Chapter 10

ST&I and the agricultural sector in São Paulo State

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The Detailed Tables for this chapter are available on the internet at: <http://www.fapesp.br/enindicadores2010>.

1. Introduction

Agriculture and agribusiness are of significant importance to the Brazilian economy. The so-called agribusiness GDP (gross domestic product) includes all agricultural activities as well as upstream industries (farm machinery and implements, chemical and biological inputs, specialized technical services, pesticides, herbicides, pharmaceuticals and fertilizer, among others) and downstream industries (processing, distribution and marketing, among others). Agribusiness expresses the input-output matrix for agricultural production. According to a survey by the University of São Paulo's Center for Advanced Studies in Applied Economics (Cepea/USP), in 2007 agribusiness contributed roughly a quarter of Brazil's GDP as calculated by IBGE, the national statistics bureau (IBGE, 2008).[1] Crop farming accounted for 17.9% of this contribution and livestock farming for 7.2%. During the period 1994-2007, the smallest contribution of agribusiness to GDP was 21.3% in 1997 and 1998, while the largest was 29% in 2003 (Table 10.1).[2]

The agricultural sector is here defined as consisting of crop farming (permanent and semi-permanent crops of long duration that can be repeatedly harvested without having to be annually replanted, as well as temporary crops of short duration, typically less than a year, that mostly have to be replanted after each harvest), and livestock farming (cattle, poultry, pigs and

Table 10.1
Contribution of agribusiness to GDP – Brazil, 1994-2007

Year	Total GDP (R$ million) (1)	Contribution of agribusiness to GDP – Agribusiness GDP – Total		Crop farming		Livestock farming	
		R$ million (1)	%	R$ million (1)	%	R$ million (1)	%
1994	1,758,232	499,675	28.4	360,447	20.5	139,228	7.9
1995	2,121,668	514,275	24.2	366,919	17.3	147,357	6.9
1996	2,284,146	505,929	22.1	363,669	15.9	142,260	6.2
1997	2,355,388	501,458	21.3	364,348	15.5	137,109	5.8
1998	2,364,134	504,364	21.3	361,161	15.3	143,203	6.1
1999	2,309,650	513,657	22.2	361,600	15.7	152,058	6.6
2000	2,248,296	514,161	22.9	354,243	15.8	159,918	7.1
2001	2,249,069	523,143	23.3	360,997	16.1	162,146	7.2
2002	2,248,854	569,220	25.3	399,444	17.8	169,776	7.5
2003	2,106,589	606,419	28.8	429,998	20.4	176,421	8.4
2004	2,199,158	621,910	28.3	442,451	20.1	179,459	8.2
2005	2,295,279	592,943	25.8	416,886	18.2	176,057	7.7
2006	2,451,488	595,626	24.3	427,859	17.5	167,767	6.8
2007	2,558,822	642,634	25.1	456,877	17.9	185,758	7.3

Source: IBGE; Cepea/USP (CNA).

(1) 2007 prices deflated by IPCA (IBGE).

Note: In 2007 IBGE changed the methodology used to calculate Brazilian GDP and also recalculated GDP for 2000-05. There may be discrepancies between the values for GDP in this table and those in other tables in the chapter as a result.

1. Cepea/USP calculates agribusiness GDP using available data for green coffee, sugarcane, unhulled rice, wheat grain, soybean, cottonseed, corn grain, and other crops; and for beef and dairy cattle, pigs, natural milk, live poultry and other livestock. Besides crop and livestock farming, the agribusiness complex comprises the following industries: wood and furniture; pulp, paper and printing; chemical elements, mainly alcohol; textiles; apparel; coffee; plant product processing; sugar; vegetable oil; other food products; footwear; slaughtering; and dairy (Guilhoto, Frutuoso & Barros, 2000).

2. Monetary amounts are presented in constant prices throughout the chapter, calculated by applying annual averages for IBGE's consumer price index (IPCA) to current values, with the base year being specified in each table or figure unless otherwise indicated. Annual averages for the IPCA in the period are set out in the Methodological Annex.

fish). Thus in this chapter, the terms "agriculture", "agricultural" and "agricultural research" encompass all types of farming.

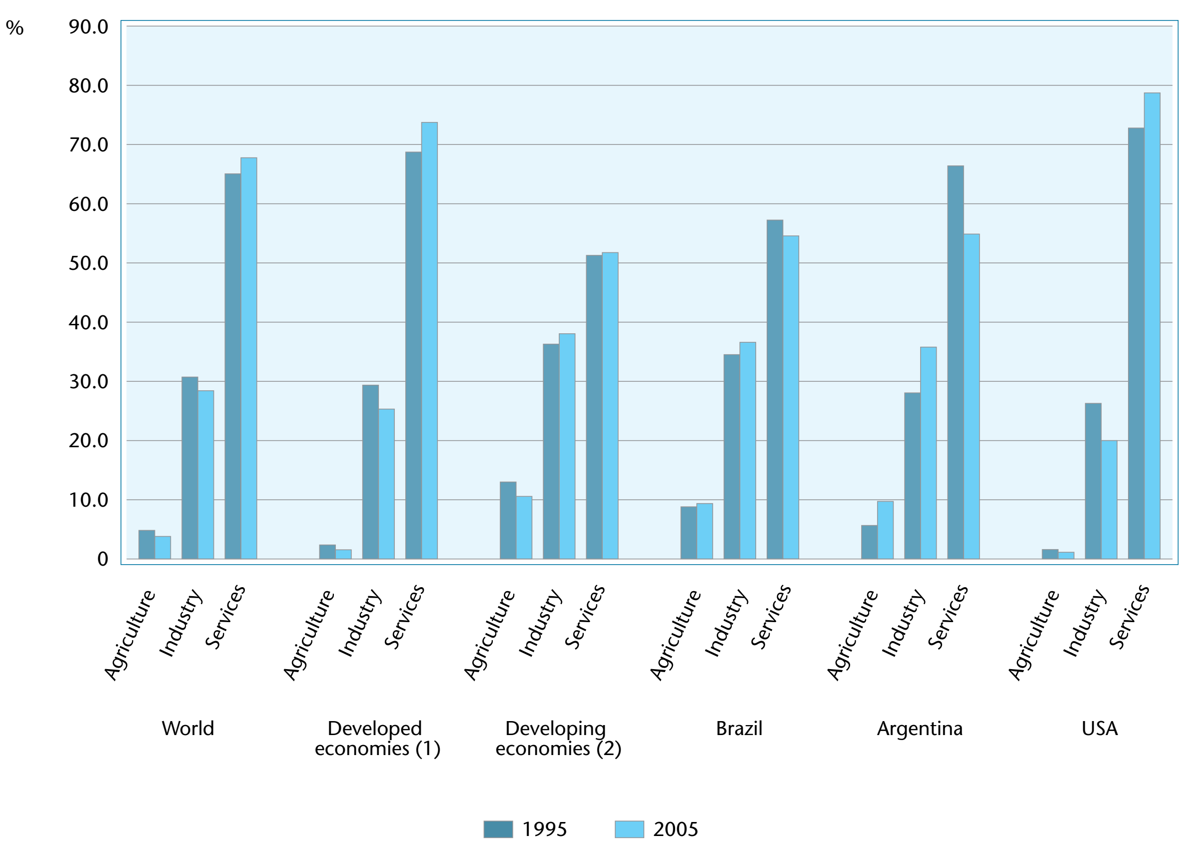
According to a survey by the São Paulo State Foundation for Statistics & Analysis (Fundação Seade), São Paulo State's share of Brazilian agricultural gross value added (see glossary) is significant, especially in light of its high level of industrialization. In 2006, crop farming, silviculture and forest production accounted for 16.5% of the total, while livestock farming and fishing accounted for 4.7% (Detailed Table 10.1). In other activities, São Paulo's share is much larger: in manufacturing it is 43.3%, for example, while in financial services, insurance and private pension funds it is 50.4%.

São Paulo's share of gross value added in crop farming, silviculture and forest production averaged 13.8% in the period 2003-06, exceeding those of traditionally important agricultural states (Minas Gerais 13.1%, Bahia 6.7%, Goiás 5%, Mato Grosso 10%, Rio Grande do Sul 11%), and peaking in 2006. In livestock farming and fishing, the largest shares were those of Minas Gerais, with 15.1%, and Rio Grande do Sul, with 10.5% (Detailed Table 10.2).

In the period 1995-2005 agriculture contributed between 7.6% and 9.6% to gross value added for the entire Brazilian economy, ending the period on 9.1% (Detailed Table 10.3). Agribusiness accounted for a significant proportion of Brazilian exports in the period 1997-2007, starting at 44.1% and ending at 36.4% (Detailed Table 10.4). Figure 10.1 compares the contributions of agriculture to value added in various countries for the years 1995 and 2005.

A comparison with Argentina shows that the contribution of its agricultural sector to total value added

Figure10.1
Contributions of agriculture, industry and services to total value added – Brazil & selected groups of countries, 1995-2005



Source: FAO (FAOSTAT).

(1) Includes USA.
(2) Includes Brazil and Argentina.

Note: See Detailed Table 10.3.

remained practically unchanged from 1995-2001 in the range of 5%, rising sharply thereafter as the service sector contracted, to reach 11% in 2003 and 9.4% in 2005, when it was similar to Brazil's (Detailed Table 10.3).

In the United States, the contribution of agriculture to total value added remained relatively stable between 1.7% and less than 1% during the period analyzed, albeit trending down (Detailed Table 10.3). However, the value of agricultural activities is significantly different in these three countries. In 2005, for example, the value added by agricultural activities in the U.S. was almost 75% greater than in Brazil and almost ten times the value added in Argentina (Detailed Table 10.3). The cases of Brazil and Argentina are particularly important in showing how much agricultural activities contribute to the respective economies, in contrast with most other countries.

In the Brazilian case, where agribusiness plays a central role in the performance of the economy, it is worth noting the outstanding rise in agricultural productivity over the past two decades. This growth in the importance of agribusiness has taken place under the aegis of intensifying modernization and productivity.

In a period of some 20 years, total factor productivity for a set of more than 20 crops rose 2.6 times in Brazil (Gasques et al., 2004). These are impressive numbers that point to two important (and complementary) developments: (i) many large portions of Brazil have only recently begun modernizing their agricultural sector (since the mid-1980s), adopting available technologies on an extraordinary scale;[3] and (ii) research efforts[4] have been converted into innovation in agriculture, both in the areas that have undergone this process of modernization[5] and in areas already modernized by the mid-1980s.

The extent to which this innovation derives from "new and more recent" research efforts or from the stock of existing technology remains to be studied. What is clear is that while productivity gains have reached a ceiling in several countries, especially the developed economies, Brazil (like other developing countries) is still completing its process of modernization in accordance with the productivist paradigm. This has an upside and a downside. The good news is that Brazil, perhaps more than ever before, is associating comparative advantages such as soil and climate with "constructed" advantages, especially research and innovation. The bad news is that current research efforts in Brazil still lag behind those of most agriculturally important countries. Because investment in research is a long-term undertaking, relatively less investment now could mean a loss of competitiveness in future.

Investment in science and technology (S&T), specifically in agrarian sciences, corresponded to 2.75% of agricultural GDP in Brazil in the period 2001-05 (Table 10.5, presented in section 10.2 of this chapter). Investment in research and development (R&D) averaged 2.09%, with a low of 1.8% and a high of 2.4% in the same period (Table 10.5).[6] In proportion to agribusiness GDP, investment in S&T and R&D averaged 0.54% and 0.41%, respectively (Table 10.5).[7]

São Paulo State's share of total investment in S&T and R&D averaged about 20% in the period (Tables

3. According to IBGE data for 2006 (IBGE, 2007a), Brazil has no less than 172 million hectares (ha) of pastureland. Most of this huge area is degraded and only 76.6 million ha are farmed. In the terms used by Salles-Filho (2008), there are two kinds of frontier: areas that are not farmed and areas that are farmed but under-utilized, or according to this author "pseudo-occupied areas," mainly for livestock farming. Thus a large pseudo-occupied area is available for use by modern technified agriculture. The Brazilian countryside is an immense innovation space.

4. See item 10.3.4 of this chapter.

5. Modernization in agriculture is understood as increased use of machinery and equipment, use of agrochemicals and fertilizer, and genetic improvement of seeds and seedlings, among other factors.

6. Investment in S&T covers a broader array of activities than investment in R&D. On this topic, see www.mct.gov.br/indicadores (last visited Mar. 22, 2010).

7. These numbers are not exact, but should be satisfactorily accurate judging from the surveys made for the purposes of this chapter. Privately funded agricultural research probably accounts for less than 48% of Brazil's total investment in S&T research (based on the average for the period used to estimate private investment in Table 10.4) and focuses much more on experimental development and testing than pure research. Moreover, the amounts invested are typically small, corresponding to less than 1% of sales for the firms or co-ops involved. Precise data are lacking but examples help illustrate the point. The 2006-07 research budget of Fundecitrus, which represents the citrus industry's research effort for both growers and processors, was R$ 3 million (Detailed Table 10.5), or about 0.3% of citrus industry sales, which totalled some R$ 10 billion in 2003 (Neves et al., 2004). In the case of the sugarcane industry, the Sugarcane Technology Center (Centro de Tecnologia Canavieira, CTC) currently invests some R$ 40 million per annum in R&D, or about 0.8% of agricultural production (sugarcane only, excluding sugar and alcohol) amounting to roughly R$ 5 billion by its members (about 30% of all mills). On the other hand, the information available on publicly funded research may be underestimated, since (as discussed later in this chapter) it omits the budgets of research foundations such as FAPESP and other state research foundations (FAPs) and also leaves out expenditure on research in higher education (calculated only for São Paulo State in this chapter and not included in the grand total for Brazil). Another factor to be taken into account is that the federal government increased its budget allocation to agricultural research in 2008, especially for Embrapa and state agricultural research organizations or SAROs (organizações estaduais de pesquisa agrícola, Oepas). The relevant calculations are explained in the Methodological Annex.

Table 10.2
Area planted and value of temporary and permanent crop production – Brazil & São Paulo State, 1996-2006

Year	Area planted and value of temporary and permanent crop production											
	Brazil						São Paulo State					
	Planted area			Value			Planted area			Value		
	Total (ha)	Temporary & semi-permanent (%)	Permanent (%)	Total (R$) (1)	Temporary & semi-permanent (%)	Permanent (%)	Total (ha)	Temporary & semi-permanent (%)	Permanent (%)	Total (R$) (1)	Temporary & semi-permanent (%)	Permanent (%)
1996	46,821,814	88.0	12.0	58,495,618	75.9	24.1	5,955,594	81.0	19.0	11,768,408	73.6	26.4
1997	48,302,405	87.8	12.2	62,875,150	75.8	24.2	5,968,266	80.6	19.4	11,843,881	74.5	25.5
1998	48,509,074	87.5	12.5	66,590,608	73.9	26.1	6,026,275	80.0	20.0	12,698,572	67.6	32.4
1999	50,700,694	87.7	12.3	68,483,820	73.6	26.4	6,185,500	80.1	19.9	11,238,180	66.4	33.6
2000	51,819,125	87.9	12.1	71,242,648	76.6	23.4	5,742,316	82.1	17.9	11,907,857	75.4	24.6
2001	51,637,167	87.9	12.1	79,538,240	77.9	22.1	5,835,340	82.9	17.1	16,785,691	65.6	34.4
2002	54,511,629	88.3	11.7	101,416,006	78.0	22.0	5,932,123	82.7	17.3	20,176,375	67.8	32.2
2003	58,460,983	89.1	10.9	118,476,559	82.7	17.3	6,243,991	83.3	16.7	19,422,293	69.3	30.7
2004	63,036,966	89.9	10.1	123,841,825	80.9	19.1	6,478,502	84.4	15.6	18,934,994	67.0	33.0
2005	64,319,313	90.1	9.9	99,552,093	78.7	21.3	6,647,645	85.0	15.0	17,474,444	68.6	31.4
2006	62,352,696	89.6	10.4	98,315,570	73.5	26.5	6,611,403	85.1	14.9	19,951,511	66.8	33.2

Source: IBGE.

(1) In 2006 constant *reais* (R$) deflated by IPCA (IBGE).

10.5 and 10.6, presented in section 10.2).[8] This lower concentration compared with other knowledge areas was due above all to better distribution of agricultural research efforts in Brazil and to a reduction in research by institutions located in São Paulo State. It should also be noted that in 2006 São Paulo State contributed approximately 20% of the total value of Brazilian crop production (Table 10.2) and 27% of the nation's agribusiness GDP (Guilhoto et al., 2007).

International studies show that developed countries invest more than 2.5% of their agricultural GDP in R&D, considering only public investment (World Bank, 2008; Pardey, Alston & Piggott, 2006). They also show that developing countries such as India and China have substantially increased investment in agricultural research in the last two decades, albeit less than Brazil in proportion to GDP but with much higher volumes of financing. In these countries, especially in Asia, the return on investment in research – measured for example by cost-benefit ratios such as the marginal product of research stock – has been higher than the averages seen in most other parts of the world (World Bank, 2008; Pardey, Alston & Piggott, 2006).

This chapter discusses the evolution of science, technology and innovation (ST&I) indicators for agriculture and is structured as follows. The first section describes the São Paulo State Agricultural ST&I System (SPInA) and its recent development, presenting the key actors in the system and their relations. The second section discusses the inputs to SPInA in terms of public and private expenditure and the formation of human resources for ST&I. The third section presents the results and impacts of SPInA, discussing scientific production (scientific publications) and technological production (patenting and plant variety protection) and the competencies formed in the system. The last section presents considerations on the outlook for SPInA in light of the situation thus depicted.

8. This percentage does not include research expenditure by FAPESP or by higher education institutions, since this information is not available for the rest of Brazil. São Paulo State's share is therefore probably larger than 20%.

2. Characterisation and recent evolution of the São Paulo State Agricultural ST&I System (SPInA)

Agricultural research is one of Brazil's most successful segments in terms of capabilities and technological development. More qualified human resources and research output are also found in knowledge areas linked to the agricultural sector than elsewhere. In public and private research centers, as well as universities, the agrarian sciences[9] have been especially important in Brazil both for the production of knowledge and for its incorporation into production.

In contrast with claims in the specialized literature of a disconnect between research systems and production systems in Brazil (or a lack of close ties between research and business, often seen as a disjunction between academia and industry), the agricultural sector is in fact an example of considerable integration between knowledge creation and adoption. From its inception, agricultural research has been closely linked to the productive sector, via public institutions and instruments providing technical assistance and rural extension (Szmrecsányi, 1976; Salles-Filho & Albuquerque, 1992; Salles-Filho, 1993). Application of content from experimental work in agricultural R&D has led to real links with production.

Perhaps because of the naturally applicable form and content of plant breeding, which always seeks agronomically active, stable and productive varieties, agricultural research is an example of successful integration between government, research and production. And it is precisely in São Paulo State that this model, capable of producing science-based solutions to the practical problems of agricultural producers, has developed most significantly. The Campinas Institute of Agronomy (Instituto Agronômico de Campinas, IAC), 121 years old in 2008, was the fountainhead of an institutional model that continues to prevail in Brazil in spite of all the recent changes.

Praise for the importance of agribusiness in Brazil today almost always foregrounds the role played by research in achieving these numbers. Embrapa, founded in 1973, has won its reputation for excellence precisely because it is one of the institutions that have been directly responsible for the success of Brazil's agribusiness sector and particularly for the positive numbers presented by crop farming since the 1990s.

The total factor productivity indices cited in this chapter highlight the significant contribution not only of research to the productivity gains seen since the 1970s, via new varieties and the inputs needed to raise yields, but above all of technological modernization. Modernization of the technical base has been a key driver of the growth in agribusiness in the last 30 years. Production grew more than 2.6 times between 1975 and 2002, even though crop acreage remained relatively stable (Gasquez et al., 2004). The increase in productivity has been due largely to the results of agricultural research (Table 10.3).

The development of new technologies has had positive economic effects for the agricultural sector, reducing production costs, boosting productivity, enabling diversification and adding value to its products (Salles-Filho & Mendes, in press). These significant results point not just to the strengthening of an innovation system but also to modernization of the technical base using technologies with a high level of economic impact. Research and production are closely allied in this sector, albeit in ways that are often tortuous and relatively inefficient. As discussed below, this relationship could be better and may indeed have to improve before the model currently in place runs out of steam, owing to diminishing amounts of certain investments in research, as exemplified by the São Paulo State Agency for Agribusiness Technology (APTA), among others.

The key players involved in agricultural research originate from different areas. Advances at the frontier of knowledge, particularly in biotechnology and in information and communications technology (ICT), for example, highlight the increasingly transdisciplinary nature of this research. The importance of linkages between public and private institutions in research networks is growing in order to address this complexity. In addition to scientific competencies, these linkages require capacity building by the actors involved so that intellectual property (IP) issues relating to the knowledge created can be satisfactorily managed. The possibility of increased appropriation of innovations and the potential profitability of the application of new knowledge to agricultural activities have attracted private investment, further contributing to the construction of a more diversified and comprehensive innovation system.

9. Agronomy, food science and technology, agricultural engineering, veterinary medicine, forest reSource and forest engineering, fishery reSource and fishery engineering, and animal science (see glossary).

Table 10.3
Highlights of agricultural census findings – Brazil, 1970-2006

Structural data	Highlights of agricultural census findings						Change 1970-2006 (%)
	1970	1975	1980	1985	1995-1996	2006	
No. of establishments	**4,924,019**	**4,993,252**	**5,159,851**	**5,801,809**	**4,859,865**	**5,175,489**	1.1
Total area (ha)	**294,145,466**	**323,896,082**	**364,854,421**	**374,924,929**	**353,611,246**	**329,941,393**	1.1
Land use (ha)							
Permanent crops (1)	7,984,068	8,385,395	10,472,135	9,903,487	7,541,626	11,612,227	1.5
Temporary crops (2)	25,999,728	31,615,963	38,632,128	42,244,221	34,252,829	48,234,391	1.9
Natural pasture	124,406,233	125,950,884	113,897,357	105,094,029	78,048,463	57,316,457	0.5
Planted pasture (3)	29,732,296	39,701,366	60,602,284	74,094,402	99,652,009	101,437,409	3.4
Natural vegetation (4)	56,222,957	67,857,631		83,016,973	88,897,582	93,982,304	1.7
Planted vegetation	1,658,225	2,864,298	5,015,713	5,966,626	5,396,016	4,497,324	2.7
No. of people employed	**17,582,089**	**20,345,692**	**21,163,735**	**23,394,919**	**17,930,890**	**16,567,544**	0.9
Tractors	**165,870**	**323,113**	**545,205**	**665,280**	**803,742**	**820,673**	4.9
Livestock inventory							
Cattle	78,562,250	101,673,753	118,085,872	128,041,757	153,058,275	171,613,337	2.2
Buffaloes	108,592	209,077	380,986	619,712	834,922	885,119	8.2
Goats	5,708,993	6,709,428	7,908,147	8,207,942	,6,590,646	7,107,608	1.2
Sheep	17,643,044	17,486,559	17,950,899	16,148,361	13,954,555	14,167,504	0.8
Pigs	31,523,640	35,151,668	32,628,723	30,481,278	27,811,244	31,189,339	1.0
Poultry (chicks, chickens, hens, pullets, roosters, in thousand head)	213,623	286,810	413,180	436,809	718,538	1,401,341	6.6
Animal production							
Cow's milk (000 liters)	6,303,111	8,513,783	11,596,276	12,846,432	17,931,249	20,157,682	3.2
Goat's milk (000 liters)	-	13,394	25,527	35,834	21,900	35,740	2.7
Wool (metric ton)	33,617	31,519	30,072	23,877	13,724	10,210	0.3
Hen's eggs (000 dozen)	556,410	878,337	1,248,083	1,376,732	1,885,415	2,834,419	5.1

Source: IBGE, Censo Agropecuário 1970-2006.

(1) In permanent crops the census covered only the area harvested with more than 50 crop plants on December 31, 2006.
(2) Temporary crops and flowers including hydroponics and plasticulture, nurseries, greenhouses and fodder crops.
(3) Planted pasture degraded by inadequate management or lack of conservation, or in good condition, or undergoing rehabilitation.
(4) Permanently protected natural vegetation and forest areas, and natural vegetation and forest areas also used for crop farming and grazing.

Technology life cycles are shortening while research productivity is accelerating, and both trends are highly likely to intensify in the near future. New plant improvement techniques, for example, are significantly reducing the time taken to develop new varieties, boosting productivity and shortening the technological life cycle.

The leading firms in the development of genetically modified seeds, both domestically and globally, are also producers of chemical inputs. The use of GM seeds requires various products developed by other sectors, such as farm machinery and implements, as well as specialized technical services etc. As noted in the introduction, the approach used in this analysis therefore takes into consideration the fact that the ST&I system in agriculture comprises not just traditional farming activities (inside the farm gate), but also their relations with the rest of the economy.

In the specialized literature on innovation, agriculture is considered a user rather than a producer of innovations (Pavitt, 1984), with linkages to technology suppliers as its main source of such innovations. This entire complex, which includes sectors upstream and downstream of agriculture, can be seen as a sectoral innovation system comprising agriculture and its relations with the rest of the economy. According to Salles-Filho (1993) and Possas, Salles-Filho & Silveira (1996), the sources of innovation in agriculture are as follows:

1. Private sources of industrial productive organization: firms that produce chemical and biological inputs and farm machinery and implements.
2. Public institutional sources, which include universities, research institutions (such as national or local agricultural research organizations), bodies that provide technical assistance and rural extension, typically responsible for creating and diffusing genetic technology and agricultural practices (crop and livestock farming techniques), and an important part of basic research geared to the production of new knowledge for agriculture.
3. Private sources linked to the segments of agroindustry that process food and produce farm inputs, whose main innovative function is to determine standards of production that affect the formation of the technical base for agricultural production.
4. Private sources in the form of collective nonprofit organizations (cooperatives and associations of agricultural and/or agroindustrial producers) that create and diffuse agricultural technology.
5. Private sources linked to the provision of specialized technical services, typically consulting in agricultural information, management and administration.
6. Agricultural production units themselves, not dynamic centers of knowledge creation but the site where all agricultural technologies come together and materialize with a coherent technical production base. Learning by using and learning by doing are the main ways in which this source influences the technical base for agricultural production.

An agricultural ST&I system emerges from the presence of these sources and their outputs to a greater or lesser extent in the formation of the technical base for agricultural production. Complementarily, development and financing agencies alongside other supporting institutions, regulatory frameworks, laws and incentives are as important as the structural elements of the system.

These sources of innovation contribute to production to a greater or lesser extent depending on the situation. Their importance will always be conditioned by reality but they all have a common feature, which is mutual dependence on the configuration of the technical base. There is coherence among the technologies, expressed by both competition and complementarity, in the sense that the performance of a technology (a GM variety, for example) depends on the use of complementary technologies (fertilising, product health and safety, harvesting etc.) and vice-versa.

Understanding how these sources protect the knowledge they create is also relevant to an analysis of the individual strategies and linkages established among the various actors in the process of research, development and innovation (RD&I). Thus the dynamics of knowledge production and use in agriculture can be understood only by analyzing indicators that reflect the logic of the whole.

Because this chapter focuses on ST&I indicators for agriculture in São Paulo State, and considering the conceptual remarks made above, the indicators are treated from a systemic vantage point. This means making the maximum possible use of indicators for the São Paulo State Agricultural ST&I System (SPInA), including in the scope of the analysis not only agricultural research in the narrow sense but also innovation (e.g. modernization of the technical base), as well as broader indicators of S&T and education and training than those applicable solely to agriculture.

The phrase "maximum possible use" was used above because of the considerable heterogeneity of the available information sources. Private research conducted by the first and third groups listed above as innovation sources is much harder to obtain than research by the second group, for example. In any event, this chapter discusses ST&I indicators for a state system (often compared with national numbers) that fosters the production of knowledge and technology for agriculture by all these sources.

2.1 Public agricultural research organizations in São Paulo State

São Paulo State has a long history of agricultural research that dates from the late 19th century. The first step was the establishment of Imperial Estação Agronômica de Campinas in 1887 by the Emperor, Dom Pedro II. Following the declaration of a Republic in 1889, it was taken over by the São Paulo State Government in 1892 and renamed Instituto Agronômico de Campinas (IAC). IAC is internationally recognized for its fundamental contributions to the development of agriculture in São Paulo and throughout Brazil, especially in the case of crops such as coffee, cotton, citrus, dry beans, sugarcane, grains and fibers. It also conducts research on soils and environmental resources, adaptation of crops such as fruit trees and rubber trees, engineering, and plant health.

The establishment of Escola Prática de Agricultura Luiz de Queiroz in 1901 at Piracicaba, incorporated 33 years later into the University of São Paulo (USP) as Escola Superior de Agricultura Luiz de Queiroz (ESALQ), further enhanced the importance of São Paulo State as a center of agricultural research and experimentation as well as education. Years later it also became an outstanding practitioner of technical assistance. During the same period other states, such as Rio de Janeiro, Bahia and Rio Grande do Sul, also set up research centers, institutes and schools of agriculture, albeit without achieving the same degree of importance as São Paulo's system (Albuquerque, Ortega & Reydon, 1986a, 1986b). Much of this evolutionary trajectory was due to the state government, which used part of the economic surplus produced by agriculture to fund research activities. Almost 12,000 professionals have graduated from ESALQ to date,[10] and its main contributions have been concentrated in agrarian sciences, environmental sciences, biological sciences, and applied social sciences.

The period during which IAC and ESALQ were established also saw the foundation of what is now known as Instituto Florestal. Its history dates from 1886, when the Geography & Geology Commission of the then Province of São Paulo set up a Botany Section. The São Paulo Botanical Gardens were established ten years later in the Serra da Cantareira region to study forest species. Its remit was extended in 1911 when it was renamed Serviço Florestal and put in charge of restoring the state's forests. In 1970 it was again renamed, becoming Instituto Florestal, and in 1987 it was attached to the Department of the Environment. It currently manages more than 90 conservation units, including 22 ecology stations, 26 state parks, 13 state forests, 19 experiment stations, two state reserves, two forest nurseries and six forest parks in 114 municipalities.[11]

Another institute now controlled by the São Paulo State Department of the Environment is Instituto de Botânica,[12] established in 1938 as an upgrade to the then state department of botany. In addition to headquarters, a biological reserve and botanic gardens all situated in the Sources of Ipiranga State Park within the city of São Paulo, Instituto de Botânica has two other conservation units: the Alto da Serra de Paranapiacaba Biological Reserve (Atlantic rainforest) and the Moji Guaçu Biological Reserve & Experiment Station (cerrado, or Brazilian savannah). Instituto de Botânica also conducts botanical research to support the state's environmental policy.[13]

Another important research center in São Paulo State is Instituto Biológico (IB), established in 1927 to foster the incorporation of animal and plant health surveillance into agriculture. IB took over responsibility for animal health in 1934 (Araújo et al., 2002). This assured special treatment for animal and plant health in São Paulo State.

The Limeira and Sorocaba Experiment Stations were established in 1928. Both were attached to IAC. Their remit was to conduct in-depth research on citrus crops, which were only then assuming significance in the state. Hitherto IAC's research activities had focused on coffee, sugarcane, forage and tobacco. Its citrus research unit, now called Centro Avançado de Pesquisa Tecnológica do Agronegócio de Citros Sylvio Moreira (CAPTACSM/IAC/APTA), began experimental research in genetic improvement and citrus breeding, partnering with several other institutions. Basic research on citrus genetics was first undertaken in São Paulo State around 1935, simultaneously by Carlos A. Krug at IAC and Friedrich G. Brieger at ESALQ. Sylvio Moreira, a researcher associated with these two groups, began working on rootstock improvement and production of nucellar seedlings, while Vitória Rossetti, a researcher at Instituto Biológico, specialized in the study of gummosis-resistant varieties. These projects were implemented and developed at what was then the Limeira Experiment Station, which in the 1930s was already becoming the main center for citrus research in Brazil.

Today this organization within IAC has one of the world's largest citrus variety collections, comprising some 2,000 exemplars held in an Active Germplasm Bank founded in 1930. IAC has several major achievements of economic and scientific significance to its credit, such as combating serious diseases, from the tristeza epidemic that decimated São Paulo's orange groves in the 1940s to citrus canker and, at present, the highly destructive CVC.[14]

In the 1950s, after World War II and as nuclear energy research was advancing in several countries, a group of researchers at ESALQ heard about the potential of this energy source for agronomic research

10. Source: <http://www.esalq.usp.br/instituicao/esalq_hoje.html>. Last visited Mar. 22, 2010.
11. Source: <www.iflorestal.sp.gov.br/institucional/historico.asp>. Last visited Mar. 22, 2010.
12. Instituto Geológico is also subordinated to the São Paulo State Department of the Environment (Secretaria do Meio Ambiente do Estado de São Paulo).
13. Source: <http://www.ibot.sp.gov.br/instituto/instituto/instituto.php>. Last visited Mar. 22, 2010.
14. Citrus variegated chlorosis.

and embarked on innovative lines of research: researchers in physics and chemistry began working with radioisotopes, while researchers in genetics took an interest in the technique of mutation induction by irradiation. They then proposed the establishment of a nuclear energy center linked to agriculture at ESALQ, which would be the obvious choice. The center did not materialise until 1966, when USP set up the Center for Nuclear Energy in Agriculture (Centro de Energia Nuclear na Agricultura, Cena) at its Piracicaba campus. Cena focuses mainly on the development of nuclear techniques in agricultural and environmental applications.[15]

A number of research centers established in São Paulo State during the 1960s are still leaders in the field today. They include the Institute of Agricultural Economics (Instituto de Economia Agrícola, IEA), set up in 1968 to focus on economic and social aspects of agribusiness as well as the organization of agricultural research itself; the Fishery Institute (Instituto de Pesca, IP), founded in 1969 to conduct fishery and aquaculture research; the Institute of Food Technology (Instituto de Tecnologia de Alimentos, Ital), also founded in 1969 to research and develop food technology, as well as providing technical assistance to agroindustry; and the Institute of Animal Science (Instituto de Zootecnia, IZ), set up in 1970 to support animal husbandry in the state. It is also worth recalling the establishment in 1968 of the Institute of Forest Research (Instituto de Pesquisas e Estudos Florestais, Ipef), a private nonprofit institution linked to the Department of Forest Sciences at ESALQ.

In the federal sphere the early 1970s saw the establishment of Empresa Brasileira de Pesquisa Agropecuária (Embrapa) to control the research institutions, experiment stations and research projects subordinated to the Ministry of Agriculture's National Department of Agricultural Research & Experimentation (DNPEA) (Beintema, Ávila & Pardey, 2001). This nationwide reorganization of agricultural research and rural extension also transferred control of many state institutions to Embrapa.

In São Paulo State, however, the leading research institutions remained under the control of the state government, which before the implementation of the federal policy had created a solid foundation for autonomous agricultural and agroindustrial research and S&T. Until the 1970s, federal policy was still closely bound up with technical assistance and expansion of the agricultural frontier (Alves & Contini, 1992). Embrapa played a key role in the modernization of the technical base for agriculture in Brazil. During the 1970s this modernization process kept pace with industrialization and rapid growth in other sectors of the Brazilian economy, involving intensive use of inputs and technologies supported by public policy instruments such as farm loans and technical assistance (Salles-Filho & Mendes, in press).

The next decade, however, was a critical period for the economy as a whole, and consequently for the agricultural sector in general. Investment and credit fell, modernization programs were shut down, and the institutions involved in agricultural research suffered severe budget cuts, which disrupted programs and projects at universities as well as research institutions. The reduction in transfers of funds and investment led to financial, political and functional destabilisation of these institutes. Efforts to reverse the effects of the crisis led to reorganization for many but the process was disorderly – "disorganized reorganization" in the words of Salles-Filho & Bonacelli (2007).

In São Paulo State the restructuring revolved around the establishment of APTA, the Agribusiness Technology Agency, in 2000. APTA controls six research institutes (IB, IP, IEA, Ital, IZ and IAC),[16] 15 regional centers designed to integrate research and rural extension throughout the state, 64 regional experiment stations and 43 research laboratories. In 2006 it had more than 2,507 employees, 853 of whom were researchers.[17]

Five of Embrapa's research units are also located in São Paulo State: Embrapa Informática Agropecuária (CNPTIA, an IT unit set up in 1985) and Embrapa Monitoramento por Satélite (CNPM, a satellite monitoring unit set up in 1986), both at Campinas; Embrapa Instrumentação Agropecuária (CNPDIA, specializing in agricultural instrumentation, set up in 1984) and Embrapa Pecuária Sudeste (CPPSE, set up for livestock research in 1975), both at São Carlos; and Embrapa Meio Ambiente (CNPMA, established for environmental management research in 1982 at Jaguariúna). Only the Federal District has more units of Embrapa than São Paulo State.[18]

15. Source: <http://www.cena.usp.br/pt/instituicao/historico>. Last visited Mar. 22, 2010.
16. Instituto Biológico, Instituto de Pesca, Instituto de Economia Agrícola, Instituto de Tecnologia de Alimentos, Instituto de Zootecnia, Instituto Agronômico de Campinas.
17. Source: Department of Agriculture & Supply (SAA/SP) – search of information system, 2008.
18. Embrapa's units in São Paulo State had a budget of R$ 75.1 million in 2007, for real growth of 33.8% compared with 2005, as discussed below.

In 2008, Embrapa launched Partnerships for Technological Innovation (Parcintec), initially in the cities of Franca and Ituverava, São Paulo State. The aim of this program is to survey requirements and build partnerships and institutional actions to help meet them. Besides Embrapa's own units, the program also involves other institutions belonging to the National Agricultural Research System, as well as scientific institutions, universities, government and the private sector. Another milestone was the 2006 launch of Laboratório Nacional de Nanotecnologia para o Agronegócio (LNNA), an agribusiness nanotechnology lab associated with CNPDIA and part of MCT's National Nanoscience & Nanotechnology Program.

In rural extension, São Paulo State followed federal guidelines and in 1967 established the Bureau of Integral Technical Assistance (Cati) subordinated to the Department of Agriculture & Supply (SAA/SP). Cati has 40 rural development offices (Escritórios de Desenvolvimento Rural, EDRs) with Casas de Agricultura in every municipality throughout the state.

The National Sugar & Alcohol Institute (Instituto do Açúcar e do Álcool, IAA) and the National Sugarcane Breeding Program (Programa Nacional de Melhoramento Genético da Cana de Açúcar, Planalsucar) were important federal government agricultural research initiatives partially developed in São Paulo State. The government set up IAA in the early 1930s to control sugar and ethanol production and marketing. Planalsucar was established in the early 1970s with four experiment stations (at Carpina in Pernambuco, Rio Largo in Alagoas, Campos in Rio de Janeiro, and Araras in São Paulo) working together to develop technological projects for the sector. The main project undertaken by the Planalsucar network was the development of new sugarcane varieties. Groups of researchers were formed at each of Planalsucar's stations, which in fact were experimental farms, and a germplasm bank was set up in Alagoas. Groups worked on research on soils, herbicides and biological pest control. With the advent of the National Alcohol Program (Programa Nacional do Álcool, Proálcool) in late 1974, these institutions gained more visibility on a national scale, but Proálcool foundered in the 1980s, while IAA and Planalsucar were shut down as part of the Collor administration's privatization program in the early 1990s.

It is also necessary to mention the importance of the Inter-University Network for Development of the Sugar & Alcohol Industry (Rede Interuniversitária de Desenvolvimento do Setor Sucroalcooleiro, Ridesa), which was established before Proálcool and is one of Brazil's leading pluri-institutional sugarcane research systems. Today it comprises seven federal universities and several departments, and focuses on sugarcane breeding in partnership with Embrapa, ESALQ, federal and state agencies, and 130 business organizations. It has some 140 researchers, 83 mid-level technicians and 68 field workers. Ridesa produces 2 million plantlets (material derived from cross-breeding) per year, to serve as a basis for the development of commercial varieties.[19]

2.2 Private agricultural research organizations in São Paulo State

Two other initiatives of great importance to the development of the economy and not just agriculture in São Paulo State that occurred in the 1970s were the establishment of Coopersucar's Technology Center, CTC (Coopersucar was the São Paulo State Cooperative of Sugarcane, Sugar & Alcohol Producers) and of the São Paulo State Citrus Defense Fund (Fundo Paulista de Defesa da Citricultura, Fundecitrus). Coopersucar's research activities in fact began in 1969 with the launch of the sugarcane breeding program. A quality analysis laboratory set up at the same time was the embryo of a future industrial research division. These two activities were later combined to create the Technical Department, which was transformed into CTC in 1979 (Ruiz Olalde, 1992). CTC became Centro de Tecnologia Canavieira in 2004, increasing the number of partners by including sugarcane growers as well as mills, and also changing the method for distributing the varieties developed. Whereas it had previously charged royalties on varieties distributed to non-members, it now restricted distribution to members only. CTC has 161 member units accounting for some 60% of Brazilian sugarcane production.

Fundecitrus, established in 1977, is funded by citrus growers and the juice industry. Its focus is on research and plant health surveillance. It monitors groves, and conducts and finances scientific research to develop new ways of combating diseases and pests or of adapting varieties to them. Since its foundation it has extended its scope from citrus canker to include

19. Source: <http://www.inovacao.unicamp.br/etanol/report/entre-marcosridesa070522.php>. Last visited Mar. 22, 2010.

other serious pests and diseases such as citrus borer, citrus leafminer, postbloom fruit drop (PFD), citrus black spot, citrus variegated chlorosis (CVC) and more recently greening (citrus huanglongbing or HLB).

In 1994 the institution established a Scientific Department to conduct research, often in partnership with universities and public research centers. Today it can be considered a service provider that is also responsible for conveying information and clarification to growers. To do this it has 14 plant health support centers throughout the main citrus growing area of São Paulo and in other states.

The effort to combat CVC led to the sequencing of the Xyllela fastidiosa genome as the first project in FAPESP's Genome Program. Launched by FAPESP in October 1997 and completed in February 2000, the Xyllela Genome Project had a budget of almost US$16 million, in addition to US$5 million from the Ludwig Institute for Cancer Research e US$500,000 from Fundecitrus. The project acted as a catalyst for opportunities to increase genomics research in São Paulo State, in Brazil, and even on the scientific frontier of the global agricultural sector. One of its most significant results was capacity building for São Paulo's laboratories and research centers (most of which are public – only three labs are private), with the participation of more than 100 researchers (the actual number of researchers involved in the project at one time or another was about 190, working at 35 labs in a network called Onsa, short for Nucleotide Sequencing & Analysis Organization), enabling Brazil to join the privileged company of countries that have mastered this knowledge area.[20]

Private agricultural research in São Paulo State, and its relations with public actors, also stand out in the national context. Participation in research by private enterprise has in fact increased, via both partnerships and intramural research in laboratories and experimental field sites. Foundations, associations and cooperatives have further extended the sector's participation in research. Even when research is not the main focus, these institutions contribute to the organization and diffusion of knowledge.

Private seed research, for example, is concentrated in the laboratories of such leading firms as Monsoy and Agroceres, both part of the Monsanto group, Bayer CropScience/Aventis, Syngenta and Pioneer, which combine research in plant breeding and biotechnology applied to inputs relating to seeds. The associations, cooperatives and foundations that work with seeds and seedlings also conduct research, especially the São Paulo State Association of Seed & Seedling Producers (APPS). Research activities in the area are performed under partnership agreements, mainly with testing laboratories. Among the most important members of APPS is the São Paulo State Citrus Seedling Nursery Organization (Organização Paulista de Viveiros de Mudas Cítricas, Vivecitrus), whose members account for 40% of the citrus seedlings produced in Brazil.[21]

Crop seed and seedling research is constantly diversifying, after focusing for a long time on soya and maize. An example of this diversification is Votorantim Novos Negócios, the Votorantim Group's venture capital and private equity fund, which invests in high-tech firms. At end-2008 VNN's portfolio held equity in three biotechnology firms: Alellyx Applied Genomics, Canavialis and Scylla.[22] Alellyx Applied Genomics was founded in 2002 as a spinoff from FAPESP's Genome Project. It focuses on applied genomics, especially for soya, oranges, eucalyptus and sugarcane. Canavialis, founded in 2003 by researchers from the Agrarian Science Center at the Araras campus of the Federal University of São Carlos (UFSCar), focuses on sugarcane breeding and genetic improvement to develop superior varieties and consulting to optimise cane plantation productivity. Scylla was founded in 2002, also as a spinoff from various genome projects supported by FAPESP. It specializes in the development of bioinformatics software firms and research centers that use biotech in their business activities. Many of these three firms' directors and researchers

20. Other genetic sequencing projects involving the agricultural sector and institutions in São Paulo State supported by FAPESP include the Functional Genome Project (researching the functions of the sequenced Xyllela genes, with 12 research labs in São Paulo); Sugarcane EST (SUCEST), between 1998 and 2003 (genes relating to the metabolism of sucrose, pest and disease resistance, and tolerance of adverse weather and soil conditions, with 23 research labs in several states plus two units of Embrapa); the *Xanthomonas Citri/Campestri Genome, between* 1998 and 2002 (combating citrus canker, with the Agricultural & Environmental Genome Network, AEG*); Xylella Fastidiosa* – Grapevines, in 2000-01 (combating Pierce's diseases, with AEG); *Leifsonia xyli*, 2001-02 (the causative agent of sugarcane ratoon stunting disease, with AEG); *Xylella* causing oleander and almond leaf scorch, 2000-01, with AEG; Forests, between 2001 and 2003 (eucalyptus breeding, with AEG); the Brazilian Coffee Genome Project, between 2002 and 2004 (ECT-based gene sequencing to develop high-yield, drought- and pest-resistant coffee varieties, with 40 institutions nationwide); Bovine Functional Genome, starting in 2003 (genes to improve beef quality, reproductive efficiency and resistance to disease, with AEG); the Structural Molecular Biology Network (SmolBNet), since early 2000 (three-dimensional structures of genes sequenced in the Human Cancer Genome, *Xylella*, *Xanthomonas* and SUCEST, with 20 university and research labs in São Paulo); and projects conducted by networks involving São Paulo State institutions, such as *Genolyptus* (eucalyptus genome sequencing) and *Crinipellis perniciosa* (the fungus that causes witches' broom in cacao trees) (Dias, 2006).

21. Source: <http://www.vivecitrus.com.br/Pagina/Default.aspx?IDPagina=1>. Last visited Mar. 22, 2010.

22. Allelyx and Canavialis were taken over in November 2008 by Monsanto, with which they already partnered, for some R$ 600 million according to Brazilian media reports. Source: <http://www.inovacao.unicamp.br/report/noticias/ index.php?cod=439>. Last visited Nov. 10, 2008.

have academic backgrounds and participated in gene sequencing programs such as Xylella fastidiosa and Xanthomonas citri as well as the SUCEST Sugarcane Genome Project.

The Orlândia Region Farmers Cooperative (Cooperativa dos Agricultores da Região de Orlândia, Carol) was founded in 1963 to minimize the cost of inputs and maximise productivity for these farmers in the northwest of São Paulo State. Today it has more than 4,100 members, mainly in the north of São Paulo but also in Minas Gerais, Goiás and Mato Grosso do Sul. Its core business is the marketing of a range of products from seeds to animal feed, besides the provision of rural assistance services. The São Paulo Coffee & Citrus Growers Cooperative (Cooperativa dos Cafeicultores e Citricultores de São Paulo, Coopercitrus), the leading distributor of inputs for the sector, and Carol joined forces with the Central Fertilizer Cooperative (Cooperativa Central de Fertilizantes, Cooperfértil), located in Campinas, to develop own-brand products for distribution, establishing a new level of competition in the sector.

The National Fertilizer Industry Association (Anda) is an important player in technology diffusion, although it does not engage in S&T activities. Founded in 1967, Anda now has more than 107 members and operates in 11 states. São Paulo State ranks first, with 33 members or 31% of the total.

Research on both fertilizers and the prevention of pests and diseases is conducted mainly by domestic and multinational chemical firms. R&D is more dynamic in agrochemicals, with firms investing in research, global networks of private and public laboratories, and experiment stations that develop adaptations using biotechnology and nanotechnology. The leaders of this segment are Dow AgroSciences, Bayer and BASF, but several Brazilian firms are also significant players in some regions.

Farm machinery and implements displayed a stable market concentration profile in the period 1990-99, during which the top eight firms in the sector accounted for 76% of aggregate net sales. In 1999-2002, however, this share increased sharply to 91% (Dutra & Montoya, 2005). Internationalization has taken off rapidly in the sector in recent years and foreign firms are now predominant, especially in wheel tractors and combine harvesters, a high value added segment. In 2002, the top firms by sales were CNH,[23] (41% of aggregate revenue in the sector) and AGCO[24] (19%), followed by John Deere Brasil, Valtra, Jacto, Kepler Weber, Semeato and Jumil (Dutra & Montoya, 2005). As can be seen from this list, there are a few medium-size domestic firms (Kepler Weber, Semeato, Jacto and Jumil), which manufacture low value added products (implements). The only large firm based in São Paulo State is Valtra.

On the demand side, in 1999 the federal government launched a farm fleet modernization program called Moderfrota to provide subsidised loans for the purchase of tractors, implements, combines and other equipment (Mantovani, Herrman & Coelho, 2008). Rising production and sales drove renewal of more than a third of the Brazilian farm fleet as well as upgrading its technology content (Vegro & Ferreira, 2008). Most research in this sector is intramural, although firms (especially the majors) may interact with research institutions, consultants and universities (Lucente & Nantes, 2008).

To conclude this item on private participation in agricultural R&D, it is worth noting the case of the Agricultural Research Development Foundation (Fundação de Desenvolvimento da Pesquisa Agropecuária, Fundepag), established in 1978 as a private-law foundation with administrative and financial autonomy to conduct experimental research and research on industrializing agricultural production, especially in the area of food.[25]

A number of other firms and organizations participate in SPInA in different ways, some more actively than others, according to the technical and innovation dynamics of the sector to which they belong and the position they occupy in the production chain and innovation system. In sum, SPInA is more than has been outlined here, but there is not enough space in this chapter for an exhaustively detailed description.

2.3 Educational institutions conducting agricultural research in São Paulo State

São Paulo State also has many educational institutions that conduct agricultural research, especially state, federal and municipal universities, as well as research activities linked to technology courses in agrar-

23. Case New Holland, which resulted from a merger of New Holland N.V. and Case Corp. in 2000.
24. AGCO Corp. later acquired Valtra, adding it to its brand portfolio, which already included Massey Ferguson, Fendt and Challenger.
25. Source: <www.fundepag.br>. Last visited Mar. 22, 2010.

ian sciences offered by Fatecs (Faculdades de Tecnologia). Some of these are widely recognized for their solid academic track record, while others are very recent. The leaders are:

A) At the University of São Paulo (USP):

i) ESALQ, one of Brazil's oldest research institutions, as noted earlier, offering six undergraduate courses (in biological sciences, food sciences, economic sciences, agricultural engineering, forest engineering and environmental management) and 16 post-graduate courses (in animal science and pasture management, food science and technology, applied ecology (ESALQ/Cena), applied economics, entomology, statistics and agricultural experimentation, agroenvironmental physics, plant physiology and biochemistry, plant pathology, plant sciences, genetics and plant breeding, irrigation and drainage, farm machinery, forest resources, soil and plant nutrition, and agricultural microbiology);[26]

ii) The School of Animal Science & Food Engineering (FZEA) on the Pirassununga campus. Activities began in 1945 at Escola Prática de Agricultura Fernando Costa and were integrated in 1989 with USP, which established FZEA in 1992;[27]

iii) Courses in veterinary medicine and animal science, delivered on the São Paulo campus under the responsibility of the Pirassununga campus. With activities dating from the start of the 20th century, the School of Veterinary Medicine was made part of USP in 1934, the year the university was founded.[28]

B) At São Paulo State University (Unesp):

i) The School of Agricultural Sciences (FCA) and the School of Veterinary Medicine & Animal Science (FMVZ) on the Botucatu campus. The Botucatu School of Medical & Biological Sciences (FCMBB), which began teaching undergraduates agronomy in 1965, was one of several isolated HEIs created in São Paulo State since the 1920s. The creation of Unesp in 1976 integrated these and FCA became an autonomous unit. Courses were introduced later in animal science (1977) at the School of Veterinary Medicine and animal science & forest engineering (1987) at FCA;

ii) The School of Agrarian & Veterinary Sciences founded in 1966 on the Jaboticabal campus, offering undergraduate courses in administration, agronomy, biological sciences, veterinary medicine and animal science, as well as ten post-graduate programs. Unesp's Aquaculture Center, on the same campus, conducts research and offers extension and post-graduate programs in inland waters aquaculture (fish, frogs, shrimp, alligators);[29]

iii) Unesp's Departments of Plant Science, Food Technology & Socioeconomics, Plant Health, Rural Engineering & Soil, and Biology & Animal Science on the Ilha Solteira campus (1976);[30]

iv) The Department of Veterinary Medicine, integrated with the School of Dentistry on the Araçatuba campus (1990). The Araçatuba School of Pharmacy & Dentistry was founded as an isolated HEI in the 1950s and incorporated into Unesp when the university was founded, in 1976;[31]

v) An undergraduate course in food engineering (1984) and post-graduate programs (master's and PhD) in food engineering and sciences at the Institute of Biosciences, Letters & Exact Sciences on the São José do Rio Preto campus;[32]

vi) More recent undergraduate courses (2003) in agricultural engineering and animal science on the Registro and Dracena experimental campuses respectively.

C) At State University of Campinas (Unicamp),[33] where research is increasingly multidisciplinary and involves the following units:

i) The School of Food Engineering (FEA), established in 1967 as the School of Food Technology, focusing on the technological and organizational development of modern industrial production and distribution of food;

ii) The School of Agricultural Engineering (Feagri), established in 1985, having until then been part of the School of Food Engi-

26. Source: <www.esalq.usp.br>. Last visited Mar. 22, 2010.
27. Source: <http://www.usp.br/pusp-p/index2.php> and <http://www.usp.br/fzea/>. Last visited Mar. 22, 2010.
28. Source: <http://www.fmvz.usp.br/historico>. Last visited Mar. 22, 2010.
29. Source: <http://www.fcav.unesp.br/>. Last visited Mar. 22, 2010.
30. Source: <http://www.feis.unesp.br/>. Last visited Mar. 22, 2010.
31. Source: <http://www.foa.unesp.br/instituicao/apresentacao>. Last visited Mar. 22, 2010.
32. Source: <http://www.ibilce.unesp.br/>. Last visited Mar. 22, 2010.
33. Source: <www.unicamp.br>. Last visited Mar. 22, 2010.

neering & Agricultural Engineering. Post-graduate courses in agricultural engineering, in existence since 1978, currently offer master's and doctoral degrees (created in 1993) in water and soil, farm building design, farm machinery, sustainable rural planning and development, and post-harvest technology;

iii) The Environmental Research Center (Nepam), established in 1982 to conduct research and extension activities not only on environmental topics but also several other disciplines relating to human activities that affect the environment, including agriculture. Offers a PhD in environment and society;

iv) Embrapa Informática Agropecuária, established in 1985 on the Campinas campus and since 2001 housing the Center for Meteorological & Climate Research Applied to Agriculture (Cepagri). The main outcomes of the close links between these two institutions are the Agritempo System, online via the internet since 2003, and the Brazilian Agricultural Risk Zoning Program;

v) The Pluridisciplinary Chemical, Biological & Agricultural Research Center (CPQBA), established in 1986 to cultivate ties with business via R&D and services in partnership with private or public institutions;

vi) The Interdisciplinary Energy Planning Center (Nipe), set up in 1992 as part of the restructuring of the Energy Center (Nuclener), created in 1984. Nipe is currently responsible for a master's program in energy systems planning (1987) and a similar doctoral program (1983). Its multidisciplinary approach has been constantly reinforced via links with Unicamp's other centers and institutes, especially the Petroleum Research Center (Cepetro), the Environmental Research Center (Nepam) and the Institute of Geoscience's Department of S&T Policy.

D) At municipal HEIs:

i) The Universidade de Taubaté (Unitau), offering a course in agronomy (from which more than 1,200 people have graduated since it was accredited in 1984) and a course in food engineering (since 2003);[34]

ii) Faculdades Adamantinenses Integradas (FAI), run by the City of Adamantina and offering undergraduate courses in agronomy, environmental engineering and veterinary medicine, and post-graduate courses in bioenergy management and biotechnology management.[35]

E) At federal universities in São Paulo State:

i) The Federal University of São Carlos (UFSCar), which has an Agrarian Science Center (CCA), located in the city of Araras. When Planalsucar and IAA were shut down in the early 1990s, UFSCar took over their São Paulo units to found CCA. Agricultural engineering was the first course offered, in 1993. The second was a bachelor's degree in biotechnology, in 2006, when the first post-graduate program in agroecology and rural development was also introduced. CCA has the following departments: Plant Biotechnology, Natural Resources & Environmental Protection, and Agroindustrial Technology & Rural Socioeconomics. The Biological Science & Health Center (at São Carlos) houses the Departments of Botany, Physiological Sciences & Ecology, and Evolutionary Biology.[36]

F) Technological courses relating to agrarian sciences at São Paulo's Colleges of Technology (Fatecs):

i) Fatec-SP, established in 1970, has trained more than 17,000 technologists.[37] Courses are offered in eight disciplines: agribusiness, food, sugar & ethanol bioenergy, agribusiness management, agribusiness logistics (two modalities), corporate networks, associations and cooperatives in agribusiness and silviculture. Courses are delivered in 14 different cities across São Paulo State: Araçatuba, Botucatu, Capão Bonito, Itapetininga, Jaboticabal, Jales, Marília, Mococa, Mogi das Cruzes, Ourinhos (two courses), Piracicaba, Presidente Prudente (two courses), São José do Rio Preto and Taquaritinga.

Besides the public universities, there are 60 private HEIs in São Paulo State that offer 92 undergraduate courses in agrarian sciences, especially veterinary

34. Source: <http://www.unitau.br/universidade>. Last visited Mar. 22, 2010..
35. Source: <http://www.fai.com.br/portal/index.php>. Last visited Mar. 22, 2010.
36. Source: <http://www2.ufscar.br/vidaacademica/cienciasagrarias.php>. Last visited Mar. 22, 2010.
37. Source: <http://www.fatecsp.br/>. Last visited Mar. 22, 2010.
38. Most private HEIs in Brazil do not conduct research activities.

medicine (33), agronomy (11) and food engineering (10), as detailed in item 10.2.3.[38]

As can be seen from the above, SPInA is highly complex and dense. It is a system with a long history (over 120 years) and with public organizations of crucial importance to the development of agriculture not only in São Paulo State but throughout Brazil. The IAC model served as a basis for most of the public research organizations that came later, both in São Paulo State and in the rest of Brazil. The private sector also contributes significantly via investment in domestic and multinational firms, as well as the activities of farmers' and agroindustrial associations. Despite its large size, however, the system is fragmented and lacks explicit coordination, which does not mean it lacks successful interaction and linkages among its participants.

Coordination occurs mainly in terms of specific crops rather than across the entire system. Thus parts of the system are coordinated to a greater or lesser extent. Citrus is one of the best examples, especially as far as plant health is concerned. Public and private actors interact successfully in all areas, from basic research to the coordination of plant health surveillance. This coordination derives from the needs of the sector as well as initiatives undertaken by research organizations via their labs and by individual researchers. Institutions such as APTA have undertaken few initiatives to promote the coordination of a ST&I system in São Paulo State, although this appears as a proposal in APTA's most recent documents (APTA, 2006). The following items present clearer numbers to show the real importance of SPInA for the ST&I system in the state and for Brazil.

3. ST&I expenditure and human resources (inputs: expenditure & HR)

This section presents data on public and private investment in agricultural ST&I, the correlation between agricultural R&D and agricultural GDP, and the competencies dedicated to agricultural ST&I in São Paulo State and Brazil.

Public expenditure on S&T in Brazil averaged about R$ 1.6 billion in the period 2001-05 (Table 10.4). As noted at the start of the chapter, private expenditure is estimated here using the proportion found between public and private expenditure in the national ST&I system (MCT, 2009). On this basis it is justified to add the above figure to private expenditure of between R$ 1.3 billion and R$ 1.7 billion, which would take total annual investment in agricultural S&T to between R$ 3 billion and R$ 3.4 billion in the period.[39] Thus investment in agricultural S&T corresponded to between 2.4% and 3.1% of agricultural GDP in the period 2001-05 (Table 10.5). Investment in agricultural R&D, estimated using the proportion between R&D and S&T for all areas and sectors, will have corresponded to between 1.8% and 2.4% of agricultural GDP (Table 10.5).

It is important to note one additional estimate. The accounting method that best captures value creation in the agricultural sector takes into consideration not just agriculture proper but also the related upstream and downstream segments, such as suppliers of inputs, service providers, and processors of food and raw materials. On this basis, investment in R&D will have corresponded to between 0.37% and 0.45% of the agribusiness GDP (see glossary) in the period (Table 10.5).

It is hard to know today whether agricultural GDP or agribusiness GDP is the correct basis for such estimates, especially because strictly agricultural R&D (inside the farm gate) overlaps with activities conducted upstream and downstream of agriculture proper. For example, a far from negligible proportion of investment by Embrapa and some state agricultural research organizations (SAROs) is allocated to R&D in both food and raw material processing and the development of inputs for agriculture. Two of Embrapa's research centers are dedicated to the agroprocessing industry, as is one of APTA's institutes (Ital). These investments are included in the numerator of the ratio between R&D expenditure and GDP, whether the focus is on agriculture proper or on agribusiness in the broad sense of the term.

Similarly, all GM seed research conducted by public and private organizations affects the seed industry, which is classified as part of agribusiness GDP for accounting purposes. Another example of this gray zone in which R&D investment inside the farm gate overlaps with investment outside the farm gate is expenditure by private-sector firms that produce inputs. The R&D

39. PINTEC statistics on national private investment in innovation in the agribusiness sector do not include seeds and seedlings, the main focus for private research in Brazil. Hence the option to use an estimate based on the proportion between overall public and private investment in ST&I for the period.

Table 10.4
Private and public expenditure on S&T in agriculture – Brazil, 2001-2005

Type of funding	Private and public expenditure on S&T in agriculture				
Total (R$) (1)	**3,012,373,974**	**3,117,975,993**	**3,067,832,582**	**3,189,914,076**	**3,386,490,432**
Public expenditure (R$) (1) (2)	1,667,026,322	1,616,698,340	1,591,468,893	1,670,391,775	1,688,148,801
Private expenditure factor (%) (3)	0.45	0.48	0.48	0.48	0.50
Estimated private expenditure (R$) (1) (3)	1,345,347,653	1,501,277,653	1,476,363,689	1,519,522,302	1,698,341,632

Source: Embrapa (Dept. of Management & Strategy); Gonçalves, Junqueira & Barros Filho (2004); São Paulo State Department of Agriculture & Supply (SAA); CGEE (2006); Portal da Transparência.

(1) In 2006 constant *reais* (R$) deflated by IPCA (IBGE).
(2) Includes data on partnership agreements involving Ministry of Science & Technology (MCT) and FAPESP for agrarian sciences, Embrapa, state agricultural research organizations (SAROs), CNPq and CAPES grants for agrarian sciences, and departments of agrarian sciences at public universities in São Paulo State.
(3) Ratio of public to private S&T investment according to MCT for Brazil and all areas (see Methodological Annex).

Table 10.5
GDP and public and private expenditure on S&T and R&D in agriculture and agribusiness – Brazil, 2001-2005

Year	GDP and public and private expenditure on S&T and R&D in agriculture and agribusiness								
	Agriculture						Agribusiness		
	GDP (value added) (R$) (1) (A)	Total S&T expenditure		R&D/S&T factor	Estimated R&D expenditure (2)		GDP (R$) (1) (D)	% S&T/ agribusiness GDP (B) / (D)"	% R&D/ agribusiness GDP (C) / (D)"
		In R$ (1) (B)	% GDP (B) / (A)		In R$ (1) (C)	% GDP (C) / (A)			
2001	98,663,993,811	3,012,373,974	3.1	0.79	2,369,749,549	2.4	523,143,000,000	0.58	0.45
2002	114,710,801,136	3,117,975,993	2.7	0.75	2,353,766,825	2.1	569,220,000,000	0.55	0.41
2003	128,918,988,457	3,067,832,582	2.4	0.76	2,335,099,843	1.8	606,419,000,000	0.51	0.39
2004	128,260,194,314	3,189,914,076	2.5	0.73	2,317,325,913	1.8	621,910,000,000	0.51	0.37
2005	109,562,565,751	3,386,490,432	3.1	0.76	2,589,376,303	2.4	592,943,000,000	0.57	0.44
Average			**2.7**		**2,393,063,687**	**2.1**		**0.54**	**0.41**

Source: IBGE (Contas Nacionais); Cepea/ESALQ; Embrapa (Dept. of Management & Strategy); Gonçalves, Junqueira & Barros Filho (2004); São Paulo State Department of Agriculture & Supply (SAA); CGEE (2006); Portal da Transparência.

(1) In 2006 constant *reais* (R$) deflated by IPCA (IBGE).
(2) Estimated R&D expenditure = (Estimated S&T expenditure) x (R&D-S&T factor).

Note: Factor for public and private investment in R&D/S&T computed based on values for Brazil in all areas (see Methodological Annex).

activities of Monsanto, Syngenta, Pioneer and Jacto, to name only a few, are included in the private expenditure estimates presented here and explained in the Methodological Annex.

It will not be possible to estimate investment in research as a share of agribusiness GDP more precisely until more detailed accounting methods have been developed than currently exist in Brazil or elsewhere in the world. In a study of investment in agricultural R&D in Latin America, Stads & Beintema (2009) counted only public expenditure on research relating strictly to crop farming (genetics, plant varieties and agronomic practices) and compared this with agricultural GDP in the countries concerned. They showed that public expenditure on R&D was in the range of R$ 1.4 billion in Brazil in 2004 and 2005. The analysis performed for this chapter concluded that public expenditure on S&T amounted to R$ 1.6 billion in Brazil in 2005, with São Paulo accounting for R$ 0.33 billion, including disbursement by FAPESP and the universities located in the state, as well as expenditure by the Ministry of Science & Technology's sectoral funds (not included by Stads & Beintema). Thus the numbers in both these studies are reasonably congruent.

Considering all the numbers presented above, São Paulo's share of national expenditure on agricultural research in the period 2001-05 will have averaged 20%[40] (Tables 10.4 and 10.6). Taking into account all the data collected for São Paulo ´plus the public and private expenditure indices calculated by MCT for Brazil, it can be concluded that São Paulo's expenditure on agricultural research fell in 2001-03 and rose in 2004-05, ending the period at R$ 671.4 million (Table 10.6).

Table 10.6
Public and private expenditure on S&T in agriculture – São Paulo State, 2001-2005

Type of funding	Public and private expenditure on S&T in agriculture				
	2001	2002	2003	2004	2005
Total (R$) (1)	**631,036,064**	**615,161,441**	**558,887,219**	**601,133,977**	**671,438,172**
Total (SP/BR) (%)	**20.9**	**19.7**	**18.2**	**18.8**	**19.8**
Public expenditure (R$) (1) (2)	349,210,867	318,966,690	289,928,345	314,782,538	334,708,622
Private expenditure factor (%) (3)	0.45	0.48	0.48	0.48	0.50
Estimated private expenditure (R$) (1) (3)	281,825,197	296,194,752	268,958,874	286,351,438	336,729,550

Source: Embrapa (Dept. of Management & Strategy); Gonçalves, Junqueira & Barros Filho (2004); São Paulo State Department of Agriculture & Supply (SAA); CGEE (2006); Portal da Transparência; FAPESP; Feagri/Unicamp; ESALQ; FZEA & FMVZ/USP; FOA; FMVZ; FCA; FEIS; FCAV/Unesp & CCA/UFSCAR; MCT (national indicators of S&T investment).

(1) In 2006 constant *reais* (R$) deflated by IPCA (IBGE).
(2) Includes data on partnership agreements involving Ministry of Science & Technology (MCT) and FAPESP for agrarian sciences, Embrapa, state agricultural research organizations (SAROs), CNPq and CAPES grants for agrarian sciences, and departments of agrarian sciences at public universities in São Paulo State.
(3) Ratio of public to private S&T investment according to MCT for Brazil and all areas (see Methodological Annex).

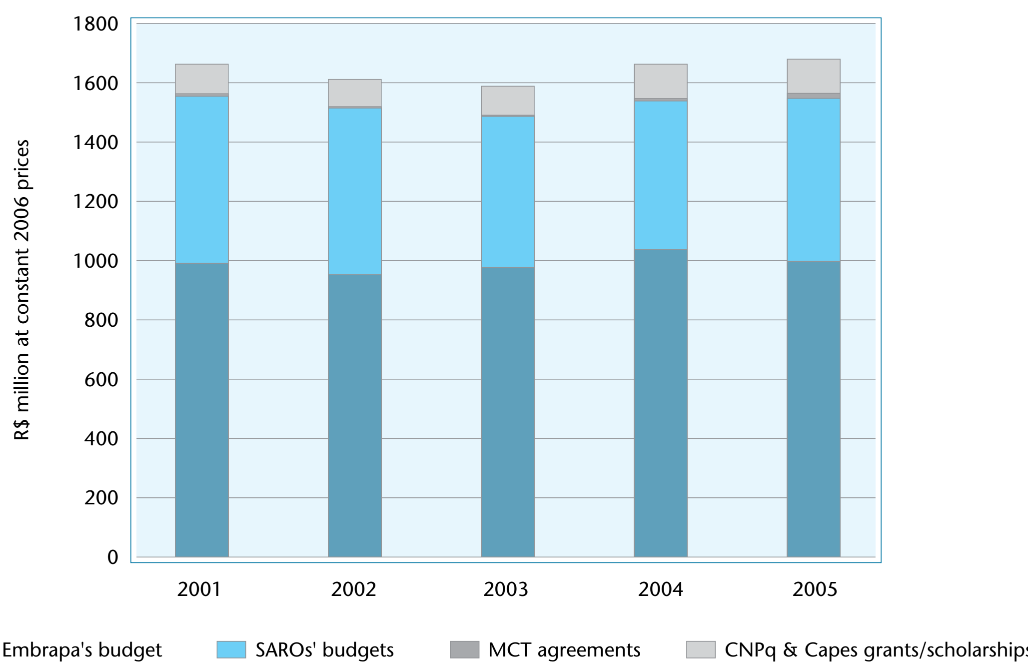
40. Not including expenditure by FAPESP and public universities in São Paulo, as shown in Detailed Table 10.19 and Figure 10.4, since this type of expenditure has not been measured for Brazil as a whole and to do so here would surpass the scope of this chapter.

3.1 Public expenditure

Public funds invested in agricultural S&T in Brazil fluctuated in the range of R$ 1.6 billion per annum in the period 2001-05, reaching R$ 1.7 billion at the end of the period (Figure 10.2). The institution with the largest agricultural research budget was Embrapa, which invested some R$ 1 billion per annum in the last few years of the period, including funds from the budget of the Ministry of Agriculture, Fisheries & Supply (Mapa) and agreements with several other ministries, among which the most important was the Ministry of Science & Technology (MCT), and other national and international agencies.

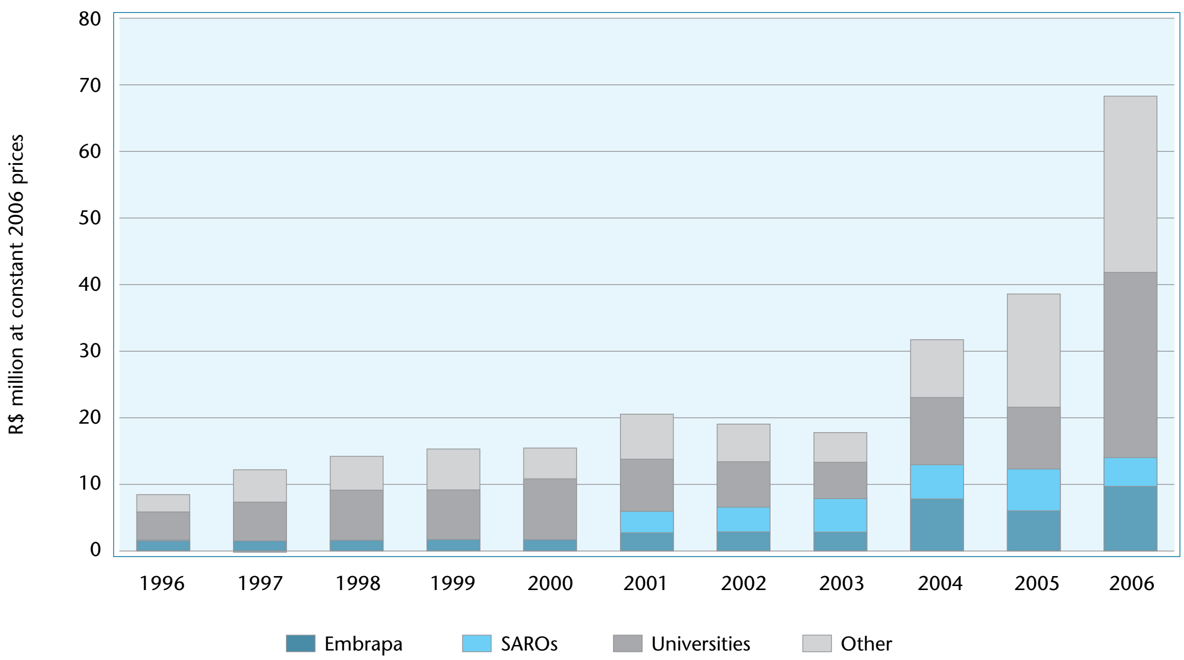
All 17 state agricultural research organizations (SAROs) received in aggregate roughly R$ 0.5 billion per annum in the same period. About 20% came from partnerships with the federal government, Embrapa and state research funding agencies (FAPs), as well as other sources in the states (Detailed Table 10.7). It is interesting to note that MCT became a major source of funding for research institutions, including SAROs, especially from 2001 onwards, with a peak in 2006 reflecting agreements with sectoral funds (Figure 10.3).

Figure 10.2
Public expenditure on S&T in agriculture by type of funding and institution – Brazil, 2001-2005



Source: Embrapa (Dept. of Management & Strategy); Gonçalves, Junqueira & Barros Filho (2004); São Paulo State Department of Agriculture & Supply (SAA); CGEE (2006); Portal da Transparência; Fapesp; CNPq; Capes.
Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. Apta and Embrapa include funding from Fapesp.
3. MCT agreements include funds transferred to universities, researchers (individuals), research institutions and other institutions but exclude Embrapa, SAROs and grants/scholarships.
4. MCT = Ministry of Science & Technology; SAROs = state agricultural research organisations.
5. See Detailed Table 10.6.

Figure10.3
S&T expenditure under federal government partnership agreements via MCT by type of partner – Brazil, 1996-2006



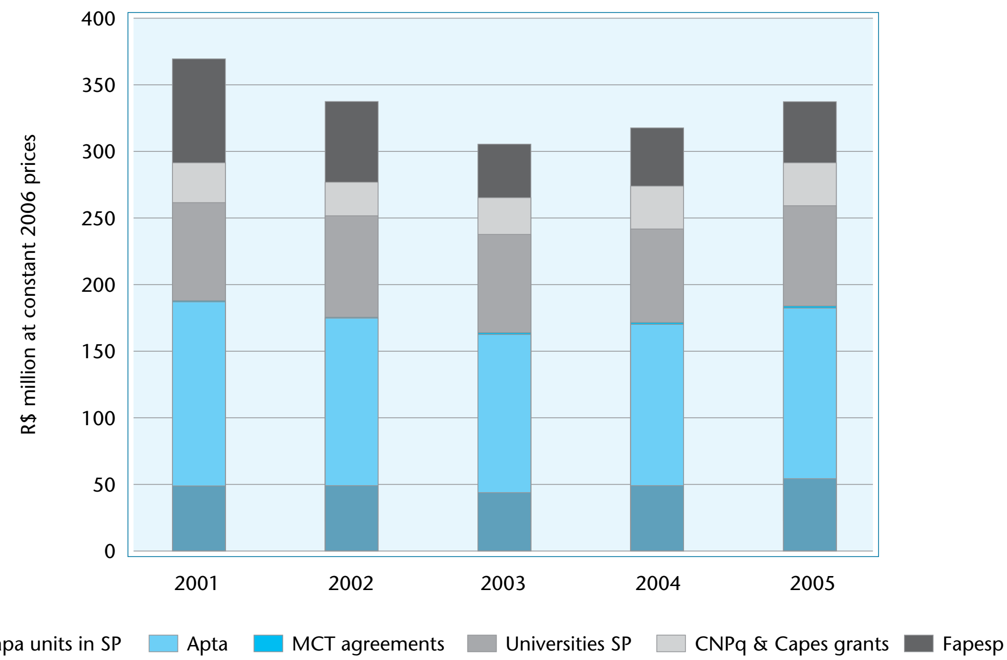
Source: Portal da Transparência.

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. MCT = Ministry of Science & Technology; SAROs = state agricultural research organisations.
3. See Detailed Table 10.8.

To take only the data for São Paulo, APTA had the largest budget, averaging R$ 117.6 billion in the period 2001-05 (Figure 10.4). This is because unlike most other states São Paulo has a history of state government investment in agricultural research, and as a result the state has built a structure that is unrivalled in the rest of the country. APTA has the largest individual budget, surpassing even the aggregate budgets of Embrapa's five units in the state (Detailed Table 10.9).

In second place came agrarian sciences at public universities located in São Paulo, whose S&T expenditure accounted on average for 22.7% of the total in the period 2001-05 (Detailed Table 10.9). Embrapa's units in São Paulo contributed significantly to the foundation of SPInA and to agricultural research overall: in the 11 years analyzed (1996-2006), their budgets grew 22.8% and their share of Embrapa's total budget rose from 4.8% to 6.1% in the period, despite fluctuations (Detailed Table 10.10).

Figure 10.4
Public expenditure on S&T in agriculture by type of funding and institution – São Paulo State, 2001-2005

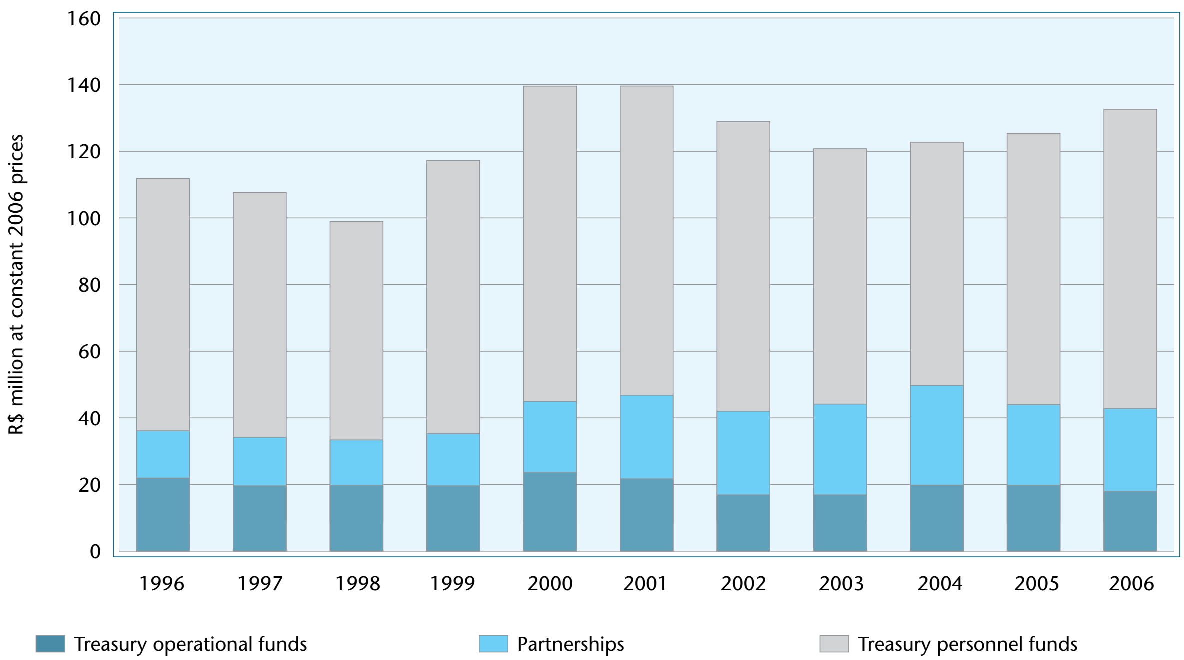


Source: Embrapa (Dept. of Management & Strategy); Gonçalves, Junqueira & Barros Filho (2004); São Paulo State Department of Agriculture & Supply (SAA); CGEE (2006); Portal da Transparência; Fapesp; CNPq & Capes; Feagri/Unicamp; Esalq; FZEA & FMVZ/USP; FOA; FMVZ; FCA; FEIS; FCAV/Unesp; CCA/UFSCar.

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. Apta and Embrapa include funding from Fapesp.
3. MCT agreements include funds transferred to universities, researchers (individuals), research institutions and other institutions but exclude Embrapa, SAROs, scholarships and grants.
4. See Detailed Table 10.9.

APTA's total budget rose 19% between 1996 and 2006 with some fluctuations, systematically exceeding R$ 100 million except in 1998 and reaching R$ 131.8 million in 2006 (Detailed Table 10.9). The volume of funds transferred under partnership agreements and contracts increased as a share of APTA's total budget, from 13.9% in 1996 to 26.7% in 2003, slipping back to 19.6% in 2006. These transfers ("Partnerships" in Figure 10.5) amounted to R$ 15.4 million in 1996 and R$ 25.9 million in 2006.

Figure10.5
Budget of Agência Paulista de Tecnologia dos Agronegócios (Apta) – São Paulo State, 1996-2006



Source: Gonçalves, Junqueira & Barros Filho (2004); São Paulo State Department of Agriculture & Supply (SAA).

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. Apta = São Paulo State Agency for Agribusiness Technology.
3. See Detailed Table 10.11.

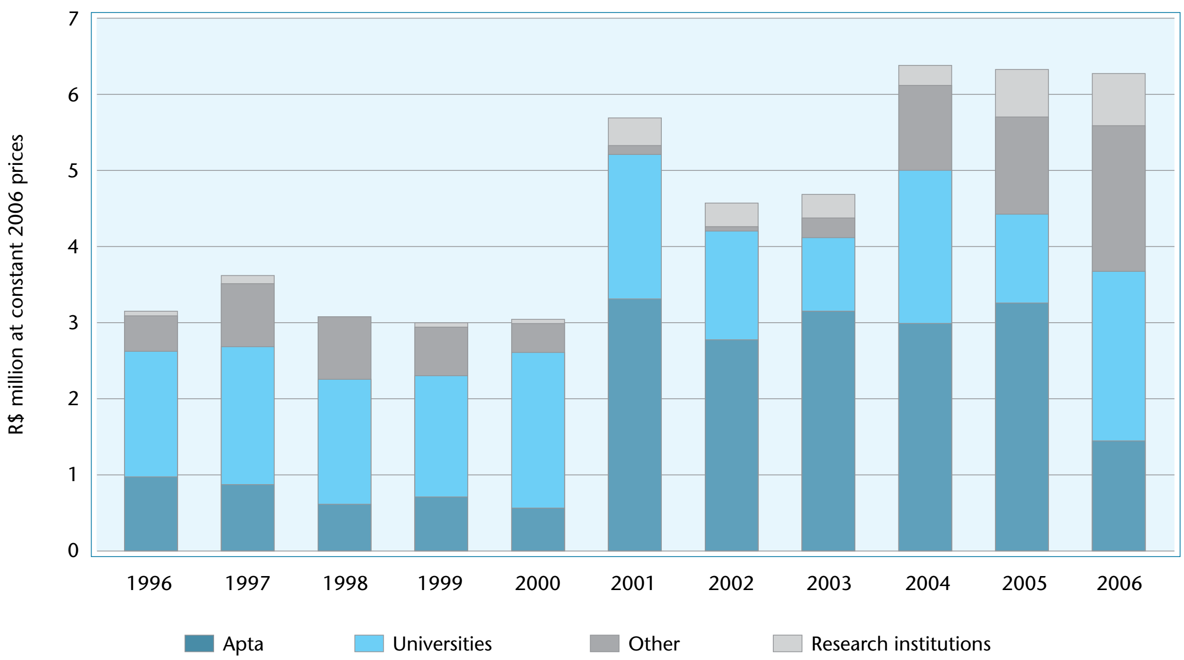
Expenditure on agriculture S&T by research institutions in São Paulo under MCT partnership agreements also rose (Figure 10.6). APTA received 41.2% of the total invested via federal agreements in agricultural research in São Paulo between 1996 and 2006, which was R$ 49.6 million. Universities received 37.4%.

FAPESP was responsible on average for 16.5% of public investment in research in São Paulo State between 2001 and 2005, especially in the form of grants and scholarships (Figure 10.4). Compared with federal funding via MCT and CAPES, FAPESP invested almost four times more in the form of grants, with an average of R$ 21.4 million per annum (Detailed Table 10.13), as against R$ 5.5 million for MCT and CAPES in the same period (Detailed Table 10.12). FAPESP invested almost the same amount in scholarships between 2001-05, with an average of R$ 22.4 million (Detailed Table 10.13), as against R$ 27.3 million for MCT and CAPES (Detailed Table 10.9).[41] Besides grants and scholarships, FAPESP also funded Special Programs and Technological Innovation Programs, which accounted respectively for 26.3% and 5.4% of the total in 1996-2006 (Detailed Table 10.13).[42]

41. Calculated using data for MCT partnerships (Detailed Table 10.12) and CNPq and CAPES scholarships (Detailed Table 10.9), on one hand, and FAPESP's grants (excluding technological innovation and special programs) and scholarships (Detailed Table 10.13).

42. FAPESP's programs are divided into two categories: Special Programs (including Young Researchers in Emerging Centers, Technical Training for Human ReSource to Support Research, Inter-Institutional Cooperation to Support Brain Research (CInAPCe), Multiuser Equipment, Scientific Journalism, Improving Public Education, São Paulo Academic Network (Rede ANSP), Scientific Electronic Library Online (SciELO)); and Research for Technological Innovation (including Biotechnology/Biodiversity: BIOTA-FAPESP & FAPESP-BIOEN, Molecular Biotechnology: Genome-FAPESP, Research, Innovation & Dissemination Centers (CEPID), Public Policy Research Support, Technological Innovation Research Programs: Partnership for Technological Innovation (Pite) and Sectoral Consortia for Technological Innovation (ConSITec), Technological Innovation Research in Small Business: Innovative Research in Small Business (Pipe), Pipe Phase 3: Pappe/FINEP & Intellectual Property Support Program (Papi/Nuplitec), FAPESP Climate Change Research Program (PFPMCG), Structural Molecular Biology Network (Smolbnet), Information Technology for Advanced Internet Development (Tidia), Virus Genetic Diversity Network (VGDN)).

Figure 10.6
Agricultural S&T expenditure under federal government partnership agreements via MCT by type of partner – São Paulo State, 1996-2006



Source: Portal da Transparência.

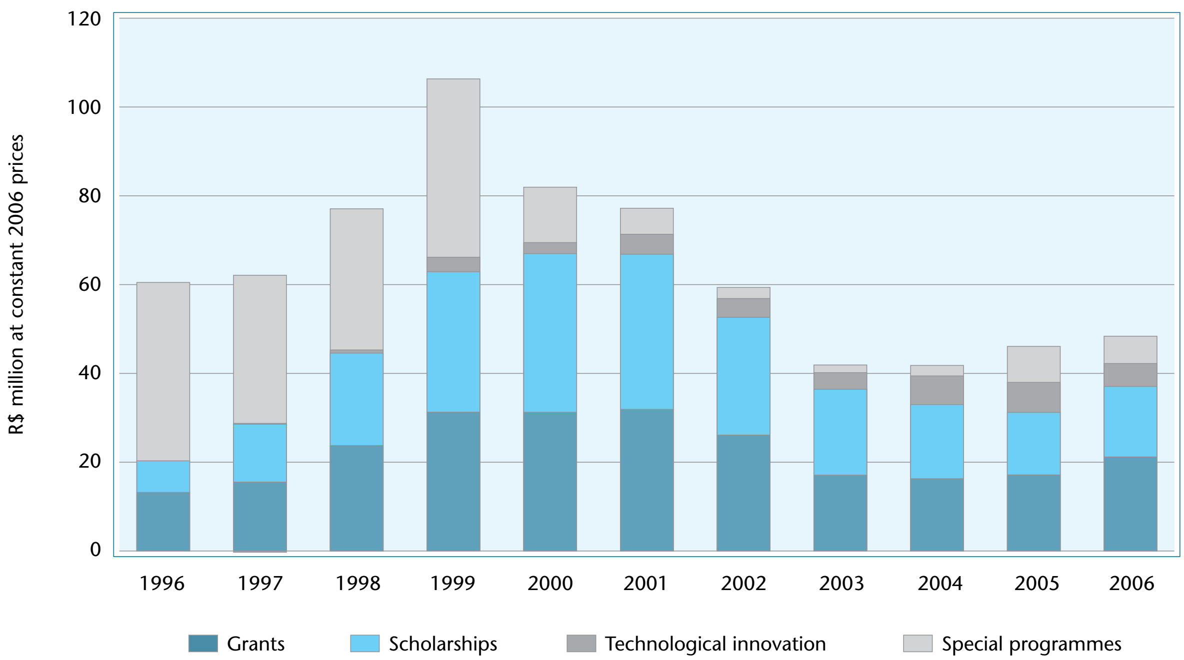
Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. Apta = São Paulo State Agency for Agribusiness Technology.
3. See Detailed Table 10.12.

Between 1996 and 2006, FAPESP invested almost R$ 700 million, with annual investment peaking in 1999 at R$ 106.1 million (Figure 10.7). The large amount invested in Special Programs between 1996 and 1999 was due to disbursements under the Research Infrastructure Support Program, which totalled R$ 144.4 million (Detailed Table 10.14).

The area of agricultural research that received most investment from FAPESP was agronomy, with a total of R$ 222.6 million in the period 1996-2006; 37.9% of all projects were funded by Special Programs, especially the Research Infrastructure Support Program, which accounted for almost all grants in this category (Figure 10.8, and Detailed Tables 10.15 and 10.16). Scholarships ranked second, accounting for 29.5% of total funding for the area (Detailed Table 10.15). Plant health and plant sciences together accounted for investment of R$ 99 million (Detailed Table 10.17). In these areas most of the investment goes to basic research, which explains why it consists mainly of scholarships, although regular grants, thematic projects and infrastructure support also account for a large proportion of the total.

Veterinary medicine ranked second among the areas that received most investment in 1996-2006, with about R$ 177 million. The main focus was the animal reproduction subarea, which accounted for 27% of the total, mainly via scholarships and regular research grants. The Young Researcher Program (JP) was also an important source of support for this subarea (Detailed Tables 10.16 and 10.17).

Figure 10.7
Fapesp disbursements for agrarian sciences by funding group – São Paulo State, 1996-2006



Source: FAPESP.

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. Includes plant genetics, botany, agricultural & resource economics, rural sociology, rural anthropology.
3. See Detailed Table 10.13.

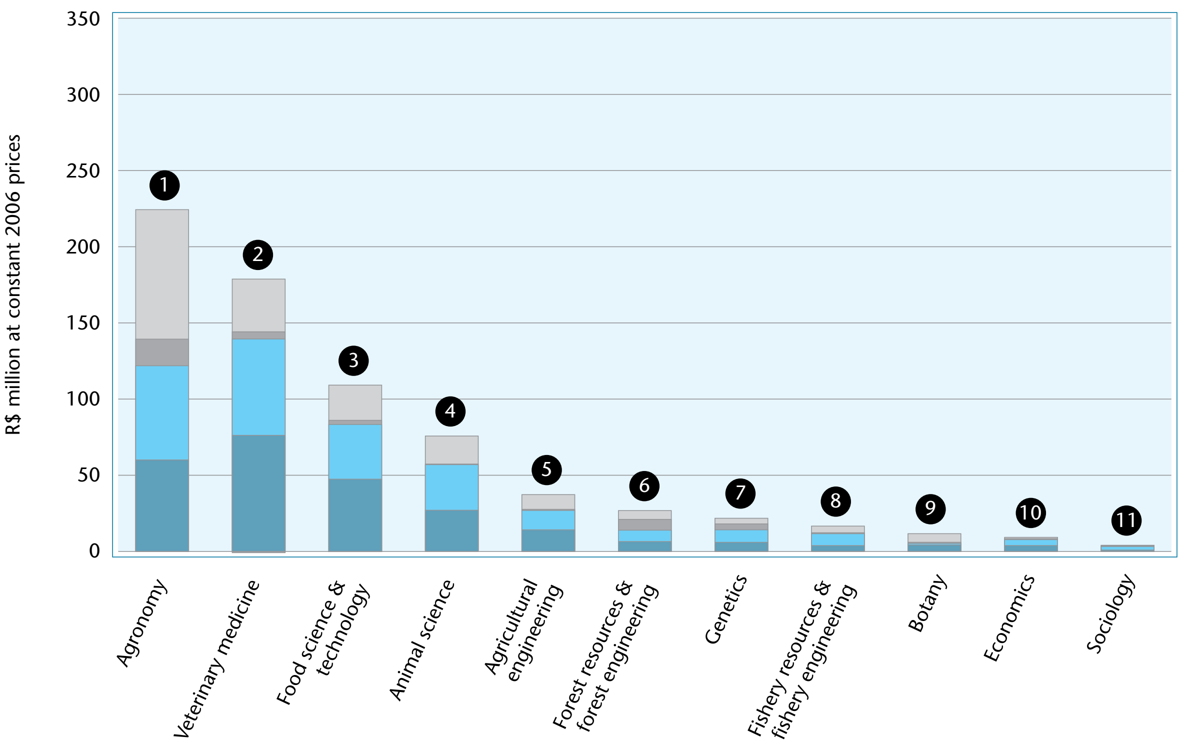
Food science and technology ranked third among the areas of agricultural research that received most investment from FAPESP in the period, with R$ 108.2 million, mainly in the form of grants and scholarships. The main subareas were food science and food technology, with 56.4% of total investment. The food technology subarea received the more varied forms of investment, including grants from Technological Innovation Programs such as Innovative Research in Small Business (Pipe) and Partnership for Technological Innovation (Pite), alongside the food engineering subarea (Detailed Tables 10.16 and 10.17). Animal science also stood out in FAPESP's disbursements for agrarian sciences, with R$ 74.8 million in the period. The other disciplines received less (Figure 10.8).

Turning to scholarships for post-graduate research, it can be seen that agrarian sciences accounted for 13%-15% of the total amount invested nationwide in such scholarships by CAPES and CNPq between 2001 and 2005 (Detailed Table 10.18). Investment by CAPES in agrarian sciences in São Paulo averaged about R$ 10 million per annum during the same period, declining in proportion to total investment by CAPES in scholarships throughout Brazil from 25% in 2001 to 20.9% in 2005 (Figure 10.9). Investment by CNPq rose from R$ 17.8 million in 2001 to R$ 20.1 million in 2005. São Paulo's share was 25.4%.

To estimate agriculture research expenditure in higher education, a survey was conducted of the agrarian sciences area of the schools of agriculture at São Paulo State's public universities (Feagri/Unicamp; ESALQ, FZEA and FMVZ/USP; FOA, FMVZ, FCA, FEIS and

43. For more details, see the Methodological Annex.

Figure 10.8
Fapesp disbursements for agrarian sciences by discipline and funding group (cumulative) – São Paulo State, 1996-2006

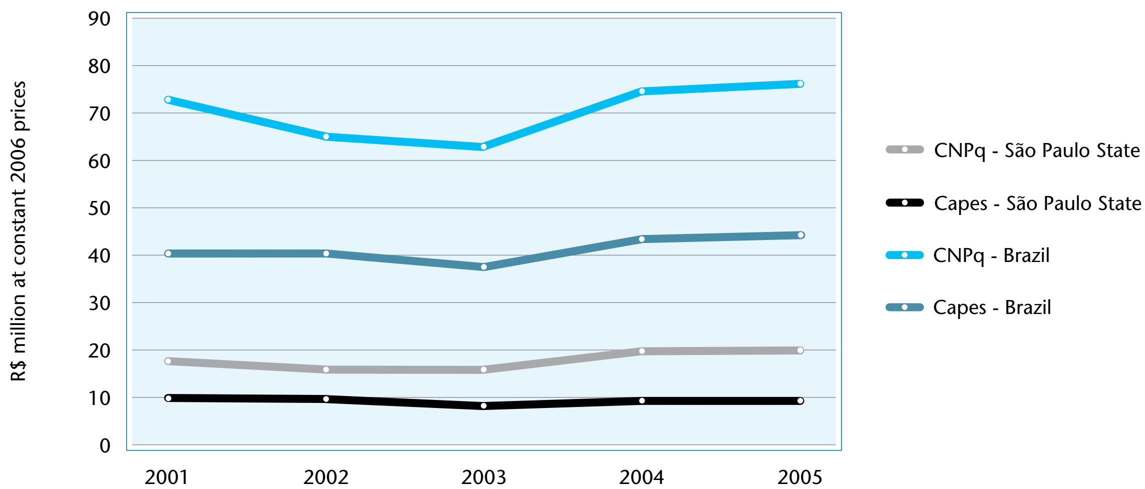


	1	2	3	4	5	6	7	8	9	10	11
Special Programmes	84,374,546	34,105,082	22,408,721	17,856,120	6,401,720	5,636,925	3,535,813	3,211,778	6,010,345	184,927	115,329
Technological Innovation	14,467 3,37	3,816,808	4,014,974	1,340,446	2,793,962	7,075,516	3,160,103	543,162	427,111	194,467	133,471
Scholarships	65,781,102	64,265,466	36,503,518	29,740,962	13,321,060	6,683,973	7,480,704	6,477,837	1,115,754	3,200,205	2,182,120
Grants	58,019,769	74,760,844	45,315,267	25,897,464	12,425,271	5,730,389	5,933,364	4,650,030	3,640,622	3,003,937	955,325

Source: FAPESP.

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. Includes plant genetics, botany, agricultural & resource economics, rural sociology, rural anthropology.
3. See Detailed Table 10.15.

Figure 10.9
CNPq and Capes disbursements for master's, doctoral, development (short-term) and post-doctoral scholarships in agrarian sciences – Brazil & São Paulo State, 2001-2005



Source: CNPq; Capes.

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. See Methodological Annex for post-graduate programmes.
3. See Detailed Table 10.18.

FCAV/Unesp; and CCA/UFSCar).[43] In aggregate these universities invested about 6% of their budgets in agrarian sciences (Detailed Table 10.19). Figure 10.10 presents the budgets of the state's universities and schools of agrarian sciences. Except for certain specific years, the amounts rose in both cases. University budgets in aggregate rose 39.1% from R$ 3 billion in 1996 to R$ 4.2 billion in 2006 (at 2006 prices). The budgets of schools and centers of agrarian sciences rose 53.3% from R$ 180.1 million in 1996 to R$ 276.2 million in 2006.

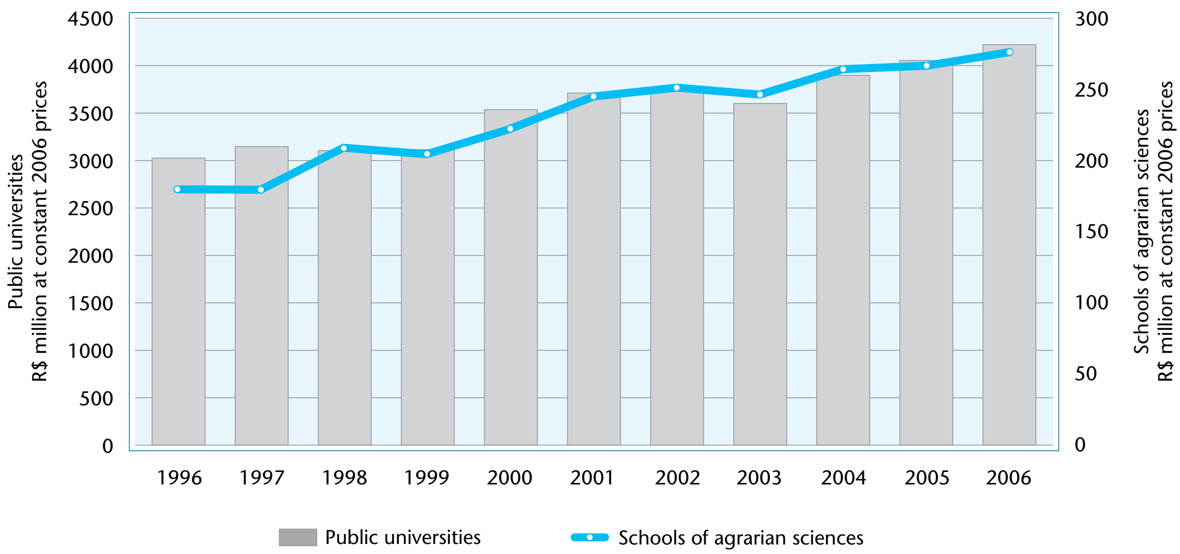
Faculty pay accounted for 36.5% of the budgets of these schools of agrarian sciences in 1996-2006, with a decline in the proportion from 40.8% in 1996 to 34.8% in 2006. Based on this subtotal it was found that some 66% of faculty pay related to research[44] (Detailed Table 10.21 and Figure 10.11).

The ten schools of agrarian sciences had 937 active faculty members in 2006. The number fluctuated during the period analyzed, reaching a low of 883 in 2003 and a high of 944 in 1996 (Detailed Table 10.22). This fluctuation was not paralleled by the budget allocation for active faculty pay, which rose during practically the entire period (Figure 10.12).

As part of the survey of expenditure on agricultural research by HEIs in São Paulo State, respondents were asked to estimate the percentages allocated to the capital costs and running costs of research projects. The values are presented in Table 10.7. The estimated budget for running costs rose 3.3 times, from R$ 2.6 million in 1996 to R$ 8.5 million in 2006, while the estimated budget for capital costs rose fourfold from R$ 656,800 to R$ 2.6 million. Both rose far more than the total budgets of the schools in question. Even so it can be seen that pay accounted for the largest proportion of the budget, with very little left over for research running costs and capital expenditure. Typically for Brazil, research funding proper came mostly from sources external to the universities.

44. Estimate made by university respondents, as described in the Methodological Annex.

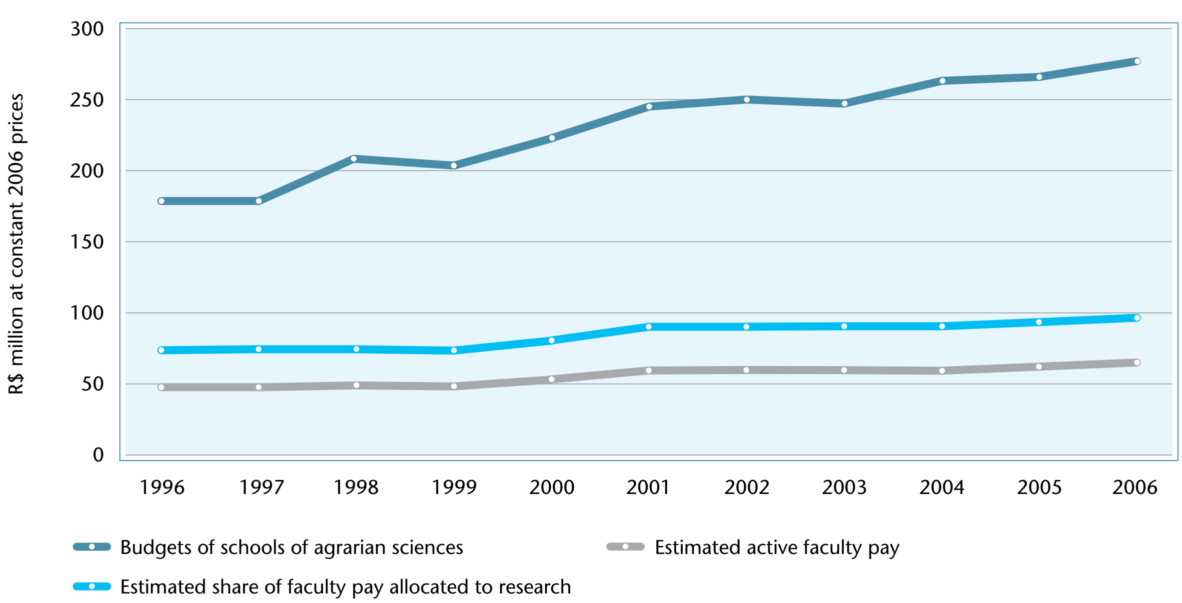
Figure 10.10
Budgets of public universities and schools of agrarian sciences – São Paulo State, 1996-2006



Source: Feagri/Unicamp; Esalq; FZEA & FMVZ/USP; FOA, FMVZ, FCA, FEIS & FCAV/Unesp; CCA/UFSCar.

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. See Detailed Table 10.20.

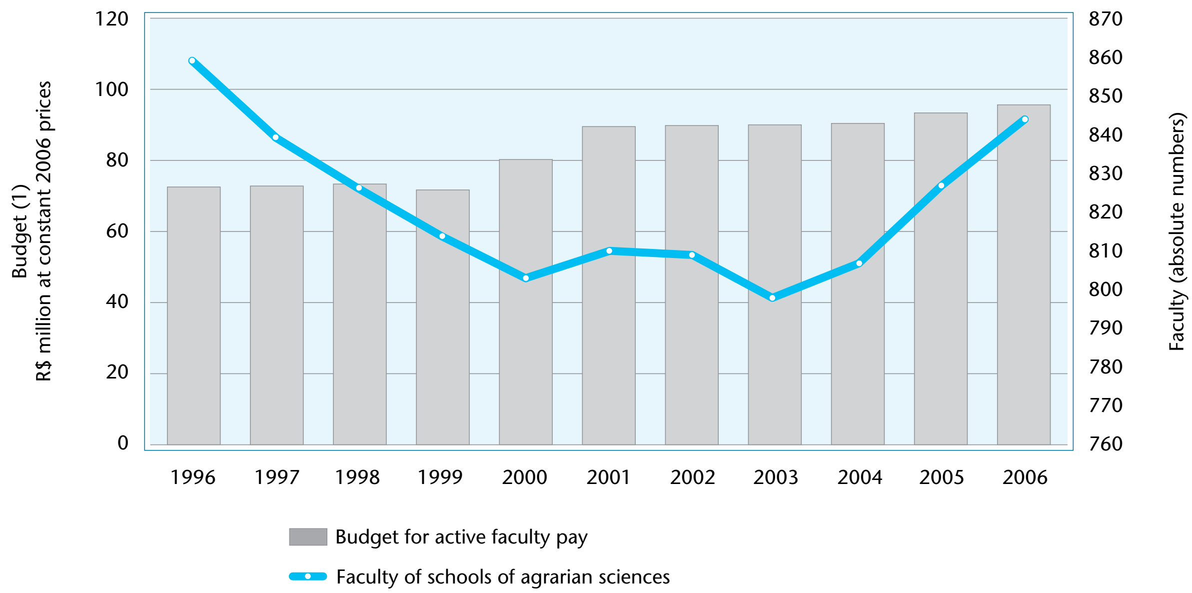
Figure 10.11
Budgets of agrarian sciences schools at public universities, estimated active faculty pay and estimated share of faculty pay allocated to research – São Paulo State, 1996-2006



Source: Feagri/Unicamp; Esalq; FZEA & FMVZ/USP; FOA, FMVZ, FCA, FEIS & FCAV/Unesp; CCA/UFSCar.

Notes: 1. In 2006 constant reais (R$) deflated by IPCA (IBGE).
2. Excludes FMVZ/USP.
3. See Detailed Table 10.21.

Figure 10.12
Active faculty of schools of agrarian sciences at public universities and budget for faculty pay – São Paulo State, 1996-2006



Source: Feagri/Unicamp; Esalq; FZEA & FMVZ/USP; FOA, FMVZ, FCA, FEIS & FCAV/Unesp; CCA/UFSCar.
(1) In 2006 constant reais (R$) deflated by IPCA (IBGE).

Notes: 1. Excludes FMVZ/USP.
2. See Detailed Table 10.23.

Table 10.7
Estimated research budgets of schools of agrarian sciences at public universities – São Paulo State, 1996-2006

Year	Estimated research budgets of schools of agrarian sciences at public universities (R$)	
	Research project running costs	Research project capital costs
1996	2,571,636	656,765
1997	3,024,550	675,019
1998	3,357,644	722,108
1999	3,095,070	597,917
2000	4,855,543	1,517,488
2001	6,321,224	2,602,349
2002	6,751,167	2,053,385
2003	6,915,702	2,573,400
2004	6,742,904	1,602,330
2005	8,606,665	2,254,937
2006	8,546,208	2,637,932

Source: Feagri/Unicamp; ESALQ; FZEA & FMVZ/USP; FOA, FMVZ, FCA, FEIS & FCAV/Unesp; CCA/UFSCar.

Notes: 1. In 2006 constant *reais* (R$) deflated by IPCA (IBGE).
2. Excludes FMVZ/USP, which participated in the survey and supplied some data but not these numbers.

3.2 Private expenditure on agricultural R&D

As noted earlier, private expenditure on S&T in agriculture is estimated to have averaged R$ 1.5 billion per annum between 2001 and 2005 (Table 10.4). An estimate was necessary owing to a lack of reliable data sources and the impossibility of collecting primary data within the scope of this chapter. This item focuses on private expenditure on innovation activities in agribusiness as measured by IBGE's Survey of Technological Innovation in Industry (PINTEC), and private investment financed by FINEP, the Brazilian Innovation Agency.

Expenditure on agribusiness innovation measured by PINTEC

According to data from PINTEC 2005 (IBGE, 2007b), expenditure on innovation activities linked to agribusiness[45] totalled approximately R$ 5.7 billion.[46]

According to the criteria adopted by PINTEC 2005, innovative efforts have the following dimensions: intramural R&D; acquisition of extramural R&D; acquisition of other external knowledge; acquisition of software; acquisition of machinery and equipment; training; market introduction of technological innovations; and industrial design and other technical preparations. It should be noted that previous rounds of the survey (2000 and 2003) did not include software acquisition.

Even considering the difference in the dimensions covered by these three rounds of the survey (due to late inclusion of software acquisition), it can be seen that total expenditure on innovation activities in Brazilian agribusiness has remained relatively flat (Table 10.8). It was about R$ 5.9 billion in 2000, and R$ 5.7 billion in 2003 and 2005. São Paulo State's share was significant: 53.5% in 2000, 38.6% in 2003 and 46.1% in 2005. The state accounted for a smaller share of the total number of innovative firms: 26.6% in 2000, 20.9% in 2003 and 26.7% in 2005.

The largest share of expenditure went to acquisition of machinery and equipment, with about 60% of the national total in the three years analyzed (Table 10.8). For all the firms surveyed by PINTEC 2005 in all types of economic activity, acquisition of machinery and equipment accounted for 43% of innovation efforts (IBGE, 2007b). This share was larger still in agribusiness, reaching 66% in 2003 in São Paulo State, which points to the importance of investment in plant and equipment as a channel for innovation compared with other types of innovation activity (Table 10.8).

Industrial design and other technical preparations ranked second, both nationwide and in São Paulo, with an average of 13% in both cases but peaking at 20.8% in 2003 for Brazil overall. Intramural R&D accounted for 10% both nationally and in São Paulo in 2005 (Table 10.8).

Table 10.8 shows São Paulo's share in total expenditure by agribusiness firms in all states, broken down by the dimensions listed above. Investment in intramural R&D by firms in São Paulo contributed 53.7% of the national total in 2005, compared with 62.4% in 2000.

Agribusiness firms in São Paulo contributed 47.2% of nationwide investment in software acquisition in 2005. Their share of investment in acquisition of machinery and equipment was 52.2% in 2000 and 42.8% in 2005. With regard to market introduction of technological innovations, they contributed no less than 67.8% of the national total in 2005. This was the category to which São Paulo's firms contributed most in proportional terms. In extramural R&D, acquisition of other external knowledge, training and industrial design and other technical preparations, São Paulo also accounted for a significant share of total investment in innovation by agribusiness firms throughout Brazil.

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45. The CNAE divisions selected as belonging or linked to the agribusiness sector were food, beverages, animal feed, agrochemicals, farm machinery and implements, wood, paper and paper products. According to the definition adopted for this chapter (see glossary), agribusiness is part of the agroindustrial complex and therefore includes agriculture (crop and livestock farming), food processing, manufacturing of inputs, and manufacturing of farm machinery, implements and equipment, among others, as noted earlier. PINTEC does not cover activities inside the farm gate (crop and livestock farming), but it does cover activities upstream and downstream of farming. Thus the items analyzed here fall within the following CNAE groups: (i) Animal slaughtering and meat and seafood processing; (ii) Processing and preserving of fruit and vegetables; (iii) Manufacturing of animal and vegetable oils and fats; (iv) Manufacturing of dairy products; (v) Manufacturing of grain mill products, starches and starch products, and prepared animal feeds; (vi) Manufacturing and refining of sugar; (vii) Coffee roasting and grinding; (viii) Manufacturing of other food products; (ix) Sawmills; (x) Manufacturing of wood and cork products and plaited materials, except furniture; (xi) Manufacturing of paper pulp from wood, bagasse and other raw materials; (xii) Manufacturing of paper, cardboard and paperboard; (xiii) Manufacturing of paper, cardboard, paperboard and corrugated cardboard packaging; (xiv) Manufacturing of paper products (writing and printing sheets, envelopes, kraftliner bags, cardboard boxes etc); (xv) Manufacturing of inorganic chemicals; (xvi) Manufacturing of agricultural chemicals; (xvii) Manufacturing of tractors and farm machinery and equipment.

46. It is important to note that R&D is only a small part of the innovation activities measured by PINTEC. Thus if investment in agribusiness innovation totalled R$ 5.7 billion in 2005 (Table 10.8), R&D will have accounted for only about 10%-15%. Private expenditure was calculated for present purposes using the overall nationwide ratio of public to private research for all areas rather than the proportions found by PINTEC because, as noted earlier, the data in question appeared underestimated owing to the omission of investment in seeds and seedlings, the main focus for private investment in agricultural R&D in Brazil.

Table 10.8
Expenditure on innovation activities in agribusiness by type of activity – Brazil & São Paulo State, 2000-2005

Type of activity	Expenditure on innovation activities in agribusiness																				
	2000							2003							2005						
	Brazil			São Paulo State			SP/BR (%)	Brazil			São Paulo State			SP/BR (%)	Brazil			São Paulo State			SP/BR (%)
	No. of firms	Expenditure		No. of firms	Expenditure			No. of firms	Expenditure		No. of firms	Expenditure			No. of firms	Expenditure		No. of firms	Expenditure		
		R$ 000 (1)	%		R$ 000 (1)	%			R$ 000 (1)	%		R$ 000 (1)	%			R$ 000 (1)	%		R$ 000 (1)	%	
Total	**8,454**	**5,924,456**	**100.0**	**2,252**	**3,170,540**	**100.0**	**53.5**	**9,268**	**5,696,810**	**100.0**	**1,940**	**2,196,724**	**100.0**	**38.6**	**7,729**	**5,710,744**	**100.0**	**2,066**	**2,633,366**	**100.0**	**46.1**
Intramural R&D	1,336	746,904	12.6	436	465,841	14.7	62.4	916	456,812	8.0	261	246,614	11.2	54.0	685	554,448	9.7	234	297,941	11.3	53.7
Acquisition of extramural R&D	335	86,219	1.5	121	31,308	1.0	36.3	207	23,759	0.4	43	8,191	0.4	34.5	232	43,724	0.8	63	16,136	0.6	36.9
Acquisition of other external knowledge	576	150,165	2.5	119	51,414	1.6	34.2	458	68,826	1.2	51	13,275	0.6	19.3	451	313,989	5.5	69	170,415	6.5	54.3
Acquisition of software	-	-	-	-	-	-	-	-	-	-	-	-	-	-	467	60,306	1.1	193	28,440	1.1	47.2
Acquisition of machinery & equipment	2,757	3,516,170	59.4	715	1,834,854	57.9	52.2	3,493	3,534,782	62.0	713	1,449,412	66.0	41.0	2,789	3,371,447	59.0	635	1,442,894	54.8	42.8
Training	1,120	105,732	1.8	238	48,178	1.5	45.6	1,111	83,475	1.5	209	32,533	1.5	39.0	869	74,127	1.3	218	35,691	1.4	48.1
Market introduction of technological innovations	1,026	528,597	8.9	261	279,474	8.8	52.9	1,239	344,620	6.0	219	158,491	7.2	46.0	1,048	447,053	7.8	309	303,006	11.5	67.8
Industrial design & other technical preparations	1,304	790,669	13.3	362	459,470	14.5	58.1	1,844	1,184,535	20.8	443	288,208	13.1	24.3	1,188	845,650	14.8	344	338,843	12.9	40.1

Source: IBGE, PINTEC 2000; 2003; 2005.

(1) In 2006 constant *reais* (R$) deflated by IPCA (IBGE).

Private investment with credit from FINEP[47]

The next five paragraphs deal with loans from FINEP for innovation in agribusiness, as classified by the agency itself.[48] Loans granted by FINEP in the period 1996-2006 amounted to R$ 3.9 billion, of which almost 20% (R$ 782.1 million) went to firms with activities linked to agribusiness nationwide. Firms in São Paulo State received the largest share, with 32.3% of total disbursements and 39.9% of agribusiness innovation loans (Table 10.9).

São Paulo's share of total FINEP loans was lowest in 2005, with 22.2% (R$ 72.3 million), and highest in 2002, with 67.3% (R$ 106.8 million). Its share of agribusiness innovation loans fluctuated even more, ranging between 25.1% in 1996 and 98.1% in 2002, with a low of 6.6% in 2006 (Detailed Table 10.24). São Paulo's share of total agribusiness loans by FINEP for the entire period was 39.9%. The fluctuation (not just in São Paulo's share but also in total lending by FINEP) presumably reflected unstable demand from private enterprise for credit to finance R&D.

A breakdown of FINEP's agribusiness loans in 1996-2006 by CNAE class shows cattle slaughtering and preparation of meat products (CNAE 1511-3) receiving the largest share, with Santa Catarina in the

Table 10.9
FINEP loans to firms in all sectors and agribusiness firms by state (cumulative) – Brazil, 1996-2006

State	Loans extended by FINEP			
	To firms in all sectors		To agribusiness firms	
	Total value (R$) (1)	Share (%)	Total value (R$) (1)	Share (%)
Total	**3,943,062,869**	**100.0**	**782,130,247**	**100.0**
Alagoas	10,366,094	0.3	8,287,103	1.1
Amazonas	60,646,497	1.5	8,666,663	1.1
Bahia	184,862,936	4.7	47,556,742	6.1
Ceará	94,182,934	2.4	21,032,682	2.7
Federal District	48,138,118	1.2	-	-
Espírito Santo	18,778,719	0.5	2,444,005	0.3
Goiás	96,284,007	2.4	29,627,910	3.8
Maranhão	19,491,638	0.5	9,143,555	1.2
Mato Grosso	8,393,273	0.2	5,946,277	0.8
Minas Gerais	222,249,035	5.6	46,189,904	5.9
Pará	3,675,635	0.1	3,276,865	0.4
Paraíba	18,522,469	0.5	2,844,041	0.4
Paraná	218,385,544	5.5	37,933,879	4.9
Pernambuco	100,928,307	2.6	40,186,770	5.1
Rio de Janeiro	383,397,882	9.7	56,799,947	7.3
Rio Grande do Norte	10,229,652	0.3	-	-
Rio Grande do Sul	590,521,985	15.0	29,692,379	3.8
Santa Catarina	559,389,430	14.2	105,152,259	13.4
São Paulo	1,274,882,588	32.3	311,691,764	39.9
Tocantins	15,354,483	0.4	14,954,273	1.9
Other	4,381,643	0.1	703,230	0.1

Source: FINEP.

(1) In 2006 constant *reais* (R$) deflated by IPCA (IBGE).

47. FINEP credit facilities are discussed in this section on private expenditure because the facilities concerned are effectively loans to private enterprise to finance RD&I projects (the agency also makes grants, which are non-refundable). The numbers cited refer to actual disbursements by FINEP.

48. FINEP classifies projects rather than firms as agribusiness-related.

lead, followed by São Paulo. Next came manufacturing of malt, beer and draught lager (1593-8), with 87% going to firms in São Paulo. Cattle ranching ranked third, with the lion's share going to Goiás, Tocantins and Maranhão. Loans to firms in the sugar industry were confined to São Paulo, with 81.3% of the total, and Pernambuco, with 18.7% (Detailed Table 10.25).

Besides its significant presence in the activities mentioned above, São Paulo also stands out in the manufacturing of soluble coffee, investment in technology for the manufacturing of machinery and equipment for crop farming, poultry farming and animal products, and production of cocoa products, chocolate, sweets and chewing gum, among other activities (Detailed Table 10.25).

A breakdown of FINEP loans by firm size shows a significant difference between loans to agribusiness firms and loans to all firms. Micro firms accounted for the largest share of loans extended nationwide and especially to firms in São Paulo, whereas large firms accounted for the largest share of all FINEP loans extended nationwide, although the share of medium and micro firms was also substantial. In São Paulo, micro firms accounted for the largest share of all, followed by medium firms (Table 10.10). The share of micro firms in São Paulo was 42.8% of all FINEP loans to micro firms nationwide in all sectors and 50.6% of agribusiness firms. The case of biotech firms is an example (Box 1).

Table 10.10
FINEP loans by firm size (cumulative) – Brazil & São Paulo State, 1996-2006

Firm size by no. of employees (1)	FINEP loans to firms in all sectors					FINEP loans to agribusiness firms				
	Brazil		São Paulo State		SP/BR (%)	Brazil		São Paulo State		SP/BR (%)
	R$ (2)	%	R$ (2)	%		R$ (2)	%	R$ (2)	%	
Total	**3,943,062,869**	**100.0**	**1,274,882,588**	**100.0**	**32.3**	**782,130,247**	**100.0**	**311,691,764**	**100.0**	**39.9**
Micro firms	1,045,017,754	26.5	447,488,077	35.1	42.8	326,643,736	41.8	165,245,282	53.0	50.6
Small firms	325,076,905	8.2	,68,933,203	5.4	21.2	37,836,904	4.8	4,803,583	1.5	12.7
Medium firms	1,195,608,477	30.3	442,416,501	34.7	37.0	176,205,287	22.5	45,113,704	14.5	25.6
Large firms	1,251,128,834	31.7	262,866,009	20.6	21.0	187,135,029	23.9	70,868,894	22.7	37.9
Unclassified	126,230,899	3.2	53,178,798	4.2	42.1	54,309,291	6.9	25,660,302	8.2	47.2

Source: FINEP.

(1) Micro firms = 1-19 employees; small firms = 20-99 employees; medium firms = 100-499 employees; large firms = 500+ employees.
(2) In 2006 constant *reais* (R$) deflated by IPCA (IBGE).

Box 1 - Profile of biotech firms in São Paulo

São Paulo is the Brazilian state with the largest number of biotech firms. A 2007 survey by Fundação Biominas, covering 71 firms engaged in biotech research in Brazil, showed that São Paulo then had 30 such firms, or 42% of the national total. This total was made up of firms conducting research in different areas: human health, animal health, agriculture, environment, bioenergy, inputs, and mixed (more than one category). According to the definition used by Fundação Biominas, biotech firms in the agricultural sector "develop or market transgenic seeds and plants, and new methods for pest control, plant cloning, molecular diagnosis, production of fertilizer from microorganisms, genetic improvement and catalyzers" (Fundação Biominas, 2007). Seven out of 16 agricultural biotech firms were located in São Paulo State, one each in the cities of Botucatu, Piracicaba and Itapetininga, and four in Campinas.

An analysis of firm size based on numbers of employees, defined by Fundação Biominas as comprising all paid personnel, including senior executives, owner-managers and interns, shows a strong presence of micro firms (up to 19 employees) in São Paulo, especially firms with between one and five employees. With regard to annual sales, most of the firms surveyed reported up to R$ 1 million, which also points to the predominance of smaller firms.

Source: Fundação Biominas (2007).

3.3 Formation of human resources for agricultural and agribusiness S&T[49]

A large number of agrarian science courses at all levels are offered in São Paulo State. The geographical distribution of technical courses is less centralized than that of undergraduate and post-graduate courses, which are mainly offered in the metropolitan areas[50] and some cities in the interior.

Technical courses

In 2006 there were 72 technical courses in agrarian sciences in São Paulo State. Most were offered in the administrative regions of Marília,[51] São José do Rio Preto,[52] Sorocaba[53] and Presidente Prudente.[54] Together these regions accounted for 66.7% of all technical courses in agrarian sciences offered in the state. Metropolitan São Paulo had no such courses in 2006. The Campinas administrative region had five (Table 10.11).

Not all the 72 courses offered by the state's 30 agricultural colleges in 2006 related strictly to agrarian sciences. They also involved areas such as environment, tourism, hotels, museology and information technology. This diversity in the courses offered by agricultural colleges may point to a tendency in response to demand for well-trained professionals in environmental management and tourism, both of which relate to "green" awareness, currently a key factor for agriculture and agribusiness. A good example is the growing number of agrotourism courses available.

The most numerous courses, evidently, were in crop and livestock farming, of which there were 24, or a third of the total. Other technical courses in related areas were forestry (five), agroindustry (four), rural business management, and sugar and ethanol technician (three). The latter had been introduced recently in response to demand created by growing biofuel production (Detailed Table 10.26). Given that the national education policy in place calls for expansion of technical education, human resources in agriculture are set to rise, especially in view of the sector's growing importance and complexity.

However, in the period 1996-2006 the number of students enrollled at agricultural colleges fell 20.9% from almost 5,600 to just over 4,400; the course completion rate was only about 50% in 2000-06; and the fail rate (including dropouts and transfers) fell only very moderately (Table 10.12).

Table 10.11
Technical courses by administrative region (RA) – São Paulo State, 2006

Administrative region	Technical courses in São Paulo State	
	Absolute nos.	%
Total	**72**	**100**
RA Marília	14	19.4
RA São José do Rio Preto	13	18.1
RA Sorocaba	11	15.3
RA Presidente Prudente	10	13.9
RA Araçatuba	6	8.3
RA Campinas	5	6.9
RA Franca	4	5.6
RA Bauru	3	4.2
RA Registro	3	4.2
RA São José dos Campos	2	2.8
RA Central	1	1.4

Source: Fundação Paula Souza. RA = Região Administrativa (administrative region).

49. Data for competencies (in formation or already formed) are presented in item 10.3.5.
50. As defined by Fundação Seade. A political-administrative map for 2003 is available at: <http://www.seade.sp.gov.br/produtos/anuario/mostra_Table.php?anos=2003&tema=car&tabpesq=car2003_04&Table=null>. Last visited Mar. 22, 2010.
51. Comprising the following municipalities: Vera Cruz, Santa Cruz do Rio Pardo, Quatá, Paraguaçu Paulista, Palmital, Garça and Cândido Mota.
52. Comprising the following municipalities: Votuporanga, Monte Aprazível, Mirassol, Jales, Fernandópolis and Catanduva.
53. Comprising the following municipalities: Taquarivaí, Sorocaba, São Manuel, Itu, Itapetininga and Cerqueira César.
54. Comprising the following municipalities: Presidente Prudente, Adamantina, Rancharia, Teodoro Sampaio and Dracena.

Table 10.12
Students enrollled at and graduating from agricultural colleges, pass rates and fail rates – São Paulo State, 1996-2006

Year	Enrollled	Graduating	Pass rates (%)	Fail rates (%)
1996	5,597	-		
1997	5,943	-		
1998	4,476	-		
1999	3,654	-		
2000	3,336	-		
2001	3,378	1,521	45.0	55.0
2002	2,838	1,653	58.2	41.8
2003	3,024	1,479	48.9	51.1
2004	3,236	1,711	52.9	47.1
2005	3,490	1,822	52.2	47.8
2006	4,425	2,361	53.4	46.6

Source: Fundação Paula Souza.

Undergraduate courses

In 2006 there were 123 undergraduate courses[55] in agrarian sciences and related areas in São Paulo State, according to the Ministry of Education (MEC) (Table 10.13). This number corresponded to 1.2% of the total number of courses offered in the state. The institutions offering them were located mainly in the Campinas administrative region and metropolitan São Paulo, which together accounted for 33.3% of all undergraduate courses in the state (Detailed Table 10.27). A breakdown by municipality shows São Paulo in the lead with 12 courses. Next came Fernandópolis, located in the west of the state but not a traditional agricultural center, with six courses all told (Detailed Table 10.28), two of them in technology. These six courses were offered by two private institutions: Universidade Camilo Castelo Branco (four courses from agronomy to veterinary medicine) and Faculdades Integradas de Fernandópolis (food engineering and sugar & alcohol production technology).

Excluding tertiary technical courses, the leading geographical areas for agricultural education were the city of São Paulo, ranking first with 12 courses (eight in animal health), Fernandópolis with six, and Campinas, Jaboticabal, Presidente Prudente, São José do Rio Preto and Marília with five. Most were offered by state universities (Detailed Table 10.28).

Sixty of the HEIs were private and eight public – four state-run (Unesp, USP, Unicamp and Fatec in Taquaritinga), three municipal (Faculdades Adamantinenses Integradas, Universidade de Taubaté and Instituto Municipal de Ensino Superior de Bebedouro Victório Cardassi), and one federal (UFSCar). The public HEIs offered 31 courses, 25.2% of the total. The private HEIs broke down as follows: 71.7% were for-profit, 18.3% philanthropic, and the rest community or faith-based (Table 10.13).

Unesp offered the most courses in 2006: 12 all told, at seven campuses (three courses at Botucatu, three at Jaboticabal, two at Ilha Solteira, and one each at São José do Rio Preto, Registro, Araçatuba and Dracena). Universidade Camilo Castelo Branco (Unicastelo, a private philanthropic HEI) overtook the other state universities in 2006, offering seven undergraduate courses in agrarian sciences, while USP offered six and Unicamp three (Detailed Table 10.29).

55. Evening and daytime courses counted as one. Technology courses included.

Table 10.13
Higher education institutions (HEIs) and undergraduate courses in agrarian sciences by type of course and jurisdiction – São Paulo State, 2006

Type of course & jurisdiction	No. of HEIs	No. of undergraduate courses
Grand total	**574**	**10,143**
Total in agrarian sciences	**68**	**123**
Total public	**8**	**31**
State	4	22
Municipal	3	7
Federal	1	2
Total private	**60**	**92**
Private for-profit	43	61
Philanthropic	11	23
Community/community philanthropic	5	6
Faith-based/community faith-based philanthropic	1	2

Source: MEC.

Of the 123 courses in agrarian sciences offered in São Paulo State in 2006, 30.9% were in veterinary medicine, 19.5% in agronomy, 13% in food engineering and 8.1% in animal science (Table 10.14). In 2006 the courses in management and production,[56] which were established in the 1990s, numbered 25, or 20.3% of the total in that year. Twelve new courses were introduced in 2006, three of them in sugar & alcohol production technology at private HEIs, demonstrating the demand for qualified professionals in this knowledge area.[57]

The number of undergraduate students who graduated from HEIs in all courses (including technology courses) throughout São Paulo State was 8.7 million in the period 1998-2006. In agrarian sciences it was 133,700, or 1.5% of the total. The number of undergraduates who received degrees in agrarian sciences rose 70.8% from 11,200 in 1998 to 19,200 in 2006 (Table 10.15).

Most degrees in agrarian sciences in São Paulo State were awarded by private universities and colleges (65%), followed by state universities (32.1%). In São Paulo State the number of agrarian science degrees in proportion to the total number of degrees awarded was highest in state universities (5.1%) (Table 10.15).

56. Agribusiness management, rural administration, agribusiness, sugar & alcohol production technology, horse farming, and agroindustrial production engineering.
57. Source: Ministry of Education (INEP/MEC).
58. Source: <http://www.capes.gov.br/avaliacao/planilhas-comparativas-da-trienal-2007>. Last visited Mar. 22, 2010.

Table 10.14
Undergraduate courses in agrarian sciences by subarea – São Paulo State, 2006

Subareas of agrarian sciences	Undergraduate courses	
	Absolute nos.	%
Total	**123**	**100.0**
Veterinary medicine	38	30.9
Agronomy (agricultural engineering)	24	19.5
Food engineering	16	13.0
Animal science	10	8.1
Agribusiness management	8	6.5
Rural administration	5	4.1
Agribusiness	5	4.1
Sugar & alcohol production technology	5	4.1
Food technology	4	3.3
Surveying engineering	2	1.6
Pulp & paper technology	1	0.8
Horse farming technology	1	0.8
Animal reproduction & artificial insemination technology (professional area: agriculture)	1	0.8
Agroindustrial production engineering	1	0.8
Licentiate degree (*licenciatura*) in agrarian sciences	1	0.8
Animal health	1	0.8

Source: INEP/MEC.

Table 10.15
Students completing undergraduate courses in agrarian sciences and total by jurisdiction – São Paulo State, 1998-2006

Year	Students completing undergraduate courses in agrarian sciences and total by jurisdiction									
	Total		Federal		State		Municipal		Private	
	Agrarian sciences	Total	Agrarian sciences	Total	Agrarian sciences	Total	Agrarian sciences	Total	Agrarian sciences	Total
Total (abs. nos.)	**133,693**	**8,737,705**	**2,050**	**73,025**	**42,963**	**837,538**	**1,738**	**446,086**	**86,942**	**7,381,056**
% total	**100.0**	**100.0**	**1.5**	**0.8**	**32.1**	**9.6**	**1.3**	**5.1**	**65.0**	**84.5**
1998	11,245	678,198	218	6,609	4,175	76,209	132	39,497	6,720	555,883
1999	12,121	740,113	226	6,754	4,514	79,499	136	35,162	7,245	618,698
2000	12,988	818,304	229	7,114	4,464	80,564	138	37,875	8,157	692,751
2001	14,240	898,643	227	7,749	4,531	83,235	139	39,930	9,343	767,729
2002	14,607	988,696	224	8,102	4,642	92,029	106	53,301	9,635	835,264
2003	15,588	1,050,054	226	8,985	4,824	96,392	151	57,653	10,387	887,024
2004	16,018	1,109,693	222	8,938	5,059	105,151	234	60,984	10,503	934,620
2005	17,682	1,185,028	233	8,963	5,256	112,183	338	60,956	11,855	1,002,926
2006	19,204	1,268,976	245	9,811	5,498	112,276	364	60,728	13,097	1,086,161

Source: INEP/MEC.

Post-graduate courses

In 2006 there were 59 post-graduate programs in agrarian sciences in São Paulo State, offered by nine HEIs: three state universities (USP, Unesp and Unicamp), one federal university (UFSCar), three private universities (Unimar, Unoeste and Unip) and two public research institutions (IAC and Instituto de Pesca). USP offered the most programs with 24, or 40.7% of the total, followed by Unesp with 23. Unicamp ranked third with five programs, all of which offered both master's and doctoral degrees. The three state universities in São Paulo offered 88.1% of the post-graduate programs available in 2006 (Table 10.16).

According to CAPES,[58] 11 institutions offered only a master's degree in 2006, while 48 offered both master's and doctoral degrees. In a 2007 assessment exercise, CAPES awarded these programs the following grades for the period 2004-06: seven programs scored 7 (the top grade); four scored 6 and 24 scored 5 (very good); 18 scored 4 (good); six scored 3 (satisfactory). São Paulo State had the best post-graduate programs in Brazil, reinforcing its tradition in agricultural education and research.

The number of post-graduate programs rose more than 20% between 1996 and 2006. They were concentrated in two geographical areas: 35.6% of the HEIs concerned were located in the Campinas administrative region (21 courses) and 20.3% in metropolitan São Paulo (12 courses). Other leading areas were the Ribeirão Preto Administrative Region (11 courses) and the Sorocaba Administrative Region (seven courses) (Detailed Table 10.30).

The number of students enrollled in master's courses in the 11 years of the period analyzed (1996-2006) rose 35.5%, from some 1,900 to almost 2,600, while enrollment in doctoral programs rose 63.1%, from just over 1,400 to almost 2,300. At the same time, the number of master's degrees awarded rose 88.1% from 404 to 760, and the number of PhDs awarded rose almost 170% from 187 to 503. Time to completion fell steadily during the period, from 41 months to 27 months in the case of master's degrees and from 52 months to 45 months in the case of doctorates (Table 10.17).

Table 10.16
Post-graduate programs in agrarian sciences by 2007 CAPES score and HEI – São Paulo State, 2004-2006

HEI	Post-graduate programs in agrarian sciences									
	Total		Master's	Master's / PhD	CAPES score (2004-06) (1)					
	Abs. nos.	%			Total	3	4	5	6	7
Total	**59**	**100.0**	**11**	**48**	**59**	**6**	**18**	**24**	**4**	**7**
USP	24	40.7	3	21	24	2	6	9	3	4
Unesp	23	39.0	1	22	23	-	9	13	-	1
Unicamp	5	8.5	-	5	5	-	-	2	1	2
Unoeste	2	3.4	2	-	2	1	1	-	-	-
UFSCar	1	1.7	1	-	1	-	1	-	-	-
IP	1	1.7	1	-	1	1	-	-	-	-
IAC	1	1.7	1	-	1	-	1	-	-	-
Unimar	1	1.7	1	-	1	1	-	-	-	-
Unip	1	1.7	1	-	1	1	-	-	-	-

Source: CAPES.

(1) CAPES awards the following grades: 5 (very good), 4 (good) and 3 (satisfactory). Grades 6 and 7 are reserved for programs that score 5 in the first stage of the triennial assessment and are considered clearly superior to other programs or equivalent to international centers of excellence. The scoring criteria are established by committees for each knowledge area.

57. Source: INEP/MEC.

58. Source: <http://www.capes.gov.br/component/content/article/44-avaliacao/2156-planilhas-comparativas-da-avaliacao-trienal-2007>. Last accessed Mar. 22, 2010

Table 10.17
Post-graduate courses, students enrollled and degrees awarded in agrarian sciences and average time to completion – São Paulo State, 1996-2006

Year	Courses	HEIs	Master's: Students enrollled (1)	Master's: Degrees awarded	Master's: Average time to completion (months)	Doctorate: Students enrollled (1)	Doctorate: Degrees awarded	Doctorate: Average time to completion (months)
1996	48	3	1,918	404	41	1,409	187	52
1997	49	3	1,778	393	39	1,505	219	53
1998	50	3	2,019	468	38	1,660	281	53
1999	53	4	2,164	452	36	1,785	274	50
2000	53	4	2,336	628	34	2,051	309	48
2001	52	4	2,444	610	33	2,228	389	48
2002	51	4	2,467	719	31	2,337	385	48
2003	52	5	2,411	800	29	2,456	492	47
2004	56	7	2,314	657	28	2,322	478	46
2005	57	8	2,418	702	27	2,363	533	46
2006	59	9	2,599	760	27	2,298	503	45

Source: CAPES; CNPq.

(1) Includes students enrollled at start of year and new students.

4. Results and impacts of SPInA

This section presents the results and impacts of SPInA in the period 1996-2006. The analysis covers three main types of result or impact: growth in agricultural productivity measured in terms of total factor productivity and correlated with investment in research; technological production measured in terms of intellectual property registration (patents and protection of plant varieties); and scientific production measured in terms of publications.

4.1 Economic impacts of agricultural R&D

São Paulo is the leading agricultural state in Brazil, contributing 15.2% of the nation's agricultural output by value in 2003 (Tsunechiro & Martins, 2006) and 27% of Brazil's agribusiness GDP in 2005 (Guilhoto et al., 2007).

Total factor productivity[59] in crop farming in São Paulo State was 2.3 times the national average in 1995 (Vicente, Anefalos & Caser, 2001). São Paulo was then the only state in Brazil that operated at the frontier of economic efficiency[60] in crop farming (Vicente, 2004). The value of São Paulo's agricultural output (crops and cattle) rose 57.9% in real terms between 1995 and 2006, for average annual growth of 5.2% after adjustment for inflation measured by the IPCA index (annual average), according to Instituto de Economia Agrícola (IEA, attached to APTA).

In crop farming, the volume output index[61] reached 138 in 2006 (1995=100), for growth of 2.6% p.a. In livestock farming, volume output (meat and milk) reached 134.6, for growth of 2.4% p.a.

59. Partial productivity indices, especially for land and labor, are widely found in the literature owing to availability of data and ease of calculation. However, such partial measures are of limited use as performance indicators: for example, land productivity can be increased by applying large amounts of fertilizer and labor productivity can be raised via intensive mechanisation. Conceptually speaking, it is advisable to take all production factors into account simultaneously. Hence the preference for total factor (or multifactor) productivity in this analysis. See also Silva (1984), Araújo *et al.* (2002) and Gasques *et al.* (2004).

60. The economic efficiency frontier is defined by the units with the highest total or economic efficiency indices. Economic efficiency is equal to the product of technical efficiency and allocative efficiency. Technical efficiency is defined as the ability to achieve a high level of output given similar levels of inputs. Allocative efficiency measures the ability to use inputs in optimal proportions at a given price level, i.e. to produce at a given level of output using the cost-minimizing input ratios.

61. Calculated using Fisher's formula, as detailed in the Methodological Annex. The indices presented in this item were calculated using the data in Table 10.31 and in Detailed Tables 10.4, 10.10, 10.11, 10.12, 10.13 and 10.14. The growth rates discussed are geometric rates, calculated as follows: Rate = (antilog b – 1) x 100, where b is the coefficient obtained by the following regression: log Y = a + b.T, in which T is time and Y is the index of productivity or volume (output or factor use).

Use of land and labor, the original production factors indispensable to agricultural production, followed distinct patterns. The labor input index fell 14.5% between 1996 and 2006 (Detailed Table 10.31), while the land input index rose 7% (Detailed Table 10.32). Cultivated area grew 24.9% and grazing area contracted 5.8% (Detailed Table 10.32). Thus labor productivity increased sharply in the period.

Use of the production factors typically associated with modernization of agriculture – fertilizer, pesticides and tractors – increased 10.6% in the same period. Use of fertilizer (N-P-K) and pesticides (insecticides, acaricides, fungicides, herbicides etc.) increased 15.7% and 81.6% respectively. The number of tractors used by rural establishments in São Paulo State fell 22.7%, according to data from the last agricultural census conducted by IBGE (2007a).

Labor productivity rose 62.7% in the period 1995-2006, for an average of 4.8% p.a. Physical land productivity rose 17.1% in crop farming and 42.2% in cattle farming. Modern inputs performed similarly, with productivity rising 10.6% in the period 1995-2006. Overall, the main driver of agricultural productivity growth in Brazil and São Paulo was labor productivity, as shown by Gonçalves (2007).

Total factor productivity in São Paulo State's agricultural sector (crop and cattle farming) rose 2.5% in the period 1995-2006, reaching 134.4 (1995=100). In crop farming alone, TFP rose a little less, reaching 130.7 in 2006 (Table 10.18). Allocative efficiency exceeded 95% in the same period (Vicente, 2008). Thus the productivity gains mentioned were almost entirely associated with technical progress or technological change.

Tornqvist TFP growth was 32.3% nationwide between 1995 and 2002, according to Gasques et al. (2004). The results could therefore be compared with the findings for São Paulo, since these two indices (Fisher and Tornqvist)[62] offer approximate measures, as verified empirically by Silva & Carmo (1986). A national productivity series was constructed for the period 1995-2006 using Fisher and Tornqvist indices, as well as the indices presented in Gasques, Bastos & Bacchi (2007, 2008). The total TFP index for Brazilian agriculture reached 156.2 in 2006 (1995=100) according to these calculations.

The indices estimated for São Paulo were recalculated to make them more compatible with the pro-

Table 10.18
Partial and total factor productivity in agriculture – São Paulo State, 1995-2006

Year	Partial and total factor productivity in agriculture				
	Total (crops + cattle)		Crops		Cattle
	TFP (1)	Labor	TFP (1)	Land	Land
1995	100.0	100.0	100.0	100.0	100.0
1996	103.3	100.3	102.6	106.7	106.8
1997	110.5	113.2	108.1	111.6	113.6
1998	111.6	108.1	110.7	113.0	116.6
1999	117.1	112.6	116.1	113.6	121.5
2000	112.3	105.9	109.3	110.5	124.7
2001	118.7	120.5	115.7	111.9	124.2
2002	124.7	130.2	121.4	117.2	132.2
2003	125.2	140.7	120.5	112.7	134.7
2004	127.1	153.7	123.0	113.3	135.9
2005	129.0	155.6	124.3	110.9	138.9
2006	134.4	162.7	130.7	117.1	142.2

Source: Instituto de Economia Agrícola (IEA/APTA).

(1) Total factor productivity (land, labor, fertilizer, pesticides, tractors).

62. The formulas for the Fisher index and Tornqvist index are presented in the Methodological Annex.

cedures adopted at the national level. This entailed including among the products measured those of poultry farming (chicken meat and eggs) and pig farming (pork), and excluding from inputs the use of pesticides, as explained in Gasques, Bastos & Bacchi (2007).[63]

When these results were combined with those obtained by Vicente, Anelafos & Caser (2001) for 1995, TFP in São Paulo State's agricultural sector was found to be equal to 318.8 in 2006. Given that the national index for the same year was 156.2 (base year for Brazil 1995=100), it can be concluded that TFP in São Paulo was roughly double the Brazilian average in 2006.

The growth in agricultural productivity in São Paulo is closely associated with over half a century of investment in technology creation and transfer by the state, via the research institutions now attached to APTA (in addition to other institutions, as described earlier in this chapter), assuring continuous efforts to expand the production and diffusion of the scientific and technological knowledge required to sustain its competitiveness and leadership.[64] It is also important to note the key role played in modernization by acquisition of machinery and inputs.

Extending the calculations in Vicente & Martins (2005) to the period 1995-2006, the marginal product of research was found to range from 12.8 to 20.4, averaging 16.9. Thus every additional *real* (R$) invested in agricultural research in São Paulo State added R$ 17 to the value of the state's agricultural output.

The coefficients estimated by Vicente & Martins (2005) for the impact of agricultural research on TFP were used to calculate the internal rate of return (IRR) on this investment.[65] IRR varied between 16.9% and 26% p.a. in the period 1981-2006, averaging 22.2% p.a. These are high rates of return, making investment in research attractive even with the very high interest rates in force in Brazil. In sum, investment in research is a driver of growth for agricultural production, boosting productivity and generating significant economic benefits.

4.2 Patenting in agriculture

Two data sources were used for this subsection: (i) agricultural patents granted and agricultural patent applications filed with the United States Patent & Trademark Office (USPTO) by Brazilian nationals or residents; and (ii) patents granted and patent applications filed with Brazil's National Industrial Property Institute (Instituto Nacional de Propriedade Industrial, INPI) by residents and non-residents. The search strategy covered applicants, assignees and inventors for the period 1996-2006.[66] The analysis covered three types of proceeding: (1) patent applications filed; (2) patents issued; and (3) (for INPI) patent applications denied, expired or dismissed.[67]

As shown in Table 10.19, Brazilians accounted for a very small proportion of agricultural patents granted by or applications filed in the U.S., the world's patenting hub, in stark contrast with the growth in Brazilian scientific production in the agricultural area (see 10.3.4 below). The total number of filings was small, and the number of agricultural filings even smaller. Forty-three applications were filed at USPTO by Brazilian inventors (researchers resident in Brazil) and seven by Brazilian assignees (firms or other organizations domiciled in Brazil), accounting respectively for 2.4% and 3.7% of the total number of Brazilian agricultural filings at USPTO during the period analyzed. In 1996-2006 USPTO issued 138 agricultural patents to Brazilian inventors, or 8.6% of the total number of patents issued to Brazilians by USPTO in the period, and 28 to Brazilian assignees, or 3.8% of the total.

The numbers for INPI were higher than for USPTO, but modest nonetheless, with non-residents in the majority. They included 738 applications by residents and only 118 patents granted to residents in the period analyzed. The numbers of non-resident applications and patents were higher, amounting to 1,150 and 256 respectively (Table 10.20).

63. These changes tend to overestimate TFP because in addition to the exclusion of pesticides, the methodology also excludes specific inputs for poultry and pig farming (e.g. feed, concentrate, vaccine and medication). The changes were made in calculating the indices for São Paulo in order to enable indices for São Paulo and Brazil to be compared on the basis of indicators estimated using similar procedures.

64. Several studies have analyzed return on investment in research for specific agricultural products in São Paulo. In addition, some authors have set out to measure the aggregate impact of such investment. Silva (1984) estimated the marginal product of agricultural research in São Paulo in the period 1956-80 as ranging from 59.6 to 101.7, depending on the time lag used. Araújo *et al.* (2002) obtained values between ten and 12 times the amount invested for the period 1960-99. Vicente & Martins (2005) found values averaging 15.3 for the marginal product of the research stock in the period 1995-2000, considering APTA's investment in research institutions and partnerships, as well as Embrapa's investment, and detected a significant impact on TFP from the third to the 26th years after investment.

65. The internal rate of return (IRR) is the discount rate that makes the net present value of all cash flows from a project equal to zero, so that the present value of all incoming cash flows is equal to the present value of all outgoing cash flows. IRR corresponds to the anticipated profitability of a project and hence to the return on the investment made. Its expression as an equation can be found in the glossary.

66. USPTO and INPI use different patent search methodologies. USPTO has separate databases for patents granted and pending patent applications. INPI has a single database, which is updated as each application is processed. Only INPI can be searched for patent applications that have been denied. The search of INPI also found 25 cases in which it was impossible to determine whether a patent had been granted, dismissed or appealed. More details on the search strategy are presented in the Methodological Annex.

67. Codes and descriptions for INPI's decisions (such as patent issuance, dismissal, denial etc.) are detailed in the Methodological Annex.

Table 10.19
USPTO agricultural patents granted to and applications filed by Brazilian inventors and assignees – Brazil, 1996-2006

Cases	USPTO agricultural patents granted to and applications filed by Brazilian inventors and assignees			
	Applications filed (1)		Patents granted (1)	
	Assignees	Inventors	Assignees	Inventors
Agricultural cases (A)	7	43	28	138
Total cases in period (B)	190	1,815	736	1,622
A / B (%)	3.7	2.4	3.8	8.5

Source: USPTO.

(1) Applications filed according to the Published Patent Applications Database. Patents granted according to the Patent Database.

Table 10.20
INPI agricultural patents granted to and applications filed by residents and non-residents of Brazil – Brazil, 1996-2006

Cases	INPI agricultural patents granted to and applications filed by residents and non-residents			
	Applications filed (1)		Patents granted	
	Residents	Non-residents	Residents	Non-residents
Agricultural cases (A)	738	1,150	118	256
Total cases in period (2) (B)	71,281	156,902	36,164 (3)	
A / B (%)	1.0	0.7	1.0	

Source: INPI.

(1) Patent applications pending. The search also identified 144 applications in all areas without identification of the applicant's origin.
(2) Applications filed by residents and non-residents in 1996 do not include PCT (Patent Cooperation Treaty) or certificates of addition (see glossary).
(3) INPI does not disclose patent statistics divided into resident and non-resident cases on its website.

Private institutions received the largest share of USPTO patents issued to Brazilian applicants in the agricultural area (18 patents, or 64.3%). Public research institutions and universities in Brazil and abroad received nine patents, five of them with co-holders (Embrapa four, UFRJ one). Embrapa alone received half the patents granted to all corporate entities, and was coholder with other Brazilian and foreign public research institutions for 25% of these. The following points are also worth noting with regard to Table 10.21:

- Institutions located in São Paulo State applied for over half the USPTO patents granted;
- Máquinas Agrícolas Jacto S.A., a corporation headquartered in the city of Pompeia (SP), received seven patents for farm machinery and implements, the highest number among private institutions. Jacto exported to 60 countries at the time of writing.[68]

A significant proportion (75%) of patents protecting Brazilian inventions were issued to institutions located in other countries, i.e. non-residents (Detailed Table 10.33).[69] Here, too, private institutions were in the majority, especially Bayer, with 52 patents and one application.

68. Source: <http://www.jacto.com.br/portugues.html>. Last visited Mar. 22, 2010.
69. Most inventors affiliated with foreign firms are not in the Lattes database and are therefore probably not academics.

Table 10.21
USPTO agricultural patents granted to and applications filed by Brazilian institutions and individuals by applicant – Brazil, 1996-2006

Applicant	State/Country	USPTO agricultural patents granted to and applications filed by Brazilian institutions and individuals	
		Patents	Applications
Total		**28**	**7**
Individuals	**-**	**1**	**0**
Christiane Campello Costa	RS/BR	1	-
Research institutions & universities	**-**	**9**	**6**
Cornell Research Foundation, Inc.; Embrapa	USA; DF/BR	1	-
CropDesing N.V.; Universidade Federal do Rio de Janeiro	Belgium; RJ/BR	-	1
Embrapa	DF/BR	4	2
Embrapa; Ecole Nationale du Génie Rural des Eaux et des Forêts (Engref)	DF/BR; France	1	-
Embrapa; University of Brasília (UnB)	DF/BR; DF/BR	1	-
Embrapa; Federal University of Pará (UFPA)	DF/BR; PA/BR	1	-
FAPESP	SP/BR	1	-
Fundação Oswaldo Cruz	RJ/BR	-	1
Federal University of Rio de Janeiro (UFRJ)	RJ/BR	-	1
Federal University of Minas Gerais (UFMG)	MG/BR	-	1
Private institutions	**-**	**18**	**1**
Annes Participações	RS/BR	1	-
Athena Mudas Ltda.	SP/BR	4	-
Justino de Morais Irmãos S/A	SP/BR	1	-
Máquinas Agrícolas Jacto S/A	SP/BR	7	-
Marchesan Implementos e Máquinas Agrícolas Tatu S/A	SP/BR	1	-
Quinta das Flores AgroExportadora Ltda.	CE/BR	1	-
Suzano Bahia Sul Papel e Celulose S/A	BA/BR	1	-
Usina da Barra S/A - Açúcar e Álcool	SP/BR	2	-
Sayyou Brasil Indústria e Comércio Ltda.	SP/BR	-	1

Source: USPTO.

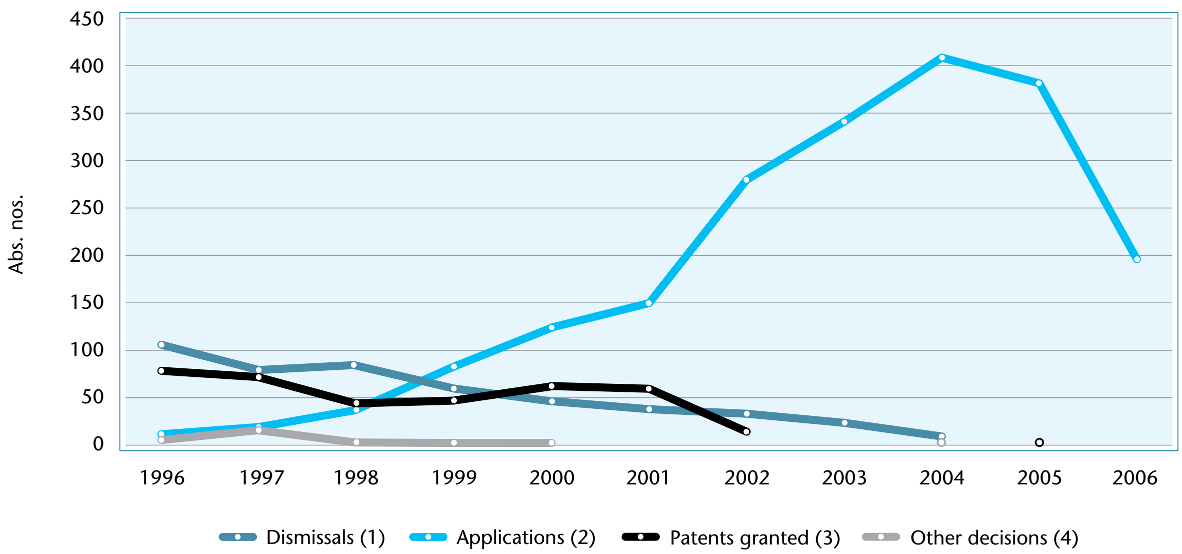
In the case of INPI, the number of applications rose 37.2 times from 11 in 1996 to 409 in 2004,[70] suggesting that a culture of IP protection via patents is developing in the agricultural sector. On the other hand, while the pace of growth was fast it is also true that the starting-point was very low at only 11 applications[71] (Figure 10.13).

Figure 10.14 presents the number of INPI agricultural filings by type (utility model, invention patent and certificate of addition) between 1996 and 2005. The strong growth in filings in the period is more evident in Figure 10.15. Most were for invention patents, which refer to relatively complex innovations and new product development. Applications for utility models, which involve less innovation, were also numerous, however.

70. These statistics for 2005 and 2006 reflect only some INPI agricultural patent applications because of an 18-month waiting period before an application can be published (unless the applicant gives consent for earlier publication). The statistics analyzed here refer to searches performed in late 2007 and early 2008.

71. INPI takes an average of eight years to analyze patent applications. Thus in this case the statistics cover only patents issued until 2002. Changes introduced at INPI in recent years will certainly speed up the processing of applications and this in turn should improve the production of statistics.

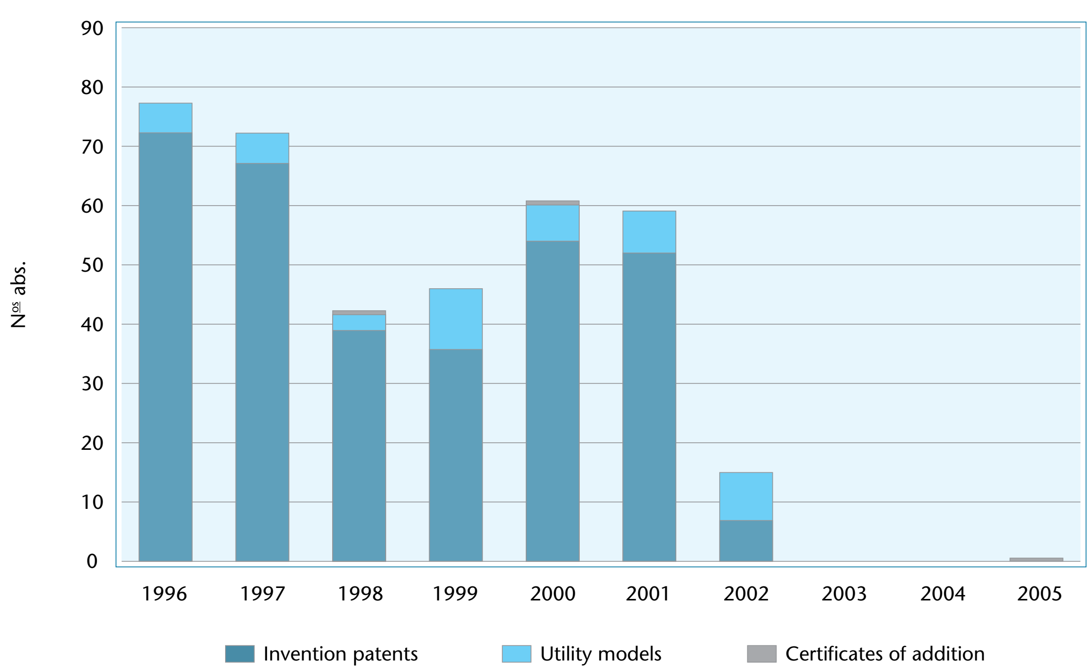
Figure 10.13
INPI agricultural patent applications, patents granted, dismissals and other decisions – Brazil, 1996-2006



Source: INPI.
(1) Decision codes: 3.5; 3.6; 6.1; 8.6; 9.2; 10.1; 11.1; 11.1.1; 11.2; 11.3; 11.4; 11.5; 11.6; 11.14; 11.5; 15.7; 23.6.
(2) Decision codes: 1.3; 1.3.1; 2.1; 2.4; 3.1; 3.2; 3.8; 6.7; 7.1; 8.7; 8.8; 12.2; 12.6; 15.11; 15.12; 15.14; 15.21; 19.1; 25.1; 25.11.
(3) Decision codes: 9.1; 16.1; 23.9; 24.4; 25.7.
(4) Decision codes: 1.2.1; 17.1; 22.15; 24.5; other.

Notes: 1. Dates refer to application filing.
2. See Detailed Table 10.34.

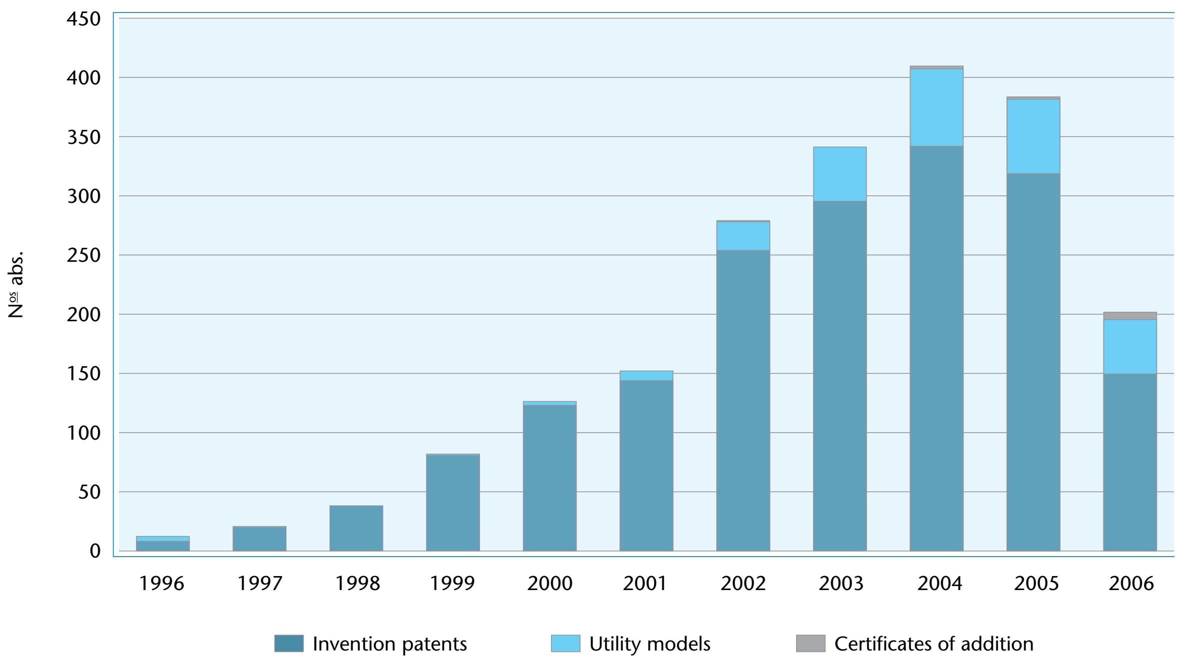
Figure 10.14
INPI agricultural patents by type – Brazil, 1996-2005



Source: INPI.

Notes: 1. Dates refer to application filing.
2. See Detailed Table 10.35.

Figure 10.15
INPI agricultural patent applications by type – Brazil, 1996-2005



Source: INPI.

Notes: 1. Dates refer to application filing.
2. See Detailed Table 10.35.

A comparison between INPI agricultural patent applications by and grants to applicants from Brazil and the U.S. in the period 1996-2006 (Figure 10.16) shows that Brazil accounted for the largest number of applications filed since 2004 (more than 180), as is only to be expected. After a sharp fall in the late 1990s, the number rose steadily in the ensuing decade. The U.S. ranked second by numbers of INPI applications, with a moderate fall in the late 1990s followed by a rise in the early years of the ensuing decade, reaching 45 applications and 32 patents, and a sharp fall from 2004 on. Other countries such as Germany and Japan also displayed fluctuation (Detailed Table 10.36).

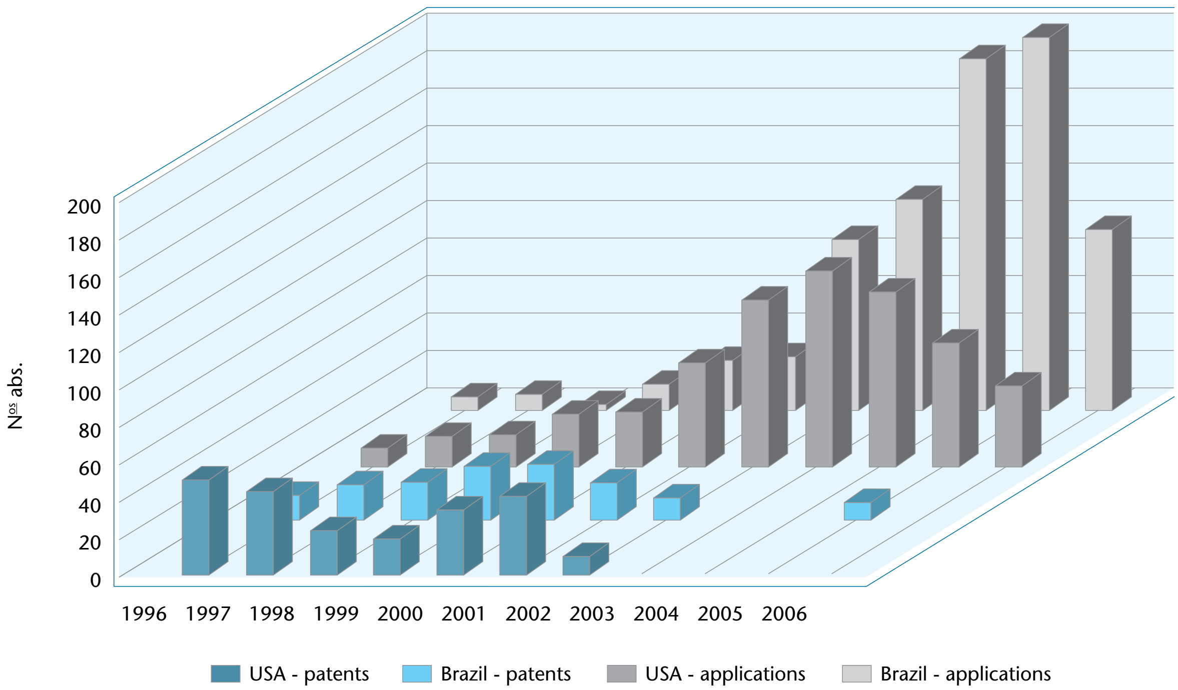
During the period analyzed 1,006 applications were filed by residents of Brazil, 40% of them domiciled in São Paulo State (Figure 10.17). In second place with 28.4% came Rio Grande do Sul (RS), where manufacturers of farm machinery and implements are headquartered.

Most applicants were makers of farm machinery and implements, led by Deere & Company, a U.S. corporation with 238 applications and 133 patents. Three Brazilian corporations, Semeato, Jacto and Marchesan, accounted together for 244 applications and 88 patents (Table 10.22). The leading public institution was Embrapa, with 49 applications and 15 patents.

Patenting is also an important protection strategy for multinationals that manufacture fertilizer and agrochemicals, such as BASF, or use biotechnology to produce genetically modified inputs, especially seeds, such as Syngenta, Monsanto, Du Pont, CropDesign[72] and Bayer Cropscience.

72. Part of the BASF Plant Science family of companies.

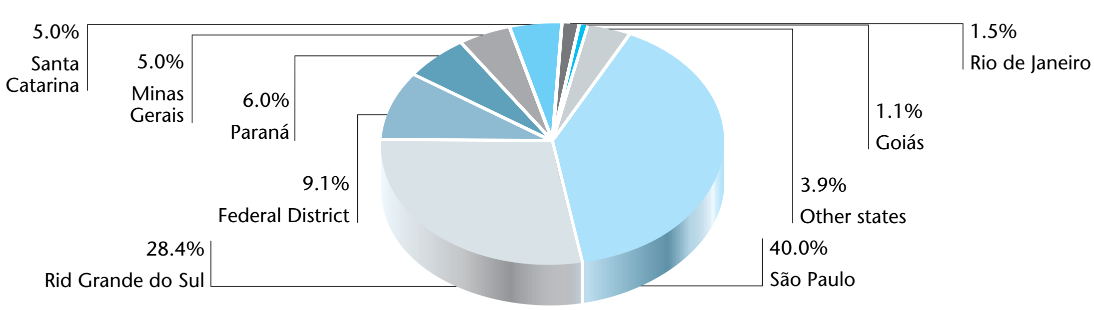
Figure 10.16
INPI agricultural patent applications and patents granted – Brazil & USA, 1996-2006



Source: INPI.

Notes: 1. Individual applicants and assignees not included (no location identified).
2. See Detailed Table 10.36.

Figure 10.17
INPI agricultural resident patents by state (cumulative) – Brazil, 1996-2006



Source: INPI.
(1) Includes: Ceará = 9; Pernambuco & Bahia = 5; Mato Grosso = 4; Mato Grosso do Sul & Paraíba = 3; Espírito Santo, Pará, Rio Grande do Norte & Tocantins = 2; Alagoas & Amazonas = 1.

Notes: 1. 1. Individual applicants and assignees not included (no location identified).
2. See Detailed Table 10.37.

Table 10.22
INPI agricultural patent cases, applications and grants by applicant (cumulative) – Brazil, 1996-2006

Applicant	State/ Country	INPI agricultural patent cases, applications and grants by applicant		
		Cases	Applications	Patents
Individuals	--	447	436	11
Deere & Company	USA	371	238	133
BASF Aktiengesellschaft	Germany	181	163	18
Semeato S/A Indústria e Comércio	RS/BR	180	141	39
Syngenta Participations Ag.	Switzerland	192	192	
Monsanto Technology Llc	USA	168	160	8
Máquinas Agrícolas Jacto S/A	SP/BR	106	62	44
Embrapa	DF/BR	64	49	15
Bayer Cropscience Gmbh	Germany	50	50	
E. I. Du Pont De Nemours and Company	USA	47	37	10
Marchesan Implementos and Máquinas Agrícolas Tatu S/A	SP/BR	46	41	5
Cropdesign N.V.	Belgium	24	24	
Syngenta Participations Ag. and Novartis Ag.	Switzerland, Switzerland	22	8	14
Fmc Corporation	USA	21	17	4
Claas Selbstfahrende Erntemaschinen Gmbh	Alemanha	18	11	7
Buckman Laboratories International Inc.	USA	14	6	8
Maschinenfabrik Kemper GmbH & Co. Kg	Germany	14	11	3
Nihon Nohyaku Co.	Japan	12	11	1
Case Corporation	USA	11	2	9
Ciba Specialty Chemicals Holding Inc.	Switzerland	10	9	1
The Goodyear Tire & Rubber Company	USA	8	3	5
Universidade Estadual de Campinas - Unicamp	SP/BR	8	7	1
Ajinomoto Co.	Japan	8	8	-
Institutions with 7 cases (applications or grants)	-	1	-	-
Institutions with 6 cases (applications or grants)	-	1	-	-
Institutions with 5 cases (applications or grants)	-	3	-	-
Institutions with 4 cases (applications or grants)	-	2	-	-
Institutions with 3 cases (applications or grants)	-	6	-	-
Institutions with 2 cases (applications or grants)	-	40	-	-
Institutions with 1 case (applications or grants)	-	250	-	-

Source: INPI.

In sum, technological development efforts by firms in Brazil, whether foreign or domestic, are relatively weak. USPTO patenting is timid and while numbers of INPI filings are higher, few firms in Brazil systematically pursue patent protection for innovations. This reflects the relatively unstable technology development capacity of farm machinery and chemical input manufacturers, the main segments that use this method of IP protection.

Patenting efforts by Brazilian firms are concentrated in farm implements. In any event, INPI patenting has intensified significantly since 2001-02, not only by agriculture but also by other sectors of the Brazilian economy.

4.3 Plant variety protection

Brazil's Plant Variety Protection Law (Law 9456/1997, LPC) is the main legal instrument for protection of innovations in plant breeding. The LPC entered into force in 1998 and since then the number of crops eligible for protection under the law has been gradually extended. Initially only eight were recognised for this purpose: cotton, rice, potatoes, dry beans, maize, soya, sorghum and wheat. The law now protects 43 species or genera.[73]

Use of this legal instrument has increased significantly in recent years. The number of plant variety protection certificates issued between 1998 and the start of 2008 totalled 1,073 (Table 10.23), including provisional certificates. This growth reflects the interest of

Table 10.23
Number of protected plant varieties by first-named applicant (cumulative) – Brazil, 1998-2007

First-named applicant	No. of protected varieties
Total	**1,073**
Embrapa (1)	292
Monsoy Ltda.	105
Coodetec	50
Copersucar	29
Naturalle Agromercantil S/A	22
Fundacep Fecotrigo	21
Du Pont do Brasil S/A - Divisão Pioneer Sementes	20
Universidade Federal de Viçosa	18
FGB B.V. Fides Goldstock Breeding	17
Lux Riviera S.R.L.	17
D & Pl Technology Holding Company, Llc.	15
Instituto Agronômico do Paraná (Iapar)	15
OR Melhoramento de Sementes Ltda.	14
Rosen Tantau, Mathias Tantau Nachfolger	14
Universidade Federal de São Carlos	14
HZPC Holland B.V.	13
Bretagne-Plants	12
Centro de Tecnologia Canavieira (CTC)	12
Fundação MT	11
Koppe Royalty B.V.	11
Preesman Royalty B.V.	11
Seminis Vegetable Seeds Inc.	11
Sakata Seed Sudamerica Ltda.	10
Other	319

Source: Ministry of Agriculture, Serviço Nacional de Proteção de Cultivares (SNPC).

(1) Embrapa is co-grantee for 11 varieties with Empaer-MS; 8 varieties with Agência Rural de Goiás; 6 varieties with Epamig and Agropecuária Boa Fé; 5 varieties with Agência Rural and CTPA; 4 varieties with Emater-GO/Agrosem; 4 varieties with Epamig; 4 varieties with Fundação MT; 1 variety with EBDA; 1 variety with Fepagro; 1 variety with Fundação MT/CTPA; 1 variety with UFLA/EPAMIG; and 1 variety with UFLA.

Note: Includes provisional certificates. Data without repetition.

73. African violet, alstroemeria, anthurium, apple, banana, barley, begonia elatior, brachiaria, carrot, chrysanthemum, coffee, cotton, dry bean, emerald zoysia, eucalyptus, gerbera, grape, guinea grass, guzmania, gypsophila, iris, kalanchoe, lettuce, macrotyloma, maize, oats, onion, pea, pear rootstock, pearl millet, pigeon pea, pineapple, potato, rice, rose, snap bean, sorghum, soya bean, strawberry, sugarcane, triticale, wheat, zantedeschia.

breeders (melhoristas) and grantees (obtentores)[74] in extending the conditions for appropriation of the results of their investment. These certificates help identify the key players involved in the process of plant breeding in Brazil.

As can be seen from Table 10.23, Embrapa owns the rights to the most plant varieties, with 2.8 times the number of certificates held by the runner-up, Monsoy (part of the Monsanto group). This situation reflects Embrapa's adoption of an active IP policy as soon as the LPC came into force. As also noted earlier in the analysis of patenting, Embrapa systematically protects its technological development efforts. Plant variety protection is especially important for Embrapa since one of its key competencies is plant breeding via genetic improvement. There are no parallels for the magnitude or importance of Embrapa's production of new plant varieties in any other Latin American country (Fuck & Bonacelli, 2007).

Other important research centers include Coodetec (linked to the Paraná State Organization of Cooperatives, Ocepar), CTC[75] and Fundacep (linked to co-ops in Rio Grande do Sul). This situation impacts the seed industry in Brazil, given the outstanding importance of private nonprofits and public organizations (especially Embrapa) as sources of agricultural technology. APTA's participation is conspicuously small: it ranks 39th among grantees, with only six plant variety protection certificates (Detailed Table 10.38).

The most protected crop is soya (Table 10.24), followed by wheat, sugarcane, roses and cotton. It is important to note that coffee is not highly protected, with only six varieties granted protection in the period analyzed. The reason for this is either that coffee is a perennial with a long technological cycle, or that the main developer of new varieties, IAC/APTA, only recently adopted an active IP protection policy. The crop for which protection most increased in the period was sugarcane, in step with expansion of sugarcane growing in Brazil to produce ethanol.

An analysis of the data by state shows that many grantees operate in more than one state and protect their innovations using the address of the department responsible for managing IP affairs. This boosts the importance of the Federal District (DF, Embrapa's headquarters being located in Brasília) and São Paulo State, where many of the leading firms in plant breeding are based. A large proportion of the 1,073 protected varieties (74.1%) were registered in the name of grantees domiciled in Brazil (Figure 10.18). The reverse applied to patents: 39.1% of patent applications and 31.6% of patents were registered in the name of residents, including multinationals with Brazilian subsidiaries (Detailed Table 10.36).

As noted, soya had the largest number of protected varieties both in Brazil, with 399 (Table 10.24), and in São Paulo, with 113 (Detailed Table 10.40). São Paulo State is not a soya seed producing area: these numbers reflect the fact that Syngenta and Monsanto are based in the state, the former with eight soya varieties protected between 1998 and 2007, and Monsoy with 105 (Detailed Table 10.41). Sugarcane ranked second in terms of the number of varieties protected by grantees in São Paulo State (Detailed Table 10.40). Grantees in the state accounted for 87.5% of the 72 cane varieties protected in Brazil (Table 10.24 and Detailed Table 10.40), a high proportion directly reflecting the efforts of Copersucar (with 29), UFSCar[76] (with 14), IAC (with six), CTC (with 12), Agropav Agropecuária (with one) and Usina da Barra (also with one) (Detailed Table 10.41). São Paulo was also important for eucalyptus breeding: firms in the state accounted for ten out of 20 eucalyptus varieties protected in Brazil (Table 10.24), with Votorantim Celulose e Papel S.A and International Paper do Brasil Ltda. holding the rights to five each (Detailed Table 10.41). Table 10.25 lists the holders of plant variety protection certificates granted to firms in São Paulo State between 1998 and 2007.

Some 26% of protected plant varieties had foreign grantees (Figure 10.18).[77] São Paulo State again had the largest share of these, with about 60% of all representatives of foreign grantees (Detailed Table 10.42). Many of these firms were located near major growing areas for the protected varieties. In the case of flowers and ornamental plants, for example, Cultivar Protection, located in Holambra, the leading area for these products, played a significant role as a legal representative of domestic and foreign firms (Detailed Table

74. A plant breeder (melhorista) is defined in the LPC as an "individual who breeds a plant variety (cultivar) and establishes descriptors that differentiate it from all others" (Art. 3). Grantees are "natural or legal persons who obtain new plant varieties or plant varieties essentially derived in Brazil" (Art. 5) and are "entitled to protection of their property rights therein according to the provisions of this Law." Thus a grantee may be a breeder or any third party to whom title is assigned (Garcia, 2004).

75. In 2004 Copersucar transferred its R&D center (then Centro de Tecnologia Copersucar) to the sugar and ethanol sector and it was renamed Centro de Tecnologia Canavieira (CTC). It had hitherto belonged to 30 sugar mills, all members of Copersucar, but more partners were brought in after the change, to include cane growers as well as more mills and distilleries.

76. In January 1991, UFSCar incorporated the São Paulo units of Planalsucar, an extinct body linked to the also extinct IAA in Araras. This certainly contributed to the university's capabilities in sugarcane breeding.

77. Foreign firms and institutions with legal representatives in Brazil.

Table 10.24
Number of protected plant varieties by crop (cumulative) – Brazil, 1998-2007

Crop	No. of protected varieties
Total	**1,073**
Soya	399
Wheat	84
Sugarcane	72
Rose	67
Cotton	61
Potato	57
Rice	56
Maize	42
Dry bean	25
Kalanchoe	21
Eucalyptus	20
Lettuce	15
Sorghum	15
Grape	12
Anthurium	11
Begonia elatior	11
Apple	11
Iris	9
Alstroemeria	7
Oats	7
Chrysanthemum	7
Coffee	6
Barley	6
Zantedeschia	6
Strawberry	6
Gerbera	5
Brachiaria	4
Guzmania	4
Triticale	4
Pineapple	3
Carrot	3
Guinea grass	2
Pea	2
Snap beans	2
Emerald zoysia	2
Millet	2
Banana	1
Onion	1

(CONTINUES ON NEXT PAGE)

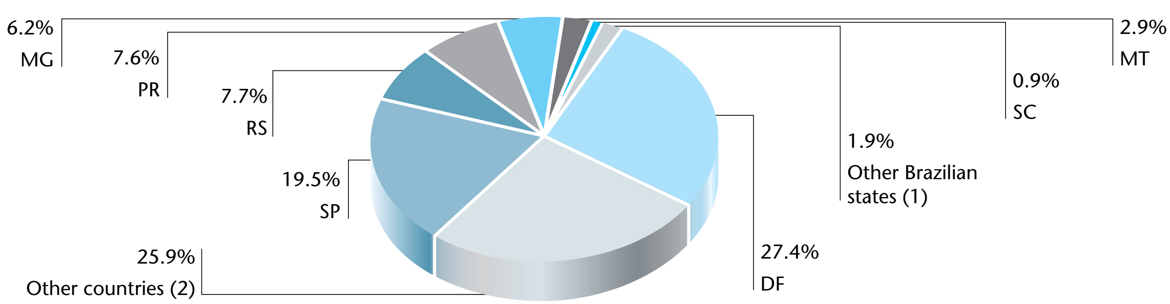
Table 10.24
Number of protected plant varieties by crop (cumulative) – Brazil, 1998-2007 (continued)

Crop	No. of protected varieties
Pigeon pea	1
Gypsophila	1
Macrotyloma	1
Pear rootstock	1
African violet	1

Source: Ministry of Agriculture, Serviço Nacional de Proteção de Cultivares (SNPC).

Note: Includes provisional certificates.

Figure 10.18
Origin of owners of rights to protected plant varieties – Brazil, 2008



Source: Ministry of Agriculture, Serviço Nacional de Proteção de Cultivares (SNPC).

(1) Includes: AL (7), ES (5), GO (5), BA (3).
(2) Includes: Netherlands (131), USA (48), France (31), Italy (20), Germany (17), Argentina (13), Denmark (5), New Zealand (4), Australia (4), Colombia (2), China (1), Mexico (1).

Notas: 1. Includes provisional certificates.
2. See Detailed Table 10.39.

Table 10.25
Number of protected plant varieties by first-named applicant – São Paulo State, 1998-2007

Applicant	No. of protected varieties
Total	**209**
Monsoy Ltda.	105
Copersucar	29
Universidade Federal de São Carlos	14
Centro de Tecnologia Canavieira (CTC)	12
Sakata Seed Sudamerica Ltda.	10
Syngenta Seeds Ltda.	9
IAC/APTA	6
International Paper do Brasil Ltda.	5
Votorantim Celulose e Papel S/A	5
Comércio e Indústria Matsuda Importadora e Exportadora Ltda.	3
Dow AgroSciences Industrial Ltda.	3
Bayer Cropscience GmbH	2
Itograss Agrícola Ltda.	2
Agropav Agropecuária Ltda.	1
Escola Superior de Agricultura Luiz de Queiroz	1
José Fernando Martins Borges	1
Usina da Barra S/A - Açúcar e Álcool	1

Source: Ministry of Agriculture, Serviço Nacional de Proteção de Cultivares (SNPC).
Note: Includes provisional certificates.

10.42). According to the firm's website,[78] its activities range from managing the procedures for protection and licensing to transfer of royalties, piracy control, and technical and legal consulting in every aspect of plant product marketing. This kind of intermediation provides important links between growers and foreign firms, or at the opposite extreme between growers and consumers, many of whom are foreign in the case of flowers and ornamental plants.

4.4 Scientific production

An analysis of scientific production by the agrarian science research groups registered with CNPq's directory between 2000 and 2006 (2000, 2002, 2004 and 2006 Censuses) shows vigorous growth in all types of production: the number of complete articles published by Brazilian and international journals in the period rose 156% and 200% respectively. The number of postgraduate degrees awarded also rose sharply, with 124% growth in PhD theses and 72% growth in master's dissertations. In proportion to other major knowledge areas, however, agrarian sciences fell as a share of both domestic publications (down from 26% to 21%) and dissertations (down from 15% to 10%) (Table 10.26).

In any event, agrarian sciences is one of the major knowledge areas with the most visibility, thanks to Brazil's long track record in agricultural research and production. This is clearly evidenced by the statistics for annual scientific production per researcher in the form of articles published by Brazilian journals. The number published by international journals is smaller because each area focuses on domestic issues more than on advancing knowledge (Table 10.26).

A search of the Web of Science database was performed to count the number of agrarian science articles authored by researchers in São Paulo State.[79] Because this

78. <http://www.cultivarprotection.com.br/Apresentacao.html>. Last visited Feb. 2, 2010. [Site inactive]
79. For details of the search strategy, see the Methodological Annex.

Table 10.26
S&T production and productivity in agrarian sciences and all knowledge areas in activities of CNPq research groups by type of production – Brazil, 2000-2006

Type of publication	S&T production and productivity in agrarian sciences and all knowledge area in activities of CNPq research groups by type of production												
	Production				Change 2000-2006 (%)	Production per researcher doctor per year (1)							
						2000 Census		2002 Census		2004 Census		2006 Census	
	2000 Census (1997-2000)	2002 Census (1998-2001)	2004 Census (2000-2003)	2006 Census (2003-2006)		Agrarian sciences 1997-2000	All areas 1997-2001	Agrarian sciences 1998-2001	All areas 1998-2002	Agrarian sciences 2000-2003	All areas 2000-2004	Agrarian sciences 2003-2006	All areas 2003-2007
Complete articles in Brazilian journals (2)													
Agrarian sciences	19,899	27,488	44,277	50,921	255.9	1.24	0.63	1.34	0.71	1.59	0.89	1.57	0.88
% total in all areas	25.9	24.5	22.0	21.4									
Complete articles in international journals (2)													
Agrarian sciences	7,096	9,965	12,099	21,257	299.6	0.44	0.64	0.48	0.69	0.43	0.59	0.65	0.78
% total in all areas	9.1	9.1	9.1	10.0									
PhD theses (3)													
Agrarian sciences	2,098	3,072	3,318	4,697	223.9	0.13	0.12	0.15	0.13	0.12	0.12	0.14	0.13
% total in all areas	14.4	15.1	12.5	13.1									
Master's dissertations (3)													
Agrarian sciences	6,959	9,681	9,405	12,002	172.5	0.43	0.38	0.47	0.43	0.34	0.41	0.37	0.45
% total in all areas	14.8	14.4	10.1	9.9									

Source: CNPq.

(1) Number of doctors as per census.
(2) Brazilian journals: language = Portuguese or undeclared; international journals: language = not Portuguese.
(3) Master's dissertations and PhD theses defended under supervision of doctors belonging to CNPq research groups.

Notes: 1. Includes only articles authored by researcher doctors registered on Lattes CV database (2000 Census: data collected to June 1, 2001; 2002 Census: to July 12, 2002; 2004 Census: to Dec. 9, 2004; 2006 Census: to Sep. 12, 2007).
2. Total obtained by addition may have entailed double counting as articles by researchers who belonged to two or more groups classified in different predominant knowledge areas will have been computed once for each area. Within any given area, double counting may have occurred in the case of coauthorship (two or more authors for the same article).

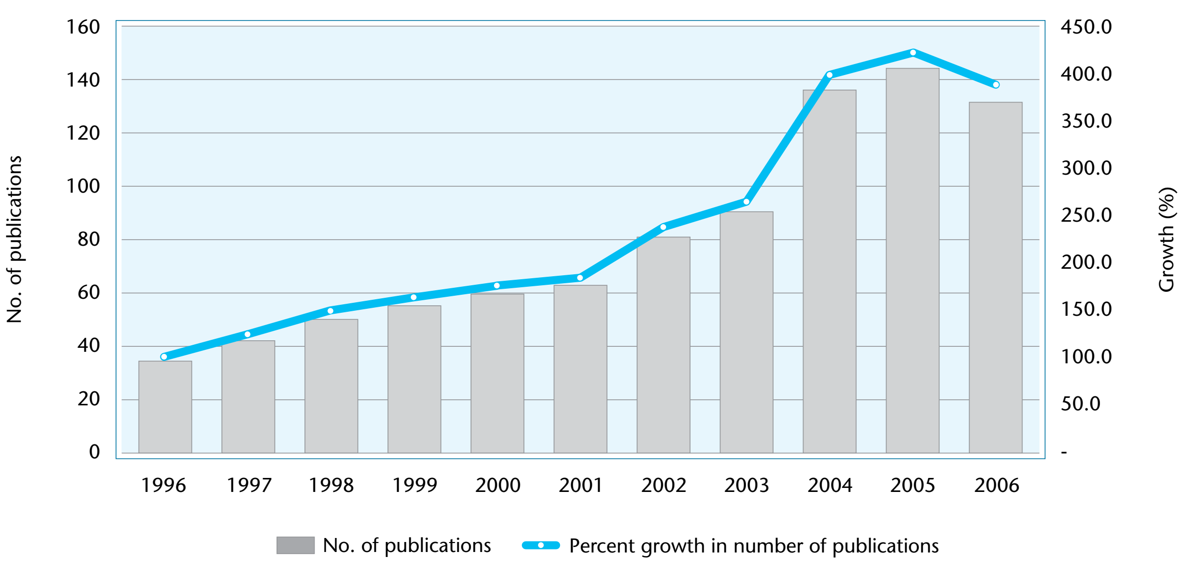
is a high-quality indexed database, the result was an accurate cross-section of scientific production by researchers in São Paulo State in terms of internationally published papers. The number of scientific articles indexed by Web of Science for the period 1996-2006 totalled 890, displaying steady growth and rising sharply in 2005. Expressed as an index with the base year 1996 = 100, the number reached 388.2 in 2006 (Figure 10.19).

The authors of these articles were affiliated with 340 institutions. The institution with the most authors was USP (463), followed by Unesp (281), Unicamp (173), Embrapa (140), and institutions attached to APTA (106). A significant proportion of the authors were located in other states of Brazil (11.7%) and in other countries (18.2%) (Table 10.27). The country with which researchers in São Paulo most collaborated was the United States (13.8% of the articles), followed by France (3.9%), Spain (2.7%) and Germany (2.6%) (Detailed Table 10.44).

Only 13.8% of the 890 articles by researchers from São Paulo State indexed by Web of Science were published in journals not indexed by Qualis (CAPES). The majority (71.3%) were published in journals classified as Qualis A international[80] (Detailed Table 10.45).

Turning to production by researchers at all Embrapa units published in journals classified by Qualis, it can be seen that the number of articles published rose 26.6% between 1997 and 2006, while productivity (articles per researcher) rose 18.7%. Specifically for researchers at Embrapa units in São Paulo State, productivity rose more than for all Embrapa researchers except in 1997 and 2000 (Table 10.28).

Figure 10.19
Publications in agrarian sciences indexed by Web of Science – São Paulo State, 1996-2006



Source: *Web of Science.*

Notes: 1. Base year 1996 = 100.
2. See Detailed Table 10.43.

80. Journals were classified on the basis of a list created by merging Qualis lists for the following areas: food sciences, agrarian sciences, biological sciences I, biological sciences II, biological sciences III, ecology and environment, geosciences, geography, veterinary medicine, animal science, and fishery reSource. Where journals were classified differently for different areas, the highest level was used.

Table 10.27
Agrarian science publications in Web of Science by author's institution – São Paulo State, 1996-2006

Institution	Agrarian science publications in Web of Science	
	Abs. nos.	%
Total	**2,018**	**100.0**
University of São Paulo (USP)	463	22.9
São Paulo State University (Unesp)	281	13.9
State University of Campinas (Unicamp)	173	8.6
Empresa Brasileira de Pesquisa Agropecuária (Embrapa)	140	6.9
Campinas Institute of Agronomy (IAC)	86	4.3
Federal University of São Carlos (UFSCar)	42	2.1
Lorena College of Engineering	24	1.2
São Paulo State Agribusiness Technology Agency (APTA)	20	1.0
Other-São Paulo State	148	7.3
Other-Brazil (except São Paulo State)	236	11.7
Other-outside Brazil	367	18.2
Unidentified	33	1.6
Other	5	0.2

Source: *Web of Science.*

Table 10.28
Articles by Embrapa researchers published in journals classified by Qualis (CAPES) and articles per researcher – Brazil & São Paulo State, 1997–2006

Year	Articles by Embrapa researchers published in journals classified by Qualis and articles per researcher			
	Embrapa – Brazil		Embrapa – São Paulo State	
	Total (abs. nos.)	Articles per researcher	Total (abs. nos.)	Articles per researcher
1997	1,186	0.64	93	0.62
1998	1,496	0.82	111	0.86
1999	1,090	0.66	115	0.94
2000	1,061	0.60	88	0.52
2001	1,132	0.66	97	0.68
2002	1,164	0.60	101	0.64
2003	1,283	0.68	148	1.05
2004	1,482	0.77	138	0.98
2005	1,410	0.74	150	0.95
2006	1,501	0.76	146	0.92

Source: Embrapa (Dept. of Management & Strategy).

Note: CAPES is the Federal Agency for the Improvement of Higher Education Personnel. Qualis is a system used by CAPES to evaluate post-graduate programs via the quality of the scientific journals that publish their intellectual output (http://www.capes.gov.br/avaliacao/qualis).

4.5 Competencies

An analysis of the statistics systematized by CNPq, based on data relating to agrarian sciences from the 1993, 1995, 1997, 2000, 2002, 2004 and 2006 censuses of its Research Group Directory, shows strong growth in the number of groups in this knowledge area (which covers agronomy, food science and technology, agricultural engineering, veterinary medicine, forest resources and forest engineering, fishery resources and fishery engineering, and animal science).

The number of registered research groups in agrarian sciences was 802 in 1993 and 2,041 in 2006, for overall growth of 154.5%, led by veterinary medicine (over 207%). These groups accounted for 9.7% of the total in CNPq's directory in 2006 (Table 10.29).

In 2006, 22.6% of all the groups in agrarian sciences were located in São Paulo State, as were 41.9% of the researchers, 21.3% of the students and 27.3% of the technicians,[81] evidencing the relative importance of the agricultural research conducted in the state. São Paulo's share of groups, research lines, students and technicians in Brazil fell between 2000 and 2006, but the number of researchers in the state rose sharply as a share of the national total in the same period, from 28.3% to more than 40% (Figure 10.20). Also in line with the overall trend, agronomy led in all respects (groups, lines etc.) and in all surveys of agrarian sci-

Table 10.29
Number of research groups in agrarian sciences by knowledge subarea – Brazil, 1993-2006 (census years)

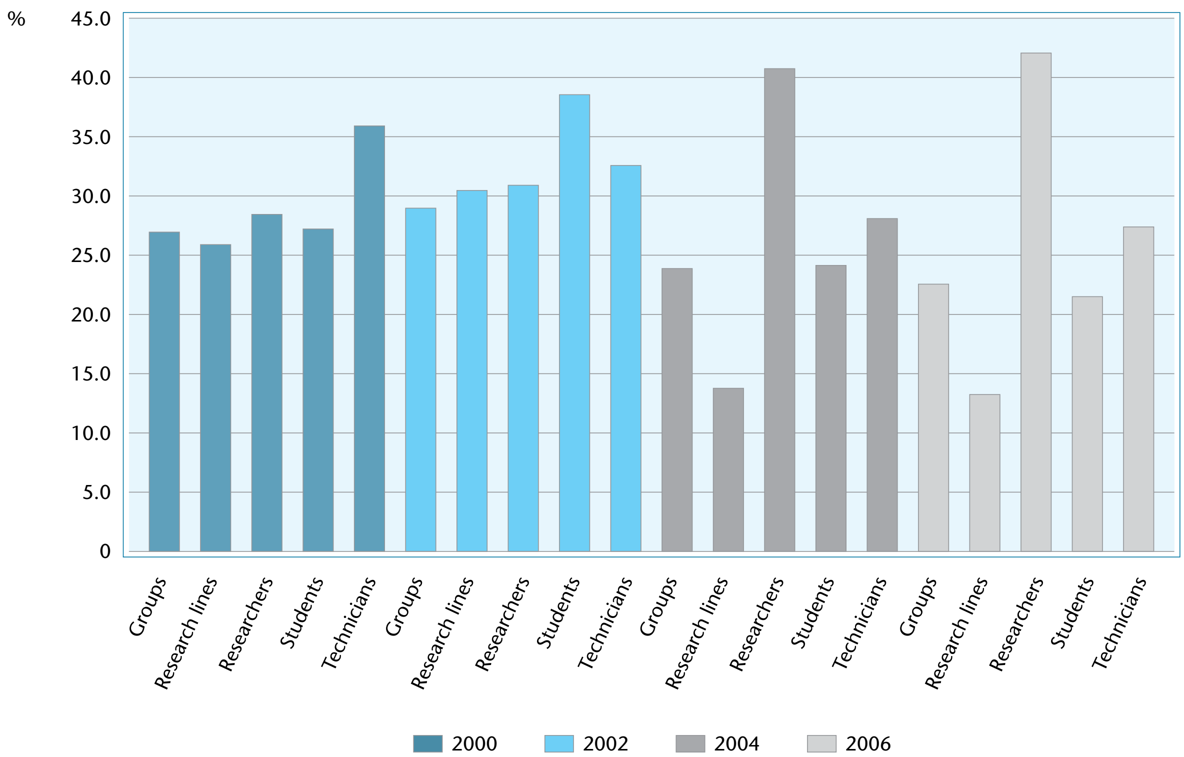
Knowledge subarea	Research groups in agrarian sciences													
	1993 (1)		1995 (2)		1997 (3)		2000		2002		2004		2006	
	Groups	%	Groups	%	Groups	%	Groups	%	Groups	%	Groups	%	Groups	%
Grand total (A)	**6,480**		**7,174**		**8,541**		**11,760**		**15,158**		**19,470**		**21,024**	
Total agrarian sciences (B)	**802**	**100.0**	**938**	**100.0**	**912**	**100.0**	**1,352**	**100.0**	**1,653**	**100.0**	**1,997**	**100.0**	**2,041**	**100.0**
Agronomy	304	37.9	371	39.6	331	36.3	535	39.6	666	40.3	793	39.7	822	40.3
Food science & technology	123	15.3	130	13.9	141	15.5	193	14.3	241	14.6	297	14.9	283	13.9
Agricultural engineering	50	6.2	36	3.8	53	5.8	58	4.3	88	5.3	103	5.2	107	5.2
Veterinary medicine	119	14.8	156	16.6	145	15.9	238	17.6	280	16.9	340	17.0	366	17.9
Forest resources & forest engineering	54	6.7	78	8.3	72	7.9	88	6.5	110	6.7	130	6.5	129	6.3
Fishery resources & fishery engineering	30	3.7	34	3.6	45	4.9	58	4.3	52	3.1	73	3.7	75	3.7
Animal science	122	15.2	133	14.2	125	13.7	182	13.5	216	13.1	261	13.1	259	12.7
Change agrarian sciences (1993 = 100)	**100**		**117**		**114**		**169**		**206**		**249**		**254**	
B / A (%)	**12.4**		**13.1**		**10.7**		**11.5**		**10.9**		**10.3**		**9.7**	

Source: CNPq, Diretório de Grupos de Pesquisa. Census years: 1993, 1995, 1997, 2000, 2002, 2004, 2006.

(1) For 1993, area is first group leader's speciality. Each researcher can declare up to six specialities, leading to double counting in cases where specialities declared belong to different areas.
(2) Excludes 97 groups that omitted knowledge subareas (but did declare major knowledge areas, as follows: agrarian sciences, 6; biological sciences, 34; health, 27; exact sciences/earth sciences, 26; engineering/computer science, 3; humanities, 1).
(3) Excludes 88 groups at Universidade Estadual de Maringá (UEM) registered by the database after tabulation was completed, and three groups that omitted predominant knowledge subarea.

81. Comparisons of research groups, numbers of registered researchers and funds allocated to agricultural research in São Paulo State are hindered by disparities in the numbers, since a significant proportion of the agricultural research conducted in the state is not done by groups registered with the CNPq Research Group Directory. Neither all Embrapa researchers nor all researchers employed by SAROs are registered with CNPq, for example. As a result, it is not possible to make direct correlations between resources allocated and numbers of researchers in research groups.

Figure 10.20
Groups, researchers, students, technicians and lines of research in agrarian sciences as share of national total for same knowledge area – São Paulo State, 2000-2006 (census years)



Source: CNPq.

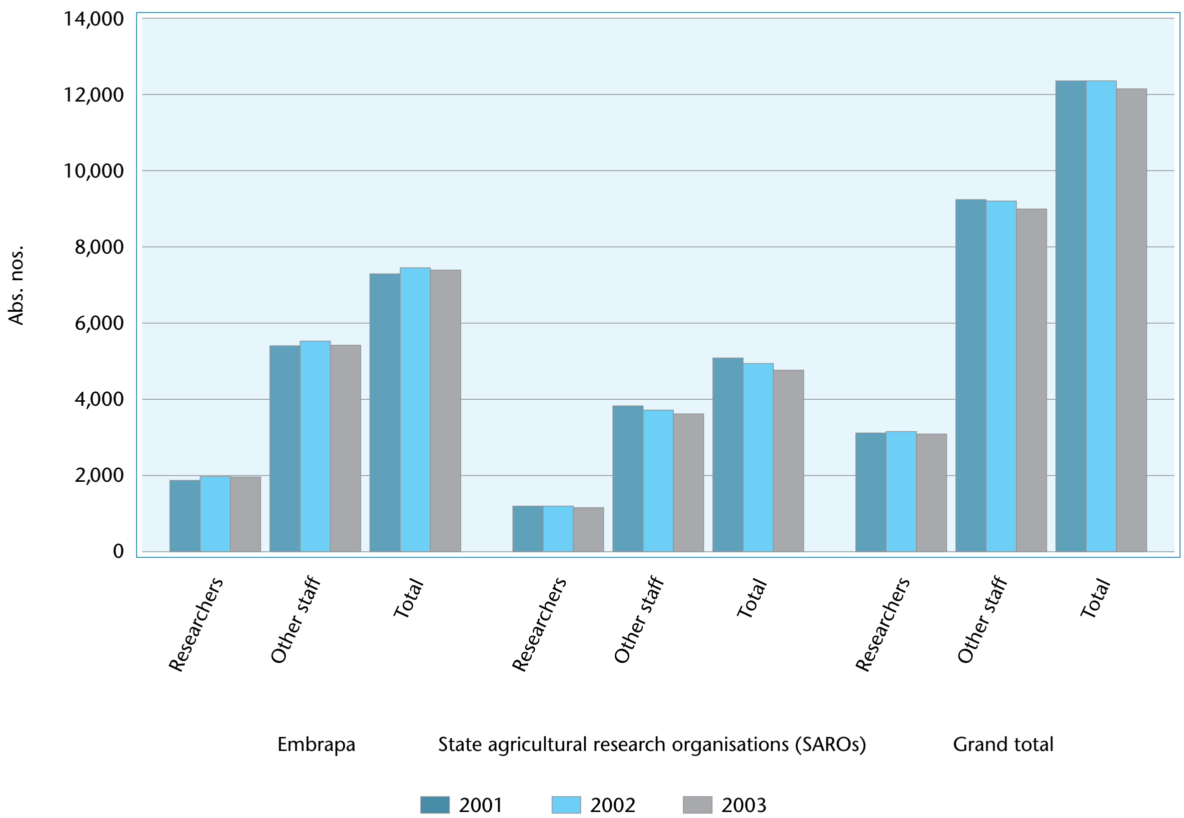
Notes: : 1. Double counting occurred in general with regard to numbers of researchers, students and technicians, as individuals participating in more than one research group were computed more than once.
2. See Detailed Table 10.46

ences. In 2006, for example, it had the most groups, with 163, followed by food science and technology, with 93, and veterinary medicine, with 88 (Detailed Table 10.47).

As noted earlier, the ten public colleges of agrarian sciences had 937 active faculty in 2006 (Detailed Table 10.22). The number of researchers at the main public agricultural research institutions (Embrapa and SAROs) rose moderately, from 3,086 in 2001 to 3,127 in 2003, while the number of other staff (support personnel, directors etc.) fell in the same period, from 9,251 to 8,982 (Figure 10.21), owing more to a reduction in headcount at SAROs than at Embrapa, which has a more stable workforce. Indeed, the fall may be due to a reduction in the number of other staff at APTA, which accounted for some 20% of the total of other staff at SAROs and Embrapa in aggregate (Detailed Table 10.48).

In the case of APTA, the number of researchers fell between 1996 and 2003 (from 791 to 592 – see Figure 10.22) and rose between 2003 and 2005 (Detailed Table 10.50). In 2007, the agency housed 852 researchers, more than in 1996 (Detailed Table 10.50). These numbers are equivalent to those reported by Gonçalves, Junqueira & Barros Filho (2004) for the start of the 1990s. Staffing levels fell from the mid-1990s onwards, for reasons linked to pay, voluntary redundancy, retirement and attrition, particularly among re-

Figure 10.21
When Apta was set up, permanent civil servants were reallocated from institutions to regional "poles" and a large competitive examination was held in 2004 to fill research staffing shortages.



Source: Embrapa (Dept. of Management & Strategy); Gonçalves, Junqueira & Barros Filho (2004); CGEE (2008).

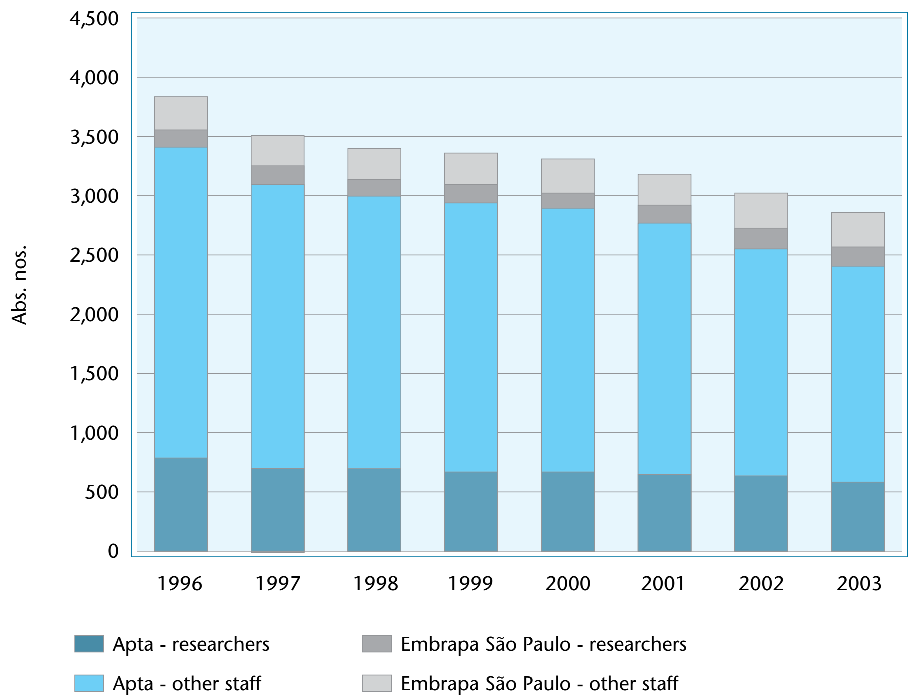
search support personnel. While growth in the number of researchers resumed in 2004 owing to the effects of the establishment of APTA[82] and the holding of competitive exams, this was not the case for other staff.

Similarly, the number of researchers employed by Embrapa São Paulo fell between 1996 and 1999, with growth resuming in 2001. In contrast with APTA, however, Embrapa took on more other staff throughout the period 1996-2003, with the exception of 2001 (Detailed Table 10.49).

APTA had proportionally more other staff than researchers: the ratio averaged 3.2 other staff for every researchers, declining from 3.3 in 1996 to 3.0 in 2003. At Embrapa the ratio rose throughout the period (from 1.6 in 1996 to 1.9 in 2003), but absolute numbers were lower than at APTA (Detailed Table 10.49).

82. When APTA was set up, permanent civil servants were reallocated from institutions to regional "poles" and a large competitive examination was held in 2004 to fill research staffing shortages.

Figure 10.22
Embrapa and Apta staff in active service – São Paulo State, 1996-2003



Source: Embrapa (Dept. of Management & Strategy); Gonçalves, Junqueira & Barros Filho (2004); São Paulo State Department of Agriculture & Supply (SAA).

Note: See Detailed Table 49.

5. Outlook for SPInA

- The São Paulo State Agricultural ST&I System (SPInA) is complex and multifaceted, comprising a large number of organizations and institutions integrated into an agroindustrial complex that requires technological dynamism and innovation capacity in agricultural production. The state accounted for roughly a quarter of Brazil's agribusiness GDP in the period analyzed (Guilhoto et al., 2007).
- Total factor productivity (TFP) in São Paulo State performed strongly, with high internal rates of return on investment and substantial economic and financial returns, demonstrating the profitability of investment in research and in technology and innovation. Both the return of approximately R$ 17 per *real* (R$) allocated to R&D and productivity gains in the last 20 years are worth noting, and were well above the national average (Vicente, 2003, 2008). TFP in São Paulo's agricultural sector reached 134.4 as an index in 2006 compared with 1995 (base year 1995 = 100).
- Another important point is that modernization via acquisition of machinery, inputs and more efficient production processes is under way and shows no sign of having approached an upper limit, either in São Paulo or in the rest of Brazil. Since the mid-1990s the agricultural sector in Brazil appears to have experienced an intensification of production that allows it to look forward to a growth horizon whose limits cannot yet be seen. Even in São Paulo, where density is greater in both production and technology, productivity gains are still significant and appear set to continue growing.
- Considering the scope for further productivity gains in livestock farming and incorporation into crop farming of land currently used for extensive animal production, the outlook for Brazilian agriculture is one of increasing avidity for technology and innovation. There is an enormous area this side of the agricultural frontier that must

be occupied by more intensive, efficient and effective crop and livestock farming. Few countries in the world have Brazil's combination of comparative advantages (climate and soil) with constructed advantages (research and technology capabilities). São Paulo State, albeit more modernized and better occupied than extensive livestock farming areas elsewhere in Brazil, also has significant scope for productivity gains and value creation in activities relating to agriculture.

- Both on the side of R&D and on that of the acquisition of technology (adoption and diffusion), there is a tendency to intensify production per unit of area and per worker in both Brazil and São Paulo State. The finding that these ratios are higher than the national average in São Paulo highlights the close link between the industrial development of agribusiness and the pursuit of innovation in agriculture. In other words, the higher the level of industrialization and modernization in the upstream and downstream segments, the greater the pressure for modernization inside the farm gate.
- An analysis of the public research system shows the importance of APTA in São Paulo State, although its scientific and above all technological production indicators are not the best in Brazil. The number of patents and particularly plant varieties registered with the SNPC is much smaller than the organization's capacity to generate technologies: APTA had six plant varieties registered with SNPC in 2008, out of a total of 209 protected varieties registered in the name of grantees domiciled in São Paulo (Table 10.25) – not including Embrapa, which is domiciled in the Federal District for the purposes of SNPC registration – and more than 1,000 protected varieties nationwide in 2008 (Detailed Table 10.39).
- Most of the varieties bred by APTA are made available to the public without any IP protection. The agency has only recently begun valuing and stimulating such protection. A specific study would be required in order to reach a conclusion regarding APTA's contribution. A structural policy change has been attempted but with some exceptions in the agency's more dynamic centers its policy is still insufficiently concerned with indexed scientific production and IP protection.
- Another question that stands out in the chapter is the difficulty of obtaining data on investment by universities in agricultural research. A significant proportion of the scientific and technological knowledge produced in this sector is found in schools of agronomy, veterinary medicine, animal science and other areas of the agrarian sciences. The survey performed for this chapter showed annual investment ranging from R$ 54 million to R$ 80 million in research allocated by the budgets of public universities and colleges in São Paulo State in recent years, or about 20% of total investment in agricultural R&D in the state (Detailed Table 10.9).
- If difficulties were experienced in verifying investment in research by universities (although data were obtained), they were even worse in the case of private investment. Statistics from PINTEC are discussed in the chapter, but a decision was made to use the overall proportion between public and private expenditure nationwide for the final calculation of private investment in agricultural R&D.
- The ratio of Brazilian R&D expenditure to value added measured by agricultural GDP was between 1.8% and 2.4% in the period 2001-05. This is high compared with countries at a similar stage of development to Brazil's. However, in proportion to agribusiness GDP the ratio falls to between 0.37% and 0.45% (Table 10.5). Based on the arguments presented in this chapter, it is important to increase investment in R&D and innovation throughout the agribusiness sector, i.e. not just in farming proper but also in all the segments directly involved upstream and downstream of the farm gate. More important than the allocation of financial resources, perhaps, is better coordination of the system, which is relatively fragmented among the main actors.
- Today, with agricultural production once again at the forefront of global concerns because of the need to increase food production and because of the importance of crops as energy feedstocks and inputs for other key processes, there is a growing awareness of the significance of agricultural research and its role in innovation systems. The very understanding of what is done and how it is done in the universe of agricultural ST&I must change so that the concepts and analytical approaches used are more appropriate to the importance of these activities. Although it is one of the most developed areas of Brazil's national innovation system, agricultural research has only recently begun to be seen seriously as a part of the system. For a long time it was treated as if it were a separate system, with neither researchers and research organizations nor governments and public policies seeing it as an integrated component of the ST&I system.
- The challenge is to increase investment in order to pursue greater technological and productive density of land use and hence greater production capacity within a framework of economic, social and environmental sustainability.

Glossary

Administrative regions of São Paulo State: São Paulo State has 645 municipalities (cities) grouped into 15 administrative regions created by executive decree to establish a new pattern of spatial organization in public administration (Negri Neto, coelho & moreira, 1993). Details available at <http://www.seade.sp.gov.br/produtos/anuario/mostra_Table.php?anos=2003&tema=car&tabpesq=car2003_04&Table=null>.

Agrarian sciences: A major knowledge area comprising the following, according to the Federal Agency for the Improvement of Higher Education Personnel (CAPES): agronomy, food science and technology, agricultural engineering, veterinary medicine, forest resources and forest engineering, fishery resources and fishery engineering, and animal science.

Agribusiness: Production, processing and supply of agricultural goods, including both upstream industries (farm machinery and implements, chemical and biological inputs, specialized technical services, pesticides, herbicides, pharmaceuticals and fertilizer, among others) and downstream industries (processing, distribution and marketing, among others). Input-output matrix applied to agricultural production.

Agriculture: Farming of permanent and temporary crops, as well as livestock (dairy and beef cattle, poultry, pigs and fish). The terms "agriculture" and "agricultural" encompass all types of farming.

Agroindustry: Post-harvest processing and preserving of food crops for intermediate or final consumption, thus downstream of farming in the production chain.

Area harvested: Total area of a crop actually harvested in a municipality during a survey reference year (IBGE, 2007d).

Area planted: Total area of a temporary crop planted in a municipality and available for harvesting (wholly or in part) during a survey reference year or vulnerable to loss due to adverse weather, pests, disease etc. (IBGE, 2007d).

Average yield: Quantity produced divided by area harvested (IBGE, 2007d).

Basic price: Excludes trade and transport margins, as well as taxes on goods.

Breeder: Individual who "breeds a plant variety (cultivar) and establishes descriptors that differentiate it from all others," according to the definition of melhorista in Law 9456/1997. The same law defines obtentores as "natural or legal persons who obtain new plant varieties or plant varieties essentially derived in Brazil," stipulating that such grantees "shall be entitled to protection of their property rights therein according to the provisions of this Law". See note 74.

Certificate of addition: Protection for an improvement or development to the subject matter of an invention, granted as an accessory to an existing patent, in accordance with Articles 76-77 of Brazil's Industrial Property Law (LPI).[83]

Geographical indication: Identification of a product or service as originating in a town, region or country and having certain qualities, being made according to traditional methods or enjoying a certain reputation attributable to that origin. In short, a GI is a guarantee regarding the origin of a good and its qualities and regional characteristics.

Germplasm bank: An organized collection of seeds or other genetic material for storage and conservation. Each genotype entered is called an accession. New varieties may be generated (immediately or in future) from such a gene bank, which does not discard any accessions, in contrast with "working collections", from which material not deemed useful for genetic improvement is removed. Germplasm collections can be classified as base or active. Base banks conserve germplasm for long periods in cold storage (between 1ºC and -20ºC), in vitro (conservation of plant parts in a growth culture medium) or using cryopreservation (in liquid nitrogen at -196ºC), and may be far away from the plant breeder's place of work. Active banks are close to researchers, with whom they exchange germplasm. They frequently plant material for characterisation purposes and conserve it only for the short or medium term (Veiga, nd).

Gross value added: The difference between gross revenue and the cost of inputs bought from suppliers (materials consumed and third-party services).

Innovation system: A set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and provide the framework within which governments form and implement policies to influence the innovation process. Includes educational, research and funding institutions, government, private enterprise etc. (Cassiolato & Lastres, 2000)

Internal rate of return (IRR): The discount rate that makes the net present value of all cash flows from a project equal to zero, so that the present value of all incoming cash flows is equal to the present value of all outgoing cash flows. Corresponds to the anticipated profitability of a project and hence to the return on the investment made. The formula for IRR is:

$$\sum_{i=1}^{n} (B_i - C_i)/(1 + j)^i = 0$$

where j is the discount rate, and B_i and C_i are flows of benefits and costs in the period i.

Inventor: The creator, "intellectual mentor" or person who had the original idea behind an invention or participated in its execution and development.[84]

Livestock farming: Animal husbandry, including:

Large animals: beef and dairy cattle, buffaloes, oxen, horses, donkeys, mules;

83. Source: <www.inpi.gov.br>. Last visited Mar. 31, 2010. (For an English translation, see the Organization of American States website, http://www.sice.oas.org/int_prop/nat_leg/Brazil/ENG/L9279eI.asp.)

84. Frequently asked questions: <http://www.cpqgm.fiocruz.br/?area=01X05X05#12>.

Medium animals: pigs, goats, sheep;

Small animals: poultry (chickens, ducks, geese, turkeys, quails, ostriches etc), rabbits, apiculture (honeybees), aquaculture (fish, shrimps, oysters, mussels etc.), raniculture (frogs) and sericulture (silkworms) (IBGE, 2006).

Market price: Consumer price including trade and transport margins as well as taxes and subsidies on goods.

Modernization of agriculture: Intensive use of equipment and techniques such as machinery and modern inputs to increase production and yield.

Patent: Protection for an invention or utility model granted by a state or group of states for a limited period to the inventor(s) or author(s) or other natural persons or corporate entities who file for the patent. The patentee has the right to decide who may or may not use the patented invention for the period during which the invention is protected. In return the patentee must disclose full details of its technical content. While the patent is in force (typically 20 years), its holder has the right to prevent others from making, selling, importing or otherwise using the patented product or service.

Patentee: A person or organization that has been granted a patent as the owner of an invention.

PCT: Patent Cooperation Treaty, concluded at Washington DC on June 19, 1970, to provide a unified procedure for filing patent applications in each of its contracting states. A patent application filed under the PCT is called an international application, or PCT application. The treaty had 137 signatories in April 2007. In Brazil the PCT came into force in 1978.[85]

Permanent or perennial crops: Crops that persist for many growing seasons and can be repeatedly harvested before they have to be replanted (IBGE, 2007d).

Plant extractivism: Extraction of native plant resources, such as wood, latex, seeds, fibers, fruits and roots, among others, by means of collection, harvesting, picking, tapping etc., either rationally to permit sustainable long-term production or in a primitive itinerant manner generally allowing for only one production cycle (IBGE, 2007c).

Plant variety (cultivar): A variety of any higher plant genus or species that is clearly distinguishable from other known plant varieties by a minimum margin of descriptors, is designated by a specific denomination, is homogenous and stable in its descriptors throughout successive generations, belongs to a species that is used in farming and forestry, and is described in a publicly available and accessible specialized publication, including the related hybrid lineage (Law 9456/1997).

Plant variety protection: Plant Variety Protection Certificates entitle holders to engage in "commercial reproduction in Brazil, third parties being prohibited during the term of protection from producing for commercial purposes, offering for sale or marketing propagating material of the plant variety without permission" (Law 9456/1997).

Quantity produced: Total volume of a crop harvest or other agricultural production in a municipality during a survey reference year (IBGE, 2007d).

Semi-permanent crops: Crops of medium to long duration, typically with a vegetative cycle of less than a year, that can be repeatedly harvested without having to be annually replanted.

Silviculture: The establishment, development and reproduction of forests for a range of applications including production of timber, charcoal and resin, environmental protection etc. (IBGE, 2007c).

Temporary or annual crops: Crops of short or medium duration, typically with a vegetative cycle of less than a year, that have to be replanted after each harvest (IBGE, 2007d).

Total factor productivity (TFP): The ratio of all outputs to all inputs, measuring aggregate output per unit of aggregate input as a guide to the efficiency of agricultural production (Gasques, Bastos & bacchi 2007). In this chapter, TFP corresponds to the productivity of land, labor, agrochemicals, fertilizer and tractors.

Value of production: Production multiplied by weighted average price (IBGE, 2007d).

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85. Source: <www.inpi.gov.br>. Last visited Mar. 31, 2010.

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