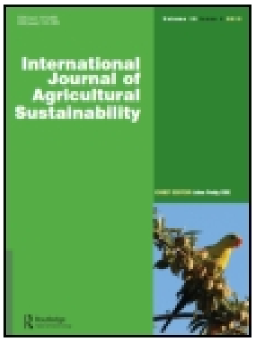

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The novelty of simple and known technologies and the rhythm of farmer-centred innovation in family dairy farming in Brazil

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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 family dairy farming sustainable 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. This paper characterizes this farmer-oriented innovation programme for 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. The study relates 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 as the critical issues to achieve sustainable production systems.

Keywords: family dairy farming; researcher–farmer relations; technological innovation; sustainability

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 (Novo 2012). 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 communities, 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 sustainable 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

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3000 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% 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 (Novo *et al*. 2013). 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. One of the authors of this paper worked for the programme from its outset in 1999 until 2008 and was 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 paper discusses how the Balde Cheio programme evolved out of a critique of conventional and unsustainable R&D and extension. We characterize the participating farmers and examine the effects of the programme on milk production and gross margin per area. The third section discusses the key elements of the Balde Cheio programme that were seen as essential for fostering innovation in 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 the 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.

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 and 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 and 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 (Pinheiro *et al*. 1997) 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 the 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 tend 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 or 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, 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 the 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 and 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, the so-called stakeholder involvement in research planning, as undertaken in the 1990s, excluded farmers. For example, in the case of dairy farming, Embrapa attempted to reshape the national research programme, firstly 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 the 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 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 2005). 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. In addition, the vast majority of the almost 900,000 Brazilian dairy farmers cannot afford such a package, emphasizing the gap between the R&D system and the reality of family farmers.

In Brazil, a major channel for technology transfer to dairy farmers is through talks given by researchers to farmers in the local communities (Souza *et al*. 2011). The limitations of such shallow extension programmes for family farmers are made clear in the following instructive event which illustrates the lack of fit between the training provided and farmers' needs. 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 and 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 in your own place. (Figueiró 2011)

This farmer's words implied that the family farmer-oriented but otherwise traditional form of extension programme did not work. This kind of criticisms was not uncommon and inspired a network of extension workers and researchers to set up an alternative form of technological innovation that would work more closely with dairy farmers. This would become the 'Balde Cheio' programme.

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 indexes. The objective of increasing income by introducing technologies at the 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. Firstly, 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. Secondly, working with family-based farmers instead of wealthier farmers (who employ labour) was more efficient. 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 because they encountered problems in applying the changes proposed owing to the lack of adequate management within the farm. Thirdly, while in its existing form the programme could not guarantee long-term assistance, and 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. Firstly, 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 adjusted to the local environmental conditions. 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 the 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 2012, more than 3800 farmers were assisted in 24 states of Brazil. In that year 535 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, non-governmental organizations (NGOs), municipalities, funding agencies (Banco do Brasil Foundation) and development agencies. 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.

Contribution of the Balde Cheio programme to the sustainability of farming

In this section, we investigate the programme's impact on dairy production and its contribution to sustainable farming. 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 (Novo *et al*. 2013). The existing data of all farmers in São Paulo ($n = 58$) who joined the first phase of the programme were analysed and the dataset was complemented by field visits and telephone calls to explore the households' profiles. Ninety-two percent of the farmers participating in the Balde Cheio programme 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 and only one-third of the farmers have off-farm income, which is on average less than the minimum wage. Table 1 summarizes characteristics of farmers and their milk production before the innovation process in São Paulo state.

The increase in milk production on those farms participating in São Paulo state illustrates the potential of the Balde Cheio approach. On average the volume of milk increased by 2.3 times (from 113 to 260 l/day) at a time when milk production in general tended to decline in the same region (−8% between 2003 and 2009). The competition for land, mainly for sugarcane

Table 1. Farm characteristics at the outset of the Balde Cheio programme in São Paulo state.

	Area dairy [a] ha	Off-farm income R$/year	Family labour Person	Hired labour days/year	Number of cows Number
Mean	16.4	1703	2.6	54	16
SD	15.5	4476	1.4	86	22
Minimum	1	0	0	0	1
Maximum	75.1	24950	6	400	96

Source: Adapted from Novo (2012); $n = 58$
[a]Area destined to dairy farming necessary to produce fodder to the whole herd as well as other areas such as shade, corridors, pre-calving paddocks and buildings.

production, and decreasing availability of labour due to the growing urban economy have contributed to the general lack of development of milk production in São Paulo state (Novo *et al*. 2012).

The increase in milk production per area and per farm had an effect on economic and productive indexes as well. The trend of better performance was observed in the study of another dataset of economic data and technical indexes from 50 farmers with at least three years of record keeping in five other regions. The results are summarized in Table 2.

In these five regions, the average gross margin per area almost doubled. This was due to a combination of gains in different indicators such as more milk produced (43%) using less area (7%) leading to 54% higher land productivity and higher productivity per cow (24%), resulting in better performance of labour (37%). The higher income was mainly due to gains in productivity. Only a minor part of the increase in gross margin results from higher prices of raw milk as milk prices increased only 7% in real terms, from 0.621 to 0.664 R$/litre. A *t*-test showed that all changes in the indicators reported in Table 1 were statistically significant ($p < 0.001$) except for decrease in area. The income increases were important, particularly when compared with local competing livelihood options at the regional scale, such as renting land to the sugarcane industry or planting soybean. The programme also generated higher income per labour force than the official minimum salaries in the city (Novo *et al*. 2013).

The outcomes of the programme in terms of productivity can be considered remarkable because farmers in the studied sample who joined the Balde Cheio and remained at least for three years reached high land productivity, equivalent to those observed in developed countries that employ more intense, sophisticated and highly specialized production systems. The possibility to produce more milk than the average initial volume using half of the area has provided an interesting opportunity for diversification of activities such as agroforestry (planting by

Table 2. Changes in economic and technical indexes of participants of the Balde Cheio programme in five regions other than São Paulo between the first and third year.

	Area (ha)	Gross margin/area[a] (R$/ha/year)	Milk volume (litres/day)	Productivity/ cow (litre/cow/ day)	Labour productivity (litre/man/day)	Land productivity (l/ha/year)
First year	20.4 ± 2.5	1700 ± 256	216 ± 30	7.88 ± 0.55	117 ± 12.0	5635 ± 601
Third year	19.0 ± 2.9	3273 ± 441	309 ± 37	9.79 ± 0.47	160 ± 13.3	8655 ± 745
Ratio of third year/ first year	0.93	1.92	1.43	1.24	1.37	1.54

Source: Adapted from Novo (2012); $n = 50$
[a]Deflated prices based on the Indíce Nacional de Preços ao Consumidor index (IBGE 2010).

themselves or renting to eucalyptus companies) on the remaining area. Farmers who stayed longer in the programme already diversified their activities. In this way, the intensification of dairy farming and diversification with other rural activities increase income and resilience of the household, which we consider a more sustainable way of farming. In addition, by providing a higher income using less land, family farmers could follow the new environmental rules which include setting aside a legal reserve in every farm by preserving natural vegetation on marginal areas of rivers, streams and high slopes (Sparovek *et al*. 2010), without compromising their livelihood.

Key elements of the Balde Cheio programme

As seen earlier, over time the Balde Cheio programme developed a specific approach to innovation whose main elements are discussed in the following sections.

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 helps minimize 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 bookkeeping 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.

Adapting to complexity and seeking novelty in re-combining technologies

One factor related to the result of bookkeeping was the choice of technological practices. Where and how to innovate were different for each farm. In this 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 and 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) 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 such as keeping basic accounts of income and expenditure and of technical data (such as calving and breeding dates, and monthly individual milk production and rainfall) and the reproductive calendar, (d) the irrigation of swards, (e) oat and ryegrass overseeding 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).

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).

Trialling and experimenting at the farm level

The strategy of conducting small trials at the 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 and relative prices of inputs). They then plan trials and future steps based on the capital available, herd size and grasses already established, amongst others. 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 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)[1] and irrigation (starting with the manual distribution of water in a few paddocks, and then shifting to a more efficient system).[2] 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 used not only for introducing, adapting and recombining known technologies but, in some cases, also for generating 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 on more efficient pumps, low-pressure systems and 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 evapotranspiration) and to work together with farmers on incremental solutions. In situations such as 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 the 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' (Glover 2011, Jansen and Vellema 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 reduces investment in troughs and cuts 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 an NGO that recycles industrial plastic waste; the adaptation of a cheap milking ditch which is made directly into the ground without the need for concrete and the use of magnetic sticks on the reproductive calendar. Many of these incremental solutions reduce costs and 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.

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 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 and 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.

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 earlier 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).[3] The experience of farmers participating in the programme (Camargo 2011, Rodrigues *et al*. 2006, Novo *et al*. 2013) suggests that the sequence of technology introduction is often more important for a more sustainable process than the proposed technology itself.

In the Balde Cheio programme, the 'gearbox' model was developed as a learning and communication tool, 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 and availability of capital), labour and household conditions (organization of labour, life cycle and farmers' goals) and others (institutional arrangements and government policies) defines the rhythm and sequence of 'gears' needed to achieve a viable pace for introducing technology. Feedback is provided by monitoring the effects of particular practices on many farms, and 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

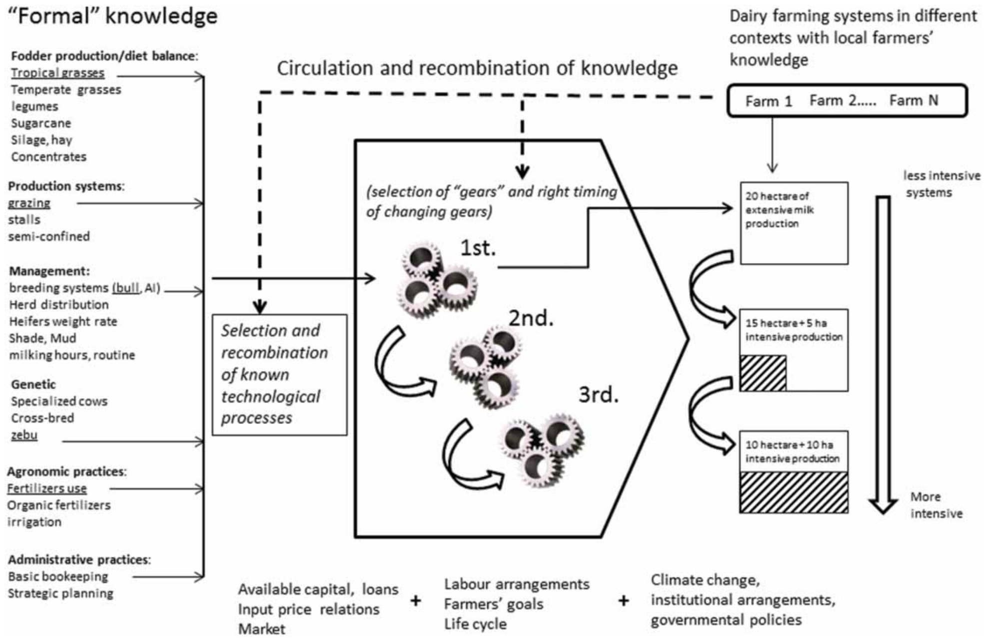

Figure 1. The gearbox model of the Balde Cheio programme.

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.[4] 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.

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, 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.

Farmers who 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, to 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 also 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 (Novo *et al*. 2013). Those farmers who dropped out referred to the long time involved in attaining positive economic results (interviews with farmers who 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.

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[5] 'brand' by other parties (development foundations, banks and NGOs) involved in economic, social and political change. Although partnerships with other 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 programmes, and their message of social concern for the development of small dairy farmers is publicized. 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.

Partnership arrangements and quality of technical assistance

The programme does not have full control over those technician-extension workers who, while 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 turnover 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.

Conclusions

This paper has analysed an innovative programme to support family dairy farmers by intensifying dairy production. It has been successful in maintaining the viability and sustainability 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, making it a more sustainable enterprise. 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. Firstly, 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. Secondly, 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. Thirdly, 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 the 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 technician-extension workers and their work.

Notes

1. 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* cv. tanzania; *P. maximum* cv. Mombaça and Tifton or Jiggs grasses (*Cynodon dactylon* varieties).
2. 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.
3. On the problems of one-sided social learning, see Stone (2007).
4. This is a form of *distributed cognition* as discussed by Jansen and Vellema (2011) and Richards *et al.* (2009).
5. 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.

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