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ENVIRONMENTAL ASPECTS ON THE SUGARCANE ETHANOL CHAIN IN THE SÃO PAULO STATE

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INTRODUCTION

The need to reduce global carbon emissions and the use of fossil fuels has become prominent in the international scene. Particularly Brazilian ethanol used as fuel for vehicles is highlighted, as it displays an extremely favorable energy balance.

Ethanol production rose from 0.6 million cubic meters in 1975 – at the outset of the Proacool Program – to almost 18 million cubic meters in the 2006/2007 harvest season, due to increases in agricultural and industrial productivity (GOLDEMBERG *et al*., 2008).

According to COELHO *et al*. (2005), subsidies granted to the Brazilian Proalcool Program in the past allowed industrial growth and the modernization of production technologies, rendering production economically competitive with comparatively low production costs. Brazilian ethanol became competitive in comparison to gasoline in both domestic and international markets.

Nowadays, Brazil is the world leader in the production of sugarcane and its major products, sugar and alcohol, and is enjoying a new growth phase as a result of the increase in domestic and foreign demand for fuel alcohol, both as anhydrous ethanol blend with gasoline, and as hydrated ethanol to be used in flex-fuel vehicles (LORA, 2008).

Such growth in the sugar-alcohol industry raises issues regarding the environmental sustainability of the Brazilian production of sugarcane and its products. Abusive environmental requirements eventually jeopardize penetration of the Brazilian alcohol in new markets, which should take industry leaders to take more stringent control actions against the environmental impact of their business.

Actually Brazil, as an efficient producer of food and energy from vegetal sources, manages to balance both products without causing environmental impact and biomes destruction, particularly in the Amazon and savanna areas. Therefore, the new sugar-alcohol international setting demands Brazil to continuously improve its environmental practices in traditional cultivation areas and make sure that new areas are environmentally suitable.

This document will discuss the current situation in the São Paulo state regarding the mitigation of environmental impacts in the sugar-alcohol industry, as this state has adequate legislation and inspection, even if considered by international standards.

ENVIRONMENTAL ASPECTS

The sugar-alcohol industry environmental impact only considers the features of sugarcane cultivation, industrial processing, and final usage. It includes effects in air quality and global climate, in the use of soil and biodiversity, in the conservation of soil, in water resources, and in the use of fertilizers and pesticides. Such impacts may be positive or negative; in some cases the sugarcane industry has very important outcomes, such as in reducing greenhouse gas emissions and the recovery of agricultural lands. Environmental regulations (including restrictions to land use) are quite advanced in Brazil, with an efficient application in the cultivation of sugarcane (MACEDO *et al*., 2005).

TABLE 1 Impacts of sugarcane cultivation on the environment, according to Embrapa.

Impact on	Type	Classification
Air	Odors	Low
	Smoke	Low
	Dust	Average
	Allergens	Average
Soil	Preservation	Extremely high
	Blanketing	Extremely high
	Increased density	High
	Loss	Average
	Salts	Low
	Biological	None
	Agrotoxic	None
Water	Salts	None
	Biological	None
	Agrotoxic	None

TABLE 2 Impacts of sugarcane cultivation on the fauna, according to Embrapa.

Animals	Ranking of impact on		
	Food	Shelter	Reproduction
Mammals	Average	Low	Low
Birds	None	Low	Low
Reptiles	Average	Average	Average
Amphibious	None	None	None
Invertebrates	Low	Low	Low

The environmental impact of the sugarcane and the alcohol cycle has been considerably reduced over the past 30 years. Embrapa classifies impacts on the physical environment according to Table 1, and those on the fauna in accordance to Table 2[1].

From the standpoint of life cycle analysis – LCA, bioenergy significantly collaborates to sustained development, as it generally causes lesser environmental impact than fossil fuel energy. Furthermore, it provides assurance that local energy will be supplied in the long run, induces new technologies, creates new jobs and income (LUCON, 2008).

Next, the relevant environmental issues regarding the sugar-alcohol industry in the São Paulo state are discussed.

[1] Embrapa presents some indicators for inputs used by sugarcane in the São Paulio state: (i) fertilizers 408 kg K/ha/year, 275 kgN/ha/year, and 146 kg $P_2 0_5$/ha/year (ii) corrective, 3t/ha/year; (iii) herbicide, 2 l/ha/year. Source: MIRANDA, Evaristo Eduardo de. (Coord.). Embrapa (s.d.). **Agroecologia da cana-de-açúcar**, 2008. Available at: <http://www.cana.cnpm.embrapa.br/canin.html>.

TABLE 3 Average emissions from vehicles approved by Proconve[2].

Fuel used	CO (g/km)	HC (g/km)	NOx (g/km)	RCHO (g/km)	CO2 (g/km)	Evaporative (g/test)	Fuel intake (km/l)
Gasoline C (with 22% anhydrous ethanol)	0.33	0.08	0.08	0.002	192	0.46	11.3
Hydrated ethanol*	0.67	0.12	0.05	0.014	200	n.d.	6.9
Flex with gasoline C	0.48	0.10	0.05	0.003	185	0.62	11.7
Flex with alcohol	0.47	0.11	0.07	0.014	177	1.27	7.8

* Note: 100% ethanol vehicles sales were virtually replaced by the flex-fuel models.

Air

Impact on air quality[2]

Due to its high efficiency and low production cost, sugarcane ethanol is today one of the best choices to mitigate greenhouse gas emissions from burning fossil fuels. The energy balance (units of renewable energy extracted per unit of fossil energy added) is extremely favorable, reaching 8.9:1, avoiding emissions of 2.86 and 2.16 tons of CO_2 eq./m^3, for anhydrous and hydrated ethanol, respectively[3] (LUCON, 2008).

The consequence is a remarkable performance of this industry, preventing greenhouse gas emissions equivalent to 13% of the emissions from the whole energy industry in Brazil (baseline 1994). For each additional 100 Mtons of sugarcane in the next few years, emissions of 12.6 Mtons of CO_2 eq. can be avoided with ethanol, bagasse and additional surplus electricity (MACEDO *et al. 2005)*.

Ethanol produced from corn or wheat in other countries fails to attain the high efficiency of sugarcane ethanol, reaching the 1.5:1 balance, which leads Brazilian ethanol to be considered as an important instrument for emission mitigation.

Major effects of the use of ethanol (pure or as an admixture to gasoline) in urban centers were: elimination of lead compounds in gasoline, reduction of carbon monoxide emissions, elimination of sulfur and particle materials, less toxic and photochemically reactive organic compound emissions (MACEDO *et al.*, 2005).

Ethanol-based vehicle technology has progressed considerably and flex-fuel automobiles present comparable or even lower emissions than those using gasoline with up to 25% anhydrous ethanol. Acetaldehyde emissions produced by the use of ethanol are less toxic than formaldehyde emissions from the use of gasoline (LUCON, 2008). Table 3 shows average vehicle emissions according to Proconve.

The use of ethanol in flex-fuel vehicles positively contributes to improve air quality in large cities, as it considerably reduces the level of hazardous emissions from fossil fuels. In rural areas, the problem of sugarcane fields being burned occurs, being often debated and forbidden by law in the São Paulo state, as described next.

Airborne emissions resulting from burning sugarcane

Sugarcane agriculture relates to impacts on air quality on two very distinctive points: the use of ethanol has led to considerable improvements to air quality in urban centers while slash-and-burn sugarcane trash in the field, on a quite different scale, causes problems with particle spreading and smoke hazards (MACEDO *et al.*, 2005).

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2 CETESB (2007). **Relatório de Qualidade do Ar 2006**, available at: <www.cetesb.sp.gov.br>. In: LUCON (2008).

3 SEABRA, J. E. A.; LEAL, M. R. L. V.; MACEDO, I. de C. **The energy balance and GHG avoided emissions in the production / use of ethanol from sugarcane in Brazil:** the situation today and the expected evolution in the next decade. Nipe, Unicamp, being published. In: LUCON (2008).

Air quality in rural areas is directly affected by sugarcane field slash-and-burn, used as a harvesting technique to make sugarcane cutting easier by eliminating trash and dry leaves.

Slash-and-burn releases large concentrations of particle material, carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x) and nitrous oxide (N_2O) to the atmosphere, which cause substantial damage to the environment and human health. It causes modifications to the chemical, physical and biologic composition of the soil, impairing nutrients cycling and causing their volatilization, consequently requiring the use of more pesticides and herbicides to control pests and weeds (LORA, 2008).

Furthermore, slash-and-burn removes the natural soil blanket, with favors surface flow of rainwater, fostering the erosion process and impoverishing the soil by the removal of organic matter.

São Paulo state, the largest sugarcane producer in Brazil, led the reduction in environmental impact of sugarcane production when it outlawed slash-and-burn in sugarcane fields in 2002.

Actions to gradually eliminate slash-and-burn in areas compatible with mechanized harvesting began with State Law n. 11 241/2002, which rules on the progressive elimination of burning sugarcane trash, forecasting 100% elimination by the year 2031. Currently in effect is 40% of burning area elimination, controlled by Sistema Integrado de Gestão Ambiental – SIGAM (Environmental Management Integrated System), from Coordenadoria de Licenciamento Ambiental e de Proteção dos Recursos Naturais – CPRN (Environmental Licensing and Natural Resources Protection Coordinating Office), of Secretaria do Meio Ambiente do Estado de São Paulo – SMA/SP (São Paulo state Environment Department).

Another, more recent, initiative in this direction was the approval of the Green Protocol (SMA), a cooperation agreement signed by sugarcane producers in the São Paulo state, setting the deadline for the elimination of slash-and-burn earlier, by 2017[4]. Companies that complied with the new protocol received an environmental compliance certificate.

The figure presents the deadlines for eliminating sugarcane field slash-and-burn according to state laws and in compliance to the Green Protocol, as well as the evolution of mechanized harvesting areas in the São Paulo state.

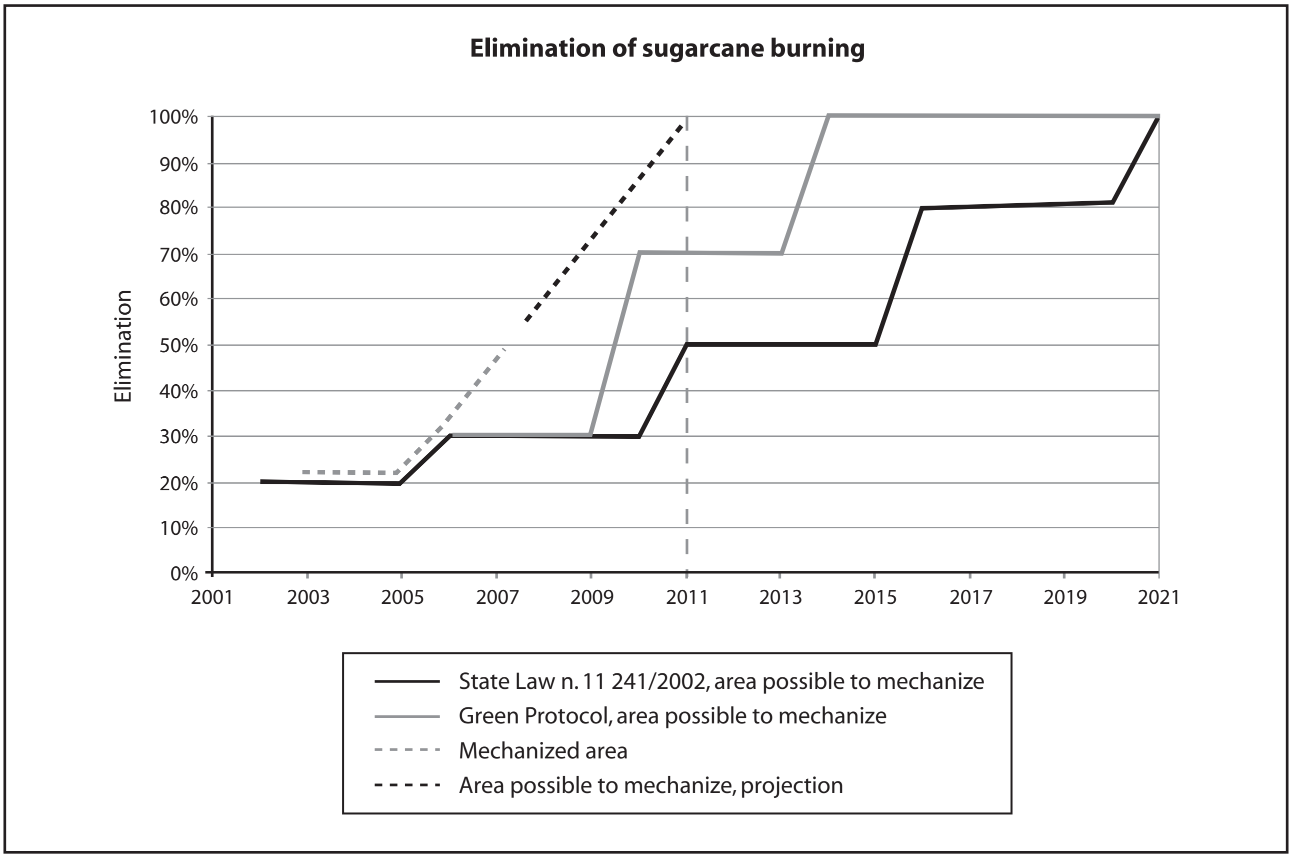
In this context, Resolution SMA 33, issued in 2007[5], contributes for increased speed in eliminating slash-and-burn as new sugar-alcohol enterprises in the São Paulo state will only be licensed by the environmental agency after it has been determined that there will be no burning of sugarcane trash. To limit slash-and-burn in the state, this resolution sets a maximum of 2.21 million hectares, reducing in 4% the licenses to burn granted to the industry relative to 2006, and encompassing 130,000 hectares of sugarcane fields.

Slash-and-burn suppression increases the availability of biomass to the sugar-alcohol industry, already being used to generate electricity or to contribute to ethanol production by making viable the so-called second-generation technologies, such as enzymatic hydrolysis, an alcohol production process from the lignocellulosic fraction of sugarcane bagasse.

On the other hand, increasing harvesting mechanization poses new challenges to the São Paulo state sugar-alcohol industry. Sugarcane harvesting mechanization offers higher productivity, however, it requires some minimum terrain flatness. Current machinery cannot cover areas with slope beyond 12%, which leads to abandoning sugarcane culture in such areas or induces to burning sugarcane trash, either authorized or done illegally. It is expected that new harvesting mechanization technologies will serve steeper terrain; however there will still be uncovered areas that could be subject to new and differentiated environmental criteria (LUCON, 2008).

[4] The protocol technical guidelines also include the development of a technical plan for forest recovery, protection, maintenance and recovery of Legal Reservation areas, as well as APP areas; the development of a technical plan for preserving water resources and a technical plan for soil conservation (LUCON, 2008).

[5] SMA Resolution n. n. 33/2007 rules the application of n. n. Law n. 11 241/2002, regulated by Decree n. 47 700/2003 as to the gradual limits for burning sugarcane trash in the São Paulo state.



Source: Available at: <http://homologa.ambiente.sp.gov.br:80/etanolverde/resultado.asp>.

FIGURE 1 Evolution of mechanized harvesting for sugarcane.

Industrial emissions

Industrial emissions are also under monitoring and control, as boilers release particle material and NO_x. Nevertheless, it is normally accepted that the most significant polluting emission from bagasse boilers is particle material, as NO_2 emissions are very low, virtually considered negligible when boilers are properly set up.

Conama Resolution n. 382/2006 determines, countrywide, maximum air pollutant emissions from fixed sources, defined by pollutant and type of source. Its Appendix 3 defines the emission limits for air pollutants from heat generation processes, i.e., including the external combustion of sugarcane bagasse.

Hence, new sugarcane bagasse-burning boilers will be subject to control on nitrogen oxides, carbon monoxide and particle material, in addition to smoke composed of small dust particles, soot and other materials. Renewable environmental licensing demands improvements to old boilers, especially to optimize burning conditions and to reduce emissions with engineering controls (LUCON, 2008).

There is no specific law or decree for industrial emissions in the São Paulo state at this time, as the aforementioned Conama Resolution n. 382/2006 is in effect.

According to DA COSTA (2008), dispersion studies introduced in the sugar-alcohol mills environmental licensing process has shown pollutant concentration values very close to those defined by Conama Resolution n. 003/1990[6], often taking over 60% of the air quality standard in the air basin[7] where they are in. When mills show dispersion studies showing values above legal levels for NO_x

[6] Conama Resolution n. 003 of July 28th, 1990, which sets air quality standards.

[7] State Decree n. 52 469/07 – Airsheds.

and PM at some points, adjustments are required to chimney stack design or the implementation of control equipments.

Water

Water availability

According to NETO (2008), the impact caused by sugar-alcohol mills on water supply are both quantitative and qualitative by its nature, being capable of degrading water resources by intense usage, causing shortage and also due to the high polluting potential of agro industrial activities and soil use.

The average water consumption of a sugar-only mill is 30m³/ton, and of an autonomous distillery it is 15 m³/ton of sugarcane, and when the mill splits its production equally between sugar and alcohol, the average water intake is close to 21 m³/ton of sugarcane (NETO, 2008). However, this author points out that 21m³/ton of sugarcane does not reflect the water intake and consumption, since it fails to consider water recycling through the circuits, and rational water usage concepts that may interfere positively on the average volume of water used, meaning a much lower intake, depending on the water reuse stage in that facility.

Industrial use water intake and discharge levels have been significantly reduced in the past few years, from about 5 m³/ton of sugarcane used (in 1990 and in 1997), it went down to 1.83 m³/ton of sugarcane in 2004 (samplings in São Paulo[8]). Reuse level is high (total intake was 21 m³/ton of sugarcane, 1997) and the efficiency of the treatment for discharge is above 98%, proving that the efforts of the sugarcane industry towards reducing water intake and consumption were extremely successful.

Such efforts focus on the rational use with maximum reuse of effluents, reduced intake by incorporating new technologies such as dry cleaning of sugarcane, biodigestion of stillage and fertirrigation.

In this aspect, the goal set by CTC (NETO, 2008) for rational use of water is the intake of 1 m³/ton of sugarcane and zero effluents discharge, with full reuse of effluents in the plantation, reduced water supply costs, and lower expenses with the treatment of effluents.

Present impacts of sugarcane culture on water supply are minor under the conditions observed in the São Paulo state[9], due to the absence of irrigation and a substantial reduction in its industrial use, thanks to water recycling processes in industry and the water reuse practices in fertirrigation systems.

According to LUCON (2008), São Paulo state mills have considerably reduced their water consumption over time; however, they are still heavy users in the areas adjacent to the rivers Mogi, Pardo, São José dos Dourados, Aguapeí,and the middle Paranapanema[10]. Nevertheless, state legislation has already implemented charges for water intake from river basins, as well as for effluent discharge[11].

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8 A recent study, carried out by CTC in 2005 (2004 data) in Unica associated mills concentrated in the São Paulo state, with the objective of checking the effect of the policy of charging for water in rationalizing the use of this input in this industry, revealed a drop in water intake to 1.83 m³/ton of sugarcane, which means a reduction to half of the proportional water demand of the sugar-alcohol industry, in comparison to all other industries (13% in 1990 to 7% in 2007) (NETO, 2008).

9 Embrapa ranks sugarcane at level 1 (no impact on water quality).

10 SIGRH. Relatório de situação dos recursos hídricos do Estado de São Paulo – síntese. Sistema de Informações para o Gerenciamento de Recursos Hídricos do Estado de São Paulo, jun. 2000. Available at: <http://www.sigrh.sp.gov.br/sigrh/basecon/r0estadual/sintese/capitulo02.htm>.
In 1990, mills used 47 m³/s of water, or 13% of the total urban, industrial and irrigation demand. Current water availability is 893 m³/s (Q7,10), for a reference flow rate of 2,020 m³/s. According to the water balance of the São Paulo state, the total flow rate of 3,120 m³/s represents 29% of the pluviometric precipitation, theoretically being the highest potential that could be explored. For economic reasons, such potential in practice is reduced to 70% of this flow. At first sight, the rain volume of 1,376 mm/year is satisfactory to ensure agricultural production; however, its distribution throughout the year is not uniform. The basic flow rate that feeds watercourses during drought periods is 1,285 m³/s, about 41% of the total flow, being the other 59% relative to direct superficial flow of 1,835 m³/s. The underground water availability in the aquifer is directly related to the basic drainage basin on the area of occurrence (LUCON, 2008).

11 State Law n. 12183/05. Implements charges on the use of water resources within the domain of the São Paulo state, the procedures for setting its limits, conditions, values and other measures.

Charging for the use of water is grounded on the principles of “pollutant-payer” and “user-payer”, based on the quantity and quality of water intake and returned to the environment. Costs that affect the industrial sector correspond to water intake, consumption and discharge.

According to the National Water Agency (Agência Nacional das Águas – ANA), charging for the use of water favors the adoption of sustainable and adequate practices for the various applications. By inducing the rational use of the resource, waste and contamination should be reduced, and it is expected that supply, sanity and purity indexes will rise. Charging is one way to manage federal and state water resources to generate funds that will allow investing in the preservation of the rivers themselves and their basins.

Water pollution

In the sugar-alcohol industry, effluents are the major potential cause of environmental impact to water resources, being stillage and washing water, with high organic content (COD/BOD), considered as the most relevant liquid residues.

Fertirrigation is used as a solution for stillage and residue water, with obvious advantages. The amount of stillage applied per unit of area was gradually reduced and new technologies were introduced to reduce the risks of contaminating water tables. Numerous studies consider the possibility of soil contamination and observe that there are no significant impacts in applications under 300m^3/hectare (LORA, 2008).

Recycling (stillage and filter residue) yields favorable results in optimizing the use of potassium, increasing the nutrients supply in the field, while efficient reuse of water within the plant and efficient effluents treatment contribute to reduce environmental impact.

Federal laws regarding the use of stillage and its soil application control appears in the 1980s, in the Minter Directive n. 323 (1978), which forbids the release of stillage on surface watersheds and in Conama Resolutions 0002 (1984) and 0001 (1986), which determined, respectively, the study and the development of standards to control effluents from distilleries, and the mandatory requirement of Environmental Impact Studies – EIA/Environmental Impact Report (Relatório de Impacto Ambiental – Rima) for new plants or expansions.

The regulation on use and application of stillage in the São Paulo state is modern; Technical Standard Cetesb/SP P4.231/2006 defines the criteria and procedures to apply stillage on agricultural soil, being the most specific measurement taken in the Brazilian sugar-alcohol industry.

Each liter of alcohol produced generates 10 to 13 liters of stillage. As the Brazilian production is around 16 billion liters of alcohol, it is estimated that the yearly production of stillage is close to 200 billion liters. Currently, all the stillage produced is being used to irrigate sugarcane plantations, being the largest example of water reuse in Brazil and in the world. Sugarcane irrigation using 100 m^3/ha of stillage results in savings on the use of potassium fertilizers worth some US$ 75 to 100 per hectare, in addition to providing plantation irrigation and improving its productivity (BERTONCINI, 2008).

Still according to BERTONCINI (2008), as demonstrated in agronomical research, the soils irrigation with stillage does not significantly alter their chemical, physical nor physicochemical characteristics. Changes that occur to the soil are temporary and result from the degradation of the residue organic load which, in spite of being high (BOD » 20.00 mg/l), is composed of weak acids and glycerols, easily degradable (30% of the carbon contained in stillage). Hence, stillage may be considered a nutritional solution, with predominating potassium ions (1 to 2 kg of K_2O per cubic meter).

However, there are still some doubts and deeper research should be carried out when it is about displacing contaminants in soils having stillage application history, and in situations such as: (i) stillage application at the end of the harvest, close to the rainy season (Southeast Region), on soils with low cationic exchange and no time available for the plants to absorb the nutrients; (ii) application of stillage in the dry season, when the absorption of nutrients by the plants is low and it remains in the soil solution. Intense precipitation at the very outset of the rainy season would foster the percolation of ions to layers beyond the reach of the roots system (buildup layer), and over time leaching would occur (BERTONCINI, 2008).

Another focus of attention and studies under way is the intense and frequent use of stillage in aquifer reload areas, which may cause long-range pollution of underground waters. Apta – Pólo Centro Sul in Piracicaba – is currently developing with Unica a study in this direction, under supervision by Cetesb, which will subsidize the maintenance or revision of Norm P4.231, which defines the criteria and procedures for applying stillage to agricultural soil.

Solutions for stillage include concentration and heat drying processes, which could make the use of stillage viable in locations farther away from mills, or even in other cultures, minimizing its applications in soils historically saturated with stillage. However, these processes involve a high energy cost, being economically viable only where the use of stillage is forbidden in actual application areas.

Heat drying stillage would require electricity equivalent to burning 30% of the bagasse generated at the mill, albeit it would include new options, like the joint drying of filter residue and the production of an organic fertilizer rich in P and K. Treatment of stillage in anaerobic reactors may generate electric power that could be used in heat drying (BERTONCINI, 2008).

Sugarcane washing waters are completely reused in most mills, within the sugar-alcohol industrial process for cooling boilers, for washing equipment or even for sugarcane irrigation. The current trend is to reduce the volume of water used for washing internodes from 6-7m^3/ton of stalks down to 1.0 m^3, as a result of harvesting raw cane (ditto).

When residue waters are not reutilized, their treatment includes decantation and stabilization lagoons, for later pouring into bodies of water.

NETO (2008) points out that since harvesting shifted to raw sugarcane, washing became unfeasible due to the more intense loss of saccharose that would take place in this operation; however, for this purpose dry cleaning technology was developed, thus eliminating the sugarcane washing operation.

Waste generation in the sugarcane industry

In addition to the liquid waste discussed previously, the sugar-alcohol industry also produces solid waste, like sugarcane bagasse (residue from process, used for cogeneration of electricity), trash and tips (available from mechanized harvesting), filter residue (residue from processing stalks to produce sugar), and ashes (resulting from burning bagasse in boilers).

Filter residue and ashes are applied directly on cultivable soil, promoting the recycle of almost 100% of the nutrients that enter the production system, reducing the use of chemical fertilizers.

Mechanized sugarcane harvesting generates 8 to 15 tons/ha of trash which, if laid on the ground improves the soil fertility, due to the return of nutrients by the mineralization process, controls erosive processes and furthers water retention, on top of fostering the soil microbiota (BERTONCINI, 2008).

This new setting requires adequate technologies to solve agronomic problems that provoke environmental effects, such as nitrogen immobilization caused by the high C/N ratio in trash, causing larger and stepped doses of fertilizer, retention of pesticides in the trash, which requires larger doses of herbicides to control weeds; and the discharge of 40-60 kg/ha of K_2O (OLIVEIRA *et al.*, 1999[12] apud BERTONCINI, 2008), from the quick rotting of trash, that should be deducted in calculations for the use of stillage.

Sugarcane offers low costs in alcohol and sugar production because all the energy used in the production process is produced from its own waste. Sugarcane bagasse, together with trash and tips, is the most representative biomass in the energy matrix, being responsible for the supply of heat, mechanical and electric energy in sugar and alcohol production plants, by means of co-generation (GUARDABASSI, 2006).

Co-generation supplies the needs of the sugar-alcohol industry, which in addition to requiring

[12] OLIVEIRA, M. W.; TRIVELIN, P. C.; PENATTI, C.; PICCOLO, M. **Decomposição e liberação de nutrientes da palhada da cana-de-açúcar em cana-de-açúcar**. Pesquisa Agropecuária Brasileira, v. 34, n. 12, p. 2359-2362, 1999.

electric and thermal power, offers waste fuel (bagasse) that is integrated positively in the process (LORA, 2008).

Contrary to what happened at the outset of Proalcool, when bagasse was deemed undesirable, being burned in low-efficiency low-pressure boilers, many mills use, nowadays, efficient equipment which, on top of supplying their own power intake, allows them to sell the surplus electricity to distributors (GOLDEMBERG *et al*. 2008)[13].

Ashes resulting from the incineration of the bagasse contain in average 85% SiO_2, 0.9% P_2O_5; 1.7% K_2O, and 0.6% MgO, so they can be used directly on the soil or used to increment the chemical formula of organic compounds. Another residue generated in mills is soot from chimney stacks that is normally washed with water reused from washing sugarcane. The content of soot is qualitatively similar to ashes, though quantitatively more diluted, as it contains from 30% to 70% water (BERTONCINI, 2008).

Yet according to BERTONCINI (2008), filter residue is generated in rotating filters for extracting leftover saccharose in the production of sugar, and its composition reflects the addition of calcium and phosphor in the bleaching process. It has around 70% water and average contents of; 1.4; 1.0; 0.7; 5.0; 0.5; 1.4; and 19% (dry base) of organic matter, N, P_2O_5, K_2O, CaO, MgO, S and ashes.

Composting solid residues like filter residue and ashes promotes improvements to physical and chemical characteristics of residues, such as: (i) reduction of water content, making distribution in the field easier; (ii) better nutrients balance; (iii) improved moisturization of the organic material, promoting increase in the soil load sites, and consequently the slow release of nutrients and retention of pollutants, in such a way that the use of waste as-is on soils should be always unadvisable. Composting is currently a reality in some sugarcane mills, which are benchmarks for other industries that should promote it, like basic sanitation and animal breeding (BERTONCINI, 2008).

Use of the soil and biodiversity

Sugarcane expansion

Nowadays Brazilian agriculture uses only 7% of the national territory (half with soybean and corn), pastures occupying about 35%, and forests 55%. Agricultural expansion in the last forty years took place mostly on degraded pastures and "dirty fields", but not on forest areas (MACEDO *et al*. 2005).

The area occupied by sugarcane today is only 0.6% of the territory, and the areas suitable for this culture are at least 12%. Sugarcane growth in areas occupied by savannas was very small; it has replaced other plantations that had already replaced the savanna (usually pastures). In São Paulo, growth occurred with the replacement of other cultures and pastures (ditto).

In 2005 sugarcane covered about 3 million hectares in the São Paulo state; in 2006 these surpassed 4 million and, for 2010, coverage is estimated as close to 6 million hectares (LUCON, 2008).

In order to characterize this expansion scenario, the National Biomass Reference Center (Centro Nacional de Referência em Biomassa – Cenbio), in 2006, carried out a study on the expansion of the sugarcane culture, as well as its influence on the expansion of other cultures, pastures and native forest areas in the 11 largest sugarcane producing Administrative Regions in the São Paulo state.[14]

Between the years 2003 and 2006, the growth of sugarcane culture in the São Paulo state hit 26%. An expressive increase was noticed in the Presidente Prudente, São José do Rio Preto, Barretos and Marília areas, which were not traditional places for sugarcane, but each of them increased more than 40% from 2003 through 2006. In the North of

[13] According to Unica (2009), bioelectricity is the most important new product in the sugar-energy industry, capable of causing a revolution in the technology development process, adding income, improving the competitiveness and sustainability of both sugar and ethanol, and, consequently, promoting market growth. Together, ethanol and sugarcane represent 16% of the Brazilian energy matrix. Sugarcane is, therefore, the second most important source of energy in the country, while petroleum and its derivates occupy the first place.

[14] Administrative regions considered in the study were Araçatuba, Barretos, Bauru, Campinas, Central, Franca, Marília, Presidente Prudente, Ribeirão Preto, São José do Rio Preto and Sorocaba.

the state, in Ribeirão Preto and Campinas, strongly saturated with sugarcane, expansion rates were the lowest, like 10.97% and 9.42% respectively (LORA *et al*., 2006).

Some reduction in the corn cultivated area was noticed while pastures area remained stable. An increase in heads of cattle per hectare was noticed, i.e. more intense cattle raising[15], with confined animals, and less requirements for grazing.

According to information from SMA, (CARRASCOSA, 2008), in spite of the extremely fast growth of sugarcane culture in the past few years, no replacement of native vegetation with sugarcane cultures occurred, except in very small sites, even considering illegal deforestation.

In this context, problems related to sugarcane expansion are concentrated in the priority areas for preserving biodiversity, i.e., areas without vegetation, however recommended to re-establish landscape connectivity and reconstruction of ecological corridors.

Maintenance of the natural vegetation in the Permanent Preservation Areas is extremely important for the control of erosion and sanding up processes in rivers, to ensure the quality of the watershed, and resources to protect local fauna. However, few properties keep Permanent Preservation Areas in the country. States like São Paulo (art. 197 of the State Constitution) and Minas Gerais have established progressive recovery policies for these areas by environmental licensing.

The riparian forests areas in the sugarcane growing regions within the São Paulo state cover 8.1% of the total area assigned to sugarcane cultivation, and in 3.4% of these there is native riparian vegetation, while only in 0.8% reforesting was carried out. The implementation of riparian forest recovery programs, in addition to protecting springs and watercourses, may promote vegetal biodiversity replacement in the long run (MACEDO *et al*., 2005).

Like it happens to Permanent Preservation Areas, Legal Forest Reservation areas (federal Law n. 7803/1989) are not maintained in farms. According to SMA mapping, a significant part of the areas noted as priority were already taken by sugarcane before 2003; however, the occupation of these priority areas being lower in later harvests.

Sugarcane producing areas display reduced levels of native vegetation and fragmented remainders, low permeability to biologic flows and extremely reduced organism diversity. (CARRASCOSA, 2008).

Nevertheless, Embrapa studies developed in sugarcane organic plantations pointed to the increase of biodiversity in such types of cultivation, in contrast with traditional methods. According to the study, between the years 2002 and 2008, biodiversity in organic plantations was four times larger than in traditional ones. From 2004 to 2008, 325 species were identified, being 26 amphibious, 239 bird, 43 mammal and 17 reptile species[16].

In September 2008, SMA issued the Agro-Environmental Zoning for the sugar-alcohol industry in the São Paulo state (Zoneamento Agroambiental para o Setor Sucroalcooleiro do estado de São Paulo). This study is based on the edaphoclimatic suitability for growing sugarcane, areas where mechanical harvesting is restricted (due to slope), availability of superficial waters and vulnerability of underground waters, conservation and preservation units, priority areas for biodiversity increase, and air quality in airsheds.

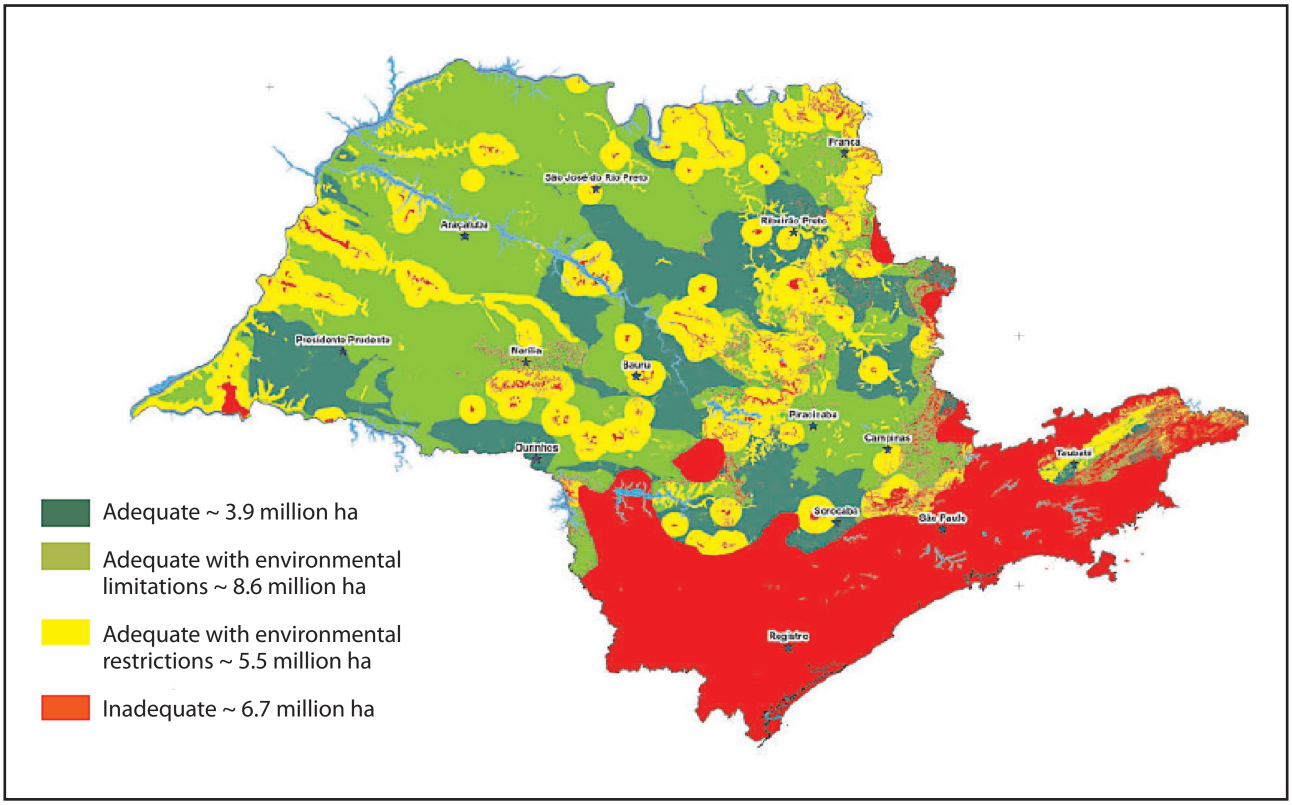
Results show that there are about 3,900,855 hectares in the São Paulo state defined as suitable for growing sugarcane without environmental restrictions. Other 8,614,161 hectares have environmental restrictions, an area of 5,546,510 hectares has environmental restrictions for growing sugarcane and 6,741,748 hectares are deemed unsuitable for growing sugarcane (LORA, 2008), as shown in Figure.

Loss of soil quality and the use of agrochemicals

Traditionally, sugarcane cultivation in Brazil shows soil loss due to relatively mild erosion, if compared to soybean and corn.

[15] This tendency can be verified by calculating the index of the number of cattle by hectare in each county.

[16] News published in the newspaper: YONEDA, F. Lavoura abriga fauna silvestre. O Estado de São Paulo: caderno Agrícola, São Paulo, p. 7, 28 jan. 2009.



Source: SMA, 2008.

FIGURE 2 Agro-environmental Zoning for the sugar-alcohol industry in the São Paulo state.

According to BERTONI *et al*. (1998[17] apud MACEDO *et al*. 2005), it may be considered that in Brazil sugarcane cultivation, in comparison with the production of grains in the same area, prevents the erosion of about 74.8 million tons of soil per year (grains: average loss of 24.5 tons/ha/year). Soil loss with soy is about 62% higher than when sugarcane is used, and with castor it's around 235% lower.

Elimination of slash-and-burn in sugarcane plantations and the introduction of mechanized harvesting in the country contribute to part of the trash being left on the soil.

According to ANDRADE and DINIZ (2007), the layer of trash protects the soil from erosion[18] and contributes to improve the organic matter content in the soil, with positive impact on the nutrients balance and for the pedologic microbiology. The presence of trash on the field also reduces the incidence of light on the ground, inhibiting the photosynthesis process, and the consequent germination of some kinds of weed[19].

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[17] BERTONI, J.; PASTANA, F. I.; LOMBARDI NETO, F.; BENATTI JR., R. Conclusões gerais das pesquisas sobre conservação de solo no Instituto Agronômico. Campinas, Instituto Agronômico, 2. impressão, janeiro de 1982, Circular 20, 57 p. In: LOMBARDI NETO, F.; BELLINAZI JR., R.: Simpósio sobre Terraceamento Agrícola, Campinas, SP, Fundação Cargill, 1998.

[18] Research by Copersucar (2001 apud RIPOLI, 2004) showed that the only effective way to avoid hydric erosion of cultivable areas is to prevent their onset, using techniques that avoid direct contact of the raindrops with the soil surface. Maintenance of the soil coverage is recommended.

[19] MANECHINI (2000 apud RIPOLI, 2004) in studies of the effects of sugarcane trash on weed control concluded that over 66% of the sugarcane residues left on the field control weeds yearly with higher than 90% efficiency, being competitive with the most successful herbicide used to treat sugarcane production.

In this sense, the sugarcane culture leftovers on the soil provide better weed control, in addition to helping to preserve moisture and protecting the terrain against erosion, thus even increasing the organic matter content of the soil by cultivation over several years; the dead blanket helps reduce the population of organisms that are hazardous to the culture, by increasing the quantity of predators (TILLMANN 1994[20] apud RIPOLI, 2004).

Cultivation of sugarcane in areas where the soil was impoverished by other cultures contributes to their recovery, adding organic matter and chemical-organic fertilization.

Sugarcane cultivation requires lower pesticide use than citrus, corn, coffee and soy. The use of insecticides is low and the use of fungicides is deemed practically null (MACEDO *et al.*, 2005). Among the larger cultures in Brazil (area over 1 Mha), sugarcane uses less fertilizer than cotton, coffee and orange, its intake being equivalent to soy.

According to MACEDO *et al.* (2005), among sugarcane's major pests, borer and sharpshooter controls are biologic; borers have the largest biologic control in the country. Ants, beetles and termites are chemically controlled, and it has been possible to significantly reduce the quantity of pesticides by means of selective use.

FINAL CONSIDERATIONS

Over the Proalcool development period, both national and São Paulo state environmental legislation has significantly evolved, contributing to the sustainability of alcohol and sugarcane production.

Some improvements are obviously possible, and they are being implemented, such as the Economic-Ecologic Zoning and stricter inspection.

Nevertheless, now it is proper to state that production in the São Paulo state is consistent with international requirements.

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