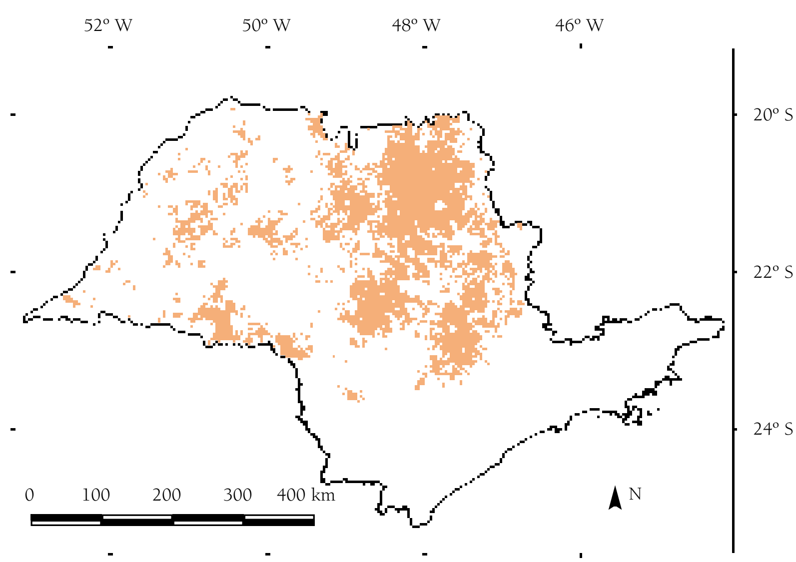
The tables show that the total crop area has been practically constant during a period (since 1990) in which sugar cane crops have been growing rapidly. What has happened is crop substitution. In this specific case, sugar cane has mostly been replacing orange and other crops, while also occupying pasture areas. The system, in fact, is known to be very dynamic, responding to prices (international prices in the case of oranges and coffee), and the crops are changed (and reversed, in some cases) after 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 São Paulo State, CTC has been mapping the growth of the sugar cane crop area for the past 8 crops (1999-2006) 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 have mainly started taking up pasture areas.

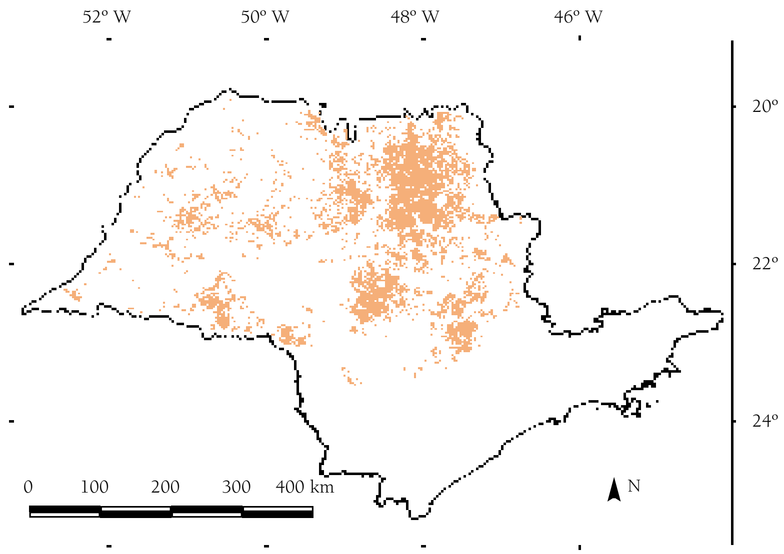
For the most part, the identified trend is towards an increase in the sugar cane growing area in the Center-South region's current production areas. The emphasis is on western São Paulo, the areas by the borders with Mato Grosso, and some areas in the states of Goiás and Minas Gerais.

Figure 6: Mapping of the São Paulo State's sugar cane areas for the 99/00 and 06/07 crops, and area increase for the period

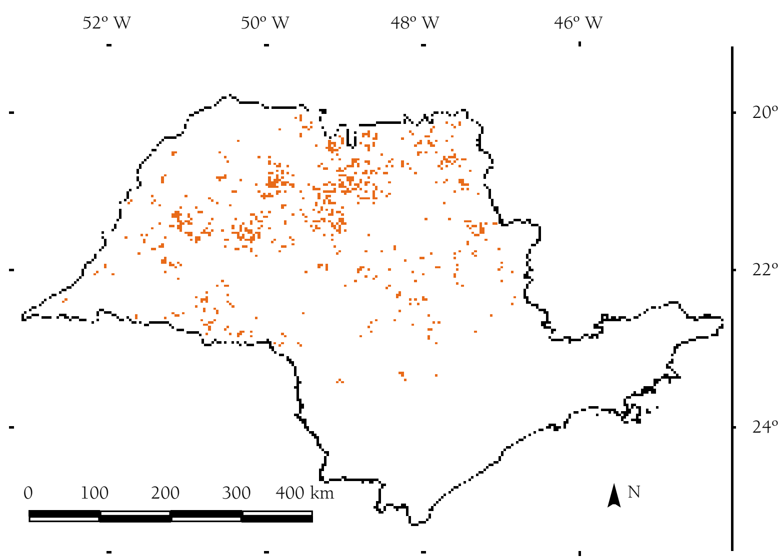


1999/2000 Crop

Source: CTC



2006/07 Crop
Source: INPE, CTC



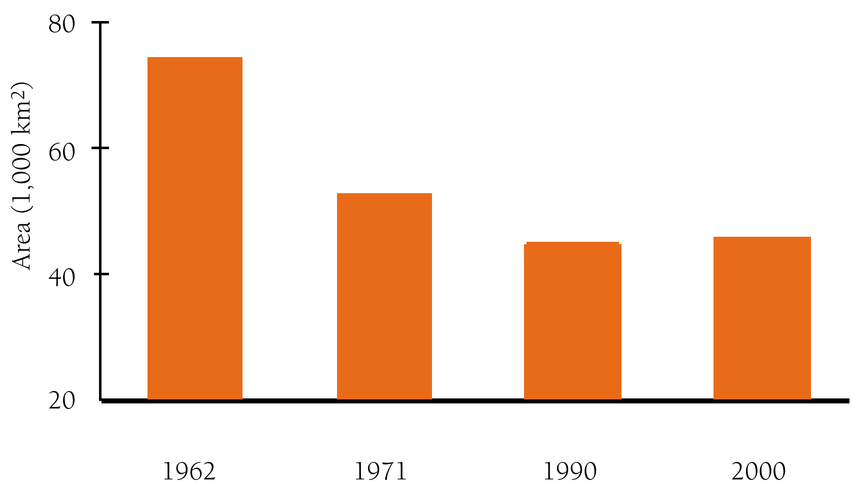
Increase in area from 1999/2000 to 2006/07 crops
Source: CTC

The forest areas once covered 82 percent of the territory in São Paulo State back when Brazil was discovered.[21] Since the beginning of the country's colonization in the 16th century, they have systematically decreased. The evolution of coffee crops was one of the main causes. In the last decade, however, this trend has reversed. The latest forest inventory has reported a rise of 3.8 percent in the area with natural vegetation. **Figure 7** shows the remaining natural vegetation area of the state, indicating that the recent sugar cane expansion periods in the state (starting in 1994) coincide with the forest area recovery period. In part, the restoration of riverside woods has contributed to this process (see **item 5.4**). This trend may be enhanced.

21 Zorzetto; R. *et al.*: "A floresta renasce", Revista Pesquisa FAPESP, n.º 91, Sep. 2003, pp. 48-52

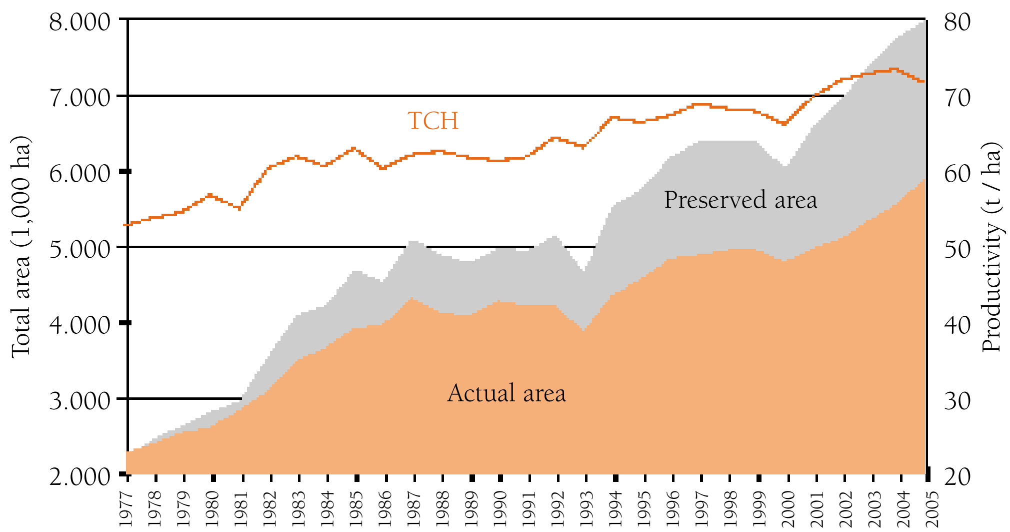
Figure 7: Remaining natural vegetation area in São Paulo State

Source: Note **21**



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 had been no productivity gain, the area to be used for growing the same amount of sugar cane would have had to be 2.0 million hectares larger than that used for the 2005/2006 crop.

Figure 8: Actual production area and area saved by the introduction of technology



6.5 Summary and conclusions

• With 850 Mha, Brazil has a large portion of its territory able to meet the conditions to economically support agricultural production, while preserving vast forest areas within 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 has taken place mostly in degraded pasture areas and *campos* (grassland with some shrubs), rather than forest areas. The area currently occupied by sugar cane crops represents only 0.7 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 thus far been relatively small, 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 in the

Center-South region occurred in existing units; new agricultural borders were involved very slightly. In São Paulo, the growth has occurred through the substitution of pastures and other crops.

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

• 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 be undergoing 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 has been the first biome to be partially replaced through the exploitation of wood, agriculture and cattle-breeding along Brazil's entire coast. Among many others, the sugar cane culture (Center-South and Northeast) is now in areas originally covered by that biome. This process by far preceded any concern for preservation, and consequently, preservation requires the 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 therefore highly important in this context.

Chapter 7: Preservation of agricultural soil

Recent sugar cane expansion in Brazil has happened mostly in poor soils (pasture land and strongly anthropized cerrados), contributing for their improvement with the addition of organic matter and fertilizers. Erosion losses are smaller than in many other important cultures; it is expected that the growing harvesting of cane without burning will further improve this condition, with the use of the remaining trash in the soil.

7.1 Introduction

Changes in the use of soil usually change the soil organic carbon content. Each type of occupation, soil and handling has a long-term "equilibrium" rate. For example, the equilibrium rate for forests with forestry activities is estimated at 45 t carbon / ha; for wood with fast rotation, 35 t / ha; and for grains,[1] 25 t / ha in the United States (the periods for equilibrium extending for dozens of years).

In the more general case of soil that used to be covered with forests (including *cerrado* vegetation) and were turned into pastures, there is a clear trend towards a decrease in the carbon content of the soil. There are studies involving direct planting practices for use with grains, showing that an appropriate handling allows the contents to be near those found in forests.[2]

In Brazil, 59 percent of the soil is latosol and clay soil, where 39 to 70 percent of the organic carbon is stored up to 30 cm deep, with great spacial variations. The growth of sugar cane crops is incorporating poorer areas (mostly extensive pastures) and shall contribute to the recovery of the soil through the addition of fertilizers and corrective substances, also including vinasse, filtercake and trash. This will lead to higher levels of carbon in the soil and decreased erosion.

Soil erosion loss is a serious problem, depending on the kind of crop, the agricultural practices, the soil type and the rainfall pattern. Pimentel[3] estimated the mean loss of soil due to erosion in the annual agricultural production in the United States at 18.1 t / ha. Corn (21.8 t / ha), soybean (40.9) and wheat (14.1) typically show high rates, whereas the rate for permanent crops and hay (upon establishment) is 0.2, and rotation forests 2 to 4 t / ha.

Today the sugar cane culture in Brazil is renowned for its relatively small soil erosion loss (compared with soybean and corn, for example). This situation keeps improving as harvesting without burning expands, thereby reducing losses to very low rates, comparable to those for direct planting in annual cultures.[4]

1 Ranney, J.W.; Mann, L.K.: "Environmental considerations in energy crop production", Biomass and Bioenergy, vol. 6, no. 3, 1994

2 Lima, M.A.: "Oportunidades: potencial de negócios em agropecuária, florestas, energia e resíduos", NT Solos e Pecuária, EMBRAPA, 2003

3 Pimentel, D.; Krummel, J.: "Biomass energy and soil erosion: assessment of resource costs"; Biomass, vol. 14, 1987, pp.15-38, cited in Ranney, J.W.: "Environmental considerations in energy crop production", Biomass and Bioenergy, vol. 6, no. 3, 1994

4 Rossetto, R.: "A cultura da cana, da degradação à conservação", Visão Agrícola, ESALQ-USP, Ano 1, Jan 2004

7.2 Soil used for sugar cane growing in Brazil; expansion tends

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Brazil covers a total area of 8.5 million km^2, and as a result, it has a wide variety of soil and climates (rainfall conditions). This makes any potential production study highly complex. In the total area, 84 percent of the soil has acidity problems (soil with high concentrations of aluminum and, on a smaller scale, iron and manganese), 16 percent lack oxygen certain times of the year, 7 percent is shallow soil, 2 percent is soil with high concentrations of salts, and 9 percent is soil with no relevant limitations on agricultural exploitation.[5] Leaving out of account the slopes where the soil is located, which can be a limiting factor to agricultural use, Brazil has a huge production/productivity potential when advanced agricultural handling practices are in place.

As a matter of fact, the successful agricultural occupation of the soil in the Brazilian *cerrado* over the past fifteen years has been supported by the application of advanced agricultural technology. The soils found in the large agricultural border formed by the *cerrados* in Brazil's Center-West region are listed in **Table 1**:

Table 1: Approximate distribution of the largest soil units in the *cerrados*

Soil types			Area (million ha)	Occupation (%)
Order	Sub-order	Group		
Latosol	Red yellow		77.4	38.0
	Red		20.6	10.1
	Ferric red		7.3	3.6
Plintosols			18.9	9.3
Neosol	Arenic		37.7	18.5
	Lithic		17.0	8.4
Clay soils	Red yellow	Dystrophic	1.9	0.9
		Eutrophic	7.3	3.6
Nitosol	Red		3.5	1.7
Cambisol	Haplite		6.1	3.0
Gleysol			4.1	2.0
Others			1.8	0.9
Total			203.8	100.0

Source: Notes 6, 7, 8

5 AMARAL, F.C.S., PEREIRA N.R.; CARVALHO JR., W.: "Principais limitações dos solos do Brasil", EMBRAPA Solos, site: www.cnps.embrapa.br/solosbr/ (2004), Rio de Janeiro, 1999

6 LOPES, A.S.: *Solos sob cerrado, características, propriedades e manejo*, Piracicaba, Instituto da Potassa & Fosfato - Instituto Internacional da Potassa, 1983

7 MALAVOLTA, E.; KLIEMANN, H.J.: *Desordens nutricionais no cerrado*, Piracicaba, Potafós, 1985

8 GOEDERT, W.J.: "Solos dos cerrados: tecnologias e estratégias de manejo", *in*: GOEDERT, W.J. (Ed.): São Paulo – Nobel, EMBRAPA, Centro de Pesquisa Agropecuária dos Cerrados, Brasília, 1986

On the other hand, a study conducted for the purpose of assessing the potential for agriculture in western São Paulo[9] using images provided by the Landsat 7 satellite and field work based on determinations of IAC,[10] has mapped the use and physicochemical properties of the soil covering approximately 583,200 hectares in two representative locations of the current sugar cane expansion areas within São Paulo State. It concluded that the vast majority of soil (or soil combinations) found in that region are the same as that found in the agricultural border formed by the *cerrados* in Brazil's Center-West region in terms of classification (unit, fertility and texture). The mean soil fertility in the sampled areas (V% = base saturation index) for soil covered by pastures and sugar cane and corn crops, decreases, as shown:

9 DONZELLI, J.L.; JOAQUIM, A.C.; SIMÕES, M.S.; SOUZA, S.A.V.: "Plano de expansão da Usina Catanduva", Piracicaba, Centro de Tecnologia Canavieira (Internal report), 2003a

10 IAC – Instituto Agronômico/Centro Nacional de Pesquisa de Solos: "Mapa pedológico do Estado de São Paulo", Campinas, 1999

Table 2: Mean soil fertility for different kinds of use

		Sugar cane	Corn	Pasture
Layer		A	A	A
P resin	mg / dm^3	2	2	2
M. O.	g / dm^3	9	11	8
pH		4,9	4,9	4,4
K	$mmol / dm^3$	1,6	1,1	0,7
Ca		11	12	6
Mg		5	5	3
Al		2	2	4
SB		17	18	10
CTC		34	35	27
V	%	50	50	36

8 see p. 140

The occupation of areas in the Brazilian *cerrado* have led to the following soil use distribution[11]:

Non-*cerrado*	49.11%
Non-anthropized	16.77%
Anthropized	17.45%
Highly anthropized	16.72%

At least two classes, "non-*cerrado*" and "highly anthropized *cerrado*", can be used for sustainable agriculture with no deforestation required, as they are areas that have already been occupied, probably with some kind of crop or pasture. The total area of the *cerrados*,[8-11] i.e. 2.0 million km^2, and

11 MACHADO, R.B.; RAMOS NETO, M.B.; PEREIRA, P.G.P.; CALDAS, E.F.; GONÇALVES, D.A.; SANTOS, N.S.; TABOR, K.; STEINIGER, M.: "Estimativas de perda de área do cerrado brasileiro", Technical report, site: www.conservation.org.br/arquivos/RelatDesmatamCerrado.pdf Brasília, Conservação Internacional, 2004

considering that a vast majority of the pastures probably fall into the "highly anthropized" class, reach 17 percent, or 34 million ha. If their soil has a base saturation index similar to that found in the studies of western São Paulo (around 36%), soil fertility can be expected to increase at a mean rate of 39 percent just by adjusting the base saturation index to V% = 50%, through the addition of corrective substances and fertilizers. This would be possible with the introduction of advanced, sustainable agricultural handling practices in these soils, which could then be effectively incorporated into Brazil's agricultural area.

Chemical correction (limestone and gypsum) and fertilizers are required, but the sustainability of the production entails the addition of organic matter (OM) to the soil. The use of this soils for growing crops that add OM and/or chemical-organic fertilization, as in the case of sugar cane, will contribute to improving their physicochemical conditions.

There is an increase in the OM contents of soil used for growing sugar cane and corn compared to those of pastures (**Table 2**). Studies[12] of the accumulation of OM in a soil where sugar cane is grown (eutroferric red latosol), conducted in the Ribeirão Preto region, found an addition of 13.5 t (MS) / ha. This data is consistent with other results obtained in São Paulo, and lower than those achieved for Brazil's Northeast region.[12] Experiments[13] have shown the great potential for sugar cane growing without trash burning of increasing the concentration of organic matter in the soil, especially arenic (AQ), which is known to have very low carbon content.

Evaluations of these results, and of studies conducted with the use of vinasse (**Chapter 9**) point to the potential for improvement of the soil through sugar cane planting in both physical (due to the addition of organic matter by the trash and roots), and nutritional aspects (through addition of wastes from the sugar and ethanol production processes, vinasse and filtercake).

12 Luca, E.F. *et. al*: "Efeitos da colheita sem queima da cana-de-açúcar sobre a matéria orgânica e a biomassa microbiana de um latossolo roxo", presented in: XXVII Congresso Brasileiro de Ciência do Solo, Brasília, June 1999

13 Feller, C.L.: "Efeitos da colheita sem queima da cana-de-açúcar sob a dinâmica de carbono e propriedades do solo", Report by FAPESP/USP/CENA (98/12648-3), Piracicaba, Universidade de São Paulo, Centro de Energia Nuclear na Agricultura, 2001

7.3 Erosion in sugar cane crops: situation and prospects

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The erosion process is the leading cause of agricultural soil degradation. The application of soil conservation techniques aim 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.*[14] 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 3**).

Table 3: Soil and water losses in annual and semi-permanent crops

Annual crop	Losses	
	Soil	Water
	t / ha·year	% 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 + beans	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 counted on 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).

Soil erosion loss assessments conducted for a period of eleven years (ending in 2004),[15] comparing in the same sugar cane crop area in the Catanduva region, São Paulo State, on a clay red yellow, eutrophic, sandy/medium-textured soil (PVA-25), showed that between the initial survey[15] and that which concluded in 2004, there were no significant

14 Bertoni, J.; Pastana, F.I.; Lombardi Neto, F.; Benatti Junior, R.: "Conclusões gerais das pesquisas sobre conservação de solo no Instituto Agronômico", Campinas, Instituto Agronômico, 2nd print, Jan 1982, Circular 20, 57 p., *in*: Lombardi Neto, F.; Bellinazi Jr, R.: *Simpósio sobre terraceamento agrícola*, Campinas, SP, Fundação Cargill, 1998

15 CTC, "Relatório final de projeto Carta de Solos", Piracicaba, Centro de Tecnologia Canavieira, Technical report 604 – Volumes I and II, 1993

changes in profile horizon thickness or in the physicochemical composition of the soil in the area (**Tables 4** and **5**).

Table 4: Physicochemical analyses of the 4 trenches (2004)

Trench	Compartment	Depth	Diagnostic horizon	Clay	Org. Mat.	Base Sum	CEC	V
		cm		g / kg	g / dm^3	mmol / dm^3	mmol / dm^3	%
1	22	0-25	Ap	102	11	35	48	73.1
		25-50	Ap/B1	183	6	30	43	70.0
		90-110	B2	324	4	22	37	60.6
2	27	0-25	Ap	101	9	27	40	67.4
		25-50	Ap/B1	268	6	23	38	61.6
		90-110	B2	325	4	28	43	64.8
3	22	0-25	Ap	110	11	27	45	60.0
		25-50	Ap/B1	198	6	25	43	57.4
		90-110	B2	250	2	21	37	56.3
4	27	0-25	Ap	118	9	46	59	78.0
		25-50	Ap/B1	160	4	30	44	67.4
		90-110	B2	381	2	36	52	69.4

For the clay content (g / kg) of the Ap horizon, the variations fall within the "very sandy" textural class; the thickness of the soil allows it to classified as clayey with Ap horizon variation of 30 cm to 60 cm. Such thickness was never lower than 35 cm, which indicates that the erosion processes in sugar cane crops were efficiently minimized, preserving the physical part of the soil.

The base sum (Ca + Mg + K) indicates the adequacy of the conservation technique applied to the area: it was maintained or, in some cases, increased, showing that there was no chemical degradation of the area. Reaffirming this trend, the *cation exchange capacity* (CEC) of the soil today is clearly higher than that found in historic data.

The base saturation (V%) of a soil shows how its cation exchange capacity (CEC) is saturated by cations (Ca + Mg + K = base sum) important to the development and growing of plants. The V% values were maintained, which demonstrates that the soil conservation technique has minimized the environmental impacts.

Table 5: Initial physicochemical analysis (1993)

Spot no.	Depth	Diagnostic horizon	Clay	Org. Mat.	Base Sum	CEC	V
	cm		g / kg	g / dm^3	mmol / dm^3	mmol / dm^3	%
148	0-25	Ap	140	13.1	28.1	38.8	72.0
	25-50	Ap/B1	140	11.6	28.4	41.1	69.0
	90-110	B2	290	9.3	26.4	43.7	60.0
150	0-25	Ap	120	13.4	24.2	36.6	66.0
	25-50	Ap/B1	160	11.6	22.7	34.2	66.0
	90-110	B2	330	9.3	30.6	41.0	75.0
155	0-25	Ap	150	10.2	19.3	32.3	60.0
	25-50	Ap/B1	140	10.5	24.0	39.4	61.0
	90-110	B2	330	7.8	34.5	43.5	79.0
156	0-25	Ap	120	12.8	18.4	38.4	48.0
	25-50	Ap/B1	180	7.4	13.8	31.6	44.0
	90-110	B2	320	7.9	30.0	42.1	71.0

The technological evolution in sugar cane growing has enabled sugar cane harvesting without trash burning in some areas. Using this technique, considerable amounts of trash (around 10-15 tons of dry matter ha·year) are left on the soil, which allows the introduction of reduced soil preparation practices[16, 17] on the re-planting of the sugar cane crop. The growing use of the two technologies (harvesting without burning and reduced preparation) may raise the soil conservation level for sugar cane crops over the next few years, since the trash protects the soil (Table 6)[14, 17] from the direct impact of rain drops, while reduced preparation contributes to smaller soil disruption, as in the case of direct planting of cereals.

16 Gandini, M.O.; Gazon, A.L.; Conde A.J.; Donzelli, J.L.: "Conservação de solos e planejamento da sulcação em áreas de colheita mecânica de cana crua", Congresso Nacional STAB, Recife, 1996

14 see p. 143

17 Conde, A.J.; Donzelli, J.L.: "Manejo conservacionista do solo para áreas de colheita mecanizada de cana queimada e sem queimar", VII Seminário de Tecnologia Agronômica, Centro de Tecnologia Canavieira, Piracicaba, 1997

Table 6: Effect of the use of crop waste on soil erosion loss

Handling systems	Losses	
	Soil (t / ha)	Water (% rain)
Burnt straw	20.2	8.0
Buried straw	13.8	5.8
Straw on the surface	6.5	2.5

Average rainfall: 1,300 mm; slopes ranging from 8.5 to 12 percent

7.4 Summary and conclusions

• Sugar cane crops have been expanding in areas having poorer soil (especially "highly anthropized *cerrados*", mostly extensive pastures). They contribute to the recovery of the soil 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, 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 of direct planting in annual cultures.

Chapter 8: Use of agrochemicals

Among the main sugar cane pests, the sugar cane beetle and spittlebug are currently biologically controlled. Plant diseases are fought with the selection of disease-resistant varieties in genetic improvement programs. No transgenic variety is used today, but the developments in course may help reducing the use of chemicals in the future. In Brazil, sugar cane crops still use more herbicides than coffee and corn crops, less herbicides than citric crops and the same amount as soybeans.

8.1 Introduction

Several principles of the Rio Declaration and, more specifically, Chapters 14 and 19 of Agenda 21, refer to the cautions to be taken in using chemicals (including pesticides). The principle concerned with precaution requires control measures for cases in which there still isn't a fully established scientific certainty about environmental degradation. The precaution principle would have us avoid some of the major problems facing us today worldwide, such as water contamination with pesticides, and very expensive cleaning actions. The inter-generation equity principle needs to be followed in order to prevent the repetition of problems for future generations, such as contaminated agricultural and aquatic ecosystems through the use of DDT, PCBs and dioxins. Another principle refers to the restriction on commercial movement of hazardous products and the people's access to information on their use and movement.

In Agenda 21, Chapter 14 includes "Integrated pest control and management in agriculture", which recommends, among other things, promoting the "use of biological control agents and organic pesticides". Chapter 19 establishes a program for control over toxic chemicals. The concerns are justified by the problems that were established during the relatively short period of intensified "modern" agriculture. For example, the use of pesticides (insecticides, herbicides and fungicides) doubled in the United States (from 400 to 800 million lb / year) between 1965 and 1985,[1] while the use of non-agricultural pesticides dropped 33 percent between 1970 and 1990.

1 GOLDMAN, L.R.: "Toxic chemicals and pesticides", *in*: DERNBACH, J.C. (Ed.): *Stumbling toward sustainability*, Washington DC, Environmental Law Institute, 2002

In several situations, there is now a growing interest in new technologies (PIPs) based on genetic modifications of plants designed to add resistance to pests or pesticide characteristics. Agenda 21 highlights some of the promises of these technologies (more specific, and cleaner in production), but also mentions the potential problems, such as the scattering of genes, adverse impacts on non-targeted organisms, potential food contamination, etc. In the United States, the EPA approved nine PIPs between 1992 and 2002 (most of which with genes for Bt toxin production) and rejected two.

There are differences between countries in legislations on PIPs. For example, in the United States there are no specific labeling procedures for GMO foods, but there are in the European Union. Brazil is gradually defining its position, especially in regard to soybean. The sugar cane industry has not yet started to make efforts to get authorizations to commercial planting of transgenic varieties, but it may do so shortly (see **item 10.3**).

Other ways to reduce the use of pesticides include the application of biological control. Brazil's major programs in this field are already in use in sugar cane crops. This has been done in a more (commercially) limited but very important way, given the results and orientation for the future, "organic" production.

Organic production is much more than reducing the use of pesticides. Organic production of brown sugar and spirits[2] has been used in relatively small areas for ten years now. Large-scale production was developed in Brazil by the São Francisco mill, based in São Paulo, where 13,500 ha of sugar cane plantations have been certified for organic production since 1997. Other mills are certified; there are a few certifying agencies for the production of sugar and spirits. The requirements vary, but they usually include the utilization of areas having not used pesticides and trash burning for a few years, and the preservation of ecosystems (forest corridors, diversity islands). The conservation of soil and water resources is checked, and the use of pesticides under predetermined amounts and other conditions may be allowed in some cases. Biological controls (pests and diseases) and soil coverage with straw (in substitution of herbicides) are given priority. One other resource is manual harrowing. Vinasse and filtercake recycling is an essential part of fertilization, for which low-solubility organic or mineral fertilizers can be used. The cautions extend to industrial production. On such an important scale, and having its production certified for seven years now, the S. Francisco mill reports rises of 10 percent in productivity and 50 to 60 percent in costs.[2]

2 Rossetto, R.: "O sistema de cultivo orgânico", Visão Agrícola, ESALQ-USP, Ano 1, Jan 2004

That work is considered very important for testing the limits of the process of reducing impacts for sugar cane crops, and should be watched very closely over the coming years.

8.2 Agrochemicals (pesticides and others)

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8.2.1 Legislation and controls in Brazil

The Brazilian legislation on pesticides was updated by Law no. 7,802, in July 11, 1989, as regulated by Decree no. 98,816 of January 11, 1990. Agrochemicals include herbicides, insecticides, fungicides, maturators, adhesive spreading agents, and defoliants, among others. "Related" products include all biological and microbial products, vegetable extracts and pheromones that are used to control pests and diseases, yet have no toxicological characteristics and risks. The legislation is complemented by Ordinances by the Crops and Livestock Protection Department, IBAMA – Brazilian Institute of the Environment and ANVISA – Brazilian Sanitary Authority.

The recommendation to use pesticides and related products is made by professionals in the agricultural, cattle-breeding and forestry industries by way of specific Agronomical Prescriptions for each place and problem, among listed products. It is incumbent upon the State Departments of Agriculture and the CREAs (Regional Councils of Engineering, Architecture and Agronomy) to inspect and notify. Pesticides are listed upon evaluation by agronomical efficiency, residue tests, and toxicological and environmental studies. The Ministries of Agriculture, Environment and Health are responsible for these evaluations.

8.2.2 Use of pesticides (insecticides, fungicides and others) in sugar cane crops

The level of consumption of insecticides, fungicides, acaricides and other pesticides in Brazil's sugar cane crops is lower than in citric, corn, coffee and soybean crops. Herbicides, which are the group most widely used as commercially available products or active ingredients, are addressed in **item 8.3**. The fungicide consumption is virtually nil, while insecticide consumption is relatively low (**Tables 1** and **2**).

Table 1: Consumption of fungicides, 1999-2003

		Coffee	Sugar cane	Citric	Corn[1]	Soybean[1]
Commercial product (kg / ha)	1999	6.98	0.00	4.54	0.02	0.34
	2000	5.22	0.00	4.98	0.02	0.40
	2001	1.62	0.00	4.71	0.03	0.37
	2002	1.32	0.00	5.02	0.03	0.42
	2003	1.76	0.00	5.51	0.03	0.56
Active ingredient (kg / ha)	1999	1.38	0.00	2.38	0.01	0.16
	2000	1.61	0.00	2.49	0.01	0.18
	2001	0.75	0.00	2.89	0.01	0.16
	2002	0.55	0.00	3.00	0.01	0.16
	2003	0.66	0.00	3.56	0.01	0.16

1 The use of agrochemicals for seed treatment was considered

Source: Table prepared from data provided by SINDAG and IBGE/CONAB

Table 2: Consumption of insecticides, 1999-2003

		Coffee	Sugar cane	Citric	Corn[1]	Soybean[1]
Commercial product (kg / ha)	1999	4.72	0.44	2.71	0.39	0.91
	2000	4.47	0.41	2.32	0.51	0.99
	2001	2.35	0.51	2.71	0.47	1.07
	2002	0.97	0.48	2.62	0.42	1.02
	2003	2.22	0.54	2.43	0.53	1.03
Active ingredient (kg / ha)	1999	0.91	0.06	1.06	0.12	0.39
	2000	0.65	0.11	0.96	0.17	0.41
	2001	0.36	0.13	0.88	0.16	0.45
	2002	0.14	0.14	0.66	0.14	0.43
	2003	0.26	0.12	0.72	0.18	0.46

1 The use of agrochemicals for seed treatment was considered

Source: Table prepared from data provided by SINDAG and IBGE/CONAB

Table 3: Consumption of acaricides, 1999-2003

		Coffee	Sugar cane	Citric	Corn[1]	Soybean[1]
Commercial product (kg / ha)	1999	0.02	0.00	12.45	0.00	0.00
	2000	0.02	0.00	13.77	0.00	0.00
	2001	0.11	0.00	14.82	0.00	0.01
	2002	0.08	0.00	16.98	0.00	0.01
	2003	0.00	0.05	16.00	0.00	0.01
Active ingredient (kg / ha)	1999	0.00	0.00	8.94	0.00	0.00
	2000	0.00	0.00	9.94	0.00	0.00
	2001	0.08	0.00	10.77	0.00	0.01
	2002	0.06	0.00	12.23	0.00	0.01
	2003	0.07	0.00	10.78	0.00	0.01

1 The use of agrochemicals for seed treatment was considered

Source: Table prepared from data provided by SINDAG and IBGE/CONAB

Table 4: Consumption of other agricultural defensives, 1999-2003

		Coffee	Sugar cane	Citric	Corn[1]	Soybean[1]
Commercial product (kg / ha)	1999	0.15	0.12	0.37	0.08	0.74
	2000	0.34	0.13	2.07	0.08	0.71
	2001	0.64	0.09	2.88	0.08	0.65
	2002	0.28	0.10	3.21	0.14	0.60
	2003	0.26	0.08	2.41	0.12	0.80
Active ingredient (kg / ha)	1999	0.06	0.03	0.28	0.05	0.52
	2000	0.15	0.04	1.83	0.04	0.45
	2001	0.32	0.04	2.34	0.06	0.43
	2002	0.17	0.04	2.70	0.09	0.38
	2003	0.14	0.04	1.97	0.09	0.51

1 The use of agrochemicals for seed treatment was considered

Source: Table prepared from data provided by SINDAG and IBGE/CONAB

For reference, the use of insecticides (active ingredients) in the U.S. was 0.38 kg / ha for corn, and 0.26 kg / ha for soybean in 1991. The use of fungicides in that country was 0.0008 kg / ha for corn, and 0.001 kg / ha for soybean.[3]

3 Ranney, J.W.; Mann, L.K.: "Environmental considerations in energy crop production", Biomass and Bioenergy vol. 6, no. 3, 1994, pp. 211-228

The SINDAG (National Syndicate for the Agricultural Defensives Industry) shows that the importation of agricultural defensives (active ingredient) decrease from 111 thousand ton in 2004 to 89 thousand t in 2005.[4]

The reduction occurred in fungicides (32.7%), acaricides (29.1%), herbicides (22.1%) and insecticides (11.1%). Total imports decreased 22.0%. Total sales to the internal market also decreased 5.6%, but the sales of insecticides increased. For sugar cane, the large increases in production led to larger defensive sales (from 292 M US$ to 362 M US$); defensives for sugar cane corresponded (2004) to 6.5% of total agricultural defensive sales in Brazil.

4 Neves, E.M.; Rodrigues, L.; Sakamoto, R.L. Defensivos: demanda em queda. Agroanalysis. Fundação Getulio Vargas/São Paulo. Outubro. 2006.

8.2.3 Main sugar cane pests and controls

Sugar cane beetle (Diatraea saccharalis)

The sugar cane is a moth species that occurs throughout the Brazilian territory and in several countries in South, Central and North America. It has been determined that for each 1-percent infestation, the mean losses in sugar cane production amount to 0.77 percent, plus 0.25 percent in sugar production and 0.20 percent in ethanol production.

Dealing with the sugar cane beetle involves mainly the biological control method, which consists of getting parasitoids and releasing beneficial insects in the most severely infected sugar cane plantations. The most commonly used parasitoid today is the *Cotesia flavipes* wasp. **Figure 1** shows the release of parasitoids and their effect on CTC associated mills between 1980 and 2005. In 2005, 39.2 million masses of *C. flavipes* were released in those units, corresponding to 1.96 billion adult wasps, which resulted in a mean Infestation Intensity of 2.6 percent of internodes damaged by the beetle.

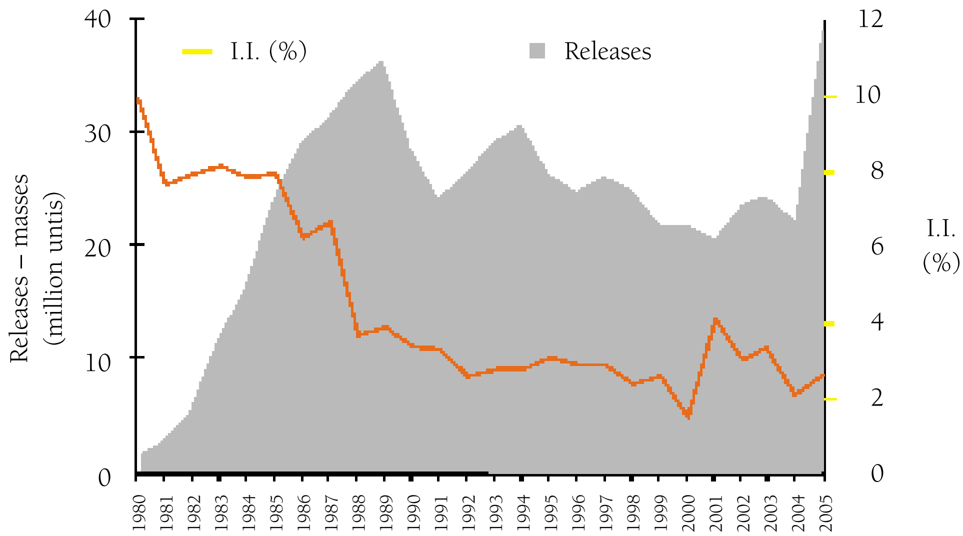
The alternative to biological control is chemical control, which has a lot of drawbacks.[5] Sugar cane crop areas with mechanical harvesting and no burning can use biological control as well.

5 Arrigoni, E.D.B.: "Uso de defensivos agrícolas na cultura da cana-de-açúcar", Report to UNICA, Piracicaba, CTC, 2005

Defoliating caterpillars

There is no efficient control for the five species of sugar cane defoliating caterpillars because they are only detected when the most damage has already taken place, and only one defoliation brings no significant loss. The control

Figure 1: Number of parasitoids released (adult Tachinid flies and masses of *Cotesia flavipes*) and Infestation Intensity (I.I.%) in CTC associated mills in the period from 1980 to 2005.



by natural parasitoids and natural predators is very high. These pests occur in virtually all of Brazil's sugar cane producing regions, and there is no trend towards an increase in occurrence of this pest in areas where harvesting is performed without straw burning.

Spittlebugs

The *Mahanarva fimbriolata* occurs in São Paulo and neighboring states. Depending on the population levels, it can cause significant losses of 15 tons of sugar cane/ha·year on average, while reducing the sugar content by 1.5 percentage points. With the growth of mechanical harvesting, there will be a significant increase in areas infested by spittlebugs. The areas where the population will reach levels needing control are estimated at 20 percent.

Microbial control by application of the *Metarhizium anisopliae* fungus is the most recommended, most efficient biological method nowadays. Today, when properly implemented, it is the best, most cost-effective option. In the 2004/05 crop, 26 tons of this fungus were used in 25,600 ha of infested areas.

Monitoring spittlebug populations is essential to define the strategy for its biological control; the preservation of the control agents for the spittlebug and also for other insects (like the sugar cane beetle) must be considered. This biological control shows economic advantages over the use of insecticides. Legal limitations in cane burning practices are increasing the need for spittlebug control.

Leaf-cutting ants

Leaf-cutting ants are important; in São Paulo State, the main species are *Atta bisphaerica* and *A. capiguara.*

Each adult leaf-cutting ant causes mean losses of three tons of sugar cane per harvesting season, and the raw material loses quality because of the decreased sucrose content. The mean infestation is currently estimated at 0.5 to 0.7 adult leaf-cutting ant nests per hectare of sugar cane crop in the Center-South region, which corresponds to losses of 1.5 to 2.1 tons of sugar cane / ha·year.

Leaf-cutting ants are controlled by specialized teams that search all of the sugar cane crops at the mills, using thermofogging with motorized equipment to apply the insecticide mixture. Mechanical harvesting of sugar cane without straw burning favors occurrence of this pest for making it harder to locate and control the nests.

Migdolus fryanus (Migdolus beetle)

Migdolus fryanus is a beetle of the Vesperidae family whose larval stage causes damage to the sugar cane root system, which begins to show drought symptoms. A mean reduction of 30 tons / ha·year occurs in infested areas compared to areas treated with soil insecticides. In São Paulo State, the sugar cane crops affected by the pest (that occurs in the Center-South region) cover an area estimated at 100,000 ha.

Mostly, it is controlled by application of insecticides on the distributed sugar cane seedling at the planting furrow, in a joint mechanical operation. This is done in order to protect rural workers from contact with the insecticide. It is indispensable to thoroughly define the infested area and the infestation level in order to reduce the use of pesticides. The harvesting method, either raw or through burning, does not interfere with the population and spread of this pest.

Sphenophorus levis (sphenophorus or sugar cane weevil)

The sugar cane weevil, of the Curculionidae family, that causes damage to the sprouts and the base of developing stalks. It causes losses of 20 to 23 tons / ha·year in infested areas.

The infested area expands rapidly, probably because of the movement of seedlings. The most recommended method to control this pest is the cultural method, consisting of the early destruction of rootstocks in the infested areas to be reformed. The control methods that include insecticide application or toxic bait distribution have the drawbacks of being more costly and requiring constant re-applications.

Mechanical harvesting of sugar cane without trash burning significantly favors the populations of this pest and infestations.

Termites and other pests

Losses in infested areas are estimated at 10 tons of sugar cane / ha·year. Control is based on identification of areas where sugar cane stumps are damaged or areas to be reformed and, using this information, a recommendation of chemical control only where there is potential for damage. The soil pest monitoring method in reform areas enabled an 70-percent reduction of chemical control (data provided by CTC), thereby reducing costs and risks to operators and the environment.

No significant difference in soil pest populations and damages caused thereby occurs in different harvesting systems.

8.2.4 Sugar cane diseases and variety improvement programs

Sugar cane, as semi-permanent culture of annual cycle and vegetative propagation, forms a crop planted with a certain variety that is reformed only after 4 to 5 years of commercial use. These characteristics determine that the only economically feasible disease control option is to use varieties genetically resistant to the main crop diseases. Diseases constitute one of the main reasons for the replacement of a commercially grown variety.

Nine bacteria, 159 fungi, 8 viruses and 1 mycoplasma are known to the 109 sugar cane producing countries and regions, totaling 177 pathogens that cause the crop diseases. Of these, only 40 of them have been reported in Brazil.

The main disease occurrences that have prompted Brazil to replace varieties and caused production losses are as follows:

- The Mosaic virus epidemic in the 1920's, which caused serious losses and led to a quick replacement of the varieties known as "noble sugar canes" with hybrid varieties imported form Java.
- A major sugar cane smut epidemic in the 1980's, associated with the occurrence of rust (1996), affected the NA56-79 variety. Thies variety, which represented 50 percent of the crop area in São Paulo State, was quickly replaced with the SP71-6163 variety.
- A new disease called "Sugar Cane Yellow Leaf Syndrome" (SCYLV), affecting the SP6163 variety in 1990, which overtook this variety in all sugar cane plantations in 3 years and caused production losses of up to 40 percent, forcing its fast replacement.

The phytopathology work performed in accordance with the variety improvement program (at CTC) has been designed to prevent the coming of new pathogens, as well as avoid or minimize losses caused by existing pathogens. There are quarantine safeguard works for foreign varieties that use pathogen testing and provision of information on progenitor responses, as well as new clones for the main diseases occurring in Brazil. These procedures contribute to the efforts of those who work to improve the selection of disease-resistant varieties, and allow the producer to choose the best variety without worrying about the damages caused by diseases.

Notwithstanding the widespread of disease-resistant progenitors in the crossings that have been made, diseases like the sugar cane smut and the Mosaic virus, which limit the use of a new variety, account for the elimination of almost 50 percent of all selected plants (at CTC), thereby reducing selection opportunities for other desirable characteristics.

Recent advances in molecular biology and genetic engineering have an enormous potential for assisting sugar cane improvement experts in producing commercial varieties featuring high productivity and improved adaptation to biotic and abiotic stresses. The first transgenic sugar cane plants produced in Brazil were obtained in 1994 at CTC. Since then, sugar cane plants resistant to the glufosinate ammonium[6] and glyphosate[7] herbicides, the Mosaic virus (SCMV), the sugar cane yellow leaf virus (SCYLV) and the main sugar cane pest,[8] the beetle *Diatraea saccharalis*, have been produced.

The efforts to obtain transgenic sugar cane varieties resistant to the damaging pests that cause agricultural productivity losses and decreased sugar and ethanol production, have been numerous. Among the relevant strategies, it is worth pointing out the use of proteinase inhibitors,[9] lectin[10] production and the *Bacillus thuringiensis* (Bt) protein.

The most commonly used strategy to induce insect-resistance in plants by genetic engineering, is the insertion of genes that encode the *Cry* proteins produced by the Bt. These proteins are toxic to insects and are activated by the alkaline pH of the digestive system of the insect and by proteinases. Upon activation, they cause the insect to die within a few hours by breaking its osmotic balance. Genetically modified sugar cane containing the Cry1Ab Bt virus was evaluated by CTC in a field experiment and displayed an excellent level of sugar cane beetle resistance.[11]

6 Falco, M.C.; Neto, A.T.; Ulian, E.C.: "Transformation and expression of a gene for herbicide resistance in a Brazilian sugarcane plant cell", Rep 19 (12) 2000, pp. 1188-1194

7 Ulian, E.C.; Braga, D.P.V.; Lavrik, P.B.; Baerson, S.R.: "Transgenic sugar cane plants for roundup tolerance obtained through microprojectile bombardment", *in*: Plant and Animal Genome VIII San Diego, Abstracts San Diego: NCGR, 2000, p. 205

8 Braga, D.P.V.; Arrigoni, E.D.B.; Burnquist, W.L.; Silva-Filho, M.C.; Ulian, E.C.: "A new approach for control of *Diatraea saccharalis* (Lepidoptera: Crambidae) through the expression of an insecticidal CryIa(b) protein in transgenic sugarcane", Proc. Int. Soc. Sugar Cane Technol, vol. 24, 2001, pp.331-336

9 Shepherd, K.M.; Smith, G.R.; Joyce, P.A., Nutt, K.A.; McQualter, R.B.; McGhie, T.K.; Allsopp, P.G.: "Engineering cane-grub-tolerant transgenic sugarcane", *in*: Pathology and Molecular Biology Workshop, Kwazulu-Natal, Abstracts, 1997, Kwazulu-Natal: SASAExS, p 16

10 Irvine, J.E.; Mirkov, T.E.: "The development of genetic transformation of sugar cane in Texas", Sugar Journal vol. 6,1997, pp. 25-29

11 Braga, D.P.V.; Arrigoni, E.D.B.; Silva-Filho, M.C.; Ulian, E.C.: "Expression of the Cry1Ab protein in genetically modified sugar cane for the control of *Diatraea saccharalis* (Lepidoptara: Crambidae)", Journal of New Seeds 5(2/3), 2003, pp. 209-222

8.3 Pesticides: herbicides

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8.3.1 Weeds and the decrease in sugar cane productivity

Weeds lead to substantial losses in sugar cane crops. The American Weed Science Society[12] estimated losses caused by infesting plants in the US at 20 percent. In Brazil (1980), production losses of 24 percent occurred,[13] and much higher losses have been reported.[14, 15] The competition between weeds and sugar cane in Brazil has been the subject of extensive studies. The interference, and interference prevention periods, may vary even with the sugar cane cycle. Productivity losses may range from 10 to more than 80 percent.[16] The interference intensity of sugar cane weeds depends on factors related to the crop (type, species or variety, planting furrow spacing, and sowing density), the weed community (specific composition, density and distribution), and environmental factors.[17]

8.3.2 Main weeds in Brazil's sugar cane crops

A total of 566 plant species found in Brazil (Lorenzi, 2000) have been described, and can be considered undesirable plants or weeds. These

Table 5: The main weeds in sugar cane crops

Scientific name	Common name
Cyperus rotundus L.	Nutgrass
Cynodon dactylon (L.) Pers.	Bermuda grass
Digitaria sanguinalis (L.) Scop.	Hairy crabgrass; large crabgrass
Portulaca oleracea L.	Little hogweed
Eleusine indica (L.) Gaertn.	Goosegrass; Indian goosegrass
Echinochloa colonum (L.) Link.	Junglegrass; junglerice
Sorghum halepense (L.) Pers.	Johnsongrass
Panicum maximum Jacq.	Guinea grass
Rottboelia exaltata L. f.	Itchgrass
Amaranthus spinosus L.	Spiny amaranth
Ageratum conyzoides L.	Whiteweed; billygoat weed
Cyperus esculentus L.	Yellow nutsedge

12 Kissman, H.: "Controle de plantas infestantes: passado em futuro", *in*: Semana do Controle de Plantas Daninhas, 10, 1990, Bandeirantes, Anais Bandeirantes: Fundação Faculdade de Agronomia "Luiz Meneghel", 1990, pp.01-02

13 Colleti, J.T.; Rodrigues, J.C.S.; Giacomini, G.M.: "Influência da época de controle da matocompetição na produtividade da cana-de-açúcar, ciclo de 12 meses", *in*: Congresso Brasileiro de Herbicidas e Ervas Daninhas, 13º, Ilhéus/Itabuna, 1980, Resumos, Itabuna, Bahia, SBHED, CEPLAC, 1980, p. 35

14 Blanco, H.G.: "Ecologia das plantas daninhas: competição das plantas daninhas com culturas brasileiras", *in*: Marcondes, D.A.S. *et al.*: *Controle integrado de plantas daninhas*, São Paulo, CREA, 1982, pp. 42-75

15 Lorenzi, H.: "Plantas daninhas e seu controle na cultura da cana-de-açúcar", *in*: Copersucar – Reunião Técnica Agronômica, 1983, pp. 59-73

16 Gravena, R.; Kuva, M.A.; Mattos, E.D.; Pitelli, R.A.; Alves, P.L.C.A.: "Períodos de convivência e controle das plantas daninhas em cana-planta (*Saccharum spp*)", *in*: XXIII Congresso Brasileiro da Ciência das Plantas Daninhas, Gramado, RS, 2002, Resumos: Gramado, RS, SBCPD, 2002, p. 95

17 Pitelli, R.A.; Kuva, M.A.: "Bases para manejo integrado de plantas daninhas em cana-de-açúcar", *in*: Semana da Cana-de-Açúcar de Piracicaba, 2, Piracicaba, Abril 22-25, 1997, anais

18 see p. 158

species are distributed among several Families and Orders of the Monocotyledone and Dichotyledone classes, Agiospermae division. Approximately 150 species of these occur in sugar cane crops most often. The 12 species that account for the most damage to the crops (1970) are listed in **Table 5**.[18]

Today, the following should be added: Signalgrass (*Brachiaria decumbens* Stapf.); Alexandergrass (*Brachiaria plantaginea*); Mexican fireplant or Wild poinsettia (*Euphorbia heterophilla* L..); Tropical spiderwort (*Commelina benghalensis* L.); and the weeds known as *Ipomea violacea* (Ipomoeas), which are comprised of several species and have become very important in crops mechanically harvested without trash burning.

8.3.3 Main control methods

The control or management of weeds encompasses specific methods or combinations of mechanical, cultural, chemical and biological methods, making up an extremely dynamic process that is often reviewed. The use of pesticides is regulated by the legislation referred to in **item 8.2.1**.

Preventive measures seek to prevent weeds from being introduced, developing and disseminating in a certain area where they don't exist. For example, using seedlings from areas that are free of pests, while maintaining and controlling weeds in vinasse channels, constitute preventive control methods.[19] And so is the cleaning of agricultural machines when shifting working places.[20]

Cultural measures are practices like crop rotation, crop plant spacing variation, and the use of green covers.

Mechanical or Physical measures include soil preparation for planting, uprooting, harrowing, ground preparation, flooding, burning, dead cover and mechanical growing.

Biological measures entail the use of natural enemies (pests and diseases) to control weeds, including the possible allelopathic inhibition of one plant by another. The control of nutgrass (*Cyperus rotundus* L) using jack bean (*Canavalia ensiformis*) is an example of this possibility.[21] In Brazil, natural enemies have not been used in weed control.

Chemical measures include the use of herbicides, many of which having a selective ability to eliminate some plant types or species, while preserving others. They are currently the main weed controlling tool, and their proper utilization can be efficient and safe.

18 Holm, L.G.; Plucknett, D.L.; Pancho, J.V.; Herberger, J.P.: *The world's worst weeds. Distribution and Biology*, Honolulu, The East-West Center, University Press of Hawaii, 1977, 609 p.

19 Lorenzi, H.: "Tiririca – Uma séria ameaça aos canaviais", Boletim Técnico Copersucar n. 36, Cooperativa Central dos Produtores de Açúcar e Álcool do Estado de São Paulo, 1986, pp. 3-10

20 Pitelli, R.A.: "Manejo Integrado de plantas daninhas", *in: Controle integrado de plantas daninhas*, São Paulo, CREA – Conselho Regional de Engenharia Arquitetura e Agronomia – SP, 1982, pp. 28-41

21 Deuber, R.: *Ciência das plantas daninhas: fundamentos*, Jaboticabal, FUNEP, vol. 1, 1992

Integrated weed management consists of simultaneously using control measures, generally of preventive nature, as well as mechanical and chemical methods. Using seedlings produced in nutgrass-free areas and leguminosae on rotation, and preparing the soil (mechanical control) help limit the necessary chemical control of pre-emerging herbicides, in order to prevent germination of weed seeds. Drastically reducing their emergence and population, these four measures make up a management technique that is widely used in weed control. The need to control several weed species (mono and dicotyledones) before the sugar cane grows and for as long a period as possible during the crop cycle makes broad-spectrum, long-residual power herbicides the most commonly used.

The use of herbicides in sugar cane crops (kg of active ingredient / ha) remained stable from 2000 to 2003. The decreased use in 1999 was due to the producers' difficult financial situation at the time (**Table 6**). Compared to other crops, sugar cane uses more herbicides that coffee and corn in Brazil, a little less than citric crops do, and the same amount as soybean crops do. However, the values are close.

Table 6: Use of herbicides in the main commercial crops[22]

Relative herbicide consumption	Destination	Coffee	Sugar cane	Citric	Corn[1]	Soybean[1]
Commercial product (kg / ha)	1999	3.38	2.78	3.23	2.51	4.44
	2000	3.10	3.91	3.28	3.21	5.24
	2001	3.99	5.24	5.80	2.84	4.57
	2002	2.57	4.23	5.53	2.58	4.45
	2003	2.42	4.14	6.69	3.31	4.92
	Mean	3.09	4.06	4.90	2.89	4.73
Active ingredient (kg / ha)	1999	1.84	1.52	1.75	1.21	2.01
	2000	1.56	2.17	1.69	1.54	2.33
	2001	2.01	2.77	2.46	1.38	2.09
	2002	1.35	2.22	2.63	1.24	2.05
	2003	1.27	2.29	3.40	1.70	2.50
	Mean	1.61	2.20	2.39	1.41	2.20

1 The use of agrochemicals for seed treatment was considered

Source: Table prepared from data provided by SINDAG and IBGE/CONAB

22 MARZABAL NEVES, E.; GASTADI, H.L.G. "Demanda relativa por defensivos agrícolas pelas principais culturas comerciais, pós-desvalorização do Real", ESALQ-USP, Aug 2004

In the United States, the use of active ingredient was 3.06 kg/ha, for corn, and 1.83 for soybean.[23]

8.3.4 Herbicide resistance of weeds

The rise of herbicide-resistant weeds is recent,[24] dating back to the 1960's, but have increased in number very fast. There are now 286 herbicide-resistant biotypes around the world,[25] spread over 171 species (102 monocotyledones and 69 dicotyledones). The countries having the highest numbers of herbicide-resistant weed biotypes are the United States (107), Canada (43), Australia (41), France (30), and Spain (26). Several cases of herbicide resistance have been reported in Brazil's rice and soybean crops since 1993. Soybean crops have the largest number of herbicide-resistant biotypes, perhaps because they are the leading herbicide users (more than 50%).[24] Even though the size of crop areas currently having herbicide-resistant weed biotypes is relatively small, their expansion has been fast and requires preventive and management measures in order to preserve the efficiency of herbicides. Strategies to prevent or retard the rise or evolution of herbicide-resistant weeds include crop rotation, mechanical control, planning on and use of different herbicides, and integrated control (cultural, mechanical and chemical).

8.3.5 Trends

The sugar cane culture in Brazil, especially in São Paulo State, will use two technologies for harvesting over the next few years: with and without trash burning for harvesting.

In the first case (raw sugar cane), the straw remaining on the soil was initially believed to be sufficient for controlling weeds throughout the crop cycle.[26, 27, 28] However, it is known today that the straw causes physical, chemical and biological change[29, 30] that favors the development of species that used to be rare or unusual in sugar cane plantations on uncovered soil. In addition, careless bush control during formation of the sugar cane crop may lead to severe infestations on the rootstocks. Therefore, herbicides are expected to continue in use, mostly in the pre-emerging mode, and integrated with mechanical control of soil preparation. An efficient sugar cane plant control will reduce the potential for infestation on the first rootstocks, thereby diminishing the need for modern herbicides. These herbicides need rain in order to reach the soil surface when used, thereby showing limited efficiency in drought times. Some mills have opted to remove the straw from

23 Ranney, J.W.; Mann, L.K.: "Environmental considerations in energy crop production", Biomass and Bioenergy, vol. 6, no. 3, 1994, pp. 211-228

24 Chistofolleti, P.J.; Ovejero, R.F.L.; Carvalho, J.C.: *Aspectos de resistência de plantas daninhas a herbicidas*, Campinas, SP, Associação Brasileira de Ação a Resistência de Plantas aos Herbicidas (HRAC-BR), 2nd ed.; 2004, 100 p.

25 Weed Science, "International survey of herbicide resistant weeds" (2004), site: www.weedscience.org/in.asp (01/05/2003)

26 Phillips, M.: "Trash blanketing on the increase in Bundaberg", *in*: BSES Bulletin, no. 55, 1996, pp. 14-15

27 Manechini, C.: "Manejo agronômico da cana crua", *in*: Anais do VII Seminário de Tecnologia Agronômica Copersucar, 1997, pp. 309-327

28 Arevalo, R.A.; Bertoncini, E.I.: "Manejo químico de plantas daninhas nos resíduos de colheita de cana crua", STAB vol. 17. no. 4, 1999, pp. 36-38

29 see p. 161

30 see p. 161

the sugar cane line in order to control the spittlebugs and reduce the herbicide application area.

In burned sugar cane areas no change is expected in weed control techniques.

8.4 Summary and conclusions

• The concern about the impacts 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 citric, corn, coffee and soybean crops; the use of insecticides is low, and that of fungicides is virtually nil.

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

• Sugar cane diseases are fought 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) 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 unusual of pests.

28 Pitelli, R.A.: "Plantas daninhas no sistema de plantio direto de culturas anuais", *in*: Congresso Latinoamericano de Malezas, 12, Montevidéu, 1995, Resumos Montevidéu: INIA (INIA. Technical Series, 56), 1995, pp. 37-42

29 Velini, E.D.; Negrisoli, E.: "Controle de plantas daninhas em cana crua", *in*: Anais do XXII Congresso Brasileiro da Ciência das Plantas Daninhas, Foz do Iguaçu, PR, 2000, pp. 148-163

Chapter 9:
Use of fertilizers

Among Brazil's large crops (area larger than 1 Mha), sugar cane uses smaller amounts of fertilizers than cotton, coffee and oranges, 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: Australia uses 48 percent more. The most significant factor is nutrient recycling through the application of industrial wastes, as vinasse and filtercake.

9.1 Introduction

Although Brazilian agriculture has been going through a great expansion period over the past few decades, and has reached a high level of competitiveness in export markets, it is not characterized by an intensive use of fertilizers in general. In 1998, the mean use intensity (kg / ha N-P_2O_5-K_2O) was equivalent to that of the United States and Venezuela, around 40 percent of the intensity in France or China, and 22 percent of that of the Netherlands. In terms of total consumption, Brazil had[1] an annual consumption of 7.68 Mt in 2002, representing around 5.4 percent of the total world consumption. At the same time, the United States used 13.7 percent, France used 2.8 percent, China 28.1 percent, India 11.4 percent, and Europe 15.5 percent.

1 FAO: Faostat Database 2004, http://faostat.fao.org/faostat , Feb 2005

The impact of fertilizers on water quality depends on many use conditions. Fertilization with nitrogen, sandy soil, irrigated soil, and soil with shallow water tables, are more vulnerable to nitrate contamination. The potential of nitrogen for reaching and contaminating water also depends on the quantity used, the use by the plant, the level of nutrients and organic matter in the soil, and the weather.

In the case of sugar cane crops in Brazil, an important characteristic is the full recycling of waste to the field. The rise in ethanol production required the vinasse to be taken care of. The solution was to recycle it for the crop. The benefits provided by this ferti-irrigation have become evident, and an optimization of potassium utilization was sought and yielded very favorable results. The infrastructure created has enabled the development to use the water from the industrial process and the ashes from boilers. Filtercake recycling processes were also developed, thereby increasing the supply of nutrients to the field. Recycling is addressed in this chapter because of its ability to reduce the need for external mineral fertilizers, and also from an environmental standpoint, i.e. water quality protection. The evolution of the applicable legislation has been very important and appropriate in this respect to the leading producing areas, such as São Paulo.

Another interesting aspect of the sugar cane culture in Brazil is that the mean nitrogen extraction by the crops is much higher than the fertilizer dose used in the first harvesting season. For example, besides the N mineralized in the crop and organic matter remainders on the soil, an explanation that has been investigated is the fixation of several bacteria in the rhizosphere and roots. The advanced uses of this possibility are the subject of studies.[2]

2 DEMATTÊ, J.L.I.: "Recuperação e manutenção da fertilidade dos solos", Visão Agrícola, ESALQ-USP, Ano 1, Jan 2004

9.2 The use of fertilizers in Brazil's sugar cane production

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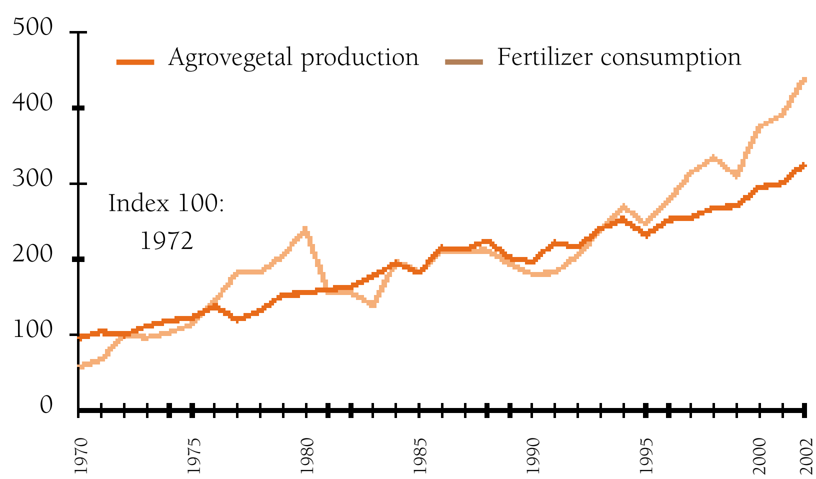
For the most part, the nutrient balance in Brazilian agriculture (taken as a whole) is unsatisfactory. In other words, the amount of nutrients taken is larger than the amount applied. The soil is progressively impoverished in terms of nutrients. Persisting in the long term, this would become a threat to the sustainability of agriculture.[3] On the other hand, both productivity and fertilizer consumption have increased[4] in Brazil over the past three decades (**Figure 1**).

3 FAO – Food and Agriculture Organization of the United Nations: "Use of fertilizer by crops in Brazil. based on Alfredo Scheid Lopes", Land and Plant Nutrition Management Service – Land and Water Development Division, Rome, 2004

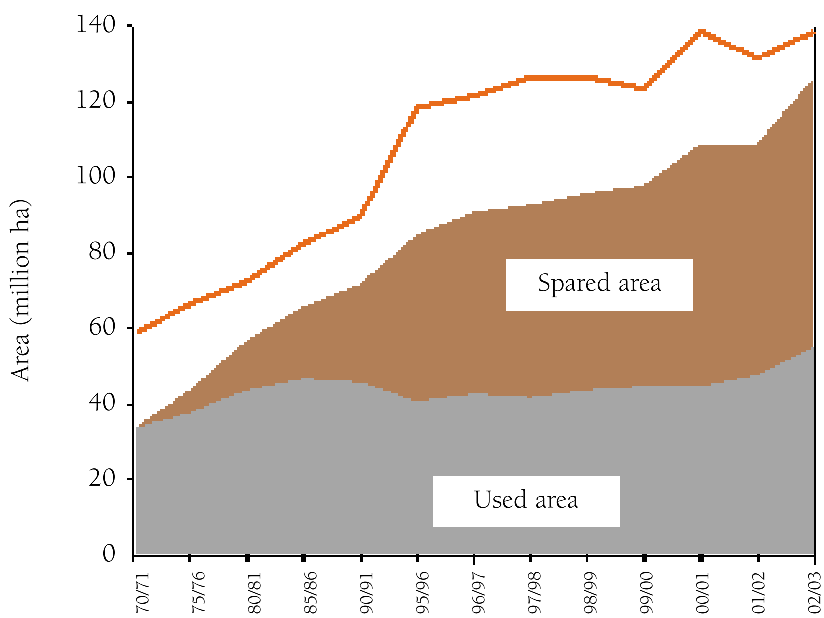
4 LOPES, A.S.; GUILHERME, L.R.G.; SILVA, C.A.P.: *A vocação da terra*, São Paulo, ANDA, 2nd ed., 2003, 23 p.

Figure 1: Agricultural production and fertilizer consumption in Brazil[4]



The use of fertilizers and the technological developments in agriculture have reduced the need to open new areas. Obtaining the 2002/03 agricultural production with the same productivity as in 1970/71 would require an additional area of around 71 million hectares (**Figure 2**).

Figure 2: Agricultural production and productivity in Brazil and spared additional area



Of all crops in Brazil that cover an area in excess of 1 million hectares, sugar cane crops rank fourth on a list of 10 users fertilizer use intensity (**Table 1**), with 460 kg of a mean formula of N-P_2O_5-K_2O per hectare.[5]

Sugar cane crops in Brazil use a low level of fertilizers compared to other countries. In Australia, the ratoon and plant sugar cane fertilization levels are 30 and 54 percent higher than in Brazil, respectively, especially in nitrogen application, with doses of up to 200 kg / ha (**Table 2**).

5 ANDA – Associação Nacional para Difusão de Adubos: *Anuário estatístico do setor de fertilizantes: 1987-2003*, São Paulo, 2003, p. 34

Table 1: Intensity of fertilizer use in crops in Brazil

Crops	Area[1] (1,000 ha)	Consumption (1,000 t)	Consumption / area
Year	2003	2003	(t / ha)
Herbaceous cotton	1,012	950	0.94
Coffee[3]	2,551	1,375	0.54
Orange[3]	823	406	0.49
Sugar cane[3]	5,592	2,600	0.46
Soybean	21,069	8,428	0.40
Corn[2]	13,043	4,082	0.31
Wheat[3]	2,489	742	0.30
Rice	3,575	872	0.24
Beans[2]	4,223	650	0.15
Reforestation	1,150	129	0.11

1 Data from the Systematic Survey of Agricultural Production – LSPA-IBGE and CONAB

2 These cultures total all of the harvested crops

3 Crops planted and harvested in the same year

Table 2: Fertilizer use level in sugar cane: Australia and Brazil, k / ha

		Cane stage	Plant	Ratoon
Country	Australia	N	200	200
		P_2O_5	58	57
		K_2O	120	145
		Total 1	378	402
	Brazil	N	50	100
		P_2O_5	120	30
		K_2O	120	130
		Total 2	290	260
Total 1/ Total 2 ratio (%)			1.30	1.54

Source: Adapted from: CaneGrowers', 1995 (Note **6**); CTC, 1988 (Note **7**);Manechini & Penatti, 2000 (Note **8**).

6 Canegrowers: *Cane Growers' Information Handbook 1994-95*, Brisbane, Australian Canegrower, 1995

7 CTC: "Recomendação de adubação para a cultura de cana-de-açúcar", Cadernos Copersucar Série Agronômica n.º 17, Piracicaba, Centro de Tecnologia Canavieira, 1988

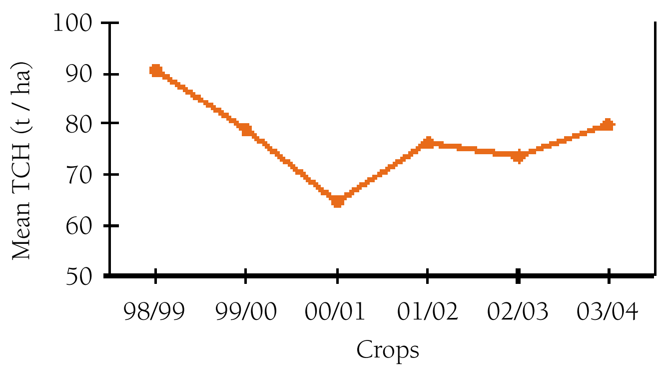
8 MANECHINI, C; PENATTI, C.P.: "Nutrição mineral de cana-de-açúcar – novos parâmetros", Agrícola Informa no. 112, Piracicaba, Centro de Tecnologia Canavieira, 2000

Such relatively low fertilization levels, as adjusted by the agricultural research in Brazil (especially at the Sugar Cane Technology Center), has not limited the agricultural productivity. However, applications below the recommended levels may result in decreased production. For example, when there was oversupply of sugar cane for the 1998/99 crop, the crop renewals and application of consumables (including fertilizers, by around 10%) were reduced in the 1999/2000 crop in several mills.[9] Consequently, this caused a fall in cane production for the 2000/01 crop (**Figure 3**).[10] In this crop, there was an increased application of fertilizers, among other management and climate-related actions, resulting in increasing production for the 2001/02 crop.

9 CTC: "Controle mútuo agroindustrial safra 2002/03", Internal report, Piracicaba, Centro de Tecnologia Canavieira, 2004

10 Paes, L.A.D.; Oliveira, D.T.; Donzelli, J.L.; Elia Neto, A.: "Copersucar Benchmarking Program", Proceedings of XXV ISSCT Congress, Guatemala, 2005

Figure 3: Mean productivity in Copersucar units[10]



An important, specific factor in Brazil's sugar cane crops is the recycling of nutrients by the application of two items of industrial waste, namely, vinasse and filtercake. Vinasse is now treated as a nutrient source (rather than residue), and its application has been optimized within the topographic, soil and environmental control limits. Many of these results are well known. For example, vinasse applications conducted for seven consecutive years on a dystrophic alic, sandy red yellow latosol[11] have shown a significant increase in the amount of nutrients available to the plant after four consecutive applications divided into four years (**Figure 4**, p. 169).

11 Penatti, C.P.; Araujo, J.V.; Donzelli, J.L.; Souza, S.A.V.; Forti, J.A.; Ribeiro, R.: "Vinasse: a liquid fertilizer", *in*: Proceedings of XXV ISSCT Congress, vol.1, Guatemala, 2005, pp. 403-411

Figure 4 shows that the potassium concentration significantly rose up to a depth of 100 cm, according to the increase in applied vinasse doses. Figure 5 shows the sugar cane productivity increasing as soil fertility and water supply rise. The maximum vinasse dose produced an additional 73 t / ha in six years, which is equivalent to one more harvesting season, compared to standard mineral fertilization (57-28-115 kg / ha of N-P_2O_5-K_2O).

The sugar cane crops in Brazil now have a potential for nutrient recycling with vinasse, filtercake and straw of 1,195.1 million t of N-P_2O_5-K_2O (Table 3). Of that potential, only the portion corresponding to the trash is not significantly used (and maybe only a part of it will, even in the future). The use of both vinasse and filtercake can still be further optimized.

Even when leaving out of account the use of boiler ashes (which partially exists already), an increased and optimized use of residues can lead to higher productivity, thereby reducing costs and the need for additional areas. The nutrient recycling ability will be important especially in Brazil's Center-West region, contributing to soil fertility improvements.

Table 3: Potential for annual nutrient recycling in sugar cane crops

Subproduct		Filtercake[1]	Vinasse[2]	Straw[3]	Total
Nutrients (kg / t)	N	12.5	0.36	3.71	
	P_2O_5	21.8	0.14	0.7	
	K_2O	3.2	2.45	6.18	
Production (1,000 t / year)		4,682	148,940	54,779	
Total available (1,000 t)		175.6	439.4	580.1	1,195.1

1 12 kg / sugar cane ton

2 Production of 10 to15 liters per liter of ethanol

3 Future: for 4 Mha harvested without burning

Source: VII e VIII Seminários de Tecnologia Agronômica Copersucar, BTC 36/87; Note **14**

14 see p. 171

Figure 4: Potassium concentration at four soil depths after six months (04/1996) and four applications of vinasse doses

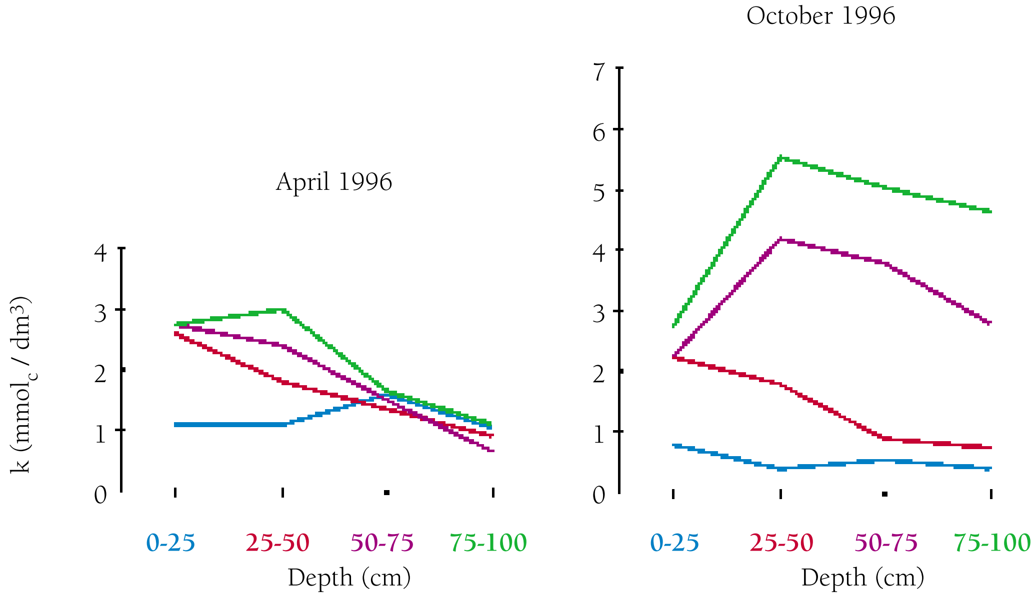
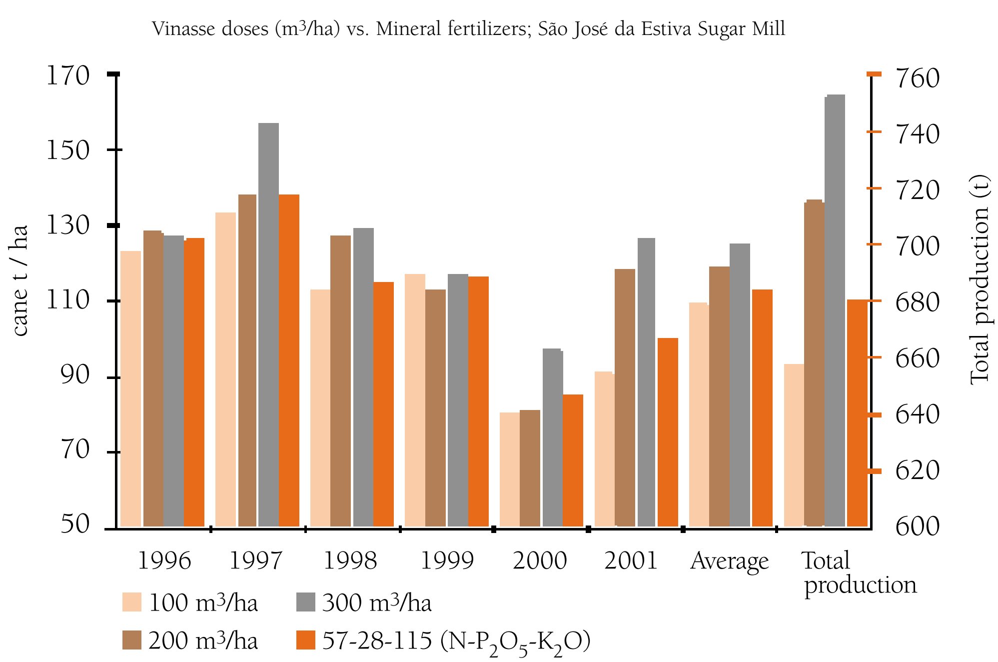


Figure 5: Sugar cane productivity/production; four vinasse dosages compared to standard mineral fertilization



9.3 Advances in the utilization of vinasse

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9.3.1 Vinasse characterization

Vinasse is the residue from the distillation of the sugar cane juice, molasses and honey alcoholic fermentation process. Its characteristics depend on the must composition (juice and molasses). For each liter of alcohol, 10 to 15 liters of vinasse are produced, depending on the sugar cane characteristics and processing. Vinasse used to be released to water streams 30 years ago (at that time, the volumes were much lower than today). It began to be recycled to the fields in 1978. The doses per area unit were gradually decreased, and new technologies were introduced with a view to expanding the ferti-irrigation area (for improved utilization of its potential) and eliminating underground water contamination risks. The current practice is full recycling, which has shown great benefits.

Generally the vinasse has a high organic matter and potassium content, and relatively poor nitrogen, calcium, phosphorus and magnesium contents. The composition depends on the origin (must), as shown in **Table 4** (data for 1984).[12, 13]

12 FERREIRA, E.S.; MONTEIRO, A.O.: "Efeitos da aplicação da vinhaça nas propriedades químicas, físicas e biológicas do solo", Boletim Técnico Copersucar, vol. 36, São Paulo, 1987, pp.3-7

13 ORLANDO FILHO, J.; LEME, E.J.: "Utilização agrícola dos resíduos da agroindústria canavieira", *in*: Simpósio sobre Fertilizantes na Agricultura Brasileira, Brasília, DF, 1984, Anais, pp. 451-475

Table 4: Chemical composition of vinasse from different kinds of must, 1984

Elements	Must		
	Molasses	Mixed	Juice
N (kg / m^3 vinasse)	0.75 - 0.79	0.33 - 0.48	0.26 - 0.35
P_2O_5 (kg / m^3 vinasse)	0.10 - 0.35	0.09 - 0.61	0.09 - 0.50
K_2O (kg / m^3 vinasse)	3.50 - 7.60	2.10 - 3.40	1.01 - 2.00
CaO (kg / m^3 vinasse)	1.80 - 2.40	0.57 - 1.46	0.13 - 0.76
MgO (kg / m^3 vinasse)	0.84 - 1.40	0.33 - 0.58	0.21 - 0.41
SO_4 (kg / m^3 vinasse)	1.50	1.60	2.03
O.M. (kg / m^3 vinasse)	37 - 57	19 - 45	15 - 35
Mn (mg / dm^3)	6 - 11	5 - 6	5 - 10
Fe (mg / dm^3)	52 -120	47 -130	45 -110
Cu (mg / dm^3)	3 - 9	2 - 57	1 - 18
Zn (mg / dm^3)	3 - 4	3 - 50	2 - 3
pH	4.0 - 4.5	3.5 - 4.5	3.5 - 4.0

Up-to-date information[14] (corresponding to current variations in must composition) on 28 mills in 1995 are summed up in Table 5. The collections were conducted in straight vinasse, i.e. with no flegmass mixture, just off the distillery. The mean vinasse flow rate was 10.85 l /ethanol l, with a standard deviation of 2.40. The potassium content is highlighted.

14 Elia Neto, A.; Nakahodo, T.: "Caracterização físico-química da vinhaça – Projeto n.º 9500278", Relatório Técnico da Seção de Tecnologia de Tratamento de Águas do Centro de Tecnologia Canavieira, Piracicaba, 1995

Table 5: Analytical characterization of vinasse, 1995

Vinasse characterization	Units	Minimum	Mean	Maximum	Standard deviation
pH		3.50	4.15	4.90	0.32
Temperature	ºC	65	89	111	9.78
DBO_5	mg / l	6,680	16,950	75,330	9,953.
Chemical Oxygen Demand (COD)	mg / l	9,200	28,450	97,400	13,943.
Total Solids (TS)	mg / l	10,780	25,155	38,680	6,792.
Total Suspended Solids (TSS)	mg / l	260	3.967	9.500	1.940.
Total Dissolved Solids (TDS)	mg / l	1,509	18,420	33,680	6,488.
Nitrogen	mg / l	90	357	885	177.
Total Phosphorus	mg / l	18	60	188	36.
Total Potassium	mg / l	814	**2,035**	3,852	804.
Calcium	mg / l	71	515	1,096	213.
Magnesium	mg / l	97	226	456	71.
Chloride	mg / l	480	1,219	2,300	417.
Sulphate	mg / l	790	1,538	2,800	514.
Sulphite	mg / l	5	36	153	32.

9.3.2 Vinasse distribution systems for ferti-irrigation; evolution and prospects

Vinasse is now fully recycled to the field for ferti-irrigation. The rate at which the areas are covered by ferti-irrigation at the mills is highly variable, depending on the topography and distribution of the mill's land. There are mills that have applied vinasse to 70 percent of their crop areas, whereas others do it at much lower fractions. For the most part, the mills' ferti-irrigation areas increase from crop to crop seeking a rational use of vinasse, with a view to greater agricultural productivity and decreased use of chemical fertilizers. This has been leading to smaller and smaller doses (m^3 / ha), drifting away from levels that could cause damage (salinization, water table contamination).

The systems currently used for ferti-irrigation with liquid residue (vinasse and wastewaters) are standard tanker trucks and application by sprinkling. For sprinkling, the direct-mounting system (pump and engine set and cannon sprinkler on a wheelbase) and the self-propelled, winding-reel system (currently the most disseminated) are used. The latter can be fed directly by channels or trucks. This is a semi-mechanical system, using less manual labor than direct mounting, but its fuel consumption is higher. **Table 6** shows the current use percentages for those systems in São Paulo.

Table 6: Vinasse application systems in São Paulo State

Application Method	Share (%)
Standard tanker truck	6
Sprinkling (channel + direct mounting)	10
Sprinkling (channel + reel)	53
Sprinkling (truck + reel)	31

15 Ferreira, E.S.; Monteiro, A.O.: "Efeitos da aplicação da vinhaça nas propriedades químicas, físicas e biológicas do solo", Boletim Técnico Copersucar, vol. 36, São Paulo, 1987, pp. 3-7

16 Orlando Filho, J.; Leme, E.J.: "Utilização agrícola dos resíduos da agroindústria canavieira", *in*: Simpósio sobre Fertilizantes na Agricultura Brasileira, Brasília, DF, Anais, 1984, pp. 451-475

17 Orlando Filho, J.; Zambello J.R.; Agujaro, R.; Rosseto, A.J.: "Efeito da aplicação prolongada da vinhaça nas propriedades químicas dos solos com cana-de-açúcar", Estudo Exploratório, STAB - Açúcar, Álcool e Subprodutos, Piracicaba, 1(6), Jul-Aug 1983, pp. 28-33

Two systems that were disseminated at the beginning of the PNA (sacrifice area and infiltration furrows) have been eliminated for failing to promote full use of the vinasse and involving underground water contamination risks. Direct ferti-irrigation with tanker trucks has been widely disseminated, but its limitations (greater soil compacting, impossibility to apply in plant sugar cane areas, difficulties on rainy days, low distribution uniformity, costs) have boosted the development into the current systems.

Studies aiming at the development of vinasse application procedures have included center pivot and subsurface dripping systems.

Center pivot systems provide a more uniform distribution, but the costs are still high, including the need for vinasse corrosion-resistant materials. The pivot systems should be of the wheeled type, as the fixed system is unfeasible due to the small amounts of water corresponding to ferti-irrigation.

Experiments conducted by CTC – Sugar Cane Technology Center show that it is technically feasible to apply vinasse by dripping, but economic feasibility would allow this only if dripping irrigation was (independently) feasible. Alternatives are being studied.

9.3.3 Ferti-irrigation; effects of vinasse on the soil

Analyses of the effects of vinasse on soil properties[15] indicate that the addition of *in natura* vinasse to the soil is a good option for taking advantage of this byproduct. It is an excellent fertilizer and provides several benefits in terms of the physical, chemical and biological properties of the soil. Advantages to using vinasse include a rise in pH, increased cation exchange capacity, availability of some nutrients, improved soil structure, increased water retention, and development of the soil's microflora and microfauna.

Not only does the vinasse provide water and nutrients, it also recovers the soil fertility, to some depth. The depth used by the sugar cane root system reaches 160 cm in some countries, but the mean depth in Brazil is 60 cm (given the low fertility of the soil). The vinasse introduces nutrients in depth, such as Ca^{++}, Mg^{++} and K^{+}, and enriches the soil.[16, 17, 18, 19] There are many experiments that demonstrate the good agricultural productivity results (sugar cane t / ha), regardless of the savings attained by buying smaller amounts of mineral fertilizers.[19, 20] Depending on the dose used and the potassium concentration, a nitrogen complementation is required in ratoon growing.[19, 20]

Several works have shown the effects of vinasse on the soil and environment over years of application. One example is the increase of potassium-content to the a sandy dark red latosol.[21]

Salinization evaluations of three soil types[22] (alluvial, 51% clay; red yellow podzolic, 38% clay; and hydromorphic, 5.5% clay) indicate that there are no saline indeces for doses lower than 400 m^3 / ha, and that applications should be made based on the salt contents and soil characteristics.

The leaching of the elements would represent a waste of fertilizer and could lead to pollution risks. In the case of vinasse, there are heavy elements at very low levels that do not represent any danger to the environment. The mineral macro- and micro-elements present at higher concentrations in leached elements would be K^{+}, Ca^{2+}, SO_4^{2-} and Cl^{-}, respectively. Risk assessments of the metals present in the vinasse[23] conducted over a period of five years concluded that the amounts of NO^{-}_{3}, NH_4^{+} and soluble phosphor were not significantly changed. There were also no significant changes in the contents of soluble zinc, copper, iron and manganese. Only SO_4^{2-} showed leaching of up to 80 cm.

Many other studies have been conducted involving specific aspects pertaining to leaching and underground water contamination possibilities at

18 CAMARGO, O.A.; VALADARES, J.M.A.S.; GERALDI, R.N.: "Características químicas e físicas de solo que recebeu vinhaça por longo tempo", Boletim Técnico IAC, vol. 76, Campinas, SP, Instituto de Agronomia de Campinas, 1983

19 PENATTI, C.P.; FORTI, J.A.: "Doses de vinhaça versus doses de nitrogênio em cana-soca", *in*: VII Seminário de Tecnologia Agronômica, Piracicaba, Anais Copersucar, Nov 1997, pp. 328-39

20 PENATTI, C.P.; CAMBRIA, S.; BONI, P.S.; ARRUDA, F.C. de O.; MANOEL, L.A.: "Efeitos da aplicação de vinhaça e nitrogênio na soqueira da cana-de-açúcar", Boletim Técnico Copersucar, vol. 44, São Paulo, 1988, pp. 32-38

21 PENATTI, C.P.: "Doses de vinhaça versus doses de nitrogênio em cana-soca durante quatro safras", Copersucar internal report, Usina São Luiz S.A., Clay soil (LR-2), 1999a

22 FERREIRA, W.A.: *Efeito da vinhaça em solos de diferentes texturas*, Piracicaba, 1980, 67 p. Dissertação (Mestrado) - Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo

23 CAMARGO, O.A. de.; VALADARES, J.M.A.S; BERTON, R.S.; SOBRINHO T.J.: "Aplicação de vinhaça no solo e efeito no teor de nitrogênio, fósforo e enxofre inorgânicos e no de alguns metais pesados", Boletim Técnico IAC, vol. 8, Campinas, SP, Instituto de Agronomia de Campinas, 1987

19 see p. 173

24 Rodella, A.A.; Ferrari, S.E.: "A composição da vinhaça e efeitos de sua aplicação como fertilizante na cana-de-açúcar", Rio de Janeiro, Brasil Açucareiro, 90 (1), 1977, pp. 6-13

25 Peixoto, M.J.C.; Coelho, M.B.: "Aplicação de vinhaça diluída em cana-de-açúcar por sistema de aspersão", Congresso Nacional da Sociedade de Técnicos Açucareiros e Alcooleiros do Brasil, 2, Rio de Janeiro, Aug 16-21, 1981, Anais, STAB, 1981, pp. 177-194

variable vinasse doses over periods of up to 15 years. On the other hand, there is a consensus among some researchers that doses in excess of 400 m^3 / ha are harmful to sugar cane (inhibiting quality and productivity).[19, 24, 25]

Today vinasse is considered an organic fertilizer, and is also released for "organic" sugar production (where no chemicals can be used: herbicides, insecticides and mineral fertilizers). Respecting the characteristics of the soil to which it is applied, as well as the location of water springs and the volumes defined as suitable to each situation, vinasse does not have any negative effects. The results obtained from tests so far indicate that there are no damaging impacts on the soil at doses lower than 300 m^3/ha, while higher doses may damage the sugar cane or, in specific cases (sandy or shallow soil), contaminate underground waters.

9.3.4 Legislation on vinasse application

The evolution of the legislation on the disposal (currently the use) of vinasse dates back to 1978.

MINTER (National Integration Ministry) Ordinance no. 323 (1978) prohibited release of vinasse in surface fountainheads.

CONAMA (National Environment Council) Resolutions no. 0002 (1984) and 0001 (1986) required studies and determination of rules on the control of effluents from ethanol distilleries, and subsequently rendered the EIA and RIMA mandatory for new units or extensions, respectively.

Law no. 6,134 (1988), article 5th, of São Paulo State provided that waste from industrial and other activities shall not contaminate underground waters.

Until the late 1970's, when ethanol production was still relatively small, there was no legislation on the matter. The practice consisted of disposing of the vinasse in surface fountainheads, thereby increasing their organic load. That changed as of 1978, when the vinasse was totally redirected to ferti-irrigation.

Recently, the São Paulo State's Office of the Secretary of Environment and the production sector developed a technical standard in order to regulate the application of vinasse in São Paulo State. The technical standard seeks a safe way to apply the vinasse by specifying permitted places, doses, protection of master channels and storage, etc. It also considered the results of years of studies seeking safe processes in respect to the various aspects of environmental protection.[26] The efficient use of vinasse is something in

26 Technical Standard P4.231: Vinasse: Criteria and procedures for application in agricultural soils, 2005

which producers are very interested given the economic return. The technologies are expected to keep on evolving in this respect, specifically involving the interaction between vinasse and the waste trash left in the field.

9.4 Summary and conclusions

• 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 Mha), sugar cane uses smaller amounts of fertilizers than cotton, coffee and oranges, 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 (Australia uses 48% more).
• The most important factor is nutrient recycling through the 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, although the use of trash has yet to be implemented. It will be very important in expansion areas.
• A large number of studies in respect to leaching and possibilities of underground water contamination with vinasse, indicate that there are generally no damaging impacts for applications of less than 300 m3 / ha. A technical standard by the Office of the Secretary of Environment (São Paulo) regulates all relevant aspects: risk areas (prohibition); permitted doses; and technologies.

III

Sustainability of the agricultural production base

The internal sustainability of an agricultural production system requires the ability to respond to pests and plant diseases and to periodical climate changes, among other things. The idea is that these interferences must not harm the production system so seriously as to make it unfeasible.

This sustainability concept is essential to Brazil, which seeks a deeper inclusion in international markets not only in sugar, but also in ethanol. In the case of ethanol, any buyer is concerned about a reliable long term supply.

The problem of periodical climate changes (other than those occurring because of global warming, which are addressed in **Chapter 4**) are usually viewed in Brazil as substantially "under control" in the case of sugar cane because the production areas are very spread, to the point of having different growing periods (as in the Northeast), over a vast territory with remarkable regional differences. As a matter of fact, historical observations of sugar cane production seem to confirm this: only once over the past thirty years was there an important production fall, and even though it took place during a drought year, part of that decrease was intentional (there was an excess of the product on the market, and many mills intentionally reduced the fertilization and cultural treatments, thereby decreasing the sugar cane output).

The ability to respond to diseases and pests is one of the main strengths of Brazil's production. The key of understanding this issue in Brazil assumes that it would be impossible (yet desirable) to maintain a strict, efficient phytosanitary barrier system in a country with such extensive borders as Brazil. The response should consist (in addition to quarantines and barriers) of an efficient disease and pest-resistant variety selection and development system and a proper use of a large number of varieties. This system is shown in **Chapter 10**.

Chapter 10:
Varieties and protection from diseases and pests

Internal sustainability of sugar cane growing in Brazil requires the ability ro respond to pests and diseases and to periodical climate changes. Protection from pests and diseases is considered a strength of Brazil's production: it is based much more on a continued supply of disease and pest-resistant sugar cane varieties than on phytosanitary barriers, allowing growers to operate with a great diversification. Varieties developed in Brazil became commercial in 1980; today nearly 500 varieties are being used.

10.1 Introduction

Brazil's sugar cane genetic improvement programs started providing varieties in the early 1980's. There are four programs today covering the sugar cane growing areas, with an emphasis on the Center-South region. In almost all cases, the search for pest and disease resistance is essential considering how difficult it is to protect the country's territory (and borders) with sanitary barriers.

The expansion areas require some new thinking for the programs with a view to a specific and, in some cases, regional orientation; this is being considered.

In the world context, Brazil has a cutting-edge sugar cane biotechnology, with the development of transgenic varieties. The introduction of such varieties may take place within a few years.

10.2 Standard genetic improvement and availability of varieties

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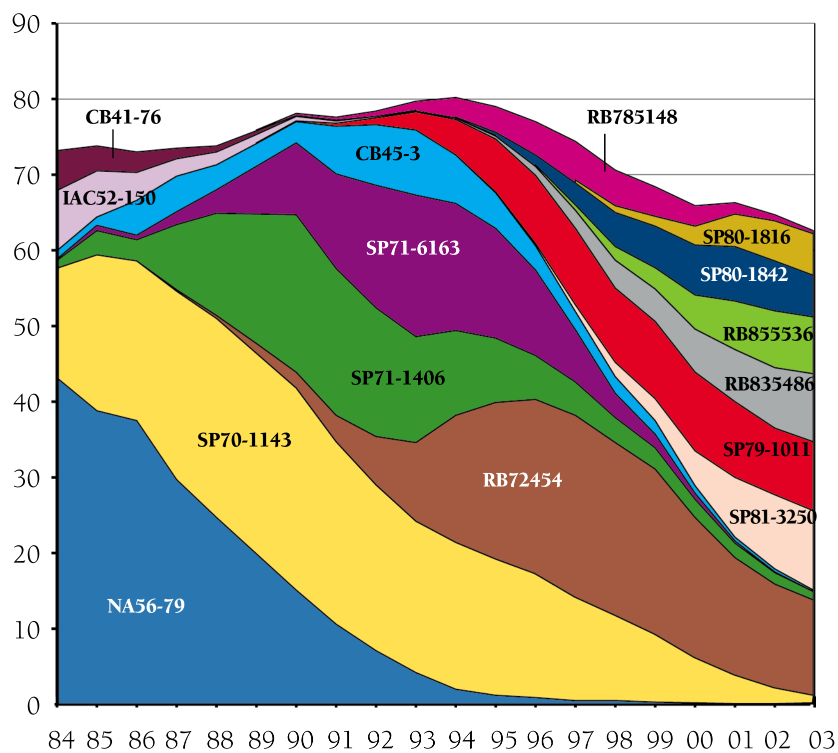
From the production sustainability viewpoint, one of the questions that needs an answer in agriculture is: does the country have an appropriate (sufficient) genetic base for a continued development of new varieties, so as to supply the growing areas with them and be sure that new diseases or pests can be controlled with acceptable losses?

Sugar cane growing in Brazil covers an area of more than 5 Mha in the 27 units of the federation (states). In the period from 1971 to 1997, sugar cane production grew at a mean rate of 5.5 percent per year, while the growing area increased by 3.9 percent per year, and productivity at 1.6 percent per year in a relatively uniform manner. In spite of the expansion to less favorable areas, the productivity increase rates can be attributed, for the most part, to the availability of genetically improved varieties that are adapted for such new conditions. Between 1976 and 1994 (data provided by the PCTS – Sugar Cane Payment System, São Paulo), productivity gains totaled 1.4 kg of sugar per ton of sugar cane each year. Over the past ten years, new varieties have delivered further qualitative advances.

Figure 1: Percentage occupation by the main sugar cane varieties in Brazil from 1984 to 2003



More than 500 varieties of sugar cane are grown in Brazil. Those varieties were produced mainly by two genetic improvement programs: Copersucar's (SP varieties), and the carried out by the Inter-University Sugar Cane and Ethanol Industry Development Network (RIDESA, in Portuguese), formerly Planalsucar (with RB varieties). A third active program, carried out by the Agronomic Institute of Campinas, which has historically been very important to the industry, has been restructured and released some promising varieties. It has recently enhanced its potential, including in biotechnology, and is advancing fast focusing on the Center-South region. Independently, a private company by the name of Canavialis was organized in 2004 to develop sugar cane varieties. That company works in conjunction with Allelyx, which develops transgenic varieties. Therefore, Brazil has two private and two public companies engaged in the genetic improvement of sugar cane varieties.

The two most active improvement programs (SP and RB) were introduced in 1970, when approximately 1.5 million hectares of sugar cane were grown in Brazil. These programs were sufficient to meet the requirements for the major increase in area thereafter. The expansion in the 1970's and 80's took place mostly in regions having less favorable edaphoclimatic conditions, and the development of adapted sugar cane varieties was important for such expansion to succeed. During that period (1970's and 80's), the programs established a broad physical base for conventional genetic improvement. Copersucar's germplasm bank has more than 3,000 genotypes, including a wide collection of "wild" species, such as *Saccharum officinarum* (423 genotypes), *S. spontaneum* (187 genotypes), *S. robustum* (65 genotypes), *S. barberi* (61 genotypes), and *S. sinense* (32 genotypes), which gave rise to modern sugar cane varieties and are sources of the great genetic variability found. It is in the best interests of the various programs for Brazil to have one of the world's sugar cane germplasm collections. A private quarantine facility (approved and inspected by the Ministry of Agriculture) processes 40 new varieties of several of the world's improvement programs every year. The improvement programs have experimental facilities located in the country's main sugar cane growing regions and complement their facility networks with areas provided by producing units.

Brazil has two experimental hybridization facilities where crossings are made: Camamu, in Bahia; and Serra d'Ouro, in Alagoas. The seedlings produced by the Brazilian improvement programs are estimated at 1,420,000 each year.

A census conducted in 260 sugar cane growing units in Brazil in 2003-2004 indicates that 51 out of the 500 sugar cane varieties in use have been released over the past ten years, and the 20 most important of them occupy 80 percent of the crop area, while RB72454, the most widely used, occupies only 12.6 percent. It is gradually noted not only that the permanence "cycles" for the best varieties get shorter and shorter, but also that these varieties coexist in larger number. This great diversification is part of the pest and disease protection strategy. As a matter of fact, the number of varieties in use has been growing faster over the past 20 years, as shown in **Figure 1**. In 1984, if a new disease to which the NA56-79 variety (main variety at that time) was susceptible had been introduced, it would have had the potential for destroying 42 percent of the country's crops. In 2003, if a disease affecting the main variety grown (RB72454) had been introduced, it would have affected only 12 percent of the sugar cane crops.

Compared to those of other important sugar cane research centers around the world (Australia, South Africa, Colombia, and Mauritius), Brazil's genetic improvement programs can be said to be more prolific, and Brazilian growers to be faster in incorporating new sugar cane varieties. Important epidemics were controlled by a fast replacement of varieties. That was the case of the sugar cane smut (1980-1985), the sugar cane rust (1987-1992), and the yellow leaf virus (1994-1997). Today, each of the main varieties occupy a maximum of 10 to 15 percent of the total sugar cane area in each mill. This has been the main defense against external pathogens in Brazilian mills.

The disease and pest-resistant varieties still haven't provided an efficient contribution to minimizing losses caused by some pests, namely, nematoids, spittlebugs, stalk beetles and migdolus.

The genetic improvement programs have also proved efficient in developing varieties adapted for the new management conditions. Recently in São Paulo State, there has been a relative increase in the use of mechanical harvesting of raw sugar cane without trash burning, which provides the crops with much different biological conditions. It hasn't been difficult to select varieties adapted for such new conditions.

Considering the success of sugar cane genetic improvement programs in the past and the wide installed physical base, we believe that the industry will have suitable varieties to safely support the maintenance and future expansion of the crops under any edaphoclimatic conditions in the Brazil. However, some cautions are required. For example, the expansion to areas that have not yet been specifically aimed at by the programs shall require new investments.

The investment in this field of research (conventional breeding) amounts to some R$ 15 million / year in São Paulo, and possibly R$ 20 million / year in Brazil. This corresponds to US$ 1.14 / ha per year; in Australia, the BSES operates with around US$ 12 / ha to create varieties; in Mauritius, US$ 82.2 / ha. Such underinvestment is partly compensated for by the involvement of dozens of companies of the sugar and ethanol industry with the final assessment stages. In the present expansion situation (and relatively new areas), it will be necessary to provide the programs with more funding in order to keep the past development pace, and also to consider the interaction with ongoing transgenic species development programs.

10.3 Transgenic varieties; present situation and prospects

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A significant development of sugar cane biotechnology has been going on in Brazil over the past ten years. The country stands out from other producers, along with Australia and South Africa, for using this modern technology in variety development programs.

In Brazil, the Sugar Cane Technology Center pioneered the creation of transgenic sugar cane varieties in 1997, and has been very active in experimental planting of its findings. CTC had been conducting molecular biology research since 1990 when it headed the conclusion of a cooperation agreement, forming the International Sugar Cane Biotechnology Consortium (ICSB, in Portuguese), an entity with a current membership of 17 institutions and 12 sugar cane producing countries. The Technical Commission on Biosafety (CTNBio) of the Ministry of Science and Technology granted to CTC a biosafety quality certificate in 1997, enabling the growing in a restricted experimental area of varieties featuring resistance to herbicides, pests, diseases and flowering obtained through modern biotechnology techniques. These materials, currently at the experimental stage, are important to the evaluation of benefits and impacts of sugar cane biotechnology.

The development of the Cane Genome project, funded by Copersucar and FAPESP, was extremely relevant. The project was carried out from 2000 until 2003, and mobilized 200 researchers from more than 20 universities and research institutes in Brazil to identify the sugar cane genes. The project described nearly 300,000 sugar cane gene sequences which were grouped into approximately 40,000 genes upon analysis. In this genetic asset of sugar cane, genes were described relating to disease resistance, response to stress, nutrient metabolization, carbohydrate metabolization, transcription factors and flowering process, among other things. Some research groups have already used those genes in genetic improvement programs. The continuity of the Cane Genome project is supported by funds (also by CTC and FAPESP) from the functional genome project initiated in 2004. The preliminary results are promising in the development of varieties which show increased resistance to pests, diseases and some important stresses, such as droughts and cold weather, which could even encourage the expansion of sugar cane crops in regions that are now considered unfit. Another private company (Allelyx) has recently started activities in this field with important resources.

Sugar cane genomics has evolved in Brazil with complementary studies as well, such as the full gene sequencing in 2002 of *Leifsonia xylli*, and important sugar cane pathogen, by a group headed by ESALQ. This will allow a better understanding of the bases on which the pathogenic bacteria and sugar cane interact and the development of mechanisms to put this disease under control. More recently, the gene sequencing was completed of the *Glucanocetobacter diazotrophicus* bacteria associated with sugar cane, which fixes atmospheric nitrogen and could substitute for part of the nitrogenous chemical fertilizers. With the genetic information obtained from the bacteria, the group responsible for this project in Rio de Janeiro expects to increase the efficiency of the microorganism.

Some lack of definition and the complexity of the legislation that governs research and development activities with transgenic organisms in Brazil have been the main barrier to the researchers' activity in this field. Planting experiments with transgenic sugar cane requires the project in question to be approved by agencies related to three ministries, the Ministry of Science and Technology (CTNBio), the Ministry of the Environment (IBAMA), and the Ministry of Agriculture, Livestock and Supply (DDIV). Each of these three agencies has its own particular protocols and requirements, depending on the type of transgenic organism to be tested. The time needed for evaluating the research proposals submitted to each of the ministries has made some projects unfeasible. In addition, there is no clear definition as to the protocol to be followed by the companies who are interested in registering a transgenic product for commercial use.

In terms of technical qualification Brazil is on the cutting-edge of sugar cane biotechnology worldwide, but a major effort should be made on the legislative front so that the country can benefit from this technology over the next 10 years.

10.4 Summary and conclusions

• The internal sustainability of sugar cane growing in Brazil requires the ability to respond to pests and diseases and to periodical climate changes.

• The production conditions in Brazil, with its regional and microclimatic diversity, have been responding appropriately to periodical climate changes.

• *Protection from pests and diseases is considered a strength of Brazil's production: it is based much more on a continued supply of disease and pest-resistant sugar cane varieties than on phytosanitary barriers, allowing growers to operate with a great diversification.*

• There are four operational sugar cane genetic improvement programs in Brazil (the two leading programs are private); they use one quarantine and two hybridization facilities, with germplasm banks. They work with around 1.5 million seedlings per year.

• More than 500 varieties are grown today (51 have been released over the past ten years). The twenty most important varieties occupy 80 percent of the crop area, but the most widely used occupies just 12.6 percent. The substantial rise in diversification over the past twenty years has provided great safety concerning resistance to exogenous diseases and pests.

• Brazil stands out from other producing countries for its sugar cane biotechnology, having had (non-commercial) transgenic varieties since the 1990's. In 2003 the identification of 40,000 sugar cane genes was completed in Brazilian laboratories; there are dozens of groups working on the functional genome, and they are already using the genes in genetic improvement programs (experimental stages). Commercial results may arise over the next five years.

• More funds are recommended in order to properly integrate the germplasm banks for all programs and to support specific developments for each expansion area.

• Efforts on the legislative front should be carried on in order to facilitate the development of biotechnological research in its final stages.

IV

Impacts of production on commercial actions

The search for external sustainability determines that agricultural production should not impose any adverse economic impacts on the external environment; the externalization of costs to be paid by other sectors of society is evidence of an unsustainable production. As much as this concept seems strict, considering the present situation of agriculture around the world and the high subsidies that are currently in use, it is appropriate to use it as a way of showing and, to some extent, quantifying the inadequacy of many practices in the current system. The remarks on sustainability and international trade in the Rio Declaration go in the same direction: "*States should cooperate to promote a supportive and open international economic system that would lead to economic growth and sustainable development in all countries, to better address the problems of environmental degradation*".

Actually the relation between more liberal standards of international trade and sustainable development has been marked by controversies and disputes between civil entities and governments; alleged (or real) environmental problems have been used to justify trade barriers, for example. It is also noticeable that some "liberalizing" initiatives focused on immediate results, which are sustained by some richer countries, have contributed in the opposite way: polarizing the disputes between rich and poor. Subsidies for agriculture (with their whole broad range of variations) have been setting a terrible example for perpetuating environmental problems. A report recently prepared by the WWF[1] indicates that the level of sugar subsidies and protection in the European Union, the United States and Japan have been inducing agricultural practices that are extremely damaging to the environment (especially related to the use of water for irrigation) in these regions, while keeping prices very low in other regions, thereby preventing them from using cleaner production systems too. Ideally, these issues would be resolved with more information and a gradual convergence to sustainability ideals.

1 "Sugar and the Environment", WWF, Nov 2004

For the most part, the promotion of specific economic interests has been the main consideration of international trade policies in most countries, instead of a broader sustainable development policy. Another problem is the position of some developed countries, who view trade policies as substitutes for international "financial aid," without considering the conditions to be attained so that the flow of funds may lead to sustainable development: for example, the payment of debts of developing countries.

The sugar cane products from the Center-South region of Brazil do not have any price support mechanism under governmental policies; there are no subsidies to sugar production or trade today, as they were eliminated years ago as part of the deregulation processes. The need for subsidies has disappeared in face of the great advances in competitiveness for the two products. The economic competitiveness of any activity is essential to its sustainability; Brazil's sugar cane industry has advanced greatly in this respect with its two main products. The competitiveness of the Brazilian sugar is now unquestionable (its cost is the lowest in the world), and ethanol can now be competitive with gasoline (international prices), while being the world's first renewable liquid fuel to accomplish this. The present situation and the prospects for next few years are analyzed below.

Chapter 11: Competitiveness of Brazil's sugar cane agribusiness

Brazilian sugar cane products do not rely on any price support mechanisms under governmental policies. There are no subsidies to sugar production or trade, and the sugar production costs in Brazil are the lowest in the world. Ethanol production costs in efficient mills is competitive with the international gasoline cost, at oil prices significantly lower than the current prices. There are good possibilities for increasing this competitiveness in the next years, and clearly the Brazilian production is sustainable in this respect.

11.1 Introduction

In the following two items, the two main products of Brazil's sugar cane industry are analyzed as to their competitiveness, using production costs, and considerations regarding transportation and export costs, as well as an examination of opportunity costs for other land uses.

Ethanol is covered by **item 11.2** in more detail because the competitiveness of the Brazilian sugar has been extensively analyzed in the specialized media over the past few years. Still concerning ethanol, the history of the industry's technological breakthroughs, which have partly led to the increase in competitiveness over the past few years, is briefly reported, and the conditions for maintaining advances over the next few years are described; this analysis obviously refers to sugar production as well.

11.2 Ethanol production: costs and competitiveness

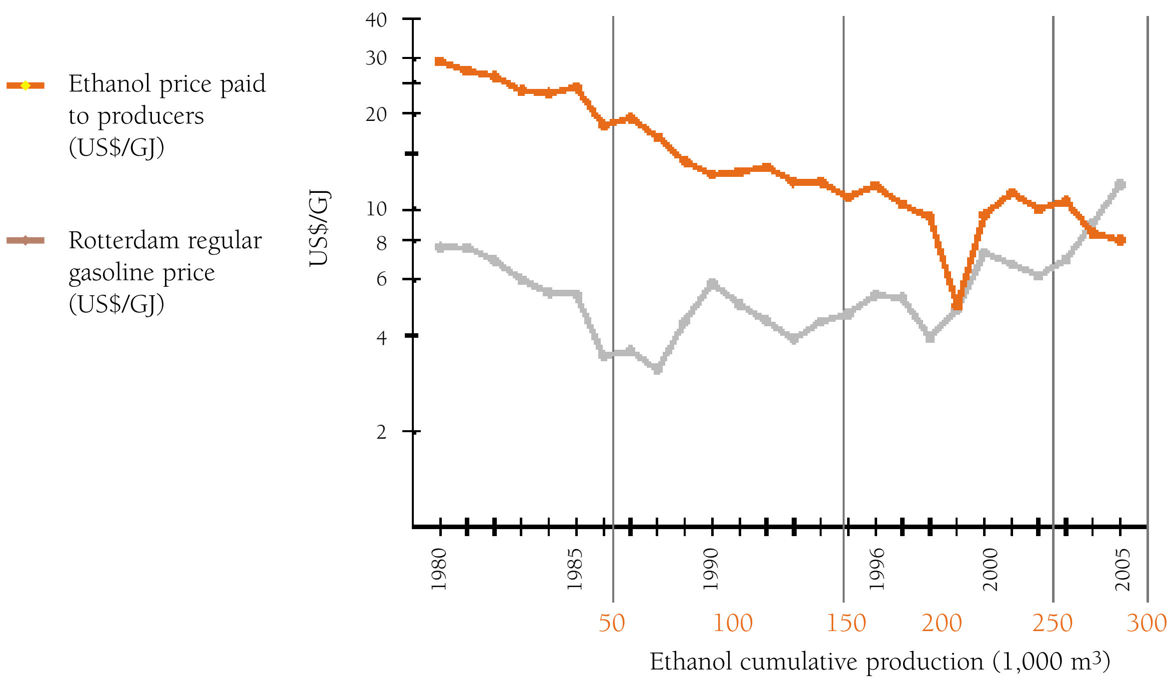
Competitiveness can be assessed based on the cost ($ / m^3) of the ethanol delivered to the consumer reliably and according to the specifications. It is influenced by local conditions (*production:* weather and soil, availability and cost of land, land structure, labor, local logistic support; and *governmental action:* interventions, taxes and subsidies, foreign exchange rates, environmental restrictions). It is also influenced by external factors, such as trade barriers, exchange rates, etc. Ethanol producers in Brazil have been taking action to improve their competitiveness, either adapting for or changing these conditioning factors, especially through investments, implementation of technologies, and political action.

The results can be summed up by the evolution of the price paid for ethanol to the producers (as a higher estimate of the production cost),[1] as shown in **Figure 1**. A comparison is shown with the international costs of gasoline production in the corresponding years. Because they refer to prices (rather than costs), the data reflect the market variations; the effect of the

1 Goldemberg, J.; Coelho, S.T.; Nastari, P.M.; Lucon, O.: "Ethanol learning curve – the Brazilian experience", Biomass and Bioenergy, vol. 26/3, London, Pergamon Press-Elsevier, 2003, pp. 301-304 Updated for reprint in 2005

oversupply of ethanol on the market (1999) and the recovery in the following years are shown.

Figure 1: Price paid to ethanol producers and gasoline cost



Source: Note **1** (see p. 189)

Given the large number of producers and diversity of situations (soil, land cost, commercial arrangements for purchased sugar cane, technological levels), it is difficult to get accurate values for production costs. Some approximations have been made based on appropriate samples.

An evaluation of the economically sustainable production cost in Brazil's Center-South region[2] used values for the *average of more efficient mills*, with the technology in use today. Mills with different capacities, management characteristics, location and land quality were considered. Also considered were the data provided by FGV – Getulio Vargas Foundation (historic series, until 1997/98), as updates for checking the consistency, and the differences arising out of the several cost concepts (economic, accounting, cash base), agricultural productivity variations, and prices of production factors.

Those economically sustainable production costs *for more efficient mills in Brazil's Center-South region* were brought up to date for January 2003 to R\$ 520 / m³; if updated for December 2004, the amount would be US\$ 0.20 / l (US\$ 1 = R\$ 2.8). Besides being computed for the more efficient sugar

2 Borges, J.M.M.: "Alternativas para o desenvolvimento do setor sucroalcooleiro", FIPE – MB Associados, UNICA, vol. 2, São Paulo, 2001

mills, this cost does not consider temporary fluctuations (for instance, the rise in land costs in times of rapid production growth, as in 2006; or peaks in some input costs, such as steel). Note that the prices paid to cane producers in the most important producing regions are indexed to the final sales value for sugar and ethanol (and the land rental cost is linked to the cane prices); this leads to a strong feed-back from international gasioline and sugar prices over sugar cane prices. A cost evaluation at the end of the season 2005/06[3] indicated R$ 35.7 / t cane, leading to R$ 647 / m^3 ethanol. The international cost of gasoline (with no additives, Rotterdam) was US$ 0.22-0.31 / l, with oil at US$ 25-35 / barrel. Over the past months it has seemed clear that the oil costs will be substantially above that level, which confirms the very competitive position of ethanol.

3 Souza, I. C. : Impacto das perdas industriais no lucro da agro-indústria sucroalcooleira; 27ª. Reunião Anual da FERMENTEC, São Pedro, March 2003

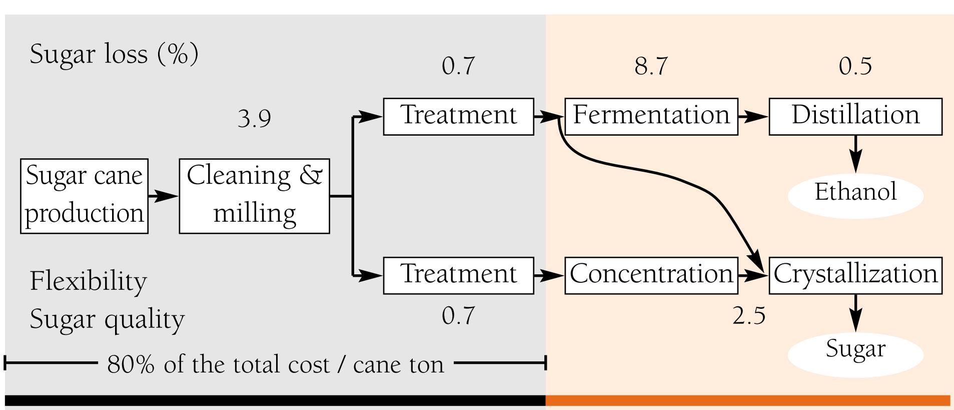
Ethanol production costs in Brazil should also be compared to the evaluated costs of corn ethanol in the United States (~US$ 0.33 / l), or wheat or beet ethanol in Europe (~US$ 0.48 and 0.52, respectively).[4]

4 Henniges, O.; Zeddies, J.: "Fuel ethanol production in the USA and Germany – a cost comparison", F. O. Licht's World ethanol and biofuels Report, vol. 1, no. Feb. 11 2003

The major cost reductions since the implementation of the ethanol program in Brazil have occurred in a context of broad discussions of political and economic conditions (initial governmental support followed by deregulation; policies for liquid fuels; building of an important set of legislations/regulations on environmental and social issues). The advances in competitiveness were supported by investments (production, logistics) and a significant development and implementation of technologies. In order to evaluate future possibilities of improvements, it is important to examine the evolution over the past few years.

Figure 2 shows the current mean values of sugar cane losses in the ethanol and sugar production processes in a typical mill in the Center-South region of Brazil.

Figure 2 Sugar conversion in the current processes[5]



5 Macedo, I. C.: "Fatores para a competitividade internacional", IV Conferência DATAGRO sobre Açúcar e Álcool, São Paulo, 2004

Such conversion efficiencies, greater flexibility in operation with the two products, and quality improvements were attained on the back of a strong process integration. The main technological advances were as follows:

1980-1990*:* Introduction of new sugar cane varieties developed in Brazil; new grinding systems; fermentation with much larger capacities; use of vinasse as a fertilizer; biological control of sugar cane beetle; optimization of agricultural operations; energy independence.

1990-2000*:* Introduction of excess energy sales; better technical, agricultural and industrial management; new sugar cane harvesting and transportation systems; industrial automation advances.

The following are some of the overall results for the São Paulo area:

+ 33% tons of sugar cane / ha; + 8% sugar cane sugar
+ 14% sugar conversion for ethanol sugar cane
+ 130% fermentation productivity (m^3 of ethanol / m^3 of reactor·day)

Technology will be of the essence in the years to come in order to strengthen the competitive position; actions shall include a solid dissemination of already commercially available technologies, innovation in ethanol production processes, and product diversification (from sucrose and lignocellulosic sugar cane residue).

In 2000, it was estimated that the additional implementation of commercially available technologies could result in cost reductions of up to 13 percent in the Center-South region's production[6]; the most important aspects were better use of sugar cane varieties, optimization of sugar cane transportation, better agronomic controls, fermentation and grinding, technical management of industrial production, and maintenance.

6 Internal report, 36 mills sample, São Paulo, 700.000 ha; CTC, May 2001

New processes include "precision agriculture", integrated sugar cane and trash harvesting and transportation systems, a much higher level of industrial automation, and new separation processes (juice and downstream processing). The genetic modification of sugar cane is advancing very quickly in Brazil (experimental scale, including field tests); the sugar cane genome was mapped in 2001 in São Paulo, and a few dozen projects (applications: functional genome) are in the pipeline in both public and private institutions.

Product diversification is being sought in two lines of activities:

Sucrose products: the low cost of sucrose in Brazil has been leading to the introduction of new industries, whether or not as additions to the mills; L-lysine, MSG, yeast extracts, citric acid and sorbitol are already in commercial production, and other products are being considered. Brazil had an important alcohol-chemical industry in the 1980's (see **item 2.3**).

Sugar cane biomass energy: the use of sugar cane biomass to produce "clean energy" may take different paths. Excluding sucrose, the energy contained in one metric ton of sugar cane (including the straw) is equivalent to ⅔ of the energy contained in one oil barrel. That biomass can be recovered for ~US$ 1. / GJ; today, less than half of it is used (see **item 1.4**). Available technologies can generate additional electricity (from the bagasse and 50 percent of the straw) corresponding to an additional 30 percent of the sale value of sugar and ethanol. The development of an efficient system for biomass conversion into ethanol (expected to occur within the next ten years) could lead to the same additional sale value.

The development and implementation of technologies have a significant potential for increase in competitiveness. However, as the case was in the past, important results can be obtained with investments and policies to improve the infrastructure (logistics: ethanol and sugar transportation/storage/shipment).

11.3 Competitiveness of sugar

All production factors (technology, investment, political action) that influence ethanol production costs are equally present in the case of sugar. Therefore, production costs are expected to be maintained and possibly reduced, notwithstanding the increase in production in new areas (with some additional transportation cost, on average). Here, however, competitiveness should be measured in comparison with the production of sugar in other countries around the world (similar to international gasoline compared to ethanol).

In a competitiveness analysis, having relatively low production costs is a factor that must be complemented with other data: transportation costs (FOB price, for international trade); and, in some cases, considerations regarding opportunity costs for agricultural production (net gain for a possible use of land for another crop). These factors, for the group of countries concerned in sugar trade, are essential to determining the possibilities of sustainability (and possible growth) of individual productions. Also important are considerations as to the capacity to expand production and the several forms of subsidies used in international trade, particularly to this product.

In short, we can say that Brazil (Center-South) has maintained the world's lowest sugar production costs for many years, and is strongly inserted in international trade as an exporter (in fact, it accounts for 40% of the sugar trade in the "free market"). The transportation and loading (shipment) costs are relatively high in Brazil, but that has not prevented it from taking a prominent position as an exporter. In the leading production area (São Paulo), crop replacements due to market prices took place (in specific cases and in a very limited way), for example, between citrus and sugar cane in the past few decades, but sugar cane production has always resumed its growth. At the moment, a strong expansion of sugar cane production is taking place, which indicates that the opportunity cost of land use (translated to the gross margin of alternative crops) does not change the competitive position of sugar.

Production costs *for more efficient mills in the Center-South region* (based on production factors), using the same database (and considerations) as that used for ethanol (see **item 11.2)**, are US$ 125 / ton of sugar (1 USD = R$ 2.8). Estimations made by LMC[7] in September 2004 also attribute these costs to the production in Brazil's Center-South region (and around US$ 220 / ton for the Northeast). More recent estimates,[8] considering the cost increases as discussed for ethanol, indicate R$ 414. / ton sugar (end of the 2005/2006 season). A comparison with other producers shows that, on a cumulative basis, for up to 20 Mt, the cost in the world is US$ 120 / ton (Center-South of Brazil); for 20 to 65 Mt, the cost rises rapidly to US$ 200 to 250 / ton, and for 65 to 100 Mt, it reaches US$ 400 / ton. Therefore, the ex-factory production cost in the Center-South is the lowest in the world.

7 TODD, M. (LMC International): "Factors that enable industries to be internationally competitive", Conferência Internacional DATAGRO sobre Açúcar e Álcool, São Paulo, 2004

8 SOUZA, I. C. : Impacto das perdas industriais no lucro da agro-indústria sucroalcooleira; 27ª. Reunião Anual da FERMENTEC, São Pedro, Março 2003

Concerning competitiveness in foreign trade, considering the mean costs for the leading exporters (excluding Brazil) to be 100 percent, the situation in the Center-South and Northeast of Brazil according to the same study is as follows:

Table 1: Sugar production and exportation costs compared to the mean costs of other leading exporters

	Center-South	Northeast
Sugar cane production costs (%)	55	85
Processing cost (%)	60	105
Transportation and loading cost (%)	185	45
Total cost (%)	65	90

Exportation costs (transportation and port fees) are clearly points that need improvement in the Brazilian production. Transportation and loading costs in Brazil are estimated at US$ 24 / t in the Center-South, and US$ 8 / t in the Northeast, compared to US$ 9 / t in Australia, for example.

Another fact to be considered in the context of international trade in sugar is that there is practically no governmental policy-supported price in Brazil, which is a factor that reinforces the country's competitiveness in a trade liberalization scenario (as expected). The availability of suitable land for expansion in Brazil is also much higher than in any other region in the world (see item 6.4).

11.4 The markets for the next few years

An evaluation of production sustainability in Brazil depends on the additional production volumes considered, notwithstanding the enormous availability of land for expansion. Many studies have focused on the future world demand for ethanol and sugar; the future is much clearer for sugar than for ethanol. The following results sum up the current knowledge.

For the domestic sugar market, a recent analysis performed by DATAGRO[9] considering the population and per capita consumption evolution points to 11.4 Mt / year; including 1.4 Mt / year of sucrose for sucrose derived products, the domestic demand for sugar is estimated at 12.8 Mt / year for 2013.

For the international sugar market, an analysis has been presented for a ten-year horizon covering ten regions around the world[10] and anticipating for 2014 an increase in exports from 45 to 71 Mt per year; Brazil would account for 40 percent of the world market (28 Mt / year). A more conservative position was presented at the same time by DATAGRO a smaller expansion of the world market would take Brazilian exports up to 20.9 Mt in 2013. The estimation by LMC is more conservative as well (world demand of 170 Mt, 2014).

For Brazil's domestic market in ethanol, the most significant new fact is the dramatic increase in demand that begins to take shape as result of the new bi-fuel cars coming into the market. The simulations conducted by DATAGRO using a model developed by the Commission for Reexamination of the Energy Base indicate that the demand for ethanol in 2013 (domestic market) would amount to 22.04 Mm^3, 9.4 Mm^3 of which being of anhydrous ethanol, 11.54 Mm^3 of hydrous ethanol, and 1.10 Mm^3 for other purposes. An evaluation made by the Sectoral Chamber of the Sugar and Ethanol Supply Chain[11] points to a domestic demand of 16.9 Mm^3 (2010) and 26.3 Mm^3 (2015). More recent analyses[12] confirm a higher demand: production would reach 35.7 Mm^3 ethanol in the 2012/13 season, with 27.5 as fuel for the internal market. Cane supply would be 680 Mton, based on projects being implanted or in expansions of existing units (2006).

Fuel ethanol is expected to strongly expand its presence in many new regions of the world.[13] As early as 2003, 13 countries in the five continents used ethanol as fuel component. Ethanol is used worldwide as a fuel, as an industri-

9 NASTARI, P.: "Projeções de demanda de açúcar e álcool no Brasil no médio e longo prazos", III Conferência Internacional DATAGRO sobre Açúcar e Álcool, São Paulo, 2003

10 DRAKE, J. (Cargill Sugar): "The future of trade flows in the World Sugar Trade", III Conferência Internacional DATAGRO sobre Açúcar e Álcool, São Paulo, 2003

11 Communication by Luiz C. Correia Carvalho, Min. Agricultura, 2004

12 CARVALHO, E. P.; Formulação de uma estratégia para garantir o aumento da produção (UNICA); Seminário "Uma estratégia para o etanol brasileiro", Rio de Janeiro, Nov 2006 ulton, L.; Hodges, A.: *Biofuels for transport: an international perspective*, IEA / EET, 2004

13 BERG, C.: "World Fuel Ethanol Analysis and Outlook", F. O. Licht, 2004

14 SAKA, S.: "Current situation of Bio-ethanol in Japan", Workshop: Current State of Fuel Ethanol Commercialization, IEA Bioenergy Task 39, Denmark, 2003

15 CARVALHO, E.P.: "Demanda externa de etanol", Seminário BNDES – Álcool: Gerador de divisas e emprego, Rio de Janeiro, 2003

16 FULTON, L.; HODGES, A.: *Biofuels for transport: an international perspective*, IEA / EET, 2004

17 "Álcool: um cenário para 2010/11", Copersucar internal report, Apr. 2005

al consumable good, and in the beverage industry. It is produced either by fermentation (93%, in 2003) or chemical synthesis. Estimations for the 2000-2002[14] period indicate that the world production of ethanol for the various purposes was 33 Mm^3 / year, 19 Mm^3 of which as a fuel, 9 Mm^3 as an industrial consumable good, and 4.5 Mm^3 for beverages. In that period, the leading producers were Brazil (13.5 Mm^3, 2003) and the United States (6.5 Mm^3, 2001).

Estimation by UNICA for 2010, presented in 2003,[15] points to the following ethanol demand values:

USA	18 -20 Mm^3
Japan	6 -12 Mm^3
EU	9 -14 Mm^3
Eastern Europe	1 - 2 Mm^3
Canada	1 - 2 Mm^3

An evaluation recently performed by IEA[16] confirms those expectations: considering the targets that have already been set by the programs in UE and US/Canada, together with the expectations of Brazil, the evaluation points to a demand of 66 Mm^3 of ethanol in 2010, starting from the 33 Mm^3 of 2003. However, the estimations of Brazilian exports have been very cautious, particularly because of the high degree of trade barriers underlying many bioethanol programs around the world; values like 4.5 Mm^3 have been used as a reference for exports in 2010.

11.5 Future evolution of sugar cane production in Brazil

Meeting the domestic and international demand for ethanol and sugar, as quantified in **item 11.3**, would require a sugar cane production of 570 Mt of sugar cane/year within ten years (an increase of 2/3 in the current production). A recent revision of the ethanol demand (domestic and export markets)[17] estimates the demand for sugar cane at 560 Mt in 2010/11. These growth rates have been reached in the recent past.

Evaluating the possibility to accomplish that growth in a sustainable manner is one of the main purposes of this study.

To finish, we should remember that ethanol and sugar originate from the same crop, and the markets will interact in the event of such a strong presence of Brazil in foreign trade. A consideration that has been made is that equilibrium prices for sugar may be between US$ 0.08 and 0.09 / lb in the future if the expansion of both markets can be supported also by the Brazilian production. A final consideration refers to the subsidies to ethanol outside of Brazil: subsidies and high import taxes cannot coexist with the formation of a market in sustainable conditions.

11.6 Summary and conclusions

• The sugar cane products from the Center-South of Brazil do not rely on any price support mechanisms under governmental policies; there are no subsidies to sugar production or trade today.
• Ethanol production cost (without taxes) in the Center-South mills was estimated at R$ 647 / m^3, which is highly competitive with international gasoline costs. Ethanol production costs in Brazil are also lower than the costs for corn ethanol in the US or wheat and beet ethanol in Europe.
• The ethanol cost reductions in Brazil since the program was introduced have occurred on the back of advances in technology and management and investments in infrastructure. A broader implementation of commercial technologies may further reduce costs in the Center-South, but the best prospects relate to new technologies being developed. These include precision agriculture, new sugar cane and trash transportation systems, and genetic modifications of sugar cane.
• In addition, the production diversification will contribute to the rise in competitiveness, as it did upon introduction of ethanol. Such diversification (in progress) includes the increase in the use of sucrose and ethanol for new products, and the production of excess energy from sugar cane biomass in several ways (also in progress).
• The sugar from the Center-South has had the world's lowest production cost for many years now, amounting to R$ 410 / t. The world production cost is currently evaluated at US$ 120 / t, for up to 20 Mt (the production of Brazil's Center-South region); for 20 Mt to 65 Mt, the cost goes up to US$ 200-250 / t; and for 65 Mt to 100 Mt, it rises to US$ 400 / t. The total sugar production and export cost in the Center-South represents 65 percent of the mean cost of other exporters.
• The high availability of adequate land for expansion and the absence of governmental policy-supported prices in Brazil would allow even more competitiveness in a trade liberalization scenario (as expected).
• Analyses of the ethanol and sugar markets point to a demand of 580 Mt of sugar cane / year in Brazil for 2010 and 680 M tons for 2012/13.

V

Socioeconomic impacts of the sugar cane agribusiness

The socioeconomic importance of the industry in Brazil is widely known and can be shown in several aspects. In **Chapter 12**, we analyze one of the most interesting aspects from a sustainability standpoint: job creation and income. However, there are two points (among several others) that we should highlight: the meaning of ethanol production for hard currency savings in the country; and the impact of the industry on the development of major equipment manufacturers, which have an international projection today.

The replacement of gasoline with ethanol has saved an important amount of foreign currency for Brazil. Computing the value of the replaced gasoline at its international market price, the imports avoided between 1976 and 2004 represented savings of US$ 60.7 billion (at the exchange rate in December 2004). Considering interest on the foreign debt, the savings amounted to 121.3 billion. For comparison, Brazil's foreign currency reserves amounted to US$ 49.4 billion (October 2004), or just US$ 24.2 billion if loans from the IMF are excluded.

The industry's development required major advances from manufacturers of equipment for both the agricultural and industrial sectors. The technological level of those manufacturers has been constantly upgraded, and some of them are world leaders in their segments. Domestically, this translates to job and income creation. Equipment for sugar and ethanol production and combined heat and power generation has now a nationalization level of nearly 100 percent. They have grown since 1975 with the National Alcohol Program (PNA), and in the 1990's they recieved a great boost from sugar exports, having now developed into more efficient systems for combined heat and power and full use of sugar cane energy. There have been several remarkable examples in this process. The pace at which the industry has developed and implemented new solutions has led to the turn-key packages for the supply of distilleries and full combined heat and power systems. In ten years, the main Brazilian suppliers produced around 200 independent distilleries (and 200 corresponding combined cogeneration plants), with a "historic" average of five plants per month. Considering production "peaks", the two leading manufacturers (Dedini and Zanini) have produced 96 milling systems in one year, and 81 distilleries per year; and an average of 63 boilers from 1973 until 1982. The leading manufacturer's (Dedini, 80% of the equipment) accumulated experience has been acquired in the course of a production of 726 distilleries (distillation units), 106 full plants, 112 combined cogeneration plants, and 1,200 boilers, with 16 full distilleries in foreign countries.

The evolution in the industry's business units, as it happens in the various other sectors of the economy, is leading companies to increasingly accept what is conventionally called "social responsibility" in the context of their business.

"Social responsibility" is a term used to describe business actions related to ethical values: compliance with the law and respect for people, communities and the environment. More specifically, it means business understood as an integral part of society, contributing to its well-being by caring about the social impacts of its policies and practices. This includes the impacts of a specific business on the levels above and below its supply chain; and the impacts of voluntary business contributions on affected communities.

Advances in this direction have intensified over the past few years, thereby consolidating principles, practices and systems for the business world and involving a growing number of companies. For example, principles are expressed in the responsibility extended to products, propositions about Factor 4 or Factor 10 in resource savings, and several voluntary codes of conduct. Practices include benchmarking, the Global Reporting Initiative (GRI), several environmental accounting methods and environmental performance indicators, life-cycle evaluations, etc. The systems include audits, ISO 14001 EMS, quality management, etc. In particular, the GRI (UNEP/several countries) creates an economic, social and environmental reporting structure in order to raise sustainability reports around the world to the level of financial reports.

In **Chapter 12**, we include a description of São Paulo-based companies in this context, although the subject is not limited to employment relationships.

Chapter 12:
Jobs and income

Compared to Brazilian 45-percent mean index workers contributing to social security (2003), the sugar cane industry`s agricultural activities now have an index of 72.9% (from 53.6% of 1992). In the Center-south, formal jobs in sugar cane production (agriculture) reach 85.8%, with 93.8% in São Paulo (2005). Differences in regional development are reflected in the industry's occupational indicators; poorer regions are characterized by lower salaries and a much larger use of labor.

12.1 Introduction

The unemployment rate in Brazil has remained at 9 to 10 percent over the past few years, a level which is a little higher than that of developed countries (except for Japan).[1] The most serious issue is job quality; for example, 55 percent of the workforce do not contribute to social security, the child (10 to 14-year-olds) labor rate was 2.4 percent (compared to 5.3% in 1992). The functional illiteracy (fewer than 3 years of study) rate of employed people dropped from 37.4 to 23.9 percent during the same ten-year period.[1] The evolution is important, but the figures are still far from ideal.

1 Neri, M.; "Trabalho", *in*: *Brasil em números*, IBGE, vol.12, 2004

The income distribution (among employed people, 2002) indicates that 53 percent were paid up to two times the minimum wage (half of whom receiving less than minimum wage), and only 1.3 percent had a salary equivalent to more than 20 times the minimum wage.

The greatest challenge facing Brazilian society is to reduce social inequality. Over the past twenty years, even though the income has generally increased, there doesn't seem to have been a substantial improvement in inequality indicators.[2] Some examples of this are the national illiteracy rate (12.8% in 2000), which goes up to 28 percent in rural areas, with a corresponding mean income variation, or 26 percent in the Northeast region, taken as a whole.

2 Carvalho, J.M.: "Uma breve história do Brasil", *in*: *Brasil em números*, IBGE, vol.12, 2004

It is difficult to find appropriate salary comparison indicators, even on a regional basis, and it is even harder to try to compare income on a country-to-country basis. In the following texts we seek to compare differences, but mainly as to analogous activities within the same region. Nevertheless, a set of data in respect of Brazil's and some of the selected countries' economies is shown below, as adjusted for Purchasing Power Parity (PPP).

According to international references,[3] in 2002 Brazil had a Gross Domestic Product of US$ 1.34 trillion (PPP: Purchasing Power Parity) and per capita income of US$ 7,600 (also in PPP). In legal tender, the GDP amounted to US$ 450 billion, and the per capita income US$ 2,630. The mean exchange rate for that year was R$ 2.912/US$ 1. For reference, still using values in PPP, the Gross Domestic Product of the United States was US$ 10.4 trillion, with per capita income of US$ 37,600.

In 2000, the per capita GDP (PPP) was US$ (PPP) 7,744 in Brazil, US$ 23,917 in Germany, US$ 22,876 in Italy, US$ 9,661 in Poland, US$ 11,062 in Hungary, US$ 7,414 in Turkey, US$ 5,795 in Colombia, and US$ 6,715 in Thailand.

3 The World Factbook 2003, site: www.bartleby.com/151/

Measurements by the Gini coefficient (the coefficient ranges from zero to one; the larger the income distribution inequality, the higher the coefficient) are more inaccurate and scattered; the same source points to 0.607 in Brazil (1998), 0.567 in Chile (1998), and 0.456 in the United States (1994).

Utilization of the several countries' official minimum wages as a reference for the salaries paid is impaired by the fact that such official minimum wages do not correspond to the same functional definition, and do not follow the definitions set for each country either, in many cases. Some of the distortions in the case of Brazil are analyzed in paper prepared by IPEA,[4] which concludes that there was (1996) a great difference to the international standards.

4 Barros, R.P.; Foguel, M.; Garcia, G.; Mendonça, R.: "O nível do salário mínimo no Brasil frente à evidência internacional", IPEA, 1996

Sugar and ethanol agribusiness complex and independent sugar cane growers

In Brazil, unlike most countries, sugar cane is used to produce sugar, ethanol and several other products. This makes the valuation of the raw material a unique process in the world, given the need to create a measurement unit capable of translating the obtention of several products from the same source. That unit, the ATR (Total Recoverable Sugars, in Portuguese), is used in Brazil to regulate the sugar cane market.

The sugar cane may be owned by industrial units or independent growers, or produced by the industry in leased land. On average, the value of sugar cane (as an input) corresponds to 58.5 percent of the income from agribusiness end-product sales. São Paulo State has the largest concentration of independent growers, with the actual market for raw material reaching 25 percent of the total; sugar cane is grown on approximately 11,000 agricultural properties.

Since the 1998/99 crop, the business relationship between the sugar and ethanol agribusiness complex and independent sugar cane growers has been governed by a joint self-management model. The new system has replaced one that consisted of pricing by the Federal Government, and is based on the quality of raw materials and the market price obtained for the end-products (sugar and ethanol).

The computation basis is the quantity of ATRs (Total Recoverable Sugars) contained in each ton of raw material, which are used in sugar and ethanol production. The ATR value is determined by analyzing the sucrose (sugar) content, the fiber content, purity of the sugar cane and the losses in the sugar and ethanol production processes. The price obtained for the end-products in the market is monitored by an independent organization.

The end price paid to producers is determined by a parametric model that forms the basis for individual negotiations between mills and sugar cane growers from the various regions. This model is not static and is constantly reviewed by the parties of a specific organization created by producers. In São Paulo State, that organization is called the Council of Sugar Cane, Sugar and Ethanol Producers, or CONSECANA-SP, which has a joint self-management coordination consisting of members of the industries and growers.

12.2 Labor legislation in Brazil and its application to the sugar and ethanol industry

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12.2.1 Brazilian labor legislation and union organization

Brazil's labor legislation consists of countless rules set forth in the Federal Constitution, Complementary Laws, Laws, Executive Laws, OIT Conventions (ratified by Brazil), Provisional Measures, Decrees, Ordinances, Instructions, Administrative and Regulatory Rules.

The union organization is governed by the same rules and based on two constitutional principles: a) free labor or trade association, which precludes the Public Power from interfering with or intervening in the union organization; b) unity, which prohibits the creation of more than one union, on any level, to represent one professional or economy category in the same territorial base. Employers and workers are represented by only one trade or labor union, federation and/or confederation.

12.2.2 Governing legislation

The Federal Constitution, articles 1 and 2, provides for the fundamental principles of the Federative Republic of Brazil, which are based on the Democratic Rule of Law, sovereignty, citizenship, human dignity, the social values of work and free enterprise, and political pluralism.

Articles 3 and 4 provide for the fundamental objectives and principles that govern the Federative Republic. Article 5 sets forth the fundamental rights and assurances of Brazilian citizens.

They are followed by Section II, which provides for Social Rights, as listed below:

Art. 6	Social rights
Art. 7	Rights of urban and rural workers, comprising 34 items
Art. 8	Freedom of labor or trade unions
Art. 9	Right to strike
Art. 10	Workers and employers' right to take part in the government agencies where their business or social security rights are subject to discussion
Art. 11	Employee representation for companies having more than 200 employees

Finally, there is article 10 in the Transitory Constitutional Provisions section, which addresses termination made arbitrarily or without cause, tenure of the employee elected for a board office at CIPA (Internal Commission for Accident Prevention), tenure of pregnant employees, period of maternity/paternity leave, and payment of contributions to support rural union activities.

Right under the Constitution, there is also the Labor Code (CLT) which provides the basis of Brazil's labor legislation and governs the following aspects, among other matters:

- General and Special Labor Protection Rules
- Special Provisions on Employment Term and Conditions
- Labor Nationalization
- Woman, Child and Adolescent Labor Protection
- Individual Employment Agreement
- Union Organization
- Collective Bargaining Conventions

Even though rural and urban labor are equalized by the Constitution (article 7, Federal Constitution), rural labor is still governed by Law no. 5,889/73 and Decree no. 73,626/74. It is worth remembering that article 4, sole paragraph, of the Decree lists the articles of the CLT that are applicable to rural labor.

The Norma Regulamentadora 31 (Health and Safety for the work in Agriculture, Pasture, Forest products and Aquaculture) is considered one of the most advanced worldwide with respect to safety and comfort for the rural worker

Also applicable to the industry are other rules arising out of the capital-labor relationships, such as, for example: Law no. 605/49 (Weekly Holiday Pay); and Law 8,036/90 (Worker Dismissal Fund).

12.2.3 Union organization

Employer and employee representation in sugar and ethanol industry set forth in the table referred to in article 577 of the CLT:

1st Group – Food Industries (sugar production)

10th Group – Chemical and Pharmaceutical Industries (ethanol production)

In rural areas, sugar cane suppliers and agribusiness companies (related to the industries) are represented by rural trade unions and the State Federation of Agriculture. The workers are represented by Workers/Rural Employees Unions and/or by the local State Workers/Rural Employees Federations.

Despite the unity principle, the Brazilian legislation accepts representation by "differentiated categories." In theory, such categories exist on account of the peculiarities involving certain groups of employees, such as drivers, for example.

12.2.4 Collective rules

The law allows the parties to set up collective rules. Today, such rules could be summed up in a Collective Work Convention (Employers Union vs. Labor Union), and a Collective Work Agreement (Companies x Labor Union).

Such rules must be filed with the Labor Stations, Labor Sub-Deparments or Regional Labor Departments, and may be effective for up to 2 years.

On the category's reference date, salary clauses are determined by the free negotiation criterion, as well as social clauses. Refusal to negotiate or impossibility to enter into a Collective Work Convention/Agreement may lead the parties to commence a collective labor dispute (by the latest labor rules, provided that the parties commence the dispute by mutual agreement).

Collective rules are "complementary" in their nature, and the clauses subject to negotiation cannot prevail over the legislation. If there are two rules (convention or agreement for the same employee or employer categories) effective for the same period, the rule setting the most beneficial conditions to the worker must prevail.

In this respect, it is worth pointing out that there is a lot of doctrinal and jurisprudential divergence as to the criterion to be adopted for analyzing the rule most beneficial to the worker. One stream of law interpretation thinks that the only the conflicting clause (or aspect) should be evaluated. The other thinks that such analysis should not be limited to a given conflicting clause (or aspect). Therefore, the rule to be regarded as the most beneficial is that which altogether provides for the most favorable conditions to the worker (principle known as "*conglobamento*").

12.2.5 Collective bargaining in São Paulo's sugar and ethanol industry

1. Sugar mills with distillery additions are represented in São Paulo State by the São Paulo State Sugar Industry's Union. Their employees are represented by 30 Food Industry Labor Unions for São Paulo State and by the Food Industry Workers' Federation for São Paulo State.

On the reference date for the category (May 1st), a Collective Work Convention is signed by the aforementioned parties. As a rule, such Convention is effective from May 1st to April 30 of the subsequent year, and provides for the rules for mill employees, such as the salary floor for the category, salary adjustments, and other social clauses.

Recently, parallel with the Collective Convention, a large number of companies have been entering into Collective Bargaining Agreements directly with the labor union for their region. Such agreements aim at providing for the rules applicable to the peculiarities of these companies for that same period (from May 1st until April 30 of the subsequent year).

Because of this new reality, the Collective Convention entered into at the state level began to expressly confirm the Collective Bargaining Agreements signed directly by the companies and the regional labor unions.

2. Ethanol distilleries are represented by the Ethanol Manufacturers' Trade Union for São Paulo State. Their employees are represented by 11 Chemical and Pharmaceutical Industry's Labor Unions for São Paulo State and by the Chemical and Pharmaceutical Industry's Federation for the State of São Paulo.

On the reference date for the category (May 1st), the Ethanol Manufacturers' Trade Union for São Paulo State and the Federation of the Chemical and Pharmaceutical Industry's Workers for São Paulo State sign a document ensuring that the reference date is May 1st and providing that the collective bargaining agreements shall be concluded on a company-to-company/region-to-region basis.

The structure of those agreements is basically identical to that of agreements between mills and food industry labor unions.

3. On the reference date, i.e. May 1st, the Sugar Industry's Trade Union for São Paulo State and the Ethanol Manufacturer's Trade Union for São Paulo State, as consenting parties (representing industry-related Agricultural Companies), sign the Collective Bargaining Convention entered into at the state level between, on the one hand, the Federation of Agriculture for São Paulo State and the rural trade unions, as representatives of the related agricultural companies and/or suppliers, and, on the other hand, the rural workers' labor unions.

Such rules replicate the basic structure of the collective rules applicable to mills and distilleries.

There are also conventions entered into by the rural trade union directly with the labor union for the region, as well as agreements entered into by the agricultural companies related to the mills and/or distilleries directly with the labor union.

Said conventions and agreements are specific to the sugar cane industry due to the creation, in 1984, of the "*Grupo Cana*", or Cane Group, with reference date on May 1st, which provided for specific rules, to wit: floor salary; compensation of the "*bituqueiros*" (workers in charge of catching the sugar cane that falls from trucks); salary adjustments; value of one ton of sugar cane for 18 months; and other specific points and social clauses.

In the rural area in the rural area, UNICA – União da Agro-indústria Canavieira do Estado de São Paulo and FERAESP – Federação dos Empregados Rurais Assalariados do Estado de São Paulo established a protocol (February 2006) aiming at improving the work relations in the sector, analysing and proposing the best practices

Finally, said collective rules usually contemplate the provision of benefits that vary from company to company, including: medical, dental, hearing and pharmaceutical care; life insurance; meals; food basket (food that meets minimum nutritional requirements set by the government); food and transportation stamps; private pension plans; disease and funeral allowances; education allowances; breakfast; Christmas baskets (packages containing the season's typical foods); agreements with supermarkets; loans; subsidized sales; and access to credit cooperatives.

12.3 Jobs and income in the agribusiness in the 1980's and 90's

12.3.1 Production system in the sugar cane industry

The sugar cane industry's production system in Brazil consisted of a large number of industrial units (> 350) with production areas ranging from 5,000 to 50,000 hectares. Such scale is much smaller if we take into consideration that the sugar cane is supplied by a group of dozens of thousands of growers, not to mention the mill owners' own growing areas; in 1986, the supply by outside growers represented 38 percent of the mills' total sugar cane.[5] That share was reduced a little less than 30 percent over fifty years, and is growing again in some regions.

5 Borges, J.M.M.: "The Brazilian alcohol program: Foundations, results, perspectives, energy", 1990, Sources 12, pp.451-461

Another relevant characteristic in terms of job creation and the quality of such jobs in the industry is the seasonal pattern of the agricultural operation; the weather and agronomical conditions for sugar cane limit the harvesting period (the most labor-intensive operation) to six or seven months a year in Brazil. The level of technology used in agriculture determines the relative demand for labor in the two periods, i.e. harvesting and in-between-harvest cycles. Great differences (high "seasonal index," defined as the "labor in the harvesting period/labor in between harvest cycles" ratio) imply more temporary labor and, as a result, low salaries. This is a universal problem in agriculture.

Since two thirds of the end cost of sugar cane products (ethanol and sugar) correspond to the sugar cane cost, which is strongly dependent on the labor cost, most of the jobs in the industry are similar those in other agricultural segments in Brazil. Employment levels, job creation cost, salaries, employment relationships and job quality are always compared with those of "other crops" for the large portion of sugar cane production employees and, in sugar cane processing, with those of similar industrial segments (chemistry, fuel processing, foods).

6 Goldemberg, J.; Monaco, L.; Macedo, I.: "The Brazilian fuel-alcohol program", *in*: *Renewable energy sources for fuels and electricity*, Island Press, 1993

7 Fundação Getúlio Vargas: "Sistema Custo/Preço – Álcool hidratado", São Paulo, 1994

In the early 1990's,[6, 7] a mean rate of 21 to 24 percent of total sugar cane cost (including land, capital costs, and all other fixed and variable costs) corresponded to direct labor costs and social taxes. Including processing costs for ethanol (and also capital, marketing and other costs), the direct labor costs would reach 20 to 25 percent of the ethanol costs; labor in agriculture corresponded to more than 60 percent of the total labor cost.

In both cases (industry and agriculture), the number and quality of jobs were strongly dependent on the level of technology used, and there were substantial regional differences in Brazil. Therefore, from the employment standpoint, the sugar cane agribusiness can be said to have essentially consisted since that time of a large group of agribusiness units that are similar to food production units, but very different than the energy (fuel) production sectors: it has much larger number of employees per energy unit produced, much lower job creation costs, a much wider job diversification, and a much more decentralized production.

12.3.2 Context: labor market in Brazil, 1980's and 90's

The official unemployment levels were low in Brazil[8]; the mean rate for the 1980's was 5 percent (minimum of 3% in 1989, and maximum of 8% in 1981). However, it was easy to realize that disguised unemployment was high: in 1988, 44 percent of the workers in agriculture, 6 percent in the industry, and 15 percent in services were paid less than one official minimum wage (reference), i.e. US$ 53 / month at that time. Only 20 percent of the workers in the industrial and service sectors and 5 percent of the workers in agriculture had salaries in excess of US$ 265/month. There were important regional differences: among the leading sugar cane growing regions (São Paulo, 66%; Northeast, 20%), salaries were much higher in São Paulo. All of these values (including the official minimum wage) are different today.

Brazil's family income distribution in 1988 indicated that 36.1% of the families were paid less than US$ 106 / month, 67.3% had an income of less than US$ 265 / month, and 94.3% received less than US$ 1,060 / month.

12.3.3 Jobs and income in the sugar cane industry

We can sum up the data for two periods: the late 1980's, and the second half of the 1990's. They will then be compared by a detailed analysis of the current situation in items 12.4 and 12.5.

In the early 1990's in São Paulo[9] (with the highest technology level and around 60% of the country's production), around 30% of all workers were specialized (agricultural supervision and industrial operations), 10% had a medium level of specialization (tractor operators and drivers, for example), and the remaining 60% had no specialization (sugar cane planting and harvesting; other industrial jobs). For every 1 M t of sugar cane, there were 2,200 direct jobs (1,600 in sugar cane production, and 600 in processing), while indirect jobs (a limited view: equipment manufacturing and maintenance, chemicals and other consumables only) were estimated at 30% of the number of direct ones. Therefore, the sugar cane industry employed a total of 380,000 people in São Paulo.

Estimations for Brazil would consider a much more intensive use of labor per production unit in the Northeast; in some cases, three times as much. The totals were estimated[10] at 800,000 direct jobs and 250,000 indirect jobs in 1990.

8 Borges, J.M.: "Geração de empregos na agroindústria canavieira", *in: Desenvolvimento em harmonia com o meio ambiente*, Rio de Janeiro, F.B.C.N., 1992

9 Borges, J.M.: "The effect on labor and social issues of electricity sales in the Brazilian sugar cane industry", Proceedings of the International Conference on Energy from Sugar Cane, Hawaii, Winrock International, 1991

10 Magalhães, J.; Machado, R.; Kupermann, N.: *Políticas econômicas, emprego e distribuição de renda na América Latina*, Rio de Janeiro, Editora Vozes, 1991

These are impressive figures *per se*, but it also important to point out the system's capacity to create jobs in a large number of places, thereby decentralizing income generation. In 1991, there were ethanol distilleries in 357 Brazilian municipalities (8% of all municipalities); the potential impact of the jobs in this industry compared to the total jobs in those municipalities was 15.6 percent, on average, reaching 28 percent in the Center-West region.

There were strong regional differences that reflected in the sugar cane industry (jobs/production unit, salaries and job quality), and technology was usually the balancing factor for the system. As the most important example, the competition for workers among the various sectors of the economy in São Paulo, in the case of sugar cane harvesting, resulted in higher salaries, better working conditions, and a much lower number of jobs (more efficient harvesting workers and, of course, higher degree of mechanical harvesting). In industrial operations, greater automation, productivity and conversion efficiency also led to a smaller number of jobs, a higher degree of specialization, and higher salaries.

11 Johnson, B.; Wright, T.: "Impactos comunitários do Proálcool", Report to STI-MIC, FEA-USP, 1983

A study conducted in the mid 1980's by the University of São Paulo[11] in 15 towns in the largest sugar cane growing areas pointed to local population growth in all cases, and reversal of the trend towards migration to large urban centers in most cases. The positive impacts (jobs, taxes resulting in infrastructure improvements) were substantial in the Center-South, but relatively smaller in other regions.

In São Paulo, non-specialized workers (sugar cane cutters) would have a mean income of US$ 140/month. In the context of the Brazilian economy at that time, such income was higher than that of 86 percent of agricultural workers, 46 percent of industrial workers, and 56 percent of the workers in the service sector. The family income of those workers (sugar cane cutters) was estimated[9] at US$ 220 / month, annual average; which was higher than the income of 50 percent of all Brazilian families. On the other hand, the seasonal index would result in US$ 280 / month in the harvesting period, and only US$ 160 / month in between harvesting cycles.

9 see p. 209

The seasonal index for sugar cane crops was estimated at 2.2 in the late 1970's[12]; coffee, with an index of 2.0, was the only major culture to be in a better situation in São Paulo. Several factors contributed to reducing that coefficient in the 1980's and 90's, including utilization of the same personnel for soil conservation and maintenance tasks in between harvesting cycles, and a strong decrease in harvesting labor requirements due to the expansion of mechanical harvesting. Estimations in the late 1980's[9] pointed to a seasonal index of 1.8, while in the 1990's several mills had an mean index of 1.3.[13] This is a clear trend, and it is now considered that most agricultural

12 AIAA – Assoc. Indústrias de Açúcar e Álcool, SP: "Açúcar e álcool: Energia para um crescimento econômico auto-sustentado", São Paulo, DATAGRO, 1991

13 Marques, J.C.: Private communication, economic consultant to Copersucar, São Paulo, 1995

jobs may be permanent, allowing training and career planning. In this aspect, also, the figures were different for the Northeast region; in São Paulo, mechanical harvesting advanced rapidly due to legal restrictions on the burning of sugar cane and the increasing cost of labor as of the mid 1990's.

The estimations of the investment required for job creation in the sugar cane industry reflect some of the aforementioned regional differences (technology, productivity levels). In the 1980's, values as low as US$ 11,000/job were attained,[12] which are probably appropriate for the Northeast region. In the Center-South, analyzes[8] pointed to amounts ranging from US$ 23,000/job, excluding the investment in land, to US$ 45,000/job, for annual jobs and including investment in land. For comparison, the mean investment in job creation in the 35 leading sectors of Brazil's economy in 1991 ranged from US$ 10,000 to US$ 125,000, with an average of US$ 41,000. Selected agribusiness activities (foods, beverage, pulp and paper) required US$ 50,000/job; US$ 44,000/job in the service sector (trade, supermarkets, communications, hotels), and US$ 125,000/job in the chemical industry. Only 14 sectors could create jobs using less capital than the sugar cane industry. In less developed regions, the investment per job was much lower than the Brazilian average.

12 see p. 210

8 see p. 209

In the late 1990's the situation was well-evaluated by a survey[14] based on the Brazilian economy's input-product base (IBGE, 1997). That allowed not only the creation of direct and indirect jobs, but also the creation of induced jobs to be evaluated. The results were as follows: 654,000 direct jobs, 937,000 indirect jobs, and 1,800,000 induced jobs. It is noticeable that even though the production of sugar cane (and other end products) increased in that decade, the number of direct jobs decreased (as expected due to the higher concentration in the Center-South region and the expansion of mechanical harvesting and automation), while many other jobs were outsourced, thereby significantly increasing the proportion of indirect jobs. Regional differences keep influencing the industry: although the Northeast region accounts for only 18.6 percent of the production, it uses 44.3 percent of the workforce (i.e. 3.5 times as many workers per product unit). The resulting difference in job quality is evident in the distribution of education levels among the industry's workers (direct jobs):

14 Guilhoto, J.J.M.: "Geração de emprego nos setores produtores de cana-de-açúcar, açúcar e álcool no Brasil e suas macro-regiões", Report "Cenários para o setor de Açúcar e Álcool", MB Associados and FIPE, Abril, 2001

Table 1: Worker distribution by education level: direct jobs, Brazil and regions: sugar cane and products

Years at school	Brazil (%)	Southeast (%)	Northeast (%)
< 1	31.5	17.1	48.8
1 - 3	27.3	29.1	27.6
4 - 7	28.0	36.4	14.7
> 8	13.2	17.4	8.9

12.4 Number and quality of jobs in the sugar cane agribusiness

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For analyzing the number and quality of jobs in the sugar cane, sugar and ethanol industries in Brazil, two databases were used: for the formal labor market, RAIS (Administrative Records of the Labor and Employment Ministry); and, as a complement to the latter, PNADs (National Household Sample Research, conducted by IBGE), which include informal jobs.

12.4.1 The formal labor market

RAIS, which covers 90 percent of the organized sector of the economy, has information formally provided by companies to the Labor and Employment Ministry. The main limitations are errors and omissions in completing the questionnaires, which occur more commonly in small towns and some specific sectors (agriculture, construction, public management). In addition, because of the structure of such questionnaires, outsourced workers are not included in the user sector, and neither are indirect jobs. In the income evaluation, the 13th salary (a mandatory annual bonus equivalent to one month's salary) is not included.

Table 2 shows the evolution in the combined number of employees of the three industries in Brazil and its sugar cane producing regions: the Northeast and the Center-South. It shows a rise of 52.9 percent in the number of direct jobs for the sugar cane, sugar and ethanol industries. In 2005, 63 percent of all formal jobs were in the Center-South region.

Table 2: Formal employees by producing region and total for Brazil 2000-2005

Producing region	Formal direct jobs			
	2000	2002	2004	2005
N-NE	250,224	289,507	343,026	364,443
C-S	392,624	475,086	557,742	618,161
Total, Brazil	642,848	764,593	900,768	982,604

Source: Prepared from RAIS data, Labor and Employment Ministry, several years

Table 3 shows the evolution in number of employees by region and by industry. It shows that the lower growth rate occurred in agriculture (16.2%). The relative share of agriculture fell from 55.5 percent to 42.2 percent of the total, while in the industrial sector it increased, reflecting the expansion of both production and agricultural mechanization.

Table 3: Formal, direct jobs by producing region and by industry,2000-2005

Industry	Region	Formal direct jobs			
		2000	2002	2004	2005
Sugar cane	N-NE	81,191	86,329	104,820	100,494
	C-S	275,795	281,291	283,820	314,174
	Total	356,986	367,620	388,121	414,668
Sugar	N-NE	143,303	174,934	211,864	232,120
	C-S	74,421	126,939	193,626	207,453
	Total	217,724	301,873	405,490	439,573
Ethanol	N-NE	25,730	28,244	26,342	31,829
	C-S	42,408	66,856	80,815	96,534
	Total	68,138	95,100	107,157	128,363
Total		642,848	764,593	900,768	982,604

Source: Prepared from RAIS data, Labor and Employment Ministry, several years

Table 4 (p. 214) shows the number of people formally employed grouped by producing region (N-NE and CS), considering age groups and education levels, for the year 2002.[15] By analyzing Brazil as a whole, we note that the 30-39 age group is the largest (28.5% of the total). By adding age groups between 18 and 49, we come up to 90.8 percent of all employees. It is important to emphasize the small share (0.2%) of employees less than 17 years of age. The data for producing regions show a similar trend to that in Brazil: small proportion of employees under 17 years of age, and a vast majority of employees (around 90%) aged 18 to 49.

15 Specific data for each region (North, Northeast, South, Southeast and Center-West), as well as for the main producing states, are found in Moraes, M.A.F.D.; Pessini, M.: "Analysis of the labor market of the Brazilian Sugar and Alcohol Sector", World Bank, 2004

Concerning the mean education level in the three sectors, Table 4 shows that the group of workers in cane production averages of 4.2 school years; the average is 4.3 for the sugar industry, and 5.8 for the ethanol industry. Considering the three sectors together, the workers having not concluded 4th grade prevailed in Brazil in 2005 (35.2%), followed by those who finished 4th grade (18.8%). An important fraction of illiterate workers is shown (11.3%).

When the main producing regions are analyzed separately, the workers' profile changes significantly. For sugar cane crops in the North-Northeast region, 29.3 percent of all workers are illiterate, and 47.8 percent did not finish 4th grade, making up 77.1 percent of the workers. A low education level is shown for sugar production as well, where 24.9 percent of the workers are illiterate and

Table 4: People employed in sugar cane, sugar and ethanol production by geographic region, considering age groups and education levels, 2005

	Brazil	North-Northeast			Center-South		
Age groups		Cana	Açúcar	Álcool	Cana	Açúcar	Álcool
Up to 17 y. old*	1,514	221	229	14	668	302	80
18-24	246,299	23,755	60,187	8,846	79,929	50,790	22,792
25-29	191,272	18,687	47,093	6,606	61,209	39,272	18,405
30-39	280,267	28,264	65,400	9,029	89,343	59,641	28,590
40-49	174,458	18,409	39,229	5,215	54,624	39,126	17,855
50-64	83,695	10,732	19,227	2,058	26,321	17,030	8,327
65 years or older	5,097	424	755	61	2,080	1,292	485
Unknown	2	2	0	0	0	0	0
Total	982,604	100,494	232,120	31,829	314,174	207,453	96,534
Education							
Illiterate	111,516	29,467	57,764	2,348	13,569	4,832	3,536
4th grade not concluded	345,652	47,993	109,945	12,908	95,248	55,773	23,785
4th grade concluded	184,290	9,530	21,040	9,578	79,152	45,172	19,818
8th grade not concluded	142,100	7,169	19,478	2,632	62,181	34,075	16,565
8th grade concluded	70,749	1,947	7,190	1,638	30,876	18,733	10,365
High school drop-out	38,911	1,697	5,548	728	12,676	12,411	5,851
High school graduate	71,537	2,216	8,920	1,437	16,504	28,743	13,717
College drop-out	5,518	143	572	123	1,465	2,195	1,020
College graduate	12,331	332	1,663	437	2,503	5,519	1,877
Total	982,604	100,494	232,120	31,829	314,174	207,453	96,534

Source: Prepared from RAIS data, Labor and Employment Ministry, 2005

* For 2005 the first age group data available is "up to 17"

Table 5: Mean monthly salary by age group and education level; sugar cane, sugar and ethanol; Brazil and producing regions, R$, 2005[1]

	Brazil	North-Northeast			Center-South		
Age groups		Cane	Sugar	Ethanol	Cane	Sugar	Ethanol
Up to 17 y.old	348.76	294.51	321.86	360.80	398.94	281.59	408.14
18-24	551.64	393.09	407.87	416.39	633.02	667.36	605.82
25-29	638.77	438.84	467.69	470.96	711.16	818.60	715.27
30-39	705.58	472.21	523.99	521.06	737.66	948.73	802.44
40-49	795.35	486.43	598.59	649.58	775.49	1121.63	934.53
50-64	758.60	456.24	621.01	738.44	728.27	1103.79	860.89
65 years old or older	826.34	528.66	955.67	983.65	735.71	996.47	800.92
Unknown	388.60	388.60	0.00	0.00	0.00	0.00	0.00
Total	674.52	448.05	504.31	517.50	710.93	899.87	768.54
Education							
Illiterate	417.92	382.07	382.05	394.26	571.72	578.45	508.79
4th grade not concluded	527.09	422.83	437.58	441.26	603.31	655.49	591.46
4th grade concluded	720.20	467.62	528.99	504.95	748.51	881.91	667.04
8th grade not concluded	684.30	553.49	581.01	553.85	666.70	806.40	698.02
8th grade concluded	780.71	552.39	682.94	550.04	746.38	905.82	804.01
High school drop-out	756.70	580.15	628.63	562.03	750.49	837.04	796.61
High school graduate	981.27	882.21	921.64	741.37	948.98	1049.59	956.85
College drop-out	1414.38	964.47	1696.33	1303.64	1159.88	1613.07	1270.66
College graduate	3353.09	2703.02	4116.29	2334.32	3001.69	3432.75	3263.44
Total	674.52	448.05	504.31	517.50	710.93	899.87	768.54

Source: Prepared from RAIS data, Labor and Employment Ministry, 2005

1 Current values in R$ for 2005

47.4 percent did not graduate from 4th grade (72.3% of all workers). The situation is better in ethanol production, but the low education level still prevails: 7.4 percent are illiterate and 40.6 percent did not conclude 4th grade.

In turn, the Center-South region has the best education indicators: in the sugar cane culture, 4.3 percent of the workers are illiterate and 30.3 percent did not conclude 4th grade (totaling 34.7 percent of all workers); in sugar production, 2.3 percent are illiterate and 26.9 percent did not finish 4th grade; and in ethanol production, 3.7 percent are illiterate and 26.9 percent failed to graduate from 4th grade.

The compensation of formal employees of the sugar cane, sugar and ethanol industries (2005) is shown in **Table 5** (p. 213).

The mean monthly salary (2005) for all three sectors in Brazil was R$ 674.52.

Considering the regions separately, the mean monthly salary for the sugar industry in the N-NE region was R$ 504.31, whereas for the Center-South region it was R$ 899.07 (78.4% higher); in the ethanol industry, the mean salary was R$ 517.50 in the former region, and R$ 768.54 in the Center-South region (48.5% higher); the lowest mean salary was found in the sugar cane culture, for which it amounted to R$ 448.05 in the North-Northeast and R$ 710.93 in the Center-South region (58.7% higher). As expected, there is a positive correlation between education level and income.

12.4.2 Inclusion of the informal labor market: PNAD

To consider both formal and informal jobs, we used the data from the National Household Sample Survey (PNAD) conducted by the Brazilian Institute of Geography and Statistics (IBGE). The PNAD and RAIS data are not directly comparable, as they result from different collection methodologies; the RAIS is a census of the formal labor market, and the relevant questionnaire is completed by the employer, whereas PNAD interviews are at the employee's home. In this case, the analysis unit is the business establishment, and the answers to the interview refer to the business establishment's main activity. Considering the peculiarities of each database, the collected variables usually show the same trends, and PNAD is very useful to evaluating the level of informal jobs, which is not detected by RAIS.

Table 6 shows the evolution of the number of employees in the sugar cane industry from 1992 to 2005. During such period, it shows that there was a decrease in number of employees of approximately 23 percent, which is partly due to the expansion of mechanical harvesting in sugar cane crops. It also shows that proportion of permanent and temporary employees was reasonably stable, and the share of permanent employees was bigger in some years.

Table 7 shows the evolution of formal employment in agriculture (sugar cane crops) for Brazil, the main sugar cane growing regions, and São Paulo State. The total number of employees with formal working papers in Brazil increased from 53.6 percent in 1992 to 72.9 percent in 2005. The level of formal employment in the Center-South region (particularly in São Paulo State) is much higher than in the other regions, in the aggregate, with 93.8 percent of all workers in the state having their formal working papers in 2005.

Table 6: Evolution of the number of permanent and temporary employees in sugar cane production

Years	Permanent		Temporary		Total
	Employees	%	Employees	%	
1992	368,684	54.7	305,946	45.3	674,630
1993	373,903	60.6	242,766	39.4	616,669
1995	380,099	61.4	238,797	48.6	618,896
1996	378,273	59.1	260,873	40.8	639,146
1997	323,699	57.8	236,012	42.1	559,711
1998	322,601	70.7	133,368	29.2	455,969
1999	300,098	65.0	161,410	35.0	461,508
2001	222,418	53.6	192,671	46.4	415,089
2002	246,357	54.6	205,000	45.4	415,357
2003	229,981	51.2	218,902	48.8	448,883
2004	252.394	51.1	241,682	48.9	494,076
2005	293.631	56.6	225,566	43.4	519,197

Source: PNAD, multiple years; no PNAD data for the years 1994 and 2000

Table 7: Employees with regular working papers (formal), agriculture

	1992		2003		2004		2005	
	Total	Formal	Total	Formal	Total	Formal	Total	Formal
Brazil	674.630	53,6%	448.883	68,8%	494.076	69,6%	519.197	72,9%
NNE	352.905	42,3%	261.283	58,9%	245.050	59%	268.759	60,8%
CS	321.725	66,0%	187.600	82,8%	249.026	79,9%	250.438	85,8%
SP	149.360	80,4%	124.534	88,4%	179.156	86,6%	153.719	93,8%

Source: PNAD, 1992, 2003, 2004 and 2005

12.5 Income of people engaged in Brazil's sugar cane agribusiness

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12.5.1 Introduction

The analysis of income distribution for people engaged in the main activity of sugar cane cropping, sugar production and/or ethanol production[16] is summarized in this paper. The group formed by everyone in these activities is considered, but with an emphasis on those who are actually employed (wage earners). The analysis is based on data from the National Household Sample Survey (PNAD) of 2005, as provided by IBGE. All statistical analyses take into account the expansion factor associated with each sample observation, as provided by IBGE. The income of people employed in the sugar cane business is compared to the income of those employed in other crops (rice, soybean, coffee, etc.). The analysis considers Brazil as a whole, and the contrast between the North-Northeast and the Center-South, which an emphasis on São Paulo State. The PNAD data allow no consideration of "migrating" workers separately.

16 HOFFMANN, R.: "Rendimento e pobreza urbana, rural e na cultura da cana-de-açúcar", Workshop: Mercado de trabalho, Setor Açúcar e Álcool: desafios atuais e perspectivas futuras, ESALQ-USP, 2004

It is important to point out that the income information is understated in the PNADs. A comparison of previous PNADs with the income information obtained by the National Accounts shows that the income stated in the former correspond to around 60 percent of the correct value. The degree of understatement is likely to be higher for higher incomes, causing the PNAD (or Demographic Census) data to underestimate the existing degree of inequality.

12.5.2 The income of people engaged in the agribusiness: sugar cane culture and sugar and ethanol industries

The mean income of employed people all over Brazil in 2005, grouped by sector (agriculture, industry, and services), is shown in Table 8. The PNAD analysis refers to 53 million private homes, with 180 million people; the *per capita* household income was R$ 436 (on average), with a median income of R$ 238 and Gini coefficient of 0.567.

Table 9 shows the main income distribution characteristics for people engaged in the sugar cane culture, the sugar industry, the ethanol industry, and three more aggregated industrial fields: foods and beverages (including sugar), fuels (coke, oil refining, nuclear fuels, and alcohol production), and the chemical industry.

Sugar cane (agricultural production) displays the lowest wages and low

Table 8: Income for all jobs; engaged people, Brazil, 2005

Statistic	Brazil	Agriculture	Industry	Services
People (1,000)	76,066	9,736	17,789	42,58
Education (years)	7.9	3.4	7.4	8.8
Income (R$/month)	801	462	770	821
Gini coefficient	0.543	0.555	0.493	0.537

mean education level, the latter being less than ⅓ of the mean education in the fuel industry and chemical industry, and less than half the value corresponding to the sugar, ethanol or food industry. The mean income in sugar cane crops is higher than half the corresponding amount in the sugar and alcohol industries, but the median income of those engaged in the sugar cane culture[16] is substantially less than half the corresponding value for those two industries; the inequality in the income distribution of people engaged in the sugar cane culture is greater than in sugar or ethanol production. The income in sugar cane crops should be compared with that of other crops.

Table 10 shows the regional contrasts in the education level and income between people working in sugar cane crops and those employed in the sugar and ethanol industries. Both the mean education level and the mean income are always higher in the Center-South than in the North-Northeast, but the differences between the two regions are much greater in the sugar cane

16 see p. 218

Table 9: Mean income in all jobs for people occupied, or engaged, in the sugar cane culture and similar industries[1]; Brazil, 2005

Statistic	Sugar cane crops	Sugar	Ethanol	Foods and beverages	Fuels[2]	Chemicals
People (1.000)	565.9	122.4	79.9	1.851.3	114.1	683.4
Mean age	34.7	34.4	34.6	34.5	34.9	34.7
Mean education level (years)	35	7.1	8.3	7.3	9.5	9.4
Mean income (R$)[3]	495.5	742.0	960.5	613.5	1.394.3	1.332.6
Gini coefficient	0.413	0.347	0.365	0.451	0.446	0.568

1 Only people having declared positive income values for all jobs.
2 Coke production, oil refining, nuclear fuel production and ethanol production.
3 R$, 2003

culture than in the two industries.

The analysis can be limited to people whose occupation is described as *employee*, excluding, therefore, stand-alone professionals, employers, workers who produce for their own consumption, and other non-paid workers. **Table 11** refers to the jobs of *employees* in sugar cane, sugar and ethanol production, along with their regional distribution for comparison with **Table 10**. Education and

Table 10: Mean income for all jobs and education level of people occupied (sugar cane, sugar and ethanol)

Activity field		Cane	Sugar	Ethanol
Brazil	I (R$)	495.5	742.0	960.5
	E (years)	3.5	7.1	8.3
N-NE	I (R$)	316.3	600.3	- [1]
	E (years)	2.3	5.5	- [1]
C-S	I (R$)	697.3	839.1	985.4
	E (years)	4.8	8.3	8.5
SP	I (R$)	810.0	836.9	1.196.4
	E (years)	5.1	8.4	9.3

I: income, R$ / month

E: education level, years

1 Only 6 people in the sample

Table 11: Mean income for all jobs and education level of employees (sugar cane, sugar and ethanol)

Activity field		Cane	Sugar	Ethanol
Brazil	I (R$)	429.1	723.4	960.5
	E (years)	3.5	7.1	8.3
N-NE	I (R$)	305.3	559.0	- [1]
	E (years)	2.3	5.5	- [1]
C-S	I (R$)	561.9	835.7	985.4
	E (years)	4.7	8.4	8.5
SP	I (R$)	642.8	836.9	1.196.4
	E (years)	4.9	8.4	9.3

I: income, R$ / month

E: education level, years

1 Only 6 people in the sample

income levels in the Center-South are always higher than in the North-Northeast, and the regional contrast is more intense for sugar cane culture employees.

12.5.3 Agriculture: people occupied in sugar cane crops

In the PNAD sample for 2005 there are 1,162 working persons whose main activity is the sugar cane culture, and that sample corresponds to a population of 608,070 people. **Table 12** shows the distribution of such people according to their working position.

The table shows that stand-alone workers, workers who produce for their own consumption and non-paid workers represent 17.1 percent of the occupations in sugar cane crops in the North-Northeast, but only 7.1 percent in the Center-South (0.5 in São Paulo), which demonstrates that the activity in the Center-South is more “corporate” in its nature. The regional differences in education and income levels in agriculture are shown in **Table 13**; the mean education level in the North-Northeast represents half of that in the Center-South, and the mean income in the former is equivalent to just 45 percent of that in the latter. Concerning the mean income of employed people in the Center-South (and SP), inequality is substantially bigger than in Brazil, taken as a whole, as shown by the Gini coefficients in **Table 13**. In the Center-South, agriculture generates higher incomes than in the Northeast, but the relative difference is particularly high for employers (businessmen).

Table 12: People working in sugar cane crops according to their working position in Brazil, the North-Northeast region, the Center-South region, and SP (2005 PNAD)

Working position		w/ working papers	w/o working papers	Stand-alone	Employ-er	Prod. for own cons.	Non-paid	Total
Brazil	Nº	378.38	141.13	36.010	12.530	1.686	38.326	608.07
	%	62.2	23.2	5.9	2.1	0.3	6.3	100.0
N-NE	Nº	163.41	105.66	25.370	5.805	1.093	30.054	331.40
	%	49.3	31.9	7.7	1.7	0.5	9.1	100.0
C-S	Nº	214.96	35.475	10.640	6.725	593	8.272	276.66
	%	77.7	12.8	33.9	2.4	0.2	3.0	100.0
SP	Nº	144.21	9.503	864	4.319	-	-	158.90
	%	90.8	6.0	0.5	2.7	-	-	100.0

Table 13: People occupied in sugar cane crops with positive income: Brazil, North-Northeast and Center-South regions, and SP, 2005

	No. of people (1.000)	Mean age	Mean education level (years)	Mean income (R$)	Median income (R$)	Gini coefficient
Brazil	565.9	34.7	3.5	495.5	320	0.413
N-NE	299.8	33.8	2.3	316.3	300	0.259
C-S	266.1	35.7	4.8	697.3	500	0.433
SP	157.2	35.8	5.1	810.0	550	0.413

12.5.4 Income for work in sugar cane crops compared with other crops

Table 14 allows us to compare people's mean income for work in sugar cane crops with the mean income in several other crops.

People's income in the North-Northeast region is always substantially lower than in the Center-South. The relative differences between the regions are generally larger in terms of the combined income of everyone engaged in the activity (including employers and stand-alone workers) than they are when the analysis is limited to employees.[16]

Table 14: Mean income for all jobs and education levels of people working in several crops, 2005

Crop		Rice	Banana	Coffee	Sugar cane	Citrus	Manioc	Corn	Soybean
Brazil	I[1]	294.8	359.0	454.1	**495.5**	591.3	235.1	227.9	1.222.2
	E[2]	2.4	3.4	3.7	**3.5**	4.6	2.1	2.5	5.7
N-NE	I	218.7	296.3	438.1	**316.3**	283.5	223.3	157.2	584.7
	E	2.0	3.0	2.8	**2.3**	2.7	1.9	1.8	4.5
C-S	I	610.6	469.9	458.2	**697.3**	734.7	306.6	338.4	1.265.5
	E	4.3	4.0	3.9	**4.8**	5.4	3.4	3.6	5.8
SP	I	-[3]	436.0	837.3	**810.0**	807.5	588.2	585.8	945.7
	E	-[3]	3.0	5.2	**5.1**	5.6	4.5	4.8	7.7

1 I: income, R$ / month
2 E: education level, years
3 Fewer than 10 observations in the sample

The lowest income levels are associated with corn and manioc crops, with a large number of small producers. For rice, it would be appropriate to consider irrigated crops in the South; in the North-Northeast region, the income level in rice crops is similar to that of manioc crops.

The income of people working in sugar cane crops is higher than in coffee crops, on average. For employees, the mean income in sugar cane crops is higher than in citrus growing.[16]

16 see p. 218

Soybean crops stand out from others for their high income and mean education levels of those engaged in the activity. 41.1 percent of the people employed in soybean crops are tractor operators, compared to 4.3 percent in sugar cane crops, 4.0 percent in corn crops, 14.2 percent citrus crops, and 22.7 percent in rice crops.

12.6 Social responsibility and benefits

Maria Luiza Barbosa
UNICA – Union of the Sugar Cane Agro-Industry in São Paulo

The direct jobs created in Brazil's sugar cane agribusiness, from cane production to processing into ethanol and sugar, are estimated at around one million, plus a few million indirect jobs (see items **12.2**, **12.4** and **12.5**). Decentralized throughout rural Brazil and with a high spreading power on the regional economies, this labor-intensive activity has a history of social insertion and interactivity with neighboring communities.

The benefits arising out of the essence of the business are determined based on a product/investment ratio that is favorably comparable to other production activities: the industry invested US$ 10,000 per job created (in some of the country's poorest areas), while manufacturers of consumer goods needed to invest US$ 44,000 per job; in the petrochemistry sector, that investment reached US$ 200,000. In the current expansion process, the industry has played a significant role in reducing migration flows to the cities. Its competitive position in the international market creates the conditions to expand socially responsible activities in the fields of education, housing, environment and health, thereby contributing to improve the quality of life of hundreds of Brazilian municipalities. The production units in Brazil maintain more than 600 schools, 200 nursery centers and 300 day care units. **Table 15** shows the frequency of benefits for a sample of São Paulo-based sugar and ethanol companies (2003).[17]

17 BARBOSA, M.L.: Internal report, UNICA, São Paulo, 2005

Surveys of projects for the social area are not part of the requirements of the Brazilian legislation. Therefore, the data they present refer to voluntary answers. A survey conducted in São Paulo State with 50 sugar and ethanol

Table 15: Benefits, sample 47 mills, São Paulo, 2003 (%)

Healthcare	95.7
Dental care	93.5
Transportation	93.3
Collective life insurance	91.5
Meals	87.0
Pharmaceutical care	85.1
Hearing care	63.8
Funeral allowance	61.7
Christmas basket	59.1
Food basket [1]	43.5
Credit cooperative	37.8
Club / association	36.4
Education allowance	35.6
Other	32.6
Food stamps	29.5
Private pension plans	23.9
Breakfast	21.3
Disease allowance	20.0
Loan / financing	15.2
Agreement with supermarkets	8.9
Subsidized sales	2.3
Consumption cooperative	0.0

1 Food that meets minimum nutritional requirements set by the government

18 Barbosa, M.L.; Sallum, E.A.A.: Internal report, UNICA, 2004

companies[18] shows that 34 million people residing in the 150 municipalities within their direct influence area have benefited from them, whether directly or indirectly. Some of the indicators concerning the relationship of the organizations that answered the questionnaire are listed below:

- 95% of the companies have daycare units/nursery centers;
- 98% of the companies have worker rooms;
- 86% provide accommodation for workers from other locations;
- 84% of the companies already have profit-sharing plans;
- 74.8% of the workers were born in São Paulo State, while the others come from other states;

- 90% of the workers are duly registered by the companies they work for, and the remaining 10% are outsourced;
- 58.3% of those companies already employ physically challenged workers at the rates required by the law (Art. 93 of Law no. 8,213/91).

The foregoing data support the acknowledgement by the 90 member companies of the Union of the Sugar Cane Agribusiness in São Paulo that their performance – starting from their increased production – needs backing according to the modern social responsibility parameters, as defined in Agenda 21, which has been consolidated during the World Conference on the Environment held in Rio de Janeiro in 1992. The industry in São Paulo State is a benchmark for all companies in Brazil, featuring the highest salary levels in the business (industry and agriculture; see **item 12.5**) and a high rate of formal employment (~ 95%), while being committed to systematizing and monitoring social responsibility actions. On the social front, 420 projects in the fields of education, health, sports, quality of life, culture and environmental information are now being carried out for the benefit of collaborators and communities.

The topics adopted by Agenda 21 cover a bread range of aspects of human life and need to be monitored by a discerning measurement system. By the highest precepts, Agenda 21 contains proposals that the nations had never bothered to quantify. Also, notwithstanding that some governments' hesitance has hindered the implementation of some of its concepts, there has been considerable progress. Decentralizing the decision-making process and appreciation of human existence are some of the required conditions to promote the evolution of environmental awareness, with special attention to spaces taken up by activities that were until then considered to be on a lower relative development level, such as agriculture. Therefore the sustainable development concept and the concern about the methods to account for problems and ongoing actions to cure them.

Sustainability is in the root of the very activity of the industry, which essentially transforms sunlight into foods and commercial energy: sugar as food, ethanol as fuel for vehicles, and also the electrical power that is produced by burning the sugar cane bagasse. Relying on that purpose for a permanent job creation and retention, as well as continued job quality improvement, from the plantation to fuel distribution, it is a stable income distribution initiative.

Monitoring the life conditions of the rural workforce in Brazil is one of the main challenges to be overcome before the country can follow the recommendations of Agenda 21. In this respect, the sugar and ethanol companies based in São Paulo State adopted in 2002 the Social Balance Sheet concept (IBASE model) through UNICA, and the reports that they prepare now serve also as a tool to detect and demonstrate, both quantitatively and qualitatively, the existing conditions and the evolution in both the internal social context and the relationship with the community.

Some of the indicators of the IBASE Social Balance Sheets[19] for 73 São Paulo-based companies (2003, denoting expenses as a percentage of the payroll) are presented below:

19 IBASE: Balanço Social (Mills associated to UNICA), 2004

Private pension plans	0.81%
Healthcare	5.9%
Education	0.93%
Capacity building and professional development	0.97%
Daycare units	0.27%
Profit-sharing programs	6.72%
Food	6.54%
Occupational safety & health	2.34%

Willing to seek internationally accepted benchmarks for those practices, the sugar and ethanol industry has established, through UNICA, a partnership with the World Bank Institute to provide researchers and professionals in the business with training on the basics of sustainable competitiveness and corporate responsibility. In 2004 and 2005, 2,500 people (executives and employees in the sugar mills) participated in the program, aiming at knowing the best practices (World Bank's methodology) and qualifying to assess practical situations and reach reliable diagnostics.

A comprehensive program to help enterprises to identify impacts and to evaluate their sustainability was established using the international methodology of the Business and Economic Development research; this work is conducted in partnership with Instituto Ethos (Brasil), BSR – Business for Social Responsibility (EUA), Institute of Social an Ethical Accountability (England) and Fundação Dom Cabral (Brasil). In 2006 the first 30 enterprises were included, with 650 participants; the next step wil involve 30 more sugar mills.

12.7 Technologies being implemented and impacts on jobs and income

The Sugar Cane Technology Center, among others,[20, 21, 22] has evaluated the impact of sugar cane harvesting without trash burning on the workforce.[23] For a future situation of 100-percent mechanical harvesting in S. Paulo, and 50 percent in the rest of the country, 165,000 jobs would be lost compared to the fully manual harvesting system. This process is in progress. On the other hand, the use of trash as an energy source may create approximately 12,000 new jobs in agriculture for the option of using balers. Indirect jobs are not included in the computation.

20 Gonçales, J.S.; Souza, S.A.M.: "Proibição de queima de cana no Estado de São Paulo: simulação dos efeitos na área cultivada e na demanda da força de trabalho", Informações Econômicas, São Paulo, vol. 28, no. 3, Mar. 1998, pp. 21-40

21 Camargo, J.M.: "Tecnificação da cana-de-açúcar em São Paulo e sazonalidade da mão-de-obra", Master's thesis – FEA-USP, 1988, 202p.

22 Veiga Filho, A.A. *et al.*: "Análise da mecanização do corte da cana-de-açúcar no Estado de São Paulo", Informações Econômicas, São Paulo, vol. 24, no. 10, Oct. 1994, pp. 43-58

23 "Manpower: Agricultural Systems", Technical report RLT-041, Project BRA/96/G31 – Biomass power generation with sugar cane bagasee and trash, UNDP/Copersucar, Centro de Tecnologia Canavieira

12.8 Summary and conclusions

• The replacement of gasoline with ethanol has saved an important amount of foreign currency for Brazil. Computing the value of the replaced gasoline at its international market price, the imports avoided between 1976 and 2004 represented savings of US$ 60.7 billion (at the exchange rate in December 2004). Considering interest on the foreign debt, the savings amounted to 121.3 billion. For comparison, Brazil's foreign currency reserves amounted to US$ 49.4 billion (October 2004), or just US$ 24.2 billion if loans from the IMF are excluded.

• The Brazilian industry supplying equipment for cane, sugar and ethanol production developed into a leading position; the largest manufacturer, alone, produced 726 distilleries (distillation units), 106 full plants, 112 combined cogeneration plants, and 1,200 boilers (including exported units).

• Brazil has had an unemployment rate of 9 to 10 percent over the past few years. Job quality and income distribution are serious problems; the Gini coefficient was 0.607 (1998) and 0.554 (2003). Notwithstanding the increase in income, social inequalities have not been significantly reduced over the past 20 years. Workers who do not contribute to the social security system are estimated at 55 percent; the rates of child labor (2.4%, 10-14 year-olds) and functional illiteracy (23.9%, less than 3 years at school) have been significantly lowered, but are still high. The per capita income in 2002 was US$ (PPP) 7,600.00.

• Brazil's labor legislation is renowned for being advanced in worker protection; the union organization is developed and plays a key role in employment relationships. For sugar cane, the specific aspects of employment relations in agriculture (specific unions) and industrial operations (unions of the food and chemical industries) are well-defined, including the conclusion of collective agreements, which advanced during the last decade. Compared to the Brazilian 55-percent mean rate of formal jobs, the sugar cane industry's agricultural activities now have a rate of 68.5 percent (from the 53.6% of 1992). In the Center-South, the rate of formal jobs in sugar cane production (agriculture) is 82.8 percent, reaching 88.4 percent in São Paulo (2003).

• The differences in regional development are reflected in the industry's occupational indicators; poorer regions are characterized by lower salaries and a much larger use of labor, consistent with technological levels (automation, mechanization).

• In the early 1990's, there were 800,000 direct jobs; for every 1 M tons of sugar cane produced and processed, there were 2,200 direct jobs (73% in agriculture); in the North-Northeast, three times as much as in the Center-South. In São Paulo, non-specialized workers (sugar cane cutters) were paid US$ 140 / month (amount at that time), which was higher than the amount paid to 86 percent of agricultural workers in general, and 46 percent of industrial workers. The mean family income of those workers was higher than that of 50 percent of all Brazilian families.

• The seasonal index for the job (sugar cane production) was 2.2 in São Paulo in the early 1980's, 1.8 in the late 1980's, and 1.3 in the mid 1990's. The decrease was motivated mainly by the mechanical harvesting of sugar cane, which enabled more training and career planning.

• In the late 1990's, with 650,000 direct jobs and 940,000 indirect jobs (plus around 1,800,000 induced jobs), the number of jobs per product unit in the Center-South region was still 3.5 times higher than in the North-Northeast; there is a correlation between the in the mean job quality (realted to years of education) and salary levels.

• The *formal, direct jobs* in the industry are now increasing in number (more 18% from 2000 to 2002), and reached 764,000 in 2002. Of those formally employed, 90.4 percent are aged 18 to 48 (0.3% under the age of 17). Jobs in agriculture decrease, while industrial jobs increase in number. People having studied for less than 4 years represent 37.6 percent of the workers, 15.3 percent of whom being illiterate (4% in the Center-South).

• Considering both formal and informal jobs (2003 PNAD sample), the income of working people in Brazil was as follows: all industries, R$ 692/month; agriculture, R$ 390/month; industrial operations, R$ 671/month; services, R$ 706/month; Sugar cane crops: Brazil, 821; N-NE, 283; C-S, 678; São Paulo, 797; Sugar industry: Brazil, 821; N-NE, 707; C-S, 865; São Paulo,

881. The amounts for ethanol are a little higher than those for sugar.

• In agriculture, the mean education level in the North-Northeast is equivalent to half the level (years at school) of the Center-South.

• In the Center-South, the income of people working in sugar cane crops is higher than in coffee, citrus and corn crops, but lower than in soybean crops (highly mechanized, with more specialized jobs). In the North-Northeast, the income in sugar cane crops is higher than in coffee, rice, banana, manioc and corn crops, equivalent to the income in citrus crops, and lower than in soybean crops.

• The income in formal jobs does not include the 13th salary or any benefit. Mills maintain more than 600 schools, 200 daycare units and 300 ambulatory care units. In a sample of 47 São Paulo-based units, more than 90 percent provide health and dental care, transportation and collective life insurance, and over 80 percent provide meals and pharmaceutical care. More than 84 percent have profit-sharing programs, accommodations and daycare units.

• Social Balance Sheet Indicators for 73 companies (UNICA, SP, 2003) show that funds equivalent to 24.5 percent of the payroll are used for such purposes as profit-sharing programs (6.72%), food (6.54%), healthcare (5.9%), occupational safety and health (2.3%), and education, capacity building and professional development (1.9%).

Appendixes

Abbreviations

APP	environmental protection area
BIG/GT	integrated biomass gasification / gas turbine combined cycle
CLT	Labor Code
CG	central power generation
CO	carbon monoxide
CO_2	carbon dioxide
cec	ionic exchange capability
DBO_5	biochemical oxygen demand
DG	distributed power generation
DM	dry mass
EIA	environmental impact evaluation
GHG	greenhouse gases
GMO	genetically modified organism
GNP	gross national product
GNV	natural gas vehicles
GRI	Global Reporting Initiative
HC	hydrocarbons
HTM	high test molasses
K_2O	potassium oxide
LPG	liquefied petroleum gas
CDM	clean development mechanism
MTBE	methyl tertio-butyl ether
MSG	mono-sodium glutamate
N	nitrogen
NGO	non governmental organization
NOx	nitrogen oxides
N_2O	nitrous oxide
OIE	internal energy production
OM	organic matter
PCTS	cane payment based on sucrose
PNA	National Alcohol Program
PNAD	National Household Sample Research, IBGE
P_2O_5	phosphor oxide
PROINFA	Program for promoting alternative electricity production, MME
PV	photovoltaic effect
RAIS	Administrative Records of the Labor and Employment Ministry
R-CHO	aldehydes
RIMA	Environmental Impact Report
RMSP	Metropolitan Area, city of São Paulo
S	sulphur
SCYLV	cane yellow leaf syndrome virus
SAFCA	cane yellow leaf syndrome
SO_2	sulphur dioxide

Entities, institutions, companies, etc.

ANVISA	Agencia Nacional de Vigilância Sanitária
CATI	Coord. Assistência Técnica Integral, Secretaria da Agricultura, S P
Cepel	Centro de Pesquisas da Eletrobrás
CONAMA	Conselho Nacional do Meio Ambiente
CREA	Conselho Nacional de Engenharia e Arquitetura
CTC	Centro de Tecnologia Canavieira
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
EESC	Escola de Engenharia de São Carlos, SP
EPA	Environmental Protection Agency (EUA)
ESALQ-USP	Escola Superior de Agricultura Luiz de Queiroz, USP
FAPESP	Fundação de apoio à pesquisa no estado de São Paulo
FCE/UFMG	Faculdade de Ciências Ecionomicas, Univ. Federal de Minas Gerais
FEA-UNICAMP	Faculdade de Engenharia de Alimentos, UNICAMP
FGV	Fundação Getúlio Vargas
IAC	Instituto Agronômico de Campinas, SP
IBGE	Instituto Nacional de Geografia e Estatística
INEE	Instituto Nacional de Eficiência Energética
INPE	Instituto Nacional de Pesquisas Espaciais
IPEA	Instituto de Pesquisas Econômicas Aplicadas
ITA	Instituto Tecnológico de Aeronáutica
IPCC	Intergovernmental Panel on Climate Change
LMC	LMC International Ltd.
MME	Ministério das Minas e Energia
OIT	International Labor Organization
PUC-RJ	Pontifícia Universidade Católica – Rio de Janeiro
SMA-SP	Secretaria do Meio Ambiente, São Paulo
UNESP	Universidade Estadual Paulista
UNICA	Union of the Sugar Cane Agro-Industry in São Paulo
UNICAMP	Universidade Estadual de Campinas
WWF	World Wildlife Foundation

Unit prefixes

k	kilo (10^3)
M	mega (10^6)
G	giga (10^9)
T	tera (10^{12})

Units

The metric system is used throughout the text, with the adequate prefixes.

º C	degree Centigrade
cal	calorie
CO_2 eq	carbon dioxide equivalent (for global warming)
ha	hectare (10^4 m^2)
ppbv	parts per billion, by volume
ppmv	parts per million, by volume
t	metric ton (1000 kg)
toe	ton (metric) of equivalent oil (energy equivalent)
US$(PPP)	Purchase Power Parity Exchange to US$
V %	index of bases saturation