Islands of dairy in a sea of sugarcane: the future of family dairy farming in Brazil

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To Denise, Érica and Aline, the reason of my existence.

To Lucca, our blessed grandson

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Chapter 1

General Introduction

1.1 Background

Driving westwards out of São Paulo city, just after leaving the outskirts of the capital of the most developed state in Brazil, the scenery gradually turns into an impressive five million-hectare sea of sugarcane. A closer look, however, reveals that the slightly hilly landscape is not completely occupied by feedstock for ethanol and sugar. Islands of alternative land uses, particularly small areas of pasture and family dairy farming, appear amidst the uniform and endless sugarcane plantations. This raises many questions about the viability of family farms surrounded by competing land uses. Can they compete with sugarcane or are they on the verge of disappearance? What kind of relationships do they have with the industrial sugarcane? How has the recent history of land use changes and government policies affected these dairy farmers? And what is the future of family dairy farming within the context of these economic changes and increasing opportunity costs?

The future of family farming is a matter of a worldwide debate that is frequently intertwined with other important issues such as climate change, globalization, food security and the economic and energy crises. There are opposing views about what could happen to small- scale farmers in literature. One vision, mainly from agronomic economists, foresees the end of small farmers due to their lack of economies of scale and low efficiency compared to modern industrial farming (Kumbhakar et al. 1989; Paul et al. 2004; Collier, 2008). This approach considers that households behave like firms, operate in fully formed and competitive markets and are profit maximizers (Ellis, 1988). Their image of the future revolves around an agrobusiness-based growth model, characterized by homogenous farms, large land holdings and high inputs of technologies and mechanization. For example, looking at the deep economic and institutional changes that took place in Brazil in 1990s, Alves (2001) has predicted that "traditional" dairy farming will disappear within 15 years if its practices are not modified. Later, Gomes (2003) foretold the end of small milk producers who would be replaced by modern farming systems with a large production scale, high technology, specialized labour and attention to the microbiological quality and nutritional characteristics of raw milk. In this scenario small-scale farmers have three options: grow big themselves, sell their land and go to the city or end up as workers on other people's land.

There is a different view which considers that peasants (or family farmers to stay closer to the most common terminology in Brazil) are less sensitive to external forces than large-scale industrial farms and are better able to resist such pressures because they are partially integrated in imperfect markets. They are better able to change, adapt and replace their internal processes and thereby face the changing world around them (Ellis, 1988). The end of family farmers has been predicted on numerous occasions and places for more than two hundred years but they have not disappeared or died out. According to Bernstein (2010) this is also due to the nature of this social class which puts up diverse forms of resistance, adapts to the surrounding environment and changes its internal processes. Following this line, some scholars argue that family

farmers are not inherently fragile but are, in fact, more efficient in terms of productivity per area or per unit of water than large-scale entrepreneurial farms (Griffin et al., 2002). Van der Ploeg (2008) argues that the specific way in which family farmers organize their labour is a strength that could support the intensification of their agricultural processes in a comprehensive process of *repeasantization*. This view suggests that family farmers will not disappear due to industrial competition but will provide a feasible and ecological alternative to feeding the world.

For many reasons, Brazil offers an interesting arena for debating the future of family farming. In the economic domain, the successful control of inflation since 1994, supported by long-term governmental policies and increasing demand for food, fibre and fuel (both internally and externally) are the main drivers that have fostered a massive growth in agricultural production. Brazil is now an important player in the international market, as the world's leading producer of sugar, ethanol, soybeans, coffee, oranges, poultry and beef. However, the increase in agriculture production area and productivity has not been evenly distributed between industrial and family farming. Comparing the last two national agricultural censuses (1996 and 2006), family farming's share of the total agricultural area declined (from 30.5% to 24.3%), indicating a process of land concentration among agribusinesses (particularly those producing soybean and sugarcane). In this context are there still opportunities for family farmers? If one looks at the gross value of agricultural production, the share of family farms has remained similar over this period (38%) even though they have proportionally less land. One possible explanation is family farmers became more involved in activities that generate a higher aggregate value. Some authors see this as an indication of the ability of family farmers to keep themselves afloat and play a strategic role in the rural economy (Mattos, 2010).

Alongside this agricultural expansion, Brazil's economy has shifted from a rural-export configuration to an urban-industrial basis over the last fifty years (Altafin, 2007). The creation of a diversified industrial base and a strong process of urbanization have influenced rural relationships and the labour market, particularly in the Southeast region, the most developed region in the country. It is still unclear what the potential impact of increasing competition for resources might have on family farming. This research aims to analyse and evaluate such changes and the opportunities and threats they pose to family-based dairy farming in Brazil.

At the national level the debate about family-based and industrial farming goes beyond academic discussions and has a clear political element, clearly visible in the dual policies of the government. Since 2000, two different ministries have been responsible for running the country's agricultural programmes: one targets small-scale family farming and land reform (the Ministry of Agrarian Development) and the other is oriented towards large-scale farming (the Ministry of Agriculture, Livestock and Food Supply). Significant changes in policy goals have shifted the focus from long-term support for large-scale farming (supporting export-oriented commodities) to land reform and family farming. The latter's share of government support in agriculture increased from 18% in 1995 to 45% in 2005 (Chaddad and Jank, 2006). The political

representation of family-based agriculture has also increased over the same period with social movements and other organizations that represent family farmers gaining influence in the national political arena.

The distinction between small and large-scale and between family and industrial ways of farming is more blurred and gradual than the distinction made so far suggests. Brazilian rurality is complex (Schneider and Niederle, 2010). The definition of the term "family farming" in Brazil is a matter of much discussion since the government, to operate its credit supply and other policies, has delimited by law what they consider to be "family-based" farms (Brazil, 2006). Although these boundaries have been delimited, the huge diversity within this definition has been subject to criticism. Some argue that a very small part (8%) of those who fall within this category are responsible for the majority (85%) of the production of 'family farming' (Alves & Rocha, 2010). The definition combines many criteria which include a maximum farm size (variable according to each region), the amount and origin of income, labour characteristics (how much hired labour, whether family members work on the farm or not) and family-based farm management. These criteria create a wide conceptual umbrella that covers a heterogeneous group of farmers who fall into a limited number of categories. By ignoring the diversity that exists among and within sub-groups of family farmers, the simplistic dualistic approach reflected in the split between the two ministries might not be the best way to create the conditions for rural development (Navarro, 2010).

Regardless of the limited land, capital and technology available to family farmers, they represent an important part of Brazilian agriculture. They represent the vast majority of farmers (84% by the government definition) as well as 75% of the labour force in rural areas. While large-scale farming predominates in crop production, family farming is responsible for the major part of livestock production - with 67% of goat production, 59% of swine, 50% of poultry meat, and 58% of milk production (Guilhoto et al., 2006). Dairy production is one of the most important activities for family farmers, not only for household consumption but also as a key source of income. Of the 1.35 million farms that produce milk, 0.93 million sell their surplus, mainly to dairy companies (the other 0.42 million only produce for self-consumption) (IBGE, 2006). Family farmers can increase their economic resilience by engaging in dairy activities which has several beneficial characteristics. It is low risk (in terms of response to extreme climatic events), there is a reasonable market throughout the country, the supply chain is shorter than for other crops typically grown on a small-scale (such as fruits and vegetables), the entry cost is low and credit is available. These aspects make dairy farming attractive to small-scale famers and as such this thesis takes dairy farming as the central issue for exploring the future of family farming in Brazil.

The dairy production chain is not only important to small farmers but also has significant national importance. In 2010 total milk production reached 30.7 billion litres/year. The total annual revenue of the dairy sector is similar to the sugarcane industry and is only behind beef, poultry and soybean in the ranking of commodities (IBGE, 2006). Milk production grew by 56% between 2000 and 2010, changing Brazil

from being a traditional milk importer to being a potential exporter of dairy products (such as milk powder, condensed milk and cheese). The Ministry of Agriculture regards dairy production as one of the most promising activities, with a projected growth of 2.8%/year, higher than the predicted population growth (Dossa et al., 2009). A superficial analysis of overall performance (in absolute numbers and growth rates) and optimistic scenarios may induce a false assumption that a steady and sustainable development of family farm dairy production is taking place. However, a closer look at how this growth process has occurred (which will be explored in detail in Chapters 2 and 3 of this thesis) will expose a broad range of fundamental weaknesses in the productive processes and economic threats that may frustrate the outcome of such "development".

Small-scale family-based dairy production can be contrasted with the powerful sugarcane industry, and the two often compete for the same land resources. A huge recent expansion of the ethanol industry has deeply modified land use dynamics in Brazil. This expansion has been fuelled by a range of factors at different levels: internal and external demands for biofuels, increasing oil prices and the availability of international capital. São Paulo state is the biggest producer of sugarcane in Brazil, it has an already high land cover of sugarcane and this has expanded significantly recently by more than 80% in the last ten years. The area used for milk and milk production within São Paulo has declined significantly by 14% and 10% respectively in the same period (IBGE and Milkpoint, 2008). Changing patterns of land use have led to a strong increase in sugarcane area and production and a sharp decline in pasture areas, the number of milking cows and total milk production. This suggests that family farming is being affected by processes of land use change. Chapter 2 analyses the relationships between the two sectors, the main factors that have shaped their very different trajectories and the potential impact upon small family farming.

The differences between the large-scale sugarcane sector and dairy farming in Brazil become even more visible when comparing their technical performance. Sugarcane production in Brazil has one of the most efficient ratios of feedstock to biofuel in the world (de Vries, 2012). By contrast, efficiency in the use of resources in dairy farming is low (Gomes et al., 1995 and 2006) making it less competitive, particularly when located in regions such as São Paulo state with soaring opportunity costs. The average productivity of 1800 kg of milk/ha per year (IBGE, 2010) is far below the attainable yields in different regions either in developed countries or even within the country (Milkpoint, 2010 and FAO, 2010). The low productivity and limited efficiency indicate that these family farmers are poorly equipped to compete with other sectors and may support the argument that they will be weeded out from dairy farming (and perhaps agriculture as a whole). But there is a possibility that technological innovation and intensification of production processes might offer opportunities to these small-scale farmers. Chapter 4 of this thesis investigates whether the use of technology and innovation at farm level could increase revenues sufficiently to counteract pressure from more profitable agricultural activities such as sugarcane.

Although small-scale family dairy farmers in Brazil benefit from good access to markets and credit (Nunes, 2007) it is still not easy for them to introduce new technologies. Farmers interested in investing in dairy farming and seeking information about available technology are offered a package which consists of Holstein cows, sophisticated milking machines, free-stall barns and uses corn silage as the main fodder (Faria and Martins, 2008). This package is unaffordable and unfit for the majority of family farmers. In this sense, there is a clear gap between the practice of introducing technology and family farmers´ reality. Policy makers and other stakeholders have largely ignored the potential that may exist in developing local solutions and making small amendments to the existing systems. This may be a feasible way to increase production and income among this specific target group. Chapter 5 of this thesis analyses how the dynamics of knowledge, embedded in a supportive environment for innovation, can provide the basis for sustainably intensifying family dairy farming systems.

1.2 Problem definition

The huge expansion of international demand for biofuels and the growing area of land in Brazil given over to sugarcane, has given rise to tensions and potential impacts in terms of land use changes and the future of small dairy producers. These are of major concern and this research analyses the viability of dairy farming within the context of competition from sugarcane. How do these family farmers react to this pressure, what are their alternatives for coping with this situation and what role might technological innovation play within this context?

This thesis research follows from the primary motivation of the researcher: to provide small dairy farmers and their families with a sustainable option for managing their land and resources that will increase their incomes and quality of life at a time when there is increased pressure on the resources they use.

1.3 Conceptual framework

Historically, agro-economic development and the transformation of the landscape have been analysed and explained by frameworks based either on political-economic drivers (Malthus, 1992; Pento, 1999; Lal, 2002; Uphoff, 1988 in Robbins (2004)) or from farming systems-based research (Rose & Tapson, 1984; Brouwer and Jansen, 1989; Maxwell, 1986; Slingerland, 2000). Rarely have the two approaches been combined. This research integrates perspectives from the social and the natural sciences, specifically by combining aspects from the Competing Claims on Natural Resources framework (Giller et al. 2008) and the Political Ecology approach (Robbins 2004).

The intense modification in land use observed in Brazil in recent years cannot be explained by a single factor, since it is related to a multi-factorial and complex

combination of forces, led by external and internal drivers operating at different scales. These influences are shown in the multi-scale driving forces model in Figure 1.1 (Giller et al., 2008) which is used in this research to position the various stakeholders and their interests at different scale levels.

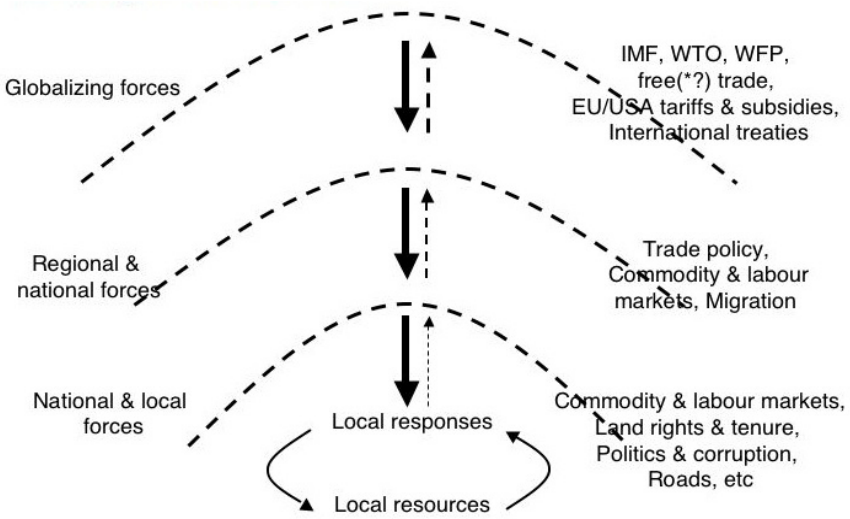

Figure 1.1. The multi-scale driving forces model (Giller et al., 2008).

This figure is used to identify the drivers at each level and how they interact with each other. This provides a framework for identifying the drivers of sugarcane expansion and the main risks and opportunities facing small-scale dairy producers. The size and the shape of the arrows identify the strength of the forces impacting on local players and the relative weakness of local responses or resources when it comes to influencing processes at higher scales. In some cases local decisions taken by a large number of farmers can influence the balance of supply and demand and change the expectations of stakeholders. However the majority of farmers' decisions are responses to policies and actions designed at higher and more powerful levels. The multi-scale figure allows the identification and classification of the important issues at different levels. This helps identify the main problems, the questions to be addressed and strategies that could be designed and negotiated.

The second approach employed is that of political ecology, a deep critique and well-grounded social approach that is used to assess and identify the political circumstances and interrelationships between the drivers of land use changes. Political ecology is a broad field that encompasses different approaches that share an interest in explaining adaptation strategies and dominant accounts of change in addition to exploring alternatives (Robbins, 2004). Political ecology aims to integrate natural and social science by combining detailed information about biophysical processes and economic data with careful examination of the relevant social and political aspects. Through a comprehensive study of the main human-ecological interrelations, I have attempted to

disentangle the interactions between the expansion of industrial sugarcane production and dairy family farming in Brazil.

One of the tenets of the political ecology approach is to avoid the "apolitical" approach adopted by most research, which ignores the influence of political and economic power. The chain of explanation, a key concept in political ecology, is a descriptive tool that helps to explain how forces act within a conflict, by contextualizing the process of change. According to Blaikie and Brookfield (1987), the chain of explanation model can explain how individual farmers and their communities manage, adapt and innovate within a changing political and economic system. There are clear similarities between the concepts of the chain of explanation and the multi-scale framework model of the Competing Claims programme since both scale up focus in order to better identify the underlying causes of problems and, hence, possible solutions.

The political ecology approach assumes that research should focus on at least five tasks. These include: establishing the overall type and direction of changes; identifying the main drivers; determining the environmental context in which changes occur; exploring specific impacts and examining alternative routes (Robbins, 2004). It is also important to recognize and take into account the relationships between political economy and biophysical characteristics at a local level, rather than simply observing the influence of the former upon the latter (Black, 1990). Although the most powerful drivers are usually the same at global level, (e.g. transnational companies, global warming and trade policies) local responses and opportunities to these can show a great variation. Therefore, as well as examining the influence of the main political and economic drivers, the thesis also pays particular attention to assessing local options, especially the role of technology in counteracting the power of these external factors.

The DEED (Describe, Explain, Explore and Design) cycle shown in Figure 1.2 is an analytical tool developed by the Competing Claims programme which has been used to organize the different approaches involved in the scope of this research. Use of the DEED cycle helped to outline the thesis chapters, addressing the questions suggested by the concepts of political ecology over the local changes observed in São Paulo state, the main region of sugarcane production in Brazil. The thesis will describe (D) and explain (E) the historical and political context in which the competition has taken place and the role of the family dairy farm within this. The feasibility of improving the use of technology in family dairy farming and the potential competitiveness of such changes (in relation other land uses and urban jobs) will be explored (E). The thesis uses the Balde Cheio Programme as a case study to explore (E) and discuss knowledge management in the intensification process as well as the re-definition of the role of science in bringing innovations to the farm level. This then leads to a discussion of some scenarios for family dairy farming which correspond to the design phase (D) of the diagram.

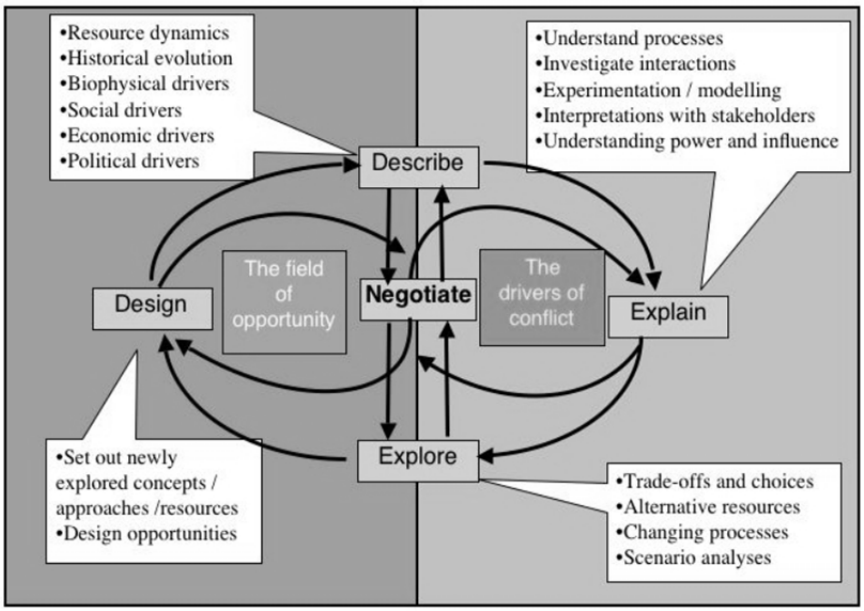

Figure 1.2. The Describe, Explain, Explore and Design (DEED) cycle (Giller et al., 2008)

1.4 Research questions

Based on the rationale of the multi-scale framework and supported by the political ecology approach, the main question addressed in the research is:

What opportunities are available to family dairy farmers in the context of increasing pressure on land by the highly competitive sugarcane business?

The secondary objectives are:

a) To identify the main driving forces and (the more and less) powerful actors who are competing for local resources and increasing the pressure on the land.
b) To understand how dairy producers are being affected and how they react to the pressure caused by the expansion of sugarcane.
c) To assess whether technology innovation could increase the profitability of dairy activities by small-scale farmers.
d) To analyse how dairy research centres could successfully interact with small dairy farmers' reality to identify and support their technological needs.

1.5 Methods

This study applies a varied range of methods and different approaches. Secondary data for land values and the relative prices of sugarcane and beef, satellite images and historical maps were collected from different sources (IBGE, CANASAT, IPEA, IEA). These were analysed from a historical perspective in order to evaluate the main

changes in land use, production technologies, product and land prices and how these all related to changing policies in Brazil. The dataset was particularly useful for evaluating the average values of renting land to sugarcane producers in São Paulo state, the gross margin of an alternative land use (soybean) and the trends in milk production over time. It has also been used to analyse different ways that farmers have responded to sugarcane expansion and the growth of medium-size cities in São Paulo state (in Chapter 3). Data on dairy farming and intensification were obtained from project documents, interim reports, farm data sheets, and through participant observation in events in the period 2008-2011. Semi-structured, open-ended interviews were used to study the complex interactions between dairy activities and sugarcane production. Thirty-four dairy farmers participated in these interviews. They came from eleven municipalities in two different sub-regions in São Paulo state (Franca and São José do Rio Preto; both regions have an active sugarcane business and dairy production). The farmers had a range of different farming systems and production goals. Interviews with other actors complemented the farmers' points of view. These farm level data were used to develop a typology in order to characterize different farmers' responses to sugarcane expansion. A complementary dataset of 324 farmers from a local dairy cooperative was used to make a further comparative analysis.

A significant part of the thesis is based on a case study of the "Balde Cheio" (Full Bucket) Programme, an initiative by the Embrapa South East Livestock Division. This programme was set up to develop production processes and administrative tools adapted to the needs of small dairy farmers and extension service technicians. This programme is a relevant case for several reasons. First, it has long-term experience (since 1999) with technology and innovation in family dairy farming. Second, it is widely distributed across the country and reaches hundreds of dairy family farmers in all regions. Third, it has achieved remarkable results in terms of technical and economic indexes. Fourth, it has gained the confidence of different actors while working with a small budget and a specific vision on technology, innovation and local development.

I have used the Balde Cheio case study to assess the feasibility and competitiveness of dairy intensification. Two different data sets of farmers were studied to evaluate agro-technological options. First, I analysed the existing data of all the farmers in São Paulo state who joined the first phase of the programme (105 farmers dispersed across 21 sub-regions). This data set was complemented by field visits and telephone calls to explore the households' profiles and their starting technological level. A principal components analysis (PCA) was used to explore the relationships among variables and to select variables for further analysis. Secondly, a detailed data set of economic data and technical indexes from 50 farmers, with at least three years of records was studied. Data envelopment analysis was used to compare the farms and the alternative strategies of family dairy farmers (Cooper, 2004).

1.6 Outline of the thesis

In this first chapter I have set out the main themes of the thesis which regard the competitive environment between dairy farming and sugarcane production and give rise to the research questions. The next chapter describes and explains the driving forces that have led land use change in São Paulo state and affected dairy production. This chapter addresses objective A. The third chapter addresses objective B, looking more closely at different dairy farmers' responses to the competition from sugarcane and stressing the key aspects of adaptation strategies and technological choices made at the local scale. Objective C is addressed in the fourth chapter, which studies the feasibility and competitiveness of the technology developed and disseminated within the Balde Cheio Programme. The fifth chapter analyses the nature of the Balde Cheio Programme and discusses the lessons it holds for enabling small-scale dairy farmers to intensify. This addresses objective D. The sixth chapter consists of a discussion and conclusion, providing answers to the research questions and drawing scenarios of the possible futures for family dairy farmers.

Chapter 2

Biofuel, Dairy Production and Beef in Brazil: Competing Claims on Land Use in São Paulo State

Abstract

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.

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2.1 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 will reduce significantly global greenhouse gas emissions. Based on this argument, for example, the European Commission announced in 1997 an ambitious plan to promote biofuels in transports in order to arrive at a 12% penetration of renewable energy in 2010 (European Commission, 1997). Other elements that have favoured recent biofuel expansion have been the rise of oil prices between 2002 and 2008 and the political view emerging in several countries (particularly the USA and within the EU) that they were too dependent upon what they considered unstable, politically unfriendly or unreliable, oil and gas producing nations. Additional arguments, mostly arising within biofuel producing nations, suggest that biofuels reverse the decline of agricultural commodity prices and offer an opportunity for agricultural and rural development.

After an initial widespread belief that biofuels could be a technical solution to a set of contemporary, interlinked environmental, economic, and political problems, counter arguments emerged. Environmentalists have criticized the massive conversion of forest land and other yet non-arable land into biofuel production, targeting, for example, oil palm expansion in Malaysia and Indonesia (Friends of Earth Europe, 2007) and have called into question its overall effect on 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, also 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, for example, decision-making bodies of the EU and the FAO. The FAO (2008) concludes that a part of the rise of food prices is an effect of the expansion of biofuel production and that it depends on the precise conditions whether biofuels will help to reduce or increase greenhouse gas emissions. FAO (2008) puts forward that the increased competition for resources resulting from some biofuel schemes needs further consideration. To date, however, we find few empirical studies of competing claims on land use, even though these seem to be central to the biofuel controversy.

In the controversial debates about biofuel, the case of Brazil performs 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 producing sugarcane and ethanol to flex-fuel[1] cars that run on biofuels, supported by a regulatory system, technical, research and financial arrangements. If there are competing claims on land use as a result of biofuel expansion they 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

[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).

presented in this paper suggest that the expansion of sugarcane area is associated with an almost equivalent reduction in pasture areas and a decrease in number of cows and milk production. The question therefore emerges whether there is a necessary relationship between biofuel expansion and changes in beef and dairy production.

The general question about 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 (e.g. biofuel expansion leading in unmediated form to decrease in milk production), this study examines complex combination of factors, involving external and internal drivers at different scales (Giller et al. 2008).

We integrate the analysis of land use changes in Brazil into an 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 explore 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 an impressive growth. Initially we looked primarily at the relationships between the ethanol industry and the milk activity but had to expand the analysis to the beef production sector in order to make sense of the available data as beef production uses large areas in the whole country and strongly interacts with dairy activity in the Brazilian farming systems. This study discusses drivers that could affect the dynamics of the sugarcane industry over 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 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 between sugarcane, dairy and beef production and possible sources of conflict.

2.2 Historical development of sugarcane in Brazil

In 2008, the total area in sugarcane in Brazilian lands increased with more than 16.5%, up to 8.2 million hectares (IBGE, 2008) of which 7.4 million (85%) are located in

Southeast region. How had sugarcane become so important in the Southeast region? Sugarcane was firstly introduced into the Northeast region in the XVI century, converting the Northeastern Atlantic forest into sugarcane to meet the European demand for sugar (Fischer, 2008). Specific environmental constrains limited the expansion of the planted area in the Northeast region and nowadays its produces only 15% of the total amount of sugarcane. The sugarcane industry found a very interesting niche in São Paulo state, where the following agro-ecological and technical conditions favoured the expansion of the sugarcane: good soils and an adequate climate leading to high productivity, flat or slightly hilly landscapes, a good infrastructure (roads, research centres, supporting industries) and the proximity to the market (the main consumers centres). However, favourable agro-ecological conditions could not explain, by itself, the huge changes in the land use over the last twenty years. Agro-ecological conditions favoured many tropical agricultural activities, but only the sugarcane industry developed at a very aggressive rate in this period. Governmental decisions and investments to the sector were as important as driving factor as the agro-ecological features of the South East region.

2.3 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 would change the landscape of sugar production as it interrupted the ship transport of the sugar produced in the North East 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 lead to an impressive expansion of sugarcane production in the South East region. The emerging "usineiros", big sugar farmers and industry owners in the Centre-South, lobbied for price differentiation between them and the North Eastern producers. Consenting to their claims, the federal government permitted higher quotes 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 United States of America and Cuba, the Brazilian government expected to supply the "new" market. It decided to increase subsidies for investments in sugarcane production leading to a more powerful role for

[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.

the IAA. However, two factors partially frustrated the national expectations to gain 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 Block (Szmrecsánti & Moreira, 1991). The partial failure in realizing 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 differential between internal prices paid to sugar producers and export prices provided the IAA 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) that aimed at improvements on industrial processes. These supported further steady growth of sugar production.

2.4 The "Proálcool" programme: subsidizing the shift to alcohol

When international sugar prices collapsed in the early 1970s an over-production crisis 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 historically high dependency of external fossil fuel but also to "rescue" the sugarcane industry. A national program, called *Proálcool*, was created to improve sugarcane ethanol production in substitution for gasoline by means of increasing subsidies to the industry and investments in research and development to generate newtechnologies (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 between 1980 to 1985, with very low interest rates, were applied 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 interests in expanding their 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 as they are nowadays. The incentives provided by Proálcool turned out to be quite effective as ethanol production raised with more than 50% in five years. Other states with less tradition of sugarcane production, as Paraná, Goiás and Mato Grosso, also started to produce sugarcane after receiving these governmental "stimuli".

2.5 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 into cars engines. The main policies were: the mandatory use of 20% of ethanol in all gasoline sold domestically, the promise by the government to buy the entire ethanol production, the concession of 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 in order to guarantee the domestic supply, and the settlement of quotas for sugar and ethanol production designated for domestic consumption, limiting exports to exceeding production (Borrel et al., 1994). In order to achieve the targets of the new plan, a new market needed to be created. The automotive industry got a decisive role: the production of adapted cars to run exclusively on ethanol. However, the proposed agreement between the government and the automotive industry was not reached for free. The industry's participation was only obtained at the expense of tax cuts and fixing the ethanol price at 65% of the gasoline price, even though the production cost of the gasoline were much lower than the fixed value in the pump. This relation was very attractive to both consumers and ethanol producers. These policy incentives resulted in a jump from 6 billion litre/year ethanol production to 12 billion/year only in four years (Savernini, 2008).

A second element of the post-1980 shift 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 between 1980 and 1985 investments in technology. Some of the most important improvements were the improved selection of sugarcane varieties, the reduction in fuel consumption at harvesting, the reduction of transport cost and residue management (returning the vinasse to the soil). Improvements within the sucrose conversion phase were also obtained on juice extraction, more efficiency on the treatment of juice, and controlled fermentation (Moreira and Goldemberg, 1999). These investments in technology innovation resulted in higher efficiency in terms of relatively lower use of fertilizers and higher productivity (more ton per area, more sugar per ton, Figure 2.1) and also more litres of ethanol per litre of juice which combined had significantly reduced the production costs of ethanol. Despite this successful reduction of costs, ethanol prices were still not able to compete with gasoline and the government kept subsidizing the sector in order to keep the Proálcool "agreement" on track.

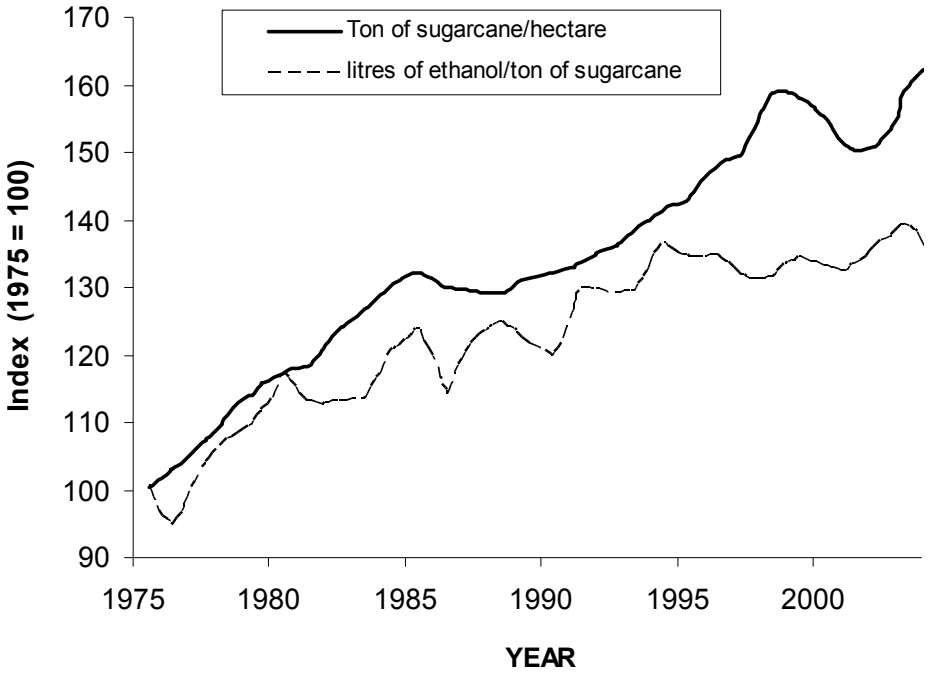

Figure 2.1. Sugarcane and ethanol productivity in Brazil, 1975-2004 (1975=100). Source: Martines-Filho et al. (2006) original data: Centro de Tecnologia Canavieira –CTC.

2.6 Deregulation and neo-liberalization (1986-2008)

Several internal and external factors supporting the Proálcool programme disappeared in the late 1980s. First, the international oil prices collapsed (new reserves were found and Saudi Arabia raised its production). Second, technological development in deep water extraction of oil in Brazil had reduced the national dependency on external petroleum. Third, the international sugar price was extremely high which made it more profitable to sell sugar in the external market and buy oil to produce gasoline rather than to produce ethanol. Fourth, the government elected in 1990, faced a very deep economic crisis and accumulated national debt and decided to reduce many subsidies, including fiscal subsidies to ethanol cars and sugar mills, leading to withdrawal of the automotive industry and mills going bankrupt. These changes immediately raise the ethanol prices and a shift in consumer's choice 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. As soon as their interests were not aligned anymore, the whole system collapsed. The end of governmental subsidies allied with the choice of the sugarcane industry to seek higher profits in the external sugar market, ruined the structures and relationships of the ethanol chain, negatively impacting the consumers that had bought an ethanol car some years before. Even though the technology development and environmental

favourable conditions were present (increasing productivity and efficiency as shown in Figure 2.1) they could not avoid the failure of the system.

A next step in deregulation, the liberalization of ethanol prices in 1996 in a rather more stable economic context, initiated a new restructuring process[3] (Vian and Lima, 2005).

New technological process and management mechanisms were applied, for instance: microelectronic and automation inside the industry, mechanization of harvesting, improving logistics, outsourcing of services and equipments, fusion and acquisitions 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 subsidizing the sector, it preserved the blending rules, defining the anhydrous ethanol mixture into the gasoline between 20-25%, 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 applied to alleviate the crisis. Since 2000 most part of the mills were self-sufficient in energy and started to sell the exceeding energy. During the last years, the energy co-generation from bagasse represents around 2,000 MW and potentially could increase up to 10,000 MW considering the possibility of collecting straw to this purpose. The electricity provided by the sugarcane mills coincides with the dry season, usually critic to 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 in cars engine represents 90% of the total new vehicles), and energy policies would over time lead to an expansion of the internal market and helped the sugar and ethanol industry to resurge even stronger in the beginning of the twenty-first century (Paulillo et al., 2007).

The most recent impetus has come from 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[5] (Jank, 2008). Attractive for international investments, at least US$ 17 billion of foreign capital has been invested in the construction of eighty six new mills (Abramovay, 2008). At least fifty new sugarcane plants will initiate production in the next two years with each mill requiring around five thousand hectares. Nowadays, the Brazilian government is very active in defending the sugarcane based ethanol not only as a commodity for the international market (Gentile, 2008), particularly seeking markets in developed

[3] At least five strategies were applied by the sugarcane industry to deviate the crisis: deep specialization in sugar and ethanol production, product differentiation, productive diversification, mergers and acquisitions, and the formation of commercialization 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 organization. The aim is to control the supply and demand of sugar and ethanol and to stabilize 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).

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

countries, but also as a powerful diplomatic tool for a new model of South-South cooperation, basically transfer the know-how to several African countries (Massarani, 2007).

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 single, recent development but the result of a long and complex trajectory with ups and downs, in which two characteristics have being decisive to the present situation: the governmental support for biofuel production, which varied in nature over time, coupled with the alignment of interests of several economic groups.

2.7 Historical development of dairy production in Brazil

In contrast to sugarcane, there is a lack of long term policies to the dairy sector, historically little to no subsidies and higher vulnerability to market forces (Meirelles, 2004). Possible explanations of the lack of governmental attention to milk production development may have been the traditional feature of a family-based and subsistence activity, orientation to the internal market, and a lower politic representation with consequently less influence compared to the sugarcane industry. Nevertheless, dairy production is growing. In 2008, the Brazilian dairy chain produced around 29 billion litres/year with a total annual revenue similar to the sugarcane industry only behind beef, poultry and soybean chains. The total amount of milk has grown with 48% in the last ten years which changed Brazil from being a traditional milk importer (Jank et al., 1999) to being potentially an exporter of dairy products as milk powder, condensed milk and cheese[6] (Conejero, 2006). This raises the question as to whether this growth is based on an intensive or extensive growth model. We will explain below that the growth of the total milk volume has been mainly achieved by the frontier expansion in traditional beef cattle areas, which slowly have shifted to dairy production (Faria and Martins, 2008) and not by an increased productivity or sustained production on existing dairy farms.

2.8 The milk frontier: the expansionist model of the dairy chain

In the 1940s only 44% of the population lived in cities but as a result of the industrialization during the 1960s, pulling people to the cities, around 80% lived in urban areas in the 1970s. The increasing urban demand for dairy products led the industry to buy raw milk beyond of the traditional regions usually located near to the cities (area A in Figure 2.2). The region of milk collection had never been very small,

[6] If Brazil would become a dairy products exporter it would not mean that all Brazilians get an adequate intake of dairy products. The milk availability per inhabitant, on average only 134 litres/inhabitant/year, is much less than the 210 litres per capita recommended by FAO.

for example located up to 350 km away from São Paulo city. But during the 1970s the average distance to supply the large cities in Brazil was expanded up to 800 km (Meirelles, 1996). Nowadays milk may be produced three thousand kilometres away from the main consumer's concentration.

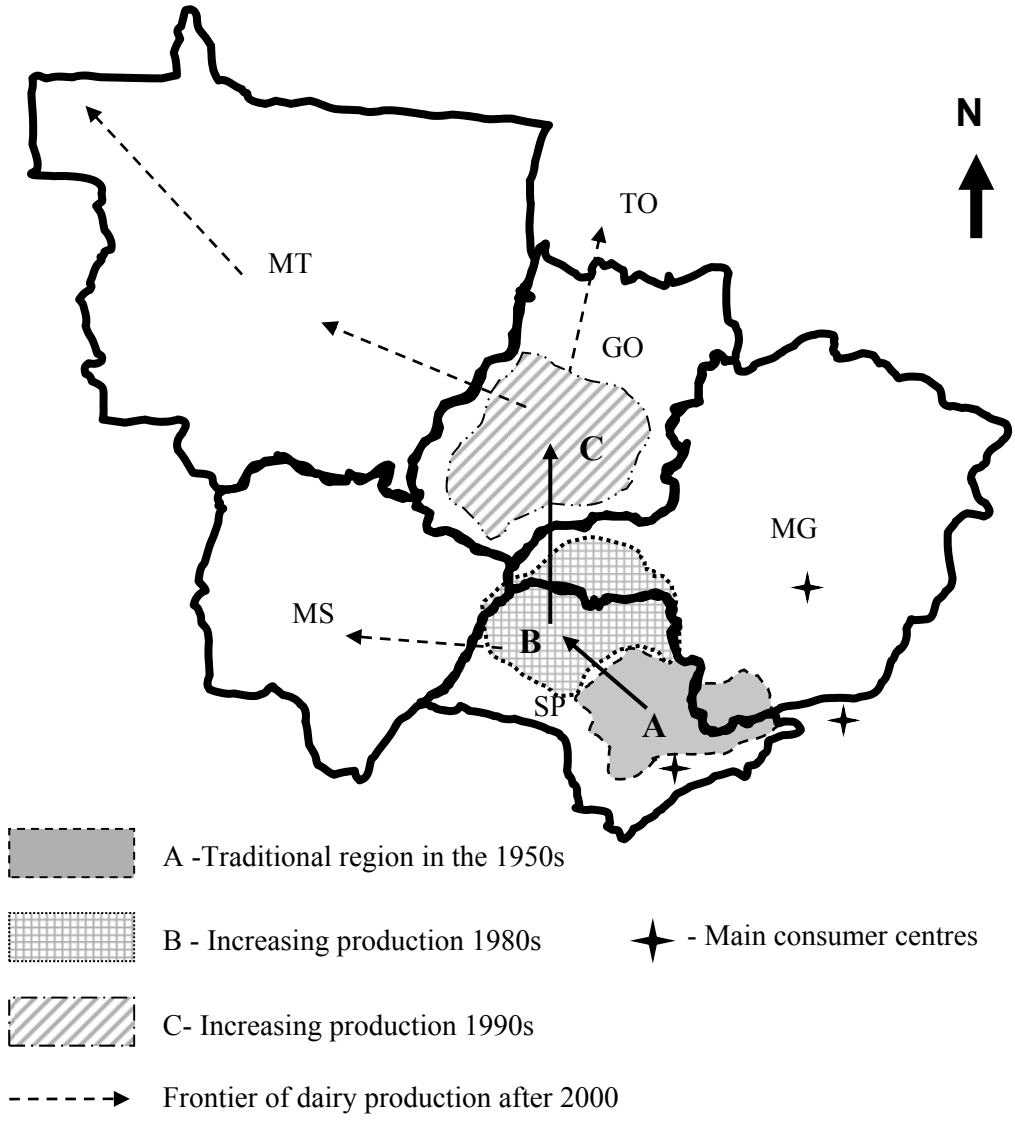

Figure 2.2. Dynamics of dairy production in the Centre-South and West regions of Brazil. Sources: Faria e Martins (2008); IBGE (2008) and Milkpoint (2008).

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 2.2), a traditional beef cattle area, has become the main milk region in the state, responsible for 22.3% 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 reduced to 11% of the total (Nogueira et al., 2006). A similar process occurred in Minas Gerais, where the Cerrados areas in the West (particularly Triângulo Mineiro and Alto Paranaíba) have become the major

region in milk production with 24.5% 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 2.2). Table 2.1 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.

Table 2.1. Sugarcane expansion and milk production, São Paulo state: area, production and number of milking cows (1990-2007) (IBGE, 2009).

Year	Sugarcane		Milk		
	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
	+ 116%	+ 137%	- 11%	-17%	- 30%

* Total beef and dairy cattle pastures.

Milk production in the frontier areas display characteristics of low productivity, beef or mixed cattle based low quality of the raw milk and infrastructural problems as poor roads and lack of electricity, the same situation of the original areas some years before. Despite the extensive character of milk production it still can export dairy products to the main consumers centres in the South-West, due to the very low population density in the frontier areas (Nogueira et al., 2006). Further evidence for the extensive growth of dairy production rather than a growth pattern of intensification can be found in data on the total milking herd in relation to the rate of total milk production (Figure 2.3). The number of milking cows increased from 9.3 million in 1970 to 20.5 million in 2005, or 120% (Yamagushi, 2001 and IBGE, 2008). The total milk production in Brazil increased in a very similar rate of the herd (135%), which is only a very slight increase if we consider the length of the period: thirty five years.

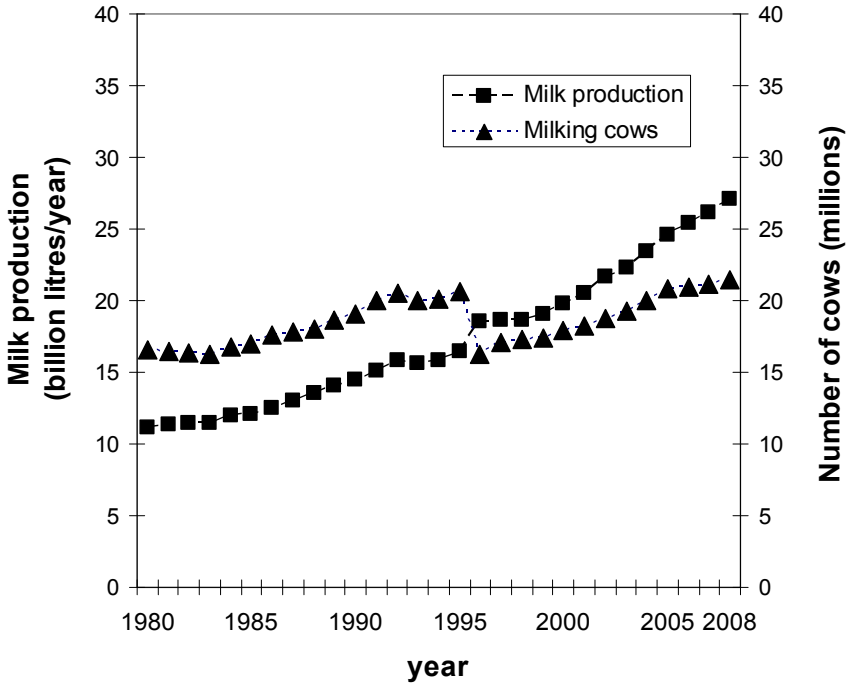

Figure 2.3. Number of milking cows and milk production in Brazil.
Source: EMBRAPA, 2008. Original data, IBGE-PPM.

Note: The drop down in the total number of cows in 1995 was due to changes in the methodology of calculation. By including the data from leather production the total number was adjusted.

The moving of the milk frontier has its roots in the availability of cheap land and enough beef cattle to initiate milk production. Although the distance to the consumer centres is longer, it may be interesting to the industry to collect milk in frontier regions due to lower prices of raw milk. In many frontier regions ranchers use to consider the milk as a by-product of the beef calf, though the opportunity to create a monthly revenue is interesting to farmers who start milking beef or mixed (cross-bred) cows. The introduction of a new activity inside a typical beef farms (large herd, available grasslands areas) perfectly matches with the adaptation process of farmers since the risk involved in the relationship with the industry is almost null. 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, as swine, poultry or even sugarcane, there was no significant reason for dairy industry to invest in vertical integration or development of suppliers if the raw product could be bought cheap and without limitations in non-traditional regions.

2.9 The role of government and the intervention period (1945 to 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, economic flexibility of possible selling at the best moment, low labour demand over large areas, among others (Hecht, 1993). It becomes possible to understand farmer's rationality of capital protection when there is inflation around 1,000% per year as observed in those times (FGV, 2008). In such a period, the low-risk investment strategy to buy 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 (Bernardes and Nogueira Neto, 1997; Jank et al. 1999; Nogueira et al. 2006). During forty five years, the amount of imported milk and the fixation of milk prices was regulated[7]. The formal discourse to regulate imports and prices referred to the "protection" of dairy farmers against the negotiation power of the industry and to improve access to milk (mainly fluid pasteurized) 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 had also 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 to achieving macroeconomic goals. Federal decisions about importing dairy products were often applied in order to tackle inflation in situations of an unbalanced supply-demand (a draught 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 to farmers who applied a specific proposed package (low interest loans with long pay back periods). Typically, the proposed technological package often turned out to be inappropriate (related to its strong focus on breeds, buildings and

[7] At that time, leaders of dairy producer organizations demanded liberalization arguing that existing regulation did not bring any contribution to consumers neither in quality of milk nor in prices and restricted the modernization of the dairy activity (Bernardes & Nogueira Netto, 1997).

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 and, invariably, would drive investing farmers to bankruptcy (Faria, 1996). Periods of high inflation rates also prevented investments in technologies to increase productivity. Farmers could avoid risks by staying away from capital intensive "improvements" whereas milking a few non-specialized cows made sense to provide a low but regular monthly income.

2.10 Deregulation, concentration and new technology in the 1990s

The same wave of liberalization that reduced the governmental subsidies to the sugarcane industry during the 1990s, also affected the dairy sector. After forty five years of price regulation and control of external dairy supplies, suddenly the government withdrew the regulations over all dairy products and broke down all the barriers to importation. Farmers were not prepared to compete under free market conditions as the absence 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 extremely fast (mainly from Argentina, Brazil, 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 reorganization of the dairy sector (Coutinho and Ferraz, 1994 in Novo, 2001). A process of fast concentration of the dairy industry and supermarkets took place mainly by acquisitions and strategic merges (Primo, 1999). The main target was the national, medium scale and family-administrated dairy industries that were bought by transnational groups. The Italian group Parmalat, for example, pushed aggressively the concentration of industry by acquisitions in several regions (it followed the same strategies in different countries; see van der Ploeg, 2008). From 1988 to 1997, more than 50% of the dairy firms disappeared (Jank et al., 1999). The concentration in the dairy industry (getting its 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, by acquisitions and mergers of supermarkets. In fact, the distribution and supermarket networks became much more powerful than the dairy industry sector[10] (Neves, 2006).

[8] During the 1960s and 1970s the introduction of capital intensive technologies from developed regions, as USA and Europe, brought towards the Brazilian farms highly specialized breeds, artificial insemination, confined systems, use of corn silage as the main fodder, milking machines, hay and fodder chopper machinery among others. The most part of the foreign technology was used without adaptation to the local situation.

[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% of fluid milk, condensed milk and cream are commercialized in supermarkets. In São Paulo state the retail sector is even more important, reaching 85% of these products sales.

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 sterilization process combined with a specific packing process). UHT milk has largely replaced pasteurized 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 three-months shelf-life commodity allows the collection of milk from distant locations, and the possibility to transport the product from the frontier to the main consumer's 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 to supermarkets. As a consequence, UHT market-share of fluid milk jumped from 14% in 1993 to 61% in only five years. Nowadays, 75% of the total fluid milk is processed by this technology (ABLV, 2009). Consumers considered the Longa Vida more convenient because of its lower price than the pasteurized milk (partly due to promotions in the supermarket) and no need of refrigeration at home. The extremely short shelf-life of the pasteurized milk[11] obliged consumers to spend time on buying milk almost daily. There are at least two important outcomes of this dramatic change to the dairy sector: firstly, the UHT technology acted as a positive force to the frontier march of milk production and, secondly, there was a clear transfer of profit margin from the productive sector to the industry and mainly to the supermarket over the last 10 years (Carvalho and Oliveira, 2006).

2.11 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 the alternatives to increase the competitiveness of dairy chain. Relevant issues as food security and the insertion in the international market motivated the creation of a new regulatory standard (Fonseca and Santos, 2000). 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 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

[11] Shelf-life of pasteurized 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.

with rural electricity supply needed for refrigeration equipment, inefficient road system, high costs of the refrigeration equipment and lack of knowledge and training to the farmers (Fonseca and Santos, 2000).

2.12 Low competitiveness as a pulling 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 cow productivity was around 1,000 litres/cow/year in Minas Gerais state, which configured not a dairy but a beef cow productivity. 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 United States of America in 1870 (Faria and Martins, 2008). Many of the milk production systems in Brazil are low risk and low capital and labour demanding. The low resource efficiency of dairy systems is a result of a traditional herd structure in which cows constitute on average only 35% of the total herd (Gomes, 2006) and lactating cows represent only 23.7%. '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 forty years ago, which had 23.6% of lactating cows (Costa, 1971). The unbalanced herd composition coupled with a very low animal density of around 1.2 head/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. Another problem that restricts efficiency is the average dismisses of at least 14% of all milk produced (Faria and Martins, 2008). Moreover, the practice of feeding calves with milk up to the weaning date (around 8-9 months) reduces significantly the amount of milk sold to the industry. We have observed that many farmers consider calves more important than the total amount of sold milk, a typical rationality 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 (Fellet and Galan, 2000 and Alves et al., 1999). 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 the offers from sugarcane producers to buy or rent land. The sugarcane industry offers at least 60% more as the mentioned income, as a net income for a six-year rental contract. When the opportunity cost is considered, land and capital applied on milk production, the traditional average income turns negative.

2.13 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 groups interests, is followed here with an analysis of the impacts of the recent expansion of the sugarcane on land prices, labour markets and milk production in order to shed light on the competing claims between different sectors. It is inevitable that we also analyse the linkages between these two systems with a third chain, beef cattle production.

2.14 Sugarcane and the land market in São Paulo state

The expansion of the sugarcane has brought large economic modifications on the land and labour market within the São Paulo state and also new relations between sugarcane mills and farmers (sugarcane producers). The expansion took place mainly in North, North-West and West regions of the SP state and also expanded beyond SP state borders; mainly Minas Gerais and Paraná states (Figure 2.4). The "new reality" of a dynamic sugarcane/ethanol sector has been pressing small dairy farmers to find alternative paths to provide a livelihood to their families by renting or selling land to the efficient sugarcane industry. The ethanol industry offers high prices for land and renting land is associated with the absence of risk, compared to other local land use options. The prior 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 of monthly payments for land lease.

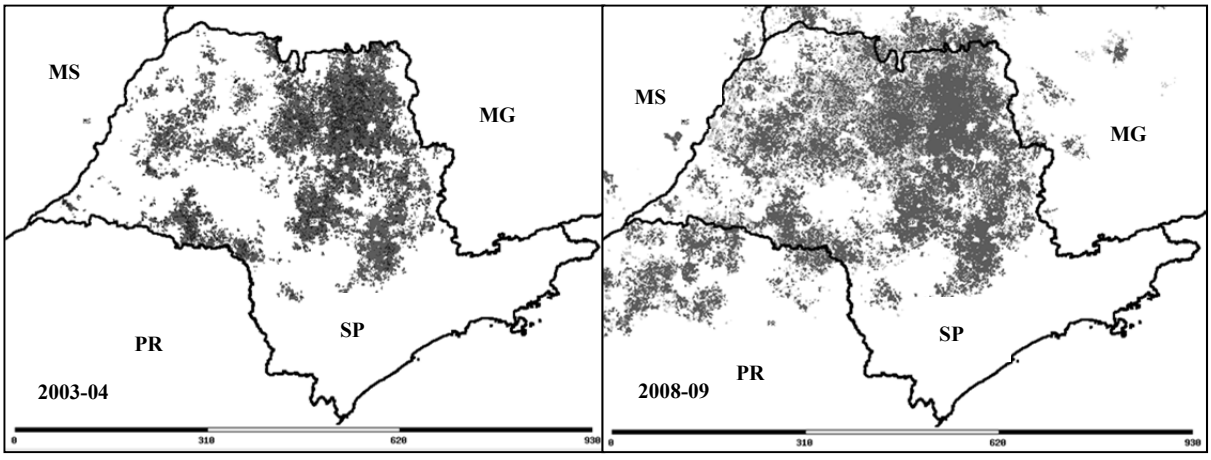

Figure 2.4. Sugar cane expansion in São Paulo state between 2003-4 and 2008-9. The grey shading indicates the spatial distribution of the sugarcane.
Source: images INPE/CANASAT, 2008.

To understand sugar mill and farmer relationships it is relevant to distinguish two categories of farmers: 'active producers' those who produce directly the sugarcane and sell their production to the mills — and 'passive landowners', who only rent their land to the mill (who thus cultivates itself a large portion of the sugarcane) or to other active farmers (Terci at al., 2007). In 1995 YEAR active producers represented only 40% of the seven thousands members associated to the SP sugarcane farmers organization "ORPLANA". The passive landowners comprised the other 60%.

Higher rents tend to increase participation in the leasing model to the sugarcane industry, particularly by small farms in a traditional sugarcane region. In 1995, 80% of renting farmers had farm sizes less than 50 hectares and most of them had already relationships with the sugar industry before the leasing option (Peres, 2003). Rents in São Paulo state have being consistently rising over the last thirteen years[12]. It suggest an increasing competition for land where sugarcane is present, reflected in rising rents offered by the sugarcane industry in six years 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 SP state (see Figure 2.5). In regions with sugarcane land prices more than four folded during the last nine years. It is highly probable that this increase is associated with sugarcane since it was the only rural activity that systematically has grown in almost all regions of SP state.

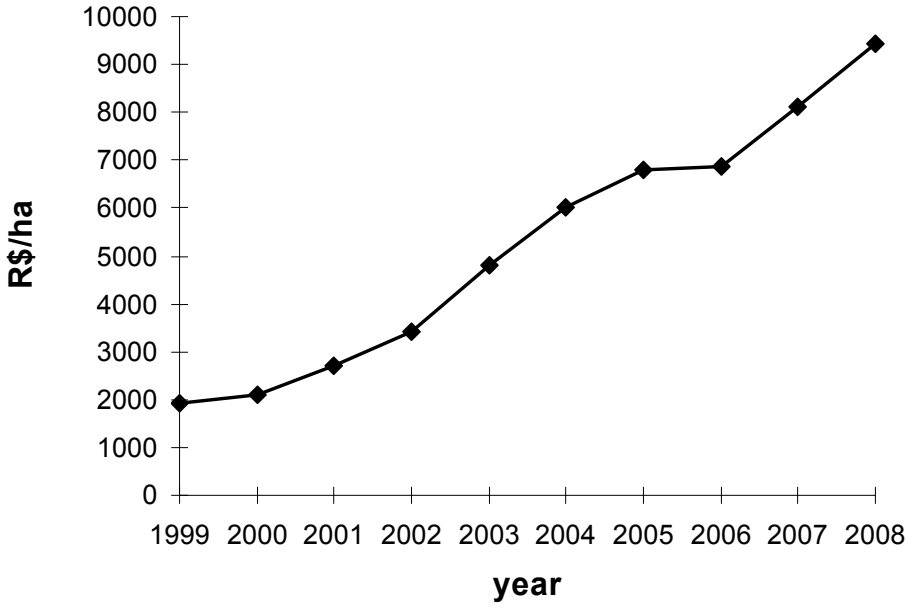

Figure 2.5. Average value of pasture land in São Paulo state, 1999-2008, deflated prices (IGP-DI), in R$/ha, mean of 38 regions.
Source: IEA (2008).

[12] Considering sixteen different sub-regions (264 municipalities) that represent the location of the new areas and also the more traditional areas in Centre, North and West of the state. In 1995, the industry used to pay an average of R$175/ha/year. In 2008, the value has increased up to R$502/ha/year (nominal values).

Table 2.2 (adapted from Nassar, 2008) shows that pasture land was the preferred terrain to expand for the sugarcane sector. From 2002-2006 approximately 90% of the new sugarcane area took place over pastures intended to milk and beef production. The same pattern happened also in other regions.

Table 2.2. Sugarcane area and land use substitution (2002-2006) in different states in Brazil.

	Planted area (1,000 ha)			**Substitution 2006-2002** (1,000 ha)			
States	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	153	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 ICONE (2008)
The column denominated "crops" also includes 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 stabilization after 1994 reduced land prices due to the partial loss of the “value reserve” that land used to have in periods of high inflation. After 2000, high prices of some main commodities like beef, citrus, soybean and maize may have pushed land prices upwards (Camargo, 2007). Our research methods does not allow for assessing the relative importance of these different processes, but there seems to be enough 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 renting out their land (or part of their land) not only based on economic calculations of costs and benefits. Comparing rents (from R$350 to R$700/hectare in 2008) to incomes obtained with the traditional low productivity milk production (R$300/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 of farmers to stop farming and decided to rent their land and the most common answer, 62% of the sample, was related to the life-cycle 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 turns their decision to quit dairy production almost irreversible so the option to take up again farming 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 big company that attracts farmers to the business. This is a contrast with the unstable economic relationship in dairy characterized by the spot market, with no contractual obligations between farmers and the dairy industries. Furthermore, renting out land provides the possibility of remaining integrated to the sugarcane farmers association ORPLANA, which provides not only voting rights, but also access to credit and right to use a good quality health service provided by the association.

2.15 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 SP state used to pay better salaries (around 30% more) when compared to other sugarcane regions (Moraes, 2007). In this period there was a clear reduction (-23%) of total workers in the sector, despite an increase of sugarcane production with more than 54%, due to the mechanization of the harvesting process. The substitution of the traditional manual process, which requires burning leaves, is a result of, firstly, regional laws aiming to reduce environmental problems and, secondly, the increasing demand for biomass for power generation within the industry. Finally, machines were introduced to reduce the dependency of manual labour, particularly in regions where the labour unions were strong and more organized (Ricci et al., 1994). Sugarcane producers in SP state paid wages around R$710/month (in 2005 values) whereas the average agricultural wage in all regions of SP for the same year was R$501/month (IEA, 2008). Other sources mention that sugarcane workers receive 80% more than those holding other agricultural jobs (Macedo, 2005 in Smeets, 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 wage paid in other agricultural work do not include non-wage benefits, as housing, transport or goods (milk, electricity, vegetables, etc.) offered by employers when workers live in the farm. The latter does not happen in the case of the sugarcane harvesters, usually migrants, who used to live in outskirts of the cities and have no complementary wage[13]. Secondly, available data do not take fully into account the high variability on the type of job considered in calculating the average wage.

[13] The seasonal feature 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% of the total employees of the sugar and ethanol sectors in the whole country in 2005 (Moraes, 2007).

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 machines operators) (Smeets, 2006). The former received almost the same as the minimum national wage, while the latter category earns much higher wages. The competition with dairy activity could be placed in this group of permanent jobs since it requires a more trained labour than the sugarcane harvesting process.

2.16 Sugarcane expansion and the beef-dairy production interaction

The analysis of the substitution of pasture for sugarcane production (Table 2.2) and the decrease in milk production (Table 2.1) in São Paulo state requires an additional examination of aspects of the internal dynamics of the bovine sector. Figure 2.6 shows the evolution of different types of bovine herds. The cattle category denominated "mix" represents the cross-bred herd, with variable levels of dairy and beef breeds in its composition. The changes in the institutional and technological environment as explained above, particularly affected specialized dairy cattle herds and systematically reduced their number during the last seventeen years. Reduced profits of specialized dairy farmers hit both traditional farms as well as more capital intensive systems in São Paulo state. Several auctions of very high productive herds, mainly Holstein pure bred cows from free-stalls systems were conducted due to the ending of big farms. The main destiny of the dairy cows sold in these auctions was the Goiás state (area C of Figure 2.2), within the Cerrados biome, the milk frontier in that period (Table 2.3). Therefore, the crisis of the specialized dairy farms from SP was at national level offset by the frontier expansion and the total national production kept growing at high rates due to the relocation of the milk production.

Table 2.3. Milk production by state and increasing rate, 1990-2007 (IBGE and Milkpoint, 2008).

State	1990*	2007*	Difference*	%
Rondônia	158	708	550	348
Mato Grosso do Sul	399	490	99	25
Mato Grosso	214	644	382	179
Goiás	1,072	2,639	1,576	148
Minas Gerais	4,291	7,275	2,617	61
Tocantins	106	214	114	108
São Paulo	1961	1,627	- 217	-11
Total	*8,043*	*13,597*	*5,554*	*69*

* million litres/year.

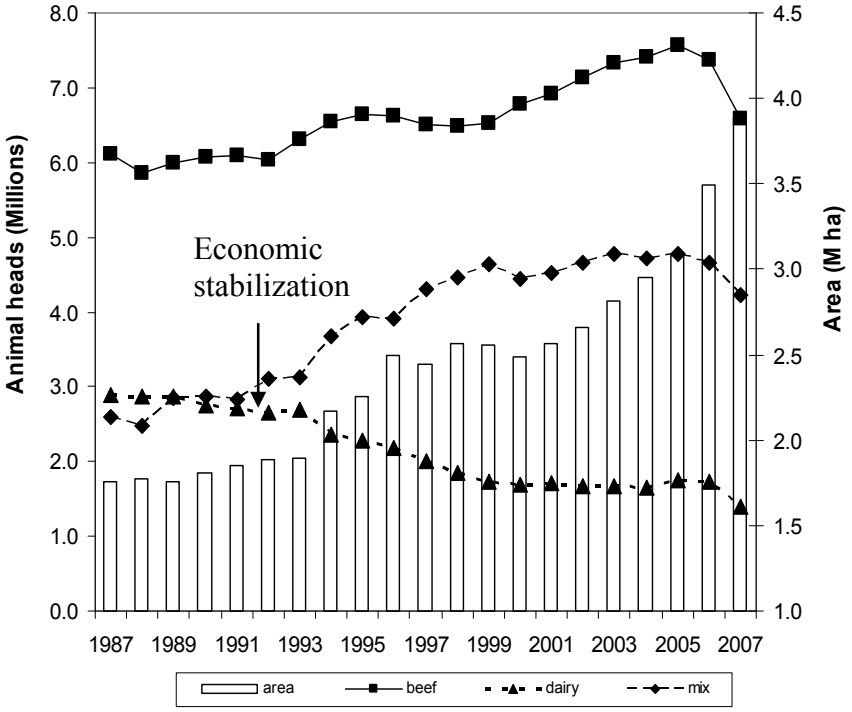

Figure 2.6. Cattle herd (beef, mixed and dairy cattle) and sugarcane area, São Paulo state, 1987-2007. Source: IEA (2008) and IBGE (2008).

The decrease in specialized dairy farming was not only linked to sugarcane expansion but also linked to the replacement of dairy herds by mixed and pure beef herds. Figure 2.6 shows the increase in number of mixed herds that took place from 1990 up to 2006 representing the gradual introduction of milk activity in beef farms, thus avoiding a large drop down in milk production in SP state after the decrease of specialized dairy herds (from 2.9 million single purpose dairy cows in 1987 to around 1.5 million, almost 50%, while milk production only reduced with 17%). Another factor that could have contributed for the systematic decreasing number of specialized cows was the decline of the "Type B" pasteurized milk after the UHT event. This specific type of fluid milk (quality controlled and produced in better hygienic conditions), aimed at wealthier consumers and it was not included in the national food basket, which meant free market prices. The profit margin of this sort of urban elite product was high enough to sustain high costs of production and the Holstein cows-confined systems widespread in SP state.

Against one of our initial hypotheses, the expansion of the sugarcane into pastures did not reduce beef cattle, at least not up to 2005. On the contrary, there was a gradual increase from 1992 to 2005 when the total number of beef cattle reached 7.5 million heads. One possible explanation relies on the intensification of the beef production system. The use of technology, by means of 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 more heads per hectare. The motivation for this technology introduction could be the high prices for beef cattle observed in that period as show in Figure 2.7. In

contrast to specialized dairy production, the intensification of the beef activity was economically feasible with beef prices around R$80.00 and 90.00 per "arroba"[14] between 2000 and 2004, even in the competing environment created by the sugar and ethanol industry.

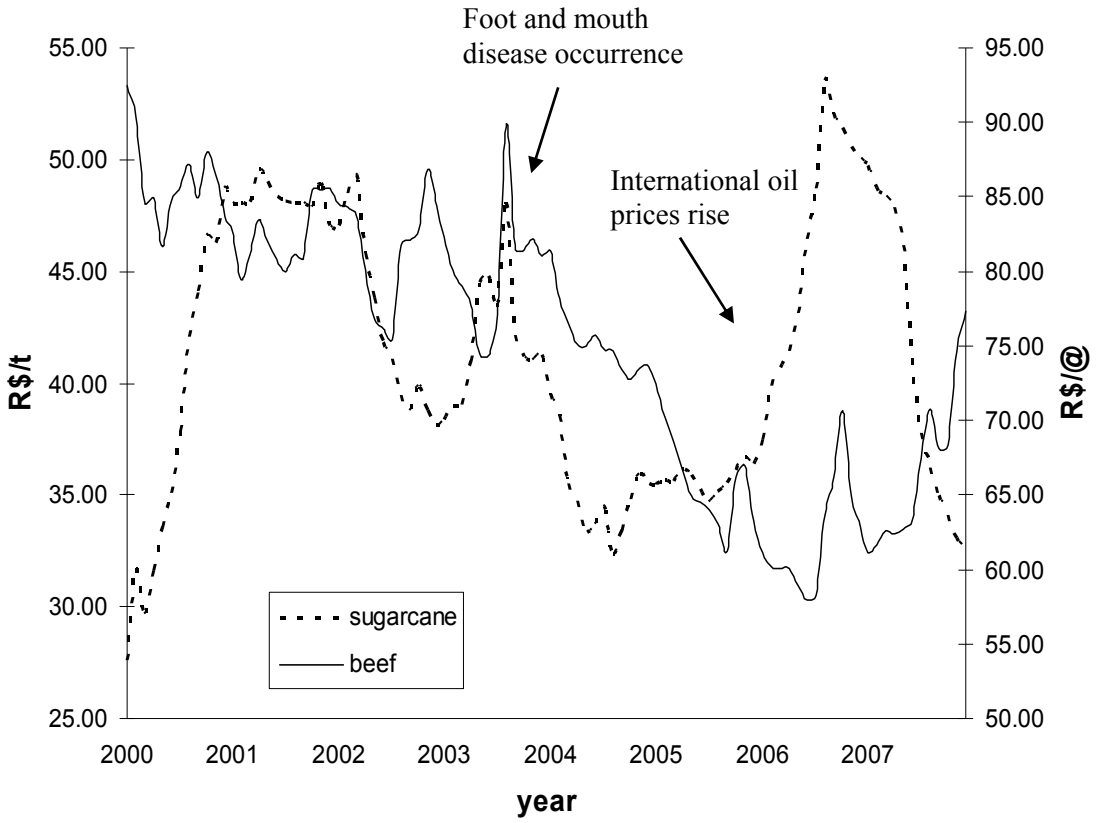

Figure 2.7. Sugarcane and beef prices (deflated values by IGP-DI, R$/ton and R$/arroba). Note: arroba (or @) = 30 kg of live weight; R is Reais. Source: IEA (2008) and IBGE (2008)

The remarkable drop in beef prices after 2004 was highly influenced by foot-and-mouth disease[15] 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 a deep crisis entered the entire national beef chain. Prices reduced up to R$60/arroba. At the same time, sugarcane prices were going up since its price, being a biofuel raw material, was linked to the international oil prices which then reached historical high values (up to US$120/barrel).

The match between these two factors, a deep crisis in the beef chain allied to the exploding demand for the biofuel, had created a perfect context for encouraging farmers to decide to shift from beef and dairy into sugarcane. This analysis shows that

[14] "Arroba" is the common measure for beef cattle prices in Brazil that is equivalent to 15 kg of beef carcass. At farm level, however, it means 30 kg of live weight, which is related to the dressing percentage (in average 50% for Brazilian traditional beef cattle breeds).

[15] A highly contagious viral disease (*Aphtae epizooticae*), typical from cloven-hoofed mammals. The last cases in Brazil brought losses around US$2.0 billion to the whole meat chain in 2004.

land use changes like the ones in SP state are driven by multiple forces at different levels. The observed expanding area of sugarcane and the biofuels boom may be understood as the outcome of a complex interaction between national and international economic factors, e.g. the strengths and weakness among competing agricultural chains, technical and ecological factors, e.g. changing technologies in the transport of dairy products and in biofuel production, and social and political configurations, e.g. the long term governmental support, which have played a major role over the biofuel boom in Brazil.

2.17 Conclusions

This paper addressed the issue whether the decrease in dairy farming and pastures in São Paulo state has been a direct result of the recent expansion of sugarcane production resulting from 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 an 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 strongly mediated by high levels of long term government support for the biofuel chain and lack of support for small-scale dairy farming. While historically the biofuel sector has been supported with a range of government policies (regarding supporting R&D, tax benefits, import controls, regulations regarding blending of ethanol with gasoline) government policies for the dairy sector were much less developmental but basically served other interests (inflation control).

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 look into the internal dynamics of dairy production and its technological configuration which shifted the milk frontier to new areas and supported the expansion of mix 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 specialized dairy farming and to sell or rent out their land to the sugarcane sector. Increased land prices and the high rents offered by the sugarcane/ethanol industry pulled farmers into this new situation.

The recent global demand for biofuel is for the Brazilian case, the major biofuel producer in the world, just one extra impetus (the high oil prices in the 2000s have probably been more important global market factor). The dynamics of the recent growth in biofuel production in Brazil should not be explained by referring only to the

global discussion about biofuel but by understanding the historical development of the specific social-technical configuration around sugarcane/ethanol production and use in Brazil, and in São Paulo state in particular.

Chapter 3

The Sugarcane-biofuel Expansion and Dairy Farmers' Responses in Brazil

Abstract

The expansion of sugarcane cultivation for biofuels is a highly contentious issue. The growth of sugarcane has occurred alongside a reduction of dairy production in São Paulo state, the main region for producing sugar and ethanol in Brazil. This paper analyses different dairy farm rationales for continuing dairy production in the context of a dramatically expanding sugarcane economy. Combining different data sets – semi-structured interviews with 34 farmers and baseline data from all members of a dairy farm co-operative – enabled us to identify different farm types. This heuristic tool is used to distinguish different strategies underpinning the decision to shift to biofuel production or to continue investing in dairy farming. The paper singles out labour availability, household resilience and the introduction of technology as the key factors within a context of complex, multiple interactions between the biofuel sector and dairy production. We will argue that sugarcane expansion does not always push dairy farming aside. Those farmers who shift to sugarcane are not simply motivated by price but mainly change as result of labour constraints, risk perceptions and the opportunities offered by diversification. For farmers who totally abandon dairy production the shift to sugarcane may pass the point of no return.

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3.1 Introduction

Embedded in a scenario of a world-wide growing energy demand and concern about global climate change requiring fuels from carbon-neutral sources (Thompson, 2008), sugarcane cultivation for biofuel production has become a new land use function. A lively 'biofuel debate' which crosscuts a number of different areas including energy security, agricultural policy, environmental protection, transportation, bioengineering, and rural development has ensued (Borras et al. 2010; Mol, 2007; Leopold, 2009). This study examines how dairy farmers in Brazil have been reacting to the expansion of sugarcane production in their region. Brazil is the world's largest sugarcane-based ethanol producer with an impressive area of 8.7 million hectares[16] (IBGE, 2009). At least three different positions on sugarcane expansion in Brazil can be distinguished. The first group enthusiastically supports sugarcane ethanol by pointing to the huge availability of underutilized land (thereby not competing with food production nor promoting deforestation), the creation of jobs, the provision of cleaner energy and the growing wealth of people. For this group the shift to sugarcane is a perfect win-win solution (Martines-Filho et al. 2006; Goes et al. 2008; Durães, 2008; Goldemberg and Guardabassi, 2009). A second group, less enthusiastic, points out some important constraints on the sustainable production of biofuel but argues that these could be removed by the introduction of best practices, technologies and new production processes (Smeets et al. 2006; Fischer et al. 2008; Wilkinson and Herrera, 2010). A third group opposes biofuel expansion (Gonçalves, 2005; OXFAM 2008; Fernandes et al. 2010), arguing that the capitalist expansion of the sugarcane area destroys peasants' territories, increases agrarian conflicts as a result of land concentration and is detrimental to the cause of social movements. It is self-evident that very different economic and political perspectives will result in controversy about the potential impact of biofuels. However, we argue in this article that the controversy also persists because of limited insights into how sugarcane expansion interacts in multiple, complex and uneven ways with other activities on the land.

In this paper we focus on the dairy sector in São Paulo state, the centre of Brazil's sugarcane production. Sugarcane expansion has preferentially replaced pastures in the Southeast region during the past few decades. Beef and particularly dairy production are probably the most affected activities (Durães, 2008; Nassar, 2008; Novo et al. 2010; Rudorff et al. 2010). At the national level, milk production increased by 68% between 1995 and 2008 whereas in São Paulo state[17] milk production decreased by 11% (IBGE, 2008 in Milkpoint, 2008). In comparison with the highly efficient sugar and ethanol chain, dairy production is a family-based activity and demonstrates a lack of competitiveness when compared to other relevant rural activities (Campos and

[16] About half of the total sugarcane production is processed into sugar and half into anhydrous ethanol (used for blending with gasoline) and hydrated ethanol (for direct use in flex fuel cars). Ethanol production reached 27 billion litres in 2010 (UNICA, 2011).

[17] São Paulo state, the main sugarcane region in Brazil, produced more than 80% of the ethanol production on 5.3 million hectare in 2010/2011 (UNICA, 2011).

Neves, 2007). Despite the growing literature on sugarcane and biofuels it still remains unclear how the expansion of land for biofuels affects people at the farm level.

Previous studies have revealed competing claims on land at the regional level between the sugarcane and the dairy sector (Novo et al. 2010). Historically, government policies have supported the biofuel sector more than the dairy sector. In the context of a strong and dynamic sugarcane economy and a weak and less dynamic dairy chain, many dairy farmers consider quitting and leasing their land to the sugar industry. Long-term contracts and a monthly rental payment make it an attractive option for farmers. A decision to lease the land is usually followed by selling the herd and equipment and dismantling the infrastructure, thereby ruling out a return to dairy farming in the future. This study focuses more on the dynamics at the farm level and examines how farmers perceive the prospects of dairy farming in the context of expanding sugarcane production and how they decide between shifting to sugarcane or continuing with, and possibly investing in, dairy farming. Compared to Novo et al. (2010) here we provide more empirical detail about the potential benefits and threats of these choices and assess them in relation to farmers' distinctive operational logics. As we will show, different types of farmers have employ different rationales and strategies for adapting to the new constraints and opportunities presented by the emergence of a strong sugarcane business that has altered local demand for land and labour.

3.2 Methods

This study examines different dairy farmers in two regions of São Paulo state (Figure 3.1). The two areas selected as research sites both had active sugarcane enterprises and dairy production. In region 1, Franca, sugarcane was cultivated on 489 thousand hectares in 2009 (around 47% of the agricultural land). Franca is considered to be a traditional sugarcane region as at least four sugarcane mills were set up near Franca as early as the 1980s. In the past, coffee was an important crop due to favourable agro-ecological characteristics such as fertile soils and high altitude. Beef and dairy production predominated on the less fertile soils. After 1975, bolstered by the support of the "Proalcool" governmental programme, the region became one of the most important regions for sugar and ethanol production of the state (SEAP, 2007). Region 2, around São José do Rio Preto, represents the new frontier of sugarcane expansion (Table 3.1). The relatively flat landscape favours mechanical harvesting, the sandy soils make high levels of productivity possible and there is a vast area of land available for pasture. As agro-ecological conditions are less favourable for coffee cultivation, other agricultural products, such as maize (1970s), citrus (1980s), beef and more recently, dairy, rubber and sugarcane have expanded in this region (IBGE, 2008).

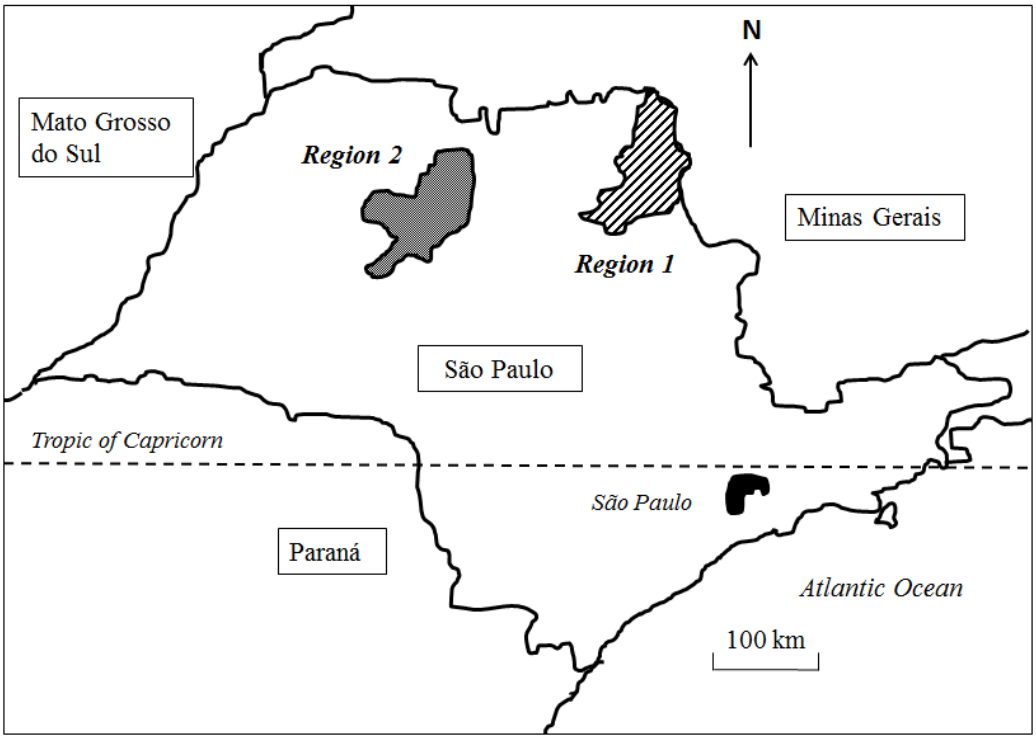

Figure 3.1. Location of fieldwork sites, São Paulo state, Brazil, 2009.

At the end of the 1990s, when beef production became less competitive in the region, mixed herds (dairy and beef) were introduced and São José do Rio Preto became the major milk producing region in São Paulo state. In both regions dairy and sugarcane clearly compete for land (Novo et al. 2010).

*Table 3.1. Shifts in sugarcane area in Franca and São José do Rio Preto, in thousand hectares, by administrative region (2003/4 to 2008/9)**

Administrative region	2003/4	2004/5	2005/6	2006/7	2007/8	2008/9	% increase 2003-2008
Franca	355.0	376.3	390.5	417.1	449.4	489.1	38
S.J. do Rio Preto	280.7	303.7	331.9	396.9	502.6	632.0	125
São Paulo state	3,002.7	3,165.4	3,364.7	3,661.2	4,249.9	4,873.9	62

(adapted from UNICA, 2011).
* An agronomic year consists of the last six months of one year and the first six months of the next.

Below we argue that the two main cities in each research site have played an important role in shaping the rural hinterland. Over time the more outlying cities of São Paulo state have increased their relative share of the gross domestic product of the state and increased their demand for labour. While the growth of the metropolis stabilized in the 1980s, there has been a large flow of population to the medium sized cities (Cunha, 2003). Franca, the main city of region 1, experienced high rates of

population growth attracted by a dynamic industrial sector (around 500 industries including shoes and food industry, coffee, sugarcane, beef and dairy processing) and the expansion of commerce and services. A similar process of urbanization and industrialization has taken place in São José do Rio Preto (region 2). This city of currently 420 thousand inhabitants also demonstrates a growing economy, based on agro industries, furniture industries and health and educational centres.

We interviewed thirty-four dairy farmers, with different farming systems and production goals, in eleven municipalities. The semi-structured, open-ended interviews focused on the complex interactions between dairy activity and sugarcane. Access to farmers' profiles (including information on farm size, family members, employees and average production levels) and the precise location of each farm was provided by local technicians of the governmental rural service (region 2) or by the technical staff of the Cooperativa Nacional Agroindustrial (COONAI)[18] in region 1. Most interviews started with a joint study of the farm's accounts, the collection of data on the history of the farm and the charting of shifts in household composition over time. It included topics such as changes in land use, changes in farming activities, and the reasoning behind decisions to invest or disinvest. Interviews with other actors complemented the farmers' points of view. The wide range of farm types interviewed (small and big farmers, professionals or settlers, peasants or absentees, amongst others) helped to identify the main factors shaping dairy farmers´ decisions over time.

Complementary data was collected on the nature of dairy activity in each region. In region 1, a database of COONAI provides data on a set of milk producers in several municipalities where the cooperative collects raw milk. A resume of several indicators from this dataset supports the impression of a wide heterogeneity of farm types (Table 3.2). The high standard deviation and extremes indicate a wide heterogeneity of situations between cooperative members. First, there is a substantial variation in farm size, ranging from peasants to large landowners. Second, almost one quarter of cooperative members has other income generating activities in the city and farming (particularly dairy) is not their main job. Third, there are large differences in educational level and, fourthly, one third of the farmers are retired.

Many researchers develop a farm typology not as a strict classification scheme but as a tool to examine how different socio-economic circumstances affect farmers' management attitudes and behaviour (Emtage, 2006; Howden and Vanclay 2000; van der Ploeg et al. 2009; Toleubayev et al. 2010). Whatmore et al. (1987) and later Landais (1998) argue that typologies are potentially a useful methodological tool as they link theory and practice but they should not be used as ends in themselves. Our farm typology does not aim to be absolute or comprehensive in any way but is used as a means of reflecting on recurrent farmers' behaviour and perceptions. In interviews

[18]Local dairy farmers founded COONAI in 1941 in order to organize the collection and sale of raw milk. For several decades, the company was associated with a central cooperative and pasteurized milk was the main product. Strategic errors of judgment on investments and expansion plans in the 1990s, led COONAI to sell the plant, the industrial equipment and others assets. Nowadays the cooperative collects only 10% of the average amount of milk collected twenty years ago.

we tested to what extent farmers self-identified with the various types depicted or recognized other farmers in them (Burton and Wilson, 2006; Vanclay et al. 2006).

Table 3.2. Average production, farm area, main occupation and educational level of farmers in the COONAI dataset.

Production/farm (litre/day)	from 5 to 1,350	Average: 158 SD= 186.8
Total area (hectare)	from 1.6 to 1,305	Average: 88,7 SD= 145.1
Landowners' main occupation	74.4% were farmers 24.6% other activity *	31.6 % of farmers are retired
Educational level	29.6% university level 14.0% high school 9.3% fundamental 46.8 % basic/no education	2/3 of those who had university level are absentee

SD=standard deviation, N= 438.
* 18% works in services (lawyers, doctors, and dentists), 6.7% in commerce and 0.8% in the industry.
Source: COONAI, unpublished data.

3.3 Farm types

In this study we identified five farm types among dairy farmers in São Paulo. A short initial characterization of these types will be helpful for our subsequent discussion of the differential responses to sugarcane expansion.

3.3.1 Farm type 1: Retired farmer

Farmers classified as retired receive a monthly off-farm revenue, mostly in the form of a government social security wage[19] and/or from leasing part of their land to the sugarcane industry or farmers of other crops. They continue farming even though working a smaller area of land than before. In general, their stable and secure monthly income has reduced the necessity to raise high revenues from farming. Therefore, farming profits have less importance than before retirement (albeit desirable to complement the income)[20]. Other factors that influence the rationale of this farm type

[19] At the age of sixty, farmers receive a state retirement pension equal to the minimum wage of around R$500/month (about US$290). People with health problems may retire at a younger age. The retirement pension of other family members may complement the family income.
[20] According to Delgado (1999), the regularity, security and monetary liquidity of social service payments not only influence family strategies and adaptive behaviour in rural areas but also in small cities.

are the age of the farmer (advanced life cycle) and the absence of sons/daughters to help with daily farm tasks.

3.3.2 Farm type 2: Family farmer

In contrast to type 1, family farmers do not have any external source of income so that farming is their only source of revenue. Farm type 2, unlike type 1, is also characterized by labour relations based on family labour given their less advanced stage of the life cycle. In most cases the whole family carries out the daily farm tasks (totally or partially) thus making possible a labour intensive activity such as dairy production. The size of the farm is usually relatively small, less than 20 hectares. To a limited extent this type hires temporary or permanent labour. The land has mainly been acquired inheritance; in our sample three farmers received land as land reform beneficiaries[21].

3.3.3 Farm type 3: Absentee farmer

The key distinguishing characteristic of this farm type is that the main economic activity of the farmer is in the city. These farmers own land and invest in farming for motivations other than profit. These include the desire to protect capital (as land values have tended to increase over time and land is considered a safe investment for money earned in an urban business), a mark of social status (as farm ownership is a sign of wealth in urban society), for leisure at weekends and holidays, and out of nostalgia. Owners tend to spend very little time on farming activities (usually less than 40% of their time) and the respective revenues received only contribute a small share to the total household budget. The purchase of land was the most common form of acquisition.

3.3.4 Farm type 4: Entrepreneurial farmer

The identification and characterization of this farm type emerged from discussions with technicians and knowledgeable actors who argued that, despite the small number of large, professionally managed farms, they represent an important segment of the dairy industry because of the high volume of production. Furthermore, it can be hypothesized that these farmers have rather different reasons for investing in

[21] Dairy production is an important source of income for land reform beneficiaries, called ‘settlers’, who like other family farmers sell their surplus to cooperatives or other commercial companies. There is an extensive literature on the key role of the Movimento dos Trabalhadores Rurais Sem Terra among settlers in reframing political identity and agrarian citizenship (e.g. Wittman 2009, see also Wolford 2010) and in linking the issue of access to land to alternative views on agrarian modernization and wider changes in society (e.g. Welch 2009).

sugarcane or milk production. This farm type is characterized by professional management (the owner is always present), the farm is conducted as a company, employs hired labour, and produces on a large scale over very large areas (in the sample from 300 to 5300 ha). Inheritance was a major form of land acquisition, but frequently additional areas have been purchased in the recent past.

3.3.5 Farm type 5: Extensive farmer

The use of extensive grazing land and low animal capacity has been the predominant form of milk production in many regions of Brazil (Faria and Martins, 2008; Gomes, 2006). Farmers and technicians recalled stories of this "traditional" farming system which involved very large grassland areas, beef or mixed herds, a high number of cows per farm and little or no use of technology. During our fieldwork, however, we did not find a single farmer who matched these traditional characteristics. Below we discuss some possible reasons for this absence. Nevertheless we decided to retain this farm type in our typology for conceptual reasons, as it forms both a point of reference for our informants as well as for our analytical discussion.

To obtain an indication of the presence of each farm type, we selected three distinguishing criteria, based on a preliminary analysis of the interview data and on a theoretical reflection of farm typologies. The three criteria selected are (1) the type of labour force (family or hired labour), (2) retirement status (whether retired or not) and (3) the amount of time dedicated to farming. Using these criteria we analysed the COONAI database (which provides detailed information of 324 milk producers in region 1). All four farm types were present in the data, suggesting that the classification scheme captures the farm types existing in that particular region (Table 3.3). It is also possible to detect the way in which the categories overlap, exposing a high degree of interaction between them (Figure 3.2).

Table 3.3. Distribution of farm types in the COONAI dataset.

Farm type	Criteria				N	Farmers producing extensively within type* (number)
	Family labour	Hired labour	Retired	Time dedicated to farming		
Family	Yes	-	No	> 40%	102	5
Retired	-	-	Yes	-	61	5
Absentee	-	-	-	< 40%	130	20
Entrepreneurs	No	Yes	No	> 40%	31	2
					324**	32

*Extreme low productivity (less than 400 kg of milk/ha/year).
** Not all farmers from the initial data from COONAI could be divided into farm types because of a lack of information about them.

For example, using a productivity index to define the degree of "extensification" (kg of milk/ha/year), gives an idea of how many farmers in each type adopt an extensive system. We selected the 10% least productive farmers in the COONAI dataset and found that these were present in each farm type, with the largest number being in the absentee farmer type.

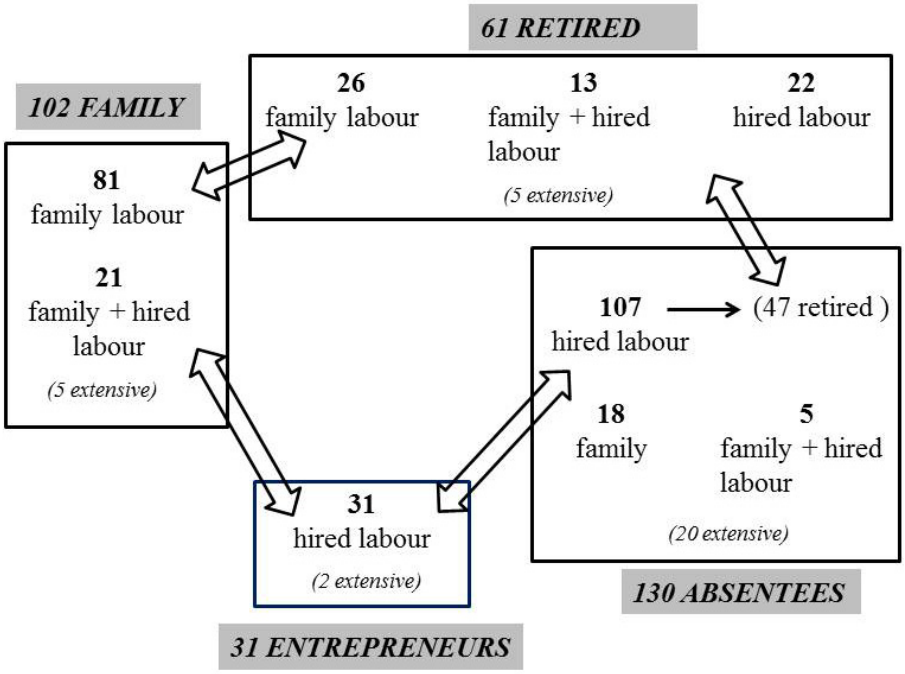

Figure 3.2. Farmers' distribution across and within types with overlapping characteristics.

3.4 Availability of labour: the major challenge facing dairy farmers

In the interviews farmers considered the organization of labour a key issue in determining the viability of production systems. At farm level, dairy activity is one of the most labour demanding activities, requiring daily and year-round labour input. This means that any labour shortage will directly affect land use decisions. The reduction of dairy production in São Paulo state may partly result from a relative increase in labour costs. Carvalho and Carvalho (2010) show that while in 1991 a farmer needed to sell 202 litres of raw milk to cover the monthly wage of an employee (before tax), by 2009 this figure had increased to 706 litres. (Milk lost 33% of its real value while the minimum wage increased by 133%, discounting inflation). This means that each employee had to produce three times more milk than twenty years ago, if the farmer was not to lose out.

At the time of this research two processes were transforming the old patterns of labour organization. Firstly, competition for labour between agriculture and the urban labour market had increased. Secondly, recent changes in labour law and its enforcement influenced the decisions of large and small labour employers in agriculture. The labour law, which is the same for urban and rural space, is adapted to the industrial sector and thereby does not consider the particularities of agriculture, such as the seasonality of agricultural production, the seven day working week, and the early morning and evening hours involved in dairy production. Since the ratification of a set of safety and health norms in 2005, Brazilian labour laws (more than nine hundred articles) are considered to be among the toughest in the world (Pires, 2008). Some of the interviewees (with different farmer types) recognized the implications of these changes for contracting labour while others did not see it as a very relevant topic. Furthermore, a concern about the changing legal context of contracting labour does not necessarily lead to a change in practice. One lawyer interviewed stated that *"Farmers are unaware of the risks of facing problems in a labour court"* since they still persist with traditional patron-worker relationships (labour lawyer, personal communication, 2009). Field observations showed that many local practices deviate from what the labour law stipulates. For example, farmers (n.3, 12, 24 and 33) required workers to feed the herd and milk the cows on a rest day. Increasingly, however, different actors consider that perceptions of the increased rigour of the labour courts have put pressure on the agricultural sector (it even reached the columns of The Economist, 2011). The results of our study show that many farmers feel that hiring an employee has become more complex. First, the small scale of milk production means that the majority of farmers cannot pay an attractive wage nor the taxes involved in registering employees, such as social security, annual extra salary, and an accountant's fee. Second, the hours of dairy activity conflict with the labour regulations with respect to worker holidays and free time. Third, housing for workers on the farm has to be arranged as the average distance from the city was around fifteen kilometres. Building a house on the farm for a worker is a big

investment for family farmers, who also run the risk that they may not even be able to find a worker to live there.

These external conditions interact with the internal labour dynamics on the farm and farmers take them into account when considering alternatives such as renting land to sugarcane, moving to the city, or investing in the intensification of dairy farming. For the retired farmer and family farmer types, the dynamic of labour availability in the household is crucial and involves a modern version of a Chayanovian life cycle-land use relationship. For the retired farmer decisive factors are his/her age and the absence (or presence) of sons or daughters. Young family members often left the farm to seek jobs in the city, motivated either by the inability of farm income to support a second family or by better opportunities in urban areas. A derived effect is that fewer people on the farm means less need for a higher farm income, making a farm household based on a retirement pension and some modest farm production viable. Retired farmers furthermore referred to their 'lack of strength' (or weak health) which made it difficult for them to keep on farming the way they used to. One interviewed farmer (n.1) stated: *"Dairy is a good business but a very exhausting activity, and I have lost the strength to handle it by myself...and I do not trust someone else to do the job, I do not know what I am going to do after my son goes to the city…"* This reference to diminishing physical capacity touches on the topic of the drudgery of labour which we also found in the reasoning of family farmers. Family farmers' decisions about whether to invest in the intensification of dairy production or to lease land to the sugarcane industry also took into account the amount of labour available in the household and the drudgery of labour involved. Though a larger family provides more labour, it also incurs more costs as children nowadays tend to study longer.

Why do farmers not quit dairy activities, lease land to the sugarcane industry and search for work in the city? One reason is the small size of the farms, usually less than 30 hectares, which is not enough to obtain a valuable monthly income from renting to sugarcane. Farmer n.16 stated: *"...in a small farm like this (8 ha) if we decide to rent to sugarcane it would be impossible to make a living, if you have a family…then you would need to find jobs in the city for the whole family if you want to survive. With dairy and cheese making we can keep on living here…"* Farmers also refer to the relatively low level of urban wages for those with little education (which includes the majority of family farmers): *"before investing in dairy, I thought about working in the city, but what kind of job would I get there? I do not have much education at all…"* (farmer n.22). The question then arises whether further intensification would overcome the labour constraints and be economically competitive.

The case of this farmer (n.22) shows that relatively high incomes are possible even on a small farm (8 ha). He a loan, intensify production and achieve high levels of productivity and profit from dairy. He later went on to invest in building another house on the farm for an employee. However, his decision to employ someone was driven not so much by profit as by the drudgery of dairy farming itself. In his words, *I've never earned so much money in my small farm as when I produced 500 litres/day, but it was no life at all! I'd rather earn less and employ someone so that I can have a*

break and enjoy a weekend with my family". He had reached the limits of relying on family labour even though he also employed a lot of technology. Despite excellent dairy profits (around five times more than the average sugarcane rental value) he could not use all the area available for dairy production because of labour constraints. This farmer is an example of a highly specialized dairy family farmer who has reached the limit of family labour and faces a labour situation in which the city attracts most labourers and hiring is difficult due to the regulations of the new labour legislation.

These latter problems are possibly felt even more strongly by the absentee farmer type, where farming is very dependent on workers and managers. The primary objective of hiring a worker, usually accompanied by his entire family, is to have someone look after the house, garden, orchard, and so on, thus reducing the risk of theft. Absentee dairy farmers then consider milk production as a means to pay the monthly expenses of the farm. The employee in charge of the dairy and milking can take care of the farm as well. In these situations, the main objective of milk production is not to provide enough income to survive, nor to complement the retirement pension, but merely 'to help' pay for the wages and other expenses of the 'caretaker'. The relationship between an absentee farmer and employees is an ongoing source of conflict. In interviews, several absentee farmers attested a high turnover of employees. For example farmer n.4 said: *"I gave up dairy production mainly because of labour constraints…over the last ten years, twenty two different employees passed through my farm…I was very dependent on their work and they took advantage of this..."*. Like many other absentee farmers, he never did any kind of farm work himself despite his farming background. This type of dependence and the lack of control over the workers' performance may also lead to a low level of labour efficiency on this farm type. Employees usually take daily decisions without consulting the owner. For example, one absentee farmer (n.7) did not know how many employees he hired for milk production and what their tasks were. The conflictive character of the relationship between workers and absentee farmers also results from the nature of dairy farming as a continuous activity. Absentee farmers are not able to hire more than one family and since many owners do not know, nor want to learn, how to handle cows, they are not capable of replacing workers on their rest days or holidays. Ensuing conflicts, the inefficiency of the labour force and, often, legal processes mean that there is a high level of labour turnover. The problem of organizing the dairy workforce has even led some absentee farmers to rent land to the sugarcane industry. This practice seems to go against the desire for seeing the land as a site of leisure and social status for those farmers who regard high revenue as less important than a beautiful view of fields and pastures full of grazing animals. Leasing the land to sugarcane production would introduce outsiders and heavy machinery (tractors, trucks, harvesting machines) and dramatically transform this idyllic landscape. Nevertheless, some absentee farmers

(n.6, n.7, n.15 and n.32) had decided to rent part of their land to the sugarcane mill. Among the reasons given was the desire to avoid problems with the labour force[22].

With respect to labour issues on the entrepreneurial farm type, large-scale production enables these farmers to employ more than one family and thereby to adhere more easily to labour law regulations regarding free days and holidays. On these farms the turnover of workers was relatively low. However, all the interviewed entrepreneurs mentioned that the labour law was unfair since it makes labour too costly with, in fact, few benefits to employees themselves. We initially assumed that workers would stay longer on this sort of farm because of the higher wages paid, but this was not confirmed by the sample. Interestingly, entrepreneurs strictly follow the labour laws and regulations and are thereby supported by officials and lawyers who control the bureaucracy involved in the registration of workers.

Above we have explored how different labour issues for each farm type influence decision-making about investing in dairy farming or leasing to sugarcane producers. This allowed us to identify a range of mechanisms, beyond the more direct costs and benefits of dairy or sugarcane production, that are of varying importance for the different farm types: family labour dynamics, age, attractiveness of urban jobs, drudgery of labour, labour law regulations, and absence of knowledge to practice farming without hired labour.

3.5 Farmers' strategies and the economic environment

The Brazilian sugarcane industry is considered to be one of the most efficient agro-businesses in the world and is highly competitive in prices (Bake, 2009). It can offer relatively good terms for long-term leasing contracts, usually displacing land from less competitive activities such as beef and dairy systems (Novo et al. 2010). The question arises as to why, if the biofuel economy is so attractive and dairy so problematic, do not all dairy farmers quit and rent land to sugarcane. The fact that not all do implies that simple calculations based on short-term profitability do not fully capture the complex reasoning underlying farmer strategies. In this section, we explore some additional elements of farmer strategies (Jansen, 2009), regarded as non-linear responses to economic circumstances and technological options, which interact with the labour situation discussed above.

3.5.1 Technology selection

Currently, technologies are available, if not as yet adopted by all dairy farmers that modernize production processes (Manzano et al., 2006). In the interviews it appeared

[22] Renting out part of the land also provided extra capital for running the rest of the farm. Those with a large farm were able to locate sugar cane production at some distance from the main leisure house. It was also mentioned that renting to sugarcane producers carried less risk of non-payment than leasing land to small local tenants.

that farmers make investments in dairy technology for a variety of reasons, and not only to increase milk production or to reduce costs. For example, retired farmers do not just continue with older technologies. Some introduce technologies such as a milking machine mainly to reduce the drudgery of the work and only secondly to obtain an extra income. In the case of absentee farmers, besides increasing output, the introduction of technology meant social recognition (show off behaviour[23]) and the ability to control the employee better. By hiring a technician to monitor the introduction of the new technology they also obtain information about the behaviour of the employee[24]. However, the success of technology introduction on absentee farms is low because of the weak overall management of the farm and the above-mentioned constraints of labour availability. On family farms, the objective behind the introduction of technology has generally been to increase the production and revenues in small areas, and thereby improve the well-being of the family. New technologies have enabled entrepreneurial farmers to attain high levels of productivity, mainly based on the owners' presence and the professional way of farming. These farmers can afford to employ one or more private professionals to supervise technical issues and train the staff.

In addition to strategizing over the adoption of new technology, farmers also strategize over their use of existing technology. In this way farmers attempt to increase their flexibility. Risk aversion (in particular for retired farmer and family farmer types) and concerns about large variations in the price of milk and the fall in its price relative to input prices[25] deter farmers from making investments. Instead farmers adapt to the unstable economic environment by acting strategically when prices increase, using their resources opportunistically. For example, when milk prices go up, they immediately respond by carrying out a second milking, reducing the amount of milk for calves, providing some concentrate to fresh calved cows among others activities that enable them to increase sales quickly without the need for long-term investments, loans or capital. Such strategies can be reassessed at any time, without major consequences for the cash flow of the farm. This form of flexibility is an important characteristic of the farm economy.

3.5.2 Resilience and cattle as savings

Despite the problems of mobilizing labour for dairy farming and the option of leasing land to the sugarcane industry, some farmers remain in dairy farming because they

[23] Farmer number 15 was highly enthusiastic about the regional milk tournaments he had won. In his view these 'important' prizes demonstrated his skills to urban society and allowed him to hold up the 'name' and reputation of his traditional family. During our visit to his fields, however, the presence of spoiled silage in the troughs, a number of dead cows lying about with no clear explanation and malnourished heifers attested that he had farm management problems..

[24] In Patrocínio Paulista (a small city near Franca) the local technician related that more than 75% of all farmers who requested regular farm visits, were absentee farmers.

[25] This phenomenon has occurred on a global scale over the past decades (Koning and van Ittersum, 2009).

value milk production as a way of obtaining a monthly income from the herd. At stake here is the issue of a resilient production system. The tendency to keep a relatively large number of cattle might have its roots in the long period of extremely high inflation (IBGE, 2010) and the unstable national economy from the 1960s to 1994. In this economic context an extensive system of cattle raising (farm type 5) flourished. High inflation and pressure from geopolitical interests to reclaim new spaces encouraged investment in cattle rearing with its relatively low risks (Hecht, 1985, Hecht, 1993). In the same economic context, farmers considered technology introduction and intensification to be highly risky. A similar view of seeing cattle as savings, instead of solely as a means of maximizing profits, is still found today. The farmers interviewed explained that they aim to enhance their liquidity position with a large herd, something which they consider to be crucial in times of crisis. Farmers reported several cases where, following extreme climatic conditions or bankruptcy, the entire herd had been sold to pay off loans. In other cases cattle were sold to pay medical bills of family members (n.11), to pay off debts accruing from other activities (n.19), to build a house for the family or a married son (n.1) or even as an strategy to buy more land (n.11). The "buffer" effect of accumulating capital in the form of cattle may partly explain why not all farmers rent land to the sugarcane industry, even when the short term monetary gain of sugar cane is higher than that of dairy activity and milk production is accompanied by many labour problems.

While the view of cattle as savings is still prominent among contemporary producers, it no longer leads to the extensive farmer type (type n.5) at least in Sao Paulo state. The combination of a stable economy since 1994, labour constraints (arising from labour legislation or stage of the life cycle), increasing land values and opportunities to rent land to sugarcane may explain the virtual disappearance of the extensive farm in the state of São Paulo. The farmers identified as extensive farmers in this case study were already intensifying their production systems or renting out land, partially or totally, to sugarcane[26]. Farmer n.12 (classified as retired) mentioned that up until 2007 extensive cattle raising had been the only way of earning money from his 300 hectare farm but since then labour constraints, economic considerations (such as large price fluctuations and the opportunity to rent land to sugarcane for a good price) and social considerations (his three teenage daughters were studying in the city and had to travel 20 km daily) meant that he had started to lease land to sugarcane producers. Another farmer (n.32), referred to by neighbours as a remnant of the extensive system, had recently intensified his dairy production by introducing rotational grazing, maize silage and concentrates. Until 2008 he had farmed extensively like his father and grandfather before him but the receipt of a retirement pension and changes in his family structure[27] had led him to change his farming

[26] As mentioned, we could not find an extensive farmer to interview in our case study locations, even though local people acknowledged their presence and named particular farmers. It could be that extensive farmers are less keen to adopt technical innovations and are consequently not known to the extension service staff who were the ones who facilitated the interview contacts.

[27] Shortly after retirement, his wife (who was responsible for milking the cows) received her own retirement pension and promptly asked for a divorce.

strategies. With his basic maintenance guaranteed and living alone, this farmer took out loans from the bank and invested in technology in order to reduce his labour load while still earning some money. It is possible to observe different reasons across the two case studies behind the decision to lease land for sugar cane or to intensify dairy production. Factors such as (family) labour supply and non-farm income might explain why it is difficult to find a typical extensive system farmer within the boundaries of the most developed state in Brazil.

3.5.3 Dairy and sugarcane as diversification alternatives

We began this paper by referring to the literature that documents the replacement of dairy by sugarcane at the regional level. However, at the farm level there are situations in which sugarcane makes the continuation or even intensification of dairy farming possible. In all the entrepreneurial farms visited, both sugarcane and dairy had been introduced between 4 and 10 years ago in order to diversify the range of agricultural alternatives[28]. In the sample, sugarcane production occupied from 10% to 25% of the available agricultural area and at least three agro-ecological and logistical factors supported the expansion of sugarcane across the entrepreneurial farm type. First, sugarcane production is more stable than soy or maize so less disrupted by extreme climatic events (such as droughts, or delays in the rainy season) and this characteristic may enhance the stability of the farm's total revenue in the long term. Second, as a semi-perennial crop, sugarcane demands few agricultural interventions. There is no need for annual ploughing, no seeds to buy, and fewer disease controls. Finally, some farmers with large farms have developed an interesting logistical strategy, locating sugarcane in the more outlying fields and thereby reducing the transport of inputs and machinery. On the other hand, dairy is still an option in fields whose topography is less favourable to crops. Entrepreneurial farmers also appreciated the monthly revenue of dairy which provides them with enough capital to run the farm while waiting for the most opportune moment to sell the harvest of soybean, maize or coffee, whose price fluctuates widely.

3.6 Discussion

The two previous sections discussed the key factors which have shaped farmers' decision-making relating to the intensification of dairy production or the shift to sugarcane production. Constraints on labour supply and the preference for more resilience, for technologies to relieve the drudgery of labour and, in many cases, for

[28] Diversification into dairy and sugarcane makes sense given the large fluctuations in commodity prices (e.g. for soy or maize) and in yields (e.g. diseases or extreme climatic events). All entrepreneurial farmers had used cheap feedstock from residues of soy and maize, thus significantly reducing production costs. (Concentrates are usually a major cost in dairy production; Rennó, 2008).

diversification have supported the intensification of dairy farming but in some cases also the diversification into sugarcane production. Figure 3 illustrates the complexity of the situation on the ground and summarizes the historical trajectory of each farm type. It shows how farmer types have changed over time within the context of wider historical changes[29], including the expansion of sugarcane (which increased twenty-fold in the area), the political-economic context (such as the rate of inflation) and labour demand in the cities (where population has increased over ten-fold)[30].

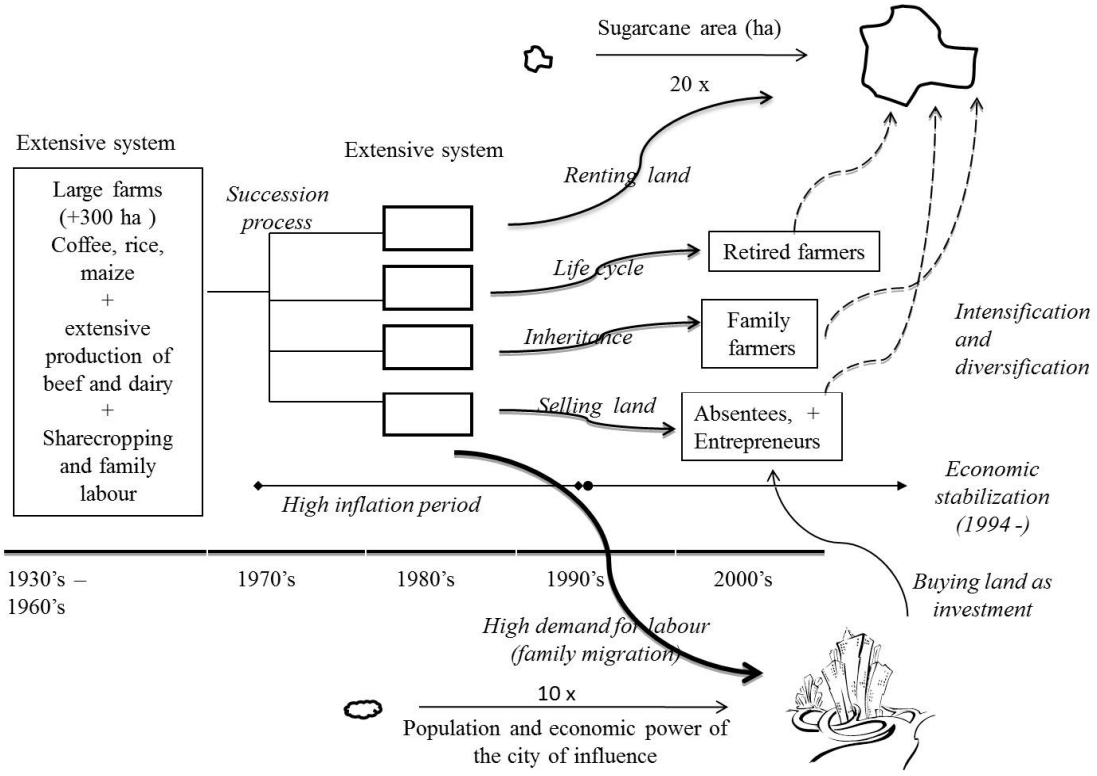

Figure 3.3. Time line model of land use changes.

In this model the role of the development of medium-size countryside cities comes to the fore. Strong urban influence over rural space has become an important feature within the boundaries of São Paulo, the most developed state in Brazil (Jacobs, 1984; Abramovay, 2000; Graziano da Silva and Del Grossi, 2011). As a result of migration to the cities, the total rural population and the labour force decreased between 1986 and 2008 (Alves and Marra, 2009), reflecting the worldwide capitalist-driven tendency for agricultural labour to decline in favour of urban wage employment (Bernstein, 2010). This process has influenced the nature of the rural household life cycle. We have seen above that the strategies of some farmer types, in particular the retired farmer and the family farmer, are interwoven with the life cycle of the household

[29] Farmers interviewed described former patterns of land use between the 1930s and the 1960s when sharecropping was a common practice in which the landlord allowed family farmers to cultivate the land against 50% of the total production.

[30] The rural population in São Paulo state decreased from 37% in 1960 to 4% in 2010 (IBGE, 2010).

(Inwood and Sharp, 2011), an idea associated with a Chayanovian model of the rural household economy (Thorner et al., 1966). Basically, the economic model of Chayanov considers that households develop their production system according to the amount of available family labour, which makes the demographic structure (the ratio between workers and non-workers in the family) fundamental to farming decisions. For example, we described cases of retired farmers who following the migration of their sons to the city, adopted a drudgery-averse mindset which attempted to avoid intense labour activities. By the same logic, many labour related strategies of family farmers are consistent with the model. (While an increase in family size provides extra labour for dairy production processes, a larger family also requires a higher income to support it). However in many other ways the situation in Brazil differs from the Chayanovian model. In particular, the presence of a formal labour market interacts with the household economy. In many cases farmers hire employees to run the dairy activity. Moreover, the influence of attractive alternative sources of work and income, mainly located in urban centres, shape the employment of rural labour, including the labour provided by family farm members. They also consider the trade-offs between, on the one hand, intensifying dairy farming and, on the other hand, seeking wage employment and/or leasing their land to the sugarcane industry.

Does this model of changes in land use enable us to reach any conclusions about the future interaction between dairy farming and sugarcane expansion? Without pretending to be able to predict the future economic, social and technical dynamics, it is possible to point to certain processes and conditions that will shape this interaction. In some cases indeed, the opportunity to lease land to sugarcane responds to needs expressed by farmers themselves: labour alleviation, 'security', monthly payments among others. In many instances the shift to sugarcane will be a 'one way road' as farmers who have sold off their herds, machinery, electricity, fences and abandoned farm buildings and houses cannot return to their former business (Sparovek et al., 2010). After six or seven years when the sugarcane crop cycle comes to an end, farmers will lack the large amount of capital required to return to dairy production and will have no other alternative but to renew the rental contract for another six year period.

In general, however, the effects of the expansion of sugarcane will be more uneven and contradictory. As mentioned earlier, in some cases sugarcane production prepares the conditions that make the intensification, or the continuation, of dairy farming possible. As a form of diversification it offers a guaranteed additional income, fitting the rationale of resilience and reducing risks and uncertainties. It has the potential to add value to any "under exploited" or under-utilized farm land[31]. For example, family farmer (n.27) had intensified dairy production on a small part of his land thereby creating a surplus area to rent out for sugarcane production. He invested the revenue he received from sugarcane in technology for his dairy activity and one year later, the high income obtained from increased milk output (which reached 900 litres a day)

[31] This could include areas of degraded grasslands or low fertile soils with consequently low animal capacity. It also includes fields which are not used because of labour constraints or lack of capital to invest in technology.

made it possible for him to store his maize and coffee harvest until prices rose outside the harvesting season. Hence, in contrast to the first strategy of quitting production and renting out the entire farm, the presence of sugarcane can lead to a strategy of intensification and diversification, enhancing stability and resilience for farmers in São Paulo state.

The question can then be raised as to why some farmers decide to lease land to sugarcane rather than adopting other forms of diversification? Fruit and vegetables, for example, could be economically feasible in terms of price levels and the existence of a consumer market in nearby cities. When farmers were interviewed about these alternative agricultural products, they presented their perception of the risks involved. The recurrent testimonies from farmers interviewed referred to non-payment during the commercialization phase, bankruptcies of agricultural industries and thefts of assets. They mentioned many cases where farmers had generated very high profits from producing fruit (avocado, mango, pineapple, watermelon) but all of them had been forced to give up fruit production because of non-payment on the part of intermediaries. Traders would initially pay on time but once they gained the farmer's confidence of the farmer, they drove up, loaded a lorry and then disappeared without payment[32]. The same scam has also occurred with citrus and coffee dealers, poultry companies and beef slaughter houses but during the interviews these were less reported cases. In comparison dairy farmers selling the unpasteurised milk and receiving a regular monthly payment run less risk of losing a large amount of money should a dairy industry goes bankrupt. Furthermore, the capital reserve in cattle can provide some money should non-payment of milk occur[33]. Non-payment also occurs in the sugarcane industry but is much less frequent owing to the well-structured market of sugar and ethanol and the existence of an established long term contract which increases the confidence of farmers in the transaction. Government support for ethanol as a worldwide commodity and as a diplomatic tool also enhanced farmers' perception of sugarcane mills as having an economically stable future. Even at times when sugarcane and dairy are not necessarily the most profitable way to exploit the land, farmers still identify them as a "safe" option, which enhances their resilience, in a context of weak market institutions.

With this consideration in mind, it is interesting to speculate on the future of sugarcane and dairy in Brazil. Assuming a scenario of high energy demand, both local and worldwide, the sugarcane industry has invested in further expansion. At the time of writing at least fifty new mills were being built in Brazil and the government support has not ceased. Each mill requires at least ten thousand hectares of sugarcane plantation so this industry will remain one of the main drivers of land use shifts in the south-east of Brazil.

[32] These intermediaries usually pay higher prices when buying "unofficially", i.e. where the agreement is oral and there are no written records of the transaction. In these cases farmers cannot file a lawsuit as they have no proof of the loads collected.

[33] Farmers also reported some cases of cattle and machinery theft and a local newspaper headline (Diário da Franca, 2010) reported on the problem near big cities. However, this does not seem to paralyse dairy farming.

The future of dairy production is more difficult to foresee but based on our interview material we can conclude that many farmers have succeeded in intensifying their dairy production, even on small plots of land. Hence, there seems to be room for increasing production. Smallholder dairy production may well grow in regions where land is cheaper, where alternative employment opportunities weak, and where there is as yet no competition from sugarcane. In the Southern region, the family-based agrarian structure also offers the conditions to increase milk production. In frontier areas some factors favourable to dairy farming are also present. The dairy industry has an interest in the North-western and the 'Cerrados' (Brazilian savannahs) regions (motivated by recent option of UHT technology, sufficient available area for pastures and the shift from beef to mixed herds. Novo et al., 2010). However, the same drivers that have modified the São Paulo landscape are becoming more important in some regions of the 'Cerrados'. In Mato Grosso and Mato Grosso do Sul e Goiás not only is the sugarcane area growing fast (from 320 thousand ha in 1996 to 1.2 million ha in the 2010) but the urban population is also increasing (from 68% in 1980 to 88% in 2010) (IBGE 2011). Therefore, the agrarian dynamics may be modified by a similar substitution process of the highly efficient sugarcane industry for less competitive activities. On the other hand, as this paper shows there have been some dairy farmers who have very successfully intensified and diversified, thereby reducing risk, increasing income and enhancing their chances of survival in a competitive and unstable environment such as São Paulo state.

3.7 Conclusions

This study has examined the dynamics of dairy farming in the context of an expanding sugarcane sector. It explores how farmers interpret the trade-offs between shifting to sugarcane, which in most cases means renting out the land to the sugarcane industry or continuing in dairy farming. The development of a farm typology turned out to be a useful heuristic tool as it helped to transcend the prevalent dichotomy between smallholder-family farms and large scale-business farms. In particular the categories of retired farmers and absentee farmers turned out to be relatively large in number occupying a considerable aggregated land area. The typology helped to explore the diversity of factors that influence farmers' strategies. In particular expectations about short and long term labour availability shape investment and land use decisions. These interact with preferences regarding resilience, reduction of the drudgery of labour and diversification. For some farmers this meant diversification into sugarcane production. Other farmers were prone to rent out land attracted by the economic offers of the sugarcane industry. This study suggests that profit maximization (particularly the higher revenue from sugarcane) is not always the farmers' main goal. Other factors such as risks perception and labour constraints are also decisive for farm development. Many dairy farmers choose to continue milk production even when inserted in a

capitalist context of strong competition from sugar cane such as observed in São Paulo state.

Chapter 4

Islands of dairy in a sea of sugarcane and soybean: feasibility and competitiveness of intensive smallholder dairy farming in Brazil

Abstract

Technology introduction and the intensive use of resources, particularly in smallholder farming systems, are at the core of debates about future food security and sustainable livelihoods. In Brazil, land use changes promoted by competing agricultural chains require a search for alternative modes of production for family farms. We analyse the technical and economic viability of intensification of dairy farming by smallholders in the "Balde Cheio" (Full Bucket) programme. On average, family farmers who joined the programme increased milk production three-fold whereas at regional level there was a significant reduction of 8% between 2003 and 2009. Comprehensive datasets from São Paulo state and four other regions across Brazil were collated and analysed to explore for whom, how and when intensive dairy production is a feasible option. Data envelopment analysis allowed us to compare inefficiencies among farms and highlight different strategies for technological changes. The empirical evidences in this study indicate the technical viability of the more intense use of resources towards family-based dairy farming systems. Higher productivity was due to a combination of more lactating cows/area (31%), higher productivity/cow (24%), better labour performance (37%) while using less land area (- 7%). The gross margin/area almost doubled although milk prices had increased by only 7%. The economic outcome of the intensified systems was on average R$3,000/ha which was competitive with R$600/ha for sugarcane leasing and R$700/ha for soybean production. Despite the smaller returns on land large landowners can have a good household income with sugarcane or soybean, but for smallholders the intensification of dairy is the only option. Compared with the alternative of wage jobs in urban areas, we found it very competitive for 40 out of 50 farmers in the sample in terms of income per family member involved in the production process.

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4.1 Introduction

Brazil is at the core of the debate concerning the global future supplies of food, fibre and fuel. The country is the world's leading producer of agricultural commodities such as sugar, ethanol, soybean, coffee, oranges, poultry and beef. Brazil is currently also fifth in the world in dairy products (FAO, 2011), with more than half of the production value generated by one million small family-based farms (Neves, 2006). The close relationship between milk production and family-run enterprises is due to multifaceted characteristics of dairy farming, such as the regular monthly income, immediate cashflow, availability of both labour and large areas of grasslands. Furthermore, investment in land and cattle were a preferred means to accumulate capital in the past (Hecht, 1993). For many decades, particularly during earlier periods of uncontrolled inflation, extensive, low input livestock farming based on trade of calves and sale of surplus milk was the safest option to protect capital. Since the economy was stabilized in 1994, the provision of income became the main issue rather than reducing risk. Increasing competition for land for other uses, such as sugarcane for ethanol in the South-east region of Brazil and soybean expansion throughout the Cerrado region, has re-shaped the farming landscape of Brazil.

Within this context of stronger competition for resources, more intensive modes of farming may provide alternative pathways to better livelihoods. A significant literature highlights the potential of milk production for the intensification of small-scale farming worldwide (FAO, 2010; Herrero et al., 2010; MacDermott, 2010; Udo et al. 2011). Nonetheless, a wide array of potential threats can restrict the development of dairy production to small households and several studies foresaw a large reduction in the number of family dairy farms (Farina, 2002; Bennett et al., 2006; Gonçalves et al., 2010). Poor resource use efficiency at farm level (Gomes et al., 2006 and Gomes & Ferreira Filho, 2007) makes dairy less competitive, particularly when located in regions with soaring opportunity costs. Further, competition for land is not the sole issue to be addressed. Shifts in technology, such as the introduction of ultra-high temperature (UHT) milk treatment in the 1990s, allowed expansion of milk production at huge distances from urban centres where it was not earlier possible (Novo et al., 2010). Strong and sustained governmental support for other agricultural commodities, the growing economy of the countryside cities, as well as the fuzzy labour laws influence investments by small- and medium-scale dairy farmers who depended upon milk production for their livelihood (Chapter 3).

Notwithstanding the huge favourable market for milk, with potential buyers distributed across the whole country, and availability of credit (Nunes, 2007), sustainable milk production is not easy for family-based farmers to realize. The lack of governmental policies and limited access to knowledge are partially responsible for the relative stagnation in productivity of the dairy chain (Martins, 2002). From a historical perspective, Novo et al. (2010) stressed the inadequacy of the technological "package" during the 1970s (strong focus on breeds, buildings and machinery) for small-scale family farmers who had little success with use of such an "exogenous" model of dairy

farming. As a result, intensification of milk production was broadly regarded as something an expensive option that would invariably lead farmers to bankruptcy (Faria and Silva 1996). Most credit facilities still promote the idea that merely buying cows and collective bulk tanks would be sufficient to allow dairy production to soar. Such approaches did not accomplish their objectives, neither increasing productivity nor generating income for smallholder farmers, as reflected by the nearly stable performance of this sector over time (Tupy et al. 2005). On the other hand, there is substantial evidence that intensification of dairy production could enhance productivity and potentially boost net incomes at farm level (Esteves et al., 2003; Tupy et al. 2003; Camargo et al. 2005; Primavesi et al. 2005 and Nogueira, 2006).

In this paper we explore the intensification process within small dairy farms in terms of technical viability and the potential to generate gains in income. In addition, we compare the economic outcome of the more intense way of farming with the opportunity costs of other competing agricultural chains (particularly leasing of land for sugarcane and soybean production), as well as the alternative to quit farming and seek a wage job in the surrounding cities. We base our analysis on the "Balde Cheio" (BCP) or "full bucket" programme, an initiative of Embrapa South East Livestock Division that aimed to develop and adapt production processes and administrative tools for small dairy farmers and extension service technicians. The programme began in 1999 in two municipalities in the states of São Paulo and Minas Gerais with a small number of farmers, but a combination of factors attracted the interest of farmers from other regions. First, the high productivity and income at farm level despite the context of small areas and restricted availability of capital for investment. Second the approach of experimentation with "new" technologies at local level underpinned the confidence of different actors who cooperated to develop incremental solutions to local problems. Finally a broad range of institutional arrangements at different levels created conditions for the Balde Cheio programme to become very popular: in 2012, there were 388 different partnerships with governmental extension services, dairy cooperatives, farmers' unions, NGO's and other funding agencies. The number of farmers assisted rose from 400 in 2010 to more than 3,000 in 2012, in 483 municipalities spread widely across the country (Camargo et al. 2011 and Camargo, 2012, personal communication).

In the technology domain, the Balde Cheio programme proposes a comprehensive and adapted set of production processes and administrative tools to attain better production and resource use efficiency. Some of the key technologies are: a) rotational grazing of pasture (tropical species) which involves soil fertility management and division in small paddocks; b) the use of sugarcane to supplement fodder supply whenever the climate conditions limits pasture productivity; c) simple administrative tools such as basic record keeping of financial and technical data, such as calving and breeding dates, individual monthly milk production of cows and the reproductive calendar to the herd management; d) pasture irrigation and over-seeding of tropical grasses with oat and ryegrass; e)gradual introduction of improved breeds of dairy cows; f) other complementary practices such as the use of by-products as concentrates,

vaccination schemes, culling of unhealthy animals, the restoration of natural vegetation on the margin of rivers and streams, provision of sufficient shade during the day and grazing during the night, among others.

4.2 Materials and methods

Two different datasets of farmers from the Balde Cheio programme were studied to evaluate agro-technological options may help to address expected strong competition for resources in the future. First we analysed the existing data of all farmers in São Paulo State who joined the first phase of the programme (105 farmers dispersed across 21 sub-regions). The dataset was complemented by field visits and telephone calls to explore the households' profiles and the starting technology level. Most variables were available, such as milk volume, average size of the area available to dairy production, entry date, family and hired labour, off-farm revenues, farm inventory (amount of capital invested in cattle, machinery, buildings, fences and others) and technology use at the starting point. Twenty nine different technological processes were identified and received a score and weight that comprised a final index of productive processes and the technology use within every farm. The main practices that set up the final index were technical book keeping, economic accountancy, breeding system, calves feeding, milking place, milking system, milk-cooling at farm level, irrigation and pasture management. From the interviews, milk volume after the BCP and rate of production change were available for a sample of 58 farmers. National statistics were used to relate the local trends in terms of milk volume with farmers' performance. A principal components analysis (PCA) (Mardia et al., 1979) was used to explore the relationships among variables and to select variables for further analysis.

Secondly a detailed dataset of economic data and technical indexes from 50 farmers with at least three years of record keeping was studied. Of these farms, 23 were visited in person, and further data collection from all farmers that remained in the BCP was done by extension service technicians. We chose a 3-year threshold to assess gradual changes over time. Within this sample, farmers entered the programme at different times between 2002 and 2008, so we compared the first and third year that the farmer participated in the BCP, instead of calendar years, to examine the impact of the programme at farm level. Moreover, the influence of seasonal climatic variations on performance of milk production is not as strongly relevant as when dealing with annual crops. Distribution of farmers over different agro-ecological zones allowed us to explore the diversity of dairy farming systems in five regions throughout Brazil.

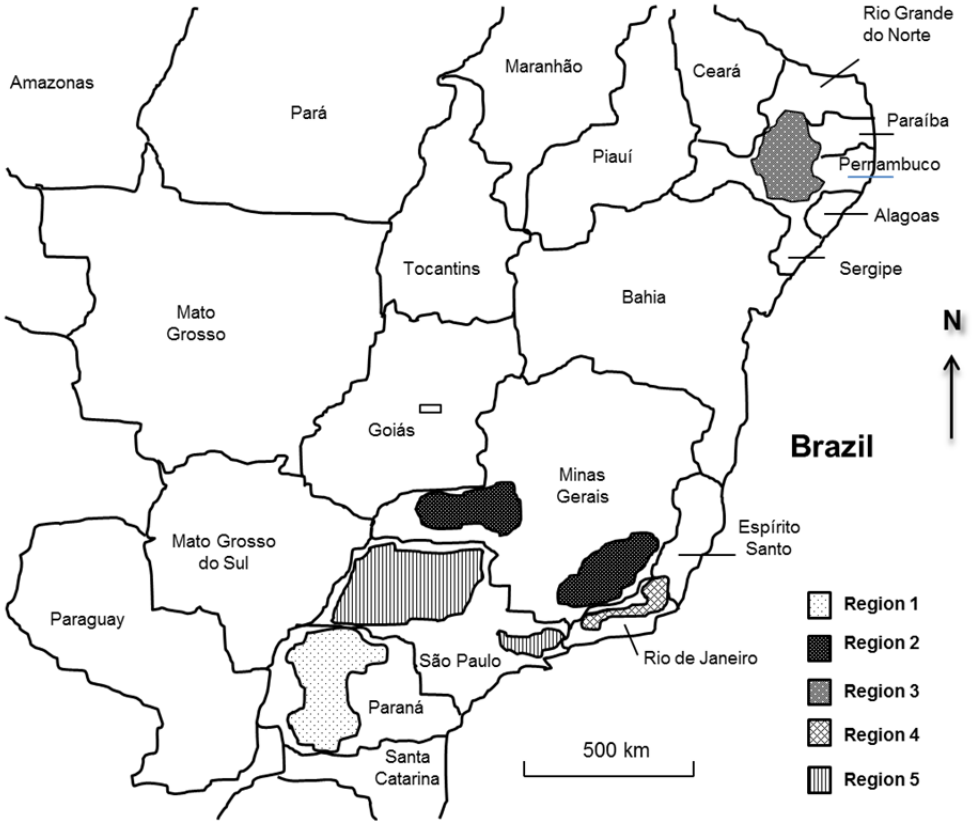

Figure 4.1. The regions in which data were collected, first dataset in São Paulo state (R5) and second dataset in four additional regions: Paraná (R1), Minas Gerais (R2), Alagoas (R3) and Rio de Janeiro (R4).

The large heterogeneity of dairy farming systems relies on a complex combination of production factors and social aspects that result in distinctive allocation of resources. Therefore, we explored the alternative strategies of dairy farmers from the second dataset using data envelopment analysis (DEA) to compare farms (Cooper, 2004). Each farm is compared with all others in the dataset and ranked according to an efficiency score, taking into account an average of the last three years. Kanellopoulos (2012) graphically described a two-dimension DEA example where different decision-making units define a frontier boundary. Every decision making unit on this frontier is efficient since the inputs cannot be decreased without decreasing the outputs, or similarly, outputs cannot be increased without the use of more inputs. We considered many dimensions including land size, labour availability, operational costs and number of cows as the inputs and milk production and herd sales as the outputs. This renders a graphic representation impossible, but the outcome is a comprehensive analysis of the frontiers of the intensification process for these farmers.

4.3 Results and discussion

The outcomes of the first data set (Table 4.1), describe the profile of farmers who joined the Balde Cheio programme. The results in terms of land tenure (92% had the possession of the land), labour characteristics (almost half of the farmers depend exclusively upon family labour and another one quarter had hired sporadic labour) and average size of the land (less than 20 ha) define the features of family farmers in the sample. Furthermore, only one-third of the households earned income off-farm income with less than one minimum salary wage on average, which represents a small contribution to their livelihood.

Table 4.1. Characteristics of the farms when they joined the Balde Cheio Programme, and their milk production before (T1) and after (T2) the programme was implemented in São Paulo state from 2003 to 2009 (n=58).

	Area	Off-farm income	Family labour	Hired labour	Inventory [a]	Technological level [b]	Milk (T1)	Milk (T2) [c]
	ha	R$/year	Person	days/year	R$		L/day	L/day
Mean	16.4	1,703	2.6	54	107,431	21.7	113	260
SD	15.5	4,476	1.4	86	75,162	11.2	89	220
Minimum	1	0	0	0	1,400	3	8	30
Maximum	75.1	24,950	6	400	406,800	50	520	1,400

[a] Capital invested in dairy, without land values.
[b] Index of productive processes and technologies applied at farm level.
[c] Time frame between T1 and T2 are variable depending the entry date of each farmer.

Remarkably, the weak productivity at the starting point of the BCP did not reflect the technological level of production. Despite several agro-technical processes being implemented before farmers joined the programme (T1), they were seldom applied efficiently or effectively. In many cases, capital was mostly used to invest in cattle, buildings and machinery alongside with fundamental restrictions to productivity such as lack of fodder, poor soil fertility and problems of animal health issues. This resulted in poor productivity of around 2500 l/ha/year, not far above the average national index of 1800 l/ha/year (IBGE, 2010). The difference between these two indexes results from São Paulo being the wealthiest state in the country, offering high opportunity costs with expensive land. As a result, extensive grazing systems are not found as frequently in São Paulo state as in the frontier regions in the North and North West of the country. During the intensification process, milk volume per farm rose sharply but the large standard deviation indicates huge differences in technical performance. One farmer in the sample decreased his production volume, six others maintained their milk production but the majority produced two to six times more milk (Figure 4.2).

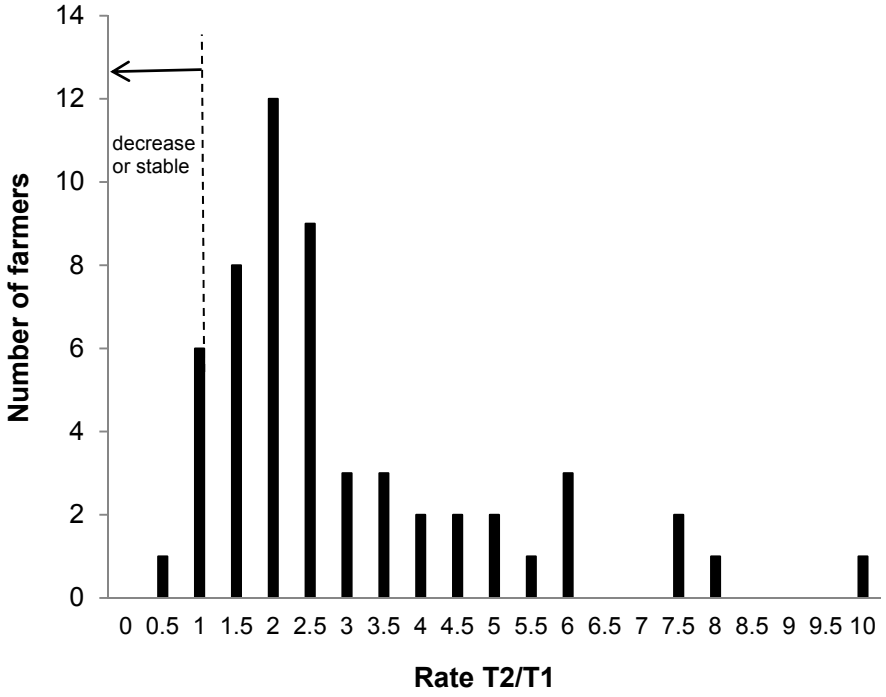

Figure 4.2. Frequency of farms with increased milk production relative to the time they joined the Balde Cheio scheme for farmers based on the first dataset.

Thus production increased substantially, on average more than three-fold, particularly when compared with the trend of local dairy production in São Paulo state where milk production decreased 8% between 2003 and 2009. The competition for land, mainly for sugarcane production, and labour due to the growing urban economy and unclear labour laws, explain the general lack of development of milk production in São Paulo state (Chapter 3). Notwithstanding, increasing milk volume may not be the only criteria to evaluate intensification. Looking closer to the seven farmers who reduced or maintained stable production after the BCP started, we found two interesting cases of land intensification. One farm produced the same volume of milk with less land and diversified activities on the farm by leasing land for sugarcane, and producing beans and coffee). Another farmer took advantage of new technologies to reduce by half his labour force rather than increase productivity.

We used principal components analysis to examine relationships between the ten variables measured (Figure 4.3). The first two principal components together explained 43% of the total variation within the dataset.

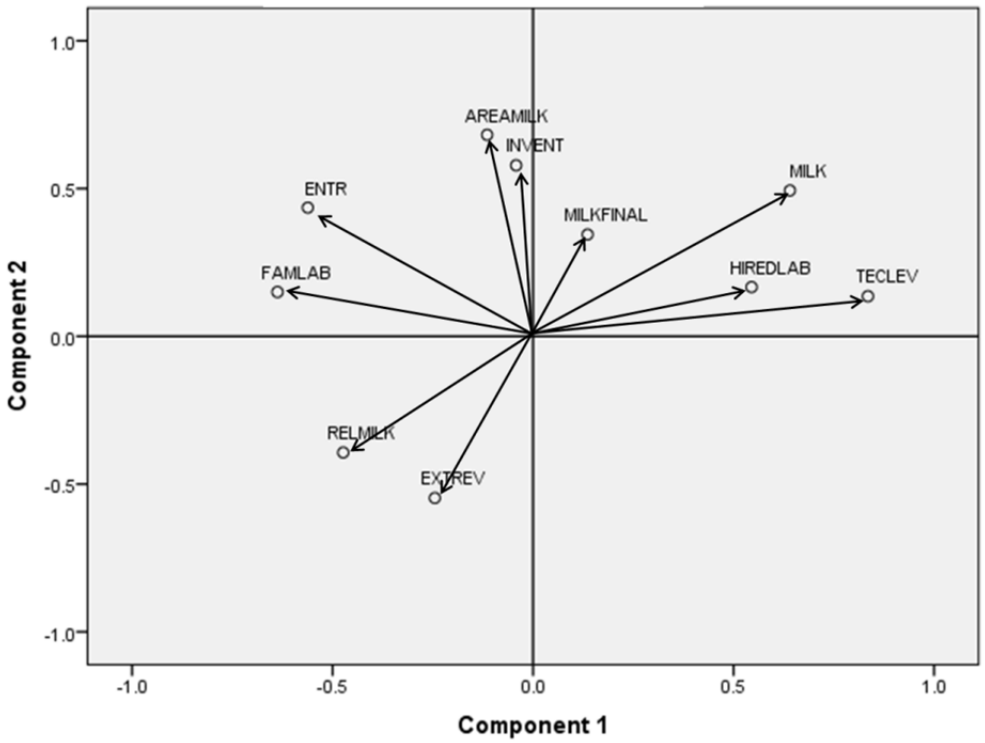

Figure 4.3. The first two components from the principal component analysis conducted on the ten variables measured on farms that had joined the Balde Cheio Programme in the first data set (n=58). Key: AREAMILK: land available for dairy production; INVENT: amount of capital invested in cattle, buildings machinery; ENTR: entry date in the BCP; FAMLAB: family labour; RELMILK: relation between milk volume in T2/T1; EXTREV: off-farm revenues; TECLEV: number of processes or technology applied in T1; HIREDLAB: amount of hired labour; MILK: milk volume produced on entry into the BCP T1; MILKFINAL: milk volume produced at the end of the measurement period T2.

The PCA (Figure 4.3) reveals the following relationships between the variables. First, farmers who first join the programme had generally a poor level of technology. This is a feature of the BCP that gives preference to small-scale family farmers to initiate the intensification process rather than to wealthier farmers. Secondly, there is strong positive correlation among hired labour, technology level and milk volume at the starting point which highlights a sub-group of slightly wealthier farmers. However, this sub-group did not increase production more than average after intensification. This can be explained because poor farmers started off by applying less technology, so that introduction of new technology gave outstanding results. Thirdly, the households with higher off-farm income produced less milk initially, presumably as they had less need to rely on milk production. On the other hand there was a strong correlation between the rate of increase in milk volume and off-farm revenue. This may reflect the ability of farmers with off-farm income to intensify production rapidly and benefit earlier from intensification. Finally, the amount of capital invested was not significantly

linked with technology level at entry into the scheme (T1) but was correlated with bigger herds and buildings respectively 0.67 and 0.90 ($P< 0.01$). To summarize, small size and family-based farmers with low initial level of technology achieved the greatest increases in milk volume, and good improvements in efficiency and competitiveness were also observed for those households who were slightly wealthier at the beginning.

The combined evaluation of farmers' profiles and the interactions among variables gave insight as to for whom the programme worked better and the average situation after intensification in São Paulo state. However, as it did not provide detailed information concerning either the technical or economic performance the insights costs and reasons for success of the intensification process were limited. Therefore, we collated and analysed another dataset from farmers beyond the boundaries of São Paulo state who also joined the programme and had collected detailed records (Table 4.2).

Table 4.2. Economic and technical indexes during the first 12 months and the third year as members of the Balde Cheio Programme, encompassing all farmers with at least three years of record-keeping in five regions (n= 50).

	Area dairy	**Gross margin/area** [a]	**Milk price** [a]	**Lactating cows/area** [b]	**Milk volume**	**Productivity /cow**	**Labour productivity**	**Land productivity**
	(ha)	(R$/ha/year)	(R$/litre)	(lact. cows/ha)	(litres/day)	(litre/cow/day)	(litre/man/day)	(l/ha/year)
First year	20.4	1,700	0.621	1.39	216	7.88	117	5,635
Std. Error	2.5	256	0.01	0.14	30	0.55	12	601
Third year	19	3,273	0.664	1.83	309	9.79	160	8,655
Std. Error	2.9	441	0.01	0.16	37	0.47	13.3	745
t	-0.96	5.33	3.42	4.05	7.41	6.93	4.36	7.13
P (2-tail)	0.342	0	0.001	0	0	0	0	0
Ratio of Third year/ First year	0.93	1.92	1.07	1.31	1.43	1.24	1.37	1.54

[a] Deflated prices accordingly INPC index (IBGE, 2011)

[b] A combined index that indicates fodder availability within the farm (number of heads per area), the reproductive efficiency (conception rate), the lactating period of the cow (lactating/dry cows) and the herd distribution (cows/heifers).

Almost all measured variables were significantly different after three years when compared with the starting situation which confirms that the intensification of the BCP caused deep and far-reaching changes in these dairy systems. Considering all regions, the land area used for milk production did not change significantly, although when we examine each region separately we observe different results which are discussed further case by case below. Gross margin/area almost doubled although milk prices increased only 7% in real terms. This was due to a combination of gains in different indicators such as more milk produced (43%), using less area (7%), underpinned by more lactating cows per unit area (31%), higher productivity per cow (24%), and resulting better performance of labour (37%). The higher income was supported through gains in productivity and not by higher prices of raw milk. This is also reinforced by the relative stable prices of inputs during the observed period and the small share of herd sales to the total income of the farms. Labour productivity increased not only by gains in milk volume/farm and productivity/cow but also by the introduction of milking machines and shifts in the production system (rotational grazing and irrigation reduced the drudgery of daily harvesting fodder). Positive gains in the number of lactating cows/area may be understood as an incremental combination of efficiencies in several processes related to milk production. This index represents the final outcome of investments in fodder production, nutrition, reproduction, longer milking period and herd distribution.

Data from all of the farms, irrespective of region, were subjected to data envelopment analysis to compare efficiencies (as output/input relationships) among different farmers with different strategies or restrictions taking into account the multiple input-output relationships involved in dairy production (Figure 4.4). The output in terms of milk production was selected as the constant factor. From the fifty farmers in the dataset the DEA model placed 27 farmers as decision making units on the frontier, and the other had some disparity from the most efficient position. Both groups of farmers were dispersed across all regions which suggest that regional biophysical constraints were not the key issue in achieving good production. We checked this assumption by running the model within Regions 1 and 2 and found the same trend of inefficiencies; hence the potential effect of one specific region over farmers' performance does not affect the final results.

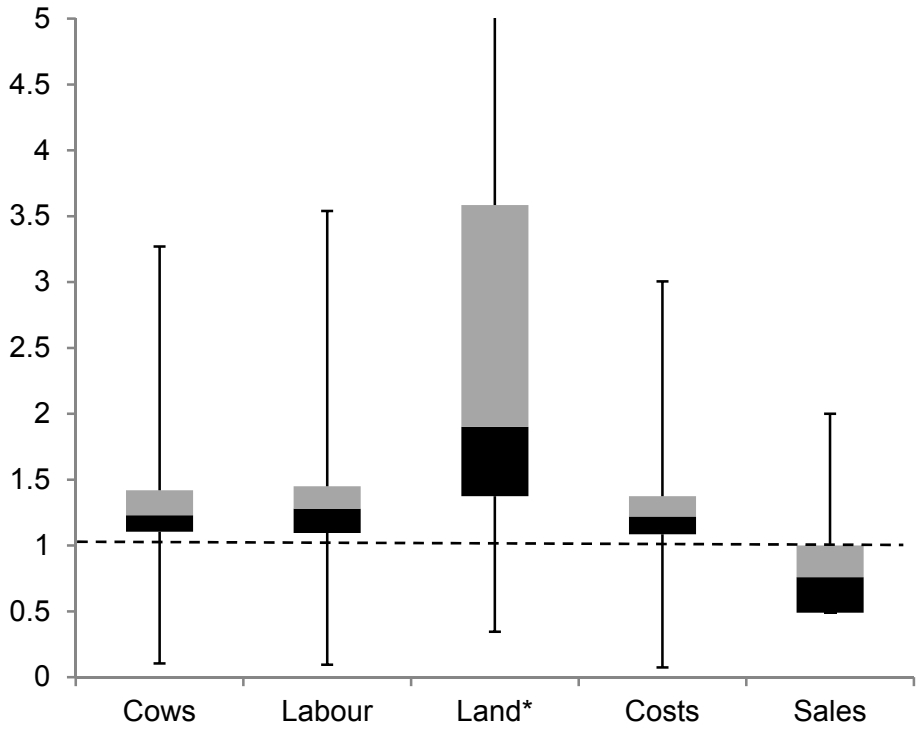

Figure 4.4. The relative distance to the frontier derived using the development envelope analysis considering the 23 inefficient farmers and the studied dimensions (see text for further explanation).

*A large standard deviation reaching a relative distance of 12 was found for the variable Land.

Considering the inefficient farmers and the full set of parameters we found that incremental reductions in the number of cows (-29%), labour use (-34%) and operational costs (-26%) and an increase in sales (32%) would bring farmers close to the frontier. Notwithstanding, land productivity is the key issue when compared with the performance of the efficient farmers. On average, farmers could use one third of the land to produce the same amount of milk. Based on this conclusion, we examine further how land productivity has evolved over time (Figure 4.5).

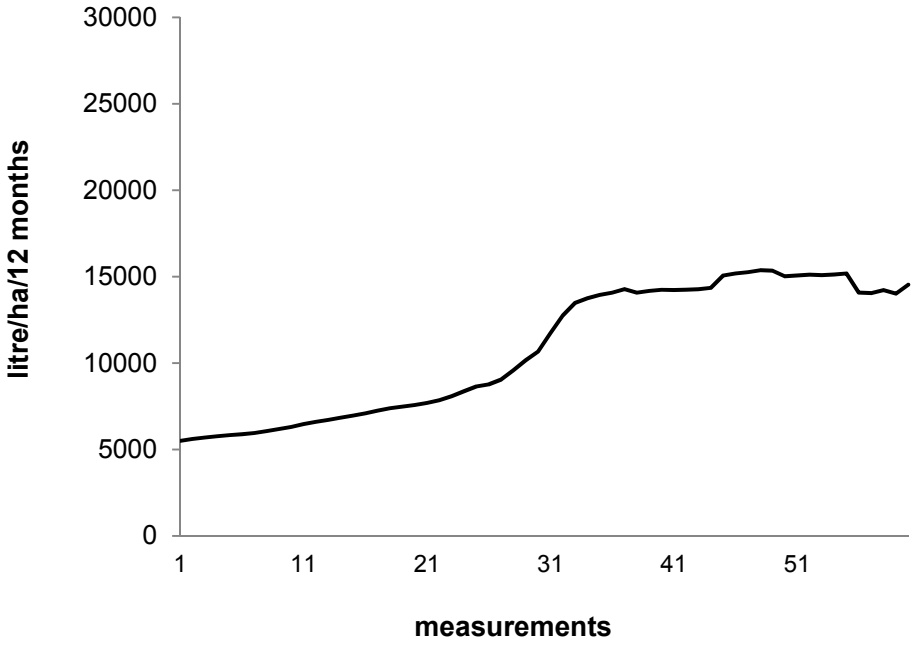

Figure 4.5. Dynamic comparison of land productivity (expressed as a rolling mean where each measurement corresponds to twelve months of record keeping, such as from January to December, February to January and so on) considering all farmers and all regions of the second dataset from the Balde Cheio Programme (n = 50).

The shallow slope of the curve up to the 24th measurement period (36 months in the BCP) for all farmers, indicates that there is a gradual introduction of practices and a slow learning process that leads to step-wise changes in production factors. For instance, investments in soil fertility take some time to be observed in productivity indices. There is also a gap between changes in agronomic practices at farm level (such as better fodder production, high quality of forage, good practices in ambience and health) and the outcome in terms of shorter calving dates or higher milk productivity/cow. Furthermore, after building up the infrastructure of the activity, farmers felt more confident to take loans, investing in herd improvements (replacement with specialized dairy breed cows or simply more cows), in irrigation systems or even reducing the area used for dairy leading to direct results. Agro-ecological limitations (such as soil fertility, lack of water to irrigation) or even (more plausibly) labour availability probably become the main reasons to the relative stabilization of the production after the 43rd observation. However, at regional scale we observed quite distinct results deviating from these average trends. Different drivers strongly influenced the rate of change, the adoption of technology and the final outcome in terms of farmers' performance. Some particular strategies illustrated by five farmers were selected and the performance plotted in terms of productivity/area (Figure 4.6). It explores the average way of production accordingly to their environment and local context that configures different resource use allocations.

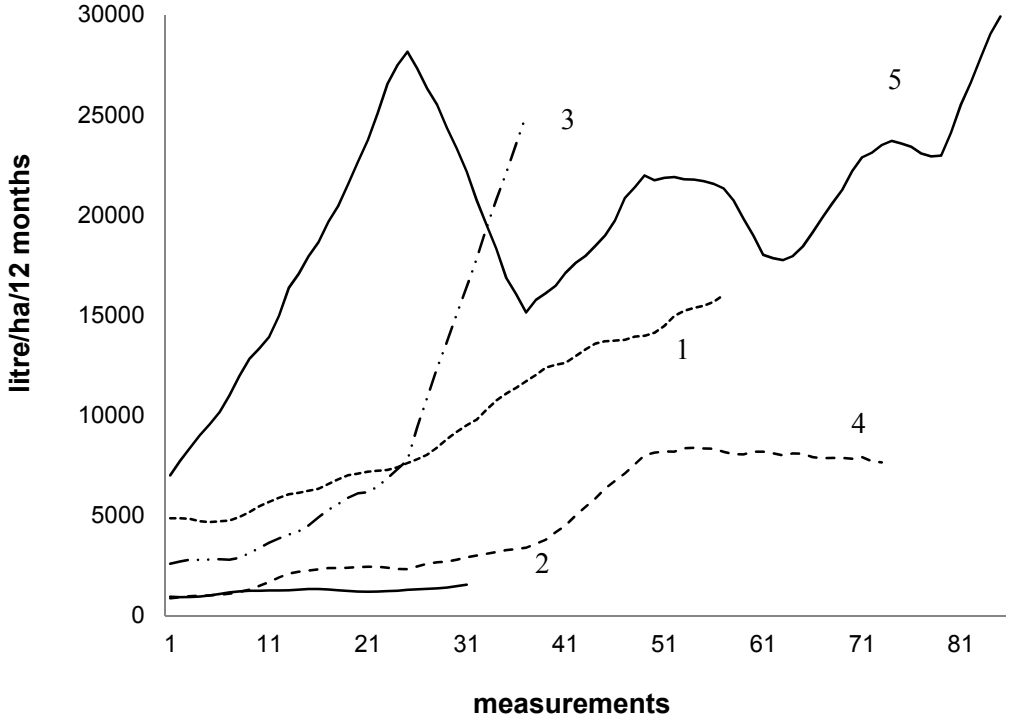

Figure 4.6. Dynamic comparison of land productivity considering only specific dairy farmers within the Balde Cheio Programme and strategies depending on the local context.

The trajectory of Farmer 1 matches the trend of Region 1: a steady increase and with no abrupt variation in the process over time. The presence of sufficient infrastructure (fertile soils and specialized cows) and labour availability within the family provide the conditions to grow in such a way. Other characteristics of Region 1 are the more regular distribution of rainfall, higher initial soil fertility and better genetic composition of the dairy herd. Social aspects such as the Italian and Germanic background with women doing the milking and less attraction to urban areas are also relevant in explaining labour availability within this region. Farmer 2 is an example of a distinct strategy, where there is no significant change in productivity over time, despite the introduction of technology. This trend was often observed in Region 2 where the farms had large areas (2.2 times above average), crossbred cattle and the absence of other alternative land uses (low opportunity cost), hence keeping the herd focused on beef production still makes sense in economic terms. Farmer 3 on the other hand represents the high potential of the Northeast region (semi-arid conditions and fertile soils) where the introduction of irrigation and better cows simultaneously trigger rapid increases in productivity after the 20th observation. In this region there was a significant reduction (-41%) in the land area allocated to dairy with increasing production. In Region 4, this particular farmer was selected mainly due a particular combination of events that expose the complexity of technology introduction and the final outcome in productivity indexes at farm level. Until the third year in the BCP, the performance of this farm was modest with a slow increase in production which was

motivated by the lack of a reliable milk market and limited access to inputs. However institutional arrangements helped to overcome these limitations and productivity increased sharply until the 51st measurement when another restriction arose as his family moved to the city reducing labour availability. The situation of Farmer 5 was again different, showing an impressive rate of increasing productivity and also large variations in trajectory. The fluctuations are explained by the intense herd trade, variations in the area available area for dairy (first inheritance of more land and later the introduction of another activity) which is a common tendency in Region 5. In summary, a complex interplay of factors at regional level such as agro-ecological characteristics (e.g. rainfall distribution, landscape and soil fertility) and opportunity costs (from other competing agricultural chains) intertwined with local features such as the size of the farm, labour availability and institutional arrangements define the rhythm of technology introduction, how and when each farmer applied more or less techniques to increase productivity.

4.4 The potential production frontier and environmental sustainability

Based on the farmers' performance in the sample, we highlight some considerations as to the potential of milk production for smallholders in the tropics. First, land productivity (on average 8.600 kg/ha/year) was equivalent – or even higher when considering the best farmers – with those observed in developed countries that employ more intense, sophisticated and highly specialized production systems (Milkpoint, 2010). Particularly on farms that reached very high productivity per area (over 15000 l/ha/year) this was achieved through a large number of lactating cows/area (4.8 lactating cows/ha), as a result of strategies that explore the high potential of dry matter production of tropical grasses, and not through achieving extremely high productivity per cow (4100 l/lactation) which is a typical strategy of non-grazing systems. Secondly, no single revolutionary technique was responsible for the farmers' performance, but rather a combination of key factors shapes the potential for milk production in Brazil. In essence, it is not sufficient to produce huge amounts of fodder without a balanced herd distribution (cows/heifers and males), attention to health problems, good reproductive indexes and long lactating period because all these variables impact on the number of lactating cows/area, the key variable to obtaining good performance in this particular case. Third, it is remarkable that these outstanding results were obtained by means of a set of agro-technical and managerial processes that cannot be considered as innovations or novelties. The rotational system of grazing for tropical grasses (identified in the 1970s), the use of sugarcane as the main fodder during the dry season (from the 1960s) and the reproductive wheel (from the 1980s) are some examples. The application of basic concepts of herd comfort, rules of animal health care and simple accountancy procedures cannot be seen as an "innovative" way of dairy farming. Fourthly, the evidence for good results across different regions and

within the two datasets demonstrates that, in this study, the agro-ecological characteristics were not particularly relevant to achieving high productivity. The way farmers allocate their resources (management) and the strength of the institutional support were more decisive in achieving good technical and economical performance. For instance, well balanced investments in a more intense way of dairy production make it possible to use less land to produce more milk creating room for diversification of land use, economic resilience and greater resource use efficiency.

On the other hand, achieving a high level of productivity and efficiency takes time. There was a clear time lag from the starting point before a good level of performance was obtained. This occurred after a steady learning process and gradual introduction of different practices. In many cases, farmers do not have enough time to wait for the outcomes and may quit dairy farming (or farming at all) seeking for alternative sources of income. Another key issue is the weakness of local institutional support that can be a constraint to the development at farm level. In some regions the lack of commitment from the regional extension service team was highlighted by farmers as the fragile point of the whole process of change.

The intensification process proposed by the Balde Cheio Programme raises questions about the potential impact on natural resources and broader issues of environmental sustainability. Rodrigues et al. (2006) analysed the BCP impacts in the north-east of São Paulo state using a hierarchical method (AMBITEC-agro) to derive environmental performance indicators of the technology introduction from field measurements. Beyond better production performance indexes, they concluded for 5 farms that the BCP reduced drudgery, increased the environmental consciousness of farmers and reduced negative environmental impacts. Furthermore, the introduction of the BCP practices on an organic dairy farm in São Paulo state (Farmer 44 in our study), with good productivity after three years, indicates an interesting path to be explored towards intense grazing systems with less inputs.

4.5 The competitiveness of intensive dairy farming

Intensified dairy within the BCP gave significant increases in farm income, but whether this remains competitive with other options within and beyond the farm gate remains to be seen. We addressed this question by comparing the average performance of dairy farmers in terms of gross margin/area with alternative local competing livelihood pursuits at the regional scale. We selected the most relevant agricultural chains that impact land allocation in Brazil, soybean and sugarcane, addressing different possible prices and production levels and then compared with the gross margin/area obtained from dairy production, both before and after intensification (Figure 7). First we took the average annual payment per hectare of the sugarcane industry for leasing land in 21 sub-regions in São Paulo state that varied from R$260 to R$660/ha in less favourable regions (hilly landscapes or low fertile soils and fewer sugarcane mills in the surrounding areas) and from R$460 to R$1300/ha in the best

regions during the sampled years (IEA-CATI, 2011). Secondly we compared average soybean production/ha in Paraná state (the traditional state for this crop, which varied from 2322 kg/ha to 3130 kg/ha) combined with price variation from R$33 to R$49 per 60 kg of soy grain at the farm gate (the gross margin was 18% and 39% respectively) during the same period (IBGE, 2011 and APROSOJA, 2011).

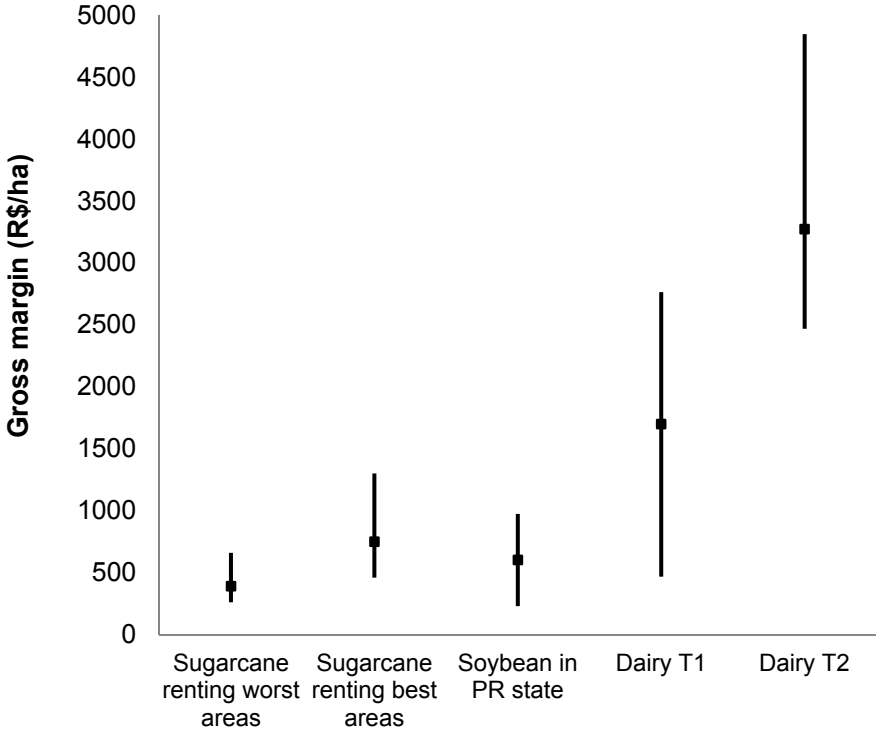

Figure 4.7. Gross margin/area (R$/ha) of competing agricultural chains based on average prices and productivity from 2008 to 2010.

Milk production was generated larger revenues for small farmers than other land use options (Figure 4.7). However, labour and capital investments vary substantially between these alternative land uses. The distinguishing feature of dairy production is the continuous daily tasks that claims a much greater labour load than soybean production (Oliveira, 2009). This is a key issue that drives farmers' decisions (Chapter 3). The amount of capital required to produce milk, with values around R$786/litre, is a further constraint (Camargo, 2011).

Beyond the farm gate, when comparing the intense dairy farming with the alternative of urban jobs we took into account the average minimum national wage plus benefits as a threshold value. Considering the low educational level of family members that would move to the cities, the range between one to one and half minimum salary is likely to represent the most common situation (Figure 4.8).

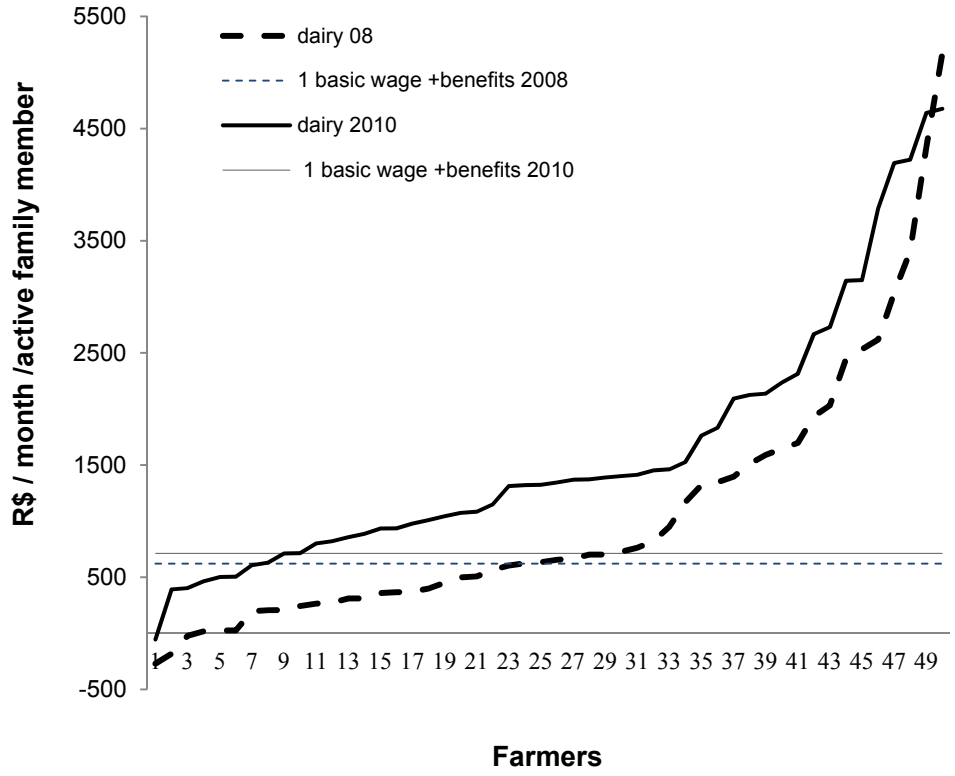

Figure 4.8. Average income for each active family member (R$/month) for BCP farmers in 2008 and 2010 (n = 50). The minimum salary was R$410/month in 2008 and R$510 in 2010, plus 40% of benefits (extra salary, vacations and others) (MTE, 2011).

In 2008, at least 27 farmers earned less than the minimum salary/month per each family member involved in the dairy production process. By 2010, after three years in the BCP, only 9 farmers earned less than the minimum wage (which in fact rose 24% in absolute terms) what indicates that dairy intensification is an interesting economic alternative to quitting farming and seeking urban jobs. Farmers who did not achieve at least one minimum wage salary/family member had less than two hectares of land, daily production lower than 50 litres/day and at least two people working on the farm.

4.6 Conclusions

The empirical evidences presented by our study of the Balde Cheio Programme indicate that the introduction of technologies for intensive dairy production provides a feasible option for smallholder farmers. The gradual and balanced investments (mainly provided by a better allocation of resources) through a set of simple but complementary techniques significantly improved farm performance, irrespective of the agro-ecological characteristics of each region. In addition, the high productivity per unit area of land offers an attractive, but knowledge intensive option smallholder milk production in tropical regions.

Beyond the improved technical performance, this approach to intensification was found to be economically competitive with other land uses and with wage jobs in the city. On average across the three years studied, intensive dairy production was an interesting opportunity for small farmers. If farmers have sufficient land to crop soybean or rent out for sugarcane production they may choose these options and have a reasonable household income. On the other hand, when the farm size is small intensive dairy systems are one of the most promising options to add value to local production and create higher income per area and per labour unit.

Chapter 5

The Gearbox as a Metaphor for Innovation on Family Dairy Farming in Brazil

Abstract

Family dairy farming is under threat from the expansion of the sugarcane economy in South eastern Brazil. This paper analyses an intervention programme which aimed to intensify dairy production and make dairy farming viable in this competitive context. The case study of the "Balde Cheio" Programme (Full Bucket) can be seen as an alternative method of knowledge generation to that of the dominant research approach which prioritizes cutting edge technologies. The paper describes the characteristics of this farmer-oriented programme of intensifying dairy farming systems, in which research, development and extension are seen as a long-term learning process. It analyses how the programme has been adapted to fit the diversity of situations found amongst farmers and to heterogeneous production conditions. Critical issues arising from the study relate to the circulation of knowledge, the search for innovation by recombining apparently simple and known technologies, the use of experiments on the farm and the adaptation of the rhythm of innovation to the specific situation of the farm.

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5.1 Introduction

Within the context of a dynamic and expanding sugarcane sector, dairy production on family farms in South eastern Brazil still survives even though in many cases it might be more profitable for farmers to lease their land to the sugarcane industry (Novo et al. 2010). Under certain conditions technological innovation which leads to an intensification of production may enable family dairy farmers to increase their profitability and competitiveness (Chapter 3). This paper describes one such programme and analyses how it differs from conventional research and development (R&D) and extension programmes. The "Balde Cheio" (Full Bucket) programme, is a rare example of how to narrow the gap between the scientific community, in this case the advanced research programmes of government research institutes and small dairy farming systems. An analysis of this programme reveals several lessons for family farmer oriented R&D and extension.

The Balde Cheio programme, an initiative of South East Livestock Division of Embrapa, the Brazilian Agricultural Research Corporation, aims to develop and adapt production processes and administrative tools for use by small dairy farmers and extension service technicians. It was launched in 1999 in São Paulo state and gradually spread, reaching more than three thousand family dairy farmers in all regions of the country. With the Balde Cheio programme Embrapa aimed to link research more closely to the needs and situation of users. The Ministry of Agriculture which provides almost 90 per cent of Embrapa's budget requires clear, quantifiable results showing the impact of innovation on family farms. Technical details of the impact of this programme have been analysed in-depth elsewhere (Chapter 4). In this paper we focus on the nature of the linkages between the programme and the farmers and the ways in which the programme has been adapted to the diversity found amongst dairy farmers and to differing production conditions. André Novo, one of the authors of this paper, worked for the programme from its outset in 1999 until 2008 and is thereby in a position to observe how it evolved over time. In addition, data collection included project documents, interim reports, farm data, interviews and participant observation in the period 2008-2011.

The first section of this chapter discusses how the Balde Cheio programme evolved out of a critique of conventional R&D and extension. We then outline the programme and discuss some key characteristics that are relevant for the general debate on R&D and extension as it relates to smallholder farming. Although relatively successful the programme did have some major drawbacks which are discussed in the final section. In the conclusions we emphasize the lessons to be drawn from the Balde Cheio programme as an alternative approach to technology innovation with its focus on seeking novelty by recombining apparently simple and known technologies, conducting trials and experiments at farm level, networking and timing of technology introduction. With regard to timing, we conceptualize this in terms of a so-called gearbox model of innovation.

5.2 Common R&D and extension models in dairy farming

Brazil, like many other countries, has attempted to shift from a linear R&D model, in which science-developed innovations are subsequently passed down to users, to a more dynamic model in which users play a more active role in innovation. In the latter case, effective technology innovation is seen as a long term process involving several stages, multiple actors and complex arrangements between actors (Bessant & Rush, 1993). Innovation, more than technology itself, should be understood as a multidimensional process with at least three dimensions (administrative/technological; product/process and incremental/radical) (Cooper, 1998; Klerkx & Leeuwis, 2008). In many areas, ranging from plant breeding (Almekinders, 2011) to adaptation to climate change (Crane et al., 2011) and biofuel production (Schut et al. 2011), farmers' knowledge and participatory mechanisms have been included in agricultural R&D processes. System perspectives have been widely discussed as a tool for pursuing integrative approaches in agricultural development (Brouwer and Jansen, 1989; Jansen, 2009).

In Brazil the predominant R&D model remains the conventional transfer of technology model (top-down, linear, blueprint, mode 1 model). Inclusive models encouraging a broader participation of farmers did not prosper in Brazil owing to a lack of support from government extension services and their relative neglect by the local scientific community (Teixeira, 2004). Many policy makers and a large part of the scientific community share the strong view that innovation is best addressed by cutting edge research, such as genomics, nanotechnology and satellite-based remote sense observations. However, the effectiveness of such research (both fundamental and applied) at farm level is questioned by others. Schwartzman (2002) shows that despite all the research funds and human resources invested, there have been few quantifiable improvements in agricultural production. Several factors discussed in the general literature on the development of technology also play a role in the Brazilian case. Firstly, much technological innovation developed by applied research remains at the prototype or pilot phase and does not reach the farmers' fields. Secondly, public agricultural research and extension tends to universalize and overlook the complexities and contradictions inherent in implementing innovations (Edge, 1995). For example, many dairy technologies and support services, implemented as part of a government programme (bulk tanks, artificial insemination, courses to increase the quality of raw milk, courses on vaccination practices) were designed without reference to local conditions. Questions can be raised about the benefit of artificial insemination in a starving herd, the utility of a new grass variety in cases of extremely low fertile soil, or the relevance of bank credit for building a milking parlour where the herd is unhealthy, and so on. Yet such situations are prevalent in smallholder dairy farming. Thirdly, most government programmes assume that use of new technology once introduced will be continued, whereas this is often not the case as insufficient attention has been paid to building up the competence of final users (Bessant & Rush, 1993). Fourthly, following federal budget cuts in the 1990s, Brazilian agricultural extension services

lack human and capital resources (IBGE, 2010) and many state-based extension services and technology centres have since stopped operating (Teixeira, 2004). Data from the national census of 2006 show that this low level of technical support persists as only 22% of farmers declared that they had received some from the technical assistance. Fifthly, so-called stakeholder involvement in research planning, as undertaken in the 1990s, did not often include farmers. For example, in the case of dairy farming, Embrapa attempted to reshape the national research programme, first by setting up regional focus groups and later in 2002 by the "Projeto Plataforma". In each case the scope was limited to formulating broad guidelines and farmers were not invited to attend (Teixeira, 2004). Though there is no guarantee that the inclusion of farmers would have led to a different research agenda, their exclusion essentially preserves the characteristics of the linear, researcher-led R&D model (Cornwall et al., 1994).

In apparent contrast to this emphasis on cutting-edge research and low investment in extension programmes, official development discourse in the 1990s gave more weight to incorporating family farmers into intervention programmes. However, efforts to put family farming at the centre of the technology transfer process largely failed (Olinger, 1998). Although some states improved their assistance to small farmers, at national level there has been a bias towards supporting wealthier and more educated farmers. In 2006 those farmers assisted had on average 228 ha whereas the non-assisted had only 42 ha. Only 16.8% of farmers with incomplete schooling received some technical assistance whereas 44.7% of the farmers with university level studies declared that they had received some (IBGE, 2010). This bias is not the result of differing farmers' responses as the majority of dairy farmers indicated an interest in receiving technical assistance (Gomes et al., 2006).

Despite the increased attention paid to family farming, technology adoption remained low. One reason for this lies in the nature of the "technology package" which consists of the acquisition of Holstein cows, sophisticated milking machines, freestall barns and corn silage as the main fodder (Faria and Martins, 2008). This package is supported by a large input supply business with a turnover of R$7.5 billion/year (US$ 4.6 billion) for the first stage of the dairy chain alone (genetics, concentrates, fertilizers, seeds, vaccines and others) (Neves and Consoli, 2006). In general, the commercial strategy of selling inputs rests on blaming the "old" technology for farmers' low income and promoting the new revolutionary technology as the solution. The package seems to work for large farms but is not so appropriate for the widespread low intensity grazing systems with zebu cows. The vast majority of Brazilian family farmers cannot afford such a package, underling the gap between the R&D system and the reality of family farmers. Another factor influencing adoption rates is the limited training capacity. In São Paulo state, for instance, the SENAR-SP (the National Service of Rural Learning in São Paulo state, funded by a compulsory contribution by all employers) carries out around 11,000 training sessions in livestock production each year involving more than 160,000 farmers and employees (SENAR, 2009). However the short length of training (on average less than 2 hours per person)

and the lack of fit between the content of the training provided and farmers' needs mean that they are not very effective. In sum, the nature of the technology recommended and the training programmes offered disregard the complexity of dairy production and the multiple dimensions of any innovation process.

The limitations of a shallow extension programmes for family farmers are made clear in the following example. In Brazil, a major channel for technology transfer to dairy farmers is through a talk given by the researcher to the local community (Souza et al. 2011). On one such an occasion, in a small community in the Vale do Paraíba region (Rio de Janeiro state), an expert spoke about new methods of production as well as the economic advantages of intensifying dairy production. At the end of the speech a local dairy farmer thanked the visitor and asked him how long he planned to stay in the community as he would like to follow his advice on his own farm. The researcher replied that he had to return to his job in the city so could not stay. The farmer then asked: *"Is there someone else with this knowledge around here who can help us improve our dairy system?"* The researcher answered: *"Sorry, I have no idea whether there is anyone in the region who has sufficient training to support you make such changes"*. The farmer responded: *"So, why did you come? (This was met with a brief silence). Before your talk, I was relatively resigned to the low income and the way of life on my small farm. There is no alternative, I thought. Then you come along and tell us that there are several technologies and processes which could definitely change my life but there is nobody here to help me do so. I now feel very frustrated. You should have stayed put"* (Figueiró, 2011). These farmer's words imply that the family farmer oriented but otherwise traditional form of extension programme did not work. It was criticisms like this that inspired a network of extension workers and researchers to set up an alternative form of technological innovation which worked more closely with dairy farmers. This would become the Balde Cheio programme.

5.3 The birth and growth of a new approach: the "Balde Cheio" programme

In 1999 a group of five researchers from Embrapa (Embrapa Southeast Cattle) drew up an official programme involving a set of technical practices (already being employed on the experimental farm) which could be adapted to local situations. The basic idea involved selecting from amongst the range of already known practices those that best fit the particular farming system and adapting technological practices to on-farm conditions (both biophysical and socio-economic). After formal approval, the programme, later known as Balde Cheio, started in the states of São Paulo and Minas Gerais with seven and five farmers respectively. The Embrapa researchers directly trained the farmers themselves and worked together with them on the farms. After three years, the programme had a positive impact on the farms in terms of productivity and economic indices. The objective of increasing income by introducing technologies at farm level, adapting processes and learning with farmers, was achieved (Esteves et.

al, 2002; Tupy et al. 2003, Camargo et al. 2006). An internal evaluation of the first phase of the programme produced some additional findings. First, acquiring experience outside the experimental farm setting yielded important insights into how and when a specific technology should be used in practical real life situations. Second, working with family-based farmers instead of wealthier farmers (which employ labour) was more efficient (Rodrigues et al., 2006). The evaluation found that migration rates for members of family farm households decreased as did the work loads of family members (so they enjoyed more time off during the day). The ability to pay for private education for teenage children was more within their reach. The farmers could also carry out some home improvements, such as purchasing some small household appliances or refurbishing the home by, for example, building an indoor toilet. In addition farmers' self-esteem increased. The experiences with wealthier farms were less positive. They encountered problems in applying the changes proposed owing to the lack of adequate management within the farm. Third, while in its existing form the programme could not guarantee long-term assistance, farmers in other regions came to request this type of support.

Following their evaluation of the first phase of the programme, the Balde Cheio group identified two major elements for developing this alternative mode of technology transfer. First, given the complexity of dairy production with its multiple interactions between soil, plant, climate, herd, labour and management, the introduction of innovation requires researchers and technicians to adopt a broad perspective which takes into account the whole production process. A second element concerned the role of technicians. In the first phase of the Balde Cheio their role was limited to organizing meetings and inviting farmers to attend. They seldom participated in decision-making on the farm and consequently were not directly responsible for the final outcome of the innovation process. Accordingly the role played by the extension service technician had to be reviewed.

At this point a fundamental shift took place in which the roles of the small dairy farmer and the technician-extension worker were reversed. The programme now came to focus on training local technicians who were contracted by a range of partners, such as other government agencies, municipalities, co-operatives and farmer associations. In general, extension service technicians have a low level of knowledge of the particularities of dairy farming. The new framework employed a practical approach in which the small family-based farm was viewed as the best setting for training local technicians. Working closely with farmers during the course of a long-term project increases the responsibility of both technician and researcher. The design of the programme also proposed that ideally farmers who participated in the programme had no off-farm revenues and focused solely on farm development. The Balde Cheio group expected researchers, technicians and farmers to share ideas and suggestions on how to promote the introduction of technology in dairy farming.

After this shift in emphasis to training technician-extension workers rather than farmers and entering into partnerships with other institutions, the Balde Cheio programme began to grow steadily. In 2011, more than 3000 farmers were assisted in

25 states of Brazil. In that year 445 technician-extension workers received training and partnerships were entered into with 388 institutions, among them government extension services, farmers' associations, cooperatives of technicians, dairy industries, NGOs, municipalities, funding agencies (Banco do Brasil Foundation) and development agencies. Only 4 researchers from Embrapa worked directly on the programme in 2011. A second tier of technicians coordinates the programme in each region and is responsible for training local technicians and visiting the farms every 4 months. Embrapa personnel monitor the work of this second tier at 8 monthly intervals. The central budget of the programme remains low, varying from R$5,000 (US$5,000) per year in 2000 to R$45,000 (US$23,000) in 2011. The budget basically covers part of the travel costs for Embrapa staff to attend local meetings (only direct expenses). In most regions, the costs of Embrapa or other personnel who coordinate the regional programme are paid for by the supporting partnership. The central focus remains on smallholder dairy farming. 92% of the participating farmers own land, almost half of the farmers depend exclusively on family labour and another quarter hire labour sporadically. The average farm size is less than 20 ha (but with a high standard deviation, ranging from 1 to 75 ha). Only a third of the farmers have an off-farm income, which is on average less than the minimum wage. The increase in milk production on those farms participating in São Paulo state illustrates the intensification potential of the Balde Cheio approach. On average the volume of milk increased by 2.3 times (from 113 to 260 l/day; n=58) at a time when milk production in general tended to decline in the same region.

5.4 Key elements of the Balde Cheio programme

As seen above, over time the Balde Cheio programme developed a specific approach to innovation whose main elements are discussed in more below.

5.4.1 Bookkeeping: tool for farmer reflection on innovation in dairy farming

The programme designers held that improving dairy production requires close monitoring of key technical and economic variables. The underlying idea is that good bookkeeping enables a realistic view of short and long term economic stability, helps to take decisions based on facts rather than on hearsay and to minimise risks to the livelihood of farmers, who are the ones providing the capital for the innovation. Simple spreadsheets have been prepared to help farmers with data collection. Balde Cheio takes a strict stance on bookkeeping: all book-keeping of accountancy and technical data has to be done under the close supervision of the technician and archived by the farmer. When the farmer is illiterate another family member assumes the responsibility (usually women or teenagers). Where records are not available on a

particular farm, programme support is withdrawn. Where farmers (or technicians) do not take the task seriously, or show a lack of interest, they are promptly excluded from the programme.

5.4.2 Adapting to complexity and seeking novelty in re-combining technologies

One factor related to and often the result of bookkeeping was the choice of technological practices. Where and how to innovate was different for each farm. In that sense the approach differs from the idea of a standard technological package which assumes universal application. Later in the programme it would also differ for each region. The selection of new technological practices by technicians and farmers jointly was based on the requirements of different domains such as nutrition (high quality fodder and a balanced diet), health (vaccination schemes, animal well-being), fodder producing systems (mainly tropical grasses due to the high potential of dry matter production) and management (technical and economic controls).

The practical experience acquired during the first phase of the programme led to a series of technical and administrative practices that could be applied in a smallholder setting. Some of the key technologies are: a) the rotational grazing of tropical grasses involving a segmentation of swards in small paddocks, b) the use of sugarcane for fodder during the dry season, c) the use of simple administrative tools like keeping basic accounts of income and expenditure and of technical data (such as calving and breeding dates, monthly individual milk production and rainfall) and the reproductive calendar, d) the irrigation of swards e) oat and ryegrass over-seeding tropical grasses, f) the gradual introduction of specialized dairy cows and g) other complementary practices such as using local by-products as concentrates, vaccination schemes, milking machines, restoring vegetation on the banks of rivers and streams, and improving the environment (providing shade during the day and grazing during the night).[34]

The novelty of introducing these individual technological practices may not be immediately apparent as most were already familiar. Indeed frontier research, which puts emphasis on the latest technology, may fail to recognize what is new about this kind of programme. In the case of Balde Cheio innovation does not refer to a body of codified knowledge (which is embodied in a new artefact such as improved seeds or machinery) but instead is conceptualized as a new way of applying existing technologies to dairy farming. By adopting known practices but combining them differently, the whole programme can be defined as novel (Van der Ploeg et al., 2004).

[34]For a more technical appraisal see Chapter 3.

5.4.3 Trialling and experimenting at farm level

The strategy of conducting small trials at farm level is central to this type of programme. During their initial meetings the Balde Cheio team and the farmer gather technical and economic information on the farming system (e.g. soil analysis, topography measurements, herd information, relative prices of inputs). They then plan trials and future steps based on the capital available, herd size, grasses already established amongst others. In many cases experiments are first carried out with rotational grazing in order to develop a farm specific practice that is effective in terms of forage supply. This is done by varying the stocking rate through trial and error adjusting the number of animals in the paddock so as to maintain a stable supply of forage per live weight. In grazing systems, a well-adjusted stocking rate determines the farmer's success. The amount of capital which farmers can contribute to the trialling plot is generally limited and not enough to cover fodder production for the whole herd. While feeding all animals adequately is an important target, the main aim in the initial phase is to stimulate learning. The size of the trial area for rotational grazing and complementary sugarcane production for fodder is influenced by the amount of money a farmer can generate (often by selling less valuable cattle such as non-pregnant dry cows, undernourished heifers, or horses). Care therefore has to be taken to ensure that the farmer does not become indebted by participating in the programme.

The method of carrying out small trials is continued in subsequent steps of the intensification process. For example, the general introduction of more specialized dairy cattle (*Bos taurus*, such as Holstein, Jersey, Swiss Brown) would require too much investment and very strict control of management and nutrition. When basic conditions are fulfilled (high quality fodder, comfort and sanitation procedures) the farmer may be motivated to shift from having two or three low quality animals to one or two better ones. The programme has observed very good outcomes from intensification with the original herd, whose productive potential had previously not been met owing to low quality fodder and poor management. Where more specialized cows are introduced (generally with higher proportions of European blood e.g. half-blood Zebu/Holstein, 3/4 Holstein/Zebu, or half-blood Holstein/Jersey-F1 cows), this can be regarded as an indicator that the intensification process has been conducted well. The process always starts with a trial, and only when the trial results are positive can the farmer increase the number of specialized cows in the herd. A similar process is followed when introducing new varieties of grasses (starting with the local established species and gradually shifting to more productive ones, when necessary)[35] and irrigation (starting with the manual distribution of water in a few paddocks, then

[35] The already established species are quite variable. The most common are the *Brachiaria decumbens*, *Brachiaria brizantha* and Napier grass (*Pennisetum purpureum*, usually planted as "capineiras" which requires manual chopping during the whole year). The more productive grasses with higher quality fodder are *Panicum maximum* v. tanzania; *P.maximum* v. Mombaça and Tifton or Jiggs grasses (*Cynodon dactylon* varieties).

shifting to a more efficient system)[36]. This well-developed trialling/experimentation phase contributes to a strong learning process (different from the classical 'recommendation' model) in which mistakes in the introduction of complex technological practices can be corrected without compromising the farmer's budget.
Farm-level trials and experiments are not only used for introducing, adapting and recombining known technologies but, in some cases, also generate new knowledge and practices. For example, the practice of over-seeding oat and ryegrass on tropical grasses was developed during on-farm experimentation and is not the result of scientific research. Another example is the use of irrigation on tropical swards in different agro-ecological conditions. This was little explored by scientists and very few studies have been conducted in Brazil so there was no formal evidence available to run a field trial. Instead a few farmers who had old irrigation equipment (for other uses in the farm) used it in the dry period when the tropical grass was growing and achieved remarkable results. Over time the Balde Cheio team gathered more information from farmers in different regions or involved in different agricultural activities (vegetables, fruit and maize production) on more efficient pumps, low pressure systems, better sprinklers, thereby increasing knowledge about irrigation for tropical grasses. This pool of knowledge made it possible to increase the efficiency of irrigation (through frequency controls and more accurate methods of measuring evapo-transpiration) and to work together with farmers on incremental solutions. In situations like this, a formal research procedure would be too time-consuming to provide a feasible and accessible solution to farmers´ immediate problems. In the case of oat over-seeding tropical grasses, it took three years after the first trial was conducted at farm level in 2002, for a research centre to formulate the relevant scientific research and recommendations (Oliveira et al., 2005).

The trialling/experimenting character of the programme increased awareness of the many adaptations made by farmers. These adaptations are often made intuitively (Nuthall, 2012) by what other scholars call 'performance' (Jansen and Vellema, 2011; Glover, 2011) rather than being planned. Balde Cheio, aware of the importance of solutions developed on the farm, took these incremental adaptations seriously and often introduced them in experiments on other farms and in other regions. In this way a wide range of new small practices was disseminated, which differed from the traditional way of doing things. Among the many examples are the use of mobile water sources which reduce investment in troughs and cut down the distance the herd has to travel; non-plough planting systems of tropical grasses which avoid erosion and destruction of mountain landscapes; a new method of multiplying Tifton grass stems quickly and cheaply by using seedling trays; sub-dividing paddocks to increase grazing efficiency; building electric fences with alternative materials, such as PET bottles, bamboos and old wire; replacing the wood on fodder troughs with "plastic wood", produced by a NGO that recycles industrial plastic waste; the adaptation of a

[36] More complex irrigation systems mean that the pump, the electric motor, the distribution system and sprinklers have to be the correct size to spread the right amount of water with as little energy and labour as possible. Low pressure systems are the most common solution for this.

cheap milking ditch which is made directly into the ground without the need for concrete; the use of magnetic sticks on the reproductive calendar. Many of these incremental solutions reduce costs, save labour and time, the main constraints in dairy production. They acquired prominence in the Balde Cheio programme as a result of its emphasis on trialling, experimenting and on-farm learning.

5.4.4 Networking for sharing information and practices across localities

The networking process is another remarkable feature of the programme. The development of a network of farms and technicians across the country and the periodic visits made by Balde Cheio coordinators to all regions make an intense circulation of knowledge possible. Even technologies that were deemed specific to particular agro-ecological conditions, have attracted the attention of other regions, been the subject of experimentation there and often led to new uses. For example, the practice of seeding temperate species over tropical ones during the winter in the southern region of Paraná, was extended to other regions, where it became popular after the introduction of irrigation. In the semi-arid northeast region of Brazil, forage cactus (*Opuntia ficus-indica*) was used as local cattle fodder as grazing systems are not possible for farmers who lack irrigation. After the Balde Cheio programme became familiar with this practice in the north east, forage cactus was trialled in São Paulo state with farmers who also lacked access to irrigation and obtained very good results. These examples of experimenting with practices in different contexts illustrate the continuous learning process which is a key feature of the Balde Cheio programme.

Networking also takes place by organizing exchange visits between farmers to discuss mutual problems in different situations of climate, soil, topography but with fundamental similarities in the social profile (family-based farmers and low resource endowment). Visits are preferably organized before the start of new trials on the farm so as to observe *in situ* the grazing management, new species of grasses or more productive cows. Another form of networking involves the exchange of information between local technicians and the Balde Cheio team by means of an e-mail social network and at annual meetings arranged specifically for this purpose. Both of these channels help to spread technological practices to other farmers and regions. For example, for several years Embrapa had recommended a particular design of shelter for calves adapted to tropical conditions (open-sided, doubled roof). This was adopted by many farmers across the country but the cost at approximately R$200 (US$ 120) each was too high for poor farmers. In 2006, farmers and technicians from the Paraná region developed an alternative shelter using natural shade (or a plastic cover) and a dog-collar and chain system that was more efficient, clean and cheap while still being comfortable for the calf. Knowledge of this innovation has spread via means of the network and many assisted farmers are gradually shifting to the new model. It is an innovation that might not have spread under a more conventional R&D and extension approach.

5.4.5 The rhythm of technology introduction: taking the farmer's pace into account

In the experience of Balde Cheio capital, or the lack of it, is not the main factor shaping technological innovation. At least as important is how and when new technological practices are introduced. We have already discussed above the how part of this equation so here the focus is on the when. The practice of carrying out small trials for the introduction of technology avoids the risk of misguided expensive investments in technology. The programme is alert to the dangers of prematurely introducing costly technology such as buying a more productive cow in cases where a well-managed grazing system to provide high quality fodder is lacking. Artificial insemination, a symbol of modern dairy farming, is almost never recommended until good reproduction indices have been achieved and a reliable process of rearing calves is in place. The programme considers that there are essential preconditions which shape the best logical sequence for each technology selected. What is recommended for one farmer may be entirely inappropriate for a neighbouring farm where the preconditions are not fulfilled, irrespective of the farmer's wealth, farm size, length of time participating in the project, or labour availability. Technicians interviewed mentioned how sometimes they had to curb the enthusiasm of farmers who wanted to implement immediately everything they had seen on other farms in the programme and persuade them to start with something that was better suited to their specific situation. Instead of simply copying and introducing technologies at speed, farmers have to engage in a slower learning process, which is adapted to the specific economic and environmental conditions of the farm. Learning from others (social learning) has to be coupled to experimenting on the farm (environmental learning).[37] The experience of farmers participating in the programme (Camargo, 2011; Rodrigues et al., 2006 and Chapter 4 in this volume) suggests that the sequence of technology introduction is often more important for a successful intensification process than the proposed technology itself.

In order to better capture the development model of the Balde Cheio programme we draw on the idea of a "gear box" to illustrate the sequential nature of technology introduction in dairy farming systems (Figure 1). This idea highlights how local farmer knowledge can be combined with and enriched by external concepts and development interventions. In the model, the selection of a specific set of practices informed by formal knowledge is applied as the first gear to shift the intensity of the system to a higher level and sequentially, other combinations of practices are used as the second gear and so on. The combination of external and internal drivers such as existing farmer knowledge and performance, the economic environment (market, relative price of inputs, availability of capital), labour and household conditions (organization of labour, life cycle, farmers' goals) and others (institutional arrangements, government policies) defines the rhythm and sequence of "gears" needed to achieve a viable pace

[37] On the problems of one-sided social learning, see Stone 2007.

for introducing technology. Feedback is provided by monitoring the effects of particular practices on many farms, giving information on the overall performance of the intensification process, any potential problems and where new research is needed.

The location of knowledge in the Balde Cheio programme does not adhere to the classical flow in which knowledge developed in the centre, in the research institute, is then transferred down to the user. Neither is it seen as arising from farmers' knowledge which is statically tied to one locality. Instead, knowledge is embedded in the whole programme, circulating and growing across the network.[38] Knowledge, skills and technical artefacts are distributed within the task-group, formed out of researchers, technicians and farmers involved in the Balde Cheio network, rather than being controlled by a single individual.

[38] This is a form of *distributed cognition* as discussed by Jansen and Vellema, 2011, and Richards et al., 2009.

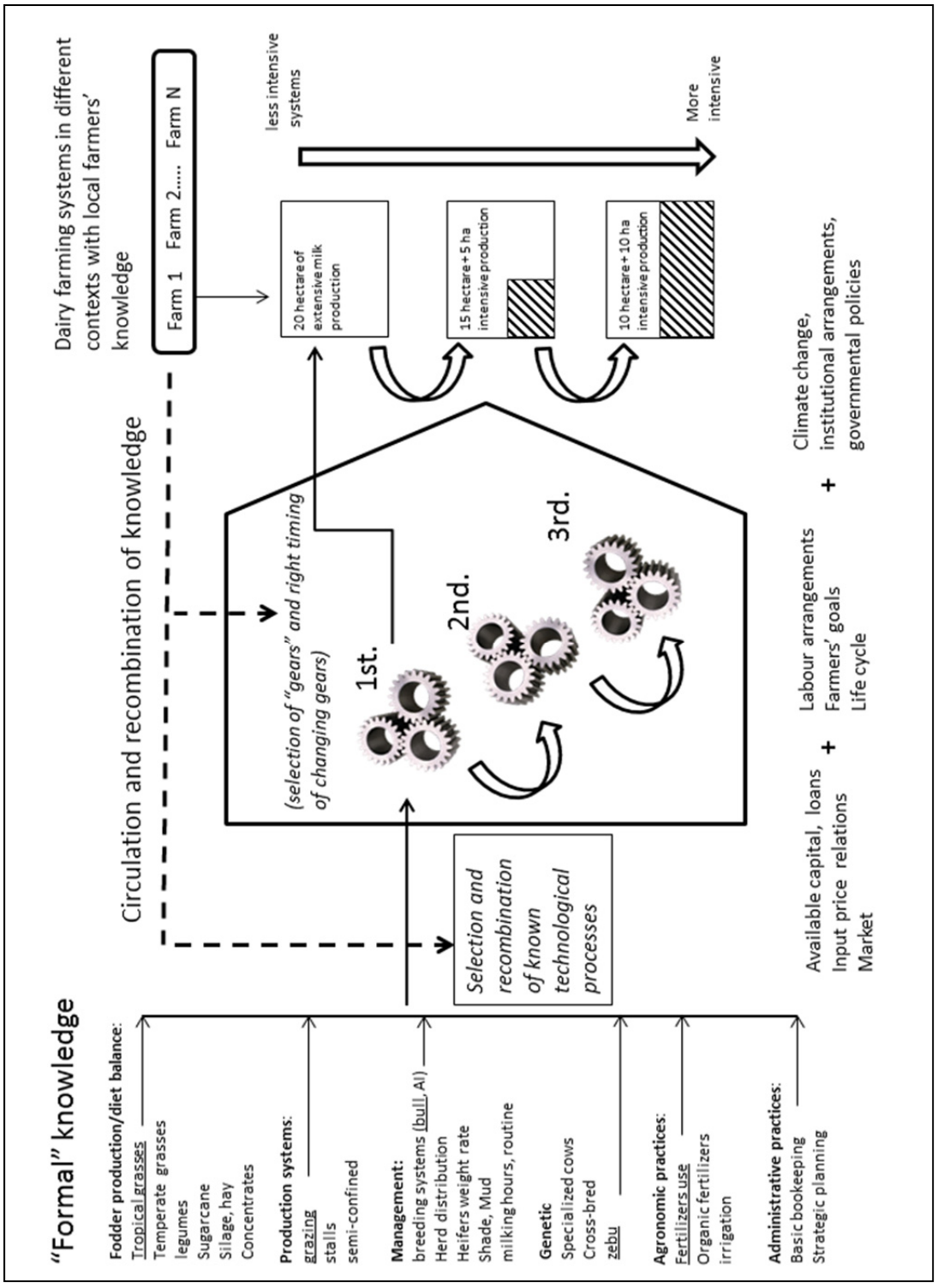

Figure 5.1. The gearbox model of the "Balde Cheio" programme.

5.4.6 Challenges and use by third parties of the Balde Cheio approach

While the Balde Cheio programme has achieved good technical and economic results in many regions (Chapter 3), the programme has not been without its difficulties. Here we discuss three major problems arising from the programme: the case of farmers who do not or cannot follow the ideal-type model, the misuse of the 'Balde Cheio' name, and the capricious nature of partnerships.

5.4.7 Farmers that do not or cannot follow the approach

Quite a few farmers rejected the practice of bookkeeping. As we have seen the programme regarded bookkeeping as a tool to improve decision-making, evaluate performance and to plan the intensification process. The programme often dismissed those farmers who failed to keep the books. Farmers did not often give very clear reasons for their failure as they generally tended to agree that it was important. The reason may lie not only in the time involved but that farmers are reluctant to put things down on paper because they lack confidence in the local technician and fear having their results exposed to others. Based on casual observations, and lacking any systematic data on this topic, we hypothesize that a decisive factor in ensuring acceptance of this practice is how a technician presents the task to farmers; whether the utility of bookkeeping is clearly explained or whether it is presented only as a formal requirement for participation in the programme.

In some cases farmers dropped out of the programme altogether. Here again, the role of the technician seems to be an important factor. Another reason relates to the length and slow pace of the learning process. The time perspective of the programme which can be seen as a strong point, significantly delays the achievement of technical and economic goals. On average, at least three years are needed to achieve good results in terms of profit/area or profit/labour force (Chapter 3). Those farmers who dropped out referred to the long time involved in attaining positive economic results (interviews with farmers that quitted in São Paulo state; interviews in July/August 2010). Some farmers withdrew after implementing a few innovations as they were satisfied with the results and did not see the point of further change.

5.4.8 The power of the 'brand' leads to misuse of the Balde Cheio name

An unforeseen side effect of the programme's success has been the appropriation of the Balde Cheio[39] "brand" by other parties (development foundations, banks, NGOs) involved in economic, social and political change. Although partnerships with other

[39] The initial name of the programme was very long (*Projeto de viabilização da pecuária leiteira e capacitação dos técnicos da extensão rural por meio do uso de uma pequena propriedade familiar de leite como "sala-de-aula*) and confusing in external communication. The shorter name 'Balde Cheio' was selected via a poll of assisted farmers and technicians.

actors have been essential for the programme's expansion and bear witness to its success, they have also given rise to new problems as interest groups adapt the programme to their own needs.

One example is the way in which business interests who participate in the programme redirect the emphasis towards making economic gains. Some dairy cooperatives and private industries support the programme by directly hiring trained technicians who adopt the same methodology with their own suppliers. Although avowedly aiming to promote the social development of small farmers by increasing milk volume per farm and improving the quality of raw milk, the focus is on profit-making rather than farm development. For example, one dairy cooperative, which had supported the programme and hired several technicians, introduced lower rates for the raw milk produced by assisted farmers. The executive board knew that such farmers were more efficient, had lower costs and appreciated the technicians' assistance. The cooperative used the programme to hold onto these farmers despite paying lower prices. The problem became public when the technical department of the cooperative (at that time formed by 32 technicians) vented their opposition, collectively resigned and founded a new cooperative which provided fair technical support to farmers and freedom of choice as to where they sold the milk (Rezende, 2010).

Dairy businesses may also forge a link with Balde Cheio for the purpose of creating an image of social responsibility (Jansen and Vellema 2004). These businesses are advertised as donors of the Balde Cheio programme in the technical media, such as magazines, newspapers and television programs, and their message of social concern for the development of small dairy farmers is publicised. By linking up with Balde Cheio they are also associating themselves with Embrapa, a strong and reliable brand across the country.

Another example of how the Balde Cheio name can be misused concerns the growing number of technicians across the country who present themselves as being part of the programme without having any official attachment. Some technicians follow a few short courses (for example on the standardized interpretation of soil analysis, fertilizer use, animal diet, or irrigation schemes) which are designed as part of the Balde Cheio's four year training programme. After receiving the short course certificate, some then claimed to be trained in the Balde Cheio approach, presenting a risk to small farmers as short theory courses fall far short of the full, long-term training programme.

5.4.9 Partnership arrangements and quality of technical assistance

The programme does not have full control over those technicians-extension workers who, whilst being trained in the programme, are under contract from one of the partners. In the case of some partners, where the local technician lacks a long-term contract, this can affect the operation of the programme. Technicians employed by government agencies of technology transfer, particularly those at state and federal

levels, generally have stable contracts (being part of the permanent staff). However they still work in a constraining environment: lack of coordination, little enforcement to deliver quality work, and the multiple tasks allocated to a single local technician (ranging from delivering information on all crops to being responsible for planning and settling farmers' loans and crop insurances). The main problem of municipalities supporting the programme is that they can only pay low salaries, which increases the turn-over of professional workers. Despite achieving excellent results, in part by the personal commitment of technicians to the programme, government extension services, both at state and municipal levels, face problems in supporting small dairy farmers in the long term.

5.5 Conclusions

This paper has analysed an innovatory programme to support family dairy farmers by intensifying dairy production. It has been successful in maintaining the viability of family dairy farming in the context of an expanding competitive sugarcane sector. We argue that a programme of this nature can help to remove the constraints on family dairy farming. This does not mean that intervention directed towards dairy intensification can always overcome the political and economic impediments to family farming, but it does mean that there are alternative development options for family farming. The programme provides several key lessons. First, it is possible for a research institute, such as Embrapa, that predominantly prioritizes knowledge development at the scientific frontier, to shift its focus to embrace impact-oriented programmes that support smallholders. Second, such a shift implies a departure from the classical transfer of technology model towards a joint learning approach. Balde Cheio is an example of how different forms of knowledge and skills can be widely circulated, supported by institutional arrangements, networking and the flexible application of relatively simple techniques. Third, the study shows that it is possible to adapt innovation to the high level of complexity found on local family farms while still adopting externally developed technologies. Key interrelated activities include closely observing variables at farm level and monitoring change (bookkeeping), conducting trials and experiments under actual farming conditions, intense networking among different types of actor, and adjusting to the farmer's rhythm of innovation. With respect to the latter, we drew on the concept of the "gearbox" as a useful metaphor. Finally, the Balde Cheio type of approach requires a commitment to fund the comprehensive, integrated and long-term training of technicians/extension workers and their work.

Chapter 6

General discussion and conclusions

6.1 Objectives of the study

This thesis aims to explore the main factors that influence the future of the family dairy farming in Brazil. It analyses the complex interface between the small scale dairy farming and a powerful and expanding agricultural activity: the sugarcane plantation. This chapter discuss how small family farmers' choices are affected by the increasing demand for local resources and how they react to the pressure on land. Can small farmers resist and adapt or will they disappear? Seeking for local responses and alternatives to the trend in an expanding biofuel economy or the tendency to move to the city, this research analysed the intensification process of smallholder dairy production in different regions. The analysis of the dynamics of the Balde Cheio programme provides insights into the interaction between technology, innovation and family farmers' needs at farm level. Based on specific findings discussed in the chapters, scenarios will be formulated on the potential of small scale dairy farming in Brazil.

6.2 Results of the thesis

6.2.1 What are the main influencing factors of changes? Is the recent biofuel boom responsible for the decrease of dairy farming in SP state?

The detailed historical analysis of the development of the industrial sugarcane activity alongside with the dynamics of the dairy and beef chains as described in Chapter 2, provided insights into the drivers of land use change in São Paulo state. The political and economic circumstances at different levels were analysed to go beyond biophysical explanations about how and why the local landscape intensively changed. I argue that the competition between agricultural chains resulted not only from the impact of the long-term governmental policies supporting the expansion of the sugarcane business but also from the internal dynamics of the dairy and beef chains. In the Brazilian situation, several drivers in different scales have played a relevant role in the replacement of pastures to sugarcane. One is the ever expanding milk frontier together with technological innovations (e.g. the UHT milk) allowing milk production to take place far from the centres of consumption where land was still cheap. Furthermore, price drops in raw milk and beef occurred after the deregulation process (the withdraw of barriers to international commerce of dairy products) and finally a concentration process took place in the dairy industry and the retail sector (similarly to the characteristics of food chain empires in other countries; Van der Ploeg, 2008). All these factors together provide a context in which dairy farming in São Paulo state became less competitive regardless the increasing strength of the biofuel economy. The recent demand for biofuels, presented as a powerful driver in the multi-scale

framework model, has a relative small role in the overall type, rate and direction of land use changes for this particular case.

The analysis at farm level (Chapter 3) provides evidences of a more complex set of interactions than just a competition between sugarcane and dairy farming. The comparison of different farm types reveals that labour availability, household resilience and technology introduction are the key factors for farmers' decisions. Remarkably, profit maximization (particularly the higher values from sugarcane leasing) is not the farmers' main goal whereas risks perceptions and labour organization at farm level are more decisive on farmers' choices regarding technology introduction, diversification or quitting farming by leasing land to sugarcane. In resume, combining the historical analysis of drivers in different levels (Chapter 2) and the analysis of farmers' responses to the competition at farm level (Chapter 3) I conclude that my initial assumption that the powerful industrial agri-business and the external demand for biofuels have been directly responsible for squeezing out dairy family farming is not valid in the Brazilian case. The expansion of the sugarcane and the demand for renewable sources of energy is only an additional factor that influences dairy farmers' choices because it altered significantly the opportunity costs of the land use, particularly in São Paulo state.

6.2.2 As sugarcane expansion is only one of the factors influencing farmers' choices, can it be viewed as a threat or an opportunity to dairy farmers?

Different farmers' strategies and resource endowments make the effects of the sugarcane contradictory and uneven. Leasing land to sugarcane may respond to farmers' needs due to the characteristics of labour alleviation, safety (less risks in terms of climatic events when compared to cash crops and the feature of capital protection in the herd) and monthly payment as stated during the interviews. Wealthier farmers with large available areas for renting can receive a reasonable amount of money due to the size of the operation. When the decision of leasing land is part of the process of quitting farming and living from the rent, the shift to sugarcane can be a 'one way road' where farmers cannot return to their former business because the entire productive infrastructure has been dismounted during the shift. For smaller farm sizes quitting farming is no option as the revenues will be insufficient to support the family living in the city. For both large and smaller size farms, sugarcane can support the conditions for intensification of family dairy farming. When only part of the land is rented to sugarcane, as a form of diversification, it offers a guaranteed extra income, fitting the rationale of resilience and lowering risks and uncertainties, and providing resources for the intensification process. For very small farm sizes neither option is feasible. The contrasting outcomes of the same process of renting land show that it is overly simple to conclude that sugarcane pushes out dairy producers as it clearly provides different opportunities to different dairy farming households. From this study

it follows that an evaluation of the potential outcomes of sugarcane for dairy farming households (as a threat or an opportunity) cannot rely on one-sided traditional profit maximization approach but should analyses the context and strategy by which the sugarcane is incorporated or rejected at farm level.

6.2.3 What else, beside sugarcane production, influences the small dairy farmers' choices?

This thesis revealed the importance of the urban influence in agricultural processes affecting farmers' choices and strategies (Chapter 3). Within the boundaries of São Paulo state, the strong economy of the medium-size cities play a relevant role in labour availability, which directly influences the production possibilities of the households. The attraction of alternative sources of work and income in urban areas creates shortages of rural labour, including the labour from family farm members, thereby affecting the decisions about dairy farming in the future. Hypothetically, the proximity with dynamic urban centres could be an opportunity for households by means of a growing market for local products. However, the dominance of large companies in the retail sector, has transformed the preferences of urban consumers (towards standardized products and global brands) and setback the role of small farmers in the local food supply chain. The dynamic urban economy affecting labour availability, at least in São Paulo state, is a clear example that the competition for resources goes beyond the limits of the rural space and that the proximity of urban centres potentially can be more decisive for the future of dairy family farmers than other agricultural commodity chains.

6.2.4 Is intensive milk production in family farming competitive when compared with other land uses and with the urban attraction?

The intensification of the productive processes on livestock was extensively studied as an alternative to smallholders to increase agricultural production with potentially good technical results across different countries (FAO, 2011; Herrero et al., 2010; MacDermott, 2010; Udo et al. 2011). In the Brazilian situation, it is possible to find some studies (Camargo, 2001; Tupy et al., 2002; Esteves et al. 2003); pointing at the potential of milk production particularly by family farmers but very few analyze if the intensification can be economically viable in the context of competition with sugarcane, soybean and the attraction of urban jobs.

To addresses these questions I have analyzed the Balde Cheio (Full Bucket) programme, an initiative of Embrapa South East Livestock Division. This programme aims to develop and adapt production processes and administrative tools for small dairy farmers and extension service technicians, widely spread in many regions across the country. The outcomes of this research indicate that the use of technology towards

intensive dairy production on small plots of land can be an alternative to family farmers, both technically feasible and economically competitive when compared with other options (Chapter 4). Remarkably, higher productivity was not obtained by a single technology but resulted from a combination of technological and administrative processes that altered many productivity indexes simultaneously. Farmers in the studied sample who joined the Balde Cheio programme reached high land productivity, equivalent to those observed in developed countries that employ more intense, sophisticated and highly specialized production systems. This was achieved through a large number of lactating cows/area, as a result of strategies that explore the high potential of dry matter production of tropical grasses, and not through achieving extremely high productivity per cow which is a typical strategy of non-grazing systems. The result of the Balde Cheio approach was that most of the participating dairy farmers reached higher revenues per hectare than could be obtained with sugarcane and soy production. They also generated higher income per labour force than the official minimum salaries in the city. Such findings can be understood as an evidence of the huge potential of dairy production in the tropics in the context of limited capital to investments, relative small areas and inserted in a competitive economic environment of the sugarcane industry and the growing urban economy of the Brazilian medium size cities.

6.2.5 What are the conditions that shape the technology introduction and innovation on family dairy farmers?

One major condition studied in this thesis is the supportive innovation environment of the study case of the Balde Cheio (Chapter 5). My analysis of the internal configuration of the programme exposes the challenges of an alternative method that fosters the intensification of family dairy farming systems. The specific processes of trialling, monitoring, adapting incremental solutions, networking and integrative research create a suitable environment to innovation at farm level. I concluded that the programme is not a simple technology transfer programme but has to be conceptualized as a long-term learning routine that engages research, development, extension service institutions and family farmers to facilitate technology introduction and intensification of dairy farming. I observed that, at least for the complex household dairy systems, the synchronized application of different strategic processes and the rhythm of introduction (schematically represented by a gear-box model) may be more relevant than the characteristics of individual technologies to obtain innovation at farm level. In resume, to achieve high levels of productivity and income to small households it is not necessary to develop high-tech solutions since the combination of organized actions, shared knowledge and commitment of all actors involved may bring better fitting alternatives to small family farmers in Brazil.

6.3 Scenarios

The evaluation of influencing factors at different levels, farmers' preferences and strategic choices allows us to hypothesize about the future of dairy and sugarcane interaction. The international market of sugar and ethanol and the availability of capital to invest seem to be important factors that shape how and how fast the sugarcane industry will grow. Considering a scenario of high global demand for cleaner energy, the sugarcane industry tends to invest in future expansion, within and beyond the São Paulo state. Furthermore, the internal demand for ethanol, resulting from the growing national economy, turns the country into an unprecedented importation of ethanol what reinforces high rates of expansion in planted area and production. Considering the long-term however, advances in other sources of clean energy such as hydrogen or even the feasibility of electricity to run cars may deeply modify the energy market, affecting the demand for land for this specific purpose. On the other hand, the flexibility to choose the destination of the final product (ethanol or sugar) and the co-generation of energy from bagasse and cellulose are important factors that may keep the important role of the sugarcane.

In dairy production, it is not simple to identify trends and the rhythm of changes due to the large diversity in farm types and their wide distribution in different agro-ecological conditions which lead to a large number of different specific local constraints. I foresee that smallholder dairy production may grow in regions where land is cheaper, where the opportunities for labour for alternative jobs are weak, and where there is no sugarcane competition yet. However, the same drivers that have modified the São Paulo landscape are becoming more important in other regions where not only the sugarcane planted area is growing fast but also the urban population is increasing. Therefore, the agrarian dynamics of frontier regions in the future may be modified by a similar substitution process of the highly efficient sugarcane industry over less competitive activities. When dairy farmers are not assisted in an intensification process many of them may quit farming and move to the cities.

6.3.1 Based on the outcomes of the intensification process towards small family farmers, what could be the scenarios for family dairy farming?

Different farm types were identified in Chapter 3, indicating different strategies regarding the land use and potentially different arrangements between the allocation of land towards dairy and sugarcane particularly in Southeast region. Plausible scenarios may vary considerably due to such diversity in farm strategies. Nevertheless the exploration of some specific situations might be useful to a better understanding of the size of the potential shifts in milk production and the evaluation of alternative futures of family dairy farming. In this chapter I selected two different approaches that will address these questions. The first one aims to give an indication of how much milk can be produced by family farmers, taking into account different trends in milk volume

after the intensification process as observed with farmers from the sample in Chapter 4. One trend considers a slight increase in productivity and another is based in more outstanding results. The second scenario takes into account not only the technical results but the main constraint to increase milk production: the organization of labour at farm level (see Chapter 3). We also explore in this scenario the alternative of intensification and diversification with other land uses.

Scenario 1: Amount of milk produced and economic feasibility based in two different trajectories of intensification.

Family farmers are responsible for 58% of the total diary production representing around 6.3 billion litres/year in 2010 IBGE (2006) in the Southeast region. Looking closer to different farmers´ trajectories in the Balde Cheio project, I will first consider the lowest trend represented by the line n.2 (in Figure 6, Chapter 4). After three years in the programme the milk volume increased 22% but showed no significant changes in land productivity due to use of extensive areas on the average farm. When all family farmers from the Southeast region would follow this trend, an additional 1.4 billion litres/year would be available (this extra volume corresponds to the whole production from Uruguay another important dairy producer in Latin America). Despite the impressive volume in absolute terms at regional level, the gains in income generation per farm would be very modest and insufficient as an economic alternative when compared to the sugarcane leasing option or the wage salary in urban jobs. For example, the initial productivity of 1800 kg/ha/year would increase to 2200 kg of milk/ha/year. If the average gross margin on milk production would be more or less similar to the farmers in the sample (R$0.30/litre) then the total value per unit of area would be around R$660/ha/year less than the sugarcane renting values for most regions in São Paulo state (see Figure 7 in Chapter 4). On the other hand, taking into account a more optimistic result, such as the average of farmers in the Balde Cheio programme in São Paulo state (Table 1 in Chapter 4) who three folded daily dairy production using the same area, the extra volume would be around 18.9 billion litres/year, 62% of the total national production in 2011 and a similar volume of New Zealand in the same year (Milkpoint, 2011). The income generation in the second case would be very attractive in economic terms by paying higher values than other land use opportunities. These scenarios are not easy to achieve and not likely to take place in a short-term period but they are helpful to understand the huge dimension of the hidden potential of intensifying family dairy farming in Brazil.

Scenario 2: Intensification when facing problems with labour availability

The second scenario is more accurate in terms of taking into account not only the technical results but also considering limitations on labour organization and labour

performance. On average, family farms from the sample worked with 2.1 people with a productivity of 160 litres/day/man after 3 years of intensification, thereby the potential volume per farm (limited by labour) would be around 340 litres/day/farm equal to ca. 120,000 litres/year. Considering the average land productivity of 11,880 l/ha/year (the average of farmers from all regions who stayed longer in the programme) the amount of land required to produce such volume would be around 10 hectares which is only half of the available area of the average farm (21.0 ha in the sample, close to the national average of 19.3 ha/family farm). This means that assisted family farmers who intensified the land use for dairy farming may produce two times more milk than the average initial volume using half of the area. The rest of the land might be available to diversification but with low labour demanding alternatives such as agroforestry (planting by themselves or renting to eucalyptus companies) or even the sugarcane leasing thereby increasing income and resilience (similarly to the case of farmer n. 27 in Chapter 3). Furthermore, by providing a better livelihood using less land, family farmers could follow the new environmental rules (which define a legal reserve in every farm by preserving natural vegetation on marginal areas of rivers, streams and high slopes, but reducing the available area for agriculture) without compromising their livelihood.

6.3.2 If intensive dairy farming is competitive with urban wage jobs, can the migration process to the city be reduced?

Better technical outcomes obtained by the best farmers in the sample, specifically on land productivity (as expressed by the trends of n.3 and n.5 in Figure 6, Chapter 4), would make available more land for diversification options and consequently higher income per area and per family member. When analysing the economic results obtained per family member (particularly of farmers 41 to 49 in Figure 8, Chapter 4 - in this case only from milk production) - we can note that intensive dairy farming can be much more attractive than the average urban salaries. Nevertheless, the decision to find a job in urban areas is not always driven by economic motivations and notions of long-term survival of the family farm. During the field work, some farmers mentioned problems in the succession process due to the withdrawal of their sons and daughters despite good profit by intense dairy farming. In the city, young people seek for social relationships (fun, marriage) and for better educational opportunities such as technical schools or universities. The increasing income per household provided by better farming makes it possible to pay private schools and training courses, thus facilitating better jobs in the future and subsequently a potential reduction of labour force at farm level. In a context of economic expansion as observed nowadays in Brazil, seeking jobs in the medium size cities of São Paulo state is not a big challenge for those who have some qualification due to the very low unemployment rate.

However, a reverse movement is also taking place. In Chapter 3 I identified absentee farmers that invested their revenues from their city jobs in a dairy farm,

appointing a manager but not actually living there. Some did it as investments with the objective to make a profit while others were more interested in having a leisure farm to spend the weekends. In the latter case dairy production was the preferred activity to make up for the costs of maintaining the farm. I also identified family dairy farms that were managed by pensioners that worked in the city before but came back to the country side. Several of them participated in the Balde Cheio programme, mainly aiming for innovations that reduce labour requirements. Thus, the scenario of intense milk production on small areas might be an alternative to a large number of families and their future generations to stay in the farm obtaining higher income and quality of life instead of going to town. It may also facilitate those that want to invest in farming next to or after having a job in the city, facilitating repopulation of the countryside.

6.4 Final conclusions

This research exposed a more complex context of competition than simply the influence of a powerful large scale way of farming such as the sugarcane industry on family dairy farmers' decisions. The organization of labour within the farm and the family is one of the most important factors that definitively shapes how and when farmers quit dairy and decide to rent the farm. The labour laws and the urban demand for labour had high impact on dairy farmers' choices. Nevertheless, even in the context of increasing opportunity costs for land and labour and competition for local resources, like those created by other commodity chains and by the urban attraction, it is possible for family farmers to be competitive if there are conditions for sustainable intensification of the productive processes. Critical issues of these conditions are circulation of knowledge, seeking novelty in the re-combination of apparently simple and known technologies, on farm experimenting and adapting to the rhythm of innovation to the farm specific situations. At national level, the impact of increasing dairy production from family farmers can shift the country to a position of dairy products exporter alongside opening an important source of income and a better future for small dairy farmers.

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Summary

The future of family farming is a matter of debate, especially because of the far-reaching economic and political changes that are occurring. One vision is that family farms will disappear because they are less efficient than large-scale industrial farming enterprises. Others foresee that they will survive, due to their ability to resist external forces and adapt their internal processes. The recent increase in worldwide demand for biofuels is changing economic and social relationships in many rural areas by creating potentially competing claims on natural resources. The huge Brazilian sugarcane industry, one of the most efficient in the world, has expanded enormously, replacing pastures. This thesis studies the (differential) impact that the increasing area of sugarcane has had on family dairy farmers in São Paulo state and the various drivers at different levels that influence land use and, therefore, the future of these farmers. Historical changes in land use, production technologies, and product and land prices are described, together with how these are linked to changing policies in Brazil. The study analyses how dairy farmers, with different rationales and resource endowments, react to the increased competition from sugarcane for land and labour. It shows that farmers have different options and strategies when considering leasing their land for sugarcane production. It also looks at local responses and alternatives to this trend and has found that intensifying small-scale dairy production holds potential for increasing the income and quality of life of small-scale farming households.

The research reveals that the increasing competition between milk production and sugarcane is not only the result of long-term governmental policies that support the expansion of the sugarcane business. It is also related to the internal dynamics of the dairy and beef chains. In the Brazilian case, different drivers (at different scales) have played an important role in the replacement of pastures by sugarcane. One factor is the ever-expanding milk frontier, which has been driven by technological innovations (e.g. UHT milk). Other factors include the price fluctuations in raw milk and beef that occurred after deregulation and the concentration that has occurred in the dairy industry and the retail sector. The study concludes that the expansion of sugarcane needs to be understood in the context of the dynamics of other agricultural sectors and the long-term national political economy rather than being seen solely as the result of recent increases in global demand for biofuel.

At the farm level, the study identified a more complex set of interactions than merely a competition between sugarcane and dairy farming. The comparison of different farm types reveals that labour availability, household resilience and technology introduction are the key factors influencing farmers' decisions. The proximity of cities that offer more attractive jobs and provide schooling opportunities for farmers' children is largely responsible for the labour shortages in family dairy farming. The effects of sugarcane expansion are contradictory and uneven according to the different strategies and resource endowments of farmers. Leasing land to sugarcane may be attractive to farmers as it reduces labour load and risk while guaranteeing a monthly income. On the other hand, farmers who abandon dairy production and totally

rent to sugarcane may be entering a 'one way street': once the infrastructure is dismantled, they cannot return to their former business. Nevertheless, when only part of the land is rented to sugarcane as a form of diversification, this can offer a guaranteed extra income, fitting the rationale of resilience, lowering risks and uncertainties, and providing resources for investing in intensification. Neither option is feasible for very small farms due to the size of their operation.

This thesis went on to examine the option of dairy intensification as promoted by the *Balde Cheio* programme. The study of this programme provides insights into the interactions between technology, innovation and family farmers' needs. It looks at a sample of farmers who joined the *Balde Cheio* programme and attained high land productivity, equivalent to that observed in developed countries that employ more intense, sophisticated and highly specialized production systems. The higher productivity was due to a combination of more lactating cows per unit area (31%), higher productivity per cow (24%) and better labour performance (37%) while using less land area (-7%). The gross margin per unit area almost doubled even though milk prices only increased by 7%. This was achieved through having a large number of lactating cows per unit area as a result of strategies that make use of the high potential for dry matter production of tropical grasses, (rather than through achieving extremely high productivity per cow - a typical strategy of non-grazing systems). These intensified milk production systems yielded an average of R$3,000/ha, which is highly competitive with R$600/ha for sugarcane leasing and R$700/ha for soybean production. The average values in terms of income per family member were also very competitive in comparison to average urban wages.

This research continued by analysing how such changes in the productive processes took place at the level of the family dairy farm. The examination of the internal dynamics of the *Balde Cheio* programme reveals several lessons for family farmer oriented research, development and extension. For example, it shows that it is possible to attain high levels of productivity and outstanding economic results without expensive 'cutting-edge' technologies but with an intense circulation of different forms of knowledge and skills supported by institutional arrangements, intense networking among different types of actors and the flexible application of relatively simple techniques. Other processes applied included trialling/experimenting under real farming conditions and adjusting to the farmer's rhythm of innovation. These processes have narrowed the gap between 'the scientific frontier' – the advanced research orientation of the governmental research institutes – and the realities experienced by small dairy farming systems. The results show that, despite the increasing opportunity costs for land and labour and competition for local resources (created by other commodity chains and the attraction of urban areas), it is still possible for family dairy farmers to be competitive if they are supported to sustainably intensify their production processes.

Samenvatting

De toekomst van agrarische familie bedrijven is onderwerp van veel debat vooral in relatie tot verregaande economische en politieke veranderingen die plaats vinden. Eén visie is dat familie bedrijven zullen verdwijnen omdat ze minder efficiënt zouden zijn dan grootschalige industriële boeren bedrijven. Anderen voorzien dat ze zullen overleven dankzij hun capaciteit om externe krachten te weerstaan en hun interne processen aan te passen. De recente toename in de wereldwijde vraag naar duurzame biobrandstoffen verandert de economische en sociale relaties in landelijke gebieden door het creëren van potentieel concurrerende aanspraken op natuurlijke hulpbronnen. De enorme Braziliaanse suikerriet industrie, één van de meest efficiënte ter wereld, vertoont een enorme expansie in areaal ten koste van weidegronden. Dit proefschrift bestudeert hoe de uitbreiding van het suikerriet areaal in de staat Sao Paolo de melk producerende familie bedrijven beïnvloed heeft en welke drijvende krachten op verschillende schaalniveaus leiden tot verandering in landgebruik en daarmee ook in de toekomst van deze boeren. Historische veranderingen in land gebruik, productie technologie en prijzen van producten en land worden beschreven, evenals hoe deze gekoppeld zijn aan veranderend beleid in Brazilië. De studie analyseert hoe melkvee bedrijven, ieder met hun eigen logica en hulpbronnen, reageren op de toenemende concurrerende aanspraken van de suikerriet producenten op land en arbeid. De studie laat zien dat boeren verschillende opties en strategieën hebben ten aanzien van het verhuren van land voor de productie van suikerriet. Daarnaast gaat deze studie op zoek naar lokaal specifieke reacties en alternatieven voor de trend richting de biobrandstof economie. Vanuit dit perspectief analyseert deze studie een intensivering proces voor melk productie op kleine familie bedrijven, met als doel het huishoudinkomen en de kwaliteit van leven te verhogen.

Het onderzoek heeft uitgewezen dat de toenemende competitie tussen melk en suikerriet productie niet slechts het resultaat was van lange termijn beleidsprocessen die de suikerrietsector ondersteunden. De competitie hangt ook samen met de interne dynamiek in de melk en rundvlees sector. In Brazilië zijn drijvende krachten op verschillende schaalniveaus van belang voor de vervanging van weidegronden door suikerriet. Eén factor is de steeds meer naar het noorden opschuivende grens voor melkproductie, sterk samen hangend met technologische innovaties (zoals UHT melk). Andere factoren zijn onder andere de prijsfluctuaties in melk en rundvlees nadat de regering stopte met prijsregulatie en de grote concentratie in de zuivel industrie en Retail sector. De conclusie van het onderzoek is dat de suikerriet expansie begrepen moet worden in de context van de dynamiek in andere agrarische sectoren en het lange termijn politiek-economische beleid van de nationale overheid en niet zozeer als uitsluitend het resultaat van de recente toename in de wereldvraag naar biobrandstoffen.

Op bedrijfsniveau identificeert de studie een meer complexe set van interacties dan slechts de competitie tussen suikerriet en melk productie. De vergelijking van diverse bedrijfstypen laat zien dat beschikbaarheid van arbeid, veerkracht van huishoudens en

introductie van technologie belangrijke factoren zijn voor boeren besluitvorming. De nabijheid van steden met hun aantrekkelijke aanbod aan werkgelegenheid en aan opleidingsmogelijkheden voor kinderen van boeren bedrijven is grotendeels verantwoordelijk voor een gebrek aan arbeid beschikbaarheid in het boeren bedrijf. Verschillende in boeren strategieën en beschikbare hulpbronnen leiden ertoe dat de opties gerelateerd aan suikerriet voor boeren bedrijven contrasterend uit kan pakken. Het verhuren van land aan suikerriet bedrijven kan een oplossing kan zijn voor het arbeidsprobleem, risico verlagen en de zekerheid bieden van een regelmatig inkomen. Anderzijds betekent het stoppen met melk productie en het verhuren van het totale areaal aan suikerrietproducenten, een eenrichting weg, omdat alle infrastructuur ontmanteld moet worden hetgeen een terugkeer naar melk productie verhindert. Echter wanneer slechts een deel van het land aan suikerriet verhuurd wordt, als vorm van diversificatie, levert dit een gegarandeerd extra inkomen op, passend bij de logica van veerkracht en verlaging van risico's en onzekerheden, en voorziet het in fondsen voor investeringen in intensivering van de melkproductie. Voor hele kleine bedrijven is geen van de geschetste mogelijkheden een optie omdat hun bedrijf te klein is.

Als alternatieve vorm van agrarische productie is de intensivering van melkproductie onderzocht zoals gepromoot door het Balde Cheio programma. De studie van dit programma levert inzichten op in de relatie tussen technologie, innovatie en de behoeften van familie bedrijven. De studie bekijkt een steekproef van boeren die deelnamen aan Balde Cheio programma en die hoge productie per hectare behaalden, equivalent aan producties in ontwikkelde landen waar deze echter behaald worden met meer intensieve en hoog gespecialiseerde productie systemen. De toename in productie bleek gebaseerd op een combinatie van meer melkgevende koeien per hectare (31%), hogere productie per koe (24%), hogere output per arbeidskracht (37%) en gebruik van minder land (-7%). De bruto inkomsten per eenheid land verdubbelden hoewel de melkprijs slechts 7% toenam. Dit werd vooral bereikt door grote aantallen melk koeien per ha, als gevolg van de strategie om de hoge droge stof productie van tropisch grasland te benutten. Dit staat in scherp contrast met het streven naar extreem hoge productie per koe, een strategie die typerend is voor een systeem dat niet op begrazing is gebaseerd. De geïntensiveerde melk productie leverde gemiddeld 3000 Braziliaanse Reais per ha op wat sterk concurrerend was ten opzichte van opbrengsten uit verhuur aan suikerriet bedrijven met een opbrengst van 600 Reais per hectare en het verbouwen van soja bonen wat 700 Reais per hectare oplevert. De gemiddelde inkomsten per familielid in intensieve melk productie waren ook hoog vergeleken bij gemiddelde lonen in de stad.

Dit onderzoek analyseert verder hoe dergelijke veranderingen in de productie plaats vonden in het melk producerende familie bedrijf. De analyse van de interne dynamiek van het Balde Cheio programma leverde verschillende lessen op voor onderzoek, ontwikkeling en voorlichting gericht op familie bedrijven. Het is bijvoorbeeld mogelijk om hoge productie niveaus en goede economische resultaten te behalen zonder toepassing van de nieuwste technologieën maar met intensieve circulatie van verschillende vormen van kennis en kunde ondersteund door institutionele

arrangementen, intens netwerken tussen verschillende actoren en een flexibele toepassing van relatief eenvoudige technieken. Andere activiteiten waren het experimenteren onder boeren omstandigheden en het aanpassen aan het innovatie ritme van de boer. Deze processen samen hebben het gat verkleind tussen de uitersten van de wetenschapsbeoefening, de oriëntatie van de onderzoeksinstituten van de overheid op grensverleggende wetenschap en de realiteit van kleine melk producerende familie bedrijven. Uiteindelijk is aangetoond dat het, ondanks de context van toenemende opportunity kosten van land en arbeid en de concurrerende aanspraken op natuurlijke hulpbronnen, zoals deze uitgeoefend worden door diverse productie ketens en de aantrekkingskracht van de steden, toch mogelijk is voor melk producerende familie bedrijven om concurrerend te zijn indien er ondersteuning is voor duurzame intensivering van het productieproces.

Sumário

O futuro da produção familiar é um assunto intensamente debatido, em particular pelas amplas mudanças econômicas e políticas atualmente em curso. Uma das principais visões sobre o tema alega que a produção baseada nos moldes familiares irá desaparecer por ser menos eficiente do que o modo industrial de produção em larga escala. Outros preveem que a produção familiar irá sobreviver devido a sua habilidade em resistir a forças externas e de adaptação de seus processos internos de produção. O crescimento da demanda mundial por biocombustíveis tem alterado as relações econômicas e sociais em diversas áreas rurais pela criação de demandas conflitantes sobre os recursos naturais. A indústria da cana-de-açúcar no Brasil, uma das maiores e mais eficientes do mundo, tem demonstrado uma expansão gigantesca, na sua maior parte substituindo pastagens. Esta tese estuda os diferentes impactos da crescente área de cana-de-açúcar sobre produtores familiares de leite no Estado de São Paulo assim como avalia outros fatores em diferentes níveis que influenciam o uso da terra e consequentemente o futuro destes produtores. Nesta tese serão descritas as mudanças históricas no uso do solo, as tecnologias de produção, as alterações nos preços da terra e dos produtos juntamente com a avaliação de como estes estão conectados às mudanças de políticas públicas no Brasil. O estudo analisa como os produtores de leite, de diferentes níveis de capitalização e formas de racionalização, reagem à crescente competição da cana-de-açúcar por terra e trabalho. O presente trabalho também avalia as alternativas locais a esta tendência e indica que a intensificação da produção em pequenas áreas tem potencial para o crescimento da renda e da qualidade de vida de pequenos produtores rurais.

A pesquisa revela que a crescente competição entre produção de leite e a cana-de-açúcar não resulta unicamente das políticas de longo prazo que sustentaram a expansão do negócio canavieiro. O processo também se relaciona com as dinâmicas internas das cadeias de leite e de carne bovina. No caso brasileiro, diferentes fatores (em diferentes escalas) tiveram um papel importante na substituição de pastagens por cana-de-açúcar. Um destes fatores é o crescimento da fronteira na produção de leite, em razão de inovações tecnológicas, como por exemplo, a introdução do leite longa-vida. Outros fatores determinantes neste processo incluem variações de preços ao produtor que ocorreram depois da desregulamentação e concentração que ocorreu na indústria leiteira e também no setor dos grandes supermercados. O estudo conclui que a expansão canavieira deve ser entendida no contexto da dinâmica de outros setores agropecuários e das políticas nacionais de longo prazo ao invés de ser entendido somente como resultado das recentes demandas globais por biocombustíveis.

Considerando agora no âmbito da propriedade rural o estudo identificou um conjunto de interações bem mais complexo do que simplesmente a competição entre leite e cana-de-açúcar. A comparação de diferentes tipos de produtores revela que a disponibilidade de mão de obra, resiliência da família e introdução de tecnologia são os fatores-chave que influenciam as decisõess dos produtores rurais. A proximidade com os centros urbanos, que oferecem melhores oportunidades de emprego e educação

para os filhos dos produtores, é largamente responsável pela redução da disponibilidade de força de trabalho nas propriedades familiares. Os efeitos da expansão da cana-de-açúcar foram identificados como contraditórios e desiguais dependendo das diferentes estratégias e recursos de capital dos produtores rurais. O arrendamento das terras para a indústria canavieira pode ser uma opção bastante interessante, pois reduz a carga de trabalho e risco, enquanto garante uma renda mensal. Por outro lado, produtores que abandonam a produção de leite e arrendam totalmente suas terras para a cana-de-açúcar podem estar entrando em uma "via de mão única"; uma vez que a infraestrutura é desmontada, dificilmente eles retornam a sua atividade original. Contudo, quando somente parte das terras são destinadas a cana-de-açúcar (como forma de diversificação) a mesma opção do arrendamento pode oferecer uma renda extra, ajustando-se na racionalidade de resiliência, reduzindo custos e incertezas e provendo recursos para investimentos na intensificação. Para propriedades muito pequenas nenhuma opção de arrendamento é viável devido ao tamanho da operação.

Esta tese continuou pelo exame da opção de intensificação da produção leiteira nos moldes do Projeto Balde Cheio. O estudo de tal programa trouxe novas visões sobre as interações entre tecnologia, inovação e as necessidades dos produtores familiares. A partir de uma amostra de produtores que ingressaram no programa Balde Cheio foi possível observar que vários atingiram alta produtividade da terra, equivalente às obtidas em países desenvolvidos que utilizam sistemas de produção mais intensos, sofisticados e altamente especializados. A alta produtividade da terra foi obtida pela combinação de mais vacas em lactação por hectare (31%), maior produtividade por vaca (24%), melhor desempenho do trabalho (37%) enquanto utiliza menos terra (-7%). A margem bruta por unidade de área quase dobrou apesar dos preços do leite terem aumentado apenas 7%. Tal resultado foi obtido pelo grande número de vacas em lactação por unidade de área resultante de estratégias que se utilizam do alto potencial de produção de matéria seca das gramíneas tropicais e não por meio de elevada produtividade por vaca, estratégia típica de sistemas de produção estabulados. Sistemas intensificados de produção de leite baseados em sistemas de pastagens renderam em média R$ 3.000/ha, valor bastante competitivo quando comparado com R$ 600/ha do arrendamento para cana-de-açúcar e R$ 700/ha para produção de soja. Os valores médios em termos de renda por membro ativo da família foram também muito competitivos quando comparados à média dos salários dos empregos urbanos.

A pesquisa analisou ainda como as mudanças no processo produtivo ocorreram no âmbito de propriedades produtoras de leite de cunho familiar. O exame das dinâmicas internas do Programa Balde Cheio revela diversas lições para a pesquisa, desenvolvimento e extensão direcionadas ao produtor familiar. Por exemplo, demonstra-se que é possível atingir-se altos níveis de produtividade e excelentes resultados econômicos sem utilização de sofisticações e vultuosos investimentos, mas sim pela circulação intensa de diferentes formas de conhecimento e habilidades suportadas por arranjos institucionais, intenso trabalho em rede entre diferentes tipos de agentes e a aplicação flexível de técnicas relativamente simples. Outros processos

utilizados incluíram treinamento e experimentação em condições reais de produção e o ajuste da introdução de inovações ao ritmo de cada produtor de leite. Estes processos reduziram a distância entre a "fronteira científica" – a orientação para pesquisas avançadas de institutos de pesquisa governamentais – e as realidades dos sistemas de produção de pequenos produtores familiares de leite. Os resultados demonstram que apesar dos crescentes custos de oportunidade da terra e da mão-de-obra e a competição por recursos produtivos locais (originados por outras cadeias agropecuárias e a atração das áreas urbanas) é ainda possível para produtores familiares de leite ser competitivos se tiverem apoio para intensificar de modo sustentável seu processo de produção.

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To EMBRAPA, for funding and allowing that analysts, and not only researchers, follow a high level PhD programme for the first time. I´m sure that such investment will make stronger the link between farmers, the domain of science and the field of innovation.

I consider it an honor to be guided by Ken Giller, Kees Jansen and Maja Slingerland. Beyond our professional connection, we´ve built a fruitful friendship among us. Maja, your clarity of thinking and lots of passion in whatever you do motivated us all. Thank you very much!

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To my parents, Maria Helena and Siegfried, my sister Ana Carolina as well as my ancestors Eulália, Júlio, Luiz Carlos and Irseo. To our extended family in Brazil (Mila, Eveline, Milena and José Cesar) and our Brazilian family in Holland (Murilo, Fábio, Gustavo). To all my colleagues from WUR (teachers, employees and students from several countries) and Embrapa (particularly the 'musketeers' Fernando Mendonça and Marcos Bergamaschi). To my academic supervisor, Oscar Tupy, for his comments during the thesis and to Waldomiro Barioni for the statistical support. To all farmers and technicians from the Balde Cheio Programme.

I dedicate this Thesis.

Curriculum Vitae

André Luiz Monteiro Novo, was born in Ribeirão Bonito, Brazil in 1963. He is the son of Luiz Carlos (doctor) and Maria Helena (teacher), is married to Denise, father of Érica and Aline and grandfather of Lucca. André has grown up in São Paulo city and concluded his secondary education in 1981 at Liceu Pasteur. He completed his bachelor degree in Agronomy in the University of São Paulo (at "Escola Superior de Agricultura Luiz de Queiróz", in Piracicaba) in 1986. In the same year André attended a course in intensive dairy farming in Tel Aviv, Israel. In the university, André met two of the most inspiring professors in animal production and tropical grasses management (Prof. Vidal Pedroso de Faria and Prof. Moacyr Corsi) who encouraged mostly his career on the huge potential of dairy and beef production in the tropics. After his graduation, André worked for two years in CATI (Coordenadoria de Assistência Técnica Integrada, a governmental extension service organization) with sugarcane and cotton production, farm insurance and technical assistance to small dairy farmers. He continued his experience with extension working as a private consultant in dairy, maize, hay production and beef farms for another two years. From 1990 to 1994 André worked in a dairy cooperative (Cooperativa de Laticínios de São Carlos) affiliated to a big central cooperative (Leite Paulista) assisting dairy farmers.

In 1994, a shift in his carrier took place by his admittance to the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) not as a researcher but as part of the staff of the communication and business department, getting closer to the reality of research and development of technologies, practices and products in a governmental research station (Embrapa Pecuária Sudeste in São Carlos, SP). Among other things, André was responsible for organizing meetings and training courses for farmers, linking research with extension service technicians, beef and the dairy productive sector. The close proximity with farmers and their problems motivated André to study the conflicting relationships between farmers and the dairy industry, particularly during a turbulent period of the dairy sector in Brazil at the end of the 1990s. In 2001, André defended his MSc dissertation entitled "Evaluation of Private Programmes of Technical Assistance in the Dairy Sector: a Case Study of the Parmalat Technical Department" in the Department of Productive Engineering of the Federal University of São Carlos. After the MSc. training André returned to EMBRAPA where he was responsible for the dairy production system of the Embrapa Pecuária Sudeste (for two years) and joined the staff of the Balde Cheio programme until 2008. Since then André studies in the Plant Production Systems group particularly with the Competing Claims on Natural Resources Programme a cooperative action between Wageningen University and EMBRAPA. After his studies, André will return to his former job helping to organize and to bring closer the available knowledge to farmers and technicians in Brazil.

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List of publications

Scientific papers:

André Novo, Kees Jansen, Maja Slingerland, Ken Giller, Biofuel, Dairy production and Beef in Brazil: Competing Claims on land use in São Paulo state. Journal of Peasant Studies, 2010. 37, 769 – 792.

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Novo, A.L.M (2011). Qual o problema de ser "grande"? Coluna "Observatório". Mundo do leite, 46, 22.

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Novo, A.L.M. (2012). Sobre vacas e bicicletas. Coluna "Observatório". Mundo do leite, 54, 17.

Novo, A.L.M. (2012). Sistemas de produção de leite e futebol. Coluna "Seguindo em frente". Mundo do leite, 55, 66.

PE&RC PhD Education Certificate

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Review of literature (6 ECTS)
- Development of farming systems for milk production as an alternative to sugarcane in the Brazilian Cerrados (2008)

Writing of project proposal (4.5 ECTS)
- Development of farming systems for milk production as an alternative to sugarcane in the Brazilian Cerrados (2008)

Post-graduate courses (5 ECTS)
- Seamless course: integrated assessment of agriculture and sustainable development; Seamless PE&RC (2008)
- Scaling and governance course; IPOP-PE&RC (2009)
- Experiment: workshop on experimental methods in social science and interdisciplinary research; WGS (2009)

Laboratory training and working visits (2.1 ECTS)
- Economic procedures for dairy farming; ESALQ-USP, Brazil (2009)

Deficiency, refresh, brush-up courses (6 ECTS)
- Quantitative analysis of cropping and grassland systems (2009)

Competence strengthening / skills courses (1.8 ECTS)
- Personal assessment; PE&RC (2008)
- Scientific publishing; PE&RC (2009)
- Moral dilemmas in daily scientific practices; WGS (2011)

PE&RC Annual meetings, seminars and the PE&RC weekend (1.5 ECTS)
- PE&RC Weekend (2008)
- PE&RC Day: selling scientific why and how scientists sell science (2010)
- WASS Day: challenges of multidisciplinary research (2011)

Discussion groups / local seminars / other scientific meetings (7.1 ECTS)
- Biofuel discussion group (2008-10)
- Technology and agrarian development group (2008-10)
- Scale and governance meetings and discussions (2010-12)

International symposia, workshops and conferences (6.3 ECTS)
- Strategic conference Brazil: EU sustainability requirements, a challenge for Brazilian ethanol? Shell, The Hague, the Netherlands (2008)
- Workshop on biofuels, land and agrarian change; with presentation; St. Mary University, Halifax, Canada (2009)
- Pan-American congress on dairy production; poster; Belo Horizonte, Brazil (2010)
- Scaling and governance conference; with presentation; Wageningen, the Netherlands (2010)

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