Impact of biofuel production in Brazil on the economy, agriculture, and the environment

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Key words: bioethanol, cattle, deforestation, ethanol, livestock, migration, rural exodus

Introduction

Brazil is divided into 26 states and a federal district organized in five geographic regions (Figure 1). In recent years, Brazil, one of the main suppliers of agricultural products in the world, has been a leading player in the beef, poultry, and pork world markets. Brazil ranks as the world’s largest meat exporter, second largest beef producer, and is home to the world’s biggest commercial beef herd. According to FAO (2010), Brazil is the largest producer of sugarcane and oranges, the second largest for soybean, and the third largest for corn. It is also an international leader in renewable sources of energy such as hydroelectric power and biofuel (sugar-based ethanol) production. The country is also a pioneer for use of ethanol as a motor fuel.

In 2010, Brazil produced 717 million tons of sugarcane, which yielded 36.1 million tons of sugar and 27 billion liters of ethanol (IBGE, 2010a), making the country the largest sugar producer in the world and the second largest ethanol producer behind the U.S. Most of the ethanol production is absorbed by the domestic market where it is sold as either ethanol fuel or blended with gasoline. All gasoline sold in Brazil is a blend of 18 to 25% ethanol.

Nowadays, ethanol substitutes for a little over one-half of all the gasoline that would otherwise be consumed in Brazil. Sugarcane bagasse is also becoming an important primary energy source for electricity production. By 2020, it could reach a production level comparable with the output of the Itaipu hydropower dam (Goldemberg, 2011), which produced around 98 million MWh in 2012.

Thus, this review will describe previous and current situations of the bioethanol industry in Brazil and how it has affected livestock and agriculture productions, as well as environmental and social economic issues.

Development of the Biofuel (Sugarcane-based Ethanol) Industry in Brazil

Background

For a long time, the sugarcane industry has been one of the pillars of the Brazilian economy. For over two centuries following the introduction of the first cane cuttings into the country in 1532, sugar was the main product of Brazil. Around 40 years ago, the sector started to undergo a transformation. In addition to sugar, mills started to focus on ethanol production (Neves et al., 2011).

According to Jank (2011a), it is important to note that this progress was achieved in spite of an absence of long-term public policies. Over the past three decades, the lack of structural regulations for this sector created great instability in the production and consumption of alternative energy. The oil crises were not sufficient to incite governmental authorities to focus on the sustainability of renewable fuels and this situation led

Implications

- Sugarcane planted area in Brazil grew by 7.56% per year during the last decade. The state of São Paulo (Southeast region) was responsible for 55.3% of all Brazilian sugarcane planted area in 2010, appreciating even more arable land values.
- Consequences of the appreciation of land prices:
  - Rural exodus happened in almost all regions, with the greatest rate found in the Southeast region
  - Bovine cattle production moved toward the Midwest and North regions
  - Cattle industry underwent a process of intensification: around 60% of the slaughtered head growth was due to an increase in slaughter rate (slaughtered head/herd size) and 40% due to an increase in herd size, indicating that production efficiency is improving
- Contribution of sugar/ethanol industry to supply co-products for cattle operations is small, and has become a recent concern for the growing livestock sector.
- In the near future, livestock production, especially beef cattle, may move to other regions and promote more intensive production systems.

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to cycles of fuel substitution with negative effects for all stakeholders, including consumers. This was especially true after the first oil crisis. Since the 1970s, short-term fuel policies sent mixed signals to the market and impaired the flow of investments. These policies could be divided into at least five distinct phases:

- **Phase 1:** “Dieselisation” in the 1970s, when gasoline was replaced by diesel, leading to an increase of the diesel vehicle fleet
- **Phase 2:** “Proálcool”, a national ethanol program that promoted vehicles powered by hydrous ethanol
- **Phase 3:** A new “gasolinisation” in the early 1990s, when ethanol began losing competitiveness compared with gasoline due to the fall in international oil prices
- **Phase 4:** Incentives for Vehicular Natural Gas (VNG) in the late 1990s, which was stimulated by a temporary surplus of natural gas leading to changes in a significant portion of the automobile fleet in major cities
- **Phase 5:** The flex-fuel revolution, which started in 2003 with the introduction of dual-fuel vehicles

The National Ethanol Program, popularly called Proálcool, was launched on November 14th, 1975 as an attempt to make Brazil less oil dependent. It aimed at developing techniques and improving inputs to produce ethanol. In the first stage (1975 to 1979), the efforts were concentrated on producing anhydrous ethanol to be added to gasoline. In 1979, a second stage (after the second oil crisis) was launched and aimed, after technical changes in the engines, to make and use the first cars powered entirely by hydrous ethanol (Barros, 2007). It was so successful that, in 1985, 95% of the light vehicles produced in Brazil were built to use hydrous ethanol. In 2003, flex-fuel vehicles were launched and currently account for about 90% of new sales, constituting the high point of Brazilian ethanol’s success story in the present decade. Nevertheless, there is still room for improvement in terms of gains in energy efficiency and environmental performance (Nigro and Szwarz, 2011).

More recently, attention has turned to bioelectricity, ethanol-based chemicals, and carbon credit trading. All this embodies the possibility of employing advanced technologies to enhance productivity and reduce costs. It adds up to a new business paradigm, where competitiveness is the watchword. However, advances in the sugar-energy sector have not been limited to only technology. New production plants in Brazil are also involved in social and environmental questions. The sugar-energy sector, one of the largest employers in Brazil, now has a working agenda that includes improving the quality of life of its workers, the rational use of land and water, mitigation of the effects of mechanized harvesting, and preservation of ecosystems. While significant progress has been made, much remains to be done if the sector is to continue its growth (Neves et al., 2011).

**Current situation**

Despite the fact that the Brazilian ethanol production is one-half of that in the U.S., Brazil has the most consolidated program in the world due to the following reasons: 1) the gasoline contains 25% of ethanol, 2) ethanol is available in all gas stations, and 3) 50% of the car fleet is “flex fuel,” 90% of all new cars are “flex fuel” (or dual-fuel, running with any proportion of ethanol and gasoline). Meanwhile, only 10% of ethanol is added to gasoline in the U.S. In 2010, ethanol was recognized by the U.S. Environmental Protection Agency (EPA) as an advanced biofuel due to its great ability to mitigate greenhouse gas emission. In spite of good performance of ethanol in the environmental and energetic areas, the sector, which had been growing at a rate of 10% per year between 2000 and 2008, was deeply affected by the 2008 financial crisis. Currently, the growth is about 3% per year, a very low rate to meet the worldwide demand for sugar as well as the ethanol needs for the “flex fuel” cars entering the Brazilian market (Jank, 2011b).

To understand the sugarcane industry growth, a study was conducted using Brazilian official databases (IBGE, 2010b) for the last two decades (1991 to 2010), and results are shown in Table 1. In Brazil, the area cultivated with annual crops increased by 2.7% per year during the last decade, reaching 59.1 million ha in 2010. Among the regions, the Midwest presented the highest growth in terms of areas used for annual crops (5.31% per year during the last 10 years), followed by the Southeast region (3.29% per year).

As shown in Table 1, in 1991, sugarcane represented 9.5% of all the Brazilian area planted with annual crops (4.2 million ha), increasing to 15.5% in 2010 (9.16 million ha). During the last decade, the area planted with sugarcane in Brazil grew at a much greater rate than the total area with annual crops (7.56% per year against 2.70% per year, respectively). Among the regions, the situation in the Southeast, the most developed region of the country, is worth mentioning. This region was responsible for 65.8% of the total area cultivated with sugarcane in the country and this culture accounted for 55.8% of the area occupied by annual crops in the region in 2010. São Paulo, one of the four states of the Southeast region, had 55.3% of the Brazilian sugarcane planted area in 2010. The Midwest region showed the highest increase in the area cultivated with sugarcane, which corresponds to 13% of the total sugarcane area and 29.1% of the total area cultivated with annual crops in the country. Although the North region showed the second highest increase in sugarcane area, it accounts for...
less than 1% of the area planted with sugarcane in Brazil (34,393 ha in 2010).

During the last 10 years, sugarcane yield grew by 9.18% per year in Brazil, reaching around 717 million tons in 2010; the productivity increased from 62 ton/ha in 1991 to 69 ton/ha in 2001 and up to 79 ton/ha in 2010. Nevertheless, during the last decade, only 17% of the increase in Brazilian sugarcane yield was due to productivity improvements, whereas 83% was due to an increase in harvested area (productivity/yield ratio = 0.17). Figure 2 shows the growth of sugarcane planted area (ha) between 1991 and 2010 in Brazil.

### Development of the Brazilian Beef Cattle Industry

For the past two decades, the cattle industry has moved toward the Midwest region, which is now home to one-third of the herd in Brazil. However, recent cattle production has started to move north because the expansion of soybean production raised land prices in the Midwest. Raising cattle in the North is 10% more profitable than in other regions because of the lower land prices, although once timber is harvested, there is competition from other land uses such as crop production (Steiger, 2006).

To understand the beef cattle industry growth, another study was performed using Brazilian official databases (IBGE, 2006a, 2006b) from 1997 to 2006 and the results are shown in Table 2. In 1997, Brazil had approximately 161.4 million bovines and slaughtered 14.8 million head (for

### Table 1. Annual average growth rate of total annual crops planted area and sugarcane planted and harvested area, yield, and productivity in different regions of Brazil in the last two decades.

<table>
<thead>
<tr>
<th>Region</th>
<th>Time period</th>
<th>Total planted area (yr)</th>
<th>Sugar-cane planted area (yr)</th>
<th>Sugar-cane harvested area (yr)</th>
<th>Sugar-cane yield (yr)</th>
<th>Sugar-cane productivity (yr)</th>
<th>Productivity/yield ratio (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>1991-2010</td>
<td>0.92</td>
<td>1.71</td>
<td>4.44</td>
<td>3.87</td>
<td>6.02</td>
<td>2.07</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td>1.55</td>
<td>2.27</td>
<td>9.09</td>
<td>10.88</td>
<td>12.16</td>
<td>1.15</td>
</tr>
<tr>
<td>Northeast</td>
<td>1991-2010</td>
<td>13.00</td>
<td>0.17</td>
<td>-0.44</td>
<td>-0.28</td>
<td>1.11</td>
<td>1.39</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td>12.45</td>
<td>1.49</td>
<td>1.13</td>
<td>1.48</td>
<td>1.96</td>
<td>0.47</td>
</tr>
<tr>
<td>Southeast</td>
<td>1991-2010</td>
<td>26.17</td>
<td>1.08</td>
<td>4.71</td>
<td>4.65</td>
<td>5.56</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td>55.80</td>
<td>3.29</td>
<td>8.71</td>
<td>8.46</td>
<td>9.99</td>
<td>1.41</td>
</tr>
<tr>
<td>South</td>
<td>1991-2010</td>
<td>1.29</td>
<td>1.08</td>
<td>5.81</td>
<td>5.82</td>
<td>6.89</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td>3.55</td>
<td>1.18</td>
<td>7.06</td>
<td>7.06</td>
<td>8.04</td>
<td>0.92</td>
</tr>
<tr>
<td>Midwest</td>
<td>1991-2010</td>
<td>3.72</td>
<td>5.89</td>
<td>8.41</td>
<td>8.70</td>
<td>9.72</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td>6.92</td>
<td>5.31</td>
<td>12.34</td>
<td>12.78</td>
<td>14.29</td>
<td>1.34</td>
</tr>
<tr>
<td>Brazil</td>
<td>1991-2010</td>
<td>9.48</td>
<td>1.93</td>
<td>3.92</td>
<td>3.94</td>
<td>5.25</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td>15.51</td>
<td>2.70</td>
<td>7.56</td>
<td>7.52</td>
<td>9.18</td>
<td>1.54</td>
</tr>
</tbody>
</table>

1 Relative sugarcane area in 1991 (% of total annual crops area)
2 Relative sugarcane area in 2010 (% of total annual crops area)
3 Annual average growth rate of total annual crops area (%/year)
4 Annual average growth rate of sugarcane planted area (%/year)
5 Annual average growth rate of sugarcane harvested area (%/year)
6 Annual average growth rate of sugarcane yield (%/year)
7 Annual average growth rate of sugarcane productivity (%/year)
8 Productivity/yield ratio

Source: IBGE, 2010b

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The pressure exerted by the sugar-ethanol industry on livestock production is definitively the appreciation of land prices, especially in those areas with high agricultural potential, characterized by fertile and well-drained soils and flat topography. For the sugar-ethanol industry, the most important thing is the proximity of these lands to the large urban centers. As in many parts of the world, such areas generally have good road network infrastructure which facilitates the transportation of inputs and outputs.

Rising prices of agricultural commodities boosted Brazilian land prices in 2010. During that year, arable land prices rose considerably, with an average appreciation of 9.1%. The most valued lands of the country are situated in the South and Southeast regions. For example, the sugarcane areas in the states of São Paulo, Espírito Santo, and Minas Gerais (all in the Southeast region) had an appreciation of 20%, with prices reaching up to R$24,000 per hectare (US$12,000/ha; FNP, 2011). Obviously, the reason is the profitability of this sector. Intensive livestock production has an annual return of R$300.00/ha (US$150.00/ha) whereas sugarcane has an annual return of R$500 to 800.00/ha (US$250.00 to 400.00/ha). Profitability of the latter varies depending on the type of contract between farmers and mills (Coan Consulting Agency, personal communication). Currently, producing sugarcane is only less profitable than eucalyptus for cellulose production which provides an annual return of R$900.00/ha (US$450.00/ha).

As a result of the land value appreciation, livestock activity, and the people who depended on it, experienced three different situations: 1) local migration, 2) regional migration, or 3) technological migration.

**Local migration**

The local migration, or the abandonment of activity, seems to have affected mainly small (up to 40 ha) and medium (40 to 150 ha) farmers. They had the appropriate knowledge for extensive livestock production requiring only basic technology, but they did not have adequate knowledge for farming, making it impossible for them to produce raw material for the sugar-ethanol industry. Instead, they chose to lease their lands to sugarcane mills. Thereby, the mills became responsible for producing sugarcane, providing a small but relatively secure source of income to the owners. The landowners are no longer ranchers and migrated to the cities where they could look for jobs to supplement their income from the land rental. This situation explains part of the rural exodus that occurred and

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**Table 2. Annual average growth rate of bovine herd, number of slaughtered heads, slaughter rate, individual carcass weight, and slaughter rate/slaughtered heads ratio in different regions of Brazil from 1997 to 2006.**

<table>
<thead>
<tr>
<th>Region (state)</th>
<th>Relative herd¹ in 1997 (%)</th>
<th>Relative herd² in 2006 (%)</th>
<th>Bovine herd³ (vehicles)</th>
<th>Slaughtered heads⁴ (mil)</th>
<th>Slaughter rate⁵ (%/year)</th>
<th>Individual carcass weight⁶ (kg)</th>
<th>SR/SH ratio⁷</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>11.96</td>
<td>19.94</td>
<td>9.83</td>
<td>20.93</td>
<td>10.10</td>
<td>0.17</td>
<td>0.48</td>
</tr>
<tr>
<td>Northeast</td>
<td>14.76</td>
<td>13.54</td>
<td>2.47</td>
<td>9.86</td>
<td>7.21</td>
<td>0.79</td>
<td>0.73</td>
</tr>
<tr>
<td>Southeast</td>
<td>22.91</td>
<td>19.04</td>
<td>0.83</td>
<td>8.42</td>
<td>7.52</td>
<td>0.47</td>
<td>0.89</td>
</tr>
<tr>
<td>South</td>
<td>16.53</td>
<td>13.21</td>
<td>0.65</td>
<td>4.35</td>
<td>3.68</td>
<td>-0.15</td>
<td>0.85</td>
</tr>
<tr>
<td>Midwest</td>
<td>33.84</td>
<td>34.26</td>
<td>3.47</td>
<td>7.98</td>
<td>4.36</td>
<td>-0.26</td>
<td>0.55</td>
</tr>
<tr>
<td>Brazil</td>
<td>100</td>
<td>100</td>
<td>3.34</td>
<td>8.72</td>
<td>5.21</td>
<td>0.07</td>
<td>0.60</td>
</tr>
</tbody>
</table>

¹ Relative bovine herd in 1997 (% of Brazilian herd)
² Relative bovine herd in 2006 (% of Brazilian herd)
³ Annual average growth rate of bovine herd (%/year)
⁴ Annual average growth rate of bovine slaughtered head (%/year)
⁵ Annual average growth rate of bovine slaughter rate
⁶ Annual average growth rate of individual carcass weight (%/year)
⁷ Slaughter rate/slaughtered head ratio

Source: IBGE, 2006a,b

a total of 3.3 billion kilograms and an average individual carcass weight of 224 kg). In 2006, Brazilian bovine herd increased to 205.9 million head and slaughter doubled, up to 30.4 million head (for a total of 6.9 billion kilograms and an average individual carcass weight of 227 kg). Slaughter rate is the number of slaughtered head divided by herd size. From 1997 to 2006, the Brazilian bovine herd increased by 3.34% per year, the number of slaughtered head increased by 8.72% per year, and the slaughter rate increased by 5.21% per year. Around 60% of the growth in the number of slaughtered head was due to an increase in slaughter rate, and the remaining 40% was due to an increase in herd size, which means that the cattle industry is becoming more efficient.

Among the five Brazilian regions, the situation in the North and Midwest is most noteworthy. The North region encompassed the Amazon forest, representing an agricultural frontier, and it showed the highest increase in bovine herd (9.83%/year), in number of slaughtered head (20.93%/year), and in slaughter rate (10.10%/year). Almost one-half of the growth in the number of slaughtered head (slaughter rate/slaughtered head ratio = 0.48) was due to the increase in slaughter rate, whereas the other half was due to an increase in herd size. The Midwest region is a traditional producer of beef cattle and grains, and it had the largest bovine herd in 2006 (34.26% of the total). It showed the second highest growth in herd size (3.47%/year), but the second lowest growth in slaughter rate (4.36%/year). As for the North region, about one-half (55%) of growth in the number of slaughtered head was due to an increased slaughter rate. The Southeast region is the most technologically developed region in Brazil. In 1997, it had the second largest herd in Brazil, but since then it has shown the second least growth in herd size (0.83%/year), as well as the second greatest growth in slaughter rate (7.52%/year). Most of the augmentation of the slaughtered heads number was due to an increase in slaughter rate (89%) but not in herd size (11%), meaning that the cattle industry in this region is getting more efficient and specialized.

Figure 3 shows the livestock growth between 1991 and 2010 in Brazil. It allows for the comparison with the corresponding sugarcane industry growth during the same period (Figure 2).
Animal Frontiers

continues to happen more intensely in the Southeast region, mainly in São Paulo state.

This is demonstrated by a third study using Brazilian official databases (IBGE, 2010c) from 1991 to 2010 and conducted to understand the pattern of Brazilian population growth (Table 3). The most recent demographic census, performed in 2010, reported a population of 190.8 million inhabitants, rising by 1.38% per year during the last two decades. During the same period, the rural population decreased by 0.95% per year, from 35.8 million in 1991 to 29.8 million. On the one hand, the Southeast region, which accounts for 42.1% of the total Brazilian population, had the highest decrease in rural population. In this region, the bucolic countryside scenery changed. Several houses have been demolished over the years to prevent trespassing and illegal possession. On the other hand, the North region showed the highest increase of total and urban populations, but it represents only 8.32% of the total Brazilian population (Table 3).

**Regional migration**

The regional migration of production systems affected mainly medium ranchers, especially those using traditional extensive production systems, based on cow-calf and stocker operations. Some of them exchanged their small farms, mostly located in the Southeast region, for extensive areas at the agricultural frontier (Midwest and North regions). These ranchers have sought to maintain their traditions and production technologies in

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**Table 3. Annual average growth rate of total, urban, and rural population in different regions of Brazil in the last two decades.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Time period</th>
<th>Rel. pop(^1) in 1991 (%)</th>
<th>Rel. pop(^2) in 2010 (%)</th>
<th>Total population(^3) (%/y)</th>
<th>Urban population(^4) (%/y)</th>
<th>Rural population(^5) (%/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>1991-2010</td>
<td>6.83</td>
<td>8.32</td>
<td>2.44</td>
<td>3.61</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td></td>
<td></td>
<td>2.09</td>
<td>2.61</td>
<td>0.78</td>
</tr>
<tr>
<td>Northeast</td>
<td>1991-2010</td>
<td>28.94</td>
<td>27.83</td>
<td>1.18</td>
<td>2.17</td>
<td>-0.83</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td></td>
<td></td>
<td>1.07</td>
<td>1.65</td>
<td>-0.35</td>
</tr>
<tr>
<td>Southeast</td>
<td>1991-2010</td>
<td>42.73</td>
<td>42.13</td>
<td>1.31</td>
<td>1.60</td>
<td>-1.48</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td></td>
<td></td>
<td>1.05</td>
<td>1.31</td>
<td>-1.89</td>
</tr>
<tr>
<td>South</td>
<td>1991-2010</td>
<td>15.07</td>
<td>14.36</td>
<td>1.12</td>
<td>1.85</td>
<td>-1.71</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td></td>
<td></td>
<td>0.87</td>
<td>1.36</td>
<td>-1.47</td>
</tr>
<tr>
<td>Midwest</td>
<td>1991-2010</td>
<td>6.42</td>
<td>7.37</td>
<td>2.12</td>
<td>2.59</td>
<td>-0.58</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td></td>
<td></td>
<td>1.91</td>
<td>2.15</td>
<td>0.20</td>
</tr>
<tr>
<td>Brazil</td>
<td>1991-2010</td>
<td>100</td>
<td>100</td>
<td>1.38</td>
<td>1.97</td>
<td>-0.95</td>
</tr>
<tr>
<td></td>
<td>2000-2010</td>
<td></td>
<td></td>
<td>1.17</td>
<td>1.55</td>
<td>-0.65</td>
</tr>
</tbody>
</table>

\(^1\) Relative population in 1991 (% of total Brazilian population)

\(^2\) Relative population in 2010 (% of total Brazilian population)

\(^3\) Annual average growth rate of total population (%/year)

\(^4\) Annual average growth rate of urban population (%/year)

\(^5\) Annual average growth rate of rural population (%/year)

Source: IBGE, 2010c

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**Figure 3. Bovine herd in relation to territorial area (animals/ha) in 1991 and 2010 (IBGE, 2006a; Cartogram created using IBGE ESTATCART).**
these new areas. As a result of this migration, some opinion leaders pinpointed the relation between sugar-ethanol producing activity and the clearing of native forest areas, caused by pressure from the industry to migrate cattle activity to “untouched” areas.

In fact, as shown in Figure 5, for the entire country, there is little association between changes in the areas growing sugarcane or occupied by pasture. In this diagram, the x axis represents the annual variation (increase or decrease) of sugarcane growing area (IBGE, 2010b) in Brazilian states from 1995 to 2006, while the y axis represents the changes in total pasture area (total = natural + cultivated) during the same period (IBGE, 2006c). The growth of these crops is represented by the slope between planted areas. In the North region, for example, the state of Tocantins lost 274,000 ha of pasture annually, but sugarcane did not contribute to this phenomenon. This culture reported annual sugarcane crop area losses of 40 ha. In the Midwest region, the state of Goiás lost 335,000 ha of pasture annually, but the area used for growing sugarcane increased by only 9,700 ha (i.e., a direct or indirect replacement of only 2.9% of one crop by another). In southeastern Brazil, the most populous region, Minas Gerais is the state with the highest loss of pasture area (664,000 ha/year), but the replacement of pasture by sugarcane crop was only 1.7%. Obviously, other crops, especially soybeans, contributed to the reduction of pasture areas (Figure 4).

It was in São Paulo state, located in the Southeast region, that this pressure was the most evident (Figure 5). From 1995 to 2006, the state showed an annual decrease of 197,000 ha in pasture area and an increase of 84,400 ha in sugarcane area, representing a direct or indirect replacement of 42.9%. Therefore, the pressure of the bioethanol industry on livestock farming is evident, although sugarcane crop alone cannot be blamed for this situation. Citrus industry, mainly for orange juice extraction, and more recently forestry, mostly for eucalyptus wood pulp production, played a growing role in this competition. Even grain crops, such as corn or sorghum, for silage production in beef cattle intensive systems may contribute to the reduction of pasture areas due to the land value appreciation.

**Technological migration**

There is no doubt that the pressure exerted by the bioethanol industry on livestock production, by raising land values, was largely responsible for technological migration. This pressure provides the incentive to change extensive production systems into intensive production systems highly specialized and requiring improved technology for finishing cattle in large feedlots associated with slaughter plants, many of them working exclusively for export. Undoubtedly, the technological migration of livestock production has been a positive side-effect of the bioethanol industry. Feedlots take advantage of the low value of steers purchased from grazing
Possibilities of Integration between Bioethanol Industry and Livestock Production

In the U.S., each liter of ethanol produced in a typical dry milling plant generates roughly 0.8 kg of dried distillers grains with solubles (DDGS; Taheripour et al., 2010). A major portion of DDGS produced from the bioethanol industry in the U.S. is used inside the country, with a minor portion (about 12.4% of the U.S. DDGS) exported to other parts of the world, such as Canada, EU members, and Mexico, as well as African and Asian countries (Taheripour et al., 2010). It is estimated that 70% of the by-products and co-products generated by the ethanol production from corn is used by the livestock sector. Nevertheless, in the U.S., in spite of the large proportion of biofuel co-products available for the livestock sector, the demand for these products is huge because almost all slaughtered animals are finished in feedlots. Therefore, distillers grains are no longer a cheap alternative to help ranchers mitigate rising corn prices in the U.S. because distillers grains and corn prices have become correlated over time (Anderson et al., 2008).

In Brazil, 98% of ethanol is produced from sugarcane crops (FAO, 2012). The supply of co-products from the bioethanol industry to livestock operations used to be large, but nowadays it is small, thus becoming a concern for the livestock sector, especially the most intensive ones. But, unlike the U.S., only 8.70% of the slaughtered cattle are finished in feedlots in Brazil (Millen et al., 2009).

Among the by-products produced by the Brazilian bioethanol industry, in natura sugarcane bagasse, hydrolyzed bagasse, molasses, yeast, and sugarcane tops can be used as animal feedstuffs.

In natura sugarcane bagasse

It is the main byproduct of the sugar-ethanol industry and its use was widespread in the 1980s, mainly in the southeast region (Ezequiel et al., 2006). Bagasse, the residual dry fiber after juice extraction, has high levels of cell walls, low energy density, and low concentrations of protein and minerals. It is considered as a low nutritive value roughage (Carvalho et al., 2006). Bagasse represents approximately 30% of the sugarcane weight (Magalhães et al., 1999).

About 10 years ago, or even less, ranchers who decided to intensify their production system, or at least part of it, easily obtained bagasse at low prices directly from the mills and they used it as a fiber source in feedlot diets. Currently, after the adoption of co-generation energy systems, burning bagasse at sugar/ethanol plants made this product nearly unavailable to ranchers. To convince big ranchers to concede large areas of land to cultivate sugarcane, some mills signed contracts ensuring bagasse supply to feedlots. Nevertheless, led by economic issues, most biofuel plants preferred burning bagasse rather than selling it to feedlots operations. Therefore, the competition for arable land between forage production and sugarcane crop made livestock production less attractive, especially to small- and medium-sized ranchers who have no opportunity to sign contracts for bagasse supply.

Hydrolyzed bagasse

Due to limited nutritional value of bagasse (Magalhães et al., 1999), several attempts were made in Brazil to improve its quality. The most common efforts include chemical (urea, anhydrous ammonia, sodium hydroxide, and other alkaline products) and physical methods (Pires et al., 2006). The hydrolysis of bagasse is the most efficient physical method and is performed using pressure and steam, making it more digestible, but with low potential for animal intake (Ezequiel et al., 2006). During processing, steam under high pressure and temperature results in acetic acid production, which promotes the acid hydrolysis of fiber. By the end of the treatment, the sudden release of steam and water present in the bagasse fragments results in the loosening of fibers, therefore increasing...
the digestibility of the material (Pinto et al., 2003). Nowadays, the technology of bagasse hydrolysis, intensively developed in the 1990s due to the abundant availability of this byproduct, is nearly forgotten. Only old sugarcane mills, which maintain their own feedlots, continue to use their obsolete equipment.

**Yeast**

Other by- or co-products generated by the bioethanol industry are even less important to livestock, resulting in poor ethanol-beef integration. For example, yeast is recovered from fermentation vats and represents a high quality protein source (Magalhães et al., 1999). Crude protein concentration ranges from 30 to 60% and total nitrogen consists of approximately 80% aminoacids, 12% nucleic acids, and 8% ammoniacal nitrogen. Its carbohydrate composition is quite variable, ranging from 15 to 60% of its dry weight (Ezequiel et al., 2000). Wet yeast is only used in feedlots owned by sugarcane mills and, therefore, located close to each other, where it is often stored in silos. The high cost of the dehydration process makes this product, when used as protein source, non-competitive. However, dry yeasts can still be marketed as a feed additive to control acidosis by stimulating the development of ruminal lactate-consuming bacteria, and to promote microbial growth, particularly cellulolytic bacteria (Newbold et al., 1995) by stimulating ruminal oxygen consumption.

**Molasses**

Molasses is a brownish viscous liquid, obtained from centrifugation of the cooked mass produced to recover sugar during sugarcane processing. This liquid contains about 75% of dry matter and 50% of sugar, mainly sucrose and minerals (Pinto et al., 2003). Availability of molasses is low because it is treated by the industry to extract sugar and its derivatives. Another drawback to the utilization of this product in feedlots is its physical properties which make it adhere to transport and feeding equipment (carts, feeding wagons, and other mixers).

**Sugarcane tops**

The sugarcane tops, the leaves left in the field after stalk harvesting, could be ensiled or used as dry hay. However, their use in cattle production (extensive or feedlots) is limited due to their low nutritional value and limited acceptability. In addition, buying equipment to use this material is considered a high risk investment because it is likely that this material will no longer be available to ranchers in the next four to five years due to the promising technology to produce second-generation ethanol (Lee and Lavoie, 2013). There is another barrier to their use in livestock farming. The removal of sugarcane tops from the field is not recommended because this material covers the soil, preventing erosion, maintaining moisture, and promoting nutrient recycling, thus reducing fertilizer costs in sugarcane crops.

**Integration**

A crop–livestock integration could perhaps be a promising association between these activities. Sugarcane is a long-term annual crop, usually with 5 harvesting periods and replanting every six years. An agronomic recommendation is a rotation with other crops between each new six-year cycle. Thus, 15 to 20% of the total area cultivated with sugarcane would be available to other crops (eg., soybean, corn, pasture, and winter fodder) which may be of interest for livestock production.

Finally, an interesting form of integration could be investments from one sector in the other one. In general, except when the mill’s owner had previous contact with livestock activity, the bioethanol industry showed little or no interest at all in investing in that sector. However, some mills performed an interesting form of integration with ranchers. To convince big ranchers to lease their lands (previously used for cow-calf and stocker operations) for sugarcane cultivation, some mills sell cattle feedstuffs and even total mixed ration to feedlot operators at highly competitive prices due to the high purchasing power of sugarcane mills.
The recent discovery of large oil fields in deep waters off the Brazilian coast, combined with the technological expertise to extract it, should decrease the high growth rate of the bioethanol sector, despite the strong pressure from international public opinion against the use of fossil fuels. That phenomenon may result in a decreased eagerness of sugar/ethanol industry for arable land, therefore reducing pressure on cattle farming, particularly in the Southeast region and its surroundings. However, assuming that crises in capitalist systems are frequent but transitory, the international search for commodities (especially soybean, corn, and wood for pulp and other purposes) by emergent countries should maintain and intensify pressure on Brazilian arable lands, especially on pasture areas in the North and Midwest regions, where the bioethanol industry is not relevant.

The existence of large land areas, previously with limited productive potential, combined with the development of agricultural technologies to enhance their quality, has benefited Brazil in recent decades due to open agricultural frontiers. Nonetheless, as a result of strong national and international pressures, the effective actions taken by the federal government have helped to inhibit illegal deforestation, reducing the attractiveness of this activity due to the great risk of heavy fines and confiscation of equipment used for deforestation. For example, in the most developed regions of the country, modern geo-referencing techniques and satellite images, combined with governmental agencies that are increasingly more active and less susceptible to corruption, have allowed for the penalization of farmers who have made even minor environmental infringements (e.g., cutting a few trees). While this paper is being written, strict forest laws are being voted by Brazilian Congress and Senate, waiting for approval by the president, which may require the ranchers/farmers to repair their environmental violations, even if done in the past, before the legislation approval.

The continuing and growing agriculture need, including the need from the bioethanol industry, for arable lands will keep the pressure on livestock. But, at the present time, livestock is “prevented” from migrating regionally, due to the closure of agricultural frontiers. In response, livestock will have to follow the technological migration (intensification) as a solution. The rising price of bullocks (steers), obtained from cow/calf and stocker operations located in areas of constant land appreciation, will reduce the profitability of feedlot fattening systems, which so far have benefited from the low costs of extensive production systems.

The constant growth of internal purchasing power of the consumer, stimulated by governmental assistance programs to the poorest classes, as well as the growth of external emerging markets avid for cheap meat, combined with the reduction of markup per animal finished, will keep pushing beef production in Brazil toward intensification. Areas with little livestock tradition may be attracted by this market if 1) they are close to regions with the new cow/calf and stocker operations; and/or to grain-producing areas; 2) the climate is dry, thus favoring feedlots; 3) they have harbor facilities and proximity, providing easy access to external markets; and 4) they are willing to invest in infrastructures, especially transport. Merely by way of speculation, the arid and traditionally poor Northeast region, which has no inflated environmental appeals, combines several of these characteristics.

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