12. Embrapa: its origins and changes

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12.1 INTRODUCTION

Brazilian agriculture is a success story. The country that until the 1960s systematically received food donations from abroad, and up to the 1980s was still a large food importer, had its agriculture profoundly changed. The traditional agriculture that prevailed in Brazil until the 1970s was progressively transformed in the following decades into a modern and highly competitive agriculture based on science. Along with this structural transformation in the primary sector, the industry and service sectors directly linked to agriculture also became two of the world's biggest and most competitive. Furthermore, as food production increased at higher rates than food demand over time, food prices decreased.[2] These gains in consumer surplus took place due partially to lower income for Brazilian farmers.[3]

Brazil is now recognized as the sole agricultural power in the tropics.[4] According to recent estimates, on a country basis, Brazil's share in world agricultural markets (8 percent) is only second to that of the United States (17 percent) (Liapis, 2010) and some analysts already suggest that Brazil's share will be similar to that of the US in the next 10 to 15 years. The Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization (FAO), from the United Nations, in their 2010 joint agricultural outlook projected that Brazilian agricultural production will increase 38 percent from 2010 to 2019 (OECD/FAO, 2010). This huge increase in agricultural production is nearly twice the global average and several times higher than the figures prospected for giants in world agriculture such as the United States, Canada and the European Union.

12.2 THE DEVELOPMENT OF BRAZILIAN AGRICULTURE[5]

12.2.1 A General Overview

Until the mid-1980s, the industrial sector was granted a series of advantages that discriminated against agriculture. These distorting policies against rural areas were translated into an accelerated rural–urban migration process starting in the 1950s. After the 1990s, the urbanization process lost impetus, in part because the rural–urbanization cycle was almost complete in the South, Southeast and Midwest regions (Alves et al., 1999), but also because of the low economic growth rates in the country during the 1980s and the 1990s that weakened the attractiveness of the cities.

The percentage of urban population in Brazil rose from 31.2 percent in 1940 to 84 percent in 2010. Alves and Rocha (2010) showed that from 1991 to 2000 the percentage of migrants from rural to urban areas was 24.7 percent of the rural population; between 2000 and 2007, the migration process dropped to 12.5 percent of the rural population.

The development of a modern agriculture in Brazil was initially prompted by the industrialization policy, especially after the late 1960s, which through urbanization[6] created higher per capita income, accelerated population growth and a strong demand for the agricultural sector.[7] In addition, opportunities for agribusiness product exports were then identified to generate funds to finance imports of technology and capital for the emerging industry.

At the same time, it became clear that the opportunities for agricultural expansion in traditional areas were becoming limited. Increasing productivity in already opened areas, and incorporating the "unproductive" Cerrado – the savannah-type biome in Brazil – was perceived as a means to guarantee the increase in agricultural production and to ensure food to the growing urban population at affordable prices. Thus, it was necessary to improve agricultural land and labor productivity significantly.

The government's response to the challenge of creating a new era in agriculture resulted in the creation in 1973 of the Brazilian Agricultural Research Corporation, Embrapa, a "research arm" of the Ministry of Agriculture, Livestock and Food Supply. This institution was given the mission of coordinating the Brazilian Agricultural Research System, composed of state agricultural research organizations, universities (agricultural colleges) and Embrapa itself.

From the mid-1990s onwards, macroeconomic stability, better relative prices for agricultural commodities in the world markets, and the maturation of tropical agricultural technologies generated in the preceding two

decades settled the basis for a new era in Brazilian agribusiness. The sector moved forward fast from a traditional to a science-based agriculture.

12.2.2 Policies

Three policies played a central role in the agricultural modernization process: (1) subsidized credit, mainly for capital financing and for purchasing modern inputs; (2) rural extension; and (3) support to agricultural research, under Embrapa's leadership.

Agricultural credit

Beginning in the mid-1960s, agricultural credit was mainly provided by the federal government through the Banco do Brasil and the Banco do Nordeste. The private sector had little participation in the loans to farmers until the late 1980s. Interest rates were more heavily (financially) subsidized from 1970 to 1985 (Coelho, 2001). Agricultural credit peaked in 1979, at US$75.8 billion.[8] Then, as a part of the imposed macroeconomic adjustment in the 1980s and early 1990s, it quickly declined to around US$11.5 billion in 1995–96; and then slowly increased to US$43 billion in 2009.[9]

Policies toward agricultural modernization did not achieve the objective of reaching most of the producers in the 1950–85 period. Limited financial resource availability, farmers' low schooling, and lack of legally regularized land ownership hampered a widespread adoption of technologies. As a consequence, rural credit was in certain terms not inclusive and benefited privileged farmers, mainly those coming from the South-Southeast regions (Contini et al., 2010).

Rural extension

In the 1950–70 period, policymakers placed a lot of emphasis on rural extension, and neglected efforts in research. Their hypothesis was that a vast array of technologies was already available for adoption. In the early 1970s, empirical evidence proved that this hypothesis was false. A virtuous cycle of tropical agricultural research was then considerably expanded and strengthened, and science-based technologies fuelled the extension service.

In this context, governmental agricultural credit was associated with public and private technical assistance. The idea was to strengthen human capital to utilize better the investments being made available for the acquisition of capital goods and modern inputs. The association of technical assistance with rural credit was compulsory until the 1990s, being paid by the farmer through a fee. In the 2000s this association was only mandatory for a few credit lines. Farmers who are well integrated into markets have been predominantly using private technical assistance.

Agricultural research

In the late 1960s, Brazilian policymakers realized that the strategy to increase food supply through the expansion of cultivated area and the adoption of practices of limited technological content should be revised. This perception prevailed in spite of the fact that more than half of the national territory remained untouched and could be occupied. However, the stock of agricultural technologies and empirical knowledge at that time indicated that the agricultural frontier – the "Brazilian Cerrado" – could, at best, accommodate only subsistence farming.

The government rejected the subsistence farming alternative and started a huge effort to transform traditional tropical agriculture toward one based on science and anchored on productivity gains instead of area expansion. The applied agricultural science unveiled the constraints imposed by the poor acid soils of the Cerrado. New crop varieties, adapted to low latitudes and to soil and climatic conditions of the tropics, and modern inputs were increasingly incorporated into novel production systems. The intensification of agricultural mechanization, particularly in grain production, was also an important part of the development of Brazilian agriculture.

In sum, the increase in agricultural production was to be achieved through the expansion of the cultivated area, increase in productivity or, more frequently, a combination of both. In the decades following the Second World War, food production in Brazil relied heavily on area expansion. However, from the mid-1970s onwards, and especially after the mid-1990s, gains in food production were mainly explained by productivity gains. The technologies developed by Embrapa, state agricultural research organizations, universities and other public and private partners (in Brazil and abroad), with the support of sectoral and more general public policies, and especially of farmers, have made it possible for Brazilian agriculture to be transformed and to present high-impact outcomes.

12.2.3 The Response of Agricultural Supply[10]

In the 1976–2011 period, grain and oilseeds area increased 32 percent whilst production increased 240 percent and yields increased 2.57 times (Table 12.1). Sugarcane production showed strong expansion between 1975/76 and 2009/10, from 89 million metric tons to 696 million metric tons. In the same period, sugar production increased 369 percent, from 6.72 million tons to 31.51 million tons. Total ethanol production (including both anhydrous and hydrated ethanol) grew from 0.60 billion liters in 1975/76, to 25.56 billion liters in 2009/10.

Similar trends were observed in the meat sector. Beef, pork and poultry production increased steadily from 4270000 metric tons in 1978, to

Table 12.1 Production, area and productivity annual growth rates in Brazilian agriculture, 1975–2010

	Rice	Maize	Beans	Soybeans	Wheat
Harvested area					
1975–2010	−2.38	0.38	−0.64	3.58	−1.63
1980–89	−0.97	1.72	1.35	3.35	5.08
1990–99	−3.25	−0.95	−3.04	2.66	−6.15
2000–10	−2.07	1.53	0.13	5.05	3.09
Production					
1975–2010	1.05	3.43	1.52	5.55	1.35
1980–89	2.98	2.98	1.13	4.16	14.76
1990–99	0.82	3.54	0.28	6.80	−2.09
2000–10	1.31	4.38	2.63	6.06	5.96
Productivity					
1975–2010	3.51	3.04	2.18	1.90	2.92
1980–89	3.99	1.24	−0.22	0.79	9.21
1990–99	4.20	4.53	3.43	4.04	4.32
2000–10	3.45	2.80	2.50	0.96	1.79

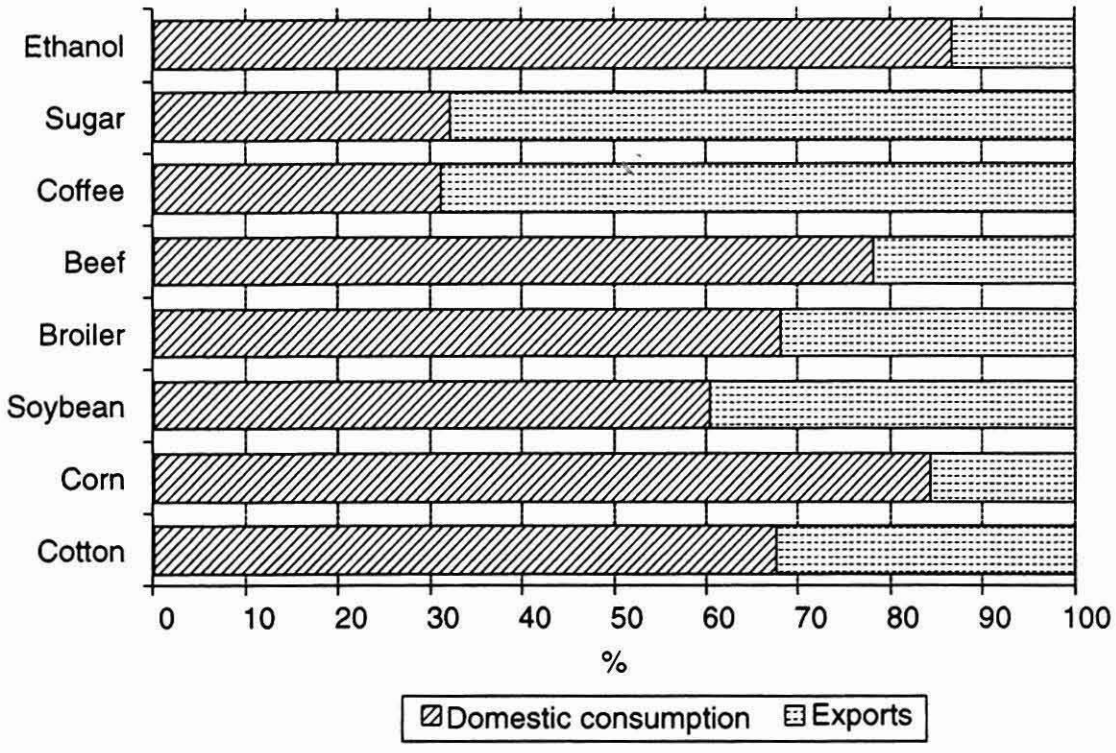
Source: Conab and IBGE's databases, elaborated by Contini et al. (2010).

25 496 000 metric tons in 2010/11. In the 1978–2011 period, poultry production increased from 1 096 000 tons to 12 928 000 tons (11.8 times), pork production increased from 1 060 000 tons to 3 384 000 tons (3.2 times), and beef production increased from 2 114 000 tons to 9 184 000 tons (4.3 times). In the 1978–2011 period, yearly growth rates registered for beef, poultry and pork were, respectively, 4.70 percent, 8.02 percent and 3.70 percent. Milk production also deserves to be highlighted, as production significantly increased from 11.16 billion liters in 1980, to 30.3 billion liters in 2009.

12.2.4 Agricultural Exports

Exports of agricultural products such as sugar, cotton and coffee have been historically important for Brazil's economy. In 1965, agribusiness exports accounted for 84.4 percent of total exports (Rodrigues, 2008). In 2010, exports totaled US$76 billion and represented 38 percent of exports. Current agribusiness exports reflect a higher participation of soybean, meat and sugar–ethanol complex products, as well as of the forestry sector (Agrostat-Brasil, 2011).

With the increased importance of Brazil in the international agricultural market, domestic food supply was not affected (Figure 12.1). Productivity



Source: MAPA (2010).

Figure 12.1 Domestic consumption and exports (2009), Brazil

will continue to be the main driver of food and feed production expansion. Production is expected to grow 2.88 percent per year, and productivity is projected to explain around 70 percent of the increased agricultural output. Cropland area is likely to increase by 9.3 million hectares (MAPA/AGE, 2010). This area, however, represents only 5.9 percent of the current pasture area in Brazil, clearly indicating that future land-saving effects arising from even small increases in pasture productivity can easily accommodate crops' demand for land (Martha and Vilela, 2009).

12.2.5 Total Factor Productivity in Brazilian Agriculture

The total factor productivity (TFP) of the Brazilian agriculture increased steadily and continuously in the 36 years of 1970–2006. Compared to 1970 (index 100), the TFP increased 124 percent, the product rose 243 percent and inputs grew 53 percent (Table 12.2). These figures reinforce the style of development of Brazilian agriculture, prioritizing productivity gains instead of land area expansion. Investments in research have been very important for these achievements. Gasques et al. (2009) estimated that a 1 percent increase in Embrapa's research expenditure increases the agricultural TFP by 0.2 percent.

In the last decade of this period (1995–2006), productivity indicators

Table 12.2 Product index, inputs index and TFP – Brazil

Years	Product index	Input index	Total factor productivity (100)
1970	100	100	100
1975	139	122	114
1980	173	142	122
1985	211	149	142
1996	244	137	178
2006	343	153	224

Source: Gasques et al. (2010).

Table 12.3 Growth rates for product index, inputs index, TFP, land productivity and labor productivity – Brazil

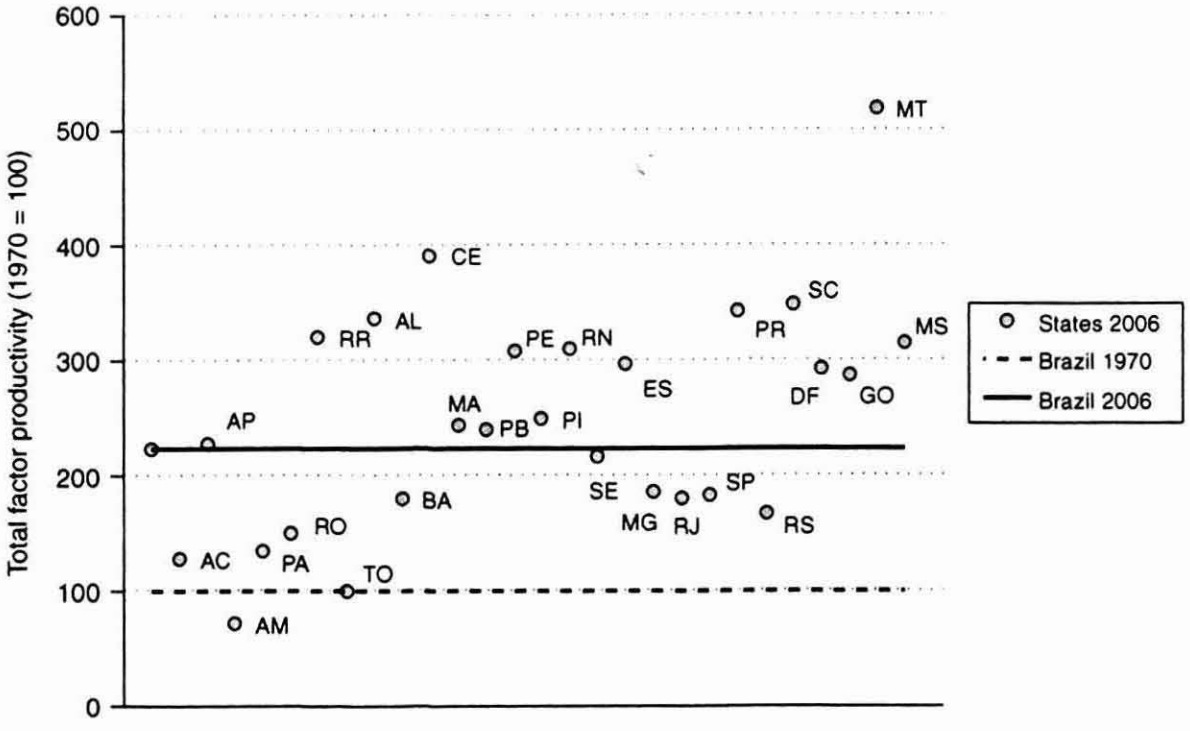
Specification	2006/1970	2006/1996
Product index	3.48	3.14
Input index	1.19	0.99
Total factor productivity	2.27	2.13
Land productivity	3.32	3.16
Labor productivity	3.53	3.40

Source: Gasques et al. (2010).

(TFP, land productivity and labor productivity) represented approximately 95 percent of the values registered in the 1970–2006 period. In comparison with the 36-year period, input and product indexes in the 1995–2006 period dropped to 83 percent and 90 percent, respectively (Table 12.3). Gains in productivity represented 65 percent of the agricultural output in the 1970–2006 period, while inputs explained 35 percent. In the decade to 2006, productivity was even more important and represented 68 percent of the production increase. The annual growth rate in the area theoretically worked per farmer (that is, labor productivity rate − land productivity rate; Table 12.3) was 0.21 percent from 1970–2006 and 0.24 percent in the decade to 2006. This slow increase indicates that there is great potential to increase agricultural mechanization in Brazil.

At the regional level, there is considerable variation in the TFP. Figure 12.2 shows that five out of seven states in the North showed lower TFP than the country average of 224 in 2006. Amazonas and Tocantins states raise concerns, because their TFP is close to Brazil's average in 1970.

Traditional agricultural states in the Southeast (SP, São Paulo; MG,



Notes: Index 100 was set in 1970, except for Mato Grosso do Sul (1975 = 100) and Tocantins (1985 = 100). North: AC – Acre, AP – Amapá, AM – Amazonas, PA – Pará, RO – Rondônia, RR – Roraima, TO – Tocantins; Northeast: AL – Alagoas, BA – Bahia, CE – Ceará, MA – Maranhão, PB – Paraíba, PE – Pernambuco, PI – Piauí, RN – Rio Grande do Norte, SE – Sergipe; Southeast: ES – Espírito Santo, MG – Minas Gerais, RJ – Rio de Janeiro, SP – São Paulo; South: Paraná, RS – Rio Grande do Sul, SC – Santa Catarina; Midwest: DF – Distrito Federal, GO – Goiás, MT – Mato Grosso, MS – Mato Grosso do Sul.

Source: Gasques et al. (2010) data, authors' elaboration.

Figure 12.2 Total factor productivity in Brazil (2006), by state

Minas Gerais) and in the South (RS, Rio Grande do Sul) had TFP below the Brazilian average in 2006, which might probably be explained by the initial higher baseline figures. The dynamic agricultural states in the Cerrado – namely Mato Grosso (MT), Mato Grosso do Sul (MS) and Goiás (GO) – expressed higher TFP than Brazil. Several states in the Northeast expressed higher TFP values than the national average in 2006 (Figure 12.2).

12.3 EMBRAPA[11]

Embrapa is a case of successful institutional innovation whose main characteristics are: a public corporation model of organization; scale of operation at the national level; spatial decentralization; specialized research units; enhanced training and remuneration of human resources; and a vision of an agriculture based on science and technology.

Embrapa's strategy thus considered the importance of a research portfolio capable of providing short-term deliverables while the (long-term) research with more significant outcomes was under way. Furthermore, it also gave special attention to the dissemination of existing results.

12.3.1 The Embrapa Model

Embrapa was created when conditions were favorable for its success. There was pressure to reform public research in agriculture, and the necessary understanding to move forward to accomplish this task; a typical case of induction of institutional reform, as provided by Hayami and Ruttan (1971).[12] To facilitate the interaction with farmers and society, the model chosen was decentralized in the territorial dimension and organized by priorities in the following order: product level, resources and themes. At a national level, the model requires strong interaction with decision-makers, at the level of the presidency of the Republic, Congress and ministries. In addition, Embrapa gave priority to transparency, to assessing the social and economic impact of its investments and, as previously indicated, gave special attention to the media.

The option to organize Embrapa as a public corporation was intended to release it from the bureaucratic rules used in the public administration, and thus give it the flexibility to administer resources and personnel, to plan, to assess performance, to implement the budget and to disseminate results in a transparent manner. Choosing CLT[13] gave Embrapa much more flexibility in the administration of personnel, construction of several careers – especially that of researcher – and in designing and implementing a personnel evaluation policy. As a public corporation, the relationship with the outside world and with the private initiative is much easier. Furthermore, the model allowed Embrapa to develop its own personality, which has characterized it at the national and at the international scenario as a unique example in the field of public research.

A concentrated and decentralized research model

In a country of continental dimensions, such as Brazil, it was soon realized that the success of Embrapa would depend on its size and on an accumulated critical mass of researchers, who should be diverse in talent and dispersed throughout the national territory.[14] It was also understood that Embrapa needed its own research network so that it could be directly responsible for its results, allowing it to be well known and evaluated on its own merits. Once it was large, diverse and decentralized,

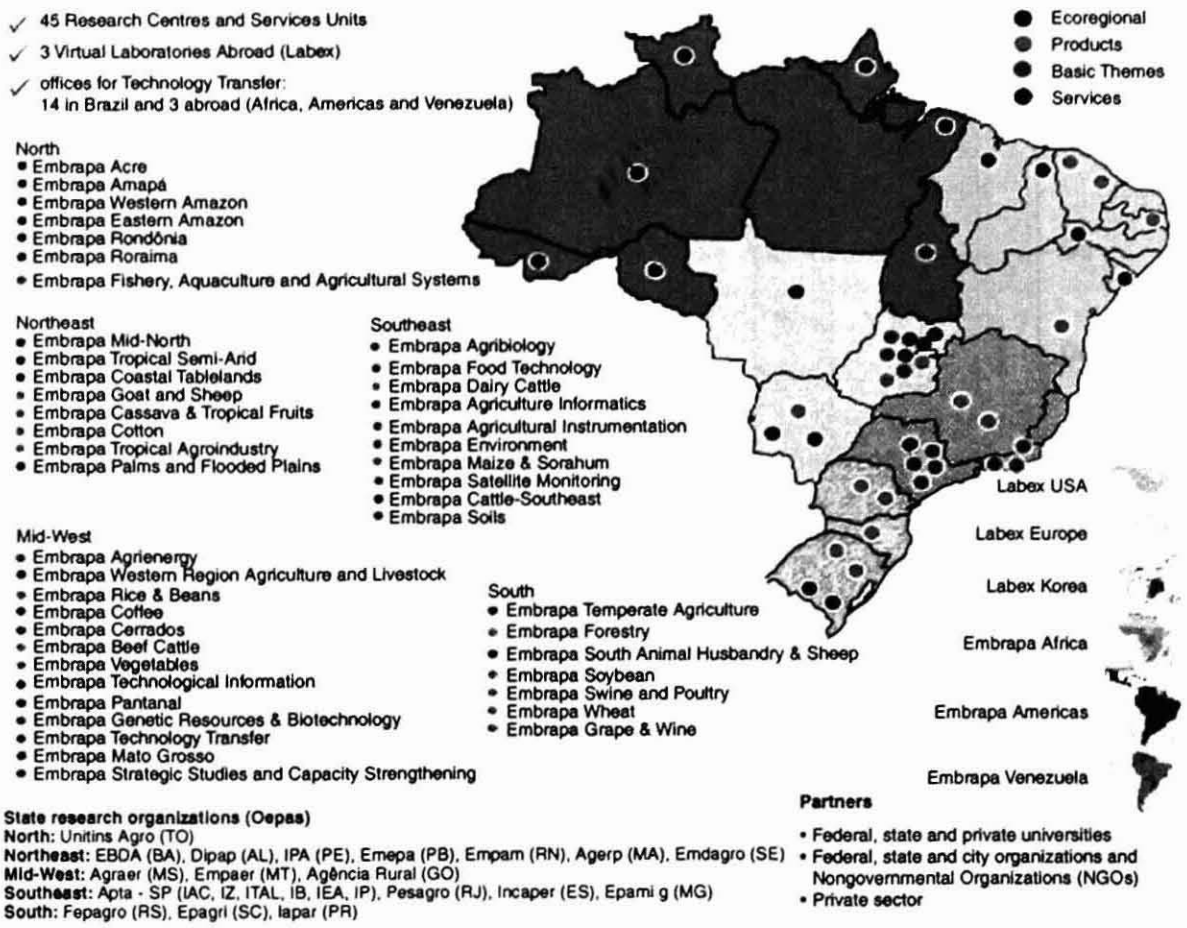
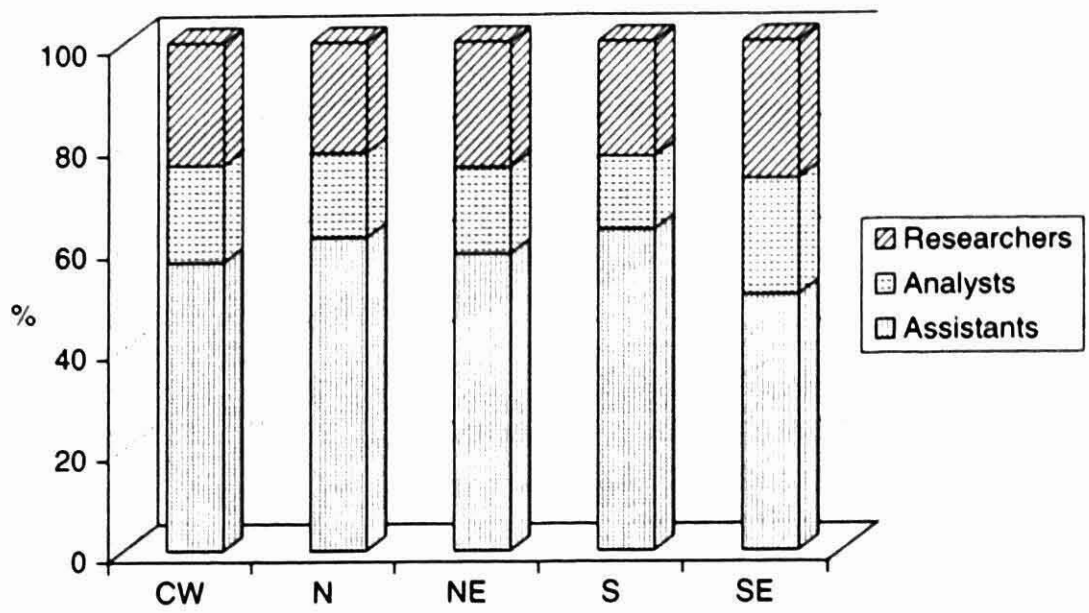


Figure 12.3 Embrapa Research Units in 2010. In 2011, a new Labex was open in China (courtesy of Embrapa's Secretariat for International Affairs)

Embrapa would have the ability to represent the federal government in an area as important as agriculture, and to receive priority both in the allocation of resources and with regard to institutional development (Figure 12.3).

This model also allowed Embrapa to seek cooperation with universities, research institutes, private sector companies and overseas partners, as equals. In the mid-1980s, states' responsibility in agricultural research and science generation at agricultural colleges was further strengthened through the creation of the National Agricultural Research System, under Embrapa's leadership.

Embrapa's inception was founded on two pillars: (1) a focused research model, concentrated on products and areas of fundamental importance for the development of the country, and which constitutes an objective way of identifying research priorities; and (2) human resource capacity building, based on strong training programs in centers of excellence around the world.



Note: CW – Center-West, N – North, NE – Northeast, S – South, SE – Southeast.

Source: Data courtesy of Embrapa's Financial Administration Department, authors' elaboration.

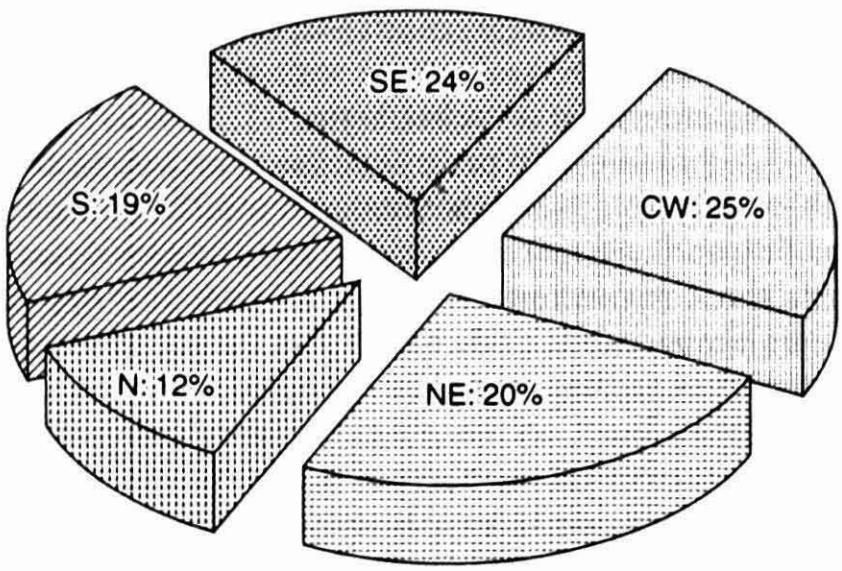
Figure 12.4 Distribution of Embrapa's employees according to categories (2009), by regions

Embrapa research units are thus distributed throughout the national territory and are specialized in products (maize and sorghum, dairy cattle, and so on), resources (*cerrado*, semi-arid, and so on) and themes (environment, satellite monitoring, and so on).[15] This structure allowed farmers and, more recently, the entire society to obtain objectively (and more efficiently) specific information and results for their demands. Similarly, researchers have a better notion of their responsibilities, minimizing ambiguities regarding goals and necessary actions.

Human resources

The human resources policy is one of the main reasons for Embrapa's success. From the beginning, Embrapa invested heavily in institution building. Across geographic regions, there is an approximately equal distribution among assistants (high school education), analysts (Bachelor's degree posts, a small percentage of which have a Master's degree, and only a few of which have PhDs) and researchers (Figure 12.4). The share of PhDs among researchers has been increasing rapidly, but the researchers in the Northern units lag behind (Figure 12.5).

The human capital policy at Embrapa, in brief, has been based on the following points:



Note: CW – Midwest, N – North, NE – Northeast, S – South, SE – Southeast.

Source: Data courtesy of Embrapa's Financial Administration Department, authors' elaboration.

Figure 12.5 Distribution of Embrapa's researchers with PhD (2009), by geographic regions

1. The establishment of a career that stimulates the desire to study and progress.
2. A competitive salary compared to universities and other research centers.
3. A retirement plan to supplement public social security.
4. A health insurance plan that helps researchers and their families with expenses in healthcare, preserving employees' health, which is the most important capital of the corporation.
5. A promotion system based on merit, ranging from the individual up to the research group/unit level. Thus, there are two products that Embrapa has to deliver: increasingly competent employees and technologies.
6. A training program at postgraduate and postdoctorate levels that meets the interests of the corporation and of researchers, and which seeks to train them at the same levels as the best centers abroad.
7. The corporation recognizes that the technology generated incorporates the effort of all of its employees. Thus, the training program is available for everyone; postgraduate training (MSc, PhD) focuses on researchers, but it is not exclusive to them.
8. Each research unit has a critical mass of researchers. They are organized around a specific target audience, a clear main problem to solve and according to the team's responsibility towards society.

9. Embrapa seeks to encourage researchers to be entrepreneurs in their field, to seek resources, to interact with the outside world and to ensure the dissemination of technologies.
10. Embrapa's communication program aims at providing accountability for work, actions to disseminate research results, giving the corporation visibility and transparency, and valuing its employers.
11. Although the corporation is always looking for opportunities to improve its human capital, one has to plan for the future and the principle of researcher replacement has prevailed.[16]
12. Ongoing efforts focus on keeping and developing "the Embrapa spirit" among the newest members of staff, firmly reinforcing the need not to overlook this point. An issue to some extent related to this one is that in research it is natural for seniority to develop over the course of time, solidifying leadership founded on knowledge and recognition among peers. An institutional goal is to find mechanisms to promote those who can work in teams, spread their knowledge, and to motivate other colleagues to cooperate comfortably in such a view.

International opening

Embrapa was open to international cooperation very early in its life, even when the external exposure of the Brazilian economy was still very small. This openness enabled it to: (1) create a positive image abroad, thus facilitating the relationship with donors, universities, and research organizations in other countries; this, in turn, was positively perceived by the federal government, which responded with increased support; (2) have an international dimension in terms of the quality of research and in measuring scientists' performance; (3) help Brazil, as an instrument of foreign policy; (4) understand that in a globalized world, science is also globalized and that it is crucial for its very existence to improve the mechanisms of interaction with other countries, universities, funding bodies, broader types of organizations and, of course, other scientists.

In addition, Embrapa, throughout its life, has kept a strong postgraduate program, sending researchers to several countries, the vast majority to the United States, and lesser numbers to the United Kingdom, Canada, Spain, the Netherlands, Germany and Australia. The good performance of students helped to form important relationship bridges with the academic world abroad. Moreover, projects financed by international agencies were important to equip Embrapa better and to help it finance training programs abroad. Because these activities were well implemented and conducted, they helped to solidify the image of Embrapa as a serious and responsible corporation.

Since the late 1990s, Embrapa has expanded its participation in international cooperative projects. In the late 1990s it created the Virtual Labs Abroad (Labex). The first Labex was established in the United States, through an agreement with the US Department of Agriculture's Agricultural Research Service (USDA-ARS), and then other initiatives were implemented in Montpellier, France (Labex Europe Headquarters), with offices in the Netherlands and in the United Kingdom, and more recently in South Korea and China. The Labex structure has allowed Embrapa to have senior scientists working together with foreign scientists, and also to seek to establish permanent cooperation links between the parties.

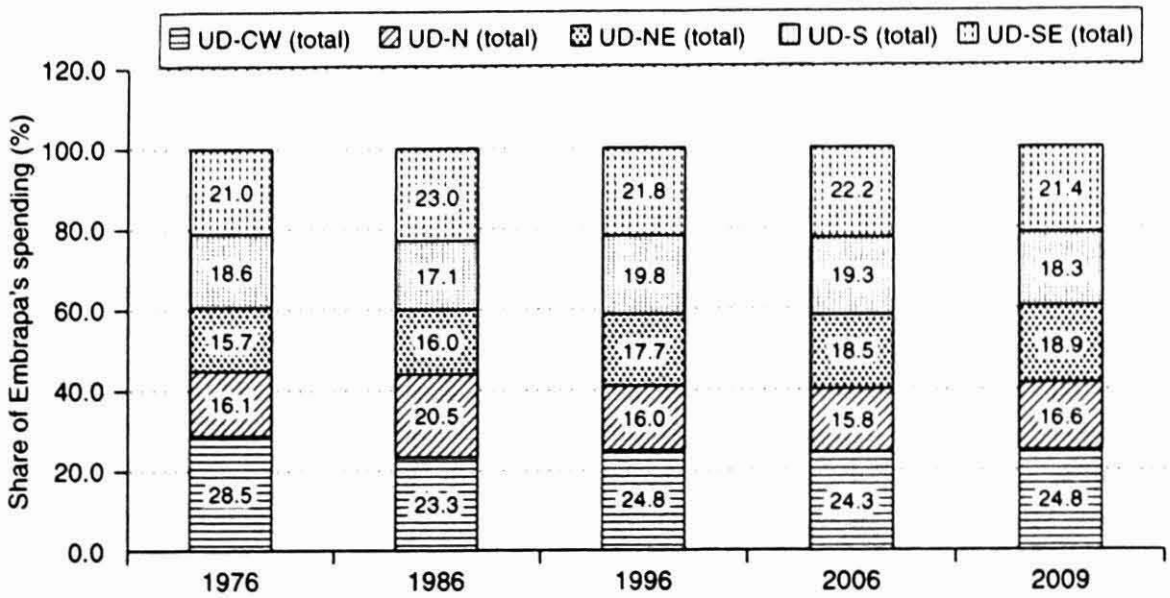
The success of Brazilian tropical agriculture motivates poor countries to seek information and support for technology transfer from Embrapa. Besides the traditional instruments of support, Embrapa decided to have researchers in less developed countries, creating Embrapa Africa, in Accra (Ghana);[17] Embrapa Venezuela, in Caracas; and Embrapa Americas, in Panama. The goal in this initiative is to transfer knowledge and technology in tropical agriculture and to look for opportunities in licensing Embrapa's technology.

Both the Labex model – cooperating in research programs with developed countries – and the structures for transferring technologies to developing countries are flexible models that can be expanded with new scientists or through occasional transfers of scientists among countries, according to the interests of Embrapa. The goal is both to benefit the development of sustainable and competitive agriculture in recipient countries, and to help them find sound solutions to improve food security for their people.

Brazilian government support

Total government spending for Embrapa grew rapidly in the period 1974–82, reaching a ceiling in 1982, and experiencing a fall between 1983 and 1984. It subsequently increased in the decade starting in 1985, peaking at 1996. Government support fell in the period 1997–2002, but this was greatly influenced by the macroeconomic adjustments of the Real Plan. In 2003, government spending on Embrapa resumed a growing trend, peaking in 2009. Payroll expenses typically represented 65–75 percent of Embrapa's total expenditure.

Embrapa's spending, in its earlier years, focused on the Midwest region (Figure 12.6). This was consistent with the need to incorporate the Brazilian Cerrado into the productive process. Huge investments were made in plant genetics and in improving resource use (soil, water) to allow for better production systems. Indeed, changing the production



Note: CW – Midwest, N – North, NE – Northeast, S – South, SE – Southeast.

Source: Courtesy of Embrapa's Financial Administration Department.

Figure 12.6 Share of Embrapa's total spending among geographic regions

environment for taking full advantage of the Cerrado's potential was perceived as a strategy to be explored in order to make the enterprise competitive with traditional production regions in the country. Consequently, an ever-increasing input use in grain-producing systems (improved seeds, fertilizers, pesticides, and so on) was observed.

Beef production in Brazil, for instance, is often criticized as a sector of low productivity that is viable as an economic alternative only through the expansion of pasture area. This is, however, a wrong view of the sector. Based on official statistics (IBGE), Martha et al. (2012) found that productivity improved from 10.1 kg/ha of carcass-weight equivalent in 1950, to 43.4 kg/ha of carcass-weight equivalent in 2006. Productivity gains explained 79 percent of the production growth rates in the 1950–2006 period, while pasture area expansion in the 1950–2006 period, which varied from 107.6 to 158.75 million hectares, was responsible for less than 21 percent of the production increase in the 1950–2006 period.[18] The observed land-saving effect arising from productivity gains in beef production in Brazil, of around 525 million hectares, was simply astonishing. Without this land-saving effect, an additional pasture area that is 25 percent larger than the Amazon biome in Brazil would be needed to meet the current levels of Brazilian beef production.

The significant investments of the Brazilian government on infrastructure and on development programs for the region (during the 1970s and

early 1980s), the availability of forage species adapted to the climate and soil conditions of the Cerrado, and the low-priced land, allowed cattle enterprises to be economically competitive despite their low productivity and economic output. These systems, which were also regarded as a capital reserve (because of cattle and land ownership, and due to the expectation of land valorization in the coming decades) ensured real economic gains to cattle farmers (Martha et al., 2007).

While the share in spending for the research units in the North, South and Southeast regions were more or less in balance from the 1970s to the 2000s, the money directed to Northeastern units as a share of total spending increased in recent years. The increased Embrapa spending effort in the Northeast is consistent with the fact that the region accounts for 47.4 percent of the farms and 47.1 percent of the rural population. The annual income per farm in the region (R$11 578.44) represents only 41 percent of Brazil's average (R$27 789.50), clearly indicating the need for greater assistance (Alves and Rocha, 2010). With the increasing importance of the environmental agenda, and considering that land-use changes, especially in the Amazon, are the main factor responsible for greenhouse gas emissions in Brazil, the spending share directed to research units in the North will eventually increase.

12.3.2 Pay-offs to Embrapa's Research

Varietal innovation played a key role in the development of the Brazilian Cerrado and, hence, in the history of Embrapa. Soybean production, by the 1960s, had been confined to the southern portion of the country, which has a temperate climate; given the research effort in genetic improvement in the following decades commissioned by Embrapa, universities, state agricultural research stations, private companies and international partners, it was possible for the crop to move north, to the border of the Amazon and Cerrado biomes, with average yields that were higher than those observed in the US and in Argentina. Simon and Garagorry (2005) found that latitudinal movement of the centroid of soybeans in Brazil moved from 26°S to 20°S between 1976 and 2001. Upland rice is another example of a breakthrough in varietal improvement in Brazil (Martha et al., 2006).

Whilst there is little doubt that the pay-offs to agricultural research and development (R&D) have been high (Alston et al., 1998; Pardey et al., 2006; Avila et al., 2010), much of the literature has been centered in varietal improvements. There is imprecise evidence regarding regional impacts of research and the impacts of an ample array of technologies. In part this reflects the difficulties in assigning adequate weights to benefits and costs among different agents involved in the process.

Pardey et al. (2006) presented a detailed study evaluating the impact of soybeans, dry beans and rice varietal improvement at Embrapa as compared to non-Embrapa investments. In the aggregate, varietal improvement in these crops from 1981 to 2003 yielded benefits of US$14.8 billion (1999 prices). Attributing all of the benefits to Embrapa, the benefit–cost ratio would be 27 for upland rice, 15 for dry beans and 149 for soybeans. Under alternative distribution rules, which indicate that Embrapa was given partial credit for the varieties developed jointly with other partners, the ratios would drop to 5, 3 and 31, respectively.

At the regional level, Embrapa assessed its impact from the 1970s to 1980s. While for Embrapa as a whole the registered internal rate of return ranged from 34 percent to 41 percent, the internal rates of return were comparatively smaller for the North (24 percent; Kitamura et al., 1989) and for the Northeast (25 percent; Santos et al., 1989), and were higher for the Midwest and Southern regions (both with 43 percent; Lanzer et al., 1989; Teixeira et al., 1990). In the 1990s, regional impact could be indirectly estimated through the research impacts in grain and oilseed varieties, because of regional distribution of these crops in the country. In the study of Evenson and Avila (1995), for example, the internal rates of returns for soybean, corn, rice and wheat were 40 percent, 58 percent, 37 percent and 40 percent, respectively.[19] These crops are mainly concentrated in the Center-South region.

12.4 AGRICULTURAL TECHNOLOGY AND SOME FUTURE DEMANDS

The role of agriculture in fostering development and as an effective tool to guarantee food and energy security requires a systemic approach, adequate investments and coordinated efforts – which are often carried out by agents that have conflicting opinions about a given matter – to find sound solutions for the different challenges in the economic, social and environmental dimensions (Mueller and Martha, 2008). In the coming decades, although food production will still be the main focus, the production process will bring forth additional issues. Brazilian and world societies are becoming increasingly concerned about other issues to be included in the "production function", such as environmental, food quality and safety issues.

A main future challenge for research, given the ample array of stakeholder pressure and funding possibilities, is clearly and objectively identifying the sequence of relevant problems that shall be solved by research in order to increase welfare in society. Classifying research deliverables

according to results, and eventually incorporating computable externalities, could be an interesting method (Antle and Wagonet, 1995; Alves, 2008). Of course, in this view, it is important to consider the need to advance continuously in a sustainable agricultural growth path.

It must be noted, however, that no concise, universally acceptable definition of sustainable agriculture has yet emerged. However, it is well accepted that technical, economic, social and environmental sustainability dimensions should be pursued (Cunha et al., 1994). Sustainability dimensions have strong interdependence linkages and, ideally, should be met simultaneously. In other words, focusing on a single dimension, such as the economic or environmental, will not reflect the multiple dimensions of sustainability. Rather than this limited view, agricultural production systems, and thus agricultural research, should design strategies that create win–win situations, that is, simultaneous gains in all sustainability dimensions. When this ideal condition is not an option, small loss, big gain situations should be targeted. And in this view, sometimes one dimension, such as the economic, must be favored at the expense of a second, such as the environmental dimension, and vice versa; that is, under certain circumstances the environmental dimension shall be favored over the economic (Martha et al., 2010b).

It seems inevitable that a science-based era will be strengthened in the future. The research response in terms of technology generation will be strong. In the example of sustainability, the development and/or adaptation of resource-saving (for example, land-, water- and nutrient-saving) technologies will be prioritized. Regional characteristics will obviously be a matter of concern. Because of high agro-ecological and social heterogeneity in Brazil, locally specific approaches will have to be designed, which will thus require an in-depth review of the R&D agenda goals.

Embrapa is an institution with the ambition of persisting for a long time into the future, serving Brazilian and world societies. In this sense, it will be prepared for the unknown and, thus, it will invest heavily in human capital, and probably more than necessary to accomplish immediate needs (Alves, 2008).

In spite of the highly favorable economic result, the investments made in agricultural research are large and it takes a long time to repay them: usually 15–20 years depending on the technology. A relevant question is how to promote a continuous stream of institutional innovation capable of sustaining a virtuous R&D and innovation cycle in agriculture. Furthermore, as knowledge advances, it is necessary to integrate diverse datasets which, when jointly analyzed, will provide important input for different disciplines as well as for research planning and policy analysis (Antle and Wagonet, 1995).

Finally, the partnership between public and private research can help to increase investments in research, thus expanding the universe of knowledge and technologies available to farmers. This partnership might additionally be interesting to society when the pragmatism of private research helps public research to contribute more objectively to meeting society's demands (Alves, 2008).

NOTES

1. Mariana Medeiros (Embrapa Studies and Training) provided insightful comments on an earlier draft, and Renner Marra (Embrapa Strategic Management Secretariat) helped in data collection.
2. Using historical data on food prices from Dieese (Inter-Union Department of Statistics and Socio-Economic Studies), concerning a food basket for the city of São Paulo, it was found that the price of this food basket in April 2010 represented, in real terms, around 53 percent of the price paid by consumers in January 1975. In 35 years, the food price to consumers decreased by half, greatly reflecting the expansion of agricultural production in Brazil. Even when the food price peaked in 2008 it had a very small impact on the prices paid by consumers (Martha et al., 2010a).
3. Barros (2006) estimated that, in the decade that followed the Real Plan, this transfer might have exceeded R$1 trillion. According to Barros, income transfer from the rural area to consumers seems to have stabilized at around R$150 billion annually.
4. Estimates by the Brazilian Confederation of Agriculture and Livestock for 2008 (Medeiros et al., 2005) indicated that Brazilian agribusiness employs 17.7 million people (37 percent of the national jobs). USP/CEPEA (2011), in turn, found that agribusiness contributed US$497.6 billion to the country's 2010 gross domestic product (GDP) (25.2 percent of the total). In 2010, Brazilian agribusiness exports amounted US$76.4 billion, representing 37.9 percent of total Brazilian exports (Agrostat-Brasil, 2011).
5. For additional details see Baer (2008) and Contini et al. (2010).
6. The increased opportunity cost of labor for the farmers and the massive rural exodus scenario led to a favorable environment for agriculture growth and modernization.
7. According to the Instituto Brasileiro de Geografia e Estatística (IBGE) (2010), the Brazilian population in 1960 was 70 million people, of which 45 percent were considered urban. In 1980 the population had increased to 119 million and 68 percent were urban. In the period 1960–1980, the gross domestic product (GDP) had an impressive yearly growth rate of 7.54 percent, which caused the demand for food, especially by those that positively responded to income increase (especially the poor), to increase even more.
8. Exchange rate R$1.75/US$1.00.
9. Data from the Brazilian Central Bank (Bacen). Values were deflated to 2009 prices using FGV (Getulio Vargas Foundation) IGP-DI. The figures do not include rural credit for family agriculture – PRONAF (the Programa Nacional de Fortalecimento da Agricultura Familiar, or Program for Strengthening Family Agriculture) – which received increased resources after the late 1980s and especially in the 2004–11 period. It is important to note that in spite of this increase in rural credit, Brazilian agriculture receives minor incentives for production. An index that reflects the amount of incentives in the sector, the producer support estimate (PSE) calculated for Brazil by the OECD, revealed a net transfer of resources from agriculture to other sectors in the economy until the late 1990s. Between 1995 and 2007, the average PSE for Brazilian agriculture was 3.25 percent of the gross value of production. This amount is substantially less than those estimated for the US (16.62 percent) and the OECD countries (29.81 percent) in the same period.

10. Discussion based on Conab database.
11. This section benefited greatly from a previous paper by Alves (2010). See, additionally, Embrapa (2006).
12. The theory of induced innovation emphasizes the interaction of farmers with researchers; this interaction indicates the priorities for research within public research institutions. For private research institutions, the market acts directly, otherwise the technology developed would not find buyers. In public research, the market influence is indirect. It creates, among farmers, demand for a certain type of technology, for example land-saving technologies, and in response to that demand farmers indicate their needs to researchers, who respond with the adaptation and/or generation of technologies that increase land productivity (Alves, 2010).
13. CLT (Consolidação das Leis do Trabalho) allowed the hiring of personnel using laws governing the private sector instead of civil service laws.
14. This presence of Embrapa throughout the national territory was important in order to attract the sympathy of the state governments and the National Congress. Embrapa has a marked presence in the Federal District and this proximity of power has played an important role in establishing and solidifying the image of the corporation near the central power and also the international market (Alves, 2010).
15. Regarding the distribution of Embrapa's research units, 23 percent are in the Southeast, 25 percent are in the Midwest, 17 percent are in the North, 17 percent are in the Northeast and 18 percent are in the South.
16. In Embrapa's case, the goal is to maintain an average of 45 years of age for PhD holders, imagining the following guideline: on average, researchers should finish their PhDs at around the age of 30, which would leave them with a horizon of around 30 years of productive work. Half of this is 15. So, 15 years should be added to 30, comprising 45 years. Thus, on average, a young researcher has 15 years of work alongside senior researchers. A complementary strategy would be the creation of conditions that would allow for competent and outstanding retiring researchers to continue doing work with Embrapa. However, there is much to be done in this regard.
17. In past decades, Embrapa's activity in Africa has focused on specific cooperation projects for technology transfer on specific products, at the request of the governments concerned. Recently, Embrapa has increasingly offered training courses for professionals from African countries in its research centers, with funding from the Brazilian government (ABC – Agência Brasileira de Cooperação (Brazilian Cooperation Agency)), international agencies or foreign governments. To meet such growing demand, Embrapa has restructured its international cooperation and has created a frame for "structuring projects" (which have more resources and last longer), aiming at better results. In late 2010, Embrapa had a total of 38 projects that were either being implemented or were under final negotiations with 16 African countries. Total resources amounted to US$16.2 million, out of which nearly US$9 million were from the Brazilian government.
18. Beef production systems, in turn, were heavily based on pasture area expansion until 1975, while productivity gains became the main channel of growth from 1985 onwards; the expansion of the cultivated pasture area mainly with *Brachiaria*, was key to the success of the Brazilian beef industry (Martha et al., 2012).
19. For an additional discussion on impact assessment, please see Avila and Souza (2002).

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