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## **Ethanol and sugarcane expansion in Brazil: what is fueling the ethanol industry?**

### **CASE STUDY**

Ana Claudia Sant'Anna<sup>Ⓐ</sup>, Aleksan Shanoyan<sup>ᐁ</sup>, Jason Scott Bergtold<sup>ᐃ</sup>, Marcellus M. Caldas<sup>ᐔ</sup>,  
and Gabriel Granco<sup>ᐅ</sup>

<sup>ᐶ</sup>*PhD. candidate, Kansas State University, Department of Agricultural  
Economics, 400 Waters Hall, Manhattan, KS 66506, USA*

<sup>ᐁ</sup>*Assistant Professor, Kansas State University, Department of Agricultural  
Economics, 304G Waters Hall, Manhattan, KS 66506, USA*

<sup>ᐃ</sup>*Associate Professor, Kansas State University, Department of Agricultural  
Economics, 307 Waters Hall, Manhattan, KS 66506, USA*

<sup>ᐔ</sup>*Associate Professor and* <sup>ᐅ</sup>*PhD. candidate, Kansas State University, Department  
of Geography, 118 Seaton Hall, Manhattan, KS 66506, USA*

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### **Abstract**

This case study describes Brazilian ethanol industry and strategic issues faced by sugarcane farmers and processors as a result of recent industry expansion into the states of Goiás and Mato Grosso do Sul. It provides detailed description of the ethanol supply chain in Brazil from field to market and discusses market drivers influencing the industry. Shaped by government regulations, market liberalization, globalization, and technological change, the Brazilian ethanol industry provides a rich context for learning and applying strategic analysis tools. The case is designed to be used in a graduate or undergraduate agribusiness management or strategic management course. The specific teaching objective for this case is to refine and reinforce students' understanding of industry analysis and the effect of market drivers on competitive forces in an industry. Students will be expected to conduct an industry analysis and provide strategy recommendations to managers of ethanol plants and farmers. The case study incorporates all of the essential information for students to understand the underlying economics of the ethanol value chain and how the external forces shape strategic growth opportunities.

**Keywords:** sugarcane, ethanol, industry analysis, Brazil, Cerrado, case study, teaching case

**JEL code:** Q13, Q16

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<sup>ᐶ</sup>Corresponding author: [acsantanna@ksu.edu](mailto:acsantanna@ksu.edu)

The future growth for transportation in Brazil should be from ethanol, but how long it takes us to get there, I really don't know.

– Soren Schroder, CEO of Bunge Limited<sup>1</sup>

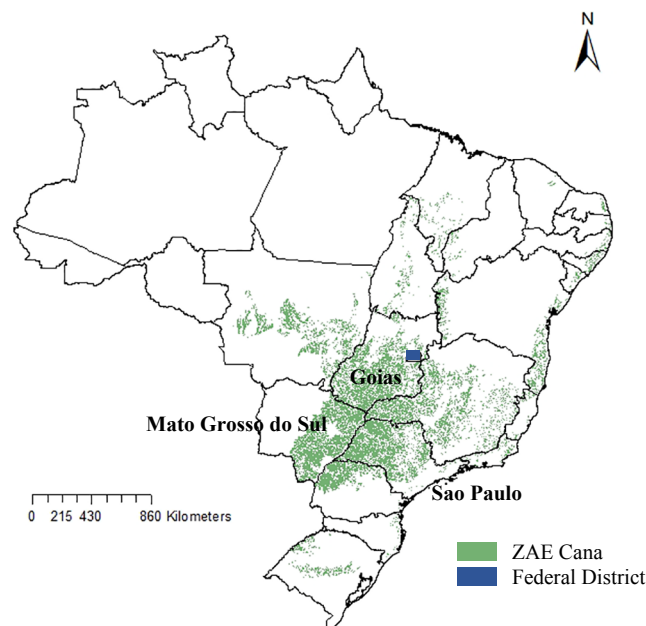
## 1. Introduction

Sugarcane production has expanded in Brazil from the North-Northeast regions of the country to the Center-South over the last decades, becoming a dominant crop in the state of Sao Paulo. Since the 2000s, there has been a significant expansion of sugarcane production into Goiás and Mato Grosso do Sul fueling land use change in states historically known for livestock and soybean production (Granco *et al.*, 2015). In order to guide the sugarcane expansion while protecting native biomes, the Brazilian government launched the Sugarcane Agro-ecological Zoning (ZAE CANA) (Barros, 2011). The ZAE CANA maps areas suitable for sugarcane production (Figure 1) accounting for weather and soil conditions, as well as environmental, social and economic aspects (Manzatto, 2009).

In the states of Goiás and Mato Grosso do Sul this zoning policy identifies over 22.6 million hectares as suitable for growing sugarcane (Manzatto, 2009). This geographic expansion in sugarcane production driven and accompanied by changes in government policies and regulations, technological innovations, domestic and global demand, have created unprecedented competitive dynamics in the Brazilian ethanol industry.

Industry players at all levels of the supply chain have been forced to reevaluate their strategies in the face of changing industry dynamics. Managers of ethanol plants have to evaluate strategic implications of geographic growth on competitive dynamics and vertical coordination. Specifically, the first strategic decision faced by managers of mills as they expand into central part of Brazil is whether to install a facility in an area with established sugarcane production and, possibly, compete with existing mills for inputs or to locate in a new

<sup>1</sup> Said at the Goldman Sachs 18<sup>th</sup> Annual Agribusiness Conference in New York City in 2014. Quoted by Oil Price Information Service (OPIS).



**Figure 1.** Map of Brazil with the states of Goiás, Mato Grosso do Sul and Sao Paulo and the Sugarcane Agro-ecological Zoning (ZAE CANA) (adapted from Manzatto, 2009).

area and have to invest in establishing a new procurement base. The second strategic decision is whether to procure sugarcane from farmers or to backward integrate into sugarcane production by renting or buying land.

Farmers in Goiás and Mato Grosso do Sul have to reevaluate their strategy in the face of increasing competition for land and labor. Specifically, farmers have to decide whether to become a part of a growing industry and enter into sugarcane production or to continue with their existing production systems. Further, if they decide to join the ethanol supply chain, then they have to make a decision on whether to produce sugarcane and supply to the plant or to rent out the land to the plant instead. In this background the government's challenge is to guide the sugarcane expansion by minimizing environmental impact while avoiding creation of unnecessary barriers for industry players. Clearly, all of these decisions are interdependent and may result in a wide range of intended and unintended consequences for every player in the industry as evidenced by the comments and remarks of farmers and processors.

Farmers in Mato Grosso do Sul have expressed concerns regarding the prices of land and labor. Specifically farmers have commented: 'the arrival of the mill increases the prices of land'; 'where the mill comes in, producers are left to fight over the lands that are left over'. Others complained about the shortage of labor after the arrival of the mill: 'the demand for workers is higher than the supply'<sup>2</sup>. The management of the mills, on the other hand, considers these concerns as 'a natural reaction to the arrival of a new crop'<sup>3</sup> according to Pedro Mizutani, the then president of Cosan Sugar and Ethanol (O Estado de S. Paulo, 2011). Furthermore, mills believe that through the expansion they 'bring development and labor opportunities to the region' in the words of SJC Bioenergia director Ingo Kalder (Siqueira, 2013). Careful industry analysis and the evaluation of strategic implications is warranted for both processors and farmers. Processors with regards to expanding capacity and securing a procurement base. Farmers, with regards to their production systems and marketing strategies.

## 2. Background and history of the Brazilian ethanol industry

Sugarcane has been grown in Brazil since 1532 (BNDES, 2008). The rise in sugar demand and high price in the 16<sup>th</sup> century led to the first commercial production of sugar in Brazil. Financial support from the Dutch East India Company at that time allowed the sugar industry to rapidly expand. In the mid-17<sup>th</sup> century, sugar production declined, with the expulsion of the Dutch from the Northeast and consequent expansion of the sugar industry in the Caribbean (BNDES, 2008).

Ethanol production began in 1905 along with the first experiments with ethanol fueled vehicles (BNDES, 2008). A maximum blend of 5% ethanol to petrol (E5) was introduced in Brazil in 1931 by the Decree Number 19.717. A year later the Department of Agriculture signed contracts to support sugar-mills in the production of pure alcohol and in 1933 the National Institute for Sugar and Alcohol (IAA) was created. The purpose of the IAA was to regulate and establish standards for the domestic sugarcane industry (Vieira *et al.*, 2007). The IAA protected the industry by setting prices through quotas (Reinhardt *et al.*, 2010).

A boost to ethanol production came in the end of the 1960s and beginning of the 1970s. First due to the decline of sugar prices, one of the country's main exports, that fell from US\$1237/t in 1974 to US\$ 172/t in 1978 (Melo, 1981). Second, due to oil imports that were equal to half of Brazil's total value of the exported goods, causing a strain on the economy. In this context, the government launched the Brazilian National Alcohol Program (PROALCOOL) in November 1975 to promote large-scale production of ethanol as a substitute for gasoline (BNDES, 2008).

<sup>2</sup> Responses from survey applied in Mato Grosso do Sul and Goiás in 2014 as part of the National Science Foundation (NSF) grant Collaborative Research: direct and indirect drivers of land cover change in the Brazilian Cerrado: the role of public policy, market forces, and sugarcane expansion for more detail see Sant'Anna *et al.* (2015).

<sup>3</sup> Spoken in relationship to the restrictions faced in sugarcane expansion in Jataí, a county in the state of Goiás.

The PROALCOOL consisted of three phases: (1) the introduction of production subsidies and establishment of an E20 blend (20% of anhydrous ethanol in gasoline); (2) launch of ethanol-only cars in 1979; and (3) a program phase out through gradual elimination of subsidies. Additional incentives of the program included: providing low interest loans for companies willing to enter the ethanol industry (1980-1985), setting ethanol prices at the pump to 59% of the gasoline price, taxation of gasoline, and reduction of value added tax for ethanol fueled cars. Despite the dictatorial regime, which allowed for strong control over the economy (e.g. price fixing and control of state-owned companies), the implementation of the PROALCOOL was difficult and costly (Zapata and Nieuwenhuis, 2009). De Almeida *et al.* (2008) estimated that between 1979 and the mid-1990s, the national government spent US\$16 billion supporting the ethanol industry. Nevertheless, the program stimulated tangible advances not only in the production of sugarcane (e.g. the introduction of operations research techniques in agricultural management and the use of satellite images for species identification in cultivated areas), but also in the production of ethanol (e.g. energy production for mills via the use of sugarcane bagasse) leading to cost reductions and productivity gains (Goldemberg, 2006). After the end of PROALCOOL program there were shortages in ethanol supply leading to price increase. Consumers reacted by switching to gasoline fueled cars or installing conversion kits (BNDES, 2008). This led to gradual decline in ethanol demand, which was further exacerbated by a reliable supply of low price petroleum, readily available at every fueling station (Zapata and Nieuwenhuis, 2009).

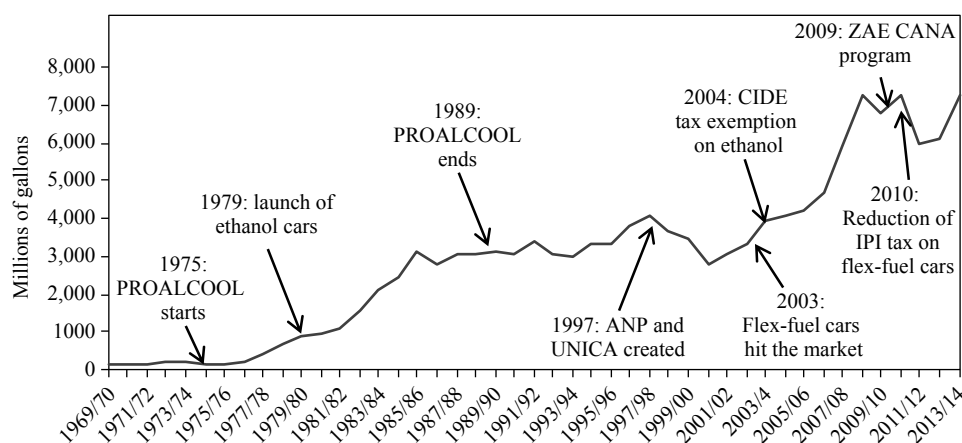
In 1990, the IAA program ended followed by liberalization of ethanol market. The price of anhydrous and hydrous ethanol<sup>4</sup>, previously controlled by the government, were allowed to be set by the market in 1995 and 1999, respectively (Figueira *et al.*, 2013). Nevertheless, the ethanol industry continued to be regulated even after the price liberalization. In 1997, the Brazilian Natural Petroleum Agency (ANP) was established to encourage industrial competition and to protect consumer interests (BNDES, 2008). In the same year, a private organization of sugar and ethanol producers in the state of Sao Paulo, the union of the sugarcane industry (UNICA), was formed (UNICA, 2015). Together with the Organization of Sugarcane Growers in the Center-South of Brazil (ORPLANA), they formed the council of sugarcane, sugar and ethanol producers of the state of Sao Paulo (CONSECANA), whose role was to consolidate the relationships between the actors in the supply chain and to improve the sugarcane quality control system (Sousa *et al.*, 2012). CONSECANA is also responsible for setting ground rules for sugarcane pricing based on total recoverable sugar (TRS), which is the amount of sugar present in the sugarcane supplied by producers minus the losses occurred during the industrial processing (CONSECANA, 2016.).

After the 2000s, a series of events further promoted the expansion of the ethanol sector in the country. These events included: a setting of official blending ratio of anhydrous ethanol with gasoline between 20 and 25%; the introduction of flex-fuel cars in 2003, allowing consumers to choose freely between ethanol and gasoline at the pump; the reduction to zero of the contribution of intervention in the economic domain (CIDE)-fuel tax applied on ethanol in 2004; the reduction of the tax on industrialized products in the sales price of new flex-fuel cars in 2010; and the launch of the Sugarcane ZAE CANA in 2009 (Brasil, 2009; Manzatto, 2009) (Figure 2).

Although ethanol production has increased since the year 2000, there has been a significant decrease in production of ethanol from 2011 to 2014 (Figure 2). During this period, mills suffered financial crises. From the 343 mills in operation in 2013-2014, 30 were in debt (Santos *et al.*, 2016). Furthermore, the Brazilian government, with the intent of controlling inflation, has been fixing the prices of gasoline. This policy resulted in unintended negative consequences on the ethanol industry, because the ethanol fuel prices were dictated by market (Granco *et al.*, 2015). This meant that ethanol prices needed to remain low, in order to remain competitive, at a time when production costs were increasing 11.5% per annum<sup>5</sup> (Santos *et al.*, 2016). Therefore, the price of oil has oscillated more than that of gasoline and ethanol providing stability to the consumer but not to the producer (Santos *et al.*, 2016). Another factor for the reduction in ethanol production

<sup>4</sup> Anhydrous ethanol is used as an additive in gasoline while hydrous ethanol is used as E100 in ethanol run cars or flex-fuel cars (BNDES, 2008, Granco *et al.*, 2015).

<sup>5</sup> Depending on the region production costs increased from 5.5 to 11.5% per year (Santos *et al.*, 2016)



**Figure 2.** Total ethanol production in Brazil from 1969-1970 to 2013-2014 harvest year and major policy events (adapted from Brasil, 2013; UNICA (<http://www.unicadata.com.br>)). PROALCOOL = the Brazilian National Alcohol Program; ANP = Brazilian Natural Petroleum Agency; UNICA = the union of the sugarcane industry and ZAE CANA = sugarcane agro-ecological zoning; CIDE = contribution of intervention in the economic domain; IPI = tax on industrial goods.

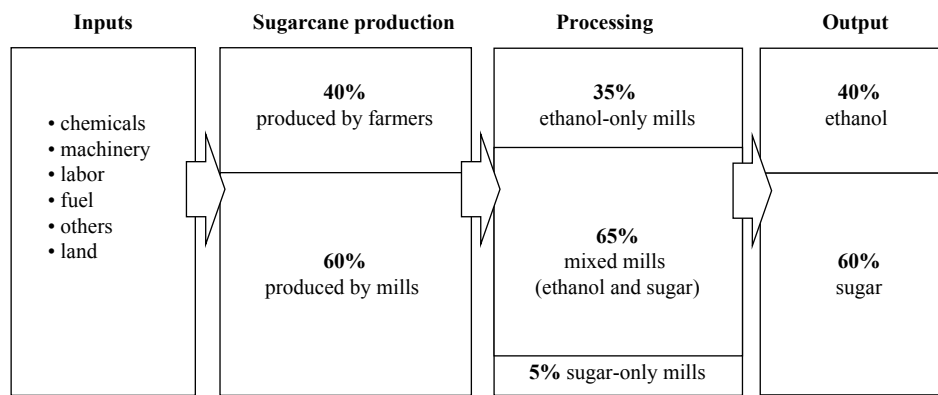
came from the reduction in the amount of funds available for loans through the National Development Bank (BNDES). From 2010 to 2011 government disbursement of loans fell by 28% and then furthermore by 36% in the following year (Santos *et al.*, 2016).

### 3. The Brazilian ethanol industry in 21<sup>st</sup> century

Between 2000 and 2012 over 85% of the world's annual supply of ethanol came from the United States and Brazil (EIA, 2015). Europe is in the third place supplying around 5% followed by Canada supplying 2% of the world's ethanol production. Brazil was the largest ethanol producer in the world in the period from 2000 to 2005, but since 2007 the USA has surpassed Brazil, increasing its ethanol production to more than double that of Brazil (EIA, 2015). This increase in US production has been attributed to a Renewable Fuels Standard implemented in 2005 and expanded in 2007. In 2014, ethanol consumption in the USA and Brazil was 13.47 billion gallons and 6.76 billion gallons, respectively, while the ethanol production was 14.34 billion gallons and 7.56 billion gallons, respectively (EIA, 2015; Gomes, 2015). In 2008, the sugar-energy sector in Brazil accounted for approximately 2% of the country's gross domestic product (GDP) (Neves *et al.*, 2010), making it an important economic activity affecting job and income generation at all stages of the supply chain.

#### *Ethanol supply chain in Brazil*

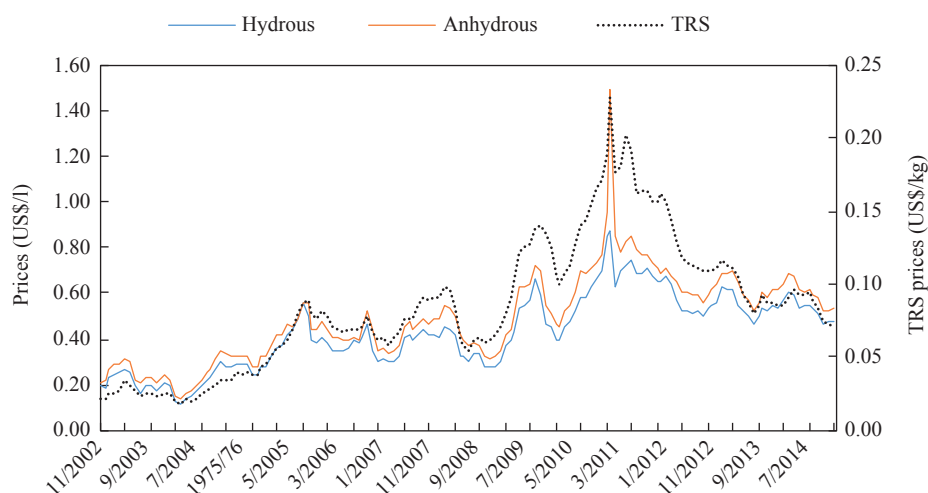
The ethanol supply chain consists of inputs, sugarcane production, processing, and distribution (Figure 3). Major inputs for production of sugarcane include: land, fuel, labor, fertilizers, soil nutrients, machinery including harvesting machines, and labor, among others. Sugarcane grows in 5 year cycles. Yields vary according to the number of cuts (harvests). Higher yields can be achieved in the first cut after which yields decreasing with each cut. The average annual yield for Brazil in 2014 was 70 tons per hectare (IBGE, 2014). Sugarcane harvesting occurs from August to April in the Northeast Region of Brazil and from April to December in the Center-South (BNDES, 2008). Traditionally, sugarcane harvesting involves the burning of the crop followed by the manual harvest of the stalks. This practice has been gradually replaced by mechanical harvesting, which accounted for 55% of the planted area with sugarcane in 2013 (CONAB, 2013).



**Figure 3.** Stages of the supply chain (adapted from Neves *et al.*, 2010 and Brasil, 2013).

Around 40% of the processed sugarcane in Brazil is supplied by farmers, while the rest is produced directly by the mills on the land owned or rented by them. The average yield for farmers is 75 t/ha while that for mills is 81 t/ha (Crago, 2010). The price of sugarcane is determined by the method proposed by CONSECANA and has high variation over time (Figure 4). Once harvested, sugarcane is transported immediately to the mills in order to prevent saccharose losses. The saccharose content in the sugarcane impacts the conversion rates to sugar or ethanol and tends to decline after the harvest. Consequently, to avoid losses in saccharose content during transportation from fields to plant, mills cannot be located more than 50 km from sugarcane producers (Neves *et al.*, 1998). The usual transportation system used are trucks with a cargo capacity ranging between 15 to 60 tons. A few companies use the waterway transporting system (BNDES, 2008).

There are three types of mills in Brazil: sugar mills, ethanol mills, and mixed mills producing both sugar and ethanol. A ton of sugarcane produces about 140 kg of sugar or 86 liters of ethanol (State of Sao Paulo Government, 2014). In 2011-2012, 49% of the TRS derived from the sugarcane production, was used to produce sugar and the rest to produce ethanol (Brasil, 2013). The cost of producing a liter of ethanol in Brazil varies between US\$ 0.23 and US\$ 0.29 (Crago *et al.*, 2010). Distilleries can store on average 3 billion gallons of ethanol (Zanão, 2009).



**Figure 4.** Monthly producer prices for hydrous and anhydrous ethanol per liter and sugarcane total reduced sugars (TRS) per kilo in the state of Sao Paulo, from 2002 to 2014 (adapted from CEPEA, 2015; UDOP, 2014).

The mills sell ethanol to distributors, a small number of firms are responsible for the retail of ethanol to consumers (Reinhardt *et al.*, 2009). Since the 1990s, gas stations in Brazil are not required to have exclusive contracts with distributors. In 1996, Ordinance number 59/96 from the Treasury Department in Brazil deregulated the sales prices of distributors and ethanol dealers in the whole country. Later in 1999, Ordinance number 28/99 from the Treasury Department and from the Ministry of Mines and Energy deregulated the fuel prices applied to final consumers. Producer prices for anhydrous ethanol exceed those for hydrous ethanol. Hydrous ethanol prices in Sao Paulo ranged from US\$ 0.19 /l in November 2003 to US\$ 0.48 /l in December 2014, while, in the same period, anhydrous ethanol prices ranged from US\$ 0.21 /l to US\$ 0.53 /l (Figure 4). In 2014, three firms controlled around 60% of the retail ethanol market (SINDICOM, 2015).

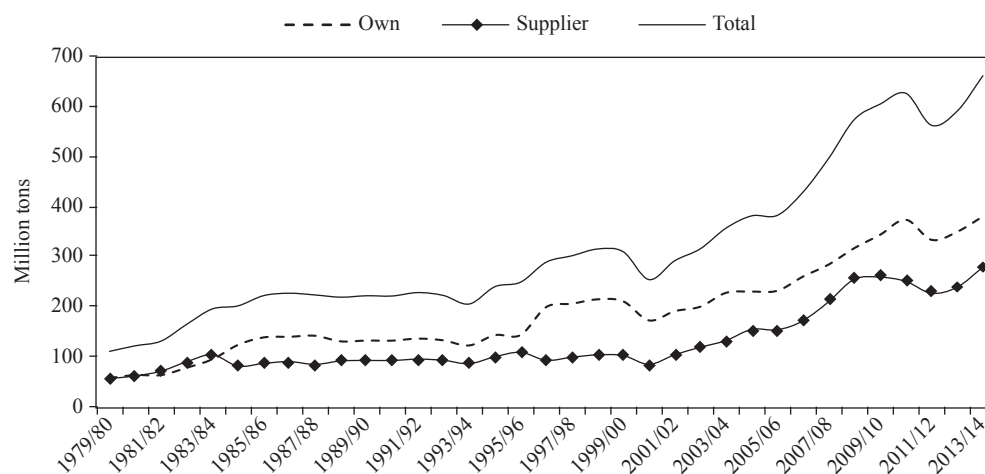
### Capacity, total production, and trends

The number of mills in Brazil grew by 171% between 2000 and 2013, reaching a total processing capacity of 3.6 million metric tons of sugarcane per day (Reinhardt *et al.*, 2009; Sant'Anna *et al.*, 2015). In 2013, there were approximately 10 million hectares planted with sugarcane producing 768 million tons of sugarcane with a production value of US\$ 19 billion<sup>6</sup> (IBGE, 2014). In the Center-South region of the country, total annual ethanol production in 2012 was 5.6 million gallons (Brasil, 2013). The sugar and ethanol production generates around 700,000 direct jobs and 200,000 indirect jobs (De Almeida *et al.*, 2008). Nevertheless, in 2014 the share of the GDP from the sugar-energy sector has declined compared to preceding years, reaching US\$ 26.7 billion from US\$ 42.9 billion in 2010 (Barros, 2015)<sup>7</sup>.

From the productivity perspective, there have been significant improvements over the last three decades. The productivity of ethanol per ton of sugarcane in 2012 was five times of that in 1975 (Brasil, 2013). By the end of the last decade, on average, a single mill crushed around 2 million tons of sugarcane per year, originating from approximately 30,000 hectares of land, to produce 170 to 200 million liters of ethanol (Reinhardt *et al.*, 2009). From 1980 to 2012, the total amount of sugarcane crushed by mills in Brazil grew more than threefold, going from 170 million tons to 560 million tons (Figure 5). This growth was accompanied with a shift in the sourcing of feedstock, from the majority produced and supplied by farmers to the majority of sugarcane produced on the land operated by the mills (Neves *et al.*, 1998).

<sup>6</sup> Exchange rate of 2013 US\$ 1.00=R\$ 2.25.

<sup>7</sup> Exchange rate for 2014 was US\$ 1.00=R\$ 2.451 and for 2010 was US\$ 1.00=R\$ 1.838.



**Figure 5.** Yearly amount of sugarcane crushed by origin (supplier or produced by the mill) (adapted from Brasil, 2013, 2015).

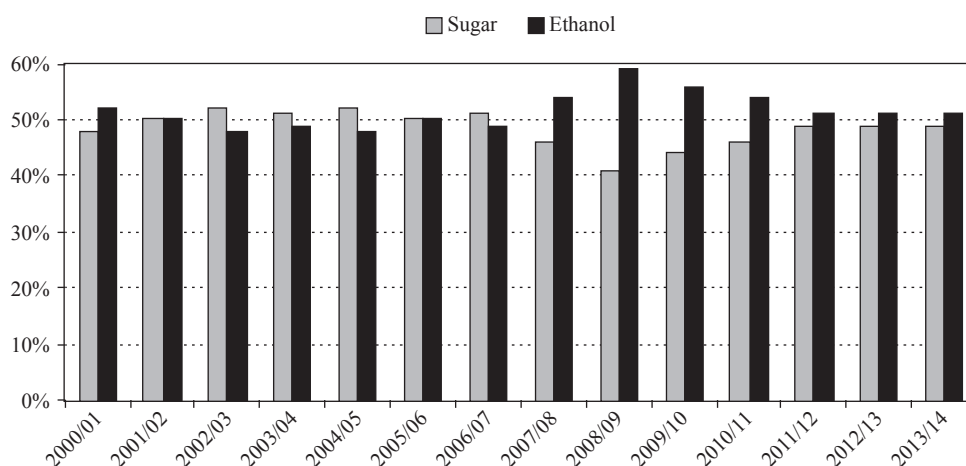
From 2008 to 2014 more than 40 mills closed due to financial problems, however the number of new mills continued to grow (Barros, 2014). Most of the newer mills are designed to produce both sugar and ethanol from sugarcane. In early 2000s the majority of the TRS was directed towards sugar production, but since 2006, more has been directed toward ethanol production (Figure 6). This change has been driven by public policies and market drivers discussed in more detail in the following sections. During the 21<sup>st</sup> century, Brazil increased its ethanol production capacity by expanding into the Cerrado region, located in the center of the country. Although most of the production still comes primarily from the state of Sao Paulo, the states of Goias and Mato Grosso do Sul have increased their contribution to the Brazilian supply of sugarcane fivefold between 2000 and 2013 (IBGE, 2014)<sup>8</sup>. This expansion resulted from cheaper and flatter land in these two states, which allowed for easy expansion and greater mechanization (Granco *et al.*, 2015). It has been argued that the expansion of sugarcane in Brazil was driven by international demand for sugar and ethanol and national policies promoting ethanol production and commercialization. Additionally, other factors such as technological changes in production (e.g. development of mills that produce both ethanol and sugar) and the vertical integration in the industry played a role in the sugarcane expansion (Günther *et al.*, 2008).

#### 4. Market drivers shaping the Brazilian ethanol industry

##### *Government programs*

The ethanol production in Brazil has been stimulated and supported by a number of government programs and policies including the PROALCOOL (Goldemberg, 2006). In addition to eliminating the CIDE-fuels tax, applied on ethanol and the lower tax rates for purchasing flex-fuel cars, in 2013, the government exempted ethanol producers, distributors and importers from paying their contribution to the Social Integration Program for financing social security (Barros, 2014). The advantages brought on by the elimination of the CIDE-fuel tax, however, began to decline in mid-2008 when the same tax applied on gasoline was reduced gradually. The CIDE-fuel tax on gasoline was reduced to zero in mid-2012 returning only in May 2015 (Ramos, 2016). On the regional and local level in center west, the state governments of Goias and Mato Grosso do Sul have provided fiscal incentives: the PRODUZIR in Goias allows a grace period for paying 73% of the tax on the

<sup>8</sup> Although the state of Minas Gerais (MG) is also an agricultural frontier for sugarcane it was not added to this study. MG has a smaller area with Cerrado and a smaller increase in sugarcane production than the states of Goias (GO) and Mato Grosso do Sul (MS). Sugarcane production in GO and MS has increased 474 and 546% from 2000 to 2012, respectively, whereas in MG it has increased 276% (IBGE, 2014). Also 61% of MS and 97% of GO are covered with Cerrado while 57% of MG is covered with Cerrado (Sano *et al.*, 2008).



**Figure 6.** Yearly destination of total reduced sugars of sugarcane towards sugar and ethanol between 2000 and 2012 (Brazil, 2013).

circulation of goods and services (ICMS) until 2020 while in Mato Grosso do Sul, the MS Empreendedor program exempts the payment of 67% of the ICMS tax for the industry (Granco *et al.*, 2015).

Historically, the Brazilian government has controlled the price of gasoline in order to help curb inflation. This policy has hurt the ethanol industry, as gasoline prices have artificially been maintained at a rate lower than its international prices, while ethanol prices were determined by the market (Freitas and Dezem, 2015). Consequently, for consumers gasoline was more price efficient than ethanol<sup>9</sup>. The policy of freezing gasoline prices along with that of reducing the CIDE-fuel tax on gasoline has been blamed as responsible for the crises to the ethanol sector. Since June 2014, with the rapid decline in the price of oil and global gasoline prices, the controlled price of gasoline in Brazil became higher than the international price, benefitting the ethanol industry (Freitas and Dezem, 2015; OECD/IEA, 2015).

In 2006, the government launched the Brazilian Agro-energy Plan with the goal of increasing the competitiveness of agro-energy supply chains (MAPA, 2006). The Plan instituted the creation of a new research unit in agro-energy (Embrapa Agroenergy) and was followed by the Sugarcane Agro-ecological Zoning program.

In 2007, the government announced a plan to construct two ethanol pipelines in conjunction with the Program for Economic Acceleration. The first is a 1,150 km extension of one of the ethanol pipelines connecting Goiás to the port of Santos in São Paulo and passing through other major ethanol producing counties. The second pipeline, 900 km in length, will connect Mato Grosso do Sul to the port of Paranaguá in the state of Paraná (Transpetro, 2007). Currently 206 km of pipeline is in operation and it is estimated that logistic costs will be reduced from US\$ 18.7 /m<sup>3</sup> for road transportation to US\$ 7.65 /m<sup>3</sup> for transport using the pipeline (Folha de S. Paulo, 2013).

In addition to lenient tax policies and large infrastructure projects, the Brazilian government also provides subsidized loans to the industry through the BNDES. The amount of loans conceded ranged from US\$ 0.51 billion in 2000 to US\$ 3.39 billion in 2011<sup>10</sup>, 65% of which were provided to industries in the South-East and Center-West (Milanez and Nyko, 2012). Among the BNDES programs for subsidized loans, is the PRORENOVA, directed towards the renewal or expansion of sugarcane fields, and the Paiss, a joint plan of BNDES and the Research and Projects Financier to fund industrial technological innovations aimed at the sugar-energy sector (Barros, 2014). To complement these programs, in 2015, the federal government increased the mandated amount of ethanol to be mixed into gasoline from 25 to 27% (Amato and Matoso, 2015).

### *Technology*

In the 2000s, the number of patents obtained by the ethanol industry increased significantly (Freitas and Kaneko, 2012). Innovations in sugarcane production included new crop varieties and mechanized sugarcane harvesting, while those in ethanol production included the development of mixed mill technologies enabling concurrent production of sugar and ethanol, as well as energy generation with bagasse, a processing byproduct. Further byproducts of sugarcane are yeasts and additives, carbon credits, bioplastics, and vinasse. These have different uses and markets. For instance, 10% of yeasts recovered from ethanol production can be sold to the livestock feed industry to be mixed into its products (Neves *et al.*, 2010). Mills also sell additives based on the sugarcane yeast. In addition, mills in Brazil sell carbon credits in the market through the clean development mechanism (Neves *et al.*, 2010). Ethanol can also be used in the production of bioplastics and the left over bagasse can be used to generate electricity (Arruda, 2011; Neves *et al.*, 2010). This energy is used in the ethanol and sugar production process and the excess is sold to local counties. The vinasse, a fertilizer substitute high in nitrogen content, can be combined with water to irrigate sugarcane planted land (fertilization), thus reducing fertilizer costs for mills producing their own sugarcane (Neves *et al.*, 2010).

<sup>9</sup> Ethanol is less energy efficient than gasoline, so it should be chosen when its price is 70% of that of gasoline.

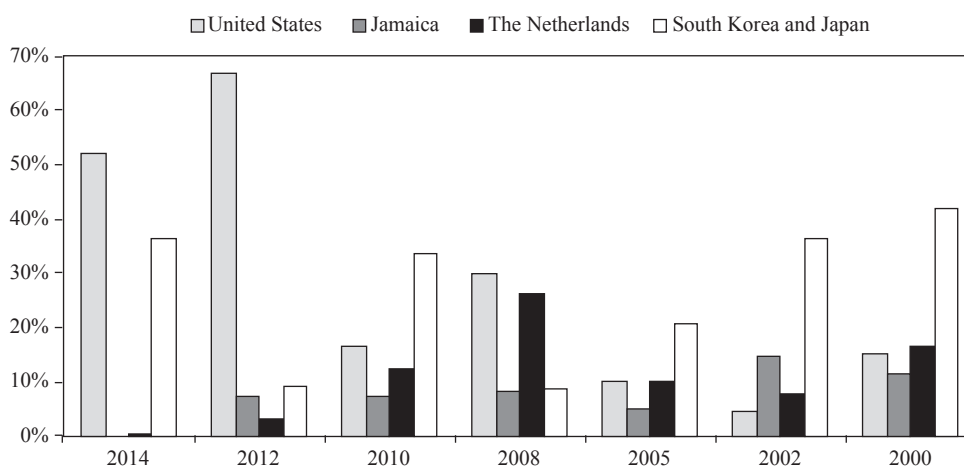
<sup>10</sup> Values reflect 2011 prices and use the following exchange rate: US\$ 1.00=R\$ 1.742.

The plant breeding research in Brazil has been driven by both private and public institutions: the Brazilian Agricultural Research Corporation (EMBRAPA), the Agronomic Institute of Campinas (IAC) and Interuniversity network for the development of the sugar and ethanol sector (RIDESA) in the public sector; Center of Sugarcane Technology funded by the sugarcane mill industry (CTC) in the private sector (Torres *et al.*, 2011). Genetic modifications to sugarcane are regulated by the Department of Science and Technology (BNDES, 2008). The CTC expects that by 2018 farmers will be able to grow genetically modified sugarcane. New varieties are expected to be pest resistant, drought tolerant, higher yielding, and with higher sugar content (CTC, 2013). These technological enhancements eased the introduction of mechanized agriculture into the states of Goiás and Mato Grosso do Sul which have more conducive geographic characteristics. Nevertheless, there has been a decline in the productivity of sugarcane due to the crises in the ethanol sector, as well as, climatic problems. On the production side, sugarcane producers were facing financial difficulties and were unable to invest in maintaining their sugarcane fields (Ramos, 2016). Additionally, productivity in the Center-South has declined due to technical issues such as the lack of adaptation to harvest mechanization, weather events (such as droughts), aging of sugarcane fields and related technology (Santos, 2016). Another productivity inhibiting factor is the time it takes to approve newly developed higher yield sugarcane varieties, which can take up to years and can delay the time from the technology development to adoption in the field (Santos, 2016). An alternative, which would be the cellulosic ethanol, or second generation ethanol made from the bagasse and straw of the sugarcane, is still inviable at the industrial scale due to enzyme costs (EMBRAPA, 2014).

On the consumer side, an important innovation which increased ethanol demand, was the introduction of flex-fuel cars, allowing consumers to switch more freely between gasoline and ethanol (E100). Flex-fuel cars have been so well accepted in the market that its production has grown from 858 thousand cars in 2005 to 2.6 million in 2010, currently representing 90% of all new cars being sold (ANFAVEA, 2015).

### Global trade

Historically, Brazil has been exporting more sugar than ethanol: on average 70% of the sugar produced went to export compared to 10% of the ethanol (UNICA, 2015). In 2014, Brazil exported 369 million gallons at an average value of US\$ 2.42 /gallon free on board (UNICA, 2015; SECEX, 2015). From 2000 to 2012 ethanol was exported mainly to five countries: United States, Jamaica, the Netherlands, South Korea and Japan. The amount imported by the United States increased since 2008, replacing exports to Jamaica (Figure 7).



**Figure 7.** Major importers of Brazilian ethanol in terms of their participation in the total amount exported (adapted from SECEX, 2015).

The removal of US tariffs on Brazilian ethanol imports in 2012 helped to increase exports to the USA. Prior to 2012, hydrous ethanol was shipped to the Caribbean where it was transformed into anhydrous and then shipped to the US (Elobeid and Tokgoz, 2008)<sup>11</sup>. The sugar and ethanol industries in Brazil have seen major investments by foreign companies since 2008-2009, when the global economic crisis affected Brazilian mills (Oliveira, 2013). By 2013, about half of the sugarcane produced (654 million tons) was supplied by foreign owned mills. This accounted for 33% of the total production of sugar and ethanol in Brazil (Oliveira, 2013). Foreign investors included US firms (e.g. Bunge and Cargil), French firms (e.g. Louis Dreyfus Commodities); Chinese firms (e.g. Noble), and others, including Shell (Oliveira, 2013). It is estimated that foreign direct investment amounted to US\$ 22 billion through the purchasing and establishment of Brazilian mills (Oliveira, 2013). However foreign land ownership and rental is limited. The Brazilian law 5709/71 regulates the acquisition of rural properties by foreigners. A judgement by the Attorney General's Office in Brazil (Judgement AGU/LA-01/2010) allows foreign companies, permitted to function in the country, to acquire up to 100 modules of land<sup>12</sup> subject to approval from Congress. This judgement defines as foreign companies those with a foreign director or with the majority of the shares belonging to foreigners.

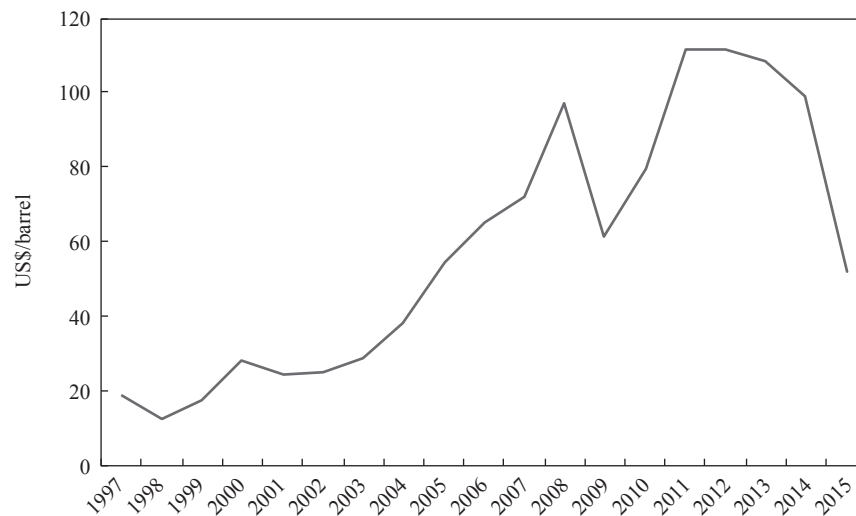
### *Oil Markets*

Changes in the oil markets affect ethanol production, not only because ethanol and gasoline are substitute goods, but also because fuels represent 10% or more of the energy input costs (Valdes *et al.*, 2016). Cheaper oil decreases demand for biofuels which, in turn, influences farmers to reallocate resources from producing sugarcane to producing other crops, such as soybeans and corn, or to livestock grazing (Valdes *et al.*, 2016). The increase of land devoted to crops and grazing may lead to a decline in their world prices due to the increase in exports. When oil prices are high, demand for ethanol increases and consequently more land is devoted to sugarcane and less to other crops. If less land is devoted to other crops, such as soybeans, this impacts Brazilian exports of these crops, reducing the world's supply in, say soybeans, and, thus increasing its world prices (Valdes *et al.*, 2016).

Supply and demand for oil plays an important role in determining crude oil prices (Figure 8). Increases in oil demand can occur due to increases in global economic growth, an example being between 2000 and 2008 (Levine *et al.*, 2014). In the second half of 2008 oil prices fell. The causes were the 2008 financial crisis bringing a decline in oil demand, aligned with an increase in oil production by OPEC countries (Levine *et al.*, 2014). OPEC countries cut down on production from 2009 onwards bringing prices slowly up. From 2010 to 2012 there was an increase in oil demand coming mainly from Asia Pacific markets, but there was also a decrease in oil supply due to political instabilities in North Africa, sanctions imposed on Iran and declines in production in the United Kingdom and Norway (Levine *et al.*, 2014). More recently, since June 2014, oil prices have collapsed. This decrease is brought by the imbalance between oil supply and demand. There has been an increase in crude oil supply from non-OPEC countries (OECD/IEA, 2015). On the demand side, a reduction in crude oil demand has been brought by: emerging countries entering a stage of development that demands less oil; environmental concerns, and; increased availability of renewable fuels, among others (OECD/IEA, 2015).

<sup>11</sup> Caribbean countries profited from this transaction due to the Caribbean Basin Initiative, which exempts these regions of paying US import tariffs (Elobeid and Tokgoz, 2008).

<sup>12</sup> The size of a module varies by county, considering the smallest and the largest modules, 100 modules of land can vary from 500 to 11,000 hectares (Landau *et al.*, 2012).



**Figure 8.** Evolution of Brent oil prices (US\$/barrel) (adapted from ANP, 2007, 2016).

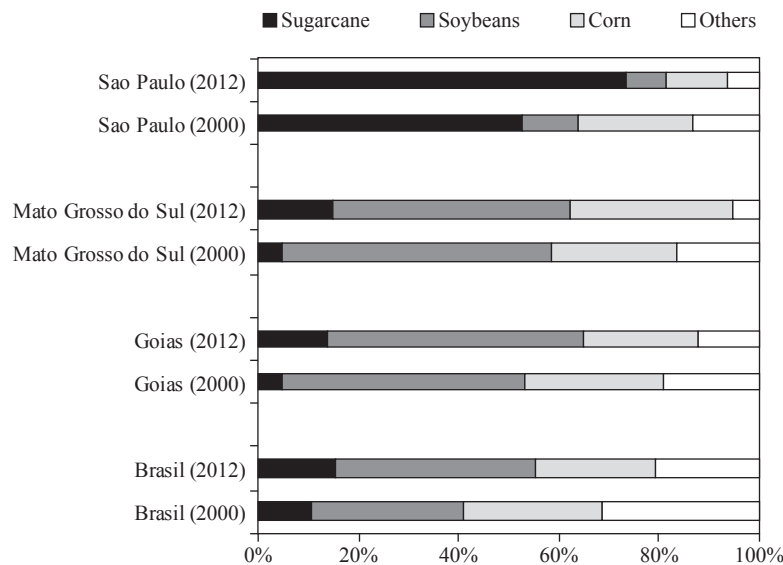
### *Social and environmental issues*

Production of ethanol from sugarcane generates less greenhouse gas emissions compared to production of ethanol from corn. The life cycle of greenhouse gas emissions from ethanol production in the Brazilian state of Sao Paulo is lower than that in the United States, 1.42-1.5 and 3.6-6.02 kg CO<sub>2</sub>-eq per gallon respectively (Crago *et al.*, 2010). In Brazil, most of the CO<sub>2</sub> is released during the harvest as a result of burning sugarcane fields prior to manual harvest (BNDES, 2008). The state of Sao Paulo passed the law in 2002 limiting the practice of sugarcane burning with plans to completely eliminate it by 2021. Additionally, the burning of the sugarcane is lessened by the replacement of manual harvesting with mechanized harvesting. This is the case in Cerrado, where an extensive plain surface allows for the use of mechanized harvest. It is estimated that 80% of the harvested sugarcane in Goias is done mechanically and 90% in Mato Grosso do Sul (Conab, 2013). While the increasing use of mechanical harvesting has positive environmental impact, it creates a social problem by reducing labor demand. One mechanical harvester replaces 100 workers (Neves *et al.*, 2010).

### *Land use change*

After 1933, the sugarcane plantations in the North-Northeast Brazil declined and, sugarcane expanded to the Southeast Brazil (BNDES, 2008). More recently, with the increase in land prices in Sao Paulo, sugarcane has expanded more intensely towards the center-west of Brazil into the states of Goias and Mato Grosso do Sul, where land is relatively cheaper and flatter (Figure 1) (Granco *et al.*, 2015). These shifts are also associated with the development of sugarcane varieties more adaptable to different climates allowing sugarcane to be grown in areas previously seen as less hospitable for this crop.

Since 2000, the agricultural enterprise mix in the Central-West of Brazil has changed. This is particularly noticeable in Goias and Mato Grosso do Sul where the percentage of area planted with sugarcane has increased (Figure 9). Although Sao Paulo continues to produce more than half of the Brazilian sugarcane, Goias and Mato Grosso do Sul have increased their share in the nation's sugarcane production from 2% in 2000 to 10% in 2013 (IBGE, 2014). During the same period the number of mills in Goias and Mato Grosso do Sul have doubled (Granco *et al.*, 2015). It is important to highlight that cattle ranching is by far the dominant land use in Cerrado but its share has decreased in recent decades by the expansion of large mechanized agriculture. This crop expansion in Cerrado has already called the attention of scholars due to its effects on land cover change in the region but also for its indirect effect in the deforestation of the Amazon. Evidences exist that increased soybean expansion in Cerrado may have led to the movement of cattle ranching to the Amazon



**Figure 9.** Percentage planted with soybeans, corn, sugarcane and others in 2000 and 2012 in Brazil and selected states (adapted from IBGE, 2014).

(Walker *et al.*, 2011; Morton *et al.*, 2006; Mc Manus *et al.*, 2016). In addition, recent study (Adami *et al.*, 2012) demonstrates the fact that sugarcane expansion in Cerrado is also occurring on degraded pasture, thus suggesting that sugarcane could be driving cattle ranching into the Amazon. Although these studies are not conclusive, they have heated the debate in both regions.

## 5. Ethanol expansion into the Cerrado: strategic implications for supply chain actors

### *Decisions facing farmers and landowners*

The shift in sugarcane production to the Central part of Brazil as a reaction to market drivers has created unprecedented competitive dynamics in all stages of the Brazilian ethanol supply chain. The arrival of mills in new areas increased the demand for land and labor. One of the farmers in Mato Grosso do Sul complains that ‘the arrival of the mill increased the prices of land’<sup>13</sup>, while that of Goias explains that ‘with the establishment of mills producers are forced to fight over the leftover land and labor’<sup>13</sup>. In referring to the fact that the price to rent the land increased from 12 bags of soybeans per hectare to 16 bags of soybeans per hectare. Andre Rocha, the president of the Syndicate of the Industries of Ethanol in the State of Goias in 2011 says ‘Obviously [the land price increase] is not in the interest of some southerners that prefer to rent the land, preferably cheap, to produce grains’ (O Popular, 2011). Statistics show that the salaries received by workers in the agricultural sector have increased from US\$ 347 in 2000 to US\$ 487 in 2014 in Mato Grosso do Sul and from US\$ 326 to US\$ 502 in Goias in the same period in 2010 values (RAIS, 2016)<sup>14</sup>. On that note, cattle farmers in Mato Grosso do Sul commented: ‘I have had difficulties in hiring people to work with cattle ranching. I have had to contract workers from Paraguay.’<sup>13</sup> and ‘The arrival of the mill created shortage of workers in cattle ranching. Workers migrated to work at the mills due to the higher salaries they offer’<sup>13</sup>. As a result farmers are contemplating a decision to enter into the sugarcane sector by reallocating land from their current economic activity. In order to make his decision the farmer has to take into account the revenue, costs and profits from each activity (Table 1). The farmer may also choose to have a variety of activities, for example rent out a portion of their land to mills and produce cattle on the rest.

<sup>13</sup> Responses given during the survey applied in Mato Grosso do Sul and Goias in 2014 as part of the NSF grant Collaborative Research: direct and indirect drivers of land cover change in the Brazilian Cerrado: the role of public policy, market forces, and sugarcane expansion (Sant’Anna *et al.*, 2015).

<sup>14</sup> Exchange rate used for 2000 was US \$1=R\$ 1.83. Wages were deflated using CPI index from Eurostat data page.

**Table 1.** Profits from various activities in Goiás and Mato Grosso do Sul (FNP, 2014a, 2014b; Lima Filho *et al.*, 2015).<sup>1</sup>

Activity	Goiás (GO)	Mato Grosso do Sul (MS)
soybeans (US\$/ha) <sup>2</sup>	\$ 555.58	\$ 405.69
corn rotation (US\$/ha) <sup>3</sup>	\$ 22.24	\$ 12.54
cattle (500 UA) <sup>4</sup>		
extensive breeding and fattening		\$ 66.18
extensive breeding		\$ 26.75
extensive – complete cycle		\$ 43.11
sugarcane production <sup>5</sup>	\$ 96.80	\$ 96.80
land rental (US\$/ha) <sup>6</sup>	\$ 324.52 - \$ 463.61	\$ 208.62 - \$ 324.52

<sup>1</sup> All values in the table are US\$. Exchange rate used is US\$1 = R\$ 2.157.

<sup>2</sup> Profits from soybeans consider a production of 9,000 kg/ha for GO (1,200 ha module) and 2,880 kg/ha for MS (850 ha module).

<sup>3</sup> Profits from corn are based on the production of 5,400 kg/ha for MS and 6,000 kg/ha for GO, for the corn planted in between the soybean rotation.

<sup>4</sup> UA = animal units. Information on cattle was only available for MS.

<sup>5</sup> Information for sugarcane production were based on rentability and production costs in the state of Sao Paulo.

<sup>6</sup> Land Rental reflects the average land rental paid per hectare in each state.

If the farmer decides to go into the sugarcane sector, there are two main options. Option one would entail producing sugarcane and supplying it to the mill. Second option would entail entering into land lease arrangement with the mill. The option to rent part of the land may be preferred by those who wish to diversify their farm activities without having to invest in adopting a new crop system. As cattle ranchers in Mato Grosso do Sul explain: 'I rent out degraded land to the mills which helps me maintain the cattle ranching'<sup>13</sup>; 'with the increase in the cost of livestock production, I have decided to rent out my land to the mill'<sup>13</sup>, while another states that 'A reason to rent out land to sugarcane is to diversify economic activities'<sup>13</sup>.

One of the limiting factors to new crop adoption is distance, sugarcane loses its sugar content rapidly after being harvested, limiting sugarcane supply to farms within a 50 km from the mill. Another limiting factor for adoption is perceived risk and uncertainty, the global crises that occurred in 2008 forced many mills into bankruptcy and closure. As a cattle rancher in Mato Grosso do Sul explains: 'There is a lack of security and stability in the sugarcane sector'<sup>13</sup>. As one farmer explained: 'Farmers are worried that the mills will not pay'<sup>13</sup>.

A farmer that decides to supply sugarcane must also understand how the price is set by CONSECANA. The price of sugarcane received by the supplier is calculated based on: (1) the amount of TRS in the sugarcane supplied; (2) the average prices of the final products; (3) the production mix of the mill; (4) how much the sugarcane represents in the production costs of each final product (Belik *et al.*, 2012). Although this system functions, there are complaints from suppliers. Specifically, suppliers complain about: (1) the fact that the price of sugarcane does not consider the prices of sub-products, such as energy and vinasse; (2) the lack of access to the mills' decisions in the marketing of the final products; (3) the lack of transparency in the process of quality inspection of the sugarcane; (4) the size of participation of sugarcane on the production costs of the final goods (Belik *et al.*, 2012). For example, one supplier in Mato Grosso do Sul complained about the lack of transparency on the product mix produced by the mill and how the TRS was not calculated for each individual supplier.

The transactions between farmers and mills are governed using three types of contracts: land rental, agricultural partnership, and supply contract. With the first two arrangements, the mill is responsible for the production of sugarcane by paying fixed rent or through a sharecropping arrangement respectively. In the case of the supply contract, the producer agrees to supply a predetermined amount of sugarcane to the mill at a certain

price and schedule. A common feature in this type of contract is the provision of harvesting, hauling and delivery services by the mill at a cost of 30% of the price of a ton of sugarcane (Neves *et al.*, 1998).

### *Decisions facing the ethanol plants*

Given the distance limitation for procuring sugarcane, mills must decide whether to install a facility in an area with established sugarcane production and, possibly, compete with existing mills for inputs or to locate in a new area and have to invest in establishing new procurement base. In order to secure sufficient supply of raw materials mills have two options: incentivize farmers into growing sugarcane, or backward integrate and organize their own sugarcane production. Both options have their costs and benefits. Backward vertical integration would provide a mill with full control over the supply of feedstock but would require significant capital investments and would expose the business to risks inherent in agricultural production (Neves *et al.*, 1998). Relying on farmers for the supply of feedstock does not require large capital investments in production but increases transaction costs associated with coordination and contract enforcement. Some mills use a combination of own production and contracted supply. One example is the ETH, Odebrecht, in the 'Polo Araguaia' in the Central-West, their sugarcane comes partially from land they own or rent and partially from farmers: 'For ETH, it does not make sense to immobilize its capital in lands. That is why we do an intense work to promote (sugarcane) planting in this area' said Luiz Pereira de Araujo, ETH's director of people and sustainability (Freitas, 2010: §6).

Irrespective of the type of arrangement, farmers expect mills to invest in building relationships and earning their trust. As one farmer stated 'If the mill did more for the community maybe it would be easier for it to rent land and to produce sugarcane'<sup>15</sup>. Mills generally argue that their arrival brings benefits to the community: 'The business (SJC Bioenergy) brings development and work to the region,' explains Ingo Kalder, director of SJC Bioenergy in 2013 (Siqueira, 2013: §16). The government also shares this vision, after all, the arrival of the mill has been associated with an increase in social welfare (Sant'Anna *et al.*, 2015).

### *Strategic implications for industry stakeholders*

Multitude of market drivers are reshaping competitive forces in the Brazilian sugarcane farming and processing sectors with important strategic implications for farmers and ethanol plant managers. The geographic expansion of sugarcane production into states of Goiás and Mato Grosso do Sul, historically known for livestock and soybean production, have forced actors at all levels of the ethanol supply chain to reevaluate their strategies. This shift is accompanied and driven by changes in government policies and regulations, technological innovations, as well as, domestic and global demand. The situation warrants careful industry analysis and evaluation of strategic implications for both, the processors with regards to expanding capacity and securing a procurement base, and by farmers, with regards to their production systems and marketing strategies. The industry analysis should provide answers to following questions:

- How the changes in industry's external environment would affect competitive forces in the farming industry?
- What are the strategic implications for sugarcane growers in Sao Paulo?
- What are the strategic implications for farmers in Goiás and Mato Grosso do Sul?
- How the changes in industry's external environment would affect competitive forces in the sugarcane processing industry?
- What are the implications for growth and vertical coordination strategy in the processing industry?
- What are the strategic implications for new and established ethanol mills in Sao Paulo, Goiás and Mato Grosso do Sul?

<sup>15</sup> Responses given during the survey applied in Mato Grosso do Sul and Goiás in 2014 as part of the NSF grant Collaborative research: direct and indirect drivers of land cover change in the Brazilian Cerrado: the role of public policy, market forces, and sugarcane expansion (Sant'Anna *et al.*, 2015).

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## Supplementary material

Supplementary material can be found online at <https://doi.org/10.22434/IFAMR2015.0195>.

**Teaching note** for 'Ethanol and sugarcane expansion in Brazil: what is fueling the ethanol industry?'

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