ELLA
Evidence and lessons from Latin America

As the sustainability of ethanol production continues to be a hot question, Brazilian attempts to improve an environmentally inefficient production process could provide pointers for those dealing with similar challenges in other countries.

BRAZIL'S EFFORTS TO MITIGATE THE ENVIRONMENTAL IMPACTS OF ETHANOL PRODUCTION

SUMMARY

Sugarcane cultivation and ethanol production can result in ecosystem damage to the soil, water and atmosphere, all of which cause significant harm to biodiversity and human health. This Brief presents the efforts made by Brazil, Latin America's largest ethanol producer, to avoid, mitigate and compensate for these impacts. Ethanol producers, or those assessing whether or not they will implement an ethanol programme, in Africa and Asia could benefit from Brazil's lessons learned in order to develop an ethanol production system that is environmentally efficient from the outset.

A COMMON CHALLENGE: REDUCING ETHANOL'S ENVIRONMENTAL IMPACTS

When Brazilian ethanol production was scaled up in the 1970s, environmental institutions and public management linked to biofuels were weak, as they currently are in many countries in Africa and Asia. For years the impacts of production caused significant damage to the environment due to a lack of proper legislation to control it. As ecological concerns and the impacts themselves gained more attention, private practices and public policies began to be developed to mitigate environmental harm. The actions taken in Brazil may be useful for countries that are considering if and how to embark on mass biofuel production. The benefit of hindsight shows that environmental management from the onset would lessen the need for reactive actions that can only provide incremental improvements to an otherwise inefficient system.

KEY LESSONS LEARNED

Establishing environmental assessments as a legal requirement for all ethanol producers has led to significant environmental improvements.

Public pressure and environmental awareness have been important in pushing forward policies to mitigate negative environmental impacts of ethanol production.

The strengthening of environmental institutions proved key to effectively supervising compliance with the law.

Reducing waste and emissions has been shown to increase efficiency, productivity and profitability in the ethanol sector.

THE BRAZILIAN STORY: IMPACTS AND MITIGATION

This Brief focuses on Brazil's efforts to reduce environmental harm as awareness of the impacts of ethanol production increased. First, a brief overview of the primary impacts is presented, followed by analysis of the actions taken to address key issues, namely sustainable location of sugarcane plantations, water management, waste management and reduction of pre-harvest burning.[1]

The Primary Environmental Impacts: An Overview

Ethanol production consists of two main phases: agricultural cultivation and industrial processing. During cultivation, the main impacts identified include: soil degradation due to monoculture practices; biodiversity loss due to unsustainable expansion; water contamination due to the use of pesticides and fertilisers; and increased atmospheric emissions and harm to both wildlife and humans through the practice of pre-harvest burning. During processing, the negative impacts of ethanol include: intensive water use and resultant water contamination from washing the cane clean of soot; massive waste generation as only certain components of the plant are required for ethanol; vinasse, a semi-solid waste generated, is corrosive and can contaminate soil and water and affect biodiversity; and the burning of sugarcane's fibrous remains, in order to generate electricity, also increases atmospheric emissions. These impacts are summarised in Figure 1, below.

Figure 1: Main Environmental Impacts of Cultivating and Processing Ethanol

Phase	Cause of Environmental Impact	Environmental Impact
Agricultural	Soil use for monoculture and replacement of other crops; construction and installation of industrial plant	Soil degradation, deforestation, damages to biodiversity Extension of the sugarcane crop into permanent preservation areas and legal reserves
	Application of chemical fertilisers and herbicides to crops to increase productivity and control pests	Contamination of water bodies and soil, eutrophication and emission of nitrous oxide and metal
	Practice of burning to increase the productivity of manual harvesting	Degradation and soil erosion, damage to wildlife, emissions (MP, CO_2, CO, SOx, NOx)
Industrial	Sugarcane washing	Eutrophication, increased biochemical oxygen demand of water bodies, soil degradation
	Bagasse burning for power generation	Atmospheric emissions (PM, CO2, CO, SOx, NOx) and generation of ash
	Application of filter cake	Contamination of soil, groundwater and streams and damage to biodiversity
	Application of vinasse	Contamination and salinisation of soil and groundwater sources, eutrophication, and damage to biodiversity

Sources: Adapted from: Carvalho, P. 2011. *Valoração das Externalidades Negativas do Ciclo de Vida do Etanol - O Caso da Queima da Palha da Cana-de-Açúcar* (*Valuation of Negative Externalities in the Lifecycle of Ethanol - The Case of Sugarcane Burning*). MSc Dissertation. Federal University of Rio de Janeiro. Silva, E. 2010. *Avaliação dos Condicionantes Ambientais na Perspectiva de Expansão da Produção de Etanol no Brasil* (*Evaluation of the Environmental Conditioning Factors from the Perspective of Expansion of Ethanol Production in Brazil*). MSc Dissertation. Federal University of Rio de Janeiro. Silva, L. 2010. *Sustentabilidade do Etanol Brasileiro: Uma Proposta de Princípios* (*Sustainability of Brazilian Ethanol: A Proposal of Principles and Criteria*). MSc Dissertation. Federal University of Rio de Janeiro.

Introduction to Brazil's Efforts to Mitigate Environmental Impacts

Ethanol production in Brazil started at a time when the country employed centralised environmental management, imposed by the State through command and control policies. In the late 1970s, the discharge of vinasse into waterways was prohibited by law. In 1981 the Federal Government introduced the National Environmental Policy, which established licensing and review of all potentially polluting activities. The mid 1980s saw the introduction of the Environmental Impact Assessment, a voluntary tool to prevent environmental harm and to aid in decision making.

The following decade was characterised by the development of private instruments such as environmental management systems, environmental audits and evaluations of environmental performance. In this period, partnerships between the private sector and local governments were forged, and the first market-based instruments for environmental preservation were launched. Water fees were introduced to reduce water use and waste, and socio-environmental certification was started voluntarily in the private sector in its search for best management practices

Since the turn of the millennium, environmental policies have been designed in the context of aiming for more sustainable development, adopting an integral approach in order to ensure economic development without jeopardising future resources. For Brazil this resulted in the Environmental

[1] This Brief presents an introduction to the environmental issues associated with pre-harvest burning. For a more detailed discussion of how Brazil is promoting the mechanised harvesting as an alternative to the practice of burning, see the ELLA Brief: From Manual to Mechanical Harvesting: Reducing Environmental Impacts and Increasing Cogeneration Potential.

Protocol, the public-private instrument which set a timeline for the elimination of pre-harvest burning, and the federally imposed Agro-ecological Zoning to prevent unsustainable expansion into sensitive areas.

The next sections of this Brief provide an introduction to each of these distinct policies.

Environmental Licensing

Ethanol producers are subject to environmental licensing as a consequence of Federal Law 6.938, passed in 1981, which states that all industrial activities that cause, or may potentially cause, pollution are obliged to obtain an environmental licence to operate. For the sugarcane industry, this rule was further enhanced by Resolution CONAMA 01/1986, which requires an Environmental Impact Assessment (EIA) and Environmental Impact Report (EIR) be prepared in order to obtain the environmental licence. Depending on the impacts identified in these assessments, the initiation of production may be allowed or denied; for those permitted to produce, mitigation measures are recommended. These impact assessments have prevented operations from taking place in fragile ecosystems, established compensatory actions where damage has been identified, and generally made production more efficient by reducing water use and pre-harvest burning and improving waste disposal.

In 1997, Resolution CONAMA 237/1997 was passed, legally requiring ethanol producers to comply with a three phase licensing process, in which producers may only begin operations after receiving approval from the Federal Environmental Institution. The three phases are:

1. Preliminary Licence (PL) – to approve the location and concept, establishing basic requirements and conditions to be met in the following stages
2. Installation Licence (IL) – to authorise the installation of operations according to specified environmental control measures
3. Operating Licence (OL) – to authorise operation when the previous licensing requirements have been fulfilled. The licence must be renewed periodically.[2]

Managing Water Resources

The water intensity of sugarcane irrigation has been reduced significantly in recent years, thanks to the introduction of fees for water use, introduced by Federal Law 9.433, in 1997. These fees aim to encourage more effective use of water, while at the same time generating financial resources for investments in the recovery and preservation of water sources. The process of imposing these fees is decentralised, being managed by watershed committees who establish values according to the amount and quality of water captured and released by each mill during the agricultural and industrial phases. On 10 April 2000, the National Water Resources Council (*Conselho Nacional de Recursos Hídricos* - CNRH), passed Resolution N°5, requiring that committees be established and composed of direct water users (40%), population of the watershed (40%) and representatives of state and federal bodies (20%).[3]

Water fees have increased the cost of ethanol production and boosted the adoption of new technologies and processes such as reuse, closings circuits and dry cleaning of sugarcane. In a study from the 1990s, a sample of 36 plants in São Paulo showed an average of 5 m^3 of water consumed per tonne of cane processed.[4] Today, thanks to Resolution SMA 67/08, passed in 2008 by the Environmental Secretariat of São Paulo, consumption rates in the State are limited to between 0.7 and 1 m^3/ton in new mills. As a result of this resolution, water consumption has been reduced significantly in recent years in both the agricultural and industrial phases.[5]

Waste Management

One of the by-products of sugar and ethanol production - the most polluting - is known as vinasse. For each litre of ethanol produced, 13 to 15 litres of vinasse are generated. The disposal of vinasse into rivers and lakes can cause eutrophication. In the late 1970s, the former Ministry of the Interior prohibited the discharge of vinasse into waterways

[2] For more information about ethanol licensing, see: Andrade, R., Miccolis, A. 2011. *Policies and Institutional and Legal Frameworks in the Expansion of Brazilian Biofuels*. Working paper 71. Center for International Forestry Research. Bogor, Indonesia.
[3] For more information about watershed committees, see the website of Brazil's National Water Resources Council. The Council, established by Law No. 9.433 in 1997, develops rules for mediation between various water users, and is largely responsible for the implementation of water resources management in the country. The Council articulates the integration of public policies in Brazil and thus it is recognised by society as a mentor for transparent dialogue in decision making in the field of water resources legislation.
[4] Environmental Secretariat of São Paulo. 2008. Resolution SMA N° 067, September, 2008. SMA, São Paulo.
[5] For more information, please see: Neto, A. 2005. Water Withdraw and Use in Sugar Cane Processing. In: Macedo, I. (eds). *Sugar Cane's Energy: Twelve Studies on Brazilian Sugar Cane Agribusiness and Its Sustainability*. UNICA, São Paulo.

via Ordinance N°323, which also required distilleries to submit projects for the implementation of treatment systems or alternative use of vinasse. To ensure adherence, regional environmental institutions took responsibility for monitoring the disposal of vinasse and its concentration in the local soil.

With the increase in ethanol production, it became necessary to find an acceptable way to dispose of the vinasse; scientific research was driven to find a solution. University and private sector research institutes worked together in partnership to discover possible uses of vinasse. One of the first solutions was to construct impermeable pools to receive the waste, but these pools were very expensive. The researchers realised that vinasse is rich in potassium and organic matter, containing a large amount of nutrients and could be used to fertilise and irrigate sugarcane, thus a more economical and effective way to eliminate this effluent was born. Putting the vinasse to productive use as a fertiliser and irrigator - fertigator - on sugarcane plantations proved to have the co-benefit of reducing the cost of soil restoration, while positively contributing to the reduction of water consumption and soil and groundwater contamination.

There are two main means of transporting the vinasse fertigator to the plantations. For plantations that sit on the brow of sloped land, the vinasse is transported via small channels, trickling downhill with the force of gravity. However, the majority of plantations are flat, meaning it must be transported by trucks, significantly increasing the cost. Transporting the vinasse further than 20km from the point of production makes use uneconomical. Thus, on average, producers choose to fertigate approximately 30% of the plantation area. They cannot over-fertilise this area with vinasse because high concentrations pollute the soil and groundwater.

Today, researchers are focusing on reducing the volume of this waste. A collaborative effort between companies including Fermentec and Dedini, the Chemistry Department of the University of São Paulo, the Federal University of Santa Catarina, São Paulo Research Company (*Fundação de Amparo à Pesquisa do Estado de São Paulo* - FAPESP) and various others, has enabled the development of a new technology to reduce vinasse production by more than 50%, without affecting ethanol volume, effectively reducing the volume of vinasse produced per litre of ethanol from 13 litres to only 5.

This constant low-temperature vinasse technology enables a much higher alcohol percentage to be obtained during the fermentation stage; with this technology 16% is achieved, as opposed to current industry standards of 8-10%. With a higher percentage of sugarcane being transformed into alcohol, and subsequently ethanol, quantities of vinasse are significantly diminished. An additional benefit of this new technology is that steam consumption is also decreased in the distillation phase because of the higher percentage of ethanol in the liquid, which boils at 78°C. [6]

Socio-environmental Certification

For the Brazilian national market, socio-environmental certification is voluntary, and as such its prominence differs from region to region. In 1997, a voluntary document entitled 'Standards for the Assessment, Monitoring and Socio-environmental Certification of Sugarcane' was developed by a multi-stakeholder working group, composed of environmental NGOs, researchers, entrepreneurs, and environmental licensing and certification technicians in São Paulo. It is based on the idea that certification must be voluntary, be conducted by a third party, have transparent procedures, be based on consistent standards and be renewed periodically.

Certification is used as a market tool to promote sustainable production in different segments of agribusiness. It became an especially important tool for ethanol producers given the negative image associated with Brazilian ethanol production in terms of working conditions and environmental impacts. Certification is a sign of commitment, giving credibility and showing transparency to stakeholders, thus strengthening the industry brand. As certification is not mandatory, ethanol producers that aim to supply the national market tend to perceive certification as an avoidable cost.

Brazilian ethanol exporters have found it increasingly necessary to adopt the socio-environmental certification requirements of their international customers in order to trade. The certification standards adopted are generally dictated by individual customers, and thus vary considerably between producers. The European Union and the United States now have laws which set certain requirements for ethanol imports. The Renewable Energy Directive (RED) states that all biofuels utilised in the European Union must be certified

[6] For more information, see: Berndes, G., 2002. Bioenergy and Water. The Implications of Large Scale Bioenergy Production for Water Use and Supply. *Global Environmental Change* 12(4) 253-271.; Donzelli, L. 2005. The Use of Fertilizers in Brazil's Sugar Cane Production. In: Macedo, I. (eds). *Sugar Cane's Energy: Twelve Studies on Brazilian Sugar Cane Agribusiness and Its Sustainability*. UNICA, São Paulo.

as sustainable. The Renewable Fuel Standard (RFS2) states that all biofuel producers that supply the United States must be registered with the Environmental Protection Agency (EPA).

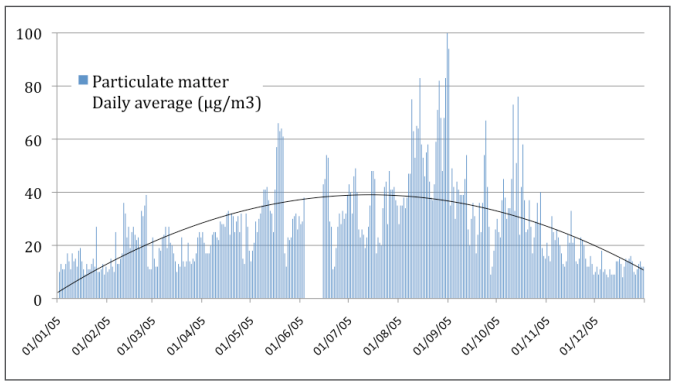
Although the specifics differ, certification for Brazil, the US and Europe generally converges on the main environmental issues: protection of forests and sensitive areas and a reduction of greenhouse gas emissions (GHGs).[7] Players both in Brazil, such as the Sugarcane Industry Association (UNICA), and abroad are working to define a global voluntary standard. Bonsucro, formerly known as the Better Sugarcane Initiative (BSI), a multi-stakeholder international group of producers, traders, retailers, NGOs and investors, has been working on the development of a voluntary international standard. Bonsucro Certification has been applied in many Brazilian production plants. Another well-known certification is the Rainforest Alliance for which several ethanol outfits in Brazil have already been certified.[8]

Reduction of Pre-Harvest Crop Burning

The burning of sugarcane barbojo - leaves, tops and straw - to increase crop productivity, is one of the most criticised and controversial issues in the sugarcane production system. This practice is described in more detail in the ELLA Brief: From Manual to Mechanical Harvesting: Reducing Environmental Impacts and Increasing Cogeneration Potential, though here we highlight the negative environmental impacts.

The intense air pollution from the burning is one of the main environmental problems, generating high levels of particulate matter, carbon monoxide, nitrogen oxides, sulphur oxides and methane that can cause serious health problems to employees and local inhabitants. Figure 2, below, shows the concentration of particulate matter (PM) in the city of Ribeirão Preto, where a large amount of sugarcane is grown. It is not possible to prove the origin of the PM emissions, but from the graph we can see that concentrations are higher when sugarcane is being harvested; harvesting season runs from April until the end of October, with the bulk of the crop being harvested between May and August. It is important to note that PM concentration observed in each period is a consequence of previous emissions, of approximately one month.[9]

Figure 2: Daily Concentration of Particulate Matter (PM) in the City of Ribeirao Preto in 2005, Expressed in Micrograms per Cubic Metre (mg/m^3)



Source: Companhia de Tecnologia de Saneamento Ambiental (CETESB), 2006. *Avaliação da Qualidade do Ar no Estado de São Paulo* (*Assessment of Air Quality in the State of São Paulo*). CETESB, São Paulo.

Agro-Ecological Zoning

Agro-Ecological Zoning (AEZ), which is described in more detail in the ELLA Brief: Sugarcane Agro-ecological Zoning: Greening the Expansion of Ethanol, is a recent Brazilian public policy that seems to be having positive impacts. Implemented by the Ministry of Agriculture, Livestock and Supply (*Ministério da Agricultura, Pecuária e Abastecimento* – MAPA), it was enacted to provide technical support for public policies aimed at curtailing unsustainable expansion of sugarcane. For example, AEZ has contributed to preventing the construction of new ethanol distilleries in water basins located in the Pantanal and Amazon Forests.[10]

The Brazilian Development Bank (*Banco Nacional de Desenvolvimento Econômico e Social* - BNDES) only provides loans to producers who respect area delimitation as set out under AEZ. This has acted as an additional impetus to prevent sugarcane production in areas that may jeopardise the conservation of biodiversity and water resources, and has encouraged production in more suitable areas.[11]

[7] Padula, A . et al. 2011. *Sustainability, Certification and Internationalization of Brazilian Ethanol*. Paper presented at International Food and Agribusiness Management Association (IFAMA) 2011 Annual World Symposium, 20-21 June 2011, Frankfurt.
[8] For more information, see Brazilian Sugarcane Industry Association. UNICA Sees "Green Certificate" for Sugarcane Mills as Major Step Forward. 30 September 2010, online publication. See also the website of the Rainforest Alliance, an institution that works to conserve biodiversity and ensure sustainable livelihoods by transforming land use practices, business practices and consumer behavior. Through the certification, the Rainforest Alliance encourages farmers to grow crops and manage ranchlands sustainably.
[9] For more information about sugarcane burning, see: Arbex, M. 2007. Air Pollution From Biomass Burning and Asthma Hospital Admissions in a Sugar Cane Plantation Area in Brazil. *Journal of Epidemiol Community Health* 61 395-400.
[10] Ministry of Agriculture, Livestock and Supply. 2009. Sugarcane Agro-Ecological Zoning - To Expand Production, Preserve Life, and Ensure a Future. Ministry of Agriculture, Livestock and Supply, Brasília.
[11] For more information, see: Giulio, V. 2010. Biofuels in Brazil and Land Use Change. *Journal of Biobased Materials and Bioenergy* 4 (3) 211-220.; Strapasson, A. 2012. Agro-ecological Zoning and Biofuels: the Brazilian Experience and the Potential Application in Africa. Routledge, Oxon.

CONTEXTUAL FACTORS

ENABLING BRAZIL'S SUCCESSFUL POLICY RESPONSE

Policies to mitigate ethanol's environmental impacts were adopted as a result of the strengthening of environmental institutions. These institutions gained more clout as public environmental awareness increased in Brazil along with the global trend, in response to issues like ozone layer degradation, climate change and Amazon deforestation. The end of Brazil's dictatorship and the new 1988 Constitution were also important, re-establishing democracy and giving power and voice not only to environmental institutions, but to all institutional systems in Brazil. Finally, international experience in environmental management contributed to the design and shape of the Brazilian system.

In response to national and international criticism from environmental movements, the Federal Government imposed mandatory environmental assessments and reports as requirements for the licensing process. A Federal Law was passed that mandated these assessments and reports in order to reduce the throughput[12] in the ethanol life cycle. These enabled great gains to be made in reducing environmental impacts where voluntary requirements may have failed. Mandatory requirements were fundamental for the development of a new administrative culture with practices based on environmental management, which otherwise may not have been adopted voluntarily by the private sector.

The government designated financial resources to cover the costs of implementing initiatives to improve efficiency and productivity, such as special loans with favourable interest rates for acquiring harvesters to eliminate burning and high pressure boilers to increase the amount of energy cogenerated. Besides efficiency and productivity gains, which improved competitiveness, both actions were seen as imperative to enhancing ethanol's image, signalling a new, modern profile.

Public-private partnerships have successfully helped the adoption of environmentally friendly practices. International non-tariff barriers led to the creation of some partnerships, but largely the main driver was public pressure. The media, academia, the middle classes, NGOs and Environmental Secretariats from more developed states pressured for more sustainable development, encouraging producers to improve their reputation in terms of environmental awareness and impact. Pressured from all sides, governments and businesses resolved to commit to reducing negative environmental impacts of ethanol production.

[12] The flow of raw materials and energy from the global ecosystem's sources of low entropy (mines, wells, fisheries, croplands) through the economy, and back to the global ecosystem's sinks for high entropy wastes (atmosphere, oceans, dumps).

LESSONS LEARNED

1. The development of a system of public environmental management to supervise the ethanol sector and establish policies to mitigate negative environmental impacts of production has been fundamental. Public and civil society environmental institutions have played an important role in scientific and statistical research, in addition to controlling, monitoring and fining producers for non-compliance.
2. Imposing Environmental Impact Assessments and Reports as a legal requirement for licensing ethanol projects has ensured that the production respects environmental standards.
3. The Brazilian example shows that increasing environmental awareness and public pressure can push governments to develop policies to mitigate negative environmental impacts of ethanol production.
4. Many measures to reduce the negative environmental impacts of ethanol production have the co-benefit of reducing costs and increasing productivity. This is true for eliminating burning, employing mechanised harvesting techniques, saving water and reusing waste.

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