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Biofuel, dairy production and beef in Brazil: competing claims on land use in São Paulo state

Andre Novo, Kees Jansen, Maja Slingerland and Ken Giller

This paper examines the competing claims on land use resulting from the expansion of biofuel production. Sugarcane for biofuel drives agrarian change in São Paulo state, which has become the major ethanol-producing region in Brazil. We analyse how the expansion of sugarcane-based ethanol in São Paulo state has impacted dairy and beef production. Historical changes in land use, production technologies, and product and land prices are described, as well as how these are linked to changing policies in Brazil. We argue that sugarcane/biofuel expansion should be understood in the context of the dynamics of other agricultural sectors and the long-term national political economy rather than as solely due to recent global demand for biofuel. This argument is based on a meticulous analysis of changes in three important sectors – sugarcane, dairy farming, and beef production – and the mutual interactions between these sectors.

Keywords: biofuels; competing claims; Brazil; agrarian modernisation; social-technical change

Introduction

Biofuel production, particularly in developing countries, is a matter that exercises many minds. Arguments in favour of the large-scale substitution of biofuel for fossil fuel underline the point that this has significant potential to reduce global greenhouse gas emissions. Based on this argument, for example, the European Commission announced an ambitious plan in 1997 to promote biofuel for transport and achieve a 12 percent penetration of renewable energy by 2010 (European Commission 1997). Other elements that favoured recent biofuel expansion were the sharp rise in oil prices between 2002 and 2008 and the political view that emerged in several countries (particularly the USA and within the EU) that their economies had become too dependent upon what they considered unstable, politically unfriendly or unreliable oil- and gas-producing nations. Additional arguments, mostly coming from nations with potential to produce biofuel, suggest that biofuels could reverse the decline of agricultural commodity prices and offer an opportunity for agricultural and rural development.

After the initial wave of euphoria over the idea that biofuels could provide a technical solution to a set of contemporary, interlinked environmental, economic, and political problems, counter-arguments emerged. Environmentalists have criticised the massive conversion of forest land and other non-arable land into

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biofuel production, targeting, for example, oil palm expansion in Malaysia and Indonesia (Friends of the Earth Europe 2007) and have called into question its overall effect in reducing greenhouse gas emissions. Development-oriented arguments have suggested that biofuel mandates in rich countries were driving up food prices and competing with other forms of land use, even when biofuel production is planned on supposedly 'marginal' lands because these are often important for the livelihoods of the poor (Oxfam 2008). These arguments have shifted views within decision-making bodies of the EU and the FAO. FAO (2008) concluded that part of the rise in food prices was due to expansion of biofuel production and that whether biofuels will help to reduce or increase greenhouse gas emissions depends on the local conditions. They further proposed that the increased competition for resources resulting from new biofuel schemes needs further consideration (FAO 2008). To date, however, there are few empirical studies of competing claims on land use, although this issue is central to the biofuel controversy.

In the controversial debates about biofuel, the case of Brazil plays a pivotal role as it is the second largest liquid biofuel producer in the world with a complete biofuel social-technical configuration in place, with a full chain from sugarcane and ethanol production to flex-fuel[1] cars that run on biofuels, supported by a regulatory system, technical research, and finance arrangements. Any competing claims on land use as a result of biofuel expansion should be visible in Brazil. In order to understand these competing claims this paper analyses land use changes in São Paulo state, the largest sugar cane- and ethanol-producing state in Brazil. The data that will be presented suggest that the expansion of the area under sugarcane is associated with an almost equivalent reduction in pasture area and a decrease in the number of cows and in milk and beef production. The question therefore emerges whether biofuel expansion has resulted in changes in livestock production.

The impact of biofuel expansion on the dynamics of agrarian change cannot be addressed without an analysis of the historical interactions between social, technical-environmental, and political economic processes. The effect of biofuel expansion is an emergent property of a complex set of mechanisms and conditions (Jansen 2009). Instead of searching for a single explanatory factor (e.g. biofuel expansion leading directly to a decrease in milk production), this study examines a complex combination of factors, involving external and internal drivers at different scales (Giller *et al*. 2006).

We integrate an analysis of changes in land use in Brazil into a historical study of political and economic changes that have shaped the dynamics of different agricultural activities (Hecht 1985). Thus, we locate some major origins of land use change in São Paulo state not so much in the very recent global surge in biofuel demand but within the longer history that shaped the social-technical configurations around biofuel. The sugar and ethanol industry expansion is definitely not new, particularly not in São Paulo state, where the total sugarcane area has steadily expanded since the 1970s. The predominance of relatively small farmers in a rather stagnant dairy sector contrasts with a powerful industry displaying impressive growth. Initially we primarily examined the relationships between the ethanol industry and milk production, but we later expanded the analysis to the beef production sector, which occupies large areas of land in Brazilian farming systems. This study discusses drivers that could

[1]Flex-fuel technology involves car motors running on gasoline, ethanol, or mixtures. It was considered a breakthrough since it allowed for purchasing the cheapest type of fuel available (Brandão 2008).

affect the dynamics of the sugarcane industry and dairy activity at the global level (such as biofuel demand and capital flows), at the national level (such as government policies, the internal demand for food and fuel, and the introduction of flex-fuel technology into car engines), as well as at the local level (such as labour demand, increasing land prices, and the lack of appropriate technologies).

A focus on the interactions between agro-ecological characteristics, government policies, and technology allows us (i) to compare differences in governmental policies towards the biofuel sector and the dairy and beef sectors during the last three decades, based on a review of historical literature; (ii) to evaluate sugarcane expansion in São Paulo state (location and rate of expansion) primarily based on the use of various databases and a spatial analysis; (iii) and to understand the relationships and possible sources of conflict between sugarcane, dairy, and beef production.

Historical development of sugarcane in Brazil

In 2008, the total area in sugarcane in Brazil increased by more than 16.5 percent to 8.2 million hectares (IBGE 2008), of which 7.4 million (85 percent) are located in the southeast region. How had sugarcane become so important in the southeast region? Sugarcane was first introduced into the northeast region in the sixteenth century when Atlantic forest was converted to sugarcane production to meet the European demand for sugar (Fischer *et al.* 2008). Specific environmental constraints (particularly the semi-arid climate) limited the expansion of the planted area in the northeast region that nowadays produces only 15 percent of sugarcane in Brazil. The sugarcane industry found a very interesting niche in São Paulo state, where the agro-ecological conditions (good soils and climate leading to high productivity, flat or undulating landscapes) and infrastructure (roads, research centres, supporting industries, proximity to the market) favoured the expansion of the sugarcane. However, the agro-ecological conditions favoured many agricultural activities, yet only the sugarcane industry developed at an aggressive rate during the past 20 years. Governmental decisions and investments in the sector were also an important driving factor.

The IAA and the governmental role in the development of the sugarcane industry

In 1933, the Brazilian government created the Instituto do Açúcar e do Álcool (IAA, Institute of Sugar and Alcohol[2]) and gave it a monopoly over international sugar trading from Brazil. In the beginning, the Brazilian government incurred large losses (Szmrecsánti & Moreira 1991). The Second World War changed the landscape of sugar production as it interrupted the transport of the sugar produced in the northeast by ship to the main consumer centres in the centre-south of the country. The IAA provided financial incentives to develop sugarcane production closer to the market. As a response to the interruptions of gasoline imports the IAA also stimulated ethanol production with financial incentives and by issuing administrative acts that fostered the blending of imported gasoline with anhydrous ethanol. Both factors led to an impressive expansion of sugarcane production in the southeast region. The emerging 'usineiros', big sugar farmers and industry owners in the

[2]Alcohol is the popular word for ethanol, which can be produced in different dilutions for several purposes, for example, anhydrous ethanol (to be used mixed with gasoline) and hydrated ethanol for direct use in flex fuel engines.

centre-south, lobbied for price differentiation between them and the northeastern producers. Consenting to their claims, the federal government permitted higher quotas of sugar production from the newer production areas.

The expansion of the sugar sector resulted in a search for new markets. After the disruption of political relations between the USA and Cuba, the Brazilian government expected to supply the 'new' market. It increased subsidies for investment in sugarcane production, which led to a more powerful role for the IAA. However, two factors partially frustrated the national expectation of gaining world market shares. First, several other countries had started to produce sugarcane in competitive ways, supplying a significant part of the North American demand. Second, Cuba joined the socialist block and was able to gain dominance in the large sugar market of the Soviet bloc (Szmrecsánti & Moreira 1991). The partial failure to realise the expected increase of the Brazilian share of the international sugar market induced the government to strengthen its biofuel program. Despite these problems, Brazil consolidated its position as the main sugar producer in the world.

The difference between internal prices paid to sugar producers and export prices provided the IAA with enough money to invest in three main development and structural programmes: *Planalsucar* (a national programme of genetic improvement), *Programa de Racionalização da Indústria Açucareira* (Programme to Rationalize the Sugar Industry), and *Programa de Apoio à Industria Açucareira* (Aid Programme to the Sugar Industry) which aimed to improve industrial processes. These supported further steady growth of sugar production.

The 'Proálcool' programme: subsidising the shift to alcohol

When international sugar prices collapsed in the early 1970s a crisis of overproduction had to be faced. The context of the first oil crisis in 1973 and the subsequent high oil prices in the late 1970s led to new initiatives of the Brazilian government not only to reduce the historical high dependency on imported fossil fuel but also to 'rescue' the sugarcane industry. A national program, called *Proálcool*, was created to improve sugarcane ethanol production as a substitute for gasoline by means of increasing subsidies to the industry and investment in research and development to generate new technologies (Paulillo *et al*. 2007). It was planned to solve the problem of the idle capacity of the sugar industry (Szmrecsánti & Moreira 1991). Proálcool involved the state-owned oil company (Petrobrás) by setting up institutional arrangements so that Petrobrás could absorb and distribute all the biofuel production. Special credit lines were opened for investments in new industries or expanding existing mills. Around US$2 billion in state loans were provided with very low interest rates between 1980 and 1985 to improve biofuel production as an alternative to sugar production (Moreira and Goldemberg 1999).

Apart from sugar producers, the sugar industry, and the Brazilian government, another interesting group got involved. The emerging automotive industry had clear interest in expanding its sales, and a large-scale introduction of ethanol in Otto-cycle motors was presented as the 'solution' for everyone's problems (Brandão 2008). In those days, environmental questions were not yet an important driver. The incentives provided by Proálcool turned out to be quite effective as ethanol production increased by more than 50 percent within five years. Other states with less of a tradition of sugarcane production, such as Paraná, Goiás and Mato Grosso, also started to produce sugarcane in response to these governmental 'stimuli'.

The 'Proálcool' programme and the shift to technological change

After the second oil crisis in 1979 when international oil prices abruptly doubled, the Proálcool programme intended to bring about a shift from anhydrous ethanol to hydrated ethanol, to be used as exclusive fuel in car engines. The main policies were the mandatory use of 20 percent of ethanol in all gasoline sold domestically, the promise by the government to buy the entire ethanol production, credits at negative real interest rates to ethanol producers, the establishment of higher prices for ethanol relative to sugar and for sugarcane relative to other crops, the imposition of export taxes and licenses on sugar and ethanol to guarantee the domestic supply, and the settlement of quotas for sugar and ethanol production designated for domestic consumption, limiting exports to excess production (Borrel *et al.* 1994). To achieve the targets of the new plan, a new market had to be created. The automotive industry was given a decisive role – the production of adapted cars to run exclusively on ethanol – but the agreement between the government and the automotive industry was not achieved without cost. The industry's participation was obtained at the expense of tax cuts and fixing the ethanol price at 65 percent of the gasoline price, although the production cost of gasoline was much less than the fixed value in the pump. These policy incentives were attractive to both consumers and ethanol producers and resulted in a jump from six billion litres per year ethanol production to 12 billion per year in only four years (Savernini 2008).

A second element post-1980 was the new focus on technological innovation (Paulillo *et al.* 2007). Before 1980 the sugar industry basically demanded federal subsidies and market protection, which, in fact, reduced the importance of technological improvements. Proálcool supported huge investments in technology between 1980 and 1985. Some of the most important developments were the selection of improved sugarcane varieties, the reduction in fuel consumption for harvesting, the reduction of transport costs, and residue management (returning the vinasse – a juicy residue after distillation phase – to the soil). Improvements within the sucrose conversion phase were also obtained in juice extraction, more efficiency in the treatment of juice, and controlled fermentation (Moreira and Goldemberg 1999).

These investments in technology innovation resulted in higher efficiency in terms of decreased use of fertilizers and higher sugar production (more ton per area, more sugar per ton, Figure 1) and also more litres of ethanol per litre of juice which together significantly reduced the production costs of ethanol. Despite this, ethanol prices were still unable to compete with gasoline and the government continued to subsidise the sector in order to keep the Proálcool 'agreement' on track.

Neoliberalisation (1986–2008)

Several internal and external factors supporting the Proálcool programme disappeared in the late 1980s. First, international oil prices collapsed (new reserves were found and Saudi Arabia increased its production). Second, technological development in deep water extraction of oil in Brazil reduced the national dependency on external petroleum. Third, the international sugar price was extremely high which made it more profitable to sell sugar on the external market and buy oil to produce gasoline rather than to produce ethanol. Fourth, the government elected in 1990 faced a deep economic crisis and accumulated national debt, and decided to reduce many subsidies, including fiscal subsidies to ethanol cars

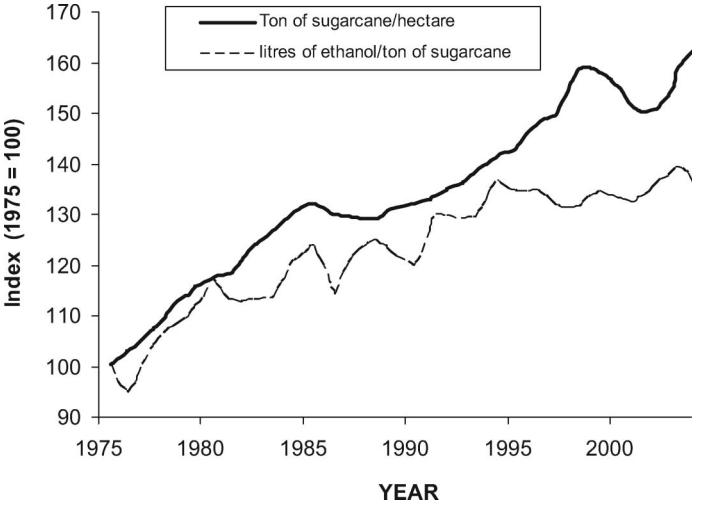

Figure 1. Sugarcane and ethanol productivity in Brazil, 1975–2004 (1975 = 100).
Source: Martines-Filho *et al.* (2006).

and sugar mills, leading to withdrawal of the automotive industry and mills going bankrupt. These changes immediately raised the ethanol prices and consumers switched to gasoline.

The resulting 'ethanol crisis' revealed an important characteristic of the whole Proálcool programme. It was based on a strong arrangement of interests among actors. When their interests were no longer aligned, the whole system collapsed. The cutting of governmental subsidies coupled with the decision by the sugarcane industry to seek higher profits in the external sugar market ruined the structures and relationships of the ethanol chain, negatively impacting consumers who had invested in ethanol cars during the preceding years. Despite the technology developments and favourable environmental conditions (increasing productivity and efficiency as shown in Figure 1) they could not avoid the failure of the system.

The next step in deregulation, the liberalisation of ethanol prices in 1996 in the context of a more stable economy, initiated a new restructuring process (Vian and Lima 2005).[3] New technological processes and management mechanisms were applied, for instance, microelectronic and automation inside the industry, mechanisation of harvesting, improving logistics, outsourcing of services and equipments, fusion and acquisition and the creation by private actors of a specific mechanism[4] to regulate prices and the supply of sugar and ethanol. Although the governmental withdrew from subsidising the sector, it preserved the blending rules, defining a

[3]At least five strategies were used by the sugarcane industry to address the crisis: deep specialisation in sugar and ethanol production, product differentiation, productive diversification, mergers and acquisitions, and the formation of commercialisation groups.

[4]The CONSECANA (Council of the Sugarcane Sector) is a voluntary payment system created in 1999 by the sugarcane producers union and the mills organisation. The aim is to control the supply and demand of sugar and ethanol and to stabilise prices. Sugarcane prices are calculated taking into account the sugar content of the stems, the domestic price level, and their variation during the crop season (Brandão 2008).

requirement for the anhydrous ethanol mixture in the gasoline of between 20–25 percent, which maintained a minimum and relatively safe internal market for ethanol. The co-generation of energy by burning bagasse was another process that the sugarcane/ethanol industry used to increase efficiency. Since 2000 most Brazilian sugarcane mills have been self-sufficient in energy and have been selling the excess energy produced. Energy co-generation from bagasse currently represents around 2,000 MW and could increase up to 10,000 MW if sugarcane straw were collected for this purpose. Electricity provided by the sugarcane mills coincides with the dry season, and can thus fill a gap in hydroelectric energy production from rivers. Due to difficulties (mainly environmental licenses) to expand the river-based electricity production, the federal government has stimulated the sugarcane industry to expand the co-generation of power. Restructuring of the sector as a result of the ethanol crisis, blending regulations, flex-fuel technology regulation (flex-fuel technology represents 90 percent of the total cars sold), and energy policies have led to an expansion of the internal market and helped the sugar and ethanol industry to reemerge even stronger in the twenty-first century (Paulillo *et al*. 2007).

The most recent impetus has come from the growing international demand for renewable fuels and the availability of capital for investments. Furthermore, national fuel consumption shifted even more from gasoline to ethanol in 2007 (Jank 2008).[5] At least US$17 billion of foreign capital has been invested in the construction of 86 new mills (Abramovay 2008). At least 50 new plants will initiate production in the next two years, with each mill requiring around 5000 hectares of sugarcane. Nowadays, the Brazilian government is very active in defending sugarcane-based ethanol not only as a commodity for the international market, particularly seeking markets in developed countries, but also as a powerful diplomatic tool for a new model of South-South cooperation – basically transfer of the know-how to several African countries (Dauvergne and Neville 2010).

This section has presented a short history of the development of the sugar and ethanol sector in Brazil. The current strength of the biofuel industry in Brazil is not just a singular, recent development but the result of a long and complex trajectory with ups and downs, in which two characteristics have been decisive: government support for biofuel production, which varied in nature over time, coupled with the alignment of interests of several economic groups.

Historical development of dairy production in Brazil

In contrast to sugarcane, there has been a lack of long-term policies for the dairy sector, with little or no subsidy and high vulnerability to market forces (Meirelles 2004). Possible explanations for the lack of governmental attention to the development of milk production are that it is a family-based subsistence activity, oriented to the internal market, with less political representation and influence compared with the sugarcane industry. Nevertheless, dairy production is growing. In 2008, the Brazilian dairy chain produced around 29 billion litres per year with a total annual revenue similar to the sugarcane industry and only behind the beef, poultry, and soybean chains. The total amount of milk has grown 48 percent in the last ten years, which changed Brazil from being a traditional milk importer (Jank *et al*. 1999)

[5]In 2007, the sum of anhydrous ethanol (blended with gasoline) and hydrated ethanol (pure) represented more than 51 percent of the total consumption of fuel in the country.

to being potentially an exporter of dairy products such as milk powder, condensed milk, and cheese (Conejero and Neves 2006).[6] We will explain below that the growth of the total milk volume has been mainly achieved by frontier expansion in traditional beef cattle areas, which have slowly shifted to dairy production (Faria and Martins 2008) and not through increased productivity or sustained production on existing dairy farms.

The milk frontier: the expansionist model of the dairy chain

In the 1940s only 44 percent of the population lived in cities but industrialisation during the 1960s attracted people to the cities to the extent that around 80 percent lived in urban areas by the 1970s. The increasing urban demand for dairy products led the industry to buy raw milk beyond that of the traditional regions usually located near the cities (area A in Figure 2). The region of milk collection had never been small, for example, the milk catchment of São Paulo city reached up to 350km in the 1950s. However, during the 1970s the average distance to the supply for the large cities in Brazil expanded to 800km (Meirelles 1996). Nowadays milk may be produced 3000km away from the main region of consumption.

Examples of milk production marching to the west can be found in the west of São Paulo state. São José do Rio Preto (area B in Figure 2), a traditional beef cattle area, has become the main milk region in the state, responsible for 22.3 percent of the state's total production in 2004. Meanwhile, milk production of the most traditional milk region located between São Paulo and Rio de Janeiro decreased to 11 percent of the total (Nogueira *et al*. 2006). A similar process occurred in Minas Gerais, where the cerrados (Brazilian savannhas) areas in the west (particularly Triângulo Mineiro and Alto Paranaíba) have become the major region for milk production with 24.5 percent of this state's production (Gomes 2006). In the last ten years, the frontier expansion to the west went beyond São Paulo and Minas Gerais into the centre-west and north regions (area C in Figure 2). Table 1 also shows the reduction of milk production in São Paulo state during the same period, reflecting reduction in milk production in areas with high competition for land and labour.

Milk production in the frontier areas displays characteristics of low productivity similar to the systems of the original areas milk-producing areas some years before. Beef or mixed cattle produce low quality raw milk in areas with infrastructural problems such as poor roads and lack of electricity. Despite the extensive nature of milk production dairy products are still exported to the main consumer centres in the southwest, due to the very low population density in the frontier areas (Nogueira *et al*. 2006). Further evidence for the extensive growth, rather than intensification, of dairy production can be found in data on the total milking herd in relation to total milk production (Figure 3). The number of milking cows increased by 120 percent from 9.3 million in 1970 to 20.5 million in 2005 (Yamagushi *et al*. 2001, IBGE 2008). During the same 35-year period the herd increased by 135 percent – a similar amount.

[6]If Brazil became an exporter of dairy products it would not mean that all Brazilians received an adequate intake of dairy products. The milk availability per inhabitant, on average only 134 litres per inhabitant per year, is much less than the 210 litres per capita recommended by the FAO (Faria and Martins 2008).

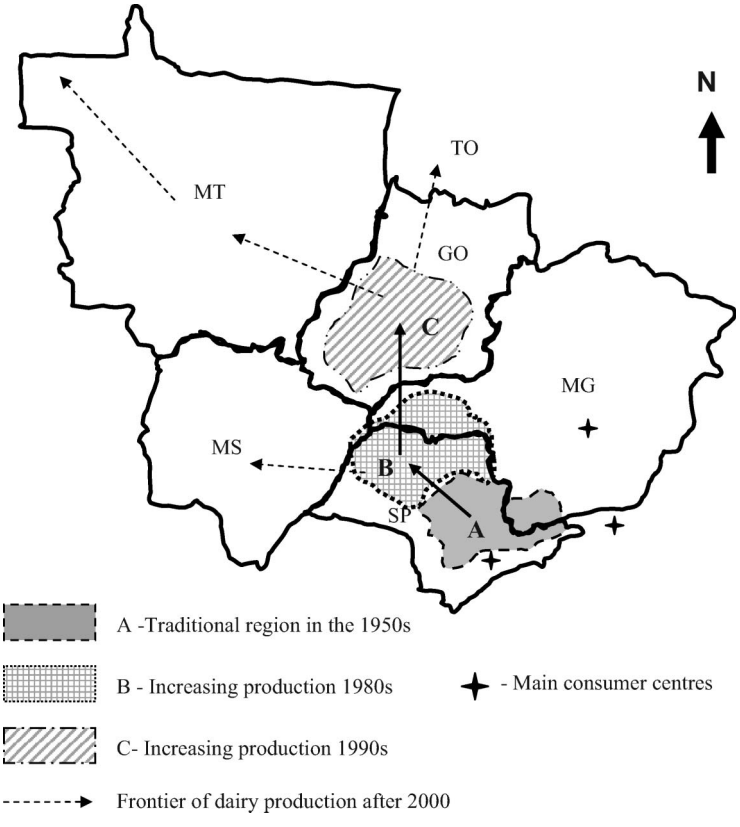

Figure 2. Dynamics of dairy production in the centre-south and west regions of Brazil. *Sources*: Faria and Martins (2008); IBGE (2008); and Milkpoint (2008).

Table 1. Sugarcane expansion and milk production, São Paulo state: area, production and number of milking cows (1990–2007).

	Sugarcane		Milk		
Year	Area (M ha)	Production (M ton)	Area* (M ha)	Production (M liters/year)	Milking cows (M)
1990	1.8	138.0	10.2	1.96	2.14
2007	3.9	327.7	9.1	1.63	1.50
% change	+116%	+137%	−11%	−17%	−30%

Source: IBGE (2008).
Notes: *Total beef and dairy cattle pastures.

The movement of the milk frontier has its roots in the availability of cheap land and sufficient beef cattle to initiate milk production. Although the distance to the consumer centres is far, the lower prices of raw milk make it worthwhile for the industry to collect milk in frontier regions. In such regions ranchers used to consider the milk a by-product of the beef calf, though the regular monthly revenue is interesting to farmers who start milking beef or mixed (cross-bred) cows.

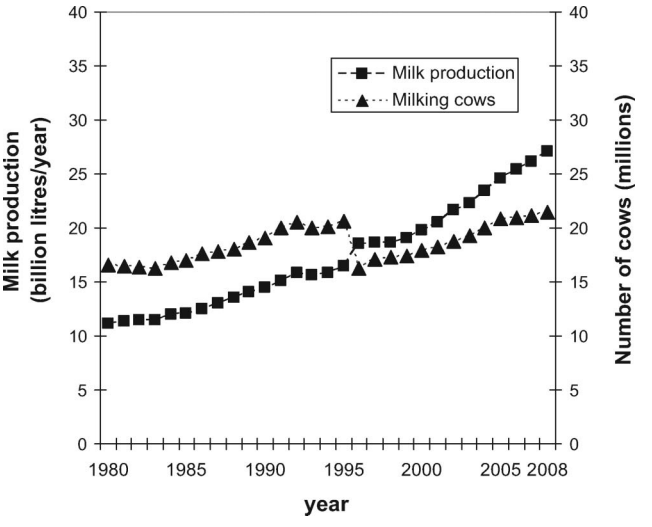

Figure 3. Number of milking cows and milk production in Brazil from 1980 to 2008.
Source: EMBRAPA (2008).
Note: The decrease in the total number of cows in 1995 was due to changes in the calculation method. After this date the total number was adjusted by including data from leather production.

The introduction of a new activity inside typical beef farms (large herd, available grasslands areas) perfectly matches with the adaptation process of farmers since there is virtually no risk involved in the relationship with the industry. In addition there is no need for specific investments and there are no contractual obligations. It turned out to be quicker and cheaper to open roads and, for the industry, to build cooling and processing plants in new regions than to intensify milk production in traditional regions (Faria and Martins 2008). Contrary to other food chains, such as swine, poultry, or even sugarcane, there was no significant reason for the dairy industry to invest in vertical integration or development of suppliers if the raw product could be bought cheaply and without limitations in non-traditional regions.

The role of government and the intervention period (1945–1990)

The government's role in the dairy sector is largely one of indirect impact resulting from general economic policies. Decades of economic instability (from 1974 to 1994), high inflation, and unclear political strategies created the conditions for a huge expansion of pastures and beef cattle, mainly in the frontier. The logic embedded in this expansion is based on some specific characteristics of pastures and livestock, such as the flexibility in the moment of 'harvesting the land' with animal production, the economic flexibility of selling at the best possible moment, and low labour demand over large areas, among others (Hecht 1993). Farmer's rationality of capital protection can be understood within the context of inflation around 1000 percent per year as observed in those times (FGV 2008). During such periods, the low-risk investment strategy of buying more available cheap land for beef cattle production was the perfect option to protect capital. High inflation rates in turn influenced the

few government policies towards milk. Several authors described the governmental intervention in milk prices as the main institutional act applied to the sector (Jank *et al*. 1999, Nogueira *et al*. 2006). For a period of 45 years, the amount of imported milk and milk prices were regulated.[7] The formal discourse on regulating imports and prices referred to the 'protection' of dairy farmers against the negotiation power of the industry and the improvement of access to milk (mainly fluid pasteurised) for less-favoured economic classes. The seasonality of milk production was also cited as a reason to exercise strict governmental control. However, the high level of intervention probably also had a more important target: inflation control. Dairy products were part of the so-called 'basic food basket' which is used to calculate inflation rates (Meirelles and Alves 2001). Any control of official inflation rates was instrumental for achieving macroeconomic goals. Federal decisions on importing dairy products were often made to tackle inflation in situations of an unbalanced supply-demand (a drought period for example) and, generally, when milk prices increased. Although milk prices were manipulated for reasons other than development of the sector, such interventions led to a guaranteed minimum price for the product.

The government never supported technological innovation in this sector as it did in the sugarcane sector. During the 1970s some brief and limited efforts were made in order to increase milk production and productivity through special financing conditions for farmers who applied for a specific proposed package (low interest loans with long pay-back periods). Typically, the proposed technological package turned out to be inappropriate (related to its strong focus on breeds, buildings, and machinery),[8] and its use remained restricted to a few regions and large farms (Faria and Martins 2008). Small and medium-size farmers who tried to use the same model had mostly no success. As a result, the idea of 'technology' for milk production was broadly identified by farmers as something quite expensive which would invariably drive investing farmers to bankruptcy (Faria and Silva 1996). Periods of high inflation rates also prevented investment in technologies from increasing productivity. Farmers could avoid risks by staying away from capital intensive 'improvements', yet milking a few non-specialised cows made sense to provide a small but regular monthly income.

Deregulation, concentration and new technology in the 1990s

The same wave of liberalisation that reduced government subsidies to the sugarcane industry during the 1990s also affected the dairy sector. After 45 years of price regulation and control of external dairy supplies, the government suddenly withdrew the regulations on all dairy products and removed all barriers to importation. Farmers were not prepared to compete under free market conditions as the absence

[7]At that time, leaders of dairy producer organisations demanded liberalisation, arguing that existing regulation did not bring any benefits to consumers either in quality of milk or in prices and at the same time restricted the modernisation of the dairy activity.

[8]During the 1960s and 1970s the introduction of capital-intensive technologies from developed regions, such as the USA and Europe, brought the Brazilian farms highly specialised breeds, artificial insemination, confined systems (Stall based, no grazing), use of corn silage as the main fodder, milking machines, and hay and fodder chopper machinery, among other things. This foreign technology was used largely without adaptation to the local situation.

of a minimum price and the high negotiation power of the industry[9] drove down milk prices. Imports of cheese and powder and fluid milk increased rapidly (mainly from Argentina, Uruguay and later Paraguay, members of 'Mercosul', the recently created multi-country commercial block).

The open market conditions and the downward pressure on prices altered power relations and arrangements between actors and led to reorganisation of the dairy sector (Coutinho and Ferraz 1994, cited in Novo 2001). A process of fast concentration of the dairy industry and supermarkets took place mainly by acquisitions and strategic mergers (Primo 1999). The main targets were the national, medium-scale, and family-administrated dairy industries that were bought by transnational groups. The Italian group Parmalat, for example, pushed the concentration of industry aggressively by making acquisitions in several regions (it followed the same strategies in different countries; see van der Ploeg 2008). From 1988 to 1997, more than 50 percent of the dairy firms disappeared (Jank *et al*. 1999). The concentration in the dairy industry (regaining strength from cost reduction through the economy of scale) increased its negotiation power and altered power relations in the dairy chain. A similar process of concentration took place in the distribution sector, through acquisitions and mergers of supermarkets. In fact, the distribution and supermarket networks became much more powerful than the dairy industry sector (Campos and Neves 2007).[10]

Both concentrated dairy industries and supermarkets had a stake in another major development that would change the nature of the dairy chain: the massive introduction of ultra high temperature processing technology (UHT, a sterilisation process combined with a specific packing process). UHT milk has largely replaced pasteurised milk as the final consumer's choice. The UHT technology ('longa vida' or long life) provides technical and economic advantages to the industry. For example, the possible use of a lower quality raw material and the shift from a perishable product to a commodity with a three-month shelf-life allows the collection of milk from distant locations. The possibility of transporting the product from the frontier to the main consumer centres without refrigeration significantly reduces freight costs. The possibility of buying bigger batches, keeping milk in stock for longer periods, and using it in promotions is very profitable for supermarkets. As a consequence, the market share of UHT milk jumped from 14 percent in 1993 to 61 percent in only five years. Nowadays, 75 percent of the total fluid milk is processed by this technology (ABLV 2009). Consumers considered the 'longa vida' more convenient because of its lower price compared to pasteurised milk (partly due to promotions in the supermarket) and the lack of need for refrigeration at home. The extremely short shelf life of pasteurised milk[11] obliged consumers to buy milk almost daily. There are at least two important outcomes of this dramatic change to the dairy sector: firstly, UHT technology acted as a positive force for the frontier march of milk production and, secondly, there was a clear transfer of profit margin from the

[9]The high power of negotiation of dairy industries has been credited to the oligopolistic nature of the sector, non-differentiation of the raw product, the low cost of substitution of suppliers, and the perishable nature of the product.

[10]In Brazil, 80 percent of fluid milk, condensed milk, and cream are sold in supermarkets. In São Paulo state the retail sector is even more important, reaching 85 percent of these products' sales.

[11]The shelf-life of pasteurised milk at home can be as low as one to three days due to the low quality of the raw material and problems in the distribution chain.

productive sector to the industry and mainly to the supermarkets over the last 10 years (Carvalho and Oliveira 2006).

New sanitary rules and the quality issue

After such deep changes, a large debate took place among farmers, the science community, the industry, and the government regarding alternatives for increasing the competitiveness of dairy chain. Relevant issues such as food security and the insertion in the international market motivated the creation of a new regulatory standard. The outcome was the creation of the 'Plano Nacional de Melhoria da Qualidade do Leite' (PNMQL 2002), a national plan that managed to replace the obsolete regulation of milk production dating from 1945. Basically, the programme aimed to improve the quality of milk through three sets of regulations regarding hygiene during the milking process, refrigeration, and time to reach the correct temperature (Xavier 2001). The dairy industry was obliged to apply systems of quality management such as HAPCC (Hazard Analysis and Critical Control Points) and the GPP (Good Production Practices). The programme also modified the regulation of the official quality control introducing new parameters for somatic cells and bacterial contamination in raw milk. However the implementation of the PNMQL in the Brazilian dairy systems has been extremely slow. Some reasons were: the problems with the rural electricity supply, needed for refrigeration equipment; the inefficient road system; the high costs of the refrigeration equipment; and the farmers' lack of knowledge and training (Fonseca and Santos 2000).

Low competitiveness as a force for land use changes

Despite the many restructurings in the dairy sector one aspect has changed very little: the low productivity and low efficiency of resource use (land, labour, and capital). In 1994, the average (beef) cow productivity was around 1,000 litres/cow/year in Minas Gerais state. Eleven years later in the same state, the mean productivity had increased to 1,183 litres/cow/year, not more than the productivity found in the USA in 1870 (Faria and Martins 2008). Many of the milk production systems in Brazil are low capital and labour demanding and therefore, low risk. The low resource efficiency of dairy systems is a result of a traditional herd structure in which cows constitute only 35 percent of the total herd on average (Gomes 2006) and lactating cows represent only 23.7 percent. 'Unproductive' cattle, as dry cows, open heifers, male calves, bulls and oxen comprise the rest of the herd. This herd structure is practically the same as that of 40 years ago, of which lactating cows were 23.6 percent (Costa 1971). The unbalanced herd composition coupled with a very low animal density of around 1.2 heads/ha leads to extremely low productivity (less than 1,800 kg/hectare/year). The maintenance of 3.5 unproductive animals for each lactating cow on the farm significantly reduces possible income generation. Moreover, the practice of feeding calves with milk up to the weaning date (around 8–9 months) reduces the amount of milk sold to the industry significantly. We have observed that many farmers consider calves more important than the total amount of milk sold, a reasoning typical of beef cattle ranchers.

Nowadays, low productivity often means that dairy farming is less competitive with other activities. Poor productivity makes it difficult to recoup investments in land, herd, fences, buildings, machines and equipment (Alves *et al*. 1999, Fellet and

Galan 2000). The average current productivity of around 1,500 kg/ha/year in São Paulo state allows a maximum gross income of R$300/ha/year (Camargo *et al.* 2006). The low income that can be made with the predominant production system in dairy farming is often insufficient to resist offers from sugarcane producers to buy or rent land. The sugarcane industry offers at least 60 percent more as a promised income, such as a net income for a six-year rental contract. When the opportunity cost of land and capital applied to milk production is considered, the income is unattractive and often negative.

Biofuel and the competition for land and labour in São Paulo state

The previous description of the historical trajectories of social-technical systems of sugarcane and dairy, identifying governmental interventions and specific group interests, is followed here with an analysis of the impact of the recent expansion of sugarcane on land prices, labour markets, and milk production in order to shed light on the competing claims between the different sectors. We also analyse the linkages between these two systems and a third chain, beef cattle production.

Sugarcane and the land market in São Paulo state

The expansion of sugarcane has brought significant economic changes to the land and labour market within São Paulo state, as well as new relations between sugarcane mills and sugarcane producers. The expansion took place mainly in the north, northwest, and west regions of São Paulo state and also beyond the state borders in Minas Gerais and Paraná (Figure 4). The 'new reality' of a dynamic sugarcane/ethanol sector has pressed small dairy farmers to find alternative paths for providing a livelihood for their families by renting or selling land to the sugarcane industry. The ethanol industry offers high prices for land, and renting land is associated with the absence of risk, compared with other local land use options. The advantage of dairy production as a monthly income has been overwhelmed by a clever strategy of the sugarcane industry that offers long-term contracts plus the opportunity for monthly payments for land lease.

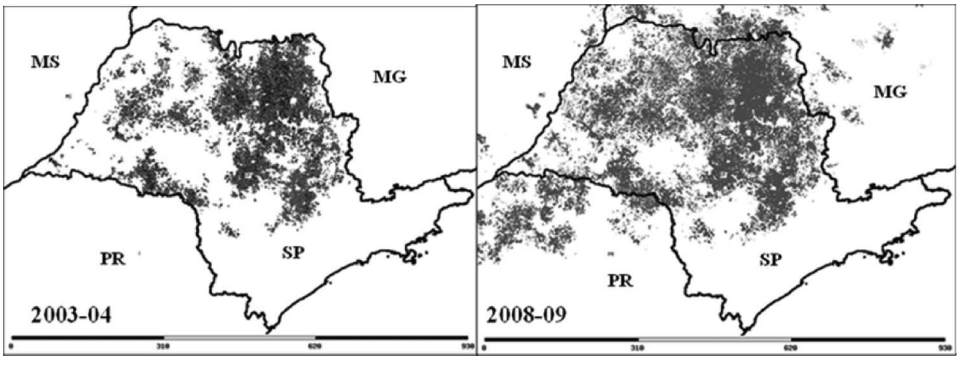

Figure 4. Sugarcane expansion in São Paulo state between 2003–04 and 2008–09.
Source: Images INPE/CANASAT (2008).
Notes: The grey shading indicates the spatial distribution of the sugarcane.

To understand sugar mill and farmer relationships it is relevant to distinguish two categories of farmers: 'active producers' – those who directly produce the sugarcane and sell their production to the mills – and 'passive landowners' who only rent their land to the mill (which is then responsible for sugarcane production) or to other active farmers (Terci *et al*. 2007). In 1995, active producers represented only 40 percent of the 7000 members of the São Paulo sugarcane farmers' organisation (Organização dos plantadores de cana da região Centro-Sul do Brasil – ORPLANA). Passive landowners comprised the other 60 percent.

Higher rents tend to increase participation in the leasing model, particularly by small farms in a traditional sugarcane region. In 1995, 80 percent of renting farmers had farm sizes of less than 50 hectares and most of them already had grown sugarcane before leasing their land (Peres 2003). The increase in area rented by the sugar cane industry not only expanded on traditional farms but also in several land reform areas (regardless of the prohibition of renting land in settlements), which created conflict between the industry and settlers (Fernandes and Gonçalves 2010). Rents in São Paulo state have risen consistently over the last 13 years in 16 different sub-regions (264 municipalities) that represent the location of the new areas and also in the more traditional areas in the centre, north, and west of the state. In 1995, the industry paid an average of R$175.01/ha/year. In 2008, the value has increased to R$502.19/ha/year. This suggests increasing competition for land where sugarcane is present, reflected in rising rents offered by the sugarcane industry in six-year contracts. Higher values are paid for better soils, favourable topography, and shorter distance to the mills.

Expansion of the sugarcane industry probably also led to a rise in land prices in São Paulo state (see Figure 5). In regions with sugarcane, land prices increased more than four fold in the nine years 1999–2008. It is highly probable that this increase is associated with sugarcane since it is the only rural activity that has grown systematically in almost all regions of São Paulo state.

Table 2 (adapted from Nassar 2008) shows that pasture land was the preferred terrain for the expansion of the sugarcane sector. From 2002–2006 approximately 90 percent of the new sugarcane area took over pastures intended for milk and beef production. The same pattern also happened in other regions.

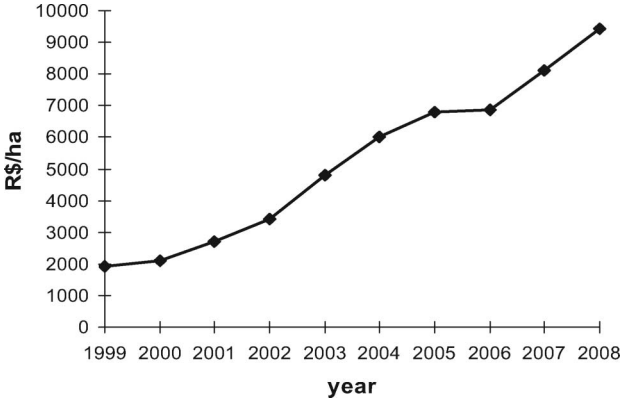

Figure 5. Average value of pasture land in São Paulo state, 1999–2008.
Source: IEA (2008).
Notes: deflated prices (IGP-DI), in R$/ha, mean of 38 regions.

Table 2. Sugarcane area and land use substitution (2002–2006) in different states in Brazil.

States	Planted area (1.000 ha)			Substitution 2006–2002 (1.000 ha)			
	2002	2006	Difference	Pasture	Crops	Total	Sugarcane
São Paulo	2,662	3,285	623	558	66	624	−1
Minas Gerais	278	431	153	148	16	165	−11
Paraná	359	433	74	92	3	95	−21
Mato Grosso do Sul	112	153	41	42	10	52	−11
Goiás	204	238	34	50	8	59	−25
Mato Grosso	177	202	25	26	10	35	−10
Tocantins	3	4	1	1	0	1	0

Source: IBGE, adapted from Nassar (2008).
Notes: The column denominated 'crops' also included sugarcane. Consequently the total value is higher than the difference due to self-replacement of sugarcane in the same field.

Not only sugarcane expansion but also other processes may have affected land prices. For instance, economic stabilisation after 1994 reduced land prices due to the partial loss of the 'reserve value' that land had during periods of high inflation. After 2000, high prices of some main commodities such as beef, citrus, soybean, and maize may have contributed to the rise in land prices (Camargo 2007). Our research methods do not allow us to assess the relative importance of these different processes, but there seems to be sufficient evidence to conclude that sugarcane played an important role in the increase of land prices since 2000. Higher land prices, as observed in all regions with sugarcane, increase the production costs of all activities. Rural activities with low efficiency cannot compete with the sugar and ethanol industry and sooner or later will shift their land towards biofuel production.

Farmers may decide to stop farming and instead rent out their land (or part of their land) not only based on economic calculations of costs and benefits. Comparing rents (from R$350.00 to R$700.00 per hectare in 2008) to incomes obtained with traditional low productivity milk production (R$ 300.00/ha, Camargo *et al.* 2001) it may seem logical that farmers stop milking cows and rent or sell their land to the sugarcane mills. But this logic intertwines with other factors. Peres (2003) analysed the main reasons that farmers stopped farming and rented their land, and the most common answer, 62 percent of the sample, was related to the lifecycle of the family. Why is renting land instead of selling it so popular? Farmers who choose to rent land have to sell cows and equipment, which makes their decision to quit dairy production almost irreversible. The option to take up farming again later may not be the biggest driver although keeping the link with the land remains an important element. Another factor is the relative security offered by a long-term contract with a large company. This is in contrast to the unstable economic relationship in dairy characterised by the spot market, with no contractual obligations between farmers and the dairy industry. Furthermore, renting out land provides the possibility of remaining integrated within the sugarcane farmers association, which provides not only voting rights, but also access to credit and to a good quality health service provided by the association.

Sugarcane expansion, wages, and labour

It is difficult to assess the competition for labour between the dairy sector and the expanding sugarcane sector due to lack of data, but some data suggest that the

sugarcane sector may be more competitive by paying higher wages. In the period between 2000 and 2005, the sugarcane sector in São Paulo state paid better salaries (around 30 percent more) than other sugarcane regions (Moraes 2007). In this period the total number of workers in the sector decreased by 23 percent due to the mechanisation of the harvesting process, despite an increase of sugarcane production by more than 54 percent. The substitution of the traditional manual cutting, which requires burning of the cane leaves, is a result in the first place of regional laws that prohibit burning to reduce environmental problems and, secondly, of increasing demand for biomass for power generation within the industry. Finally, machines were introduced to reduce the dependence on manual labour, particularly in regions where the labour unions were strong and more organised (Ricci *et al.* 1994). Sugarcane producers in São Paulo state paid wages around R$710.93/month (in 2005 values) whereas the average agricultural wage in all regions of São Paulo for the same year was R$501.57/month (IEA 2008). Other sources mention that sugarcane workers receive 80 percent more than those holding other agricultural jobs (Macedo 2005 in Smeets *et al.* 2006).

At this moment it is not yet possible to conclude firmly that these higher wages make the sugarcane sector more competitive in the labour market. Firstly, available data on the average wages paid for other agricultural work do not include non-wage benefits, such as housing, transport, or goods (milk, electricity, vegetables, etc.) offered by employers when workers live on the farm. This does not happen in the case of the sugarcane harvesters, usually migrants, who previously lived on the outskirts of the cities and have no complementary wage.[12] Secondly, available data do not take fully into account the high variability in the type of job considered when calculating the average wage. There is a clear separation between seasonal jobs (harvesting workers, the vast majority) and permanent employees (semi- or high-skilled agricultural workers, lorry drivers, and machine operators) (Smeets *et al.* 2006). The former receive almost the minimum national wage, while the latter category earns much higher wages. Competition with dairy activity could be placed in this group of permanent jobs since dairy requires more skilled labour than sugarcane harvesting.

Sugarcane expansion and the interaction between beef and dairy production

The analysis of the substitution of pasture by sugarcane production (Table 2) and the decrease in milk production (Table 1) in São Paulo state requires an additional examination of aspects of the internal dynamics of the cattle sector. Figure 6 shows the evolution of different types of cattle herds.

The cattle category denominated 'mix' represents the cross-bred herd, with variable proportions of dairy and beef breeds. The changes in the institutional and technological environment has led to systematic reductions in the number of specialised dairy cattle herds during the last 17 years. Reduced profits of specialised dairy farmers hit both traditional farms as well as more capital-intensive systems in São Paulo state. Several auctions of very highly productive herds, mainly Holstein

[12]The seasonal nature of the agricultural labour demand, particularly for the harvesting process, makes the analysis more complex. Temporary workers for the manual harvesting procedure were 43.4 percent of the total employees of the sugar and ethanol sectors in the whole country in 2005 (Moraes 2007).

pure-bred cows from free-stalls systems, were conducted due to the demise of big farms. The main destination of the dairy cows sold in these auctions was the Goiás state (area C of Figure 2), within the Cerrados biome, the milk frontier during that period (Table 3).

Therefore, the crisis of specialised dairy farms from São Paulo was offset at national level by the frontier expansion, and the total national production kept growing at high rates due to the relocation of milk production.

The decrease in specialised dairy farming was linked not only to sugarcane expansion but also to the replacement of dairy herds by mixed and pure beef

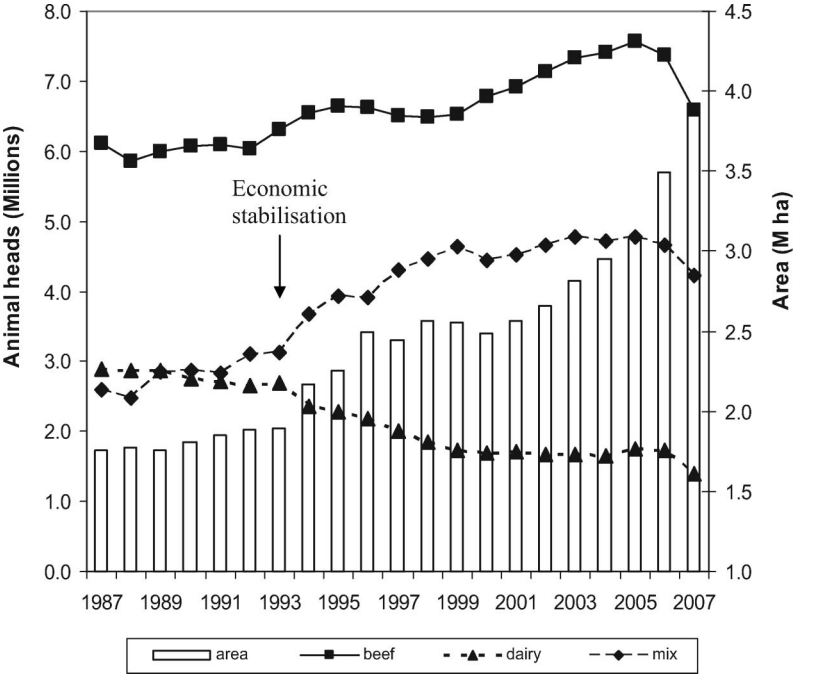

Figure 6. Cattle herd (beef, mixed and dairy cattle) and sugarcane area, São Paulo state, 1987–2007.
Source: IEA (2008), IBGE (2008).

Table 3. Milk production by state and rate of increase, 1990–2007.

State	1990*	2007*	Difference*	%
Rondônia	158	708	550	348
Mato Grosso do Sul	399	490	99	25
Mato Grosso	214	644	382	179
Goiás	1072	2639	1576	148
Minas Gerais	4291	7275	2617	61
Tocantins	106	214	114	108
São Paulo	1961	1627	−217	−11
Total	*8043*	*13597*	*5554*	*69*

Sources: IBGE (2008), Milkpoint (2008).
Note: *million litres/year.

herds. Figure 6 shows the increase in the number of mixed herds that took place from 1990 up to 2006, representing the gradual introduction of milk activity in beef farms, which prevented a large reduction in milk production in São Paulo state as a whole despite the drop in the number of specialised dairy herds (from 2.9 million single-purpose dairy cows in 1987 to around 1.5 million, almost 50 percent, while milk production only decreased 17 percent). Another factor that could have contributed to the decrease in the number of specialised cows was the decline of 'Type B' pasteurised milk after the introduction of UHT. This particular better quality milk (quality controlled and produced under more hygienic conditions) was aimed at wealthier consumers and was subject to free market pricing as it was not included in the national food basket. The profit margin on 'Type B' milk as a product for the urban elite was high enough to sustain the high costs of production and the Holstein cows-confined systems that were widespread earlier in São Paulo state.

Contrary to one of our initial hypotheses, the expansion of sugarcane into pastures did not reduce the number of beef cattle, at least not up to 2005. On the contrary, there was a gradual increase from 6.2 million heads in 1992 to 7.5 million in 2005. One possible explanation relates to the intensification of the beef production system. The use of technology, such as better grass species, artificial insemination, the use of feed lots, and the technology of supplementing fodder during the dry season could have had a significant role in intensifying beef production in terms of increased number of heads per hectare. The motivation for introduction of this technology could be the high prices for beef cattle observed in that period, as shown in Figure 7. In contrast to specialised dairy production, the intensification of beef production was economically feasible with beef prices around R$80–90 per 'arroba'[13] between 2000 and 2004, even in the competitive environment created by the sugar and ethanol industry.

The remarkable drop in beef prices after 2004 was strongly influenced by foot-and-mouth disease[14] in Mato Grosso do Sul and Paraná states (Ângelo and Gonçalves 2006). Meat exports to the European and North American markets were immediately blocked and the entire national beef chain entered a deep crisis. Prices were reduced by up to R$60 per arroba. At the same time, sugarcane prices were increasing rapidly since, as a raw material for biofuel, its price was linked to the international oil prices, which reached a historical peak in value (up to US$120/barrel).

The combination of these two factors – a deep crisis in the beef chain and the exploding demand for biofuel – had created a perfect context for encouraging farmers to shift from beef and dairy into sugarcane. This analysis shows that land-use changes such as those observed in São Paulo state are driven by multiple forces at different levels. The observed expansion in the area of sugarcane and the biofuels boom may be understood as the outcome of a complex interaction between national and international economic factors. The strengths and weakness of competing

[13]'Arroba' is the common measure for beef cattle prices in Brazil; it is equivalent to 15kg of beef carcass. At the farm level, however, it means 30kg of live weight, which is related to the dressing percentage (in average 50 percent for Brazilian traditional beef cattle breeds).
[14]A highly contagious viral disease (*Aphtae epizooticae*), typical of cloven-hoofed mammals. The last cases in Brazil caused losses close to US$2 billion in the whole meat chain in 2004.

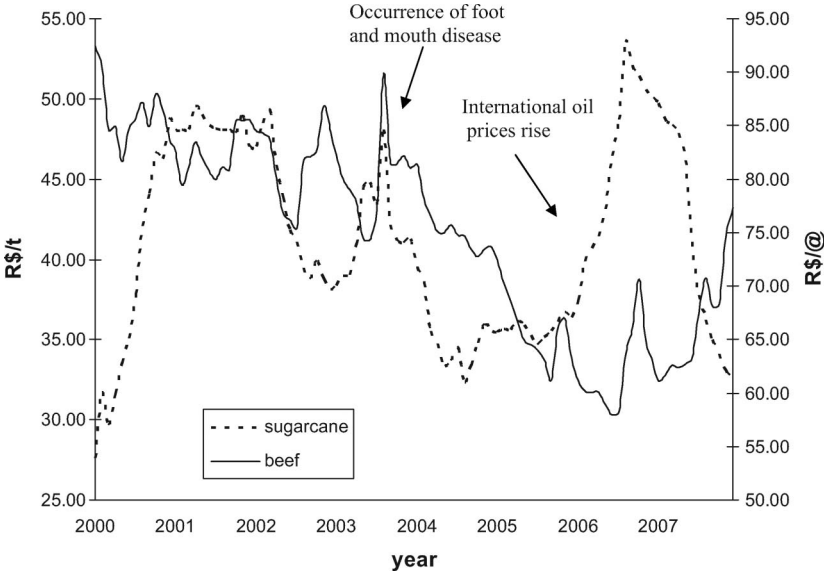

Figure 7. Sugarcane and beef prices.
Source: IEA (2008) and IBGE (2008).
Notes: arroba (or @) = 30 kg of live weight; R is Reais; deflated values by IGP-DI, R$/ton and R$/arroba.

agricultural chains, technical and ecological factors, the technological changes in the shelf-life and transport of dairy products and in biofuel production, the social and political configurations, and in particular the long term governmental support of sugarcane have all played a major role in the biofuel boom in Brazil.

Conclusions

This paper has addressed the issue of whether the decrease in dairy farming and pastures in São Paulo state was a direct result of the recent expansion of sugarcane production driven by a global demand for biofuel. In order to identify the different factors that might impact upon the competing claims between sugarcane/ethanol production and dairy and beef production we used a historical perspective on both technological and land-use changes, as well as economic and political changes. This made it possible to identify a spectrum of determining factors and their interactions over time.

The relationship between biofuel and beef/dairy is not simply a result of recent global market demand but has been strongly mediated by strong, long-term government support for the biofuel chain and a corresponding lack of support for small-scale dairy farming. While historically the biofuel sector has been supported by a range of government policies (regarding research and development, tax benefits, import controls, regulations regarding blending of ethanol with gasoline), government policies for the dairy sector were much less directed toward the development of the sector and basically served other interests such as control of inflation.

Furthermore, we have argued that the decrease of dairy production in São Paulo state can only be understood if we look beyond the strength of the biofuel economy and into the internal dynamics of dairy production and its technological configuration, which shifted the milk frontier to new areas and supported the expansion of mixed herds. The option of an ever-expanding milk frontier together with technological innovations, such as UHT milk, and political and economic developments, such as price drops after deregulation and the concentration in the dairy industry and the retail sector, provide a context in which dairy farming in São Paulo state became less and less competitive. It was in this context that many farmers decided to stop specialised dairy farming and to sell or rent their land to the sugarcane sector. Increased land prices and the high rents offered by the sugarcane/ethanol industry attracted farmers to this new opportunity.

The recent global demand for biofuel is for Brazil, the second largest biofuel producer in the world, just one additional impetus. The dynamics of the recent growth in biofuel production in Brazil cannot be explained simply by reference to the global debate on biofuels but need to be understood within the historical development of the specific social-technical configurations for sugarcane and ethanol production and use in Brazil, and in São Paulo state in particular.

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