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Understanding sugarcane production, biofuels, and market volatility in Brazil—A research perspective

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Current underlying production trends

Sugar has been a key product for Brazilian politics and its economy since the early colony times (Canabrava, 2005). Brazil is currently responsible for nearly a quarter (23%) of the world's sugar production and 50% of exports. In 2013–2014, approximately 9 million hectares of sugarcane were cropped, producing 659 million tons (Mt) of harvested cane, 38 Mt of sugar, and nearly 28 billion liters of bioethanol (BE) (CONAB, 2014). The average farm yield has been increasing gradually, reaching 80 tons ha^{-1} but has since decreased by around 12% after 2010 (Figure 1). After soybean and corn, sugarcane is the third most important crop in Brazil in terms of land use. Indeed, Brazil is the second largest BE producer after the United States, which mostly produces maize ethanol, and the two countries collectively account for nearly 90% of the global BE production. The main state producer is Sao Paulo, but a rapid expansion in the central region (Cerrado) of Brazil has also been witnessed over the last decade.

Brief historical perspective and biofuel market volatility

Sugarcane BE is an alcohol-based fuel produced from the fermentation of sugarcane juice, molasses and, more recently, cellulose through the so-called "second-generation" approaches (Goldemberg et al., 2014) that had recently gained interest after the increase in discussions on climate change and oil prices in early 2000. It has been produced in Brazil since the early 20th century but was firmly established in the late 1970s by the National Bioethanol Program (PROALCOOL) in which the Brazilian Federal Government mandated the mixture of anhydrous BE in gasoline (blends up to 25%) and encouraged car makers to produce engines running on pure hydrated ethanol (100%) (Walter et al., 2014). The Brazilian adoption of mandatory regulations to determine the amount of BE to be mixed with gasoline was essential to the success of the program. The motivation was to reduce oil imports that were consuming one-half of the total hard currency from exports. Although it was a decision made by the federal government during a military regime, it was well accepted by civil society, the agricultural sector, and car manufacturers (Goldemberg, 2007). After a period of strong growth during the 1980s, a huge sector depression was then witnessed during the 1990s with the end of government subsidies and low oil prices (Moraes and Zilberman, 2014).

After 2002, a new cycle of high oil prices, low land prices, and a general mood of optimism around the country resulted in building a large number of large new mills (greenfield projects) (Scarpare et al., 2016). Currently, 371 mills are now in regular operation across Brazil. However, after the 2007–2008 global financial crisis, the sector fell deeply into debt and was unable to raise finance from the banks, forcing several mills to reduce crop inputs (fertilizers, herbicides, and diesel), cut its workforce, and change important agricultural management practices (e.g. seed production, cane-field renewal, and mechanization) (Scarpare et al., 2015). The fast pace of mechanization also led to problems associated with soil compaction, high cane losses, and ratoon damage, contributing to the steady decrease in yield after 2010, as shown in Figure 1. From 2011 to 2014, the National Oil Company (Petrobras) started controlling gasoline prices and thereby reducing BE net margins (since owners of flex fuel cars usually switch to gasoline when BE prices rise up to 70% of the gasoline price). Meanwhile, international sugar prices fell significantly between 2010 and 2014. It has been reported that 43 mills closed. However, most of those that survived the economic difficulties were re-engineered to improve their operating processes and to reduce running costs; despite the high financial cost that still threatens some of them, most are showing signs of growth since early 2015.

Biofuel national strategy benefits

Sugarcane (*Saccharum* spp.) is an important crop for coping with climate change mitigation as both BE and biomass for energy are produced. It is also important for food security, as nearly 75% of the world's sugar comes from sugarcane plantations (De Souza et al., 2008). Nowadays, despite recognition that renewable energy can provide solutions to current global energy and economic crises, especially in

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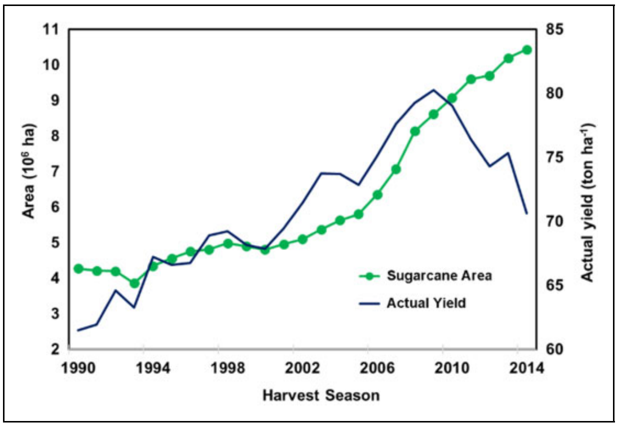

Figure 1. Trends in sugarcane harvested area (10^6 ha) and fresh stalk yield (ton ha^{-1}) in Brazil between 1990 and 2014. Data obtained from IBGE (http://www.sidra.ibge.gov.br).

developing countries (Joly et al., 2015), the current low oil prices and concern regarding food security and loss of habitats for biodiversity from direct and indirect land use change are recognized as important issues for evaluating future options to fuel production. However, in Brazil the benefits from relying on sugarcane as a pillar crop far outweigh the negative aspects the country is still trying to overcome (Martinelli and Filoso, 2008). The main direct positive aspects include the number and quality of employment, mainly after the adoption of mechanized harvesting and the enforcement of labor rules. Also, energy security for the country and hard currency savings from the balance of trade were crucial for national development. Indirectly, there has also been significant employment in heavy industry in regions where mills have been located, supporting employment and economic development. Over the last three decades, Brazil has reduced its levels of poverty and hunger and successfully transitioned from a dictatorship to a democracy (Thaler, 2013) with the agricultural sector underpinning the economic basis for such change. Focusing only on the BE market, it must be remembered that BE costs have declined as production increased on average by 6% per annum, from 0.9 billion gallons in 1980 to 3.0 billion gallons in 1990 and then up to 4.2 billion gallons in 2006 (Goldemberg, 2007). The cost of BE in 1980 was approximately three times the cost of gasoline, but governmental cross-subsidies paid for the price difference at the pump. The subsidies came mostly from taxes on gasoline and were thus paid by automobile drivers. All fuel prices were controlled by the Brazilian government. Overall subsidies to ethanol are estimated to be around US$30 billion over the last 20 years (Goldemberg et al., 2008) but were more than offset by a US$50 billion reduction in petroleum imports as of the end of 2006. By 2014, both BE- and bagasse-based bioelectricity produced from sugarcane mills supplied almost 16% of national energy demand (BRASIL, 2015).

Future prospects and industry challenges

The brief historical perspective provided above highlights a period of significant production and market turbulence, so what are the future prospects over the coming decades for the Brazilian sugarcane sector? Brazil has a comparative advantage to help meet demand for greenhouse gas–mitigating biofuels because it has a plentiful land resource base; future climate scenario seem to be more positive for Brazil (or less negative) (Marin et al., 2013) compared with other countries (e.g. Knox et al., 2010; Singels et al., 2013). Considering the availability of water resources, Brazil is lucky to be privileged with plentiful surface and groundwater (Walter et al., 2014); at present only about 1% of the total cane area is currently irrigated, in contrast with other major producing countries (Carr and Knox, 2011). However, although sugarcane production has more than doubled from 2000 to 2013, most (88%) of this increase came from the expansion of the sugarcane production area, since the rate of sugarcane yield gain in Brazil has been relatively low, with only 12% being attributable to yield increase.

The challenge now is therefore to increase sugarcane yields on existing farmland given concerns regarding the land conversion to crop production and the rapidly increasing global demand for sugarcane BE. So, a key issue is the extent to which the rate of yield gain can be accelerated above the yield trajectory of the past two decades to achieve greater sugarcane production through higher yields without further (or at least with minimum) expansion of the sugarcane production area. Based on the yield gap approach (van Ittersum et al., 2013), Marin et al. (2016) completed an assessment of potential sugarcane production across all major sugarcane producing regions in Brazil to determine the current sugarcane yield gap (Y_g) and to estimate the additional production that could be achieved by closing the exploitable Y_g. This analysis also assessed the degree to which the extra production might satisfy the expected future demand for sugarcane while avoiding or minimizing any sugarcane area expansion. The upscaled national average water limited potential yield (Y_w) sugarcane in Brazil was estimated to be 134 tons ha^{-1}. Given that the current national average actual yield (Ya) is 82 tons ha^{-1}, the average Y_g was estimated to be 52 tons ha^{-1}, which represents over a third (38%) of Y_w. The exploitable Y_g (based on 80% of Y_w, or 107 tons ha^{-1}) would be 25 tons ha^{-1}. These results confirmed previous studies using different approaches (Marin et al., 2008; Marin and de Carvalho, 2012) and benchmark observed yields from well-managed commercial fields. Using two (low and high) future sugar and BE demand scenarios for 2024, it was found that Brazil has the potential to meet projected high-demand scenario with only a modest expansion of the cropped area (+13%), and even with an 18% reduction in cropped area under the low-demand scenario. However, this would require a significant acceleration in the rate of yield gain compared with the observed historical trend, which would be difficult to achieve without a concentrated and well-funded research and extension effort. In contrast, if yields continue to increase following the historical trajectory of the last two decades, then a respective expansion of +5% and +45% in the sugarcane cropped area would be needed to satisfy the low- and high-demand scenarios by 2024, respectively.

Research gaps

Considering the Brazilian sugarcane sector is starting a new period of growth after five years' stagnation (and/or depression) (Figure 1), one may suggest that specific attention in needed to improve crop production prioritizing among others the following research gaps: (i) breeding programs focusing on the expanding areas in the Cerrado should be reinforced, as well as focusing new varieties for reducing inter-row spacing and improving crop tillering; (ii) the transition to the mechanized harvest remains to be accomplished, as the yield decline observed in the last few years (Figure 1) is in part due to mechanical damage on the crop ratoons and soil compaction due to intense machinery-trafficking in fields; (iii) the trash blanket is still demanding significant adjustments in agronomic management ranging from irrigation, cultivar selection, and fertilizer application (Walter et al., 2014); (iv) the development and improvement of available systems for mechanical no-till planting are also considered a breakthrough for reducing costs and improving soil quality; and (v) development and improvement of planning, management, prediction, and control tools for increasing input use efficiency and reducing costs for agricultural production. While the outlook for Brazil's sugarcane industry appears positive, it will be strongly influenced by the extent to which science and transfer of research knowledge can be successfully translated into practical change and improvement at the farm scale.

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