

Chapter 2

Biofuels and Food Security in Brazil

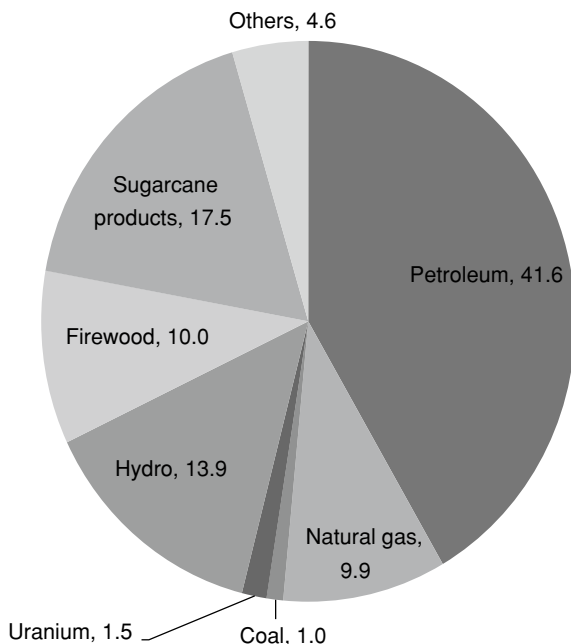
Abstract To reduce its oil import bill, the government of Brazil inaugurated a national bioethanol program (PROALCOOL) in 1975. An important direct effect of the program was the creation of huge domestic demand for its sugarcane market because sugarcane is the feedstock of bioethanol production, which has increased in Brazil since 1975. In the late 2000s the Brazilian government achieved the original policy target of PROALCOOL to reduce dependency of petroleum imports. The Brazilian bioethanol industry, including bioelectricity, is growing as one of the main energy industries in the Brazilian economy. While it is possible Brazil will expand sugarcane production to the *Cerrado area*, this may cause land-use change and environmental problems. Bioethanol and sugar are produced from sugarcane and the allocation rate for bioethanol and sugar is decided by the relationship between domestic bioethanol and sugar prices. Since 1990, more than half of Brazil's harvested sugarcane has been for bioethanol use. Therefore, bioethanol and sugar production are competing by allocating sugarcane production. Soybean oil accounts for 71.7–90.9 % of the feedstock of Brazil's biodiesel program, which the government has been promoting. Since 2005, production has increased rapidly; in 2012 the soybean oil use ratio in domestic soybean oil consumption increased to 32.2 %. This means the Brazilian biodiesel program has had an impact on global soybean and soybean products markets.

Keywords Brazil • PROALCOOL • Flexible-fuel vehicle • Sugarcane • Soybean oil

2.1 Introduction

After the United States, Brazil is one of the world's largest bioethanol producers. Brazilian bioethanol production increased from 13,544 million L in 2004 to 21,620 million L in 2012 [1]. Until 2004, Brazil was the largest bioethanol producer but the US assumed this position the following year (2005). Today, Brazil

Fig. 2.1 Brazilian total primary energy demand share (2010) (reproduced from MME [13])



accounts for 25.9 % of world bioethanol fuel production. Brazil is the largest bioethanol fuel exporter, and in 2012 its net exports were 1,750 million L (41.4 % of the world's bioethanol fuel exports) [2]. In addition, the government of Brazil started the *National Biodiesel Production Program* (PMPB) in 2004. Brazilian biodiesel production increased from 69 million L in 2006 to 2,718 million L in 2012. That year Brazil accounted for 10.4 % of world biodiesel production [3].

According to IEA data [4], in 2010 bioenergy in Brazil accounted for 31 % of total domestic primary energy demand (TPED). On the other hand, the world average accounted for 10 %, the US 4 %, and the EU an 8 % share of TPED [4]. The Brazilian bioenergy share of TPED is much higher than other countries and regions. According to Brazilian statistics, Brazilian sugarcane products account for 17.5 % of total primary energy demand (TPED) (Fig. 2.1). Brazilian biofuels account for 20.0 % of total transportation demand, which is much higher than the USA (4.3 %), the EU (4.1 %) and the world average (2.5 %) [4].

Several studies have covered the Brazilian biofuel markets. Goldemberg [5] analysed Brazilian biofuel programs and the industry. Hira and Oliveria [6] analysed Brazilian bioethanol policy implications. Rovere and Pereira [7] surveyed Brazilian biofuel programs and sustainable energy development. Hall et al. [8] analysed the Brazilian biodiesel program and the social fuel stamp system. Silva et al. [9] analysed the Brazilian biodiesel production chain and the software of biodiesel. This chapter analyses the Brazilian biofuel program, the market, its structure, policy implications and problems and biofuels and food security.

2.2 Bioethanol Program and Markets

2.2.1 Bioethanol Program

Brazil is the world's largest producer of sugarcane and sugarcane-based bioethanol. The country has a long history of producing sugarcane. The first sugarcane plantation was planted in 1532. After that, Portuguese colonists expanded plantations in the north-eastern area, and Brazil dominated most of the sugar production and exports of the mid-18th century [10]. Sugarcane and sugar production in Sao Paulo and Northern Parana state have expanded since the 20th century. Brazil has conducted a bioethanol program since 1931. The federal government set a mandate to blend bioethanol to imported gasoline at 5 % in 1931. In 1933, the Sugar and Alcohol Institute (IAA) was established to conduct policy interventions and regulate sugar and bioethanol production and exports. In 1951 bioethanol production was 170 thousand L, which increased to 666 thousand L in 1973 [11].

In 1973, the world price of crude oil increased from 4 USD/barrel to 14 USD/barrel in 1973 because of the first oil shock. As Brazil crude oil imports accounted for 76.9 % of the country's total oil consumption in 1973, high crude oil prices severely damaged the Brazilian economy at that time. In addition, the decreasing world sugar price had a negative impact on Brazilian sugar producers and Brazil's economy at that time. In 1975, the government of Brazil inaugurated the national bioethanol program (PROALCOOL). The major target of the program was to reduce its oil import bill. An important direct effect of the program was the creation of huge domestic demand for its sugarcane market. The creation of PROALCOOL provides a much-needed cure for its sugar producers, who are frequently faced with problems due to excess sugar production and huge fluctuations in the price of sugar. With the second oil shock in 1979, the government decided to enlarge the program by providing enhanced support to large-scale hydrated bioethanol producers to supply cheaper fuel prices. Two institutes played vital roles in implementing the national bioethanol program. The IAA controlled sugar and bioethanol production and exports by implementing a production quota and fixed the purchasing price for bioethanol. Petrobras, being a monopolistic state oil company, controlled domestic bioethanol sales and distribution. The government set the sugarcane price for independent growers.

In the 1980s the government implemented a number of investment support programs. National bioethanol production was expanded to over 16 billion L per year. Despite this achievement, the program has faced criticism since the middle of the 1980s. In 1982 the Brazilian *debt crisis* dried up sources of finance, followed by a decline in international oil prices that started in 1986. An inadequate bioethanol supply and demand management caused serious market disruptions in the early 1990s and resulted in the loss of consumer credibility in bioethanol fuel. The production of bioethanol powered vehicles, but *alcohol vehicles*¹ have been declining

¹ It can run nearly 100 % of bioethanol.

since then. In 2012, only 1 percent of vehicles were powered by bioethanol [12]. To address this trend, the government set the anhydrous bioethanol blend to gasoline at between 20 and 25 % of the product. The government introduced radical bioethanol and sugar program reforms between 1997 and 1999. In 1997, the price of hydrated bioethanol was liberalized, followed by the decision to liberalize the price of anhydrous bioethanol in 1999 and to abolish the distribution monopoly given to Petrobras. The government also decided to reduce subsidies to bioethanol blend gasoline producers. Currently, there are no policy restrictions on bioethanol production; the only tool left to the government is setting the anhydrous blend ratio to gasoline. The Ministry of Agriculture determines the actual percentage of the blend ratio as a means of balancing the relationship between supply and demand of sugar and bioethanol.

Over the past three decades, the government of Brazil has implemented powerful intervention programs in its sugar market through its bioethanol program, but changed its role in the late 1990s. With the deregulation of its bioethanol program, implemented during 1998–1999, the government no longer exercises direct control over sugar production and exports. Within the remaining range of permitted controls, the government can only set the bioethanol-to-fuel blend ratio. At present, the government can only exert influence by setting the anhydrous bioethanol blend ratio for gasoline in the 20–25 % range as a means of balancing the relationship between supply and demand for domestic sugar and bioethanol.²

2.2.2 Bioethanol Market

Brazilian bioethanol production increased from 170 thousand L in 1951/1952 to 556 thousand L in 1975/1976 (Fig. 2.2). As a result of PROALCOOL, bioethanol production expanded dramatically from 556 thousand L in 1975/1976 to 11,920 thousand L in 1989/1990. Although the bioethanol production growth rate stagnated from 1990/1991 to 2001/2002, its production started increasing again from 2003/2004. As alcohol vehicle sales increased from 1979/1980, hydrated bioethanol³ consumption and production increased from 1979/1980. Hydrated bioethanol production increased from 681 thousand L in 1979/80 to 10,468 thousand L in 1989/1990. As a result of losing consumer credibility in bioethanol fuel, the number of alcohol vehicles sold dropped from 1990/1991 to 2001/2002, and hydrated bioethanol production decreased from 10,229 thousand L in 1990/1991 to 4,933 thousand L in 2000/2001. Contrary to this, anhydrous bioethanol⁴ consumption

² Bioethanol is applied for preferential tax measures. CIDE (Contribuicao de Intervencao no Domini Economico) is charged at 0.28 R\$/L for gasoline and fixed at zero for bioethanol. PIS/COFINS, a social tax, is charged at 0.2616 R\$/L for gasoline and 0.048 R\$/L for bioethanol producers or 0.12 R\$/L for bioethanol distributors.

³ Anhydrous bioethanol has an alcohol content of more than 99.3 %.

⁴ Hydrated bioethanol an alcohol content of between 92.6 and 99.2 %.

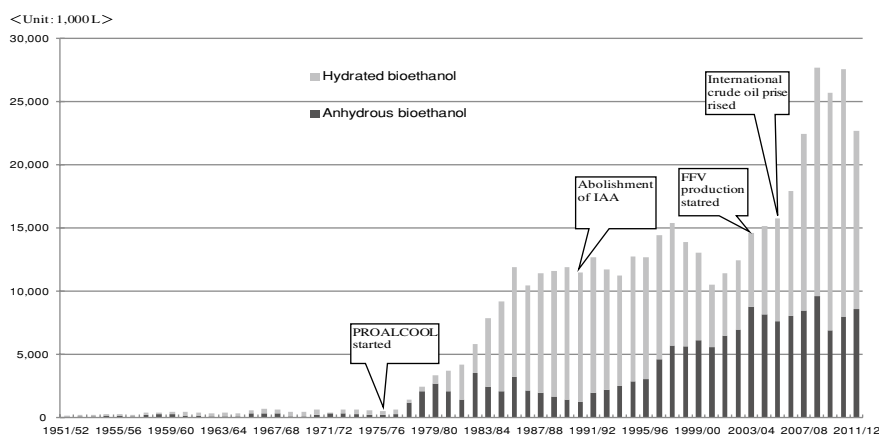


Fig. 2.2 Brazilian bioethanol production (reproduced from MAPA [11])

increased from 1990/1991 to 2000/2001, as the number of bioethanol blended gasoline vehicles sold increased. Thus, anhydrous bioethanol production increased from 1,287 thousand L in 1990/1991 to 8,768 thousand L in 2003/2004.

In the early 2000s high world crude oil prices boosted the marketing of bioethanol, making it once again marginally profitable and competitive with gasoline. Developments in Brazil have led to the creation of flexible-fuel vehicles (FFV) capable of running on gasoline, bioethanol or any combination of both fuels. FFV motors are capable of running bioethanol blends from 0 to 100 %. The technology is based on sensors in the fuel system that automatically recognize the bioethanol level in the fuel. The engine's electronic control unit then self-calibrates for the best possible operation; if bioethanol is not present, the engine will self-calibrate to gasoline-only operation [5].

Since 2003, as sales of FFVs have increased dramatically, the Brazilian bioethanol market structure has changed accordingly. Sales of FFVs increased from 48 thousand units in 2003 to 3,163 thousand units in 2012 (Fig. 2.3). In 2012, 92 % of new vehicles sold in Brazil were FFVs. As a result of the increasing number of FFVs, hydrated bioethanol consumption increased from 4,520 thousand L in 2003 to 12,998 thousand L in 2012 [13].

2.2.3 Bioethanol Production Structures

There are 439 bioethanol/sugar producing facilities in Brazil. Among these facilities, 302 have both bioethanol and sugar-producing facilities.⁵ In Brazil sugarcane and molasses are used for bioethanol production. From 1948/1949 to 1975/1976,

⁵ Interviewed from UNICA (May 2011).

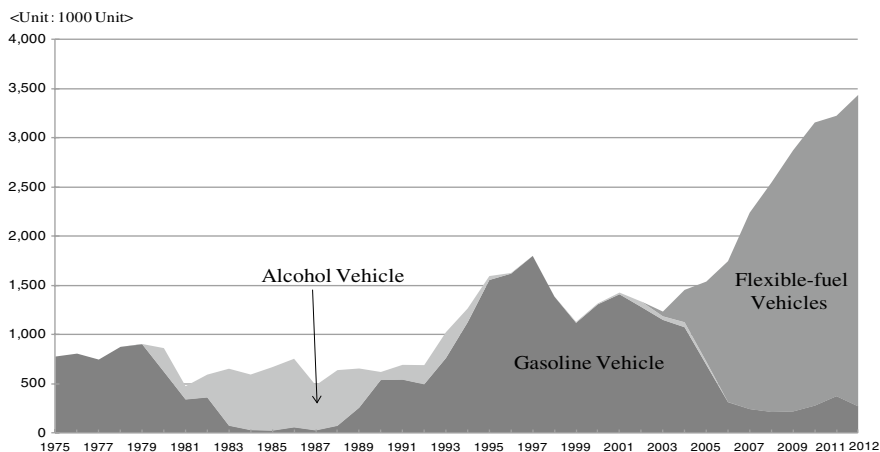


Fig. 2.3 Brazilian light vehicles sales by fuel type (reproduced from ANFAVEA [12])

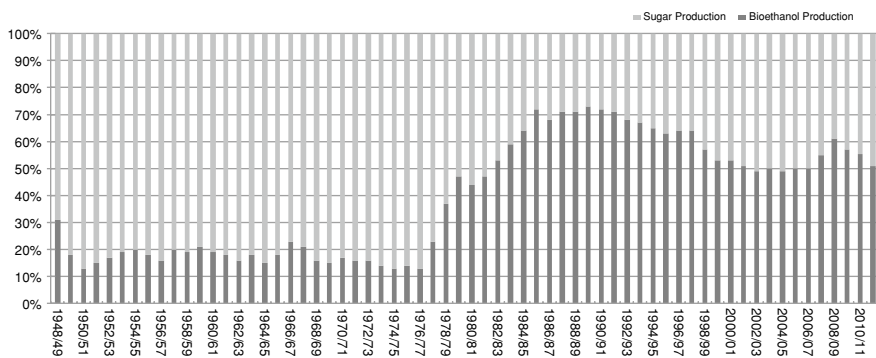


Fig. 2.4 Sugarcane allocation rate for bioethanol and sugar production (reproduced from MAPA [11])

the sugar allocation rate from sugarcane was more than 80 %. But the bioethanol allocation rate has increased since PROALCOOL started in 1975. From 1982/1983 to 2011/2012, more than half of the sugarcane produced in Brazil (between 50.6 and 71.0 %) went toward bioethanol production, with the remainder going toward sugar production (Fig. 2.4). As the IAA abolished the regulation of bioethanol and sugar production, bioethanol and sugar are produced from sugarcane and the allocation rate for bioethanol and sugar is now decided by the relationship between domestic bioethanol and sugar prices. Thus, bioethanol and sugar production are competing by allocating sugarcane production. Figure 2.5 shows the domestic anhydrous bioethanol price, the hydrated bioethanol price and the sugar price (crystal sugar). It appears that domestic bioethanol and sugar prices are correlated.

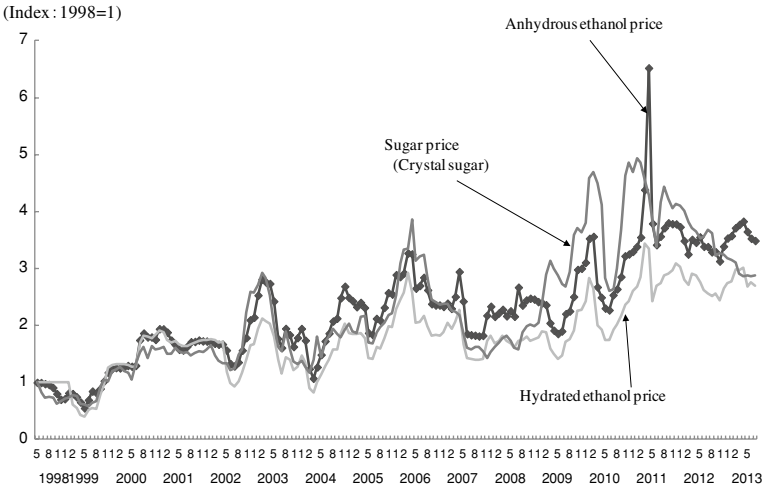


Fig. 2.5 Brazilian bioethanol and sugar prices. *Source* CEPEA [14]

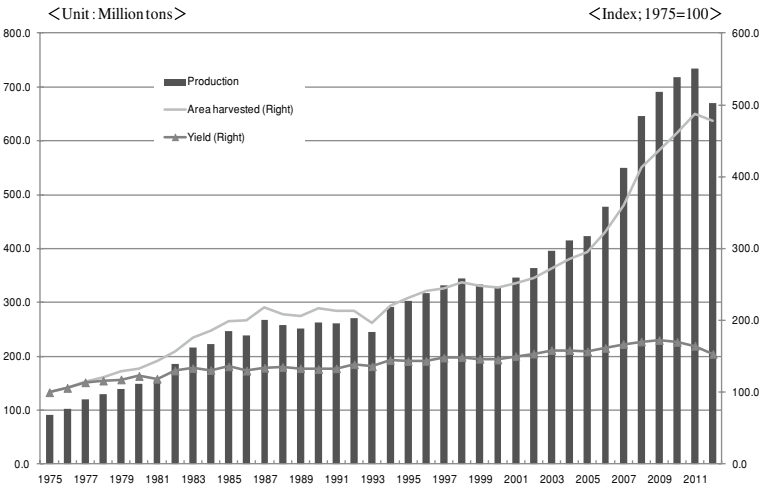


Fig. 2.6 Brazilian sugarcane production, area harvested and yield. *Source* FAOSTAT [15]

Brazilian sugarcane production increased from 91.5 million tons in 1975 to 670.8 million tons in 2012 (Fig. 2.6). The harvesting area has increased from 1.9 million ha in 1975 to 9.4 million ha in 2012. On the other hand, its yield has increased from 46.5 ton/ha in 1975 to 71.3 ton/ha in 2012. Figure 2.6 shows that the growth rate of the sugarcane harvest area is much higher than the yield. Thus, the growth of the sugarcane harvest area contributed to its production between 1975 and 2012.

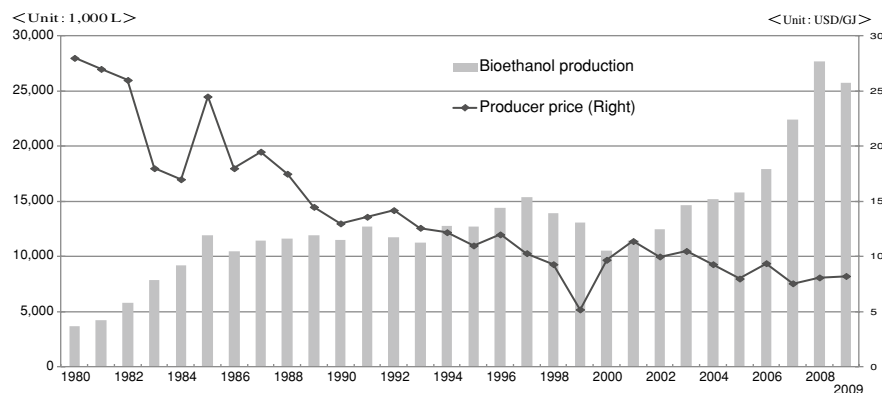


Fig. 2.7 Bioethanol production and producer price (reproduced from CEPEA [14] and MAPA [11]). Producer price means price received by producers in Sao Paulo state. It was derived from the State of Sao Paulo sugarcane, sugar and ethanol growers council (CONSECANA) and the University of Sao Paulo's College of Agriculture" Luiz de Queiroz " (ESALQ)

The south-eastern part of Brazil is the main production area for sugarcane, sugar and bioethanol, accounting for 70 % of the total production of sugarcane, sugar and bioethanol.

San Paolo state accounts for 57.9 % of total sugarcane production, 63.4 % of total sugar production and 55.9 % of total bioethanol production [16].

The production cost of Brazilian bioethanol has been decreasing since 1980, due to increasing investments in bioethanol production, transportation and technological innovation such as fermentation. Figure 2.7 shows how Brazilian bioethanol production costs have been decreasing, while production has increased since 1980.

Bioethanol production in Brazil was initiated with a highly subsidized program. The price paid to producers in 1980 was 28 USD/GJ; over the intervening years, gains in technology and economies of scale have driven the cost down, as low as 8.2 USD/GJ in 2004. By 2004 bioethanol in Brazil had become economically competitive with gasoline based on international prices of oil (equivalent to 40 USD per barrel) [5]. In 2005/2006, the bioethanol production cost of 0.24 USD/L was lower than the gasoline price of 0.31 USD/L [17]; Brazilian bioethanol has a cost advantage for gasoline prices. In 2006/2007, the cost of bioethanol was 0.30 USD/L, due to the currency crossover from the Brazil real to the US dollar. In spite of this increase, it is lower than the US bioethanol production cost of 0.49 USD/L [18]. Bioethanol productivity increased dramatically from 8.13 L/sugarcane ton in 1975/1976 to 40.51 L/sugarcane ton in 2011/2012 [11].

It is estimated that Brazilian FFV vehicle sales and registered numbers will increase in the future due to increasing global prices of crude oil and high economic growth. Thus, Brazilian hydrated bioethanol consumption will increase and anhydrous bioethanol consumption will decrease in future.

In September 2005, the Ministry of Agriculture, Livestock and Food Supply (MAPA; Ministério da Agricultura, Pecuária e Abastecimento) published the "Agroenergy National Plan" (Plano Nacional de Agroenergias) to promote renewable

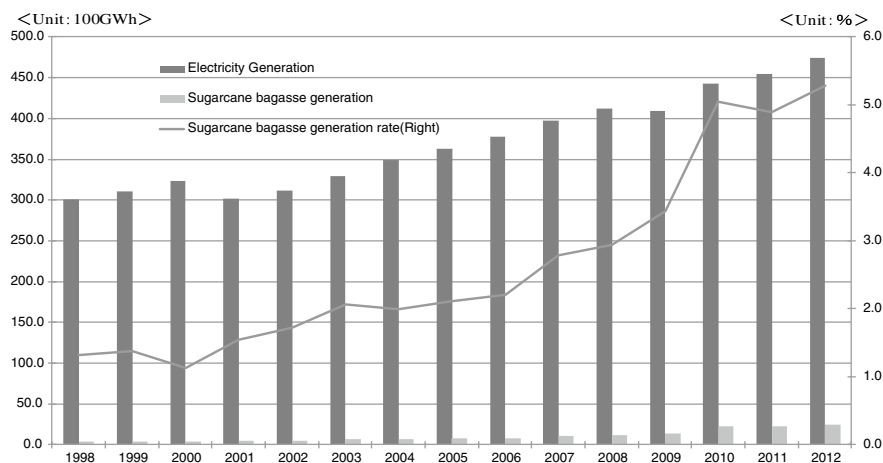


Fig. 2.8 Sugarcane bagasse based electricity generation (reproduced from MME [13])

energy utilization from agricultural products. This plan indicated that Brazil would expand bioethanol exports in the future. In September 2006, the Ministry published the “*Agroenergy National Plan—2006–2011*” (*Plano Nacional de Agroenergias 2006–2011*). The plan indicated that the government would expand the promotion of technology and international cooperation for bioethanol production.

Brazil is the world’s largest bioethanol producer and in future will expand bioethanol exports to Japan, China, the EU and other countries. Brazil is also the largest sugar producer and exporter. The country produces 38.6 million tons of sugar, which account for 21.9 % of world sugar production. Its sugar export is 27.7 million tons and accounted for 48.9 % of world sugar exports in 2012/2013 [19]. Brazil will have to increase sugarcane production and exports in the future. However, the sugarcane yield has been stagnant and it is estimated that Brazil does not develop enough new varieties to expand sugarcane yield dramatically. Thus, Brazil will have to expand its harvestable sugarcane area to expand production. MAPA projected that the sugarcane production area could increase from 9.42 million ha in 2010/2011 to 11.52 million ha in 2020/2021 [20]. In this projection, sugarcane production will expand not only to Sao Paulo state but also in Goias, Mato Grosso, Mato Grosso Sul and Minas Gerais states.

Brazilian sugarcane mills harness the energy contained in *bagasse* by burning it and converting it into bioelectricity. After the sugarcane is harvested, the straw can be burned alongside bagasse in highly efficient boilers to produce even more bioelectricity. A growing number of mills generate an energy surplus, which is sold to distribution companies and helps light up numerous cities throughout Brazil [21]. Bioethanol facilities produce large amounts of electricity from burning *bagasse*. Sugarcane *bagasse* production increased from 82.1 million tons in 1989 to 154.1 million tons in 2012 [13]. Electricity generation from sugarcane bagasse increased from 4,000 GWh in 1998 to 25,066 GWh in 2012 (Fig. 2.8). The sugarcane bagasse generation rate to total electricity generated increased from 1.3 % in 1998 to 5.3 % in 2012. The federal government will promote increased generation of bagasse in the future.

2.2.4 Implications of the Bioethanol Policy

There are three main advantages of Brazilian bioethanol compared to biofuels in other countries and regions. The first is that Brazilian bioethanol production costs are much lower than the cost of other bioethanols and are economically competitive with the gasoline price. The advantage is that net energy return on investments for sugarcane based bioethanol is much higher than other biofuels.⁶ The net energy return on investments for Brazilian sugarcane bioethanol is 9.3 [22]. On the other hand, the net energy return on corn is 0.8–1.7, that of sugar beet is 1.2 and that of soybean oil is 1.0–32. Table (1.5). The third advantage is a reduction in GHG emissions from Brazilian sugarcane-based bioethanol, which are much higher than other biofuels. Brazilian sugarcane-based bioethanol has 71 % of default GHG emission saving compared with fossil fuels.⁷ On the other hand, wheat-based bioethanol has 16 % of default greenhouse gas emission saving, and palm oil-based biodiesel has 49 % of default greenhouse gas emission saving (EU Parliament and of the council [23]).

It is highlighted that an investment of 5 billion USD (2001 USD) was made between 1975 and 1989 in the agricultural and industrial sectors to expand bioethanol production for automotive use. Moreover, savings with foreign imports evaluated at international prices amounted to 52.1 billion USD (January 2003 USD) between 1975 and 2002 [24]. Brazilian external dependency on petroleum decreased from 27.1 % in 2000 to –2.6 % in 2010. The Brazilian government achieved the original policy target of PROALCOOL to reduce dependency on petroleum imports and the self-sufficiency of petroleum. The government succeeded in creating a new renewable energy industry—the bioethanol industry. As mentioned before, Brazilian bioenergy accounted for a 31 % share of total primary energy demand (TPED) and Brazilian sugarcane products accounted for a 17.5 % share of total primary energy demand (TPED) in 2010. Brazilian biofuels account for 20.0 % of total transportation demand [4].

The number of formal jobs in the Brazilian bioethanol, sugar and sugarcane industries increased from 642.8 thousand in 2000 to 982.6 thousand in 2005. The Brazilian bioethanol program created about one million direct jobs. In addition, it is estimated that another one million job opportunities have been created in the bioethanol, sugar and sugarcane sectors as well as the transportation sector, the agricultural machineries sector and the agricultural chemical sector. Brazilian GDP delivered by the bioethanol, sugar and sugarcane industry, amounted to 28 billion USD and accounted for 1.8 % of total GDP in 2011. The bioethanol and sugar export share of total agribusiness export products was 18.0 % in 2010 [21]. In addition, bioelectricity from bagasse is growing as a new energy industry in Brazil. Thus, the Brazilian bioethanol industry, including bioelectricity, is growing as one of the main industries in the Brazilian economy.

⁶ The net energy return on investments for bioethanol is defined as the ratio of energy contained in a given volume of bioethanol divided by the fossil energy required for its production.

⁷ This default GHG emission did not cover indirect land use change.

2.2.5 Brazilian Bioethanol Problems

Brazil will meet both domestic and international demand for bioethanol; at the same time, it will meet domestic and international demand for sugar. Accordingly, Brazil will expand the sugarcane area harvested to increase bioethanol and sugar production. The big challenge is to increase bioethanol production in a sustainable way to meet the expected growth in demand for sugar and bioethanol in the domestic and international markets [25]. Sugarcane production will expand not only to Sao Paulo state but also to the *Cerrado* area (Goias, Mato Grosso, Mato Grosso Sul and Minas Gerais state). It is possible Brazil will expand sugarcane production to these *Cerrado* areas. However, this may cause land-use change and environmental problems. There are two categories of land use change: *direct land-use change* and *indirect land-use change*.

Direct land-use change occurs when feedstock for biofuel production comes from new crops directly established on forestry or grasslands [26]. The impact of *direct land use* can result from the expansion of the sugarcane area from Sao Paulo to *Cerrado* and other areas. The Brazilian federal government plans to increase sugarcane production in the future. However, sugarcane production has expanded not only in conventional crop areas, but also in areas with environmental restrictions, such as the *Amazon* region, the *Pantanal* and the *Paraguay River* basin. Environmental groups are concerned about the negative impacts on these areas. The federal government, knowing that it must establish rules and laws to promote sustainable sugarcane production, decided to set up a *sugarcane agro-ecological zoning* system based on administration rule No. 6961. The sugarcane agro-ecological zoning system regulates land adaptation for sugarcane production in each region. It is expected this system may lead to sustainable sugarcane production in Brazil. As a next step, it is noted that the federal government will establish a monitoring system for the zoning areas based on the *sugarcane agro-ecological zoning* system.

In Sao Paulo state, sugarcane and other commodity crops are competing for the use of agricultural land. Since 1990, most of the areas used for cotton and other commodities have been converted to sugarcane areas. The government will expand the sugarcane area from Sao Paulo state to the *Cerrado* area (Goias, Mato Grosso, Mato Grosso Sul and Minas Gerais state). However, this expansion will compete with pastureland used for feeding cows in these areas. Based on an Institute for International Trade Negotiations (ICONE) and Brazilian Institute of Geography and Statistics (IBGE) analysis, sugarcane production increased by 996,000 ha from 2002 to 2006 in the main sugarcane producing states (Sao Paulo, Minas Gerais, Parana, Mato Grosso Sul, Goias, Mato Grosso, Tocantins, Bahia, Maranhao and Piaui). This increase was partly attributed to an increase in the sugarcane production area (917,000 ha were converted from pastureland to sugar production and a further 113,000 ha of other cropland were converted for sugar cane production [27]). This means pastureland absorbed most of the land used to expand sugarcane production, due to the intensification of pastureland use for sugar. From 1996 to 2008 pastureland decreased by 2.17 %; at the same time, beef

production increased by 57.8 %, the slaughter rate increased by 22.1 % and beef per hectare increased by 61.3 % [27]. As a result of sugarcane expansion, pastureland decreased; on the other hand, the pasture intensification rate increased, leading to an increase in beef production. Pastureland played a key role in buffering the expansion of the sugarcane area harvested.

From 2007 to 2008, the sugarcane area harvested increased by 2,143 thousand ha in the south-central region. However, 991 thousand ha was converted from pastureland and 1,152 thousand ha were converted from other cropland [27]. From 2007 to 2008, most of the sugarcane area harvested was converted from other crop areas. We need to conduct further studies of this land-use change impact by utilizing data after 2008. If most of the land required for sugarcane expansion is converted from other crop areas, this expansion will have an impact on other crop markets. On this point, the key issue is whether the crop yield will expand in the future or not. However, the growth rate of grains (corn, soybean and wheat) yields in Brazil has stagnated since 2005. If the growth rate of the yield does not increase, the land conversion from crop areas to sugarcane areas will increase and have an impact on grain and agricultural markets.

The indirect impact on food security and the environment can be caused by *direct and indirect land-use change*. The basic concept of *indirect land-use change* is that natural ecosystems elsewhere might be converted to croplands to replace crops (either animal feed or food) that are lost due to biofuel production [28]. This can imply land-use change (by changing e.g., forest into agricultural land), which implies that a substantial amount of CO₂ emissions are released into the atmosphere [29]. *Indirect land-use change* occurs when the feedstock for biofuel production does not trigger land-use change on site, but elsewhere due to the need to compensate for production now used for biofuels. This is why biofuels might not include land-use change locally, and might well lead to the “displacement” of food or pastureland for livestock production, which then would move to other regions, and be responsible for deforestation in those regions [30].

2.3 Biodiesel Program and Markets

2.3.1 Biodiesel Program

The Brazilian federal government is promoting a biodiesel program and a bioethanol program. The national Biodiesel Production Program (PMPB) was launched to promote domestic biodiesel utilization and production in 2004. Before PMPB, the Brazilian federal government tried to promote a biodiesel program. Because of the *oil crisis* in the 1970s, the government began to research the production of biodiesel from vegetable oil. In 1983, the government planned the *National Program for Energy from Vegetable Oils (OVEG)* project to test the utilization of biodiesel-blended diesel for vehicles powered by diesel engines. However, the

government prioritized the bioethanol program, namely the Brazilian National Alcohol Program (PROALCOOL) over the OVEG project. As a result, the national biodiesel program was not developed and promoted after the 1980s.

The economic gap between the southeast and northeast regions has been one of the most important social problems in Brazil. Although the per capita GDP in the southeast region was R\$19,277, GDP in the northern region was R\$9,134, and in the northeast region it was R\$6,749 in 2007 [31]. In Brazil, policy measures have been required to alleviate regional economic disparities within the country. These policy measures have been the promotion of biodiesel production and utilization, alleviating regional economic disparities and generating jobs and income through the inclusion of family farmers in the north and northeast. PMPB's directive also covers reducing GHG emissions, reducing diesel imports and promoting biodiesel exports. The main directive of PMPB is to reduce regional disparities and develop the north and northeast regions.

Federal Law #11,097, enacted in 2005, which defines biodiesel as fuel, made it a legal requirement to utilize biodiesel as fuel. The law determined a mandatory mixture of 2 % biodiesel (B2) from January 2008 and a mandatory mixture of 5 % biodiesel (B5) until 2013. The government created the *Social Fuel Stamp* system in resolution #1 and #2 in 2005. This system is an incentive for biodiesel producers who buy feedstock from family farmers. Biodiesel producers are required to comply with purchasing a minimum percentage of feedstock from family farmers, assuring the purchase of available quantities, and providing technical assistance and training.

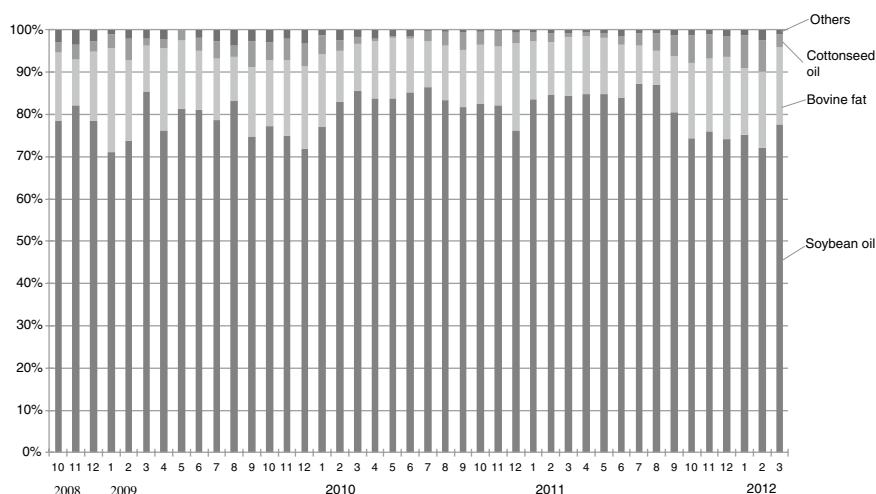
The Brazilian government promoted the biodiesel program in advance, namely it started the B3 program from July 2008, the B4 program from July 2009 and the B5 program from January 2010. It is estimated that Brazilian biodiesel production capacity satisfied more than 5 % of biodiesel blend consumption in 2010. In addition, the Brazilian biodiesel industry will expand production capacity in the future. The Brazilian federal government plans to increase the biodiesel blend ratio to diesel after 2014. It is assumed that the increasing biodiesel blend ratio could have an impact on the Brazilian and world biodiesel markets, and the world soybean and soybean products markets.

2.3.2 Biodiesel Markets

Biodiesel consumption and production have expanded since 2005. Brazilian biodiesel consumption was 1 million L in 2005 and 2,754 million L in 2012 and its production was 1 million L in 2005 and 2,717 million L in 2012 (Table 2.1). In 2012, biodiesel consumption amounted to 5.8 % of total domestic diesel consumption in Brazil [13]. Biodiesel can be produced from a wide variety of feedstock, such as castor bean oil, soybean oil, palm oil (*dende*), sunflower oil, cotton oil, jatropha carcass (*pinhao manso*), animal fats oil (*sebo*) and other vegetable oils in Brazil. Castor beans are produced mainly in the northeast area, and palm oil is produced mainly in

Table 2.1 Biodiesel production and demand (reproduced from MME [13]) (million L)

	2005	2006	2007	2008	2009	2010	2011	2012
Production	1	69	404	1,167	1,608	2,397	2,673	2,717
Consumption	1	69	404	1,121	1,558	2,347	2,547	2,754

**Fig. 2.9** Biodiesel feedstock (reproduced from MAPA [11])

the northern area. To develop the north and northeast regions when PMPB started, the Brazilian government originally planned to utilize castor bean oil and palm oil as the main feedstock for biodiesel production. However, castor bean oil, palm oil, sunflower oil, jatropha carcass and animal fats did not have much production potential compared with soybean oil [32]. Taking into account production costs, production potential, profitability and production amount, and soybean oil has had an overwhelming advantage over other crops as a source of biodiesel production.

In September 2005, the Ministry of Agriculture, Livestock and Food Supply gave the following breakdown of biodiesel production in Brazil: northern area 9 %, northeast 14 %, midwest, south and southeast regions 77 % [33]. In the 2005 breakdown, the government implied that soybean oil was the main feedstock for biodiesel production, because the midwest, south and southeast are the main soybean production areas.

In Brazil, 43 facilities were authorized by the Petroleum, Natural Gas and Biofuel Agency (ANP). The main feedstock used in biodiesel production is soybean oil. From October 2008 to March 2012, soybean oil accounted for 71.7–90.9 % of the feedstock used for biodiesel production; animal fats from cattle accounted for 7.8–24.5 %; and other feedstock, such as palm oil, sunflower oil, castor bean oil and cotton oil accounted for 5 % in 2008 (Fig. 2.9). These use rate variances depend on feedstock prices. The midwest is the major biodiesel producer. In 2008 this region

comprised 46 %, the south comprised 23 %, the northeast region comprised 18 %, the southeast comprised 10 % and the northern region comprised 3 % of biodiesel production. Vehicle manufacturers comply with B5. The biodiesel prices received by producers are determined by the public auction system. Producers are not allowed to change the sales price set at auctions, and consequently must search for low-cost feedstock and/or hedge their activities to offset risk [34]. Feedstock costs account for about 80 % of the total production cost. This means feedstock prices have a significant impact on biodiesel production, as well as other biodiesel producing countries.

2.3.3 Biodiesel Policy Implications and Problems

It is assumed Brazilian biodiesel production will be concentrated on the centre and western regions, not the northeast region. This program will benefit large agribusinesses in the central and western regions, but not small farmers in the northeast region because of the expansion of soybean production for Brazil's biodiesel program. This is also different from the original purpose of Brazil's biodiesel program. Due to its growing conditions, it is difficult to expand palm oil production other than in Para state. The expansion of palm oil production in Para state poses a threat to tropical rain forests in the *Amazon* region. The extraction costs of glycerine are much higher than other feedstock, because castor bean oil has strong viscosity. Because of these problems, it is estimated biodiesel production from castor beans and palm oil will pose technical and environmental limitations on future expansion. From a domestic and international perspective, foreign governments and companies wishing to purchase Brazilian biofuels and/or invest in the country's biofuel manufacturing infrastructure need to understand and respect schemes such as the *Social Fuel Stamp* [8].

The main purpose of introducing biodiesel is different from PROALCOOL. However, the Brazilian biodiesel industry is heading for the mass-production of biofuels, including bioethanol. If the government wants to recover the original purpose of the biodiesel program, it will have to modify the program as soon as possible.

At present, soybean oil is the main feedstock for biodiesel production. Increasing demand for soybean oil for biodiesel use is increasing and will increase in the future. To minimize the negative impact on the soybean and vegetable oil markets, the Brazilian government should diversify the feedstock for biodiesel production. Technical innovation is needed to diversify the feedstock, especially from non-food products, such as waste oils and agricultural residuals.

2.4 Biofuels and Food Security in Brazil

Bioethanol and sugar are produced from sugarcane, and the allocation rate for bioethanol and sugar is decided by the relationship between domestic bioethanol and sugar prices. Therefore, bioethanol and sugar production are competing by

Table 2.2 Brazilian biodiesel use (reproduced from USDA-FAS [19] and USDA-FAS [35]) (Units; 1,000 tons)

	2005	2006	2007	2008	2009	2010	2011	2012
Biofuel use rate (2)/(1) (%)	0.03	1.6	8.0	21.4	22.6	32.1	31.6	32.2
Brazilian soybean oil consumption (1)	3,091	3,395	3,955	4,275	4,980	5,205	5,400	5,544
Brazil biodiesel use (2)	1	54	317	916	1,126	1,671	1,707	1,785

allocating sugarcane production. In Brazil, 295.5 million tons of sugarcane were used for bioethanol production in 2012 [35]. Brazil accounted for 16.7 % of world sugarcane production in 2012.⁸ The world sugar and bioethanol markets have a strong influence on each other because more than half of most sugarcane goes toward bioethanol production in Brazil, which is the world's largest producer of sugarcane and sugarcane-based bioethanol. Therefore, bioethanol developments in Brazil have considerable implications for world sugar markets. The Brazilian bioethanol program does not severely damage food security directly, because sugar is not a staple food. However, it is a crucial source of income for sugar-producing countries. Thus, indirectly, the Brazilian bioethanol program could have possible impacts on food security in many sugar-producing countries. Another indirect impact on food security can be caused by *indirect land-use change*.

If sugarcane land is converted from lands for crops such as soybeans, corn, rice and others, the Brazilian bioethanol program could have an impact on other agricultural and livestock markets because Brazil is a major producer of soybeans, corn, coffee, orange, beef, chicken and other agricultural and livestock products. There are concerns that these indirect impacts could affect global agricultural markets.

Brazilian soybean oil used for biodiesel production rose from 1 thousand tons in 2005 to 1,785 thousand tons in 2012 (Table 2.2). The soybean oil-use ratio in domestic soybean oil consumption increased from 0.03 % in 2005 to 32.2 % in 2012. This means one third of soybean oil was used for biodiesel production. Brazil is one of the largest soybean producer in the world. In 2012/2013 it produced 82.0 million tons, while US production was 82.5 million tons [19]. In the same period Brazil exported 41.9 million tons of soybeans while the US exported 35.9 million tons [19]. This implies that the Brazilian biodiesel program had an impact on the world soybean and soybean products (soybean oil and meal) markets.

Thus, the Brazilian bioethanol and biodiesel program has an impact on its feedstock markets and related agricultural commodity markets. This chapter does not conclude that this impact is good or not for food security on a global, national, sub-national or household level. It is necessary to evaluate how the Brazilian biofuel program could impact food security at any level by using economic models. This chapter does not conduct an econometric analysis on the way in which Brazil's biofuel program will

⁸ Sugarcane data are derived from [15].

impact world agricultural markets. Chapter 6 covers an econometric analysis on the impact of Brazil's bioethanol and biodiesel on the world's sugar and soybean markets.

In addition, the bioethanol and biodiesel program may cause *indirect land-use change* as a result of the expansion of these productions. There are concerns that such expansion could generate indirect pressure, pushing cattle into the Amazon region, which would lead to further deforestation in that area, but there is no direct evidence for that [5]. Even if no direct land-use change is observed (biofuels are produced on existing cropland), such biofuel production could “push” the displaced food/feed or other production towards forests and grasslands in a “domino-like” effect (indirect land-use change) [26]. Further studies are needed to analyse the *direct land-use change* and *indirect land-use change* impact on agricultural markets.

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