Implications of biofuel sustainability standards for Brazil

Case Study #2
Winrock International aims to support the efficient development of sustainable biofuels standards by assisting in providing access to relevant data on the technical, social, economic and environmental characteristics of biofuels.

Winrock International will develop three technical White Papers on GHG emissions, the role of water and building capacity to monitor standards. Three country impact evaluations of applying standards in national settings will be undertaken for the US, Brazil and Indonesia.

This country impact evaluation focuses on the implications of applying biofuel sustainability standards in Brazil.

For questions or comments contact: Jessica Chalmers or, David Walden
Winrock International
2121 Crystal Drive, Suite 500
Arlington, VA 22202

+44 (0) 7985 499 061
Email: jchalmers@winrock.org

+1 (703) 302 6557
Email: dwalden@winrock.org

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1.0 EXECUTIVE SUMMARY

With the recent rising concerns regarding energy security and the environment, interest in biofuels has grown substantially. Consideration of biofuels has been due to their potential beneficial impact on energy security, mitigation of Greenhouse Gases (GHGs) in the transport sector and rural economic development. Growing concern surrounding the sustainability of biofuels has led to numerous initiatives that attempt to define sustainability in the context of biofuels. Their aim is that, if adopted, these standards will deliver a sustainable outcome.

The majority of standards for biofuels and biofuel feedstocks are without a national context (with the exception of the Roundtable on Sustainable Palm Oil - RSPO and forthcoming national interpretations in the Roundtable on Responsible Soy - RTRS). This paper addresses the concept of biofuel sustainability in Brazil. The aim is to support the effective development of sustainability standards by gathering the available information and interpreting impacts and outcomes in a specific national context. The report assesses the status of key issues for and potential implications of applying sustainability standards in Brazil, in terms of market relevance, potential production areas and volumes and the capacity to implement and monitor standards.

The term biofuels can be used to cover solid biomass and liquid and gaseous fuels derived from biomass. This report is focused primarily on liquid biofuels. While there are many feedstocks for liquid biofuels, the scope of this paper is limited primarily to soybean for biodiesel and sugarcane for bioethanol.

Biofuel in Brazil

The biofuel industry in Brazil is well established for ethanol. Large-scale ethanol use began in 1975 and is second only to the USA in terms of production volume of ethanol. Centers of supply and demand for bioethanol are well matched at present (Center-South dominated). Such concentration has enabled economies of scale to be realized and ethanol is competitive with gasoline both in Brazil and globally (despite international tariffs applied to Brazilian imports e.g. in the US and Europe). Despite around 85% of domestic production being consumed in Brazil it is currently and is forecast to continue to be the world’s largest exporter of bioethanol. Feedstock costs represent up to 80% of the cost of production of bioethanol and improving yield is a key driver for further cost reductions. Substantial R&D capacity exists and is applied in Brazil, which has led to such economic improvements over time and continues to focus on further improvements through a recently established center. Ensuring economic sustainability from increased production requires an infrastructure that can cope with increased volumes. Investments are planned for pipelines in the Center-South to connect the producing regions with ports.

Brazilian biodiesel production is substantially lower and the National Biodiesel Program (PNPB) is focused on delivering socio-economic goals. Soybeans are however exported or crushed and exported and the soy oil is a biodiesel feedstock used for international production, notably in Europe where mandates have steadily increased and the transport fleet is diesel-dominated.
The report considers the following implications of applying sustainability standards in Brazil:

- Market relevance of sustainability standards
- Implications for production potential and plans
- Capacity building implications

**Market relevance of sustainability standards**

In January 2008, the European Parliament mandated that biofuels must represent 10% by energy of Member States transport fuel sales and that the biofuels must meet several criteria in order to count towards these targets. These criteria are that biofuel feedstock must not come from areas of high carbon stocks and must conserve biodiversity and that the resulting biofuels must reduce GHG emissions by at least 35%. Other voluntary schemes such as the Roundtable on Sustainable Biofuels (RSB), Roundtable on Sustainable Soy (RTRS) and Better Sugarcane Initiative (BSI) are intended to be developed and applied as a certification scheme at the site scale. Most schemes have developed evaluation criteria, but not necessarily the detailed indicators that would be used to determine whether there is compliance.

Some biofuel sustainability schemes have largely arisen in response to the mandates for biofuel consumption enacted in the US and EU (though many commodity feedstock standards such as the RSPO were initiated by the food industry) and are based on market demand. The relevance of these standards for Brazil varies; they will impact the exported ethanol and soybeans used for biodiesel. By 2017, one forecast (OECD-FAO, 2008) suggests that 85% of international trade in bioethanol (8.5 billion liters) will originate from Brazil, but it should be recognized that the majority of its production (around 85%) is used for domestic consumption. Recently proposed legislation on protecting specific land types will influence the location of domestic sugarcane production. Soybean production is an area of interest for sustainability standards owing to its use (soy oil) as a biodiesel feedstock internationally. Brazil is the world’s largest soybean exporter, exporting 24.5MT (US$ 10,952 million) of soybean in 2008 and 2.31MT (US$ 2,671 million) of soy oil in the same year. Volumes of soy oil specifically for biofuel use are not yet quantified and therefore the impact on Brazil’s soy exports is unknown. Soy oil is a by-product of the main product, soy meal, and therefore the driver and implications of sustainability standards for only part of crop is also uncertain.

Domestically, Brazil’s objective for biodiesel production is socio-economic development. Relevant socio-economic goals have not been fully realized, but biodiesel is still in the early stages of development. The current national production capacity of biodiesel crops (castor been, peanut etc) is far below what is needed to meet the demand that would be created by the biodiesel mandate. The main problems are that crop yields are low and infrastructure is poor in the North and Northeast regions. The relative economic attractiveness of soy has led to its dominant use for biodiesel; the North and Northeast regions produce only 2.2% and 8.7% of biodiesel compared to 42% in the

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1 Indirect land use change (iLUC) is not addressed in the current criteria but the European Commission are required to explore options to address iLUC.
Center-West. Crop research programs, technical assistance and infrastructure development are among the actions required to deliver socio-economic development goals of this program. International standards based on trade and market-demand for certification in this case are not relevant, and only domestic programs will be effective.

**Implications of standards for production potential**

Given the relatively substantial impact of sustainability standards on sugarcane ethanol for export and soybeans as a biodiesel feedstock, a GIS analysis was conducted at a national scale that combines spatially explicit data to obtain the geophysical suitability of land for soybean and sugarcane and excludes land that represent key risk criteria in biofuel sustainability standards. The results excluded the following types of lands:

- Forested areas
- Peatlands
- Protected areas
- Land at risk of erosion

Annex 1 details the datasets and methodology. Landcover data are for 2004.

The land that is geophysically satisfactory for crop growth and is not one of those identified above as excluded is categorized as ‘geophysical plus’. The results indicate that the implication of applying high level sustainability criteria with an emphasis on avoiding high carbon stocks and protecting sensitive areas does not necessarily inhibit Brazil’s ability to meet domestic and international demand for biofuels. Further expansion of cane is more likely in the Center-South and high level analysis indicates that there is substantial land available in the region (and elsewhere) that meets selected environmental sustainability criteria. Based on GIS techniques used for this study, approximately 790Mha were defined to be suitable for growing sugarcane based on geophysical criteria only (soil type, rainfall and slope). This area decreases to approximately 100Mha when forest, peat land, protected areas and land with high soil and water erosion, and flood risk are excluded but could still produce 683,000 million liters of bioethanol (assuming 6794 liters ethanol per ha) which is 27 times national gasoline demand. The magnitude of availability of suitable land is substantiated by detailed regional studies where approximately 64Mha has been identified as ‘sustainable’ through a more detailed national agro-ecological zoning approach.

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2 Note: Protected areas are used as a proxy for areas of high biodiversity. In many cases, a High Conservation Value (HCV) approach is advocated to establish environmental and social conservation areas, but this was beyond the scale and scope of this study. Information is available from www.hcvnetwork.org

3 Excluding production on forests, peatlands and wetlands, protected areas, riparian zones and areas at risk of soil and water erosion.
The State of Sao Paulo originally already developed an agro-ecological zoning approach for expansion of sugarcane (Figure B) and a larger survey, the National Agro-Ecological Zoning for Sugarcane (ZAE Cana) study, which defined lands suitable for sugarcane production based on environmental, economic and social criteria has led to the Government proposing new legislation (in September 2009) that will restrict the lands permissible for sugarcane farming and processing in any area of native vegetation, or in the Amazon, Pantanal or Upper Paraguay River Basin regions. This results in approximately 64Mha available for sugarcane compared to the approximate 8.9Mha already cultivated.⁴

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In addition, the land use dynamics in Brazil illustrate that expanding sugarcane does not necessarily lead to indirect land use change. IGBE statistics as well as recent studies (Nassar et al., 2008) demonstrate a national trend of increasing livestock density from 0.4 head of cattle per hectare in 1920 to 1.0 head per hectare in 2006. This will vary regionally, but gives an indication of the general trend towards intensification. Expanding sugarcane onto pastureland in the Center-South region is now well accepted as a land use dynamic. These changes are regarded broadly to be ‘positive’, from a land use change perspective. However, the condition of the pasture is important in the calculation of carbon emissions. Carbon stocks are higher in improved pastures and lower in unmanaged pastures. Substituting unmanaged pastures with sugarcane probably results in a carbon uptake, but some Brazilian scientists believe this is not the case for managed pastures. Consensus does not yet exist on carbon stocks and implications of converting pastureland to land for growing sugarcane. One of the limitations of monitoring compliance with such standards is the lack of application for determining different types of pastureland through remote sensing.

Soy

Many expansion plans for soybean production appear not to have been undertaken with sustainability standards for biodiesel in mind. Substantial areas of the Center-West, where soybean expansion is expected owing to favorable economics, do not appear to meet the selected sustainability criteria (see Figure C).\footnote{Note that the analysis has been conducted on a national basis and a regional approach with more detailed data may alter these results.}
Based on this high-level analysis estimated geophysical potential for soybeans of 80Mha is reduced to around 26Mha when sustainability criteria representative of EU requirements are applied. Assuming an average yield of 2.77t/ha this could represent around 13,000 million liters of biodiesel which represents around 36% of national diesel requirements for transport based on 2008 data.\(^6\) Production of soy could be undertaken on low carbon stock cerrado or grassland with accompanying cattle intensification to avoid indirect land use change. There are estimated to be 60Mha of planted pastures in the cerrado region, 70-80% of which are degraded (Sano et al. 1999; Macedo 1995; Vilela 2004). In total, the analysis indicates potential for soybeans on cerrado is around 20Mha and 1.1Mha on ‘grassland’. Discounting 35% of the area for legal reserves this area could produce around 7,200 million liters of biodiesel which represents around 20% of national transport diesel requirements in 2008. In reality only a proportion of this area would be available for production, owing to use as pasture, so the resulting production volume would be lower. Use of only 25% of this area would produce around 1,800 million liters. This represents approximately 5% of national diesel requirements for transport; the required B5 blend by 2013). However, the same limitation exists as for sugarcane; the ability to distinguish managed and degraded pastureland would substantially improve sustainability assessments. Carbon stocks on these land types differ substantially and GHG implications are too variable to make broad conclusions.

**Figure C:** A comparison of areas that are both geophysically suitable for growing soybean and that meet selected sustainability criteria, and the main soybean producing states

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\(^6\) This assumes a diesel requirement of 44,764 million liters (ANP statistics) of which 80% is transport-related.
Potential socio-economic impacts
There are an estimated 4.1 million people dependent on the sugarcane industry, with the majority of these jobs being low-income positions associated with manual harvesting. The Northeastern sugarcane workers that migrate to the Center-South will be significantly impacted by the move towards mechanization both in the voluntary Sao Paulo State Protocol and proposed national legislation. Increasing sugarcane production in the Northeast may address employment issues but could the benefits could come at the expense of environmental criteria such as water availability and deforestation.

Other impacts also vary regionally, for example expansion of sugarcane has different impacts depending on the location. Municipalities in the Center-South with significant sugarcane expansion have experienced higher GDP growth related to the expansion compared with other areas of Brazil. In addition, expansion in the Center-South has not appeared to be at the expense of other cropland (e.g. for food crops), but there has been some potential displacement elsewhere. More than just considering these sustainability impacts on a project-by-project basis, sustainability monitoring will be required on a regionally appropriate basis in order to capture the effects that are broader than the site scale.

Socio-economic development is the main goal of the national biodiesel program. However, soybean has grown in its dominance as a biodiesel feedstock and moved from centers of production in the Center-West rather than the North and Northeast regions that have higher incidence of poverty. Growing soybeans for has often proved to be unsuccessful for small farmers. The opportunity costs for pursuing alternative feedstocks to soy are high. While soybeans require higher investment costs, they could produce higher returns per hectare (R$0-525/ha), compared to alternatives promoted through the national biodiesel program such as castor (R$155–540/ha), cotton (R$840/ha) and sunflower (R$150/ha). Farmers that have fully embraced the agri-business model based on soy, usually receive the bulk of their income during one or two periods per year, when their products are sold to processing and refining plants. Family farmers though, need a more stable monthly income to plan local expenditures and investment.

Table A indicates the minimum quantities of feedstock that biodiesel producers should purchase to receive the Social Fuel Certification. Government studies forecast that replacing just 1% of fossil diesel with biodiesel from family farms would directly help create 45,000 jobs at an average cost just over R$4,900 per job (family agriculture employs one worker per 10 hectares, whereas commercial agriculture employs one worker per 100 hectares). Furthermore, every R$1 invested in family agriculture adds R$2.13 to the family's annual gross income.
Table A: Minimum quantities of feedstock that biodiesel producers need to buy from small/family farmers to receive the “Social Fuel Certification”

<table>
<thead>
<tr>
<th>Geographical region</th>
<th>Participation of family agriculture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>10%</td>
</tr>
<tr>
<td>Northeast and semi-arid</td>
<td>30% (originally 50%)</td>
</tr>
<tr>
<td>Center-west</td>
<td>10%</td>
</tr>
<tr>
<td>Southeast</td>
<td>30%</td>
</tr>
<tr>
<td>South</td>
<td>30%</td>
</tr>
</tbody>
</table>

Source: PNPB (www.biodiesel.gov.br)

Biodiesel is still playing a minor role in the biofuel industry in Brazil, especially when compared to ethanol. The implementation of the PNPB is presenting several challenges e.g. selection of the most appropriate feedstock, feedstock supply, farmers’ engagement, creation of the right incentives to biodiesel producers and logistics. The PNPB is still under development and it is therefore too early to draw final conclusions. However, biodiesel currently appears to present limited social benefit for the poorest regions and for the smallest farmers, as evidenced by the following points:

(i) The share of oilseed to be used by small farmers has been lowered from 50% to 30% in the Northeast region;

(ii) Today, about 90% of biodiesel in Brazil is produced in the richest areas (South, Southeast and Center-West);

(iii) Nearly all of Brazil’s biodiesel is produced with soy oil, which is produced mostly on large monocultures and only marginally by small farmers

Capacity for compliance with standards

Brazil has a number of national initiatives in addition to legislation that address sustainability issues and are directly relevant for biofuels e.g. the voluntary code for sugarcane in Sao Paulo state and proposed new legislation based on agro-ecological zoning. These codes and programs have not yet been benchmarked against other sustainability requirements to assess the extent to which they already meet criteria laid down. Geospatial data is critical for proving compliance and monitoring sustainability standards. INPE is a leading institution in remote sensing data and Embrapa Satellite Monitoring and Embrapa Agricultural IT, both located in Campinas, are also working with remote sensing, geo-processing and computing for agriculture (BNDES & CGEE, 2008). Substantial technical capacity exists within Brazil to undertake compliance monitoring and resources focused on improving the scope of data collection (e.g. land use monitoring outside the Center-South) and quality of some data (e.g. differing pasture types) would improve conclusions for biofuel sustainability.

Confidence in enforcement will be key. Enforcement capacity differs between states and results in varying levels of confidence; in Sao Paulo state for example, there is a greater capacity and
confidence in enforcement within this state than elsewhere. Additionally, capacity to prove and monitor compliance exists in the Center-South as a whole through the sugarcane remote sensing project run through INPE (CANASAT). The CANASAT project’s potential, both as a monitoring mechanism in the Center-South and as a model for expanding to other regions and crops, has been proven through its application to sugarcane.

Poor labor conditions and forced labor still exist within Brazil. The Government’s Mobile Verification TaskForce has had some successes in protecting workers. However, effective enforcement among different federal states and municipal authorities is challenging for effective monitoring of compliance with labor standards.

Water footprints for biofuels are a feature of some standards, but in countries such as Brazil, with a majority of rainfed agriculture, this is not necessarily the best indication of sustainability. Of greater importance is the need for regional (watershed) assessments and management and monitoring of water to ensure net carrying capacities of watersheds are not exceeded with respect to water availability as well as water quality. Converting sugarcane to pastureland for example, would have hydrological implications that could be assessed within a set of sustainability standards. Assessments of water resources in the State of Sao Paulo are advanced and could be further expanded in relevant feedstock and biofuel production watersheds. Capacity is currently being established within Brazil to effectively manage watersheds through Basin Committees, and statistical data is collected by the National Water Agency (ANA).

Most studies on GHG emissions from sugarcane ethanol originate from Brazil where data gathering and academic rigor are standard. There are areas in the GHG calculations that are still uncertain, including \( N_2O \) emissions: specific data, rather than IPCC defaults, would provide more robust calculations. Research institutes in Brazil do not yet have this data, but they are capable of developing it. The availability of statistical data that serves to assist implementation and monitoring of standards is also substantial in Brazil. Organizations such as Instituto Brasileiro de Geografia e Estatistica (IBGE - the Government Agency responsible for national census surveys), CEPEA, CONAB, ANFAVEA, and CENBIO, and Universities such as University of Sao Paulo\(^7\) are important resources for obtaining detailed information relevant for biofuels.

There have been innumerable studies on the sustainability of Brazilian biofuels, largely focused on bioethanol. Therefore, there is much that is understood about the impacts of biofuels and about what further research is required. However, one limitation is that work published in Portuguese, is not accessible to the wider international community studying biofuels.

Table B summarizes the levels of impacts of implications for applying biofuel sustainability standards in Brazil that this analysis has indicated, and where relevant, how they differ between cane and soy.

\(^7\) Decree 52284 in 2007 established the Database on Bioenergy at the Agricultural Economics Institute in Brazil (IEA)  http://www.iea.sp.gov.br/out/banco/menu.php
Table B: Summary of the implications of applying biofuel sustainability standards in Brazil (high impact to low impact)

<table>
<thead>
<tr>
<th>Relevance</th>
<th>Status</th>
<th>Potential</th>
<th>Capacity for compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance of international market-based sustainability standards</td>
<td>Existing application of sustainability criteria for biofuels (and feedstock)</td>
<td>Potential area of production that meet high level environmental sustainability criteria</td>
<td>Technical strength to undertake planning &amp; monitoring including using GIS applications</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X (exported feedstock/fuel)</td>
<td>X (cane)</td>
<td>X</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X (cane)</td>
<td>X (soy)</td>
<td></td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X (domestic biofuel)</td>
<td>X (soy)</td>
<td></td>
</tr>
</tbody>
</table>
2.0 INTRODUCTION

Over recent years, as energy security and environmental concerns have risen within various political agendas, there has been a substantial interest in biofuels and their potential contribution to energy security, mitigation of GHGs in the transport sector and also in delivering rural economic development benefits. However, the benefits of promoting biofuels have been challenged in recent years by some non-governmental organizations and scientists. This is due to the fact that in some cases the intended benefits of biofuels have not been delivered, and instead negative consequences, such as increased GHG emissions through land use changes (direct and indirect), have been reported.

In recognition of the desire to ensure intended benefits are delivered, there are numerous organizations, alliances and policy-makers involved in developing standards for liquid biofuels and biofuel feedstock production. Some of these standards serve as tools for guiding public policy decisions at the national level (such as those established by taskforces under the Global Bioenergy Partnership), while others are intended for application at the field or project level (i.e. voluntary standards such as the Roundtable on Responsible Soy – RTRS or mandatory criteria in the EU Renewable Energy Sources Directive). These standards are at different stages of development; some standards are already being implemented and others are in the initial criteria development process.

The biofuel industry in Brazil is well established for ethanol. Large-scale ethanol use began in 1975 with the establishment of the Prolcool Program that set a goal of 20% ethanol in gasoline. This goal was met only in 1983 (Goldemberg, Nigro, & Coelho, 2008). The oil crisis of the 1970s, interest in expansion of agriculture, and diversification of the sugar industry are considered critical factors in the establishment of the program. The initial strategy led to 85% of vehicles running on hydrous ethanol which, when oil and sugar prices recovered, became a more expensive option than traditional fuels. In the 1990s, the Prolcool stalled, but in 2003 the ethanol market gained momentum again with the introduction of Flex-Fuel vehicles (Goldemberg, Nigro, & Coelho, 2008).

Total ethanol production for 2009/10 is projected to be approximately 28.55 billion liters (8.5 billion liters of anhydrous ethanol and 20 billion liters of hydrated ethanol). Such a large value is attributable to the Prolcool Program. Domestic demand for ethanol is expected to increase to 24.5 billion liters in this same year, due to sales of flex vehicle cars and attractive ethanol prices compared to gasoline (Barros, 2009). **Domestic consumption, rather than export, is the main end-use for Brazilian ethanol.**

Experience with biodiesel in Brazil is relatively new compared to ethanol, but is receiving similar Government support through policies such as the National Biodiesel Program (PNPB). Soybeans from Brazil are a readily available feedstock for biodiesel production in other countries and regions.

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8 In Brazil flex-fuel means the vehicle can run on a 20-25% anhydrous blend with ethanol or can run on hydrous ethanol or any blend of the fuels. The engine is equipped with sensors that recognize the mixture and adapt the combustion to such mixture. The combustion efficiency of FFVs is lower than that of pure or gasoline ethanol cars (Goldemberg, Nigro, & Coelho, 2008).
(such as the EU). Brazil, the US and Argentina are the dominant suppliers of soy to the world market; the three countries accounted for almost 90% of supply in 2003. Brazil took the lead over the USA as the world’s biggest soy exporter in 2003 (Dros, 2004). Deforestation in the center-west and northern regions of Brazil to meet increasing soy demand has been a key criticism of the use of soy for biodiesel production purposes.

3.0 BACKGROUND

Growing concern surrounding the sustainability of biofuels has led to numerous initiatives that attempt to define sustainability in the context of biofuels. Their aim is that, if adopted, these standards will deliver a sustainable outcome for biofuel use.

In January 2008, the European Parliament agreed that biofuels must represent 10% by energy of Member States’ transport fuel sales and that the biofuels must meet several criteria in order to count towards these targets. These criteria are that biofuels:

- Must represent at least 35% GHG emission reduction compared to fossil fuel (50% by 2017)
- Conserve carbon stocks. Include no raw material from:
  - Wetlands, that are covered with or saturated by water permanently or for a significant part of the year; or
  - “continuously forested area”, defined as >1 hectare with trees higher than 5 metres and a canopy cover of more than 30%, or trees able to reach these thresholds in situ; or >1 hectare with trees higher than 5 metres and a canopy cover of between 10% and 30%.
- Conserve biodiversity. Include no raw material from:
  - forest undisturbed by significant human activity;
  - highly biodiverse grassland; or
  - nature protection areas.

Biofuels can additionally receive a GHG credit of 29gCO2eq/MJ under the EU approach if they are produced on “degraded land”, which is intended as a way to avoid indirect land use change. The credit is earned if there is evidence that the land was not in use for agriculture or any other activity in January 2008 and if it falls into one of the following categories: (i) severely degraded land, including such land that was formerly in agricultural use; (ii) heavily contaminated land.

Some of the terms used in the EU Renewable Energy Directive such as ‘highly biodiverse’ or ‘significant’ have not yet been sufficiently defined in order to enable practical application. Work is currently underway to develop guidelines and identify data sources to assist in compliance.
There are voluntary standards in addition to those developed as mandatory by the EU. For example, the Roundtable on Sustainable Biofuels (RSB) has developed Version Zero principles and criteria for sustainable biofuels that are intended to be further developed into a certification scheme. The RSB will benchmark other standards (such as the Roundtable on Responsible Soy) against its own to determine whether they meet RSB’s requirements. RSB does not intend to replace other standards, but rather to enable identification of their ‘missing criteria’ relevant for biofuels, such as those related to GHG emissions.

Mandatory sustainability criteria in the EU, and a growing move towards establishing criteria within project financing institutions, will affect the development of projects in Brazil. Initial impacts will be on export markets for soybeans and sugarcane ethanol, but there may also be impacts for domestic projects that require international financing as well. There are two main objectives for these standards: to mitigate negative impacts of biofuel expansion and to promote ‘better’ management practices.

Table 1: Summary of sustainability principles relevant for biofuels and/or feedstocks (This list is not exhaustive and is for indicative purposes only as details within criteria differ)

<table>
<thead>
<tr>
<th></th>
<th>European Directive (REsD)</th>
<th>UK Sustainable Biofuels</th>
<th>Better Sugarcane Initiative</th>
<th>Roundtable on Sustainable Palm Oil</th>
<th>Roundtable on Responsible Soy</th>
<th>Sustainable Biodiesel Alliance</th>
<th>Sustainable Agriculture Network (biofuels addendum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory (M) / Voluntary (V)</td>
<td>M</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>Draft (D) / Agreed (A)</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td><strong>Legality</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow all applicable laws of the</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>country</td>
<td></td>
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<td>**Consultation, planning &amp;</td>
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<td>Design &amp; operated projects under</td>
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<td>appropriate, comprehensive,</td>
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<tr>
<td>transparent, consultative, and</td>
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<td>participatory processes that involve</td>
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<td>all relevant stakeholders</td>
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<td><strong>Land rights</strong></td>
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<td></td>
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</tr>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Free Prior and Informed Consent</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>**Climate change / Conservation of</td>
<td></td>
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<td>Reduce GHG emissions as compared</td>
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<td>✓</td>
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<td>✓</td>
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<tr>
<td>to fossil fuels</td>
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</tr>
<tr>
<td>Conserve above and below ground</td>
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<td>✓</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td></td>
</tr>
<tr>
<td><strong>Human &amp; labor rights</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>European Directive (REsD)</td>
<td>UK Sustainable Biofuels</td>
<td>Better Sugarcane Initiative</td>
<td>Roundtable on Sustainable Palm Oil</td>
<td>Roundtable on Responsible Soy</td>
<td>Sustainable Biodiesel Alliance</td>
<td>Sustainable Agriculture Network (biofuels addendum)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>No violation of human rights or labor rights, ensure decent work and &amp; well-being of workers</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Rural &amp; social development</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Contribute to the social and economic development of local, rural and indigenous peoples and communities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
<tr>
<td>Food security</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Biofuel shall not impair food security</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Conservation &amp; biodiversity</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Avoid negative impacts on biodiversity &amp; ecosystems</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Soil</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Promote practices that seek to improve soil health and minimize degradation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Water</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Optimize surface and groundwater use, Minimizing contamination or depletion No violation of existing formal and customary water rights</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Air</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Air pollution from shall be minimized</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Economics</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Note: Some criteria noted with a dash in this table are addressed within standards but have not stated a performance indication e.g. minimize.

### 4.0 Scope and Aim of the Report

The majority of standards for biofuels or feedstock noted in Table 1 have been developed without a national context, although national interpretations for the RSPO and RTRS (forthcoming) are notable exception. This paper addresses the concept of biofuel sustainability in Brazil and is specifically focused towards assisting organizations that are developing sustainability standards for biofuels. The aim of the report is to support the development of effective sustainability standards by presenting relevant information and interpreting impacts and outcomes in a specific national context.
The report assesses the relevance of standards to Brazilian biofuels and/or feedstock, the status of key issues and the potential implications of applying sustainability standards in Brazil, both in terms of potential production volumes and locations as well as its capacity to implement and monitor standards.

The term biofuels can be used to cover solid biomass and liquid and gaseous fuels derived from biomass. This report is focused primarily on liquid biofuels. While there are many feedstocks for liquid biofuels, the scope of this paper is primarily focuses on soy for biodiesel and sugarcane for bioethanol, but it also considers additional crops such as castor bean oil for biodiesel.

**Approach**

To assess potential implications of applying sustainability standards, a qualitative and quantitative approach has been utilized. The study and supporting data are based on interviews with, and research from, Brazilian stakeholders, as well as published peer-reviewed literature and datasets. The study attempts to illustrate how techniques to determine sustainability outcomes (such as GIS analysis) can be used and applied in Brazil, to identify the extent to which these techniques can be used to draw conclusions related to biofuels and to identify the capacity in Brazil to implement such techniques as well as the extent to which they are already in use.

The background and introduction have been set out in Sections 2.0 and 3.0. Bioethanol from sugarcane is considered first in the report. Section 5.0 sets the context for assessing the market relevance of biofuels sustainability standards for bioethanol within Brazil. Section 6.0 assesses the extent to which sustainability standards for sugarcane impact Brazil by exploring key issues for sustainability standards and the national capacity address these issues. This section also covers many general issues that are also relevant for soybeans. Section 6.0 also addresses the extent to which standards may have implications for future production potential of bioethanol. To support this work, a national-scale GIS analysis of the geophysical potential of two key biofuel crops (sugarcane and soybean) was conducted and complemented by data obtained from experts and published literature. Additionally, the GIS analysis of geophysical potential excluded land with that did not meet key sustainability criteria identified in many standards. The resulting land availability is termed the ‘geophysical plus’ potential throughout the report (See Annex 1 for methodology and data sources).

Types of land that were excluded from the analysis were:
- Forested areas (based on 2004 MODIS data)
- Peatlands
- Protected areas
- Land at risk of erosion

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9 Note: Protected areas are used as a proxy for areas of high biodiversity. In many cases a High Conservation Value approach is advocated to establish environmental and social conservation areas, but this was beyond the scale and scope of this study. Further information on HCV areas www.hcvnetwork.org
Consideration of biodiesel follows in Section 7.0, which sets the context for assessing the market relevance of biofuels sustainability standards for biodiesel within Brazil and discusses existing legislation and voluntary programs to address sustainability issues. Section 8.0 addresses socio-economic and environmental impacts of sustainability criteria and standards for biodiesel feedstocks and assesses the extent to which these standards may have implications for future biodiesel production potential.

Conclusions on the impacts of sustainability standards for Brazil are presented in Section 9.0.

5.0 BIOETHANOL IN BRAZIL

5.1 Sustainability priorities: national energy security

Until recently, Brazil was the world’s largest bioethanol producer, and it remains the world’s largest bioethanol exporter. While Brazil exported 3.4 billion liters of fuel ethanol in 2006 and 3.5 billion liters in 2007 (MAPA, 2008) to markets in the United States, the European Union (e.g., Netherlands and Sweden) and Japan (BNDES & CGEE, 2008), the majority of its 20.2 billion liters is for domestic consumption (Figure 1). Only 13-14% of national production is therefore exported.

Sugarcane is the main feedstock used for bioethanol in Brazil. The bulk of sugarcane production (ethanol + sugar) is in the Center-South region of Brazil (87% in 2007) and 60% of total production takes place in the state of São Paulo. Only 0.6% of sugarcane is produced in the states of the Amazon region (mainly for sugar manufacturing) although 0.2% of Brazilian ethanol is produced in the Amazon region (Walter, et al., 2008). Sugarcane for ethanol production is grown on less than 1% of Brazil’s total land area.

Figure 1: Global ethanol production forecast 2005-2017 (Billion liters)
Figure 2 illustrates that domestic ethanol production and use are forecast to increase substantially in Brazil. However, its exports of bioethanol (net trade) are also expected to increase through 2017. The OECD-FAO forecasts that 85% of global ethanol exports will originate in Brazil by 2017 (OECD-FAO, 2008).

The reason for substantial domestic consumption of bioethanol is that all motor gasoline sold in Brazil contains 20-25% ethanol on volume basis (E20–E25). Ethanol in gasoline is mandated and is the result of public policy from the 1970’s to incentivize ethanol use and reduce oil dependency. It is used either in the form of 100% hydrous for neat ethanol vehicles, or is anhydrous and blended with gasoline. Flex-Fuel Vehicles (FFVs) can be fuelled with hydrous ethanol (alcool) that is cheaper than anhydrous ethanol (Walter, et al., 2008). The sale of FFVs in Brazil is increasing rapidly and represents upwards of 85% of new car sales today (see Figure 3).

Biofuels also play a key role in domestic energy security through electricity production. Brazil has one of the cleanest energy profiles in the world; nearly 45% of all energy produced is from renewable energy sources and close to 80% of electricity generation is from hydropower sources. While large hydro will continue to play an important role in the energy matrix, “alternative” sources are forecast to grow to 10 times current capacity by 2030 (marked in green on the Table 2). Biofuel production plays a key role in this growth as electricity from sugarcane bagasse is forecast to grow dramatically through 2030 (Table 2).
Figure 3: Vehicle sales (new cars) in Brazil by fuel type (2005–2008)

Source: Anfavea, accessed July 2009

Table 2: Installed electrical generation capacity, currently and forecast, in Brazil

<table>
<thead>
<tr>
<th>Source</th>
<th>2005</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Hydro</td>
<td>68.600</td>
<td>156.300</td>
</tr>
<tr>
<td>Thermal</td>
<td>16.900</td>
<td>39.897</td>
</tr>
<tr>
<td>NG</td>
<td>8.700</td>
<td>21.035</td>
</tr>
<tr>
<td>Nuclear</td>
<td>2.000</td>
<td>7.347</td>
</tr>
<tr>
<td>Coal</td>
<td>1.400</td>
<td>6.015</td>
</tr>
<tr>
<td>Others</td>
<td>4.800</td>
<td>5.500</td>
</tr>
<tr>
<td>Alternative</td>
<td>1.400</td>
<td>20.322</td>
</tr>
<tr>
<td>SHP</td>
<td>1.300</td>
<td>7.769</td>
</tr>
<tr>
<td>Wind Power</td>
<td>-</td>
<td>4.682</td>
</tr>
<tr>
<td>Sugar Cane Bagasse</td>
<td>100</td>
<td>6.571</td>
</tr>
<tr>
<td>Urban Residues</td>
<td>0</td>
<td>1.300</td>
</tr>
<tr>
<td>Other Generation*</td>
<td>5.800</td>
<td>-</td>
</tr>
<tr>
<td>Import</td>
<td>7.800</td>
<td>8.400</td>
</tr>
<tr>
<td>Total</td>
<td>100.500</td>
<td>224.919</td>
</tr>
</tbody>
</table>

* Isolated Systems in the North mostly diesel powered.
Source: Goldemberg, 2009.
5.2 Bioethanol economics

The share of gasoline consumption in different regions of Brazil has not changed substantially over the past 10 years (see Figure 4). The Southeast, with the largest population density, accounts for 50% of gasoline sold (2007 figures) and the North and Center-West account for only 6% and 9%, respectively.

Figure 4: Sale of gasoline according to the different regions of Brazil

![Sale of gasoline in the different regions](image)


The prices of gasoline do not vary substantially by region, but are consistently higher than diesel prices. In 2007, the Southeast had the lowest gasoline price at R$2.45, and the North and Northeast had the highest at R$2.66 and R$2.62/liter, respectively.

Ethanol production costs

Most of the Brazilian distilleries can produce two different types of ethanol:\(^\text{10}\):

- **Hydrous ethanol**: This is ethanol with an alcohol content of 92.6-93.8%. It can be used either in ethanol cars or in flex fuel vehicles.

- **Anhydrous ethanol**: This is ethanol with an alcohol content of at least 99.3% that is blended with gasoline (20% to 25% in volume) to form the “gasohol”, commonly known also as “gasolina C”. The mixture varies according to ethanol supplies (law n. 8.723/93). (ANP, 2007).

In 1975, ethanol production costs were over R$2/liter (actual 2007 values), as shown in Figure 5. Owing to technological innovations and better sugarcane varieties, the cost of production has

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\(^\text{10}\) The direct sale of hydrous and anhydrous ethanol to the retailers is not allowed under resolution ANP nº 116 of the 5th of July of 2000 that sets the criteria for the commercialization of liquid fuels. This resolution supports a centralization of the production and distribution: producers (the distilleries) can sell ethanol only to distributors that deliver it to retailers (gas stations) where consumers buy the finished product.
decreased dramatically. Today, the most efficient sugarcane plants produce ethanol at R$ 0.40-0.60/liter, corresponding to US$0.2-0.3/liter (De Oliveira, 1991; Moreira and Goldemberg, 1999; UNICA, 2007). Investment costs have dropped four fold, from over R$ 400/liter (US$ 230) in 1976 to less than R$ 100/liter (US$ 57) installed today (Pereira, 1986; Dedini, 2008). Sugarcane yields have increased from 46.8 tons per hectare in 1975 to current levels of around 75 tons per hectare (MAPA, 2007).

For most automobile models currently available, 70% is understood, on average, as the break-even ratio between ethanol and gasoline prices (BNDES & CGEE, 2008) i.e. ethanol prices must be 70% that of gasoline. Only on several occasions has the price ratio between ethanol and gasoline actually been close to 70% (e.g., August-September 2000; February-March 2003; March-April 2006); during harvesting periods there is a surplus of ethanol and prices drop. In the sugarcane region of the São Paulo countryside, the ethanol gas station pump price can be as low as 40% of the gasoline price (R$ 1.00 / R$2.50 per liter). Ethanol is generally cost competitive with gasoline.

**Figure 5: Price paid to the producers of anhydrous and hydrous ethanol in Brazil from January 1976 to November 2007. All prices are expressed in November 2007 R$ (1 USD$ ~ 1.75 R$)**

![Graph showing price paid to producers of anhydrous and hydrous ethanol in Brazil](image)

The Government has, at certain points, regulated and controlled ethanol fuel rising prices at the gas station pump to ensure energy security was not compromised by high prices. One measure was to store ethanol between seasons to accommodate volume fluctuations.

**Sugarcane production costs**

Today, sugarcane represents around 62.1% of the production cost of alcohol (CONSECANA, 2006). This percentage can change with time according to technological innovations and it is revised by
CEPEA every two to three years through statistical analysis of monitored production plants. Knowing the price of sugarcane allows a derivation of the production cost of ethanol.

On average, one ton of sugarcane produces more than 80 liters of ethanol. Assuming an average of 85 liters per tonne (l/t) and a cost of sugarcane around R$ 38/t (the average over the past few years), a rough estimation of the price of ethanol can be made as follows:

1. \[38 \text{ [R$/t]} : 85 \text{ [l/t]} = 0.447 \text{ R$/l} \text{ (accounting for 62.1\% of total production costs)}\]
2. \[0.447 \text{ R$/l} : 62.1\% = X : 100\%\]
3. \[X = (0.447 \times 100/62.1) = 0.719 \text{ R$/l} \text{ ( = 0.36$/l at an exchange rate of 2 R$/ per 1 US$)}\]

The price of sugarcane is based on the amount of total recoverable sugars (ATR) according to a methodology developed by CONSECANA that, using the information of CEPEA, calculates the price of ATR and communicates it monthly to both independent producers and distilleries or sugar refineries.

**Box 1: Key organizations and the price of cane**

The price of sugarcane in the state of Sao Paulo and other states of the South and Southeast regions (accounting for over 80\% of total Brazilian production) is determined according to very specific rules that have been agreed upon and defined by the three different organizations representing the interests of independent sugarcane producers and ethanol and sugar distilleries. These organizations are:

- CEPEA (Centro de Estudes Avançados em Economia Aplicada) is an independent research institution that has been nominated by UNICA and CONSECANA to monitor the national and international price of alcohol and sugar. CEPEA also monitors the average production costs of sugar and ethanol that are used to establish the price of sugarcane.

- UNICA: represents the ethanol and sugar producers of the state of Sao Paulo and other Center-South states. UNICA has 122 members and represents 60\% of ethanol production in Brazil.

- CONSECANA: represents the interest of sugarcane growers, sugar producers and ethanol producers. It aims to create a common ground for dialogue and negotiation between these three groups.

The long-term price of sugarcane is shown in Table 3.
Table 3: Price variation between sugarcane and anhydrous and hydrous ethanol for (1976–1978) and (2005–2007)

<table>
<thead>
<tr>
<th></th>
<th>Sugarcane (R$/Ton)</th>
<th>Anhydrous ethanol (R$/l)</th>
<th>Hydrous ethanol (R$/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average price, 1976-1978</td>
<td>88.89</td>
<td>2.10</td>
<td>1.94</td>
</tr>
<tr>
<td>Average price, 2005-2007</td>
<td>51.43</td>
<td>1.01</td>
<td>0.91</td>
</tr>
<tr>
<td>Price drop (%)</td>
<td>42%</td>
<td>52%</td>
<td>53%</td>
</tr>
</tbody>
</table>

Increasing productivity

Increasing productivity has been one of the significant contributors to reductions in costs of production within the ethanol industry and is key to the long-term viability of the industry.

The following issues have been identified as the most relevant for increasing productivity in the Center-South region (BNDES & CGEE, 2008):

- Development of processes for recovery and use of excess plant fiber and bagasse;
- Development of transgenic (GM) varieties of sugarcane; transgenic sugarcane cannot be planted at present as it is illegal in Brazil;
- Selection of cultivars (conventional improvement for new cultivation areas and adoption of the concept of energy sugarcane to maximize the global results that are possible by processing both sugar and fiber for energy production);
- Development of equipment and processes for juice extraction and bioethanol treatment, fermentation and separation;
- Development of precision farming systems, in which interventions in cultivation are aided by geoprocessing techniques and global positioning systems (GPS);
- Use of biological pest and disease control;
- Selection of sugarcane cultivation practices compatible with mechanical harvesting;
- Development of new sucrochemical and alcochemical products and processes;
- Advances for bioethanol end uses (improvements in biofuel engine technologies and bioethanol-operated fuel cells).

The research, development and demonstration capacity within Brazil to achieve these results are already substantial and is growing. The following are some of the key players in these advances:

*Embrapa Agroenergy*, created in 2006, aims to enable innovative technological solutions for sustainable and equitable development of the Agroenergy business in Brazil for the benefit of society. It coordinates Agroenergy R&D actions at Embrapa and executes R&D projects. Embrapa Environmental Research, in Jaguariúna, focuses on themes associated with the rehabilitation of damaged areas, sustainable use of water and biological control of pests and diseases. Strategic priorities of Embrapa Agroenergy include development of new energy technologies (ethanol from
cellulose, products of bio-refinery, hydrogen), technologies for economical use of by-products and residues, novel production systems and raw materials with superior characteristics for energy production, and technologies and production systems for using degraded areas for bioenergy production. Embrapa is also undertaking zoning and evaluation of environmental, economic and social impacts for the identification of areas for the competitive and sustainable production of agroenergy. Sugarcane R&D in Brazil includes a network of around 100 scientists in eight of Embrapa’s R&D centers, as well as in two Universities.

**CTC - Center of Sugarcane Technology (Centro de Tecnologia Canavieira)** is a civil association of private, non-profit organizations dedicated to the technological development of the sectors for cane sugar, sugar, alcohol and bioenergy. Its main program is for the development of new cane varieties. It is the only research center dedicated to sugarcane so it provides a critical indicator of the technological innovation. CTC has an approximate annual budget of R$ 30 million, which comes mostly from the sale of the sugarcane the Center produces and from membership contributions.\(^\text{11}\)

The recently established **Center for Bioethanol Science and Technology** located within the Pólo Tecnológico de Campinas (Campinas Technology Center) is dedicated to a wide spectrum of technologies of interest for the efficient conversion of biomass into energy. As a research Institute, it is involved with the following tasks: it will perform competitive RD&I for improving feedstock and conversion routes for bioethanol production from sugarcane; it will be a partner of other research organizations working in related areas, through a network of associated laboratories in universities and research institutes; and it will also serve as a technology supplier for the industry, providing strategic information on mutual concerns. Its main research programs include basic science, pilot plant development for process development and low impact mechanization for no-till farming of sugarcane.

**The Brazilian Reference Center on Biomass** (CENBIO), founded in 1996, is a bioenergy research group in located in the University of São Paulo, in the Electrotechnics and Energy Institute (IEE). CENBIO was established with the main goal of promoting the development of research activities and the disclosure of scientific, technological and economic information to make the use of biomass, as an efficient energy source in Brazil, feasible.

**Supply and demand proximity**
Brazil's priorities of energy security are well addressed by sugarcane ethanol which is produced predominantly close to centers of demand. The average price of ethanol is higher in the regions with low production quantities, especially when transporting ethanol from other states is required. The price difference is mostly due to higher production costs, transport and taxes. Figure 4 illustrates that the greatest ethanol demand is in the southeast and Figure 6 illustrates that this region coincides with the export region for sugarcane and has some of the lowest ethanol prices. Regions with the lowest gasoline demand (North and Northeast) are areas of low production and low import requirements.

However, Figure 6 illustrates that the price differential between gasoline and ethanol is, in most cases, not significantly different to that of the Southeastern region (though local variations will occur).

The number of states that had to import ethanol has increased in two years from 14 to 16. In 2007, there were seven states that had virtually no production of hydrous ethanol and there were an additional six states (including Rio de Janeiro, Rio Grande do Sul, Ceará and Bahia) that imported over 50% of what they consumed (ANP, 2008). Low production capacity generally correlates with low population density, limited availability of good quality soil and land, poor infrastructure, and a topography and climate not appropriate for large-scale sugarcane plantations.

The difference in the average price at the pump between importing and exporting states was 7% in 2006 and 11% in 2007. However, the values are average estimations and there can be large variations within states. In July 2008, for example, consumers of several municipalities in the state of Acre, paid around R$ 2.78/liter for hydrous ethanol while the price in several municipalities of the state of São Paulo was as low as R$ 0.999/l, almost 3 times less. This price difference is also visible for diesel as all fuel produced elsewhere faces the same logistical problems in the North and Northeast of Brazil. In 2006, the margins of gas stations in some regions of Rio Grande do Sul varied between R$ 0.17/liter to R$ 0.40/liter (State Commission of Rio Grande do Sul, 2006). Such large differences were attributed to differences in volumes of commercialization and also to higher profits among distributors and retailers in areas with low consumption density and low price competition.
Figure 6: Exports, imports and prices of hydrous ethanol in different regions of Brazil compared to gasoline prices (2006-2007)

Source: Statistics from ANP Anuario Estatistico 2008

Improvements in ethanol production and consumption within states appear possible. For example, areas of Parana Rio Grande do Sul, Goais and Tocatins have the capacity for sugarcane production, according to selected sustainability criteria, but either very low exports or, at least, relatively low exports compared with the main export state of Sao Paulo (Figure 7).
Figure 7: Distribution of “geophysical plus” potential area for sugarcane, percent of total import and export of hydrous ethanol per state for 2006 and 2007 and locations of major exporting ports of hydrous ethanol with their ethanol export volumes

Infrastructure and distribution improvements
The distribution of ethanol is structured in a pyramidal way through storage at intermediate locations. In 2006, 18% of the fuel storage capacity of 3.9 million m$^3$ was used for ethanol (the blends were 20-25%). The distributor usually collects the fuel (ethanol, diesel or gasoline) at the refinery or distillery with large trucks, usually with 45 m$^3$ capacity, and transports it to a regional storage point. According to local consumption density, the fuel can be transported from the regional storage points to smaller intermediate storage facilities. From the regional and/or local storage points, smaller trucks of 15 m$^3$ transport hydrous ethanol and “gasohol” (gasoline C) to supply several gas stations within a specific area. Usually, the gasohol is made by mixing pure gasoline with anhydrous ethanol during the local transport from the base to the retailers.
Generally, distribution costs range from R$ 0.05/l to R$ 0.1/l to deliver ethanol locally or regionally less than 500 Km and R$ 0.1/l to R$ 0.3/l to deliver ethanol about 500-1000 Km from the production point. The transport cost ranges from 3% to 20% of the final cost to consumers.

Brazil intends to develop a high capacity and high efficiency logistics network of pipelines which is expected to increase capacity and reduce costs in the long term. There are three major new infrastructure projects planned by Petrobras, Brenco and Uniduto that plan to construct pipelines to connect ethanol producing regions to the main ports in the Center-South (Figure 8). This could improve the opportunity to address the potentially sustainable production routes in states other than Sao Paulo in the Center-South. Improvements in infrastructure directly relate to improvements in export potential. The potential area for expanded sugarcane growth, illustrated in Figure 7 for internal consumption, is unlikely to be served by these improvements though, because of the limited geographical scope of the proposed pipelines.

Figure 8: Planned investments in ethanol pipelines in the Center-South

Source: UNICA pers comm
Existing domestic legislation, codes, and programs

Many sustainability standards refer to compliance with existing legislation. The Brazilian environmental legal framework constitutes a range of federal and state laws. In order to receive a licence to operate, feedstock and biofuel producers must comply with the legislation. Frameworks such as Environmental Impact Assessments are also required for new projects (Amaral, Marinho, Tarasantchi, Beber, & Giuliani, 2008). Table 4 provides an overview of the main environmental laws in Brazil relevant to biofuels.

Table 4: Summary of the main environmental laws in Brazil relevant to biofuels

<table>
<thead>
<tr>
<th>Law</th>
<th>Objective</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4771 (1965)</td>
<td>Forest Code</td>
<td>Creates Permanent Preservation Areas (APP)</td>
</tr>
<tr>
<td>No. 997 (1976)</td>
<td>Environmental Pollution Control</td>
<td>Environmental permissions</td>
</tr>
<tr>
<td>Portaria do Ministerio do Interior No. 323 (1981)</td>
<td>Prohibits release of vinho into water</td>
<td></td>
</tr>
<tr>
<td>No. 6938 (1981)</td>
<td>National environmental policy</td>
<td>Establishes mechanisms &amp; instruments (e.g. environmental zoning, Environmental Impact Assessment)</td>
</tr>
<tr>
<td>CONAMA deliberation No. 001/7986</td>
<td>General guidelines for the evaluation of environmental impacts</td>
<td>For industrial complexes and units and agro-industry</td>
</tr>
<tr>
<td>No. 6171 (1988)</td>
<td>For the preservation and conservation of agricultural soil</td>
<td></td>
</tr>
<tr>
<td>No. 11241 (2002)</td>
<td>Gradual elimination of burning sugarcane straw in fields</td>
<td>Elimination of the use of fire by 2021 as a method and facilitator for harvesting sugarcane</td>
</tr>
<tr>
<td>12183/05</td>
<td>Charges for use of water</td>
<td></td>
</tr>
<tr>
<td>Law</td>
<td>Objective</td>
<td>Comment</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>50889 (2006)</td>
<td>Legal Reserve of Landed Property in the State of Sao Paulo²</td>
<td>Obligation of reserving an area equivalent to 20% of each rural property</td>
</tr>
<tr>
<td>SMA deliberation 42 (2006)</td>
<td>Prior environmental license for distillers of alcohol, sugar plants and units of production of spirits</td>
<td>Defines criteria and procedures</td>
</tr>
<tr>
<td>Agricultural and Environmental Protocol of sugar/ethanol industry</td>
<td>Prominence to anticipate the legal period to end the use of burning in the harvest of cane by 2014 in the area cultivated by plants</td>
<td>Government of State of Sao Paulo and UNICA</td>
</tr>
<tr>
<td>Protocol for elimination of burning sugarcane in the ethanol/ sugar sector of Minas Gerais protocol</td>
<td>Eliminate burning by 2014</td>
<td>SIAMIG/ SINDACUCAR-MG and Governments of the State of Minas Gerais.</td>
</tr>
</tbody>
</table>

Source: Amaral, Marinho, Tarasantchi, Beber, & Giuliani, 2008

Notes to the table:

1 The Brazilian law addresses forestland conversion. The criteria for minimum forest area in Brazil on private farmland have been increased several times for different Brazilian regions. Owners of a property in the Amazon region under transition forest may clear 50% of the land for development, whereas only 20% of rainforest is allowed to be cleared. Owners of cerrado lands can clear a much larger proportion of their area (65-80%). The law also requires landowners with less than the minimum area to plant 1/10 of the minimum requirement every third year until the minimum required area has been reached. There is no established procedure however, to prosecute farmers that do not meet the minimum area requirement (Sparovek, Berndes, Egeskog, Freitas, Gustafsson, & Hansson, 2007).

2 There is specific legislation on Permanent Protection Areas (APP) that directly addresses water quality issues. APPs have a special function of protecting riparian vegetation along water bodies. Forests and other forms of natural vegetation are considered permanent preservation units when located: a) along rivers or any water stream, in a width of 30 m for water stream up to 10 m wide; b) 50 m of vegetation for water streams of 10-50 m; c) 100 m of vegetation for water streams of 50-200 m; d) 200 m for water streams of 200-500 m; e) 500 m for rivers with more than 600 m; f) surrounding lagoons, lakes, natural or man-made reservoirs; g) and in a radius of 50 m around springs and wells (Walter, et al., 2008). However, the cost effectiveness of restoring APP land to address water quality in some areas may be lower than others (such as those on flat land that are at lower risk of soil erosion).

The following are some more detailed descriptions of specific legislation, codes and programs:

*Proposed legislation based on Agro-Ecological Zoning (Sept 2009)*

Embrapa coordinated an agro-ecologic zoning study for sugarcane at a national level covering: a) soil and weather adequacy, b) topography, c) water availability and water requirement, d) areas with sensitive ecosystems where sugarcane cannot be planted, and e) areas where other crops are being
produced. This zoning was developed by a multidisciplinary group of state institutes/universities, government organizations and private consultants. The results are intended to be guidelines for licensing and credits concession. For example, INMETRO would not certify a sugarcane mill located outside the adequate areas, as indicated by the zoning study (Walter, et al., 2008).

Based on this National Agro-Ecological Zoning for Sugarcane (ZAE Cana) study, which defined lands suitable for sugarcane production based on environmental, economic and social criteria, the Government has proposed new legislation (in September 2009) that will restrict the lands permissible for sugarcane farming and processing in any area of native vegetation, or in the Amazon, Pantanal or Upper Paraguay River Basin regions. This results in approximately 64Mha available for sugarcane compared to the approximate 8.9Mha already cultivated.\(^{12}\)

**Sugarcane voluntary code**

A Voluntary Environmental Protocol has been introduced in Sao Paulo State by the Government of the State and UNICA. In February 2008, it was reported that 141 sugar and ethanol businesses had signed the Protocol, covering more than 90% of the total sugarcane production in that state (Amaral, Marinho, Tarasantchi, Beber, & Giuliani, 2008). A similar initiative is in development in the State of Minas Gerais.

**Box 2: Audits from Brazil show examples of high standards**

The UK has an operational carbon and sustainability reporting scheme that has provided experience for biofuel suppliers in advance of the forthcoming EU requirements. Greenergy is the UK’s largest biofuel supplier and has undertaken a number of independent audits of its suppliers in Brazil, both from the Center-South region and the Northeast. The audits have in general illustrated high standards of practice and commitment to issues such as phasing out burning. These independent audits have been carried out owing to the absence of operational sustainability certification standards for sugarcane.

**INMETRO**

INMETRO (National Institute of Metrology, Standardization and Industrial Quality that belongs to the Ministry of Development, Industry and Foreign Trade) has begun a voluntary Brazilian Program of Biofuel Certification to foster biofuel export. INMETRO already has a similar program for certifying forest management (CERFLOR), which is internationally recognized. According to the initial proposal, an ethanol producer could only start the certification process if the following conditions are fulfilled (Walter, et al., 2008):

---

- Sugarcane production is in accordance with the national Agro-Ecologic Zoning (for legislative purposes)
- All environmental licences are obtained;
- Evidence of water recycling is provided;
- Electricity is be generated on-site, from sugarcane residual biomass;
- Evidence of trash deposition over the soil is provided.

It is not yet clear if the procedures proposed by INMETRO will be adopted, as the process has stalled somewhat owing to uncertainty of compatibility with the mandatory criteria set out in the EU Renewable Energy Sources Directive.

**Agro-ecological zoning – Sao Paulo**

The results of an Agro-ecological Zoning study in 2008 is used by the Environment Secretary for licensing new mills. The zoning includes: a) soil and weather constraints, b) topography, c) water availability at the surface and risks to water sheds, d) the existence of protected areas, e) areas that should be preserved considering conservation of biodiversity, and f) air quality.

Figure 9 illustrates land that is considered adequate for sugarcane in orange, medium-adequate areas in yellow and inadequate areas in grey. Areas in dark green have environmental constraints.

**Figure 9: Agro-ecological zoning for sugarcane in Sao Paulo state**

The total cultivated land in São Paulo was estimated in 2006 as 7.9 Mha, and in that year 4.3 Mha were already cultivated with sugarcane. According to the Zoning study, there are 3.9 Mha of land that are adequate for sugarcane cropping and an additional 8.6 Mha that are considered adequate for sugarcane cropping but have some (non-serious) environmental constraints.

**Enforcement**

Enforcement of legislation differs between states, but in many cases it is limited. The Brazilian federal environmental control agency (IBAMA) and state-level environmental control agencies are generally poorly resourced and understaffed. In 2005, for example, IBAMA allocated 850 officials to police a region of 1.9 million square miles, the equivalent of one staff member for almost 2,300 square miles. Lack of staff assigned to high territorial areas creates the conditions for several environmental crimes. Remote sensing technologies have been applied to identify areas where such crimes have occurred or are occurring. Nevertheless, even with the application of high-resolution satellite imagery technology, law enforcement in the field is not as effective as desired due to lack of specialized labor and human resources available. At the state level, there are also environmental agencies to carry on the state legislation. In cane producing regions such as Sao Paulo State, it is generally acknowledged that enforcement of environmental legislation is higher than in neighboring states, but some non-compliance remains (e.g. a smaller area for Permanent Protected Areas is seen on some lands than is legally required).

**Summary**

Brazil has a number of initiatives underway that could address some or all of the sustainability criteria listed in Table 1. Guidance on how these existing approaches and monitoring programs can be effectively used within sustainability standards is needed to avoid unnecessary duplication of efforts and costs.

## 6.0 ISSUES FOR SUSTAINABILITY STANDARDS FOR BIOETHANOL IN BRAZIL

### 6.1 Environmental issues

Driven by pursuit of national security goals, to meet domestic demand, and by increased export opportunities, ethanol production has developed rapidly. Recently though, a number of environmental issues associated with ethanol have become prominent. The following sections addresses environmental criteria (such as those identified in Table 1) and discusses their relevance in Brazil, as well as the capacity in Brazil to assess implications or results of scientific studies which consider such criteria.

13 [http://www.prospect.org/cs/articles?article=the_role_of_the_public_sector](http://www.prospect.org/cs/articles?article=the_role_of_the_public_sector)
Air pollution

The State of São Paulo and its ethanol producers have agreed to terminate the practice of burning the sugarcane straw prior to harvesting, by 2014. The practice was undertaken to improve harvesting conditions. Even though this protocol will not be compulsory post-2014, close to 50% of the producers are already adopting such practices and the forecast is that even before 2014, the “zero burning” target will be achieved. This has a direct impact on air pollution through reduction of smoke particles. On the other hand, demand for more specialized human labor will increase as technology and mechanization is further introduced and manual cane cutting jobs are lost.

Climate change

Over the past three decades, Latin America has been affected by increased El Niño occurrences that are likely directly related to climate change (IPCC, 2007). El Niño brings serious droughts, especially to the southern states such Rio Grande do Sul (Berlato and Cordeiro, 2005), affecting total crop yield. In addition to this, the agricultural productivity of Rio Grande do Sul, Parana and Santa Catarina has also been suffering from a below average precipitation over the past 10 years caused by the deforestation of local forests, reducing the strengths and intensity of the rainy seasons. For these reasons, soybean yield in this part of Brazil has decreased.

While the Brazilian Government has a compensation system for agricultural losses caused by natural disasters, it is often difficult for farmers to receive full, or even partial, compensation. Below average harvesting undermines the capacity, especially of small farmers and independent producers, to repay the loans made for planting new crops for mechanized land operations. This has pushed some of the farmers into serious financial losses and even bankruptcy.

Sugarcane today may present a possible alternative productive model, especially for local farmers, because it is a more drought-resisting crop compared to soy. It is also possible that due to climate change, some of the regions that today have no or little sugarcane culture, such as Rio Grande do Sul, will become also producers of sugarcane.

Process GHG emissions

While the primary drivers of sugarcane ethanol development were not necessarily related to climate change, GHG savings associated with use of Brazilian sugarcane are generally agreed to be some of the most significant, cited with around 80% to 90% emissions reductions compared to fossil gasoline (although these figures do not account for any land use change). Most of the comprehensive studies on GHG emissions from sugarcane ethanol originate from Brazil.

Some sustainability standards impose a cut-off or threshold for GHG savings compared to a fossil reference. For example, the EU requires biofuels to meet a 35% GHG saving target to be considered towards their targets. Brazilian ethanol exceeds threshold values that have been set for the EU and exceeds the threshold for others for example in the US where land use change penalties are added (not considered as process emissions for the discussion in this section).
A sensitivity analysis of a generalized GHG emissions profile (Figure 10) illustrates that yield is the most significant parameter influencing GHG emissions. Electricity and bagasse surplus as co-products of bioethanol production and therefore credited to its production are the second most influential parameters, and on-farm energy (diesel) use also can have a significant impact. For some high efficiency plants already optimizing electricity export, the on-farm energy could even be the second most influential parameter next to yield.

**Figure 10: A sensitivity analysis of the GHG emissions for sugarcane ethanol in Brazil**

Emissions from fertilizer can play a large role in some areas. Most of these emissions are from fertilizer manufacturing, and others are from its transportation and application. Urea is the most used fertilizer in Brazil and has the lowest of fertilizer emissions, as determined by a Life Cycle Analysis (LCA), of all nitrogen-based fertilizers. However, the actual amount of GHG emissions will differ depending on where it is produced and how it is transported. There have been large variations over a number of years. Ten years ago, urea produced by Petrobras in Brazil was the most commonly used fertilizer for sugarcane. Then, with the strong devaluation of the US dollar, importation grew fast (reaching 60 – 70% of total fertilizers). In the last few years, devaluation of the R$ lead to a large reduction in imports, and for the coming years most of the fertilizer will be produced in Brazil again.
These changes are not reflected in GHG calculations and more information on emissions from regional fertilizer manufacturing and use is required.

N₂O emissions within the biofuel chain pathway are significant, but are some of the most uncertain parameters in the overall emissions calculation. According to the 4th IPCC report, the Global Warming Potential of this GHG is 298 times greater, weight for weight, than CO₂ (IPCC, 2006). Significant direct anthropogenic emissions of nitrous oxide occur from agricultural soils through nitrogen (N) fertilizers, animal manure and mineralization of soil organic matter and crop residues (including trash left on fields). Indirect emissions can also occur from N leaching from fertilized soils into ground water (where it is denitrified).

There are very few studies on field emissions of N₂O in Brazil. An analysis of the Brazilian N₂O emissions in agriculture (by Embrapa – MA, 2006: Report to the Inventory: Emissão de N₂O proveniente de solos agrícolas) shows that the IPCC default values are used for emissions calculations because of the lack of local data (Macedo, pers comm.).

Stehfest & Bouwman (2006) have conducted the most comprehensive assessment of data on NO and N₂O emissions internationally to identify the factors that most significantly influence their emissions from agricultural fields and soils under natural vegetation. The conclusions of this study are that factors with a significant influence on N₂O emissions from agricultural soils were:

- Environmental factors (climate, soil organic carbon content, soil texture, drainage and soil pH);
- Management-related factors (N application rate per fertilizer type and type of crop, with major differences between grass, legumes and other annual crops);

GIS techniques could be used to identify and avoid N₂O hotspots in Brazil, for instance, by using soil pH, organic carbon content, slope, precipitation and management practice information. There is substantial capacity within research institutions in Brazil to undertake such activity.

Opportunities for further GHG emissions reductions

A recent study (Macedo & Seabra, 2008) evaluated alternative technology paths for future development of ethanol in Brazil. One scenario maximizes the co-generation of heat and electricity from trash and surplus bagasse. An alternative scenario utilizes the same feedstock for ethanol production instead, through advanced processing techniques. The study calculated that the greatest GHG savings would be produced through using bagasse and trash for optimization of electricity generation, rather than to produce ethanol through advanced technology processes. Figure 11 illustrates that net emissions (accounting for co-products) were -2.5tCO₂eq/m³ ethanol for optimized electricity production compared to -2.0 tCO₂eq/m³ ethanol for advanced ethanol processes.¹⁴

¹⁴ Co-product credits were determined using a substitution approach. Sensitivity analysis revealed little difference and did not change conclusions on the basis of energy allocation for co-product treatment.
Increasing renewable electricity production from bagasse appears to provide larger GHG emission savings than focusing on further biofuel production through advanced processes.

**Figure 11: Avoided emissions from ethanol use under two different scenarios in 2020 (assuming use of E25)**

Source: Macedo & Seabra (2008)

**GHG emissions & land use change**

Recent discussions surrounding land use change for biofuel feedstock cultivation have focused attention onto the implications of land use change (both direct and indirect) on GHG emissions from biofuels. Some land use changes can be sufficient to negate the GHG benefits of biofuels.

Total arable land in Brazil dedicated to ethanol production represents less than 1% of the Brazilian territory, while pastures account for 24.7% of land use in Brazil. Recent research (Nassar, Rudorff, Antoniazzi, Aguiar, Bacchi, & Adami, 2008) confirms ethanol production has been expanding to degraded pasture lands. In other research, direct deforestation from sugarcane expansion was found to be minimal and largely related to expansion in the Northeast (Sparovek, Barretto, Berndes, Martins, & Maule, 2008). Table 5 (below) shows land use in Brazil.

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15 In the Central Expansion area, a significant reduction in pastures and cattle heads was seen and expansion did not generally contribute to direct deforestation. In the Peripheral Areas outside the Central area where sugarcane expansion occurred, several negative impacts, including direct deforestation, were observed.
Table 5: Land use in Brazil

<table>
<thead>
<tr>
<th>Area</th>
<th>Million ha</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon Forest</td>
<td>360</td>
<td>42.3%</td>
</tr>
<tr>
<td>Pasture</td>
<td>172.3</td>
<td>24.7%</td>
</tr>
<tr>
<td>Yearly crops</td>
<td>57.9</td>
<td>5.8%</td>
</tr>
<tr>
<td>Perennial crops, except sugar cane</td>
<td>11</td>
<td>1%</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>7.8</td>
<td>0.8%</td>
</tr>
<tr>
<td>Cultivated forests</td>
<td>6</td>
<td>0.7%</td>
</tr>
<tr>
<td>Non exploited</td>
<td>101</td>
<td>11.9%</td>
</tr>
<tr>
<td>Cities</td>
<td>20</td>
<td>2.4%</td>
</tr>
<tr>
<td>Protect areas</td>
<td>52</td>
<td>6.1%</td>
</tr>
<tr>
<td>Others</td>
<td>38</td>
<td>4.5%</td>
</tr>
<tr>
<td>Total</td>
<td>851</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Golemberg, USP 2009

As large areas are still available for cropland expansion in the Central region, where climate, infrastructure and environmental restrictions and more favorable, the largest expansion of sugarcane is likely to remain in this region. Therefore, it can be inferred that direct deforestation is not a real risk.

GHG emissions from land use change depend on:

- The carbon stocks of the land (the amount of carbon contained in, and able to be released from, the land)
- The amount of land converted
- The carbon stocks of the final land use.

Many sustainability standards have advocated conservation of land areas of high carbon stock (such as forestland and peatland) in order to minimize the release of large quantities of GHG emissions that would result from their conversion.

Figure 12 shows the results of recent studies prepared by Embrapa on land use change in São Paulo over the past 36 years. It illustrates high growth of agriculture in the last decade followed by reduction of pasture lands.
IGBE statistics from 1920 to 2006 provide data on cattle herd numbers and areas of grassland that can be used to determine the average density of cattle in Brazil. The national trend supports the pastureland trend decrease shown in Figure 12; results show increasing density from 0.4 head of cattle per hectare in 1920 to 1.0 head per hectare in 2006. This will vary regionally, but gives an indication of the general trend towards intensification.

Expanding sugarcane onto pastureland in the Center-South region is now well accepted as a land use dynamic. These changes are regarded broadly to be ‘positive’, from a land use change perspective. However, the condition of the pasture is important in the calculation of carbon emissions. Carbon stocks are higher in improved pastures and lower in unmanaged pastures. Substituting unmanaged pastures with sugarcane probably results in a carbon uptake, but some Brazilian scientists believe this is not the case for managed pastures. There is no scientific consensus.

Furthermore, different values for sugarcane carbon stocks are used in Brazil than elsewhere and there is no consensus in the academic community on what these values should be. The carbon stocks depend also on the practices used in the sugarcane production (burning, tillage, rotation practices, etc.).

*Much of the scientific literature on this subject (including carbon stocks) is written and published in Portuguese. Better scientific communication on these subjects could be delivered through translation of such literature, and subsequent publications, in both English and Portuguese.*
Being able to identify land use and land cover changes is key to understanding sustainability risks and drawing robust conclusions about biofuels. Brazil has an active and first-rate academic community that is working on these issues (ICONE, University of Sao Paulo and INPE, for example, have recently published research in this area) as well as undertaking further research into soil and crop carbon stocks.

INPE is the National Institute for Space Research. It has leading expertise in remote sensing technologies and land cover monitoring programs for deforestation monitoring purposes. It has developed software (SPRING) that allows remotely sensed images that are acquired on different dates to be coupled, providing a good visual interpretation to aid monitoring. Embrapa Satellite Monitoring and Embrapa Agricultural IT, both located in Campinas, are working with remote sensing, geo-processing and computing (BNDES & CGEE, 2008).

INPE coordinates The Canasat Project in Brazil\(^\text{16}\) which provides information about the spatial distribution of cultivated sugarcane area in Central-South states. The Project has used remote sensing satellite images since 2003 in São Paulo State and since 2005 for the remaining sugarcane producing States in the Central-South of Brazil (see Figure 13).

**Figure 13:** Screenshots from the CANASAT Project, Brazil, illustrating changes in cane distribution from crop year 2005/6 to 2008/9

Source: CANASAT Project (2009).

INPE illustrates the large technical capacity that exists within Brazil to implement and apply monitoring techniques that can assess biofuel sustainability. Projects such as this one, require expanded scope to address a greater number of feedstocks, as well as a larger area, if complete

\(^{16}\) INPE has also developed TerraAmazon, open-source software for large-scale land change monitoring. INPE’s new Regional Centre for Amazonia in Belem is under construction and will work on local and international capacity building for monitoring tropical forests.
monitoring is required. Future developments, such as the identification of degraded pastures through remote sensing, could be incorporated into such systems in the future. Additionally, monitoring programs and institutions at the state level (e.g. the Mato Grosso Forest Monitoring Agency (FEMA)) would likely have to be involved in such state-wide monitoring schemes for biofuels.

Box 3: An integrated sugarcane and cattle system for increasing land productivity and reducing expansion pressures

An expansion model for sugarcane that integrates sugarcane ethanol production with existing local agriculture and cattle production has been explored (Sparovek et al, 2007). Through the use of bagasse and its subsequent hydrolyization, sugarcane’s value as an animal feed increases. The process uses high pressure steam and acid hydrolysis to solubilize the hemicelluloses component which increases digestibility from around 30% to around 65%. Molasses, filter-cake, vinasse and yeast are also added to complete the feed production. The feed has a low production cost but cannot be stored for long periods owing to high water content.

Through this model, livestock activities can be intensified, which reduces the risk of ‘leakage’ from indirect land use change and can benefit the local economy. In drier winters, pasture availability is low. This coincides with the sugarcane harvest period which means that low cost feed would be produced at a time when there is a winter feed problem. Dedicated pasture land could be reduced by around 30% and maintain the same size of herd. The significant amount of land required to maintain spare pastures in the winter would instead be able to be cultivated for cane. Labor requirements would increase, owing to intensification of processes, and the local economy would be expected to grow because of the more diverse range of production chains. External specialists are likely to supply the needs for expanding the sugarcane base, but if livestock producers do not move away as was envisaged, the supply market for goods and services will have to intensify locally.

The technology to produce the animal feed is commercially viable and proven. As of 1995, 120 plants were equipped with this technology, but that has reduced to around 30 owing to the use of bagasse as a fuel source for the plant (cogeneration of heat and electricity). This opportunity cost of bagasse is a key component to the success of an integration model.

In a case study of Pontal in Sao Paulo State, use of the integration model for settlers was used to forecast impacts on income and GHG emissions through interviews and modeling. Positive impacts could be delivered by the integration model. After 15 years, the intensified milk production led to a stable net annual income 10 times higher than previously obtained by settlers in the region. However, economic viability of this integrated system relies upon ethanol plants providing cattle feed at low cost since cattle feed is the largest cost component in milk production. Mechanical harvesting allows trash recycling, which improves soil carbon GHG sequestration and substantially improves the GHG emission profile.
Water

Water issues are commonly the source of some criteria within sustainability standards. At a high level, water footprints can be carried out that aim to illustrate the water use per unit of crop or biofuel. Use of water in the crop-based biofuel conversion process conversion is usually around 10% of the total water consumption as the majority is in the crop cultivation stage (Berndes, 2008; Winrock, 2009). Sugarcane water requirements per hectare are often higher than other crops, such as soy. Table 6 shows that sugarcane requires 1500mm of water per year, compared to 450mm for soy, although these numbers can differ depending on location, as climate influences water requirements.

Apart from climatic influences, water footprints vary depending on:

- **The metric used**: sugarcane has a higher biofuel yield per hectare than soy, therefore water consumption considered on a per GJ of fuel basis appears more favorable than on a per hectare basis for sugarcane in these examples.

- **The treatment of co-products**: A bioenergy system that includes electricity production in the biofuel process yields substantially more energy. Water use per unit of bioenergy produced is therefore less than if all the water was allocated to the biofuel only.

**Table 6: Illustrative water requirements for sugarcane and soybean based on their use for biofuel production only vs total bioenergy production**

<table>
<thead>
<tr>
<th></th>
<th>Water required mm/yr</th>
<th>Water required m3/ha.yr</th>
<th>Yield biofuel (GJ/ha)</th>
<th>Water consumption m3/GJ biofuel</th>
<th>Consumptive water use (m3 water/ GJ bioenergy)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>1500-2500</td>
<td>15000-25000</td>
<td>146</td>
<td>103-171</td>
<td>37**</td>
</tr>
<tr>
<td>Soybean</td>
<td>450-700</td>
<td>4500-7000</td>
<td>13</td>
<td>349-544</td>
<td>145</td>
</tr>
</tbody>
</table>

* These numbers refer to systems where harvest residues (50 percent of total) are used for power production (at 45 percent efficiency), except lignocellulosic feedstock where lignin is used for internal energy requirements.

**Cane-ethanol system design exports electricity. Includes steam conservation, electricity generation using bagasse during milling season, and tops and leaves during off-season. Electricity generation in excess of onsite needs is 286kWhMg-1 fresh stalk during 160-day milling season, and 435kWhMg-1 fresh stalk during off-season: average 370kWhMg-1 fresh stalk.

Source: Rajagopal & Zilberman, 2007; Berndes 2002, 2008 ; de Fraiture & Berndes, 2009

Many parts of Brazil have a suitable climate for rain-fed agriculture and are not classed as water scarce: so, for these areas, does focusing on reducing the water footprint deliver a more sustainable outcome?
Sufficient consideration of water availability and other water impacts requires a more detailed understanding of the interconnectedness and interdependence of water use within river basins. Water scarcity at a national scale may not be apparent, but this could change at regional and more local levels.

**Figure 14: Distribution of water resources, surface water and population**

Carrying capacity is a key concept to consider for both water use and water quality. Improving water use efficiency in the areas that do experience water scarcity, may not be sufficient to deliver a sustainable outcome (even with large improvements) if net abstractions are greater than water availability. Similarly, individual biofuel plants may meet water effluent discharge standards, but the net effect of the total discharge may be toxic for the local river basin. **Land use changes will impact the hydrological cycle and sugarcane requires more water per hectare than pastureland. Of potentially greater concern than calculating water footprints though, is that the implications of potentially large scale conversion of pasture land to sugarcane on water resources has not yet been explored.**

Assessments at a river basin scale, rather than site-specific or plant-specific scales, are the only suitable way to determine impacts of biofuels on water. Viewing a river basin as a continuum of
nested ecosystems assists in understanding how changes in one part of a basin affect both water availability and environmental health in other parts of the basin.

The State of São Paulo in the Southeast, pioneered water resources management policy in response to the grave pollution problems afflicting its water sources. The policy was developed in 1991 by drawing up and promulgating state policies to regulate the integrated management of water resources. Walter, et al., (2008) highlight the results of a recent study carried out by the Environmental Secretariat and the Agriculture Secretariat in state of São Paulo (Figure 15). This study illustrates that the region around Piracicaba, one the most traditional regions of sugarcane production in São Paulo, has a critical water status, and the region close to Ribeirão Preto, the largest sugarcane producer region in the country, is considered highly vulnerable.

**Figure 15: Current status of water resources in the state of São Paulo**

In São Paulo, the law enforcement regarding the Permanent Protection Areas ("APP"), which directly influences soil erosion runoff and water quality, has not been satisfactory, and research has shown that APPs in some areas are still below the legal minimum (Sparovek et al, 2007).

Owing to the inter-connectedness of water across different regional boundaries, cooperation among different administrative levels is necessary for effective water management in most river basins. In Brazil, the management of water basins can be considered a relatively recent experience. The
National Water Resources Policy, created in 1997, was the culmination of over 20 years of attempts to construct a water resources management structure based on the catchment as a management unit.

There are three main administrative levels involved with regulating water bodies and the use of water resources in Brazil: 17

1. **The National Policy on Water Resources (PNRH)** established that the hydrological basin is the territorial unit at which policy and the National System for the Management of Hydraulic Resources should be implemented. The National Water Resources Council is the highest body in the hierarchy of the National Water Resources System and promotes the coordination of water resource planning with national, regional, state and user planning levels. It comprises representatives of the Federal Government, State Water Councils, water resource users and civil society organizations.

2. **The National System for the Management of Hydraulic Resources (SINGREH)** is a public entity formed by representatives from different public bodies belonging to the Federal, State, district and municipal levels that has to develop general guidelines, instruments and objectives to manage the water resources in the hydrological basin. SINGREH regulates, controls and decides upon the use of water resources. It also establishes the price for the use of resources. The SINGREH manages conflicts related to water resources and implements the PNRH.

3. **The Committee of Hydrographic Basin (Comitês de Bacia Hidrográfica)** is formed by representatives from Federal, State and local bodies, end-users and local authorities. It is akin to a “local parliament” that decides on matters for the management of local water resources. The Basin Committee is responsible for designing the pricing mechanisms and defining the prices to be charged in accordance with the uses authorized. Local water agencies implement the decisions made by the Basin Committees.

The National Water Agency (ANA) is an administratively and financially autonomous government agency, subordinate to the Ministry of the Environment. It is responsible for implementing the National Water Resources Policy and the National Water Resources Management System. It is also responsible for lending support to the installation and working of Basin Committees along rivers under federal domain.

The water basin as a management unit may have different boundaries than the administrative division of the country into states and administrative regions and is therefore a challenge. ANA (2002) notes that operational Basin Committees are essential for implementation of the National Water Resource Planning System. In order to coordinate a planning and management unit on rivers under both federal and state domain, the states must give the necessary priority and disposition, and they must make the required political decisions for the implementation and/or strengthening of the respective State Water

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17 Federal Law nº. 9.433, of 08.01.1997
Resource Management Systems. New institutional arrangements may be necessary to do this as legislation defines which rivers are federal and which are state, but does not define their relative subordination.

The first experience of Basin Committee formation and operation was with the Sao Francisco river basin. This basin has diverse physical, economic, political, institutional and cultural characteristics in a 645,000 km$^2$ catchment area that covers six states and 503 municipalities. Traditionally, public officials have made decisions unilaterally and it is therefore likely that the greatest challenge in solving water use conflicts at the river basin level is in changing political culture to address coordination and cooperation. To address cooperation and resolve potential conflicts, ANA is implementing Management Pacts through agreements among Basin Committees and States to implement the integrated management of water resources by harmonizing criteria and procedures for the implementation of technical and institutional management instruments.

Figure 16: Basin Committees and hydrographic regions of Brazil. Red dots indicate Basin Committees

Source: ANA, 2002
6.2 Socio-economic issues

During the first period of the ProAlcool Program (1975-1979), new distilleries were annexed to the existing sugar mills. Then, during the 1980s, new autonomous distilleries were built and nearby farmers began producing cane to supply to the facilities. In 2007, 273 mills were able to produce both ethanol and sugar with some degree of flexibility between the two products (generally, the production varies from 40% to 60% ethanol, and consequently, 60% to 40% sugar). Seventy-seven mills were only able to produce ethanol (autonomous distilleries), and 16 mills were able to produce only sugar.

Brazilian plants produce the majority of sugarcane processed from land owned, rented, or belonging to shareholders and agricultural businesses linked to the plants. The proportion of sugarcane crushed at mills in Brazil that is sourced from independent suppliers, rather than the mills’ own land, declined from 49.2% to 31.9% between 1960 and 2000, and has since then increased again, to 39.2%, as shown in Figure 17. The bulk of the production in Sao Paulo is from the larger suppliers, but there are a significant number of small-scale suppliers: 77% of suppliers are producing sugarcane on less than 22 hectares (Walter, et al., 2008). Smaller production facilities have lower average yields than the larger facilities, but the yield over large ranges of production (from 800t/yr to over 10,000t/yr facilities) barely differs despite the substantially smaller area represented by the smaller facilities (Figure 18).

Figure 17: Sugarcane production profile in Brazil (1960-2005) illustrating production from suppliers and the mill’s own production.
Electricity Access
Despite the large installed capacity in Brazil, access to electricity is limited because of non-uniform distribution. In the North and Northeast of the country, as well as large parts of the Central West, there is a lack of electricity distribution infrastructure in remote communities. In the North of Brazil, most of the energy generation is based on fossil diesel and is more expensive than hydropower. Biofuels can contribute not only through cogeneration of sugarcane bagasse, but can also have a key role to play as a direct energy source to improve access to energy in such regions.

Food, fuel and rural development
Biofuels can have varying influences on rural development, food and labor issues. Impacts of sugarcane expansion from 1996-2006 have been studied and have been found to produce varying impacts depending on the location (Sparovek, Barretto, Berndes, Martins, & Maule, 2008). In the Central expansion area of sugarcane, cropland areas used for crops other than sugarcane experienced similar impacts whether or not they were expanding areas. The conclusion was that pressures on food crops and their subsequent displacement were not significant. Possible explanations include: 1) improvements in infrastructure stimulated by sugarcane expansion also stimulated cultivation of other crops, or 2) soybean, peanut and cover crops are traditionally cultivated in areas where sugarcane is renewed, which represents 10-20% of the area cultivated with cane – therefore the opportunity for these crops to expand also increases. However, in peripheral expansion areas outside the Legal Amazon cropland, areas for crops other than sugarcane declined. This
includes a region of family agricultural based food production for self consumption where the local market is dominant. Food security impacts may be felt there.

Within the same study, in the Central expansion areas in the south, municipal GDP was greater and increased faster in expanding areas of sugarcane than non-expanding areas. Differences in Municipal GDP between expanding and non-expanding sugarcane areas were not as pronounced in municipalities outside the Legal Amazon and no differences were found within municipalities within the Legal Amazon.

Other Brazilian academics have undertaken substantial research into the socio-economic implications of agricultural development in various regions of Brazil. For more detailed analyses see Walter, et al., (2008).

**Box 4: Small-scale ethanol for socio-economic development in Rio Grande do Sul**

Producing biofuel feedstock combined with food is the production strategy of COOPERBIO, a cooperative of small farmers in the state of Rio Grande do Sul. COOPERBIO’s aim is to vertically integrate small farmers in the production chain of both biofuels and food. Small farmers could increase their profits and mitigate financial losses if they transformed raw material into finite products of higher aggregated value instead of selling it to manufacturing and refining plants. COOPERBIO is doing this by:

a. Promoting small-scale ethanol production;

b. Testing a new logistical and distribution system for ethanol based on local production and consumption; and

c. Developing and applying specific knowledge to integrate food and biofuel production.

The project consists of the integrated production of hydrous ethanol and food by engaging about 100 to 200 families of small farmers in nine neighboring communities. Each family owns, on average, 20 hectares of land. The project’s ethanol component involves producing hydrous ethanol through nine small-scale ethanol distilleries that sell ethanol directly to consumers in a cooperative-to-cooperative agreement. Today, this is the only commercialization option that is possible in Brazil because producers cannot sell ethanol directly to the market. The results of this experience have been encouraging, showing a relatively substantial increase in the income of farmers and no competition with food production. However, the low production volumes and the higher production costs of small scale distilleries (1 R$/l) compared to large scale producers (0.6 R$/l) may limit the opportunity for exports from these sources.
Labor

The relationship between bioethanol production and human labor is fundamental for the social viability of the sugarcane industry. According to the National Statistics Institute (IBGE), in 2005 the industry generated nearly one million jobs. For each direct job created in this industry, there are 1.43 indirect ones and 2.75 others induced in other areas (BNDES, 2008). Therefore, there are an estimated 4.1 million people dependent on the sugarcane industry, with the majority of these jobs being low-income positions associated with manual harvesting. Studies estimate that for typical sugarcane distillery crushing two million tons per year, there are around 2,500 staff people (depending of the level of mechanization of the plant) (Macedo, 2005). Mechanization has cut job positions while also demanding more specialized staff.

Box 5: Small scale ethanol production technology developed in Brazil

Usinas Sociais Inteligentes (USI) has developed low-cost, small-scale ethanol production technology. A plant can produce between 500-5,000 liters per day from sugarcane, cassava, sweet potato or sweet sorghum. The present focus is on a 1,000 liter per day system which operates for 11 months of the year and would require 1 hectare of sugarcane per week (50ha/yr) to produce between 66-70kW of electricity in a continuously-operating) bioethanol electric generator. Depending on the end-use required, the ethanol could be used in converted tractors or vehicles or as a cook stove fuel to reduce the use of firewood and charcoal. Bagasse from the sugarcane process can be hydrolyzed and used as animal feed.

A 1,000liter/day unit would cost approximately US$100,000, plus shipping, erection, civil works and infrastructure. The costs of production are estimated at R$0.35-0.50/liter (US$0.18-0.25/liter)

The approach for cassava, sweet potato and sweet sorghum uses a raw starch-hydrolyzing enzyme. The liquefaction and saccharification are done simultaneously with yeast fermentation and without cooking. (The starch is hydrolyzed to glucose, which is converted to ethanol and CO₂ by yeast in a single production stage and under the same conditions which significantly helps to save time and energy during the process.

Waste treatment is critical. Biopolymers can be used remove the organic content of the effluents (through flocculation & coagulation) and to formulate the products for use in animal nutrition and as fertilizers. The remaining water meets discharge standards.

Source: Mallmann, pers comm
A study conducted by Balsadi in 2007 evaluated the level of education, income, benefits and formal job creation in the sugarcane sector and concluded that there had been significant socio-economic improvements in several indicators in the past decade: there were improvements in income, access to formal social security services, extra-hours payment and medical assistance, among others. Reductions in incidence of child labor and improvements in levels of basic school education have been established through rural workers associations, collective workers’ conventions and agreements and the improvement of labor legislation.

At present, bio-ethanol production per unit of energy produced demands 152 times more human labor than oil production, 50 times more than hydroelectricity production does and 38 times more than mineral coal production (Goldemberg, 2002). Even with the inevitable technology development and lower human demand imposed by modernization, bio-ethanol production will continue to generate higher quality jobs with increased average salaries. The Northeast migration of sugarcane workers to the Center-West is shown in Figure 19, which illustrates that the increasing move towards mechanization will not only impact workers in the Center-South, but also those in the Northeast.

**Figure 19: Migration of sugarcane workers for harvesting in Brazil and per capita Gross Internal Product (GIP)**

Compared to other sources of energy generation, sugarcane is behind only solar technology (both photovoltaic and thermal technology) in job creation, as shown in Figure 20. This demonstrates that the industry has a direct impact on the social development of low income population and small farmers.
Despite the opportunities and potential benefits, poor labor conditions are still documented. In 19 operations, mobile labor units (operated by the Government) released 2,553 victims from forced labor on sugar plantations. Approximately half of the more than 5,000 men freed from slave labor in 2008 were found exploited on plantations growing sugarcane for the production of ethanol, electricity, and food. Government officials and researchers also found that slave labor on Brazilian cattle ranches involves a higher degree of human exploitation; more so in land- and forest-clearing activities than in sugarcane production (US Department of State, 2009).

Labor trafficking is criminalized, which prohibits trabalho escravo ("slave labor"), including slavery by means of debt bondage. However, other means of non-physical coercion or fraud used to subject workers to forced labor, such as threatening foreign migrants with deportation unless they continued to work, is not necessarily criminalized. In 1995, Brazil’s Ministry of Labor and Employment created the Mobile Verification Task Force. The Government of Brazil it is making significant efforts to comply with the minimum standards for the elimination of trafficking. Last year, the government sustained strong efforts to rescue victims of slave labor through mobile inspection operations in the Amazon and other remote locations, and improved coordination of law enforcement efforts to prosecute and punish traffickers for forced labor crimes (US Department of State, 2009). **Effective coordination among differing federal, state, and municipal authorities is a challenge for effective monitoring and enforcement of labor legislation.**

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18 Pursuant to Section 149 of the penal code
6.3 Implications of environmental sustainability criteria on expansion plans

Based on unofficial information, 35 to 45 million hectares of land within areas where the bulk of sugarcane cropping already occurs are identified as sustainable (e.g., São Paulo, Paraná, Minas, Mato Grosso Sul and Goiás). The real ‘sustainable’ area is a matter of controversy and depends on the criteria set (Walter, et al., 2008). One of the key exclusion criteria in defining this area was existing cropland.

Based on GIS techniques used for this study, approximately 790 million hectares were identified as suitable for growing sugarcane based on geophysical criteria alone (e.g. soil type, rainfall and slope). When forest, peat land, protected areas and land with high soil, water, erosion, and flood risk are excluded, the amount of suitable land decreased to 100 million hectares, which could produce approximately 683,000 million liters of bioethanol.

Consideration of additional sustainability criteria would further reduce this figure. For example, excluding existing cropland area at around 77Mha (including existing sugarcane production) would reduce the area calculated to be sustainable and available to 23Mha, which could produce approximately 159,000 million liters of bioethanol. This amount of bioethanol represents over six times the 2008 gasoline consumption in Brazil of 25,175 million liters. By 2017, OECD-FAO (2008) projections suggest domestic consumption of around 32,000 million liters and exports of around 9,000 million liters. The analysis of high-level environmental criteria suggests this can be met.

The cerrado and grassland categories suitable for sugarcane production are in the region of 50Mha. Producing sugarcane on cerrado or grassland only, along with cattle intensification (so as to avoid indirect land use change) could produce 342,285 million liters of bioethanol. As only a proportion of this area would be available for production, owing to the additional use as pasture, the resulting production volume would be even lower. Nonetheless, use of only 25% of this area (around 12.6 million hectares) for sugarcane, would produce around 85,600 million liters of bioethanol. This is more than three times the national gasoline demand and still surpasses the OECD-FAO projections for domestic requirements and exports from Brazil in 2017.

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19 Understood to be Gasoline C which is 25% anhydrous ethanol with 75% fossil gasoline.
20 Assumes an average yield of 79t/ha in areas of ‘geophysical plus’ potential on cerrado and grassland and discounting a conservative 35% of the cerrado area for legal reserve)
Detailed studies on sugarcane suitability have been conducted for Sao Paulo state (see Figure 9). However, the key limitation of these approaches relates to the appropriate identification of pasture land, and in particular, the identification of degraded pasture land. The technical capacity exists within Brazil to undertake such work. Focusing resources on this effort would improve the accuracy of GHG emissions estimates and, therefore, would improve the capacity to make conclusions about biofuel sustainability.

Sustainability trade-offs?
The Northeast is one of the poorest regions of Brazil (see focus of biodiesel program in Section 7.1), and highlights tradeoffs that must be considered in a sustainability assessment of biofuel production. This region has a relatively small proportion of the national ethanol production (8% of national production), but ethanol is, nonetheless, an important industry for the region; the Northeast has around 50% of the jobs in the sugarcane and ethanol sectors, nationwide. This high concentration of labor is due to the region’s use of manual harvesting, whereas other regions’ ethanol industries are more mechanized.

To facilitate economic development in the Northeastern region, the Brazilian Government created the “New Irrigation Model Project”. This project is one of the 42 projects constituting the “Brazil in Action Program” and represents a new conceptual structure for the modus operandi of irrigation agribusiness (França & Gondim, 2000). A study on the economics of ethanol development at a large scale in the
Northeast, as part of an irrigation cluster has illustrated that the economics of sugarcane production for ethanol could be attractive. Although, production costs could be around R$728/m³, compared to around R$682/m³ in the Center-South, higher yields could be achieved by irrigation (over 100tons/hectare) such that the profitability would be reasonable. The payback period for this investment is estimated at around 10 years (Projetec, 2008)

Water issues, in addition to economic ones, must be taken into consideration in a sustainability assessment for this region. Brazil, in general, has plentiful rainfall, but the Northeast region has water scarcity issues, shown in Figure 22. Consequently, an environmentally-focused sustainability assessment would indicate that it is not a good region for sugarcane production.

**Figure 22: Water scarcity at a national scale**

![Water scarcity map](image)


A project, such as the New Irrigation Model Project, could influence societal indicators as well. Migration of sugarcane workers in Brazil occurs from the poorest regions of the country (in the North-Northeast region), to Sao Paolo State (the richest and the most important producer of sugarcane in Brazil - see earlier Figure 19). Increasing mechanized harvesting in the Center-South will lead to a substantial layoff of workers, negatively impacting the labor market and potentially socio-economic indicators in the Northeast states.
7.0 BIODIESEL IN BRAZIL

7.1 Sustainability priorities: socio-economic development

The Brazilian biodiesel policy has been developed specifically to address socio-economic development. The North and Northeast regions are the poorest regions of Brazil; according to the Brazilian Institute of Geography and Statistics, in 2006, 66% and 73% of people living in the North and Northeastern regions had the equivalent of a monthly per-capita salary of or below R$350 (US$175) per month, which is 40% to 50% less than the average in other regions (IBGE statistics). In addition, there are around 40,000 communities in the North region, many of which depend upon stationary diesel generators and therefore, logistics of fuel distribution mean that fuel scarcity is a real risk (Abreu, Viera, & Ramos, 2007). The biodiesel policy aims to address these issues.

The Brazilian biodiesel program has introduced mandatory targets and is characterized by specific objectives. These targets are:

- 2% blend (B2) by 2008 (changed to 3% by July 2008\(^\text{21}\)); and
- 5% blend (B5) by 2013.

The B2 blend represents approximately 800 million liters and B3 approximately 1,100 million liters. Installed capacity at the end of 2007 was around 1,600 million liters.

The National Biodiesel Production and Use Program (PNPB) is an innovative program trying to link an energy policy (biodiesel production) with a social policy (rural development and poverty reduction). It was established with the aim to ensure biodiesel is produced with an emphasis on social inclusion that aims to promote regional development through job creation and income generation. Under the program, biodiesel producers that buy at least a percentage of their feedstock from family farmers can receive the “Social Fuel Certification” (see next section) and sell their biodiesel to the national market.

PNPB’s three main objectives are to:

- Enhance environmental sustainability and social inclusion;
- Supply the market with biodiesel of high quality and at a competitive price; and
- Produce biodiesel in different regions of the country using a wide range of feedstock.

The political framework that coordinates efforts for biodiesel program development and implementation within the PNPB is shown in Table 7. The Inter-ministerial executive committee is formed by most of the ministries, but has an especially strong presence from the Ministry of Mines and Energy (MME), Ministry for the Environment (MMA), Ministry for Agriculture (MAPA), among certain others.

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\(^{21}\) CNPE - Resolution nº 2/2008
A central part of the PNPB is its “Social Fuel Certification” (SFC). The SFC was introduced to allow small farmers that live in the poorest regions of the country to receive some of the economic benefits created by the growing Brazilian biodiesel industry. In theory, only the biodiesel producers with the

### Table 7: Government ministries and their roles within the National Program for the Production and Use of Biodiesel (PNPB)

<table>
<thead>
<tr>
<th>Ministry</th>
<th>Interministerial Executive Commission</th>
<th>Management Group</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Cabinet of the Presidency of the Republic</td>
<td>Coordinator</td>
<td>X</td>
<td>Financial resources for drawing up and implementing the Program</td>
</tr>
<tr>
<td>Secretariat of Government Communications</td>
<td></td>
<td>X</td>
<td>Biodiesel publicity plan</td>
</tr>
<tr>
<td>Ministry of the Treasury</td>
<td></td>
<td>X</td>
<td>Taxes: price policies</td>
</tr>
<tr>
<td>Ministry of Transportation</td>
<td></td>
<td>X</td>
<td>Structuring, institutionalizing and monitoring program execution</td>
</tr>
<tr>
<td>Ministry of Agriculture, Livestock, Food Supply</td>
<td></td>
<td>X</td>
<td>Quantification of domestic and foreign markets</td>
</tr>
<tr>
<td>Ministry of Labor &amp; Employment</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ministry of Development, Industry &amp; Foreign Trade</td>
<td></td>
<td>X</td>
<td>Quantification of domestic and foreign markets</td>
</tr>
<tr>
<td>Ministry of Mines &amp; Energy</td>
<td>Coordinator</td>
<td>X</td>
<td>Establish boundaries of regions economically attractive for biomass production</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Determination of the growth ramp</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Industrial plants: commercial</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Risk analysis</td>
</tr>
<tr>
<td>Ministry of Planning, Budget &amp; Management</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ministry of Science &amp; Technology</td>
<td></td>
<td>X</td>
<td>Technological development</td>
</tr>
<tr>
<td>Ministry of Environment</td>
<td></td>
<td>X</td>
<td>Environment</td>
</tr>
<tr>
<td>Ministry of Agrarian Development</td>
<td></td>
<td>X</td>
<td>Social inclusion &amp; impacts</td>
</tr>
<tr>
<td>Ministry of National Integration</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ministry of the Cities</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>National Economic and Social Development Bank</td>
<td></td>
<td>X</td>
<td>Establish funding lines</td>
</tr>
<tr>
<td>National Petroleum, Natural Gas and Biofuels Agency (ANP)</td>
<td></td>
<td>X</td>
<td>Adaptation of the regulatory framework</td>
</tr>
<tr>
<td>Brazilian Petroleum Corporation</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Brazilian Agricultural Research Corporation</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
SFC could sell biodiesel in the national market. The National Petroleum, Natural Gas and Biofuels Agency (ANP) uses the SFC to evaluate the total production capacity of biodiesel producers; only if biodiesel producers are unable to meet the market demand with SFC biodiesel, will the market be open also to those producers without SFC. This flexibility has been introduced in the market because of the difficulties in engaging small farmers in feedstock production.

The SFC certification is given to biodiesel producers that fulfill three main conditions:

1. **Feedstock is supplied by small farmers**: The first condition is that biodiesel producers acquire a minimum amount of feedstock from ‘small’ producers and family farmers. The amount has been established based on the share of small farmers that live in the different regions of Brazil (listed in Table 8). For example, the Northeastern and semi-arid regions are the poorest of Brazil and experience a land concentration problem (few and powerful large land-owners dominate land ownership), but also have the highest concentrations of small farmers. Therefore, the SFC requires that biodiesel producers located in these regions buy a larger share of feedstock from small farmers.

2. **Contracts**: The second condition is that the feedstock is bought through contracts so that the farmers know who their buyer will be and at what price and under what conditions the exchange will take place. This is also a way to introduce contracts among small farmers and protect them in case biodiesel producers do not pay the agreed amount. Contracts are signed in partnership with, or under the supervision of, civil society organizations. Although the government does not outline how the partnerships are created, they do provide some guidance by way of existing methodologies developed by the Ministry of Agricultural Development, such as the ATER, the Rural Extension service, which aims to support small farmers e.g. EMATERCE (www.ematerce.ce.gov.br) in the state of Ceará.

3. **Technical assistance**: The third condition is that the biodiesel producer is also responsible for technical assistance and for the preparation of the overall agricultural production framework. It is the industry’s responsibility to guarantee that the farmers are empowered and develop appropriate technical capacity.

<table>
<thead>
<tr>
<th>Geographical region</th>
<th>Participation of family agriculture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>10%</td>
</tr>
<tr>
<td>Northeast and semi-arid</td>
<td>30% (originally 50%)</td>
</tr>
<tr>
<td>Center-west</td>
<td>10%</td>
</tr>
<tr>
<td>Southeast</td>
<td>30%</td>
</tr>
<tr>
<td>South</td>
<td>30%</td>
</tr>
</tbody>
</table>

Source: PNPB (www.biodiesel.gov.br)
Companies that have the SFC may also get a net reduction of total federal taxes, depending on the region and type of feedstock used, as shown in Table 9.

Table 9: Reduction of fiscal taxes for biodiesel produced in specific regions and activities

<table>
<thead>
<tr>
<th></th>
<th>North</th>
<th>North and semi-arid</th>
<th>Center-West</th>
<th>Southeast</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family farmers</td>
<td>100%</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Agri business</td>
<td>30.5%</td>
<td>30.5%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Castor seed</td>
<td>100%</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Palm tree</td>
<td>100%</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Any raw material</td>
<td>67.9%</td>
<td>67.9%</td>
<td>67.9%</td>
<td>67.9%</td>
<td>67.9%</td>
</tr>
</tbody>
</table>

Source: Pousa et al, 2007

The tax reduction is used as an incentive to encourage entrepreneurs to invest in the particular region and compensate them for the higher risks associated with working in less economically developed areas. The Brazilian government has especially been supporting the use of castor bean and oil palms (“dende”). SFC certified companies or projects which provide fiscal evidence of purchase from small farmer are also entitled to receive the following financial benefits:

- Up to 90% financing of the industrial facilities at the official long-term interest rates, plus 1% for micro, small and medium projects, and plus 2% for large projects;
- Biodiesel purchase agreements with ANP at a pre-established price;

For farmers, the Brazilian government has introduced favorable financing mechanisms to purchase machinery that can already use a minimum of a B20 blend, such as tractors and other harvesting machines. Small farmers have access to credit lines (Pronaf) at subsidized interest rates (1-4%) to buy seeds and basic equipments to start producing appropriate feedstock. The total amount of credit allocated to support small farmers was US$50 million in 2005/06.

Despite these initiatives, the production capacity of biodiesel producers with SFC is not enough to fulfill the full demand for B3 of around 1,100 million liters. The national production of biodiesel in May 2009 was 103.7 million liters, which was 1.3% lower than production in April 2009, but 36.4% greater than in May 2008. The accumulated production in 2009 has increased by 42.1% compared to same period in 2008. Latest figures in September 2009 indicate authorized capacity has increased to around 360 million liters – still only one third of the required volume for the mandate. The majority of existing biodiesel is supplied by soy oil.

---

22 CIDE, fixed at 0.07 R$/l and PIS/COFINS fixed at 0.148 R$/l and a state tax (ICMS) which varies.
Table 10 illustrates that existing planted area of crops other than soy could almost meet a B2 mandate but there are other alternative uses at present.

Table 10: Potential biodiesel production from alternative feedstocks than soy oil based on planted hectares

<table>
<thead>
<tr>
<th>Region</th>
<th>Current diesel demand (liters)</th>
<th>Potential biodiesel production peanut (liters)</th>
<th>Potential biodiesel production Castor bean (liters)</th>
<th>Potential biodiesel production sunflower (liters)</th>
<th>Potential proportion of diesel demand met</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>4,028,755,708</td>
<td>166,363</td>
<td>405,230</td>
<td>-</td>
<td>0.01%</td>
</tr>
<tr>
<td>Northeast</td>
<td>6,714,592,846</td>
<td>4,801,811</td>
<td>44,463,192</td>
<td>10,251</td>
<td>0.73%</td>
</tr>
<tr>
<td>Southeast</td>
<td>20,143,778,538</td>
<td>84,734,073</td>
<td>3,475,689</td>
<td>-</td>
<td>0.44%</td>
</tr>
<tr>
<td>South</td>
<td>8,952,790,461</td>
<td>6,233,752</td>
<td>359,849</td>
<td>10,910,012</td>
<td>0.20%</td>
</tr>
<tr>
<td>Center-West</td>
<td>4,924,034,754</td>
<td>5,470,916</td>
<td>2,016,540</td>
<td>18,930,983</td>
<td>0.54%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>49,176,653,562</strong></td>
<td><strong>131,525,930</strong></td>
<td><strong>1,129,661</strong></td>
<td><strong>426,423,192</strong></td>
<td><strong>1.92%</strong></td>
</tr>
</tbody>
</table>

* Based on planted hectares (IGBE 2008 statistics)

According to businessmen and specialists in the industry, there are a number of bottlenecks that prevent growth in the biodiesel market:

- The lack of a viable raw material plant for the rapid expansion of the program;
- The system tenders for the purchase of biodiesel made by ANP;  
- The uncertainty over the Petrobras's role in the biodiesel industry;  
- The entry of many investors in the sector in a short time, which should keep the excess production capacity in coming years; and
An undeveloped supply chain for the transport of fuel from biodiesel plants to the Petrobras refineries where the mixture with the mineral diesel will be made. Tank trucks transport most of the biodiesel for blending and distribution.

The economics of the biodiesel industry and implications for socio-economic development are discussed in the following section.

### 7.2 Biodiesel economics

The share of diesel consumption by region has not changed substantially over the past 10 years. The Southeast dominates, with a 45% share of total diesel consumption in 2007, while the North represented only 9% of total diesel consumption in the same year.

**Figure 24: Sale of diesel in the different regions of Brazil**

The average price of diesel to consumers varies between the different regions. The North is the most expensive region (R$1.99/liter in 2007), closely followed by the Center-West (R$1.97/liter in 2007). The Southeast and Northeast are the least expensive (around R$1.85/liter in 2007). In 2007, the price of diesel in the South was R$1.89/liter.
Lowest priced bids for biodiesel sales win supply contracts
Since 2005, ANP has undertaken reverse auctions for biodiesel sales. These auctions happen regularly, three to four times per year. The fuel usually needs to be delivered to the ANP within six months to a year from the day of the auction. The ANP assigns quotas to all the distributors to mix the biodiesel with regular diesel. Several days before the auction, the maximum price to be paid for the biodiesel is communicated. The volume of biodiesel to be auctioned is divided into ‘lots’. The company that will provide the largest volume for the lowest price wins the lot. The reference price is determined based on the price of vegetable oil, as this accounts to 80% to 90% of the total production costs.

The initial objective of the auction was to create a market to stimulate production of sufficient quantities of biodiesel for the market. Since the beginning of the PNPB program there have been 14 auctions undertaken by ANP to secure the minimum legal mandatory mix (3%) of biodiesel into the petro diesel. Petrobras has issued several other auctions to create a stockpile to compensate for fluctuations, in case the biodiesel plants cannot produce as expected. Owing to limited supplies of biodiesel with the Social Fuel Certification, the 9th auction was open to producers without such certification.

Biodiesel and feedstock economics
High feedstock prices are the major deterrent to biodiesel producers. Oilseed prices nearly doubled in 2008 and were traded at a rate of US$1,200-2,000/ton, which represents a fixed cost of US$1-1.8/l. Transesterification, transport, taxes and marketing add an additional 25-40% for a total cost at the pump of 2.2-3.2 R$/l (1.2-2 US$/l). At the beginning of the auctions, the maximum offering price was close to the diesel price (1.9 R$/l). However, because of high feedstock prices, most of the producers sold at a loss, and ANP and Petrobras subsequently raised the maximum bid price to R$ 2.8/l in 2008.

Since fossil diesel prices in Brazil were below 2.00 R$/l in 2006 and 2007 (around 1-1.20 US$/l), it is clear that it is not currently cost competitive to produce biodiesel for diesel displacement.
The extra cost of production associated with higher feedstock prices is passed on to consumers. The B3 mandate resulted in an extra cost of R$0.08/l of diesel.

Brazil has many different feedstock options with different production costs (see Section 8.1). Soybean, though, is by far the main source of feedstock for biodiesel. In 2006, the joint production of castor bean, cotton seeds and peanuts was just 6% of the soybean production. To achieve the B3 blend, in 2008, Brazil needed about 945,000 tons of vegetable oil, equivalent to just 8-10% of the current Brazilian soybean production. The same requirements would have absorbed almost the whole volume of other oilseed production.

Soybeans are the main biodiesel feedstock sourced from Brazil for biodiesel production in other countries and regions (such as the EU). Generally the beans or oil, rather than the finished biodiesel itself, is exported.

- Brazilian soy bean production 2008: approx 61MT
- Brazil soy bean export in 2008: 24.5 MT (US$ 10,952 million)
- Brazil soy oil export in 2008: 2.31 MT (US$ 2,671 million)
- Brazil biodiesel production in 2008: 1.16 billion liters

There is a lack of robust data on how much biodiesel originates from soy globally, as well as how much biodiesel originates from soy from Brazil. Therefore it is not possible to say definitively how much of the Brazilian production will be impacted by sustainability standards. Anecdotally, 5% of biodiesel is assumed to be produced from vegetable oil and a large proportion is imported as beans.
and crushed in Europe. If 5% of Brazilian soybean export was affected by such sustainability standards this would represent around 1.2MT (or US$548 million).

**Soybean production and economics**

Economics plays a key role in determining quantity and location of land for crop expansion. While soy oil is the feedstock used for biodiesel, Figure 26 illustrates the fact that soybean meal is the primary economic driver for planting. Despite higher prices for soy oil than soybean meal on a by weight basis, one hectare of soy yields around 0.4 t of oil and 2.06t of meal. Therefore, returns for each product on a value per area of land, basis favor soybean meal. Future increases in meat demand will require increases in protein feedstuffs, of which soymeal plays a key role.

**Figure 26: Productivity and value per hectare of soy products**

Yields and transportation infrastructure play a significant role in production costs. Despite lower production costs per hectare, Rio Grande do Sul has yields of only 2.5t/ha and therefore has comparable costs per tonne to Mato Grosso, which has higher production costs per hectare (given the infrastructure logistic) but higher yields of 3t/ha. Para state has both high costs per hectare and low yields, and therefore has higher costs per tonne. Plantation costs are responsible for the largest contribution to cost of production (between 57%-63% for the three states shown in Figure 27). Post harvest costs (including transportation) account for 10%-11%, and land rent accounts for 10%-19% (based on CONAB statistics). Mato Grosso has the lowest land cost per hectare but highest cost of production, whereas Rio Grande do Sul has highest land cost but lowest cost of production on a per hectare basis. The cost of land is therefore, as important a variable in cost of production as post harvest cost.

Figure 27: Comparison of soybean cost of production for three Brazilian states in the 2008/09 crop season

Improving productivity
Genetically modified (GM), or transgenic, crops have been addressed within some standards, including the Roundtable in Sustainable Biofuels. Brazil is the world leader in production of non-GM soy, which represents 40-45% of total production in Brazil. Goiás is among the main Brazilian producers of non-GM soy, alongside Mato Grosso, Paraná, Tocantins and Bahia. There is one approved GM variety that is used in Brazil. Table 11 provides an estimation of the planted area for soybeans in Brazil.

Table 11: Estimated planted area for GM and non-GM soybeans in Brazil

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000 ha</td>
<td>%</td>
<td>1000 ha</td>
</tr>
<tr>
<td>Total</td>
<td>21.313,10</td>
<td>100%</td>
<td>21.563,10</td>
</tr>
<tr>
<td>GM</td>
<td>11.935,34</td>
<td>56%</td>
<td>11.859,71</td>
</tr>
<tr>
<td>NonGM</td>
<td>9.377,76</td>
<td>44%</td>
<td>9.703,40</td>
</tr>
<tr>
<td></td>
<td>8.840,00</td>
<td>40%</td>
<td>8.840,00</td>
</tr>
</tbody>
</table>

Source: ABRANGE, 2009 pers comm.

There are no official statistics, however, about how much of Brazil’s soy crops are GM. For the next crop year (2009/2010) ABRANGE estimates that the GM soybean will account for 60% of the total planted area of Brazil. These figures are expected to remain relatively constant unless the benefits
that are promised by new biotechnology are not realized, and consequently, farmers switch to non-GM soy.

Figure 27 illustrates the key role that yield plays in improving the economics of production per ton of product. For soy, **GM varieties have been seen as a key technological innovation to increase yields.** GM soy can, for example, be grown on degraded lands to recover the productivity of an area. In just the first couple of years, these crops can offer a higher yield than standard varieties.

**However, productivity varies by region and management practices.** GM soy has not benefited from a breeding program that has adapted their use to this area therefore the non-GM yields are currently better. In the state of Mato Grosso, non-GM soybeans have a higher productivity than the GM soybeans (ABRANGE *pers comm*; Negri, *pers comm*). Table 12 illustrates that owing to the productivity gains from non-GM soy in Mato Grosso, total production costs are R$126/ha lower than GM-soy.


<table>
<thead>
<tr>
<th>Region</th>
<th>Variety</th>
<th>Total Cost (R$/ha)</th>
<th>Total cost (bags²/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campo Verde</td>
<td>GMO</td>
<td>1936</td>
<td>49.2</td>
</tr>
<tr>
<td>Canarana</td>
<td>GMO</td>
<td>1708</td>
<td>46.7</td>
</tr>
<tr>
<td>Diamantino</td>
<td>NGMO</td>
<td>1652</td>
<td>43.2</td>
</tr>
<tr>
<td>Sapezal</td>
<td>NGMO</td>
<td>1723</td>
<td>46.9</td>
</tr>
<tr>
<td>Sorriso</td>
<td>NGMO</td>
<td>1715</td>
<td>46.2</td>
</tr>
<tr>
<td>Average GMO</td>
<td>GMO</td>
<td>1822</td>
<td>47.9</td>
</tr>
<tr>
<td>Average NGMO</td>
<td>NGMO</td>
<td>1696</td>
<td>45.4</td>
</tr>
<tr>
<td>Difference</td>
<td>GMO - NGMO</td>
<td>126</td>
<td>2.5</td>
</tr>
</tbody>
</table>

1 Number rounded
2 1 bag = 60kg

Source: ABRANGE, per comm.

The use of GM varieties, often to recover productivity of degraded lands, has caused yield problems because of weed infestation because of the resistance of the crop to glyphosate (herbicide). There are 12 known types of weeds that have caused yield losses (up to 40%) around the globe. This is especially true in Brazil, where there are two species of super-weeds: *Conyza Benariensis* and *Conyza Canadensis*, called ‘buva’. In the South of Brazil, around 9Mha of land is infested with buva and subsequently is negatively impacting the productivity of soy (ABRANGE, *pers comm*). Embrapa is conducting research into relevant management practices that can reduce the superweed problems, such as including crop rotations to reduce weed infestation.
Embrapa has also developed a rust-resistant variety of soybeans for use in the Center-West. This variety is likely to be released for use in the 2010/11 crop year. Rust that is not controlled can cause losses of up to 70% of the soybean crop. Soybean producers will still need to use fungicides, but instead of three (the average in Brazil) or more applications, as currently needed in many parts of the country, the rust-resistance variety will only need one. The average cost for spraying against rust in Brazil is US$50 per acre (for the three applications). Under the current system, spraying at the right time is challenging for farmers (especially those with large land areas), and with rust-resistant varieties, farmers will have a greater timeframe in which they may spray.

The dominance of soy biodiesel

Table 13 illustrates the discrepancy between the focus of the PNPB on socio-economic development in the North and Northeastern regions and the reality of where current production areas are located. In 2005, over 90% of biodiesel production took place in the North and Northeast, and in 2009 these regions only produced 11%. Most of the biodiesel production today is concentrated in the South and Center-West, where most of the soybeans are produced and where biodiesel demand is greatest.

Table 13: Share of production volume of biodiesel by region.

<table>
<thead>
<tr>
<th>Region</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>69.3%</td>
<td>3.5%</td>
<td>6.6%</td>
<td>1.4%</td>
<td>2.2%</td>
</tr>
<tr>
<td>Northeast</td>
<td>21.2%</td>
<td>50.4%</td>
<td>42.6%</td>
<td>10.8%</td>
<td>8.7%</td>
</tr>
<tr>
<td>Southeast</td>
<td>6.0%</td>
<td>31.2%</td>
<td>9.2%</td>
<td>15.9%</td>
<td>18.6%</td>
</tr>
<tr>
<td>South</td>
<td>3.5%</td>
<td>0.1%</td>
<td>10.6%</td>
<td>26.8%</td>
<td>28.5%</td>
</tr>
<tr>
<td>Center-West</td>
<td>0.0%</td>
<td>14.7%</td>
<td>31.1%</td>
<td>45.1%</td>
<td>42.0%</td>
</tr>
</tbody>
</table>

Source: ANP statistics

7.3 Existing domestic legislation, codes, and programs

Table 4 and Section 5.4 illustrated many of the laws relevant to environmental and social issues for agriculture in general in Brazil. This section largely focuses on other programs that are specifically relevant for issues concerning soy cultivation.

Deforestation (land use change)

Deforestation and accompanying impacts on GHG emissions and loss of biodiversity are some of the most widely discussed topics of biofuel sustainability. The Brazilian Forest Code allows owners of a property under transition forest to clear 50% of the land for development, whereas only 20% of rainforest is allowed to be cleared. Owners of cerrado lands can clear a much larger proportion of their area (65-80%).

So far, direct conversion of natural habitats in the Legal Amazon to soy cultivation has been limited to the cerrados of Tocantins and Rondônia, Campos Naturais or poorly drained savannahs in the Humaitá region of Amazonas state and the Lavrado savannahs of Roraima. Where soy has been
planted in former transition land or rain forest, mostly in Pará, Mato Grosso and Tocantins, it has been in areas that had previously been cleared for cattle production or subsistence farming (Dros, 2004). The development of soy storage and transport facilities in Mato Grosso, Pará and Rondônia increases pressure on deciduous transition forests, between the drier cerrado ecosystem and the Amazon Rainforest (Dros, 2004).

Brazil has developed a number of innovative approaches to monitoring the production and expansion of soy, detailed in the following sections.

**Soy and sustainability – The Soy Moratorium:**
The Soy Moratorium in the Amazon Biome was declared in 2006 by industries and exporters associated to ABIOVE\(^23\) (Associação Brasileira das Industrias de Óleos Vegetais/Brazilian Association of Vegetable Oil Industries) and ANEC. The Moratorium was recently renewed through 2010.

In the 2008/09 crop season, soybean cultivation was recorded in 2,157ha (1,385 of plantations), out of a total monitored area of 157,896ha. Plantations represent 0.88% of the total monitored area and 1,025ha (or 74%) are found in the state of Mato Grosso, with the remainder located in Para. The remainder of land occupation in 2008 was classified as pasture, natural regeneration, deforested, cleared by fire, rice land or forest.

**Table 14: Monitoring within the Soy Moratorium**

<table>
<thead>
<tr>
<th></th>
<th>Monitored area in 2009 (ha)*</th>
<th>Increase in monitored area from 2008</th>
<th>Total soybean area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mato Grosso</td>
<td>123,415</td>
<td>71%</td>
<td>5,811,907</td>
</tr>
<tr>
<td>Para</td>
<td>31,007</td>
<td>56%</td>
<td>70 810</td>
</tr>
<tr>
<td>Rondônia</td>
<td>3,474</td>
<td>80%</td>
<td>103,110</td>
</tr>
<tr>
<td>Total</td>
<td>157,896</td>
<td>68%</td>
<td></td>
</tr>
</tbody>
</table>

* Numbers are rounded and therefore may not sum exactly
Source: ABIOVE, IBGE statistics

**Soy and sustainability - Lucas do Rio Verde, Brazil:**
The municipality of Lucas do Rio Verde, whose 200Mha of soy fields account for 1% of Brazilian grain production, brought together farmers, industries and non-government organizations\(^24\) to evaluate and solve environmental and labor problems of its local rural properties. In a one year period, the group

\(^{23}\) Formed in 1981 and has 12 members companies who are responsible for approximately 72% of Brazil's soybean processing volume. ABIOVE's objective is to represent the vegetable oil industries, cooperate with the Brazilian government with regard to policies related to this sector, promote Brazilian products, support its members, generate statistics and prepare sectoral studies.

\(^{24}\) Coordinated by the City of Lucas do Rio Verde and by the non-profit, The Nature Conservancy, and supported by Syngenta, Figril, Sadia, Instituto Sadia de Sustentabilidade, Lucas do Rio Verde Rural Trade Union, Fundação Rio Verde, the local prosecutor and the Environmental Secretary of Mato Grosso state.
analyzed the vegetation of 670 farms. Over 10% of the vegetation coverage that should have been preserved had been removed – and legally would have to be recovered. The municipality’s efforts identified financial mechanisms and other funding sources that might sponsor the adoption of low impact technologies and the promotion of the social and environmental activities to make the corrections required.

Summary
Based on information in Section 5.4 and that presented here, there are existing programs, codes and legislation which should be benchmarked against requirements in external markets (for sustainability standards) to ensure maximum use is made of existing participation of producers in national initiatives to avoid duplication of efforts and costs.

8.0 ISSUES FOR SUSTAINABILITY STANDARDS AND BIODIESEL IN BRAZIL

8.1 Socio-economic issues

The challenge of feedstock economics for PNPB and socio-economic development

The PNPB program is intended to increase income for small farmers. Government studies forecast that replacing just 1% of fossil diesel with biodiesel from family farms would directly help create 45,000 jobs at an average cost just over R$4,900 per job (family agriculture employs one worker per 10 hectares, whereas commercial agriculture employs one worker per 100 hectares). Furthermore, every R$1 invested in family agriculture adds R$2.13 to the family’s annual gross income. There is also a multiplier effect for employment; in reality, for each job that is directly created, three additional jobs are indirectly created, and therefore a total of 185,000 jobs could be created by including 1% biodiesel.

The regional soybean production model is based the typical agri-business principles of large-scale, mechanized monocultures, especially of transgenic (GM) soy. However, the socio-economic and environmental impacts of this production model do not help, and sometimes harm, small farmers. The main criticism made by several NGOs in the region, is that transgenic (GM) soy tends to be profitable only under the following conditions:

- Land above 50 hectares;
- Location in flat lands or on gentle slopes;
- Fully mechanized land preparation, maintenance and harvesting; and
- Use of fertilizers and chemicals to boost yield and control pests.
These conditions are not feasible for small farmers of states like Rio Grande do Sul, that usually own less than 20-30 hectares. Their lands are often located in steep, less productive or less accessible areas. They do not own tractors and usually have to rent all the machines that are required to grow transgenic (GM) soy. For all of these reasons, their production costs are much higher than those of large land owners and producers. Table 15 gives an indication of the average production and income of small farmers that use 20 hectares of land to produce soy. The margins, on average, are limited, and a year with a lower yield can bring severe economic losses.

**Table 15: Soybean production costs and income of an average family of farmers in Rio Grande do Sul**

<table>
<thead>
<tr>
<th>.Quantity (1 bag=60 kg)</th>
<th>R$/Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average local price of soybeans (10 years)</td>
<td>1 bag</td>
</tr>
<tr>
<td>Land productivity, soybeans</td>
<td>30-35 bags/Ha</td>
</tr>
<tr>
<td>Input cost: fertilizers, pesticides, machineries</td>
<td>20-30 bags/Ha</td>
</tr>
<tr>
<td>Net income, per hectare</td>
<td>0-15 bags/Ha</td>
</tr>
<tr>
<td>Net income, per farmer, per 20 Hectares</td>
<td>0-300 bags</td>
</tr>
<tr>
<td>Average monthly income from soybeans</td>
<td>0-25 bags per month</td>
</tr>
<tr>
<td>Average monthly income per farmer</td>
<td>12.5 bags per month</td>
</tr>
<tr>
<td>Minimum monthly salary in Brazil in 2008</td>
<td>0-15 bags/Ha</td>
</tr>
</tbody>
</table>

Source: COOPERBIO

Growing soybeans in the southern states has often proved to be unsuccessful for small farmers. Farmers that have fully embraced the agri-business model based on soy, usually receive the bulk of their income during one or two periods per year, when their products are sold to processing and refining plants. Family farmers though, need a more stable monthly income to plan local expenditures and investment.

The Northeastern region is climatically diverse. The Zona da Mata is an area of significant, commercial scale agriculture; 15% of national sugarcane production is produced there. The area’s history of sugarcane production has engendered a culture of monoculture, rather than rotational farming. There appears to be a lack of research to identify agricultural alternatives and there are few experimental plantations that could advance regionally-appropriate biofuel opportunities. In the semi-arid zone, the climatic conditions have supported beans, cotton, cassava and corn. Castor has been grown there successfully, owing to the potential to intercrop and rotate with existing crops. Western Bahia and southern areas of states of Maranhao and Piaui are cerrado areas, and palm is seen to

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25 Data provided by Marcelo Leal, Executive Director of COOPERBIO, on March the 3rd-5th 2008.
have important potential; babassu palms in Maranhao cover around 18 Mha (Abreu, Viera, & Ramos, 2007).

Researchers in the Northeast are focusing on castor beans for biofuel; this region accounts for around 96% of national castor bean production (200,000t annually), with Bahia being the leading producer in the state. There are reportedly more than 3 Mha of land where castor beans could be farmed in the region under dry conditions, yielding 1.2t/ha with 47% oil content. Experiments with mechanized castor bean farming have also been undertaken in the Northeast (Abreu, Viera, & Ramos, 2007). However, the Northeastern region still has very low crop yields because of structural problems related to technology access, agricultural capacity, credit and recurrent droughts. Owing to this, farmers are unlikely to get a major benefit from castor beans because of the low yields. It is possible that with new castor bean varieties (such as the BRS energia), the feasibility will improve.

According to data from the biodiesel production plant of Quixada, in the state of Ceara, small farmers that produced castor beans were just earning about R$200 per hectare per year. This is about 50% of the minimum income required. Although this production was heavily supported by the Brazilian government, so far, the results in terms of social benefits have been below expectations. Small farmers in the poorest regions of Brazil grow seed oil on two to three hectares of land, and therefore, the contribution of castor bean to their total income is limited (Table 16).

**Table 16: Income of small farmers from the production of biodiesel feedstock**

<table>
<thead>
<tr>
<th>Productivity, cotton (Kg/Ha)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity, cotton seed (R$/Ha)</td>
<td>840</td>
</tr>
<tr>
<td>Price paid, cotton seed (R$/Kg)</td>
<td>0.95</td>
</tr>
<tr>
<td>Ratio Income/Min per month salary (R$415/ Ha), cotton</td>
<td>2.0</td>
</tr>
<tr>
<td>Productivity, castor Nordestina Municipality (Kg/ Ha)</td>
<td>650</td>
</tr>
<tr>
<td>Productivity, castor Nordestina Municipality (R$/Ha)</td>
<td>155</td>
</tr>
<tr>
<td>Price paid, castor seed Nordestina Municipality (R$/Kg)</td>
<td>0.70</td>
</tr>
<tr>
<td>Ratio Inc./Min. per month salary castor Nordestina Muni.</td>
<td>0.4</td>
</tr>
<tr>
<td>Productivity, castor BRS Energia (Kg/ Ha)</td>
<td>1200</td>
</tr>
<tr>
<td>Productivity, castor seed BRS Energia (R$/Ha)</td>
<td>540</td>
</tr>
<tr>
<td>Price paid, castor seed BRS Energia (R$/Kg)</td>
<td>0.70</td>
</tr>
<tr>
<td>Ratio Inc./Min. per month salary (R$415 per Ha), castor BRS</td>
<td>1.3</td>
</tr>
<tr>
<td>Productivity, sunflower (Kg/ Ha)</td>
<td>900</td>
</tr>
<tr>
<td>Productivity, sunflower (R$/Ha)</td>
<td>150</td>
</tr>
<tr>
<td>Price paid, sunflower seed (R$/Kg)</td>
<td>0.50</td>
</tr>
<tr>
<td>Ratio Inc./Min per month salary (R415R$ per Ha), sunflower</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Source: PBNB, based on the production cost of the Quixada biodiesel plant of Petrobras, state of Ceará
The opportunity costs for pursuing alternative feedstocks to soy are high. According to data presented in Table 15 & Table 16, soybeans require higher investment costs, but could produce higher returns per hectare (R$0-525/ha), compared to sunflower (Rs 150/ha) about the same as castor (R$155–540/ha) but less than cotton (R$840/ha).

The economics of biodiesel in different regions of Brazil is likely to drive different feedstocks and business models. One study (Barros, Silva, Ponchio, Alves, Osaki, & Cenamo, 2007) explored the regional variations in Brazil and concluded that:

- Biodiesel produced from cottonseed would be more cost competitive (production cost of R$0.71/l) than castor beans (production cost of R$2.2/l), in the Northeast region.
  - Cottonseed is expected to be able to supply a 40,000t/yr biodiesel plant, but other markets for the cottonseed will provide price competition which could drive up production costs.
- Biodiesel produced from soybean would be more cost competitive (R$0.95/l) than from sunflower (R$1.25/l) or cottonseed (R$0.98/l), in the Center-West region.
  - However, regions of the Center-West may be not meet environmental sustainability criteria set by international sustainability standards for growing soybean.
- Biodiesel produced from sunflower seeds would be the more cost competitive (R$0.89/l) than from soybean (R$1.42), in the South.
  - However, sunflower farming is rare, and scale and irregularity of supply would be significant obstacles.

Summary
Biodiesel is still playing a minor role in the biofuel industry in Brazil, especially when compared to ethanol. The implementation of the PNBP is presenting several challenges e.g. selection of the most appropriate feedstock, feedstock supply, farmers’ engagement, creation of the right incentives to biodiesel producers and logistics. The PNBP is still under development and it is therefore too early to draw final conclusions. However, biodiesel currently appears to present limited social benefit for the poorest regions and for the smallest farmers, as evidenced by the following points:

(i) The share of oilseed from small farmers has been lowered from 50% to 30% in the Northeast region;

(ii) Today, about 90% of biodiesel in Brazil is produced in the richest areas (South, Southeast and Center-West);

(iii) Nearly all of Brazil’s biodiesel is produced with soy oil, which is produced mostly on large monocultures and only marginally by small farmers.
Box 6: Native oleaginous trees and oil palm

Oil can also be derived from tree species native to the Amazon. One project has identified 11 native species including Virola, Andiroba and Acai that are suitable for reforestation and recuperation of degraded areas. Source: http://www.ecomapua.com.br/projects.html

Brazil has large areas suitable for oil palm production (see maps below) but since many are located in the North and Amazon basin much of the area is protected. In the North and Northeast of the country, there is a lack of electricity distribution infrastructure in remote communities and most of the energy generation is based on fossil diesel and is more expensive than hydropower. Development of local sources of fuel could address these environmental and socio-economic issues.

Agropalma is the largest producer in Brazil and has contracts with independent landowners that live near by the production area. Agropalma provides necessary inputs for palm cultivation, courses and technical assistance. The group works on environmental projects supported by Conservation International. While opportunities exist to plant oil palm on degraded pastures, there are limitations to its development. With high levels of investment and a long lag time (more than 4 years) before palms mature to provide returns on the investment the opportunity costs are high. In addition, planting on degraded land requires reforestation of 80% of the area which can impact on investment returns with no financial reward.
8.2 Environmental issues

Environmental issues considered by many of the sustainability standards were discussed in relation to bioethanol in Section 6.0. The sections on water quality and quantity broadly covered soy and therefore the environmental issues considered in this section focus on GHG emissions.

Soy-biodiesel and process GHG emissions

Studies of process GHG emissions for soybean biodiesel from Brazil do not illustrate as favorable of a GHG balance as for sugarcane. Figure 28 illustrates that yield is the most significant determinant of the overall emissions, and the co-product credit for soymeal plays a large role as well. Despite the significant transportation distance (by sea) from Brazil to the EU, in this example, transportation is not a key parameter and, in fact, domestic transportation to the crush (by truck, and therefore less efficient) has almost as high an influence as the co-product credit does.

Figure 28: Sensitivity analysis of GHG emissions of Brazilian soybean exported to the EU and processed to biodiesel (gCO2eq/MJ)

Source: Data based on RFA, 2008

EU values for GHG saving

As part of the EU Renewable Energy Sources Directive the EU has defined typical and default values for biofuels that must be used (if no net carbon emissions from land-use change can be shown). The legislation defines that soy biodiesel has a default GHG saving of 31% which is below the threshold
of 35% where that biofuel is allowed to count towards the EU mandate. Therefore, producers wishing to demonstrate their compliance with the GHG saving minimum of 35% are required to show that actual emissions from their production process are lower than those that were assumed in the calculation of the default values. This means the provision of qualitative and/or quantitative data and verified calculations.

**US values for GHG saving**

Based on analysis by the California Air Resources Board as part of its rulemaking for the Low carbon Fuel Standard, Midwest soybean biodiesel for use in the US represents a **GHG saving (excluding land use changes) of 78%**. Including land use changes (through a modelling exercise to forecast land use implications) reduces these GHG savings to **12%**. The US EPA is undergoing a similar exercise but results are not available at the time of writing.

**GHG emissions, land use change and management practices**

Gibbs et al (2008) conducted a regional assessment of the yield potential for crop production and credited the associated biofuel production with displaced fossil gasoline and diesel emissions. The results are shown in Figure 29, which illustrates the carbon payback times for different feedstocks and reference land uses. The examples do not include the well-to-wheel emissions of biofuels which would increase the payback time but represent a high yield situation (crop-specific yields across the world are in the 90th percentile) and therefore represent faster payback periods than a current yield scenario.

The range of carbon payback years for each of the bars in Figure 29 illustrates it is not generally possible to make definitive claims about the specific carbon impacts of land use change based on generic land categories such as woody savannah. Soybeans, owing to lower yields than other crops, have longer carbon payback periods for conversion from most land categories, but this is also true for castor bean (one of the products promoted by the PNPB – National Biodiesel Production Program – to for socio-economic reasons) While degraded pasture (from a carbon perspective) or cropland offers a good opportunity for these feedstocks from a carbon perspective, above & below ground carbon data differ substantially across woody savannah biomes for example and represent significantly different emissions associated with conversion to cropland. Soil carbon stocks also vary substantially and are not robustly mapped at detailed scales which could significantly alter results.

Opportunities for increasing carbon sequestration through better management practices can be realized, but have not yet been included within many well-to-wheel and land use change analyses for biofuels. The potential size of this opportunity is wide ranging, according to different sources. There is evidence that through judicious management, it is possible to increase the soil organic carbon pool in some soils and agro-ecosystems. Reducing tillage has been cited as a best management practice.

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26 Process emissions of 21.25gCO₂eq/MJ biodiesel compared to an average ultra low sulphur diesel refined in California of 94.71gCO₂eq/MJ diesel.

27 On a logarithmic scale this is unlikely to represent a substantial deviation from the results as illustrated.
both to reduce emissions and increase soil carbon sequestration. Data on soil carbon sequestration rates varies substantially. Soil carbon sequestration is not only affected by harvesting method: climate, residue harvesting and soil type are amongst other factors that play a role.

**Figure 29: Carbon payback times for a high yield scenario (90th percentile) from Gibbs (2008) & Kim & Dale (2008).**

Between 1972 and 1998, Brazil increased its zero-till practice to over 8.7Mha of land (around 20% of the area of annual summer crops) (Landers, 2001). Primarily initiated by farmer actions, the public research and development effort for zero-till farming has now become a driving force with Embrapa research centers, universities and state research organizations playing key roles. The benefits of zero-till agriculture for Brazilian agro-ecosystems are cited by a broad range of stakeholders to include (Landers, 2001):

- Increased yield (following initial years at a lower yield)
- Lower operating costs (reduction in diesel fuel costs by >50%)
- Higher profitability
- Reduced soil erosion (and consequent reduction of river siltation and improved water quality through reduced nutrient runoff)
- Increased organic soil carbon
- Reduced flood risks through greater rainfall infiltration

Note: Gibbs (2008) assumes no well-to-wheel emissions, no benefits of land management or co-product residue optimisation (land use change emissions and displaced liquid fossil fuel only). Background N₂O emissions from natural vegetation are not included. Asterisk refers to peatland conversion payback period of 918 years.

Brazil’s considerable experience under a wide variety of agronomic conditions, and the expertise within its national research institutions, positions it as a leader for technology and knowledge transfer to regions with similar conditions, worldwide. Similar conclusions for soy are drawn as for sugarcane, namely, that scientific agreement on carbon stocks for no-till systems has not yet been reached; potential will vary according to climate.

### Box 7: Rotational agricultural systems to improve productivity and reduce negative GHG impacts of land use changes

Soybeans are often rainfed and mono-cropped. Zero tillage (ZT) is well-practiced in Brazil and as physical soil degradation has been hardly noticeable under ZT, some have disregarded crop rotation. Clearing for pasture in the last 20 years has largely been on infertile soils in the Cerrado, subject to rapidly falling stocking rates as initial fertility declines and little or no fertilizer is used. This has led to even more clearing to compensate for loss of carrying capacity. (Landers, 2007). Rotating annual crops (soybeans as nitrogen fixing plants) with ZT into degraded pastures allows intensification of land use and increased productivity per hectare. This would mitigate or reduce risks of land use changes and their GHG emissions (from both direct and indirect land use changes).

![Diagram of rotational agricultural systems](image)


This rotation of pastures with field crops is one of the most effective ways of maintaining them in a state of high productivity, thereby reducing the need for clearing of additional land for pasture or arable land. The Integrated crop–livestock zero tillage systems (ICLZT) incorporates numerous models and systems to intensify land use through ICLZT (different crops, rotation patterns etc). Depending on the systems adopted, land use intensification through increased stocking and absorption of crop expansion in areas of degraded pasture has been calculated to mitigate or ‘save’ land clearing (and therefore indirect land use change) on the scale of approximately 0.25 to 2.5 hectares for every hectare in ICLZT (Landers, 2007). Extensive grazing supports some specific habitats and therefore land use intensification which may lead to loss of such habitats is not supported by all stakeholders interested in biofuel sustainability.
8.3 Implications of environmental sustainability criteria on expansion plans

Domestically, soy is important for the biodiesel industry, but it has not yet been subject to mandatory sustainability criteria. Production and/or expansion in areas that are deemed sustainable (based on limited criteria used in this analysis) is heavily influenced by other factors, including economics. Figure 30 illustrates that the fact that states that could produce soybean according to selected sustainability criteria, are not necessarily those that have become the largest producers.

Figure 30: A comparison of areas that are both geophysically suitable for growing soybean and that meet selected sustainability criteria, and the main soybean producing states

Source: Statistical data on production from IGBE

The introduction of sustainability standards for biofuels in regions such as the EU, with dramatic increases in biodiesel required by 2020, could affect expansion of the multi-million dollar soy industry in Brazil. Based on GIS analyses at the national scale (detailed in Annex 1), approximately 80Mha were defined to be suitable for growing soybean, based on geophysical criteria alone. This would produce approximately 40,000 million liters of biodiesel (almost matching total national demand for diesel in 2008 of 44,764 million liters). Approximately 26Mha are available for soybean cultivation after excluding areas identified as unsuitable by sustainability standards, such as forest land, peat land, protected areas, areas with high and very high water erosion and areas at risk of flooding. This would produce approximately 13,000 million liters biodiesel or 36% of 2008 transport biodiesel requirements (compared to the B5 goal). Neither scenario discounts existing cropland currently in use and therefore these are over-estimates.
To avoid areas of existing production soy-based biodiesel could be produced on cerrado or grassland with accompanying cattle intensification to avoid indirect land use change (assuming GHG implications of such land use changes were favourable. Approximately 20Mha of potentially suitable land are on cerrado or grassland. Discounting 35% of the area for legal reserves results in around 14Mha which could produce approximately 7,200 million liters of biodiesel. In reality, only a proportion of this area would be available for production, owing to its use as pasture as well. The resulting production volume therefore, would be even lower. **Use of only 25% (3.5Mha) of this area would produce around 1,800 million liters, providing approximately 4% of total national diesel requirements and 5% of transportation diesel requirements based on 2008 demand data (a B5 blend is the goal for 2013).** Box 7 highlights opportunities for sustainable agricultural systems.

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**Box 8: An integrated bioethanol and biodiesel business model**

The Barralcool plant is located in the city of Barra do Bugres, in the interior of Mato Grosso state, one of Brazil's poorest regions. Mato Grosso has been producing ethanol since 1983, bioelectricity since 1996 and most recently biodiesel as of 2006. The plant produces 150 million liters of sugarcane based ethanol, 57 million liters of sunflower and soybean based biodiesel (50,000t capacity) and 40,000t of raw sugar per annum.

Soybean production takes place on 70% of the sugarcane renovation area (occurs every 6.7 cuts), which equates to 15% of the cane harvesting area. Any greater an area than this, interferes with sugarcane management practices. The 2009 forecast is a yield of 11,500t grain (5,030t oil), which is 10% of the capacity of the plant. The remaining 90% is supplied by third parties through partnership agreements with small and family farmers to whom the mill also supplies seeds and technical support. This arrangement enables the Social Seal Certification and therefore, relevant tax reductions.

To increase the proportion of its own production, the Barralcool mill is developing procedures to produce two crops, soybean and peanut, on the same area. This is expected to increase yields per ha by 30%. Biodiesel is used in the mill equipment (e.g. harvesters), and 2.1 million liters of biodiesel out of a total requirement of 7 million liters of fuel are forecast to be used in 2009 (2.8 MT of cane at 2.5 liters fuel/t cane), which is forecast to save US$300,000 in fuel costs.

The integrated mill enables optimization of costs through use of existing technical, administrative and management structure. The cost of production is calculated as US$680/m³ biodiesel for a non-integrated mill, compared to US$604/m³ for the integrated mill. The capital cost of an integrated plant was calculated to be 22% lower than a non-integrated plant. In addition, the feedstock costs are lower, which is critical as vegetable oil represents around 85% of production costs.

GM and labelling
Legislation in Brazil requires that products such as meat or vegetable oil that are based on (or have been fed on) GM crops be labeled. As a result, Brazil is the world leader in terms of certification for non-GMO commodities, such as soy, and has substantial experience in traceability and certification issues.

CTNBIO is the national approving body in Brazil for GM crops. The process of approval for GM varieties is relatively weak (de Sousa, pers comm.). The companies applying for approval supply the necessary documentation that includes self-identified descriptions of the positive and negative aspects of the variety and any risks that may be apparent. CTNBIO does not undertake their own trials verification of crops and relies on the self declaration of the biotechnology companies. There are no long terms studies or programs that assess the implications of GM crops on biodiversity, soil or long-term productivity.

Control within the supply chain is critical and challenging. There are no soybeans facilities specifically dedicated to non-GMO products, which is causing some contamination. Furthermore, a trader purchasing non-GM soybean could have farmers supplying the product without contamination, but if transportation or storage equipment within the chain is not cleaned properly, the certification cannot be made. This is especially challenging for smaller non-GM producers who may share equipment with others who produce GM crops. The effort and commitment of the third party involved to ensure the equipment is cleaned, among other precautions, are critical to the sale of soy identified as GM-free.

In 2008, European consumers did not pay a premium for non-GM soy. If production costs are likely to be lower, then some question why a premium should be paid. However, the supply chain costs for ensuring non-GM soy require that an initial investment be made, such as for separate storage facilities. Additionally, care must be taken to ensure production at close to capacity; if the capacity of warehouses or trucking of non-GM is not reached, the additional costs per tonne would be higher than if the facilities were used at full capacity. Furthermore, the additional costs (R$/t) for producing certified GM-free soy will vary by region. In some areas where there is a prevalence of GM-free soy, the necessary infrastructure and operational practices are already established, which reduces additional costs.

At present, farmers are evaluating the use of non-GM and GM crops. In order to sustain the market to ensure there are options available for non-GM crops in the future, the market needs to develop and be sustained to ensure necessary investments in infrastructure and agronomy to provide the relevant access to the non-GM market. In the US, for example, the choice to switch to non-GM is rarely available and without a comparison between the two options farmers are unable to have confidence in any switching decision. Commitment to growing non-GM would have to be made after a period of non-GM crop growth, because ‘traces’ of GM may otherwise still be detected, and therefore it will be several crop seasons before certification is likely.
CONCLUSIONS

Brazil is a leading biofuel and biofuel feedstock producer. Bioethanol growth has been as part of a conscious effort to address national energy security issues, and biodiesel growth is developing with the intention of contributing to socio-economic development.

The results of the research presented here show that biofuels can be produced sustainably in Brazil, so long as the necessary precautions are taken. The economic viability and production locations of sugarcane ethanol fit well with national energy security costs are competitive with fossil fuel, and production is concentrated in the Center-South where demand for the gasoline substitutes is highest. Improved export earnings are also expected from future plans for ethanol pipelines to facilitate increased exports. Owing to infrastructure availability and good geophysical conditions, the Center-South is expected to be the main area of expansion for sugarcane, and initial research concludes that expansion can take place that meets the sustainability criteria laid down by previously identified standards. Substantial institutional and technical capacity within the Center-South exists to undertake sustainability assessments; the agro-environmental zoning in Sao Paulo is a good example. This analysis also identified the positive socio-economic impact that biofuels can have in Brazil. Most ethanol production is large scale, focused on national security goals and provides around 4.1million jobs. Research has illustrated positive impacts on local GDP and no negative impacts on food production in areas of sugarcane expansion in the Center-South. Small scale technology or integration of cattle farming with large-scale sugarcane could deliver improved socio-economic outcomes.

Biodiesel still plays a minor role in the biofuel industry in Brazil compared to ethanol and is focused on developing smaller-scale production to meet these socio-economic goals. Although most of the biofuel production is for domestic consumption (around 85% of ethanol production is consumed domestically), a substantial amount of ethanol is exported and Brazil is expected to remain the world leader in this trade. Consequently, international standards, legislation and policy will impact Brazil’s bioethanol industry but also its soybean exports for biodiesel production overseas.

Summary

Banning GM crops for biofuel will not influence sugarcane ethanol, but will impact soybean volumes used for biodiesel, as GM soy represents up to 60% of production volume of soybean in Brazil. Banning its use may have some trade offs - GM soy for example, can be used as a tool to restore degraded land to higher than average productivity in the initial and most difficult years. Restoration of degraded land is the goal of some sustainability standards for biofuel.

Requiring transparency on use of GM crops is not a unique requirement; there is considerable experience within Brazil of traceability techniques for GM crops, despite challenges associated with contamination.
Of immediate relevance for Brazil’s ethanol and soybean (or oil) exports are other countries’ regulatory sustainability standards such as the EU RED and US RFS. Reductions in GHG emissions are the goal of most international biofuel sustainability standards. Brazilian sugarcane is an extensively studied product for GHG emissions and is widely agreed to provide a substantially positive GHG balance; however, soy-biodiesel does not have as significant of an impact on reducing GHG emissions though co-product treatment plays an influential role in the results and therefore differences in calculation methodologies alter these results.

The high-level analysis presented here indicates that while around 790 million hectares were identified as suitable for growing sugarcane based on geophysical criteria alone (e.g. soil type, rainfall and slope), when forest, peat land, protected areas and land with high soil, water, erosion, and flood risk are excluded, the amount of suitable land decreased to around 100 million hectares which could produce approximately 683,000 million liters of bioethanol (assuming 6794 liters ethanol per ha). Consideration of additional sustainability criteria would further reduce this figure. For example, excluding existing cropland area at around 77mha would reduce the area available to 23Mha, which could produce approximately 159,000 million liters of bioethanol, which is over six times the 2008 gasoline consumption in Brazil of 25,175 million liters. Assuming OECD-FAO forecasts in 2017 of domestic demand in the region of 30,000 million liters this potential allows an export of 129,000 million liters, which is greater than the combined bioethanol demand of both the EU and US for transport today. To avoid indirect land use changes and promote sugarcane expansion on pastureland would require only 25% of geophysically suitable cerrado or grassland (along with accompanying cattle intensification to avoid indirect land use change) which represents around 12.6Mha and could produce around 85,600 million liters of ethanol which is over three times the national gasoline requirements. The infrastructure requirements and costs implications have not been assessed here but existing studies illustrate that substantial opportunities exist in the Center-South where infrastructure investments are already planned.

The GIS results illustrate there may be much greater risk of soy expansion over areas identified as unsustainable. In addition, the expansion of soy in the Center-South and its use for domestic biodiesel production does not appear to address the socio-economic goals that drive biodiesel policy. The results of the analysis for biodiesel showed approximately 80Mha were defined to be suitable for growing soybean, based on geophysical criteria alone and approximately 26Mha after excluding areas with key sustainability limitations which could produce around 13,000 million liters of biodiesel or around 36% of national diesel requirements (well above the 5% mandate for 2013). Focusing on using 25% of suitable grassland and cerrado (with accompanying cattle intensification) could meet 5% of national diesel requirements (based on 2008 demand). To address national socio-economic goals through biodiesel production, it would be most advantageous to build capacity in the North and Northeast. However, the analysis also showed that sustainability tradeoffs would have to be considered in (in the case of ethanol) for example between water scarcity and job creation.

The GIS analysis conducted is, however, a high-level approach and was limited only to sugarcane and soy. More detailed regional studies have been conducted for sugarcane within Brazil. It is recognized that improvements in the accuracy and methodology of the analysis and datasets have
the potential to change the results – in particular for different scales of assessment and different feedstocks. A more detailed regional analysis for biodiesel for example may identify additional lands on which feedstocks could be grown sustainably. Two key limitations in drawing conclusions around the implications on GHG emissions for utilizing pastureland is that a process for identification of degraded and non-degraded pastureland (where carbon stocks differ substantially) is not yet available. Resources focused on this effort would considerably improve conclusions about GHG emissions impacts, as well as improve capacity to conduct wider monitoring assistance for indirect land use changes. Second, implications of large scale land use conversion from pasture to sugarcane have not yet been explored from a hydrological perspective. Land use dynamics in the main sugarcane region illustrate sugarcane expansion generally occurs over pasture land, so it is critical that the implications be well understood.

Data availability and collection is relatively substantial and well-organized in Brazil and several institutions are well established in such activities. Improvements in for example the scientific data behind GHG calculations could be improved by obtaining more information on emissions from regional fertilizer manufacture and, perhaps more significantly improving local data for N₂O emissions rather than rely on IPCC tier 1 defaults. It was beyond the scope of this report to assess specific gaps in data that could improve capacity for monitoring for each national and international sustainability standard.

Given the substantial legislative framework and number of voluntary codes and initiatives in Brazil, it is unlikely that compliance with international sustainability standards will be the primary obstacle in achieving a sustainable biofuel industry. Of greater significance than existence of international sustainability standards themselves, is the integration of national legislation and programs with the emerging international sustainability initiatives. Creating new requirements for compliance may not be necessary. Existing programs, codes and legislation such as the voluntary sugarcane protocol in Sao Paulo and its compliance mechanisms could be benchmarked against requirements in external markets to ensure maximum use is made of existing participation in approaches. Brazil is already a world leader in terms of certification for non-GMO commodities such as soy, and the country has substantial experience in traceability and certification issues. There is therefore significant internal capacity for compliance efforts. Enforcement of legislation presents an additional challenge. Enforcement differs between states and therefore strengthening will be required in some areas to provide confidence in the law as a successful compliance mechanism.

Domestic policies, rather than international standards alone, have a critical role to play in delivering sustainable outcomes. The National Biodiesel Production and Use (PNPB) and its Social Fuel Certification (SFC) have the potential to deliver social benefits if obstacles can be overcome. The SFC links socio-economic goals with a market demand, but there is insufficient capacity from small-producers to meet demand. The implementation of the PNPB has also run into several challenges such as in selecting the most appropriate feedstock and feedstock supply, engaging farmers, creating the right incentives for biodiesel producers and managing logistics. It should be noted that the PNPB is still under development and therefore these are not final conclusions of the program.
The analysis also shows it is important for sustainability standards to address the local context appropriately. It is valuable to note for example that, in general, Brazil doesn’t suffer from water resource issues and reducing water footprints per se (at a site scale as some sustainability standards advocate) are unlikely to be as effective as local and regional scale resource assessments and action. The state of Sao Paulo has already undertaken such an exercise for example. In addition, land use changes that are critical to ensuring GHG emission reductions are complex in Brazil as much sugarcane expansion is taking place on pasture land which is itself increasing in productivity in general and therefore direct or indirect land use changes owing to biofuels are not necessarily a one-to-one relationship. Improving access to data that is relevant for sustainability discussions between policy-makers involved with development of sustainability standards is critical. An element of making data available is translation; many substantial scientific works, including those associated with soil carbon stocks, are only available in Portuguese.

This paper has shown that Brazil has substantial capacity to deliver sustainable outcomes through the production of biofuels and feedstocks. It has the capacity to meet its bioethanol goals, and potentially its biodiesel goals, sustainably, and in doing so, address both energy security nationwide and socio-economic development in the poorest regions. The drive for sustainability standards required by international legislation, and policy means that the main challenge that Brazil is ensuring compliance and proof of results, and to do that will involve increased enforcement capacity, as well as improved techniques and methodologies for evaluating biofuel and feedstock against sustainability indicators.
10.0 REFERENCES


ABRANGE (2008) Personal written and telephone communication with Ricardo de Sousa, Executive Director of ABRANGE on 08/19/09 and 08/27/09


Dedini, 2008: Personal written communication with João Eduardo Pereira, Export Manager of Dedini, on 05/21/2008. www.dedini.com.br


Moreira, J. R. (). *Water Use and Impacts Due Ethanol Production in Brazil*. CENBIO.


UNICA (2009) Written personal communication with Emmanuel Desplechin, Chief Representative in the EU on 7/13/09 and telephone communication with Luiz do Amaral, Environmental Advisor, on 8/25/09


**Statistical and other references**

ANP, weekly price: This link gives weekly price of all the fuel by region and municipality ion Brazil: http://www.anp.gov.br/preco/

ANP, Anuario Estatistico: the most complete source of production, consumption, price and use of fossil fuels and bioenergy ion brazil: http://www.anp.gov.br/conheca/anuario_estat.asp

CEPEA: research organization that communicates the price of ethanol from producers to distributors. Weekly price of ethanol: http://www.cepea.esalq.usp.br/alcool/


ORPLANA: it represents a good source of info on on-going production and cost trend for sugarcane and other commodites (best source through phone calls) http://www.orplana.com.br/index.html

UNICA: organization that represents the interest of sugar and ethanol producers. It collects information on sugarcane production, historical ethanol price and volume: http://www.unica.com.br/dadosCotacao/estatistica/


FGV: Getulio Vargas Foundation. Source of info on several production price, rent of land, etc... http://www.fgvdados.fgv.br/index.htm

IBGE: The Insititute of Geopgraphy and Statistics has a database on historical price and production of several commodities: http://www.ibge.gov.br/servidor_arquivos_est/
CONAB: This is another source of price and consumption of different products and fertilizers in Brazil: http://www.conab.gov.br

MAPA: Ministry of agriculture. In their statistics page (click “Estatistica” in the main page) it is possible to access information about production and price of several commodities, fertilizers, etc. http://www.agricultura.gov.br/

SIDRA/IBGE: general statistics about agriculture in Brazil: http://www.sidra.ibge.gov.br/bda/default.asp?z=t&o=1&i=P
## Annex 1: GIS Analysis Methodology

### Input data

Following spatial datasets were obtained and used in the spatial analysis:

<table>
<thead>
<tr>
<th>Spatial dataset</th>
<th>Original Scale/Resolution</th>
<th>Source/Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Landcover data –MODIS 2004</td>
<td>Global scale/1 km/grid</td>
<td></td>
</tr>
<tr>
<td>5. Wetlands lands</td>
<td></td>
<td>USAD Wetlands</td>
</tr>
<tr>
<td>6. World Database on Protected Areas (WDPA)</td>
<td>Global scale</td>
<td>World Database on Protected Areas (WDPA) Annual Release 2009 (web download version), February 2009. The WDPA is a joint product of UNEP and IUCN, prepared by UNEP-WCMC, supported by IUCN WCPA and working with Governments, the Secretariats of MEAs and collaborating NGOs. <em>(Dataset obtained April 25, 2009 from URL: <a href="http://www.unep-wcmc.org">http://www.unep-wcmc.org</a>)</em></td>
</tr>
</tbody>
</table>
Spatial dataset | Original Scale/Resolution | Source/Reference
---|---|---


### Soil type geophysical potential criterion

FAO soil types for Brazil were classified as suitable and not suitable for cultivating sugarcane and soy bean\(^{28}\) (Table 1). Suitability of soil type was considered based on whether the soil can support the growth of these crops without extensive irrigation and drainage.

**Table C. FAO soil types according to Harmonized World Soil Database for Brazil and their suitability for growing sugarcane, soy bean and oil palm.**

<table>
<thead>
<tr>
<th>FAO soil type</th>
<th>Sugar cane</th>
<th>Soy bean</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrisols</td>
<td>No</td>
<td>No</td>
<td>Strongly acidic; seasonally dry</td>
</tr>
<tr>
<td>Alisols</td>
<td>NO</td>
<td>No</td>
<td>Highly acidic</td>
</tr>
<tr>
<td>Arenosols</td>
<td>No</td>
<td>No</td>
<td>Sands; required application of high amounts of organic matter</td>
</tr>
<tr>
<td>Cambisols</td>
<td>Yes</td>
<td>Yes</td>
<td>Recently formed soils</td>
</tr>
<tr>
<td>Ferralsols</td>
<td>Somewhat</td>
<td>No</td>
<td>Extensively withered; required high levels of fertilizer</td>
</tr>
<tr>
<td>Fluvisols</td>
<td>Yes</td>
<td>Yes</td>
<td>Alluvial Lowlands</td>
</tr>
<tr>
<td>Gleysols</td>
<td>No</td>
<td>No</td>
<td>Water logged (Muck soils), required drainage for cultivation</td>
</tr>
</tbody>
</table>

\(^{28}\) Soil type suitability for oil palm was also assessed and included in Table 1.
<table>
<thead>
<tr>
<th>FAO soil type</th>
<th>Sugar cane</th>
<th>Soy bean</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptosols</td>
<td>No</td>
<td>No</td>
<td>Eroded uplands; required high amounts of fertilizer</td>
</tr>
<tr>
<td>Lixisols</td>
<td>No</td>
<td>No</td>
<td>Found in dry areas</td>
</tr>
<tr>
<td>Luvisols</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Nitisols</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Phaeozems</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Planosols</td>
<td>No</td>
<td>No</td>
<td>Under careful management they can be cultivated for sugarcane</td>
</tr>
<tr>
<td>Plinthosols</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Podzols</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Regosols</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Solonchaks</td>
<td>No</td>
<td>No</td>
<td>Very saline</td>
</tr>
<tr>
<td>Solonetz</td>
<td>No</td>
<td>No</td>
<td>High amounts of sodium</td>
</tr>
<tr>
<td>Vertisols</td>
<td>No</td>
<td>No</td>
<td>High clay content; drainage a problem</td>
</tr>
</tbody>
</table>

### Annual rainfall geophysical potential criterion

The annual rainfall for Brazil ranged from 346 to 3953 mm according to WORCLIM bioclimatic raster (BIO). The annual rainfall was grouped into four suitability categories for growing sugarcane: (1) very suitable with rainfall of 1500-1700 mm/yr, (2) suitable with rainfall of 1700-2000 mm/yr, (3) moderate with rainfall of 2000-2500 mm/yr and (4) low suitability with rainfall of 1000 – 1300 mm/yr. The remaining rainfall categories were designated as unsuitable for growing sugarcane.

For soy bean crop annual rainfall was adopted from WHRC study, where rainfall with more than 450 mm/yr was considered suitable for growing soy bean crop and rainfall less than 450 mm/yr was considered unsuitable.

### Slope geophysical potential criteria

Based on in country expert opinion, slope less than 12 degree was considered suitable for growing sugarcane and soy bean

### Legal Reserve Requirements and Permanent Preservation Areas (APP)

Permanent Preservation Areas (APP) are defined as riparian vegetation with buffer size of 30 to 500 m, depending on the size of the rivers and at least 50 m around water sources. Additional to these

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29 Source: [http://tebu.mine.nu/penilaian_kesuburan_lahan/faktor_pisik_lahan.htm](http://tebu.mine.nu/penilaian_kesuburan_lahan/faktor_pisik_lahan.htm)

areas, steep slope greater than 45 degree and hilltops are included. The APP should be excluded from the “Geophysical PLUS” potential as area prohibited by the Brazilian government for crop cultivation. Our analysis was done at course scale resolution (1km) and excluded areas at flood risk along the largest rivers in Brazil (see map in Appendix1 – C) as well as areas with slope greater than 12 % (~13 degree). Therefore, the area defined as “Geophysical” potential addresses the slope issues for APPs and the area defined as “Geophysical PLUS” potential addresses both, the slope and riparian vegetation issues for APPs. To identify the Legal Reserve Requirements for the “Geophysical” potential area for sugarcane and soy bean, the forest area (ha) and savannas (cerrado) area (ha) were estimated from landcover data. As forest land is already excluded from the analysis (for carbon stock calculations) for the remaining landcover it was assumed that 35% must be maintained across all suitable cerrado land (ha). This is assumed to be conservative as it covers all land holdings (rather than private only).

Table D. Reference table showing the description of the MODIS IGBP Land Cover categories and reclassification for the purpose of this analysis.

<table>
<thead>
<tr>
<th>IGBP Land Cover Units</th>
<th>Description</th>
<th>Biofuel reclassification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen Needleleaf Forests</td>
<td>Lands dominated by woody vegetation with a percent cover &gt;60% and height exceeding 2 meters. Almost all trees remain green all year. Canopy is never without green foliage.</td>
<td>FOREST [excluded]</td>
</tr>
<tr>
<td>Evergreen Broadleaf Forests</td>
<td>Lands dominated by woody vegetation with a percent cover &gt;60% and height exceeding 2 meters. Almost all trees and shrubs remain green year round. Canopy is never without green foliage.</td>
<td>FOREST [excluded]</td>
</tr>
<tr>
<td>Deciduous Needleleaf Forests</td>
<td>Lands dominated by woody vegetation with a percent cover &gt;60% and height exceeding 2 meters. Consists of seasonal needleleaf tree communities with an annual cycle of leaf-on and leaf-off periods.</td>
<td>FOREST [excluded]</td>
</tr>
<tr>
<td>Deciduous Broadleaf Forests</td>
<td>Lands dominated by woody vegetation with a percent cover &gt;60% and height exceeding 2 meters. Consists of broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.</td>
<td>FOREST [excluded]</td>
</tr>
<tr>
<td>Mixed Forests</td>
<td>Lands dominated by trees with a percent cover &gt;60% and height exceeding 2 meters. Consists of tree communities with interspersed mixtures or mosaics of the other four forest types. None of the forest types exceeds 60% of landscape.</td>
<td>FOREST [excluded]</td>
</tr>
<tr>
<td>Closed Shrublands</td>
<td>Lands with woody vegetation less than 2 meters tall and with shrub canopy cover &gt;60%. The shrub foliage can be either evergreen or deciduous.</td>
<td></td>
</tr>
<tr>
<td>Open Shrublands</td>
<td>Lands with woody vegetation less than 2 meters tall and with shrub canopy cover between 10-60%. The shrub foliage can be either evergreen or deciduous.</td>
<td></td>
</tr>
<tr>
<td>Woody Savannas</td>
<td>Lands with herbaceous and other understory systems, and with forest canopy cover between 30-60%. The forest cover height exceeds 2 meters.</td>
<td>SAVANNAS [reported separately]</td>
</tr>
<tr>
<td>Savannas</td>
<td>Lands with herbaceous and other understory systems, and with forest canopy cover between 10-30%. The forest cover height exceeds 2 meters.</td>
<td>SAVANNAS [reported separately]</td>
</tr>
<tr>
<td>Grasslands</td>
<td>Lands with herbaceous types of cover. Tree and shrub cover is less than 10%.</td>
<td>GRASSLAND [reported separately]</td>
</tr>
<tr>
<td>Permanent Wetlands</td>
<td>Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present in either salt, brackish, or fresh water.</td>
<td>FLOODED VEGETATION [excluded]</td>
</tr>
<tr>
<td>Developed and Mosaic Lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>Excluded</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Croplands</td>
<td>Lands covered with temporary crops followed by harvest and a bare soil period  (<em>e.g.</em>, single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.</td>
<td></td>
</tr>
<tr>
<td>Urban and Built-Up Lands</td>
<td>Land covered by buildings and other man-made structures.</td>
<td>URBAN</td>
</tr>
<tr>
<td>Cropland/Natural Vegetation Mosaics</td>
<td>Lands with a mosaic of croplands, forests, shrubland, and grasslands in which no one component comprises more than 60% of the landscape.</td>
<td></td>
</tr>
<tr>
<td>Non-Vegetated Lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snow and Ice</td>
<td>Lands under snow/ice cover throughout the year.</td>
<td>excluded</td>
</tr>
<tr>
<td>Barren</td>
<td>Lands with exposed soil, sand, rocks, or snow and never has more than 10% vegetated cover during any time of the year.</td>
<td>excluded</td>
</tr>
<tr>
<td>Water Bodies</td>
<td>Oceans, seas, lakes, reservoirs, and rivers. Can be either fresh or salt-water</td>
<td>WATER</td>
</tr>
</tbody>
</table>

Figure D below shows the general flowchart of spatial procedure and rules for creating ‘Geophysical’ and ‘Geophysical PLUS’ potential maps for growing sugarcane and soybean.

![Flow chart](image)

*Figure D. Flow chart of spatial analysis for identifying area with ‘Geophysical’ and ‘Geophysical PLUS’ potential for sugarcane and soybean. Blue oval blocks represent geophysical criteria; green oval blocks represent criteria that were excluded in both, sugarcane and oil palm analysis; red rectangular blocks represent results for ‘Geophysical’ and ‘Geophysical PLUS’ potential.*