Brazil's Sugar Cane's Ethanol: Villain or Panacea?

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Introduction

Clearly ethanol emissions are far better than fuels from oil derivatives - and ethanol mainly comes from sugar-cane of tropical countries, a source of renewable fuel - but sufficiently to earn a "clean fuel" definition? This 'clean' energy cannot, though, be produced by deforesting and displacing small farmers in these countries to give way to large monoculture extensions. The human, social, economic and environmental impacts of sugar cane production, the primary produce for ethanol, are here evaluated for Brazil, resulting in a negative balance across the board. So, Brazil's National Ethanol Production Plan should be looked upon cautiously by its prospective buyers and adequate measures taken so that it might represent a more sustainable source of renewable fuel.

A general framework

Today Brazil produces massive quantities of soy beans and sugar-cane products whilst eucalyptus plantations[1] are fast spreading within its landscape, mainly for paper production and domestic fuel (Figure 1). The two new areas for expansion of these crops are the Amazon and the Brazilian *Cerrado,* a grassland-woodland mosaic, both biomes of the highest known biodiversity.

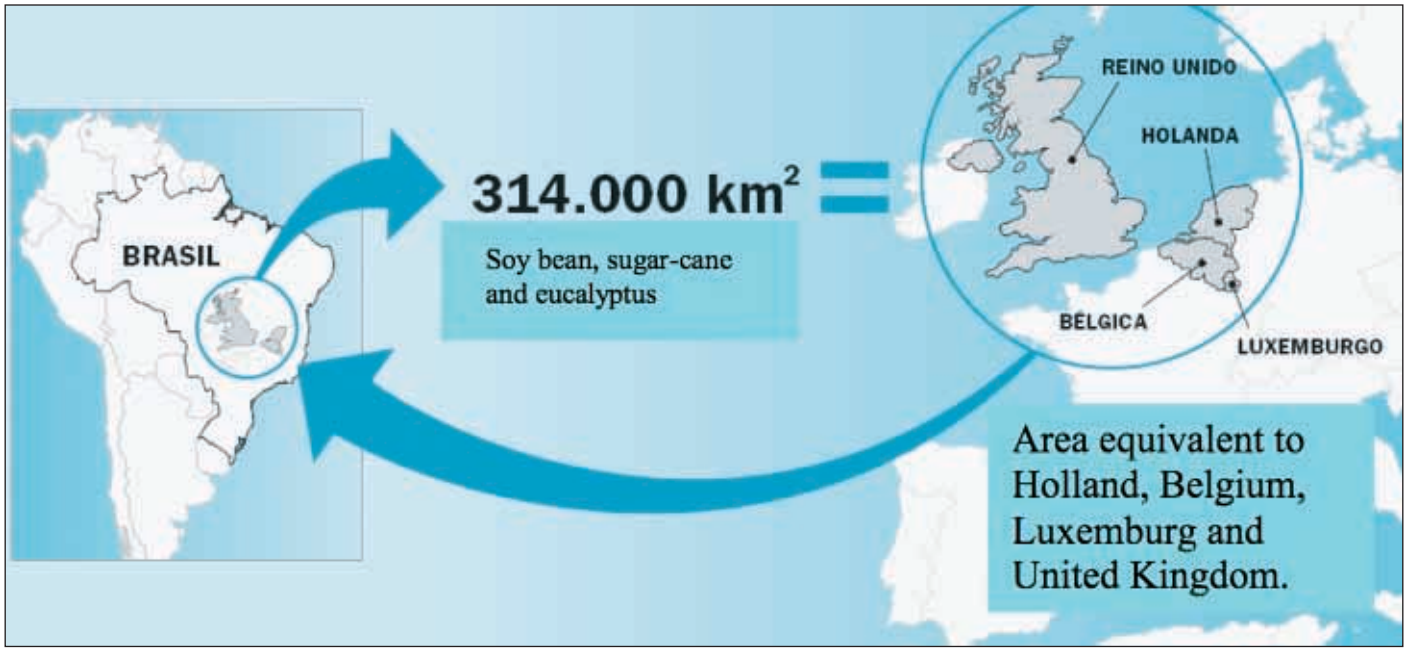

Fig. 1 – Planted areas for soy bean (22.2 millions ha), sugar-cane (6.2 millions ha) and eucalyptus (3 millions ha), for a total of 31.4 millions ha, or 314,000 km^2. Image from *Agronegócio e biocombustívesi: uma mistura explosiva – Impactos da expansão da monoculturas para a produção de Energia.* (Agribusiness and biofuels: an explosive mixture – Impacts of monoculture expansion for energy production). Núcleo Amigos da Terra/Brasil and Fundação Heinrich Böll. 2006. Project: *GTEnergia do Fórum Brasileiro deo ONGs e Movimentos Socialis para o Meio Ambiente e o Desenvolvimento (FBOMS).*

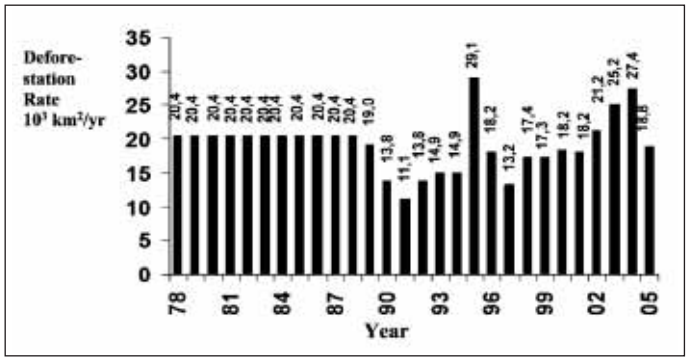

Fig. 2 – Brazilian Amazon Deforestation rates in 10^3 km²/year. Fearnside 2006.

Most of these products are for export: soy[2] to feed European and other animal stocks, ethanol from sugar cane as a fuel substitute, paper from eucalyptus. Because of their lower labour and environmental costs, they are obviously of increased interest to the international market, but their externalities heavily impact Brazil as a whole and should be taken into account for their implications.
These monoculture agricultural production systems can be classified as "high input agriculture", totally dependent on exogenous energy sources, require highly sophisticated and polluting chemical inputs, concentrate land[3] and income, displace small farmers[4] to urban slum dwellings[5], remove traditional cultures from their natural habitats[6], massively deforest, mostly illegally (see Figure 2 – much due to soy bean crops), induce regional climate change with erratic rain patterns, increase soil erosion rates, deposit sediment loads within water courses and use great volumes of water, besides pumping carbon into the atmosphere in the massive burning of sugar-cane and filling up hospital beds with respiratory problems. Today, such a pattern doesn't need extensive study to prove its drawbacks for the country and new production and consumption patterns must be sought and experimented. In Brazil, due to disproportionate income concentration, government policies should privilege small land tenure systems – defined in Brazil as "Family Agriculture" (*Agricultura Familiar*) – from planting and environmental conditions to marketing and distribution with a view to product diversification and aggregate value.
Although Brazilian environmental laws are well conceived, they are poorly enforced as corruption sets into normal everyday practice – government employees are not well paid, lack equipment and adequate infra-structure and departments are understaffed to properly operate. This then calls for a better informed and articulate society, more effective regional social organization and international pressure on government policies, enterprises and joint-ventures, to adequate their social and environmental practices to a more appropriate standard, known in Brazil as "Socio-environmental Certification"[7] – where products are evaluated right along their life cycle and quantitative and qualitative socio-economic and environmental indicators are assigned to each step of the way, from the growing or acquisition of raw resources to final processing and distribution.

Water consumption: "Virtual Water" calculations

One of the strong factors, besides warm tropical climates and arable land for export crops, is water availability in Brazil. Water is an expensive product in developed countries or countries like China, which import great quantities of Brazilian soy beans. According to the environmental accounting using *emergy*[8], water, either precipitation or irrigated, is one of the most expensive inputs into agricultural production, something which is not traditionally accounted for. In simpler terms, "virtual water"[9] can be considered as the quantity of water used to produce a good or service. Virtual water is thus embedded in the product, as it is absolutely essential for the productive process.
As an example, the above figure shows 18 million tons of soy beans imported by China from Brazil and other countries in 2004. This is equivalent to 45km3 of virtual water, inasmuch as, by comparison, yearly world domestic water consumption is of 65km3. Brazil's Biodiesel National Plan is based on this water availability – the problem is that in most areas traditionally used for sugar-cane production, groundwater is heavily polluted and in due time, if the country doesn't manage natural resources properly, it will also encounter water shortage for energy crops such as sugar-cane, castorbean (*Ricinus communis L.*), a very rich source of oil (up to 46% in the bean), and other options.

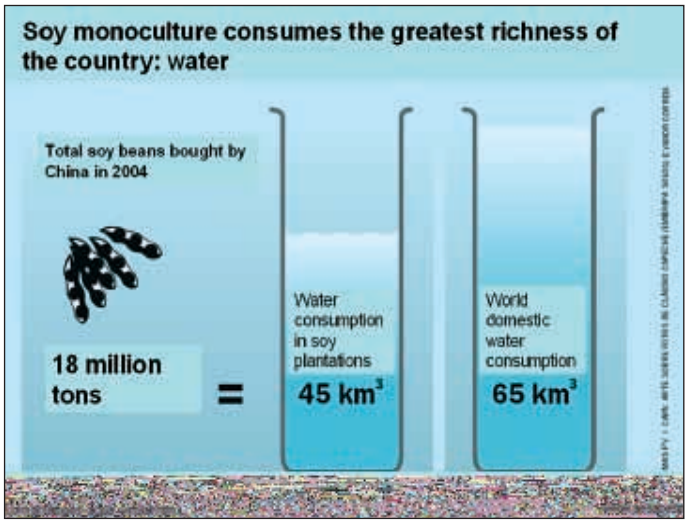

Fig. 3 – Soy beans bought by China in 2004, comparing water consumption in soy plantation with yearly world domestic water consumption.

Medium and long-range plans from energy crop importing countries should account for this factor in their planning, before committing themselves to long term goals and specific contracts. One more reason to closely scrutiny the whole process and demand better environmental and social care with these agricultural systems.

Sugar-cane and ethanol

Production

Brazil is the world leader in sugar-cane production, with 6.0 million hectares, which produce 28 million tons of sugar and 16 million m^3 of ethanol, processed by 306 sugar-cane processing plants, with an expected 17 million m^3 for the 2006/2007 crop[10], of which 3.5 million m3 are to be exported. A technology developed during the past 30 years, a splendid tropical climate for the fastest growing C4 type plant, combined with cheap labour, appalling working conditions and total environmental carelessness, resulted in Brazil's ethanol production declining (Figure 4) costs 50% cheaper then the US corn produced counterpart and much better than this in comparison with European processes, from beetroot[11]. But even greater exports do not necessarily mean better living conditions in the rural areas, in fact, quite the opposite is true.

For the 2004/2005 crop Brazil's sugar-cane areas reached 5,791 million ha, by 2005/2006 the figure had risen to 6,171 million ha. Previsions for 2011 are of 8,991 million ha, plus a 3.6 million ha just because of ethanol demand from industrialized countries, without accounting for sugar demand. To substitute 10% of the world gasoline consumption, Brazilian ethanol from sugar-cane must be incremented by 400% (Folha de Sao Paulo, 2007), which means multiply by a factor of 5 the existing planted area, according to studies by the Ethanol Project (Interdisciplinary Nucleus for Energy Planning of the State University of Campinas-UNICAMP- and the Ministry for Mining and Energy. FSP (2007).

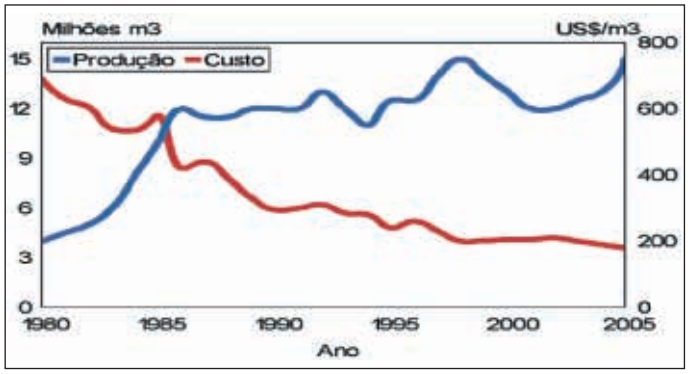

Fig. 4 – Brazilian Ethanol production costs are fast decreasing in US$/$m^3$. The blue curve represents production and the red one cost. Production, on the left scale is in Millions m^3; cost, in the right scale is in US$/$m^3$. (Source: Ministério da Agricultura, Pecuária e Abastecimento – MAPA/Secretaria de Produção e Agroenergia/Departamento da Cana-de-açúcar e Agroenergia. 2005).

Social and public health aspects

When taking into account ethanol's life cycle - the planting, harvesting and processing of Brazilian sugar cane - human, social, economic and environmental liabilities emerge in scaring proportions.

Although Europe in general is cheering the Brazilian national ethanol production programme as an excellent way of dealing with fuel shortage, few people know, or are even superficially aware, that the useful work-life of a sugar-cane cutter is 15 years[12], when back in Imperial Brazil a slave's was 10. Besides the technological advances of industrialized, high-input agriculture of sugar-cane production, not much has changed with the hand cutting process of more than 400 hundred years ago. Few years ago one person was cutting 6 to 10 tons of sugarcane per day. Today, with the same technique and tools he is expected to cut from 12 to 20 tons/day.

Year	Daily Tons of cut sugar cane[15]
In the 80s	5 to 8
1999	8 to 9
2004	12 to 15 (up to 25)

Mean worker's age is dropping; women have already been excluded for sometime, as they cannot keep up with the work load. It's so bad that the firms provide isotonics, to replace body fluids and salts – very high perspiration rate - and vitamins, to prevent muscle rigidity. This is during the day. At night booze runs free. The combination is critical. Workers are so lit up that, after a minimum of a 12 hours working day, they come back from the fields and go to play soccer (football). They don't realize they are exhausted, as the cocktail combination turns them on. In the last crop in the State of Sao Paulo, the greatest producer, 20 cases of heart failure have been registered due to fatigue. It's quite a sad picture for a "clean" fuel. Many sugar-cane cutters are Indigenous people in this area and they are getting sicker every day. When the cane is burnt[14], the *maturators* (organic agents to homogenize the cane's growth) put out cancerous gases which are ingested by nose and mouth, through the cold food eaten in the fields. This obviously accumulates in the worker's blood and reduces his life span. Small urine doses from sugar-cane cutters during cutting season killed specimens of the bacteria *Salmonella typhimurium*, indicating high toxicity levels in their organisms[15].

The burning of sugar cane to allow manual cutting is also affecting heavily public health, by lowering relative humidity up to 5%, depending on winds directions and other climatic conditions (below 20% health posts and hospitals already crowd with children and the elderly with breathing problems). It also causes cancerous gas releases from the sugar cane itself, heavily pollutes the air, produces erosion and leaching of soil nutrients, increases rivers sedimentation and effects negatively biodiversity.

Environmental impacts

By far the greatest environmental impact is the great monocultural sugar-cane extension on the regional biota, principally the Amazon and the *Cerrado* region, causing deforestation and reduction of their high biodiversity as the remaining natural habitats are taken over. This goes jointly with high erosion rates when the culture is burnt every year[16], as this leaves the soil uncovered and exposed to the elements with little organic matter being recycled.

Burning of sugar-cane itself liberates carbon, ozone, nitrogen and sulfuric compounds gases, responsible for acid rain, temperature rise and drop in relative humidity. Figure 7 maps the spatial distribution of potential environmental impacts of sugar-cane burning in Brazil in terms of World Global Warming Potential (t CO_2 equivalents), Acidification Potential (t SO_2 eq.), Tropospheric Ozone Formation Potential (t C_2H_4 eq) and Potential for Human Toxicity (m^3 of air). The more intense areas concentrate in the states of Sao Paulo, Mato Grosso do Sul and Mato Grosso, in South-Central Brazil, with a strip in the North Eastern coastal states and the State of Spirito Santo, north of Rio de Janeiro.

Fig. 5 – Sugar-cane cutter with heavy self-made clothing outfit to withstand the impact of cutting. This causes profuse sweating in hot tropical climates. Foto: Daniella Rosário
http://www.danellarosario.com.br

Different sizes of particulates are also produced by burning, each with specific toxic effects.

Whilst course particles, greater than 10?m, can be blocked by nostril hair, fine ones penetrate the lungs, some being captured and eliminated by mucus and some aggregated by the alveolus. The ultra fine are though absorbed by the blood with toxic consequences on the system.

The excessive use of herbicide and insecticide heavily pollutes groundwater, as registered in the State of Sao Paulo. 12 litres of byproduct leachate from ethanol (ethyl alcohol) production (Portuguese: *vinhoto*), a pasty and foul smelling residue from distillation of sugar-cane broth, are produced for each litre of ethanol. If directly disposed in water, it produces an intense deoxygenation, resulting in fauna mortality. Its storage in open-air temporary ponds is also a risky procedure. It has been greatly used in the fertilization/irrigation of sugar-cane fields, mostly indiscriminately, without following correct procedures for adequate soil characteristics and conditions, provoking contamination of groundwater.

Results of an Emergy Evaluation I conducted about 12 years ago[17] - and processes haven't changed that much: at the time plants were already recycling sugar-cane bagasse and producing with it their own electrical energy requirements and extra energy that went to the national network - at one of Sao Paulo State's largest sugar and ethanol plant (around 30,000ha of plantations), the emergy ("memory energy")[18] output was slightly smaller than the input, giving a 0.93 for sugar and 0.95 for ethanol (below the 1 to 1 even point line).

Fig. 6 – Sugar-cane cutter clutching a batch of sugar-cane. Repetitive movements, bodily strain and extreme environmental and working conditions have a dehumanizing effect on this segment of society. This is not a job fit for human beings, once machines have been invented and are available. Is is ample time for mankind to review its standards and pay just prices for correct processes. Foto: Daniella Rosário
http://www.danellarosario.com.br

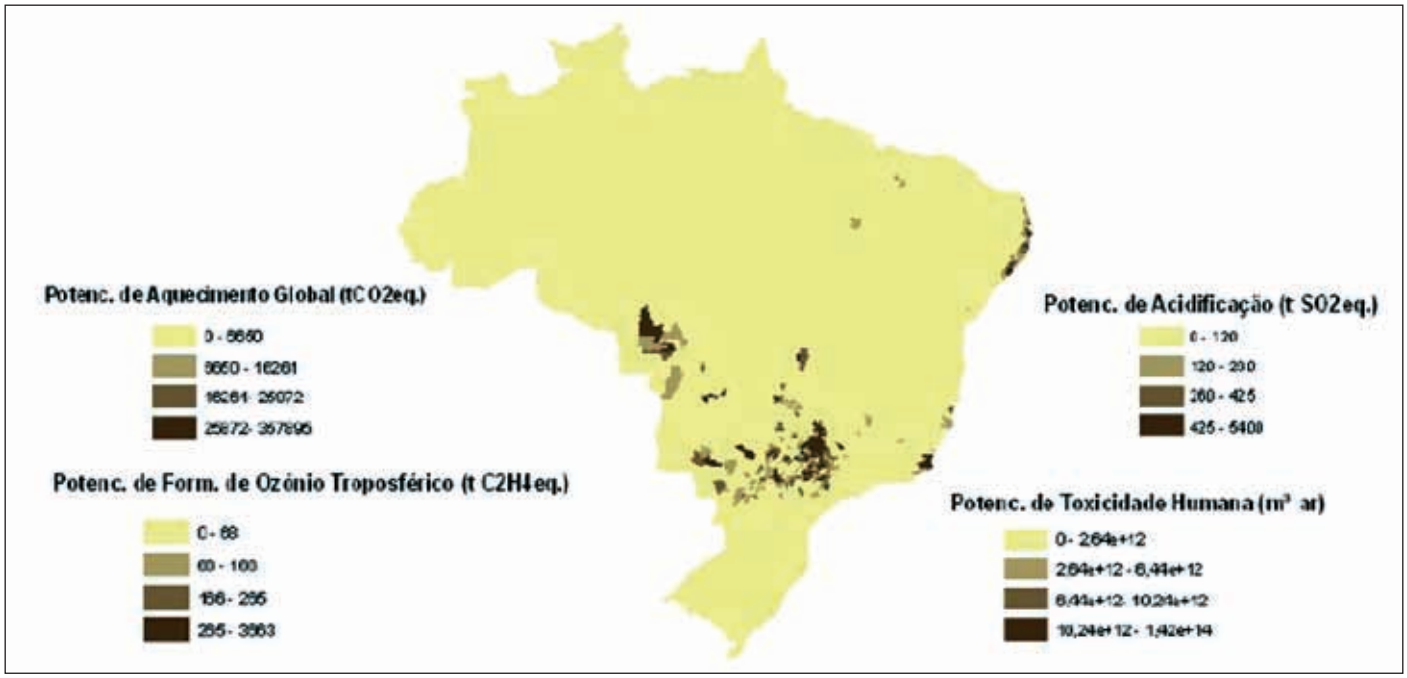

Fig. 7 – Spatial distribution of potential environmental impacts of sugar-cane burning in Brazil. Legend and figures: Top Left – World Global Warming Potential (t CO_2 equivalents); Top Right – Acidification Potential (t SO_2 eq.); Bottom Left – Tropospheric Ozone Formation Potential (t C_2H_4 eq.); Bottom Right – Potential for Human Toxicity (m^3 of air).

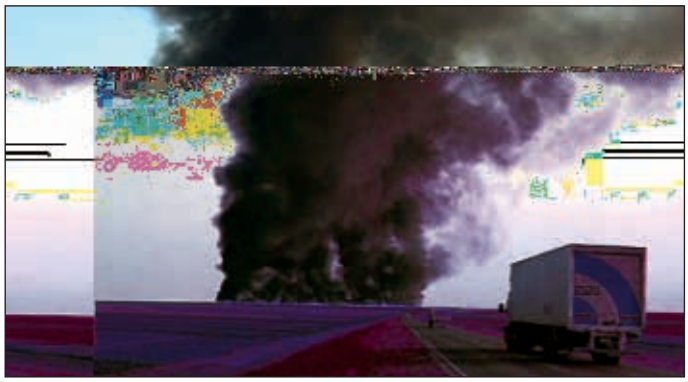

Fig. 8 – Sugar-cane plantation burning at Sonora, Mato Grosso do Sul, Brazil, 2006.

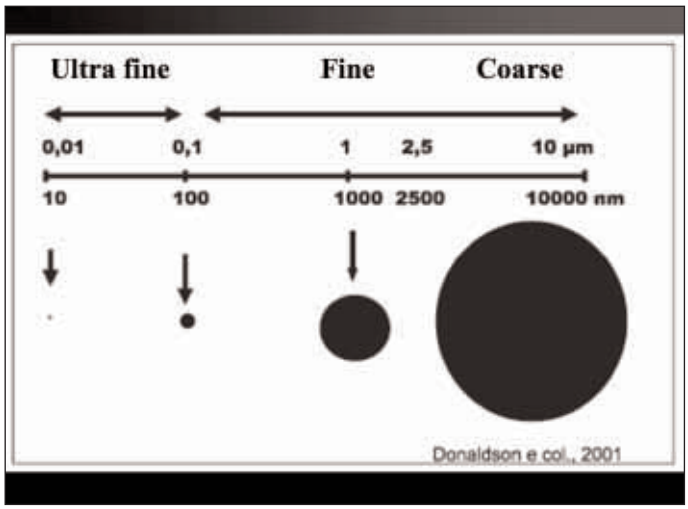

Fig. 9 – Particles from sugar-cane burning. Course, fine and ultra-fine size particles differently effect human organism and biota in general.

Also sugar cane production (agricultural) was a heavily subsidized process (high inputs agriculture) at the rate of 9 emergy inputs from man to 1 emergy input from natural sources (renewable and non-renewable). The bottom line being that, on a macro scale, the overall economy – considering here the environmental accounting, through emergy calculations, embodied in the evaluation – had to somehow subsidize sugar and ethanol. This still without accounting for the disruption of the rural social fabric by rural population displacement to urban centres and environmental damages like soil depletion, erosion and groundwater pollution.

The Brazilian State of Sao Paulo was responsible in 2006 for 60.7% of the total plantation area for sugar cane in Brazil[19]. Sao Paulo State, with its present 336 ethanol and sugar producing plants, accounts for 62,4% of Brazil's ethanol production[20].

An estimated 100 new plants are expected until 2010 for the production of 8 million liters of ethanol[21], whilst there is a prevision of more than 40 new plants just for the State of Mato Grosso do Sul, which has already lost most of its natural vegetation and fauna - has high erosion rates and water losses - by soy production. There is an urgent need to enact municipal and state legislation to induce better social and environmental procedures in all the steps of production, since the planting to the final products distribution – the above mentioned Socio and Environmental Certification.

Alternatives and future actions

Ending sugar-cane burning - besides stopping high public health costs, environmental pollution, soil erosion and biodiversity loss, forces industry to use machinery to cut sugar-cane, thus avoiding a slave cutting situation – must be a priority. An ideal set of measures would be: 1) no burning of sugar cane (with positive socioeconomic and environmental effects); 2) full mechanization[22] of sugar cane cutting; 3) land zoning for sugar cane crops (limiting its total percentages in the landscape, avoiding slopes and important natural assets, implanting a network of Biological Corridors); 4) annual crop rotation for sugar-cane, combined with other crops (mainly soy and corn); 5) stricter requirements for native forest recuperation and water resources management; 6) better social conditions and infrastructure for sugar and ethanol plants; 7) Social and Environmental Certification for the sugar and ethanol industry (links with Fair Trade Labelling Organizations-FLO; 8) in order to avoid small farmers selling or renting their land for sugar-cane crops, develop research and development programs providing them with diversified production alternatives, jointly with technical support, better credit conditions, facilitating their marketing and commercialization; 9) organic sugar-cane, sugar and ethanol production, to lessen environmental and social negative impacts and open new markets in food and pharmaceutics. These are all a long way from being implemented or even discussed in the State of Mato Grosso do Sul, whilst the State of Sao Paulo has passed State legislation to enforce mechanization only starting from 2021 and 2025, according to different areas. A sad drawback on its past public policies.

Pressure from low-cost sugar-cane cutting procedures is still winning across the board and the very workers unions are against mechanical cutting, due to the loss of jobs, a real dilemma.

So, a "clean fuel" is still a great fake as foreign investors are crowding at Brazil's borders to get their share of the action. Forward thinking is the best policy and prevention has always been better than cure. An informed market can exert political and entrepreneurial pressure on these processes, on government and private agencies and help establish a more just and long-lasting balance. Without doubt, the new areas contemplated for sugar-cane expansion shouldn't witness the same mistakes and socially and environmentally degenerative processes as the traditional ones and the faulty development of one region should not be necessarily copied by others. We have room for innovation, but it must come from a concerted effort and certainly backed up from inside and outside pressures.

Fig. 10 – Sugar-cutter's hand sharpening his machete.
Foto: Daniella Rosário
http://www.danellarosario.com.br

What is most needed is the development of mechanisms which might stimulate responsible production systems, committed to the concept of Ecodevelopment and other mechanisms which inhibit irresponsibility in social and environmental issues. The Social and Environmental Certification proposed by Rainforest Alliance and its adhering institutions in Brazil, to which we are aligned, which stimulate and promote responsible production patterns is one good way to start.

Literature cited

1) Bosso R. M. do Valle – UNESP/Ribeirao Preto-SP, Brazil. Cited by Julio Zanella in www.unesp.br/aci/jornal/198/capa.php , n. 198, March 2005.
2) Comar, M.V. 1994. *Emergy Evaluation of the sugar cane, sugar and alcohol at the Ester Plant, Cosmópolis County, São Paulo State, Brazil.* 2nd Brazilian Congress of Energy Planning, UNICAMP, Campinas, December 1994.
3) Comar, M.V., Ortega, E.R. *Some results of emergy analysis of Brazilian agricultural and Agro-industrial projects.* Paper presented at the 'International Workshop of Energy Flows in Ecology and Economy', May 1998, Porto Venere, Italy.
4) Folha de São Paulo Para substituir 105 da gasolina do mundo plantação de cana deve subir 400% - Caderno Dinheiro- B12 10/02/2007
5) Ferraz, J. M. G., L. De S. Prada, M. Paixão. 2000. *Certificação Socioambiental do Setor Sucroalcooleiro.* Joint edition: Embrapa-Meio Ambiente, Imaflora, FASE. P. 192.
6) Instituto de Economia Agrícola.Cana-de-açúcar Para Indústria: O Quanto Vai Precisar Crescer. Analise e Indicadores do Agronegócio. Vol.1, n. 10 outubro, 2006
7) Marchi, M.R. UNESP/Araraquara-SP, Brazil. Cited by Julio Zanella in www.unesp.br/aci/jornal/198/capa.php , n. 198, March 2005.
8) Núcleo Amigos da Terra/Brasil and Fundação Heinrich Böll. 2006. *Agronegócio e biocombustívesi: uma mistura explosiva – Impactos da expansão da monoculturas para a produção de Energia.* Project: *GTEnergia do Fórum Brasileiro deo ONGs e Movimentos Socialis para o Meio Ambiente e o Desenvolvimento (FBOMS).*
9) Odum, H.T. *Environmental Accounting: EMERGY and environmental decision making.* 1996. John Wiley and Sons. 370 p.
10) Odum, H.T. April 2000. *Emergy Accounting.* Environmental Engi-

neering Sciences University of Florida, Gainesville, Florida, USA.
11) O Globo. Produção de Etanol deve Crescer 10% Em 2007 http://g1.globo.com/Noticias/Economia/0,,AA1449921-5599,00.htm acessado em 20/02/2007.
12) Orplana. Produção de Cana-de-Açúcar, Açúcar e Álcool no Brasil Disponível em http://www.orplana.com.br/corpo_estatisticas_ producao.asp acessado em 20/11/2006.
13) Lage, J; Zafalon, M. País precisa de cem novas usinas de etanol até 2010. Folha de São Paulo. Disponível em: http://www1.folha.uol.com.br/folha/dinheiro/ult91u114318.shtml 07/02/2007.
14) Philip, M. Fearnside. 2006. *Desmatamento na Amazônia: Dinâmica, Impactos e Controle.* Acta Amazônica, in press.
15) Rodrigues Vania. www.aesabesp.com.br/artigos_agua_virtual.htm
16) Umbelino A., in *A OCM e os efeitos destrutivos da indústria da cana no Brasil*, 2006. Rede Social de Justiça e Direitos Humanos e Comissão Pastoral da Terra.

[1] Eucalyptus, as a renewable energy source, is important here for part of it is transformed into charcoal, as a fuel for industrial heating and it is also a large monoculture enterprise.

[2] Starting in 2007 a massive Brazilian government plan will use soy as the basis for *H-Bio*, a Biodiesel fuel developed by Petrobras, State Agency for petrol and natural gas extraction, refining and distribution.

[3] Just 3% of Brazilian rural properties are larger than 1,000ha and still occupy 56.7% of agricultural land.

[4] Small properties in Brazil generate 87.3% of job offers; medium size properties 10.2% and large 2.5% (Ariovaldo Umbelino, in "A OCM e os efeitos destrutivos da indústria da cana no Brasil", 2006. Rede Social de Justiça e Direitos Humanos e Comissão Pastoral da Terra).

[5] According to the Brazilian Institute of Geography and Statistics – IBGE- between 1999 and 2001, 5.3 million people abandoned rural areas. Between 1985 and 1996, 941,000 rural establishments were closed, 96% of them with an area less than 100ha.

[6] Brazilian indigenous people, who have suffered a process of historical genocide, are still fighting a loosing battle to secure their land rights and most live in destitute social and environmental conditions. Confined on reservations and small pockets of land while they wait on rulings about their land claims, they are left dependent on the federal government Indian affairs agency, Funai, which they claim fails to meet event its most basic commitments.

[7] José M. Gusman Ferraz et al. 2000. *Certificação Socioambiental do Setor Sucroalcooleiro.* Joint edition: Embrapa-Meio Ambiente, Imaflora, FASE.

[8] Odum, H.T. *Environmental Accounting: EMERGY and environmental decision making.* 1996. John Wiley and Sons.

[9] Virtual water is the amount of water that is embedded in food or other products needed for its production. For example, to produce one kilogram of wheat we need about 1,000 litres of water, i.e. the virtual water of this kilogram of wheat is 1,000 litres. For meat, we need about five to ten times more. http://www.worldwatercouncil.org/index.php?id=866, consulted Jan 11, 2007, 17:00h, Brasilia time.

[10] Article by Vania Rodrigues. www.aesabesp.com.br/artigos_agua_virtual.htm

[11] Scanty data is available on Brazilian hydrological resources in the new areas being opened for sugar-cane and biofuel type crops in general. Such is the case for the State of Mato Grosso do Sul, where more then 40 new ethanol production plants and relative crop areas are planned within the next few years. Although scientific data is not available, many rivers in Mato Grosso do Sul have reduced their total volume and their beds have been heavily altered by sedimentation of eroded soils. This points to an urgent need for research.

[12] J. M. Gusman F. – personal communication (December 2006). Orplana (2006).

[13] In the Brazilian State of Sao Paulo, sugar production cost is of US$ 165/ton, whilst in the European Union sugar extracted from beetroot is estimated at US$ 700/ton.

[14] Which literally means that the worker is quite incapable of fending for himself. Because of more than 10,000 daily repetitive movements, he cannot use a hoe, he cannot even sweep his own house and many simple tasks are a great burden due to pains in his spine, back, chest, headhackes and nervous tension.

[15] J.M. Gusman Ferraz (2006, personal communication)

[16] Sugar cane is burnt for three main reasons: 1) its burning allows for hand cutting, with cheaper prices than mechanized cutting ; 2) fire evaporates most water vapour in the cane, keeping sugar to overall weight ratio high, lowering handling and transport costs; 3) with higher sugar to weight ratio, mill prices are lower.

[17] Rosa M. do Valle Bosso – UNESP/Ribeirao Preto-SP, Brazil. This research also points out to aromatic polycyclic hydro carbonates, released by burning sugar-cane, with a proven high mutagenic potential, leading to the formation of cancer cells (Mary Rosa Marchi, UNESP/Araraquara-SP, Brazil). Both cited by Julio Zanella in www.unesp.br/aci/jornal/198/capa.php , n. 198, March 2005.

[18] Soil erosion is greatly reduced in the case of mechanized cutting without burning, as straw is shredded into small pieces and incorporated into soil; a great improvement on the traditional hand cutting method.

[19] Comar, M.V. *Emergy Evaluation of the sugar cane, sugar and alcohol at the Ester Plant, Cosmópolis County, São Paulo State, Brazil.* 2nd Brazilian Congress of Energy Planning, UNICAMP, Campinas, December 1994.

[20] Since there is available energy in everything that is recognizable (even information), an energy-based measure, emergy, spelled with an "m," can be used to evaluate real wealth on a common basis, but calories of different kinds are not added. Emergy recognizes and measures the universal energy hierarchy, which should be regarded as a 5th energy law. Systems of nature and humanity on all scales are part of a universal energy hierarchy, which is the network of energy transformation processes which joins small scales to larger scales, and these to even larger scales. Available energy (potential energy = exergy) at one level is used up in each transformation process to generate a smaller amount at the next larger scale. Self organization reinforces designs in which the energies further down the process, which tend to produce a more significant effect on the system, feed back to reinforce the input process (autocatalytic feedback). (ODUM, April 2002, *Emergy Accounting.*)

[21] It is estimated that, by 2015, this will fall to 54.9%, mainly due to greater land availability at lower prices in other Brazilian regions.

[22] A produção de cana-de-açúcar do Estado de São Paulo (242.828.824 toneladas), correspondeu, na safra 2005/2006 a 72% da produção da Região Centro/Sul e 62,8% da produção brasileira, enquanto que a produção de açúcar (16.723.500 toneladas) representou 76% da Região Centro/Sul e 64,7% do Brasil enquanto que a do álcool (9.951.893 m3) representou 69,4% da produção do Centro/Sul e 62,4% da produção brasileira. Orplana (2006).

[23] Today there are 336 plants, 248 in the Centr South region of Brazil and 88 in the North East. LAGE e ZAFARONI (2007).

[24] However, mechanization of sugar-cane cutting has not diminished burning and in the state of Sao Paulo 80% of planted areas were burnt, although 30% is already mechanized. This is because, for mechanical cutting , burnt sugar-cane can represent up to 30%