AGRICULTURAL R&D IN BRAZIL

Policy, Investments, and Institutional Profile

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The International Food Policy Research Institute was established in 1975 to identify and analyze alternative national and international strategies and policies for meeting food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and on the poorer groups in those countries. While the research effort is geared to the precise objective of contributing to the reduction of hunger and malnutrition, the factors involved are many and wide-ranging, requiring analysis of underlying processes and extending beyond a narrowly defined food sector. The Institute's research program reflects worldwide collaboration with governments and private and public institutions interested in increasing food production and improving the equity of its distribution. Research results are disseminated to policymakers, opinion formers, administrators, policy analysts, researchers, and others concerned with national and international food and agricultural policy. IFPRI is member of the Consultative Group on International Agricultural Research (CGIAR).

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The Brazilian Agricultural Research Corporation's mission is to provide feasible solutions for the sustainable development of the Brazilian agribusiness by generating, adapting and transferring knowledge and technology that benefits the Brazilian Society. From the very beginning, on April 26, 1973, Embrapa has generated and recommended more than nine thousand technologies for Brazilian agriculture, reduced production costs and helped Brazil to increase the offer of food while, at the same time, conserving natural resources and the environment and diminishing external dependence on technologies, basic products and genetic materials. Networking through 37 research units, 3 services and 15 central units, Embrapa is present in almost all the states of the Union, each with its own ecological conditions.

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Established in 1998, the Regional Fund for Agricultural Technology is a consortium to promote strategic agricultural research of relevance for the Latin American and Caribbean Region, with direct participation of the countries of the region in priority setting and funding of research projects. FONTAGRO's purpose is to promote the agricultural sector's increase in competitiveness while protecting natural resources and reducing poverty in the region, through the generation of agricultural technologies with international public goods characteristics, and by facilitating the exchange of scientific knowledge among research organizations within the region, as well as with other regions. FONTAGRO's financial resources are basically the contributions of the member countries to an endowment fund, whose income finances regional and strategic research projects on a non-reimbursable basis. Research projects are developed and implemented by national research organizations (research institutes, universities, NGOs, and private organizations) and international and regional research centers working in association with national research entities. Projects are selected on a competitive basis, in accordance with the objectives of the Fund and its priority research areas defined in the Medium Term Plan, and evaluated by economic, technical, institutional, and environmental criteria established in the Fund's Manual of Operations.

ABSTRACT

In 1996, Brazil employed more than 5,000 full-time equivalent researchers and spent more than $1 billion (1993 international dollars) on agricultural R&D; about one half of the total agricultural research spending throughout Latin America in that year.

Most of the research spending is done by public agencies; 79 percent by federal and state organizations and 15 percent by higher education agencies. Embrapa, a corporation established by the federal government in 1972, is still the country's dominant research agency, accounting for 57 percent of total spending in 1996 (slightly higher than its spending share of two decades earlier).

The intensity with which Brazil invests in agricultural research is high by Latin American standards and becoming comparable with the intensities found in some developed countries. In 1996, Brazil invested $1.70 for every $100 of agricultural GDP. Since 1976, financial support for agricultural R&D has generally trended upwards. However, since the mid 1990s Embrapa's funding has been significantly curtailed—partly due to a reduction in nominal funding and partly due to the effects of inflation—along with funding for many of the state research agencies, resulting in several closures and merges with state extension agencies.

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ACRONYMS*

ACIAR	Australian Centre for International Agricultural Research
AgGDP	Agricultural Gross Domestic Product
AGROMAIS	Taxa Voluntária de Desenvolvimento Tecnológico (Voluntary Tax for Technology Development)
APTA	Agência Paulista de Tecnologia dos Agronegócios (São Paulo Agency for Agribusiness Technology)
CAN	Conselho Assessor Nacional (National Advisory Council)
CEPEC	Centro de Pesquisa do Cacau (Research Center for Cacao)
CEPLAC	Comissão Executiva do Plano da Lavoura Cacaueira (Executive Commission for Cocoa)
CNEPA	Centro Nacional de Ensino e Pesquisas Agronómicas (National Center of Agricultural Training and Research)
CONSEPA	Conselho Nacional dos Sistemas Estaduais de Pesquisa Agropecuária (Council of State Organizations for Agricultural Research)
COODETEC	Cooperativa Central Agropecuária de Desenvolvimento Tecnológico e Econômico Ltda (Central Agricultural Cooperative for Technology Development and Economics)
COPERSUCAR	Cooperative dos Produtores de Cana, Açúcar e Alcool do Estado de São Paulo Ltda (Cooperative for Sugarcane, Sugar, and Alcohol Producers of the State of São Paulo)
CPA	Coordenadoria da Pesquisa Agropecuária (Agricultural Research Coordinating Unit)
DPEA	Departamento de Pesquisas e Experimentação Agropecuária (Department of Agricultural Research and Experimentation)
DNPEA	Departamento Nacional de Pesquisa Agropecuária (National Agricultural Research Department)
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
EPE	Escritório de Pesquisa e Experimentação (Research and Experimental Office)
ESALQ	Escuela Superior de Agricultural "Luiz de Queiroz" (Higher School of Agriculture "Luiz de Queiroz")
FTE	Full-time equivalent
FAPESP	Fundação de Amparo à Pesquisa do Estado de São Paulo (State of São Paulo Research Support Foundation)
FINEP	Financiadora de Estudos e Projetos (Financing Agency for Studies and Projects)
FUNCAFE	Fundo de Defesa da Economia Cafeeira (Fund for Protection of the Coffee Economy)
FUNDACEP	Fundação Centro de Experimentação e Pesquisa Fecotrigo (Foundation Center for Wheat Experimentation and Research)
FUNDAG	Fundação de Apoio à Pesquisa Agrícola (Foundation for Agricultural Research Support)
FUNDECITRUS	Fundo de Defesa da Citricultura (Fund for the Citrus Plant Protection)
FUNDEPAG	Fundação de Desenvolvimento da Pesquisa Agropecuária (Foundation for Agricultural Development and Research)

* List includes general acronyms used in the text only; for an overview of all Brazilian agricultural R&D agencies, including their acronyms, see Appendix Table B.1.

ACRONYMS (continued)

GDP	Gross Domestic Product
IAC	Instituto Agronômico de Campinas (Agronomic Institute of Campinas)
IB	Instituto Biológico (Biology Institute)
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute for the Environment and Renewable Natural Resources)
IDB	Inter-American Development Bank
IEA	Instituto de Economia Agrícola (Agricultural Economics Institute)
IFPRI	International Food Policy Research Institute
IIBA	Imperial Instituto Baiano de Agricultura (Imperial Agricultural Institute of Bahia)
IIFA	Imperial Instituto Fluminense de Agricultura (Imperial Agricultural Institute of Rio de Janeiro)
INIA	Instituto Nacional de Investigación Agropecuaria (National Agricultural Research Institute)
INPA	Instituto Nacional de Pesquisa da Amazônia (National Research Institute of the Amazon)
IPA	Instituto Pernambucano de Pesquisa Agropecuária (Agricultural Research Institute for the State of Pernambuco)
IRGA	Instituto Rio-Grandense do Arroz (Rio Grande Rice Research Institute)
ITAL	Instituto de Tecnologia de Alimentos (Food Technology Institute)
IP	Instituto de Pesca (Fisheries Institute)
IZ	Instituto de Zootecnia (Zootechnical Institute)
MAA	Ministério da Agricultura e do Abastecimento (Ministry of Agriculture and Food Supply)
MMA	Ministério do Meio Ambiente (Ministry of Environment)
PEPA	Programa Especial de Pesquisa Agropecuária (Special Program of Agricultural Research)
PPP	Purchasing power parity
PROCENSUL	Projeto Fortalecimento da Pesquisa e Difusão de Tecnologia na Região Centro-Sul (Project for Strengthening Research and Technology Transfer in the Center-South Region)
PRODETAB	Projeto de Apoio ao Desenvolvimento de Tecnologia Agropecuária para o Brasil (Agricultural Technology Development Project)
PROMOAGRO	Programa de Madoernização Tecnológica da Agropecuária da Região Centro-Sul do Brazil (Program for Modernization of Agricultural Technology in the Center-South Region of Brazil)
PRONAF	Programa Nacional de Fortalecimento da Agricultura Familiar (National Program of the Strengthening of Family Agriculture)
R&D	Research and development
SNPA	Servico Nacional de Pesquisas Agronômicas (National Service for Agronomic Research)
S&T	Science and technology
SSE	Secretaria de Apoio aos Sistemas Estaduais (Secretariat for Support to the State Systems)
UFIR	Unidade Fiscal de Referência (Fiscal Reference Unit)
USAID	United States Agency for International Development

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1. INTRODUCTION

Brazil is a large country in many respects. It is the world's fifth-largest country in land area, has the ninth-largest gross domestic product (GDP), and accounts for about half of the total public agricultural research and development (R&D) investments in Latin America (Pardey and Beintema 2001). Size alone means developments in Brazilian agricultural R&D are of consequence for Latin America, and the developing world more generally.

Central to agricultural R&D in Brazil is the Brazilian Agricultural Research Corporation (Embrapa), created in 1972. In addition, Brazil has a large number of state government research agencies and numerous faculties and schools of agriculture, plus

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some nonprofit agencies, a growing number of for-profit private enterprises, and various multinational companies conducting agricultural research in Brazil.

By way of background, Brazil had a total population of 166 million in 1998, accounting for half of South America's total population. Like many of its neighboring countries, Brazil's economy grew briskly during the 1970s and early 1980s, followed by a series of economic crises including bouts of hyperinflation, shrinking levels of output, and increasing rates of unemployment. During 1986–94, there were five attempts by the government to stabilize the Brazilian economy, including four major devaluations of the currency in 1986, 1989, 1993, and 1994.[1] The currency unit *real* was introduced with the final devaluation in 1994. For a couple of years thereafter inflation rates declined and the economy strengthened, but during 1996–99, it once again fell into crisis, and appears to have recovered only slightly since then (EIU 1998 and 2001). Agriculture's share of total GDP fell from 25 percent in 1950, to 13 percent in 1980, and 8 percent in 1990, remaining fairly constant since then and even appearing to have increased slightly in conjunction with a set of trade liberalization policies. In 1998, 18 percent of the labor force worked in the agricultural sector (FAO 2000 and World Bank 2000). Traditionally the Brazilian government has pursued import-substituting industrialization policies despite the country's abundance of natural resources and comparative advantages in agricultural and wood products. Following the trade liberalizing policy reforms introduced during the early 1990s, production and productivity in crop and livestock products have increased substantially (EIU 1998). Brazil is a significant exporter of

[1] In addition, the Brazilian currency was renamed in 1990 (from new cruzado to cruzeiro) without being devalued.

several agricultural products. In 1998, close to one third of the country's total value of exports came from primary products (excluding minerals). The main agricultural export commodities were soybeans, coffee, and sugarcane, which accounted for 30, 16 and 12 percent of total primary export revenues (again excluding minerals). Brazil is the largest coffee producer in the world and the second-largest producer of soybeans (following the United States) and sugarcane (following India). Soybean production increased substantially in recent years, replacing production of other food crops such as beans, rice, and cottonseed (EIU 1998 and IBGE 1999a).

In this paper we outline key historical developments then provide a more detailed review of recent policy and institutional changes regarding agricultural research in Brazil. We support this review with new quantitative indicators of agricultural R&D that draws directly from a comprehensive survey undertaken by the International Food Policy Research Institute (IFPRI) and Embrapa between 1997 and 2000.

2. POLICY AND INSTITUTIONAL DEVELOPMENTS

2.1 HISTORICAL PERSPECTIVES

Federal Agricultural R&D before the 1970s[2]

Formalized forms of agricultural research began in Brazil in the mid 1800s, although the Botanical Garden of Rio de Janeiro, established in 1808, conducted some research in the first half of the century. During this period, Brazil's predominant

[2] This section draws largely on Schuh (1970), Rodrigues (1987a, b, and c), and Macêdo (1997). Other references used in specific parts of this section are cited in the text.

agricultural products were export crops such as coffee and sugarcane—products that were central to the country's economy. The production of these crops was heavily dependent on slave labor, but slave trade was prohibited in 1850.[3] Fearing serious labor shortages, many landowners pressured the government to help modernize the agriculture sector and offset the lost labor with new tools and production methods. As a result, in 1859-60 the Emperor approved the establishment of five Imperial Research Institutes in the provinces of Bahia, Rio de Janeiro, Pernambuco, Rio Grande do Sul, and Sergipe.[4] The first two were the only ones to commence operations; an estate was acquired in Pernambuco for the third, but research activities were never initiated there; and the last two were never in fact established. The two institutes that were successful, the Imperial Agricultural Institute in Rio de Janeiro (IIFA) and in Bahia (IIBA), focused mainly on sugarcane and coffee, and were organized along the lines of the generally successful "European Model."[5] IIFA undertook both research and extension activities.

Following the establishment of IIBA, its director sought to expand the institute's operations and requested the creation of the Agricultural School of Bahia, which was established in 1877. During its first few decades, IIBA played an important role through its research results and policy advice to the Ministry of Agriculture. IIBA was transferred to the state government of Bahia in 1904, and a few years later was incorporated into the newly created Agricultural Institute. The state claimed it had insufficient resources to

[3] Slavery was officially abolished in 1888.

[4] Brazil gained independence from the Portuguese in 1822 and two Emperors ruled until 1889, when the country became a republic (Skidmore and Smith 1997).

[5] Many European countries created experiment stations or institutes in the first half of the nineteenth century. The institutes generally had a specific thematic or commodity mandate and were organized into various research departments with a separate administrative unit. Grantham (1984) provides a good description of the evolution of agricultural research institutes in Europe in the nineteenth century.

maintain both the institute and the School of Agriculture, so responsibility for the institute was transferred to the federal government in 1919. Seven years later what was left of the institute was transferred back to the state government.

By the end of the nineteenth century, the principal location for coffee production had moved from the state of Rio de Janeiro to São Paulo, which became the most important state for the Brazilian economy at that time. Under pressure from coffee farmers, the government established the Imperial Agronomic Station of Campinas in 1887. The station was a federal institute for only a few years, then transferred to the state government of São Paulo in 1891 and renamed the Agronomic Institute of Campinas (IAC), which still exists today.[6]

The creation of the Republic of Brazil in 1889 had substantial, and generally negative consequences for the country's agricultural sector and its research institutes (with the exception of IAC). The Ministry of Agricultural Trade—established in 1860—was downgraded to a directorate within the Ministry of Trade in 1892. The Imperial Agricultural Institutes were either closed or had their activities severely curtailed, a situation that continued until the early 1900s. The National Society of Agriculture was established in 1897 to assume some of the duties of the former Ministry of Agriculture, but research and experimentation were only conducted during a very short period from 1902 to 1908. Although the Society undertook little research, it played an important role in the eventual reestablishment of the federal Ministry of Agriculture in 1909.

[6] IAC was an exception in the developing world as most (if not all) of the other research centers that were created during this same time were established by colonial powers.

In the 1920s, several research institutes were established and coordinated by the ministry. Among these (with establishment dates shown in parentheses) were the Campos Experiment Station (1910), the Escada Experiment Station (1911), the Barbacena Experiment Station (1912), the Bento Gonçalves Experiment Station (1913), the Cotton Experiment Station (1913), the Chemistry Institute (1918), and the Agricultural Protection Biology Institute (1920).[7] All of these research stations were situated in the richer states, and focused on export crops like coffee and sugarcane. During 1920–21, in an effort to diversify its research, the Ministry was reorganized into four specialized service units for cotton, seed, grape, and forestry research. Notwithstanding these changes, the research conducted by these new service units continued to emphasize traditional export crops.

World economic crisis in the 1930s and the collapse of coffee prices accelerated the shifting emphasis of the Brazilian economy from agriculture to industry. Many agricultural workers migrated to urban areas to find work in factories. This exodus also had an impact on the type of research conducted. Initially the agricultural sector consisted predominantly of plantations, and research focused on expanding production of those plantations. With increasing scarcity of agricultural labor and an increasing demand for food crops to feed a growing urban population, agricultural research increasingly sought to improve labor productivity and shifted its emphasis away from traditional export crops. The government's policy bias toward industrialization also led to a reduction in resources available for agriculture – especially for agricultural research. The resultant

[7] The Chemistry Institute was closed in 1936; the Agricultural Protection Biology Institute was closed in 1938, and from it the Institute for Agricultural Experimentation was created.

decline in agricultural research was exacerbated by the diminished opportunities for international trade during World War II, however, most of the institutes survived this period.

The Ministry of Agriculture underwent several rounds of restructuring in the 1930s reflecting the broader changes in the economy and society. A short-lived Scientific General Directorate was created in 1933, which barely a year later was replaced by three national departments for crops, animals, and minerals. Some research institutes were closed and others were relocated to different ministries.

Following the creation of the "New State" in 1937,[8] the Ministry created the National Center of Agricultural Training and Research (CNEPA), formed by merging the National Agronomy School and some of the research institutes in an effort to link research and teaching more closely along the lines of the rapidly expanding land-grant college system in the United States. CNEPA was restructured in 1943, and its training component was separated to form the Rural University of Brazil. CNEPA's experimental research entities were consolidated into one agency, the National Service for Agronomic Research (SNPA). SNPA consisted of three central units and a network of experiment stations grouped into five regions (each having three to eight experiment stations). Most of SNPA's facilities were located initially in the southeastern region, but the system slowly began to spread to other regions as well.

In 1962 the Ministry was reorganized, and SNPA and the National Animal Production Department were merged to form the Department of Agricultural Research

[8] A new constitution was established through military invention, characterized by fascism akin to Hitler's Germany and Mussolini's Italy (Skidmore and Smith 1997).

and Experiment (DPEA). DPEA consisted of a general directorate, six central units, and six regional institutes (the five regional centers under SNPA were reorganized into six new regions: north, northeast, east, central-west, central-south, and south). Rodrigues (1987c) reports that DPEA's overarching objectives were to enhance food production and generate additional foreign revenue as a consequence of its research.

A military government was formed in 1964, leading to a reorganization of the federal administration in 1967. DPEA was renamed the Research and Experimental Office (EPE) and its headquarters was moved from Rio de Janeiro to the newly built capital, Brasilia. In addition, several new central units were established along with three new regional institutes in the west, meridian, and western Amazon, increasing the total number of regional institutes to nine. A national network of 75 experiment stations supported these nine institutes. The office was renamed the National Agricultural Research and Experiment Department (DNPEA) in 1971, and some additional central units were created.

The military regime focused on attracting foreign capital and promoting exports, which meant that the agricultural sector needed to become more competitive internationally. This stimulated a move to modernize agriculture, including a comprehensive restructuring of the Brazilian agricultural R&D system. With this change came a substantial increase in resources for agricultural research.

In 1972, DNPEA suggested the creation of a Special Program of Agricultural Research (PEPA). The primary focus of PEPA was to improve the technological capacity of DNPEA and other agricultural research institutes by training their researchers to the postgraduate level. Another aspect of the program was to conduct research projects on

commodities and areas considered priorities for national development. This strategy formed the basis for the agricultural research model that was developed over the next two years.

Embrapa's Establishment and Development

In 1972, the Minister of Agriculture appointed a special committee to evaluate DNPEA. The committee's final report outlined both the positive and negative aspects of DNPEA with the negative far outweighing the positive. The main pluses reported were an extensive network of research institutes covering the main agricultural commodities and regions, a workable infrastructure, and some successes in scientific terms. The main negatives reported were the researchers' lack of awareness of the basic needs of agriculture; the lack of intradepartmental and external interaction among researchers, extension workers, and farmers (which had led to instances of unproductive duplication of research efforts); the lack of incentives for researchers (particularly indicated by low salaries); the low level of postgraduate training (12 percent the scientific staff at the time); and, finally, the insufficient, and often irregular, financial resources available.

The committee also evaluated the various institutional models that could be implemented in Brazil, and the model of a public corporation was preferred. In December 1972, Congress ratified the creation of Embrapa, which commenced operation in April 1973 (Alves 1981 and Homem de Melo 1986).

Embrapa assumed DNPEA's research institutes, experiment stations, and existing projects. During its first period (1973–79) Embrapa's board focused on areas of national priority, namely applied research, undertaken in national commodity centers and regional

centers throughout the country. This was intended to complement the more basic research conducted by the universities, and a network of state-level agricultural research institutes responsible for state priorities (Alves 1992). During the same period a substantial training program was established with funding from the Brazilian government through new loans from the World Bank and IDB. Large number of Embrapa researchers—those previously employed at DNPEA along with new personnel—were sent to universities in Brazil and abroad for postgraduate training.

During the 1970s and early 1980s, funding for Embrapa increased markedly and the agency achieved significant research results, but beginning in the mid 1980s the government suffered a series of financial crises, with the result that most public institutes experienced severe budget cuts to the point of threatening their ability to operate. Embrapa's performance was also beginning to be questioned as the corporation had received substantial public funding over the years, but definitive returns on these investments to the Brazilian economy were hard to pinpoint. As a reaction to these criticisms, Embrapa and some of the state institutes prepared a number of socioeconomic impact studies to demonstrate the benefits from investment in agricultural research (Cruz et al. 1982, Avila et al. 1983, Avila and Ayres 1987, and Barbosa et al. 1988).

In 1990, a new board of directors initiated a reorganization process with the intent of developing a new institutional model. The stated objective was to refocus the agency's research priorities toward the perceived needs of Embrapa's clients and end users (Silva and Flores 1993). In addition, multidisciplinary and inter-institutional research projects were established. Some aspects of the administrative management of the institute were decentralized giving the research centers more freedom on matters of budget and resource

allocation matters, but human resource policies and practices as well as decisions about major capital and maintenance expenditures continued to be made centrally. At the conclusion of this reorganization process, Embrapa as a whole, as well as each research center, had prepared a strategic plan (called a Director Plan) that consisted of a clear statement of each center's mission, objectives, human resource and infrastructure needs, and priorities for a five-year period beginning in 1993.

With the change of federal government in 1995, Embrapa had a complete change of its board of directors.[9] This new board introduced a set of management and institutional directives, the principal ones being:

- Center directors to be chosen through a national selection process rather than by the federal government
- Develop and adopt a new, results-based system of evaluation and awards (both for each center within Embrapa and all scientific and support staff)
- Adopt a new management information system
- Define a new and integrated set of policies for communication, R&D, and technology transfer
- Establish new rules for intellectual property rights
- Establish of a modern, satellite-based communications system for the Embrapa units
- Devolve assets and reduce of fixed costs
- Strengthen international R&D presence involving collaboration with international centers and national agricultural research agencies in developed countries
- Establish an aggressive policy of updating, training, redeploying, and generally renewing the agency's staff.

[9] At this time, Embrapa was also designated the coordinating body for Brazil's entire public agricultural research, but in reality its role in this regard has been limited and predominantly supportive.

State Agricultural Research[10]

In 1887, IAC became Brazil's first state institute when its funding and management were transferred to the São Paulo state government after an initial three years within the federal system. During its first decades, IAC's research focused on improving upon the varieties of coffee used widely in the state. With reorganization in 1927 came greater emphasis on basic research such as genetics and entomology. Although coffee remained the main priority, research was initiated on other crops such as maize, edible beans, wheat, and rice.

In 1927, the state government also created the Biology Institute (IB) to address plant and animal protection concerns. In 1934 the São Paulo University was founded. One year later IAC and IB were transferred to this university, but IAC was able to maintain its administrative autonomy and influence on the state's agricultural sector. During the period 1927–42 IAC had a demonstrably positive impact on the state's agricultural sector. As a result of the broader changes in the economy and society (see previous section), the Secretariat of Agriculture of São Paulo was significantly reorganized in 1944. The secretariat was divided into three departments, separating research and extension activities (previously responsibilities of IAC). IAC was renamed the Experimentation and Research Division and lost, among other things, direct contact with its users, as this responsibility was given to the Development Division. Along with these changes came pressure for IAC to produce direct, short-term research results, which undercut its long-term research program eventually sending the institute into crisis.

[10] The historical developments in São Paulo state described in this section draw largely on de Albuquerque et al. (1986a and b) and information gathered in surveys.

Following World War II, IAC's situation improved marginally by strengthening its links with agricultural input firms. Things improved markedly after the mid 1960s when state agencies in São Paulo were generally strengthened.

During the 1960s four additional state agricultural R&D agencies were established in São Paulo:

- In 1960 the Division of Fisheries and the Protection of Forestry and Animal Production became the Fisheries Institute (IP)
- In 1968 the Agricultural Economic Institute (IEA) was established from the Economic Rural Division that was created ten years earlier
- In 1969, the Food Technology Institute (ITAL) began operating as IAC's Division of Soils, Agricultural Machinery, and Technology, which later became a Laboratory of Agricultural Technology
- The Department of Animal Production (created in 1942) was reorganized to form the Zootechnical Institute (IZ) in 1970.

During the 1960s, agricultural research in most other states was insignificant; exceptions were Rio Grande do Sul and Pernambuco. The Secretariat of Agriculture in Rio Grande do Sul supported 11 experiment stations and a research program associated with the Rio Grande Rice Research Institute (IRGA). IRGA was established in 1939. The Institute of Agricultural Research (IPA) in Pernambuco, created in 1935, was well funded by the state government and developed a strong research program combined with relatively highly trained staff (Schuh 1970).[11]

The early 1970s were difficult years for IAC. Many staff left the institute largely because of dissatisfaction with low and declining salaries. In an effort to improve the effectiveness of the state's research institutes, in 1974 the government of São Paulo

[11] Most research staff in state agencies were trained to the BSc level, but in 1966 IPA had 10 researchers trained to the MSc level and a few with PhD's (Schuh 1970).

sought to privatize them. However, there was significant opposition to this development, and with a change of government in 1975 the decision was reversed.

During the 1970s and continuing into the 1980s, Embrapa stimulated the creation of state corporations for agricultural research based on its own (semipublic) model, which allowed greater flexibility of management practices. This resulted in a new SNPA with one research agency for each state (other than the Northern states and Piauí, where Embrapa remained the only agency responsible for agricultural research). Only São Paulo and Rio Grande do Sul maintained the traditional, "European" model with institutes having a specific thematic or commodity focus. During this period Embrapa provided considerable financial and technical support to all the state agencies.

During the late 1980s and early 1990s, state support for agricultural research declined substantially. The federal government reduced the amount of funding it channeled through Embrapa to the state institutes in response to changes in 1988 to the constitution that gave the states and municipal districts an increased share of federal tax revenues. Most states suffered from financial crises and poor management (Alves 1992), and the return to democracy in 1986 politicized many of the state governments in ways that negatively impacted agricultural research agencies. This was especially severe in the Northeast, the poorest region of the country (Alves 1992). In recent years, the agricultural research agencies in the northeastern states of Ceará, and Maranhão were closed. Research agencies in various other states specifically Bahia, Espírito Santo, Goiás, Mato Grosso, Mato Grosso do Sul, Santa Catarina, and Sergipe) were merged with the state extension agencies.

Higher Education Agencies[12]

In contrast with Spain, Portugal did not allow the creation of higher education agencies in its colonies; Brazilians who wanted to embark on university training went abroad, often studying at the Portuguese University of Coimbra. During the nineteenth century, following independence, a few professional schools of law, medicine, and engineering commenced and in the early twentieth century the first universities were established, such as the University of the Amazonas. In 1931 legislation was approved for the creation of universities. During the 1930s an attempt to create a university in Rio de Janeiro failed, but the establishment of the University of São Paulo succeeded. A number of tertiary schools were created—often by the states—during the 1940s and 1950s. Soon after they were incorporated into various federal universities, but continued to operate largely as separate entities lacking postgraduate studies and research programs. Further, only a very small percentage of the faculty had postgraduate degrees. The number of students enrolled at federal universities increased during the 1950s, reflecting a growing demand for higher education. Many private universities were created during the 1960s to help meet this demand.

The first agricultural school was the School of Agriculture at Bahia, which was established by the Emperor of Brazil in 1877, but was transferred to the state government of Bahia in 1904. In 1968 the school was eventually incorporated into the Federal University of Bahia and still exists in that form. The second higher school of agriculture in Brazil ("Eliseu Macedo") was established in 1883 and commenced its activities in

[12] This section draws largely on Schuh (1970) and de Mello e Souza (1991). Other references used in specific parts of this section are cited in the text.

1890 in the city of Pelotas, Rio Grande do Sul. The Faculty of Agronomy of the Federal University of Rio Grande do Sul in Porto Alegre was established in 1899 (ABEAS 1997). The higher school of agriculture "Luis de Queiroz" located in Piracicaba, São Paulo, began operating in 1901 and for many years was the only school to carry out a significant program of research (ABEAS 1997). In 1960, Brazil had twelve higher schools of agriculture and eight veterinary schools, but none undertook much research.

In 1963 an intensive collaboration began between four Brazilian and four U.S. universities, financially supported by the U.S. Agency for International Development (USAID).[13] This program ended in 1973, but the following year a second USAID program began, initially focusing on extension at the Federal University of Viçosa. One of the objectives of the program was to upgrade the quality of Brazilian university staff (which often involved postgraduate level training abroad, mainly in the United States); another was to develop postgraduate training programs at a number of Brazilian universities (Sanders et al. 1989).

Other Historical Developments

In 1946 the Executive Commission for Cocoa (CEPLAC) was created, making it the first statutory organization to focus on a single product. CEPLAC initially concentrated its activities on the state of Bahia, but was soon expanded to other parts of

[13] These four Brazilian universities and their counterpart American universities were the Federal University of Ceará with the University of Arizona, the Federal University of Viçosa with Purdue University, the Higher School of Agriculture "Luiz de Queiroz" (ESALQ) of the University of São Paulo with Ohio State University, and the Federal University of Rio Grande do Sul with the University of Wisconsin (Sanders et al. 1989).

the country appropriate for cocoa production, such as the Amazon. CEPLAC was a nonprofit organization, funded mainly through a tax on cocoa exports. It was controlled by the Banco of Brazil, but the cocoa producer organization exerted a strong influence. In 1990 CEPLAC, having experienced management problems, was placed under the Ministry of Agriculture thereby losing most of its administrative independence (Alves 1992).

In 1959 the sugarcane producers of São Paulo established the Cooperative for Sugarcane, Sugar, and Alcohol Producers of the State of São Paulo (COPERSUCAR). A decade later COPERSUCAR established a small research laboratory, but it wasn't until 1979 that research activities really began. In the late 1980s the sugarcane industry was in crisis causing COPERSUCAR's total number of research staff to drop by 50 percent, and three of its seven experimental stations to be closed.

Research by the private sector was insignificant prior to the mid 1940s. In 1945 Sementes Agroceres was created to produce hybrid maize seed, but over the years the company diversified its operations. Examples are sorghum research, begun in 1970, and vegetable research, begun in 1991. Sementes Agroceres became the dominant Brazilian seed company and built strong links with multinational enterprises as well as with Brazilian universities, the latter through research contracts (Echeverría et al. 1996). Monsanto—which recently became part of Pharmacia—acquired Sementes Agroceres in 1996 having already acquired the Brazilian national company FT Sementes, the year prior.[14] FT Sementes sold soybeans seeds and conducted soybean research. In 1998

[14] Agroceres' activities in veterinary areas were not sold to Monsanto.

Monsanto acquired two more companies—Braskalb, which was part of the multinational DeKalb and conducted maize and sorghum research, and Cargill's international seed operations that included Cargill's activities in Brazil (Monsanto 2000). Most, but not all, of the other national and multinational private companies initiated their research activities in the 1970s.

2.2 CONTEMPORARY DEVELOPMENTS

The organization of agricultural R&D in Brazil is complex partly because of its size and the number of agencies involved, and partly because of the involvement of both federal and state governments. Embrapa continues to be the central agency and falls under the administration of the Ministry of Agriculture and Food Supply (MAA).[15] Embrapa was created as a "corporation," largely unencumbered by the customary government regulations in the hope of increasing its flexibility in terms of funding mechanisms and management practices. However, its semi-autonomous status has eroded over time, and funding from general government revenues continues to predominate. Embrapa conducts applied research and currently consists of 15 central units, two service units, and 37 research centers located throughout the country. The research centers are grouped as 13 ecoregional, 15 commodity, and nine thematic centers.[16] Around half the centers consist of just a headquarters facility, while others also have between one and five

[15] For statistical purposes, agricultural R&D agencies are often grouped into three major institutional categories: government agencies, business-sector agencies, and higher education agencies (see appendix A and OECD 1994). Embrapa is considered a government agency under this classification.

[16] Embrapa has no research centers in five of Brazil's 26 states, namely Alagoas, Maranhão, Mato Grosso, Rio Grande do Norte, and Tocantins.

experiment stations. CPATU is the exception with 14 experiment stations.[17] Embrapa has 16 research and three development programs (see Appendix C) along with elaborate priority-setting, planning, and implementation processes. In 1999, Embrapa had partnerships with more than 200 national and international agencies, among these around 40 Brazilian universities (Reifschneider et al. n.d. and Embrapa 1999a).

Embrapa is governed by a board of trustees, consisting of six members: two representatives each from the government and the private sector, the president of Embrapa, and the vice-minister of MAA. Representatives from the private sector are chosen by the MAA from a group of nominees developed from a national call for candidates. To implement the decisions of the board of trustees, Embrapa has an executive board of directors, consisting of a director-president and three executive directors, who are appointed following the recommendations from MAA.

Embrapa centers have limited autonomy, with most decisions, such as human resource policies and practices as well as decisions about major capital and maintenance expenditures, made at the national level by the executive board of directors with input from the National Advisory Council (CAN) which includes representatives from the federal government, private sector, state agencies, national research council, and various other agencies. The allocation of funds for specific research and institutional development projects is determined by national technical committees; one for each research program. Each center submits project proposals for evaluation to a relevant national committee. A center's annual research budget is based on an assessment of the

[17] For complete names and additional information about the Embrapa centers, see Appendix Table B.1.

operational funds required to support approved project proposals, total salary costs, and projected capital investments and maintenance costs.

Two other federal agencies are involved in agricultural R&D.[18] The first agency, also under the administrative responsibility of MAA, is CEPLAC, which oversees the Research Center for Cacao (CEPEC). In 1996, CEPEC's 89 researchers focused predominantly on cocoa, but also conducted research on other crops such as oilpalm, tropical fruits, and pastures, as well as on livestock and natural resources. CEPEC consists of a headquarters in the state of Bahia and has 11 experiment stations (CEPEC 1999). The second agency, the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA), falls under the Ministry of Environment (MMA) and conducts research on fisheries, forestry, natural resources, and environmental research. IBAMA has five fisheries research and extension centers, and five forestry fauna management centers in various regions of Brazil (IBAMA 2000).

Presently, there are state government agricultural research agencies operating in 16 of the 26 states.[19] Six states in the northern region (Pará, Amazonas, Acre, Rondônia, Roraima, and Amapá) as well as Piauí in the northeastern region have no local institutes, foundations, or private firms engaged in agricultural research. In Ceará and Maranhão, the state agencies were closed in 1998/99. In the state of Tocantins agricultural research is conducted at the Faculty of Agronomy of the University of Tocantins.

[18] A fourth federal agency, the National Research Institute of the Amazon (INPA), which falls under the responsibility of the Ministry of Science and Technology, also conducts some agriculturally related research, but as these activities are small and difficult to separate from the institute's nonagricultural research activities, INPA is excluded from further consideration here.

[19] See Appendix Table B.1 for acronyms, names, research focus, and number of researchers of all state and other agricultural R&D agencies in Brazil in 1996, and Appendix Table B.2 for an overview of specific developments within the state agencies.

All 16 states have a single state government research agency, with the exception of São Paulo, which has six, including IAC, the oldest and most important state agricultural research agency in the country. Each of these six agencies in São Paulo has a distinct mandate. IAC focuses on agronomic research while the other five agencies conduct research on agricultural economics, food technology, zootechnics, bio-sanitation, and fisheries, respectively. They each have their own network of experiment stations across the state. In 2000, these six São Paulo agencies employed a combined total of 675 researchers in 64 experiment stations and 43 research laboratories (APTA 2000). The general directors of the institutes are appointed by the State Secretary of Agriculture and Food Supply. As a result, the institutes have been (and continued to be) influenced by political changes and decisions at the state-level, which have not always been beneficial. This has also been a problem in many of the agricultural research agencies in other states (Albuquerque and Salles-Filho 1997).

São Paulo's agricultural R&D agencies are currently being reorganized. In May 2000, Agricultural Research Coordinating Unit (CPA) was renamed the São Paulo Agency for Agribusiness Technology (APTA). Plans also exist to make APTA an autonomous agency, with a degree of independence from the state government that will increase its flexibility to change management practices and attract private funding. APTA is also negotiating with the state government to transfer ownership of the institutes' land and infrastructure from the state to the institutes. Currently the institutes hold large tracts of land and have vacant buildings that could be sold to generate resources for research. The system will be organized regionally rather than along distinct lines of research, in addition to the six institutes, a network of 11 regional centers will be established, each

responsible for four to five experiment stations. The intent of these proposed changes is to improve collaboration among the research centers—often lacking with the current set up—thereby making better use of increasingly scarce financial and human resources (IAC 2000).

In the 1990s the Council of State Organizations for Agricultural Research (CONSEPA) was created by the state agencies to facilitate research integration and to discuss themes of common interest. CONSEPA consists of the presidents of the boards or general directors of all state agencies involved with agricultural research. Embrapa has a standing invitation to participate when the council meets, and typically presents an overview report on projects and other initiatives developed with one or more state agencies.

The future of the state agricultural research agencies is unclear: presently only a few agencies have sufficient resources for effective research. Several agencies were merged with their respective state agricultural extension agency and appear to focus more on extension than on research. Further, state governments are becoming less willing to fund the state institutes as they feel that agricultural research is primarily the federal government's responsibility via Embrapa. As mentioned, the agricultural research agencies in the states of Ceará and Maranhão were closed in 1998/99. The agricultural research and extension agency in Goiás was also insolvent and in 1999 was combined with the institutes for land reform and sanitary control and various other state rural institutions into one agency. The agricultural research agency in Alagoas is also insolvent, but cannot be closed because funding is lacking to reconcile its existing debt (Albuquerque 2000).

Embrapa is assisting the state agencies in developing new institutional arrangements in an effort to overcome their financial and operational difficulties. Embrapa also provides technical support, through its Secretariat for Support to State Systems (SSE), which assists the state agencies in training staff and in developing projects. SSE works closely with CONSEPA (Embrapa-SSE 1998). Technical support is also given by other institutions—contracted by Embrapa—such as the University of Campinas (Albuquerque and Salles-Filho 1997).

Brazil has a substantial number of universities with over 100 faculties or schools of agricultural sciences that conduct research. Most of these are federal and state universities; only a few of the private universities offer training, and consequently research, in the agricultural sciences (Alves 1992).

We identified five Brazilian nonprofit institutions engaged in agricultural research in the late 1990s.[20] COPERSUCAR is a cooperative of 36 sugar mills located in São Paulo and has a technical center that conducts sugarcane breeding and postharvest research as well as technology transfer activities. COPERSUCAR's technical center consists of a headquarters and four experiment stations; three in São Paulo and one in Bahia. Technical assistance is also provided to sugar mills that are not part of the cooperative. The royalties and service fees received through these activities account for about one third of the center's total budget. COPERSUCAR is one of the world's leading sugarcane research agencies, including its research on genetically modified sugarcane varieties. The Fund for Citrus Plant Protection (FUNDECITRUS) was established in

[20] See appendix A for an explanation of the institutional classifications used in this paper.

1977 to monitor citrus health and to finance research on pest and disease control methods. FUNDECITRUS is financed by a tax on citrus production.[21] It funds citrus research projects conducted by various Brazilian agencies, but also conducts its own research at its Citrus Research Center (created in 1994) in collaboration with various national and international agricultural organizations (FUNDECITRUS 2001). The Rio Grande Rice Research Institute (IRGA) mainly conducts rice research, but also does some maize, sorghum, and soybean research. The institute is attached to the Secretariat of Agriculture and Food of the state of Rio Grande do Sul, but operates quite autonomously and receives almost all its funding from a tax on rice production.[22] IRGA's headquarters is located in Porto Alegre and it has five experiment stations throughout Rio Grande do Sul. Two other nonprofit institutions that conduct agricultural research are the Foundation Center for Wheat Experimentation and Research (FUNDACEP) and the Central Agricultural Cooperative for Technology Development and Economics (COODETEC), which are linked to and financed by producer organizations in Rio Grande do Sul and Paraná, respectively. Both these agencies conduct research on corn, wheat, and soybeans; COODETEC also conducts cotton research.

Brazil has an active and growing private sector providing technologies and technical services concerned mainly with farm inputs (including agri-chemicals, animal feeds and breeding services, fertilizers, seeds, veterinary medicines, and machinery) and

[21] The tax is two cents per box of citrus produced; one cent paid by producers the other cent by industrial buyers (Portugal et al. 1999).

[22] IRGA is funded via a producer tax, equivalent to 18.83 percent of the current Fiscal Reference Unit (UFIR)—a national financial index used primarily by the tax office to index tax payments. In 2000, the UFIR was 1.0641 reais, such that the tax payment was 0.1883 x 1.0641 for each 50 kilograms of rice (IRGA 2001).

food processing. There is little specific information to be had on the local research underpinning these technologies, but the impression we gleaned from qualitative responses to our surveys and various other sources is that many of the technologies represent spill-ins to Brazil from research done elsewhere.[23] Some of the national seed companies do conduct some research in Brazil, much of which involves local testing and screening of improved germplasm developed elsewhere. Since the mid 1990s, a considerable number of these national seed companies (and especially those marketing corn and soybeans) have been taken over by multinational corporations. For example, Sementes Agroceres, Braskalb (the Brazilian operations of DeKalb), Cargill's local seed operations, and FT Sementes were all acquired by Monsanto (itself recently becoming part of Pharmacia). As a result, in 1998/9, Monsanto accounted for 63 percent of the Brazilian seed corn market, various other foreign firms had 22 percent, and the remaining 15 percent was supplied by Brazilian seed companies (which includes Unimilho, an association of local private firms that adapt and market seeds based on material supplied by Embrapa) (Filho and Garcia 2000). Other noteworthy firms are Souza Cruz (part of British-American Tobacco), which has five experiment stations mainly engaged in breeding new tobacco varieties, as does Profigen, a U.S. company. Agristar along with SVS do Brasil (the Brazilian branch of the Mexican firm Seminis, which includes Asgrow, Horticeres, Petoseed and Royal Sluis) develop a range of improved vegetable varieties.

[23] Roseboom (1999) reached a similar conclusion in a separate study of the sources of Brazil agricultural technologies.

Appendix Table B.1 includes information on firms for whom it was possible to obtain some data on the size of the local research effort. Appendix Table B.3 includes firms that supply technologies to Brazilian agriculture, but for whom the extent of the local research effort (if any) could not be confirmed. The tabulation includes several national companies engaged in veterinary medicine research. Tortuga has four experiment stations located in the state of São Paulo and focuses on animal health, while Agroceres-Pic and Agroceres-Ross (the residual parts of Agroceres following the sale of its seed-related activities to Monsanto) focus on poultry, swine, and animal nutrition research. RJR Nabisco and Perdigão seem to conduct some food processing research in Brazil.

National Science and Technology Policy Developments

In 1996 Brazil's Science and Technology (S&T) expenditures totaled 9.5 billion reais, the local currency, with R&D expenditures accounting for 62 percent of this total (5.5 billion reais)—considerably higher than its 1990 share of 47 percent (MCT 1999).[24] Nearly 60 percent of these R&D expenditures were provided by the government, but when measured on a by-performer basis, the government accounted for only 11 percent of total R&D expenditures (Table 1). Higher education agencies financed only 3 percent of total Brazilian R&D expenditures, but performed 44 percent of total research. Private firms accounted for roughly equal shares of total funding and expenditures by performer (46 and 40 percent respectively). In 1996, the higher education sector employed three-

[24] The remaining S&T expenditures are for scientific and technical education, training, and services.

quarters of total Brazilian researchers while 17 percent worked for the government and only 8 percent for private firms.

Table 1— *Share of Total R&D Expenditures by Institutional Classification, 1996*

Institutional Classification	Total Expenditures		Research Staff by Performer
	By Performer	By Funding Source	
	(*percentage*)		
Government	11.0	57.2	17.1
Private enterprises	45.5	40.0	7.8
Higher education agencies	43.5	2.8	75.2

Source: RICYT (2000).

In 1996, Brazil's total R&D expenditures were about 0.75 percent of total GDP. This was somewhat higher than the corresponding research intensity for Chile (0.63 percent in 1996) and roughly double the intensity ratios for Argentina (0.38 percent) and Mexico (0.31 percent) (MCT 1999). While Brazil's overall research intensity is high by Latin American standards it is still quite low compared with developed countries like the United States (2.55 percent in 1996) and Germany (2.26 percent) (National Science Board 1998).

3. FUNDING SOURCES AND MECHANISMS

Embrapa is primarily funded by the federal government, and the state agencies receive the majority of their funding from state governments (Table 2). The two nonprofit institutions in our sample are IRGA and FUNDACEP. IRGA is primarily funded through a commodity

tax paid by rice producers, while FUNDACEP is funded through revenues from product sales (as is COODETEC for which quantitative details on funding sources were not available).

Table 2—*Funding Sources, 1986, 1991–96, and 1999*

	Government Agencies						Nonprofit Institutions	
	Embrapa[a]				State			
	1986	1991–95	1996	1999	1991–95	1996	1991–95	1996
				(*number*)				
Number of agencies in sample	1				11[b]		2[c]	
Sources of funds				*(million 1996 reais per year)*				
Government	287.0	445.8	498.0	401.3	114.7	106.4	–	–
Donor contributions	29.1	22.3	47.6	7.3	–	–	0.0	0.0
Taxes/funds	–	–	–	3.6	–	–	1.9	2.8
Research contracts	3.3	2.3	14.5	1.6	6.5	13.8	0.1	0.2
Sales	47.3	35.8	53.0	28.0	9.4	10.7	1.6	1.3
Other	–	–	–	–	0.0	0.0	0.1	0.1
Total	*366.7*	*506.1*	*613.2*	*441.9*	*130.5*	*130.8*	*3.7*	*4.4*
				(million 1993 international dollars per year)				
Government	294.6	457.7	511.3	412.0	117.8	109.2	–	–
Donor contributions	29.9	22.9	48.9	7.5	–	–	0.0	0.0
Taxes/funds	–	–	–	3.7	–	–	2.0	2.9
Research contracts	3.4	2.3	14.9	1.7	6.6	14.1	0.1	0.2
Sales	48.5	36.7	54.4	28.7	9.6	10.9	1.6	1.3
Other	–	–	–	–	0.0	0.0	0.1	0.1
Total	*376.4*	*519.6*	*629.6*	*453.6*	*134.0*	*134.3*	*3.8*	*4.5*
Shares				(*percentage*)				
Government	78.3	88.1	81.2	90.8	87.9	81.3	–	–
Donor contributions	7.9	4.4	7.8	1.7	–	–	0.9	0.3
Taxes/funds	–	–	–	0.8	–	–	52.0	64.9
Research contracts	0.9	0.4	2.4	0.4	5.0	10.5	3.0	3.6
Sales	12.9	7.1	8.6	6.3	7.2	8.1	42.5	28.6
Other	–	–	–	–	0.0	0.0	1.6	2.7
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

Source: Compiled by authors from IFPRI/Embrapa survey. Embrapa data from Embrapa-DAF (1999).

Note: No data were available for the other institutional categories.

a. Embrapa funding data exclude "indirect funds" such as grants to fund non-Embrapa temporary researchers, payments for publications and events by third parties, and donations.

b. Included in the sample are EMAPA, EMCAPA, EMEPA, EMPAER-MS, EMPARN, EPAGRI, EPAMIG, IAC, IAPAR, ITAL, and PESAGRO.

c. Included in the sample are FUNDACEP and IRGA.

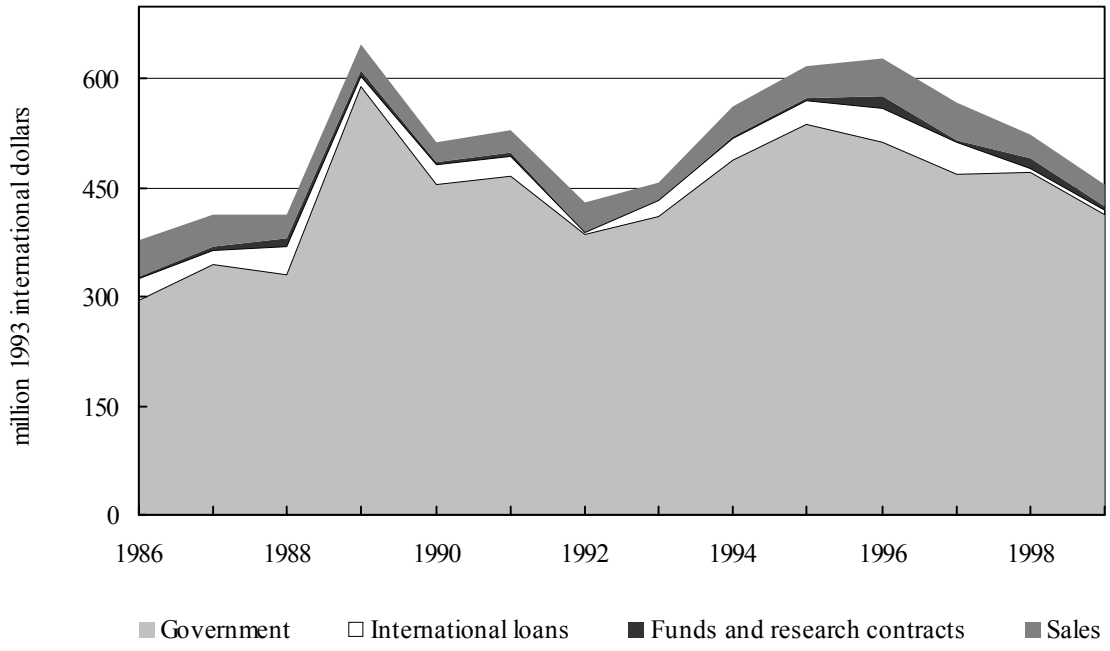
Figure 1 shows the changing amounts and sources of Embrapa's funding since 1986. In nominal terms, total funding for Embrapa has trended up overall from 1986 to 1996 but with some marked fluctuations. In more recent years, however, total funding has declined: In 1999, Embrapa's total funding was $454 million (1993 international dollars) or 442 million 1996 reais, which was 28 percent lower than the 1996 total funding of $630 million (613 million 1996 reais).[25] This recent decline occurred in all four funding categories but is higher in nongovernment than in government funding, resulting in a 91 percent government share of total funding in 1999, which highlights Embrapa's continuing dependence on the government.

Over the years Embrapa has had three loans from the Inter-American Development Bank (IDB) and four from the World Bank.[26] With the exception of the last World Bank loan, these funds have been used to improve Embrapa's infrastructure and train its research staff. The fourth World Bank loan was approved in 1996 and 60 percent of the total was assigned to operational expenses disbursed through a competitive funding arrangement (see next section). A new loan to Embrapa, financed by IDB, is currently being negotiated by the Brazilian government.

[25] The financial data in this paper were converted to 1993 international dollars by first deflating funds compiled in current local currency units using a Brazilian GDP deflator with the base year 1993, and then converting to U.S. dollars using a 1993 purchasing power parity (PPP) index from World Bank (2000) (see also appendix A). PPPs are synthetic exchange rates used to reflect the purchasing power of currencies, typically comparing prices among a broader basket of goods and services than do conventional exchange rates.

[26] The three IDB loans were the Project for Strengthening Research and Technology Transfer in the Center-South Region (PROCENSUL) I and II (US$66.4 and 67.8 million), and the Program for Modernization of Agricultural Technology in the Center-South Region of Brazil (PROMOAGRO, US$77.8 million); the four World Bank loans are known as the Agricultural Research Projects I, II, and III (US$40, 60 and 42 million), and the Agricultural Technology Development Project (PRODETAB, US$60 million).

Figure 1—*Trends in Embrapa's Funding Sources, 1986–98*



Source: Embrapa-DAF (1999).

Note: Embrapa funding data exclude "indirect funds" such as grants to fund non-Embrapa temporary researchers, payments for publications and events by third parties, and donations.

The Embrapa funding data in Table 2 and Figure 1 only include "direct" funding such as transfers from other government institutions, sales revenues, and research contracts with the federal government and other institutions, excluding funds from indirect sources such as donations and payments-for publications and events by third parties (as well as scholarship support to researchers not formally employed at Embrapa such as undergraduate and graduate students or temporary staff). The amount of indirect funding coming to Embrapa increased during the 1990s, but remains a small share (3 to 4 percent) of overall (that is, direct and indirect) funding (Table 3). In 1998 these indirect funds totaled to $17.3 million (in 1993 international prices) or 16.8 million 1996 reais, less than the corresponding 1997 figure, but more than in 1996.

Table 3—*Embrapa's Total Indirect Funds, 1996–98*

	1996	1997	1998
Indirect funding—			
in million 1996 reais	15.7	19.6	16.8
in million 1993 international dollars	16.1	20.1	17.3
		(*percentage*)	
as share of total funding[a]	2.8	3.8	3.5

Source: Embrapa-DAF (1999) and Table 2.

a. Includes direct and indirect funding sources.

The 11 state government agencies in our sample depended mainly on contributions from the state governments (Table 2). In 1996, 81 percent of total funding for these state agencies came from government contributions, most of which came from the state governments with only a minor share of funds from the federal government via Embrapa. Revenues from research contracts and sales accounted for 11 and 8 percent, respectively. During 1991–95 total funding increased annually, but declined in 1996. Four state agencies reported increases in total funding, but this was more than offset by overall declines for the other seven agencies.

It appears that this decline in funding for the state agencies has continued in recent years. As mentioned in section 2.2, two state agencies have been closed, a few others are bankrupt but lack sufficient funding to reconcile their debt, and others have been merged with state extension agencies. State government contributions are declining and are often only sufficient to cover salaries and basic operational costs such as electricity. During the 1990s state agencies have become increasingly reliant on funding from nongovernment sources (Table 2).

During 1995–98 IAC received an average of 80 percent of its funding from the state government (77 percent directly and 3 percent by way of a special fund). The

remaining 20 percent came from various public and private foundations (Table 4). These funds were predominantly used for operational costs, but also covered some expenses made for capital improvement and salaries paid to additional research staff (often hired as consultants). Close to 10 million 1996 reais or more than half of the "other" funds IAC received during 1995–98 came from the São Paulo Research Support Foundation (FAPESP). This foundation funded, among other things, a large genome project on bacteria in citrus fruit in which IAC participated. FAPESP was established in 1962 as an independent organization to provide research support. FAPESP competitively allocates research grants and fellowships, and is funded by a 1 percent earmarking of the state's total tax revenue. In 1998 FAPESP's total expenditures were around US$250 million of which about 30 percent was spent on training fellowships. (IAC 2000 and FAPESP 2000). A number of federal organizations made up the balance of IAC's funding support. Embrapa provided a small amount of funds for joint research on sugarcane. Some additional federal funds came via the Fund for Protection of the Coffee Economy (FUNCAFE), for coffee research; the National Program for Strengthening Family Agriculture (PRONAF), for research relevant to small-scale farmers; and the Financing Agency for Studies and Projects (FINEP) of the federal Ministry of Science and Technology. In addition, IAC was funded by two private foundations—the Foundation for Agricultural Research Support (FUNDAG) and the Foundation for Agricultural Development and Research (FUNDEPAG)—which together accounted for an average of 5 percent of IAC's total funding for the period 1995–98.

Table 4—*IAC's Funding Sources, 1995–98*

	Total Funds				Shares			
	1995	1996	1997	1998	1995	1996	1997	1998
	(in million 1996 reais)				*(percentage)*			
Direct funds								
State budget	18.4	17.9	17.8	14.0	80.4	72.0	78.0	80.0
State fund	0.9	0.9	0.4	0.5	4.0	3.7	1.8	2.9
Subtotal	*19.3*	*18.9*	*18.2*	*14.5*	*84.4*	*75.7*	*79.8*	*82.9*
Other funds								
FUNDAG	1.0	1.1	1.6	0.6	4.5	4.6	7.1	3.4
FINEP	0.8	0.2	0.7	0.3	3.5	1.0	3.2	1.8
FAPESP	1.7	4.6	2.2	1.1	7.4	18.3	9.6	6.5
FUNDEPAG	0.0	0.0	0.0	0.2	0.1	0.0	0.1	1.1
Embrapa	0.0	0.1	0.0	0.0	0.0	0.4	0.1	0.1
PRONAF	–	–	–	0.4	–	–	–	2.4
FUNCAFE	–	–	–	0.3	–	–	–	1.8
Subtotal	*3.6*	*6.0*	*4.6*	*3.0*	*15.6*	*24.3*	*20.2*	*17.1*
Total	*22.9*	*24.9*	*22.8*	*17.5*	*100*	*100*	*100*	*100*

Source: IAC (2000).

Embrapa is also examining new mechanisms for financing the agricultural research conducted by federal and state government agencies spurred by the recent declines in public funding. The main proposal currently under evaluation is the creation of a voluntary, but statutorily sanctioned, tax for research and promotion based on the "check-off" programs existing in other countries such as the United States and Canada. This program is called the Voluntary Tax for Technology Development (AGROMAIS) and one of its objectives is to increase the role of the private sector in financing agricultural technology development (Portugal et al. 1999).

2.1. COMPETITIVE FUNDING MECHANISMS

In many developing countries competitive funding mechanisms have been introduced as one of a number of new instruments for disbursing research resources.[27] This is so for a number of Latin American countries where diminishing public support for agricultural research beginning in the 1980s led to various institutional and policy reforms regarding the funding of research. Competitive funding mechanisms have gained favor among some (but not all) policymakers, donors, and even researchers. They are seen as a means of redirecting research priorities, increasing the role of the private and academic sectors in the performance of research, and, perhaps, forging new links among government, academic, and private research agencies. The use of competitive funding over block grants has advantages and disadvantages. Competitive funding mechanisms involve relatively high transaction costs (such as writing and screening proposals) and rent-seeking costs (for example, lobbying for support), but could lower social costs because they could reduce funding misallocation. Further, competitive funds tend to increase flexibility, but often causes research to take on a short-term applied orientation at the expense of more basic, longer-term research (Echeverría et al. 1996, Echeverría 1998, and Alston and Pardey 1999).

Competitive funding mechanisms have existed in Brazil for some time. Since its inception, Embrapa has disbursed resources to finance projects via a competitive national program, which is open to Embrapa's research centers and all other national public research agencies such as state agencies and universities. This program funds between

[27] For a discussion of the various funding options see Echeverria (1998) and Alston and Pardey (1999).

500–600 projects each year. About 95 percent of the funded projects are from Embrapa scientists, although state and higher education agencies had a larger presence in the program during the 1970s and 1980s. The new IDB loan, currently being negotiated, would establish a new competitive fund similar to the one currently in place as part of the fourth World Bank loan.

Agricultural Technology Development Project (PRODETAB)

A fourth World Bank loan of $60 million was approved in 1996 to support an Agricultural Technology Development Project (PRODETAB) over a five-year term. The loan funds were matched by an additional $60 million provided by the Brazilian government, Embrapa, and various other public and private agricultural R&D agencies. PRODETAB has three components. The largest share, 60 percent, supports a competitive funding program; 37 percent of the funds are earmarked for institutional development and training activities at Embrapa and state government agencies (particularly in the historically weak north and northeast regions), as well as the development of international research linkages; and the remaining 3 percent supports the administration, monitoring, and evaluation of PRODETAB itself (Reifschneider and Lele 1998).

The primary objective of PRODETAB is to enhance the integration and diversification of the national agricultural R&D system through collaborative research and technology transfer, thereby promoting private sector participation. Five priority areas were established: biotechnology, natural resource management, small-farm

development, agribusiness, and strategic research on high-priority issues not undertaken by Embrapa's programs (Lele 1998 and Lele and Anderson 1999).[28]

The PRODETAB Council is part of the National Advisory Council (CAN), both of which are chaired by Embrapa's president. The PRODETAB Council consists of representatives from research agencies and producer organizations and works closely with PRODETAB's Executive Committee. The Executive Committee consists of eight representatives from within and outside Embrapa, and, with the assistance of an Executive Secretariat, is responsible for the coordination and implementation of the competitive grants program. There are five Technical Project Committees for each of the priority areas identified to manage the technical project review process. Representatives from Brazilian, regional, and developed-country organizations assist each Technical Committee in reviewing proposals and advising on their technical merit (Lele 1998 and Embrapa 1998).

All Brazilian institutions working on agricultural R&D or related areas can submit proposals within one of the five priority areas, however a number of conditions must be met.[29] Projects must be executed by at least two independent agencies (that is, a multi-institutional partnership).[30] Each agency must have an active role, at a minimum executing one of the subprojects within the proposal, so that a project must have at least two components, but cannot have more than five. Each institute is required to offer

[28] Lele (1998) summarizes of the project's objectives, and Embrapa (1998) provides more detailed explanation of the five priority areas.

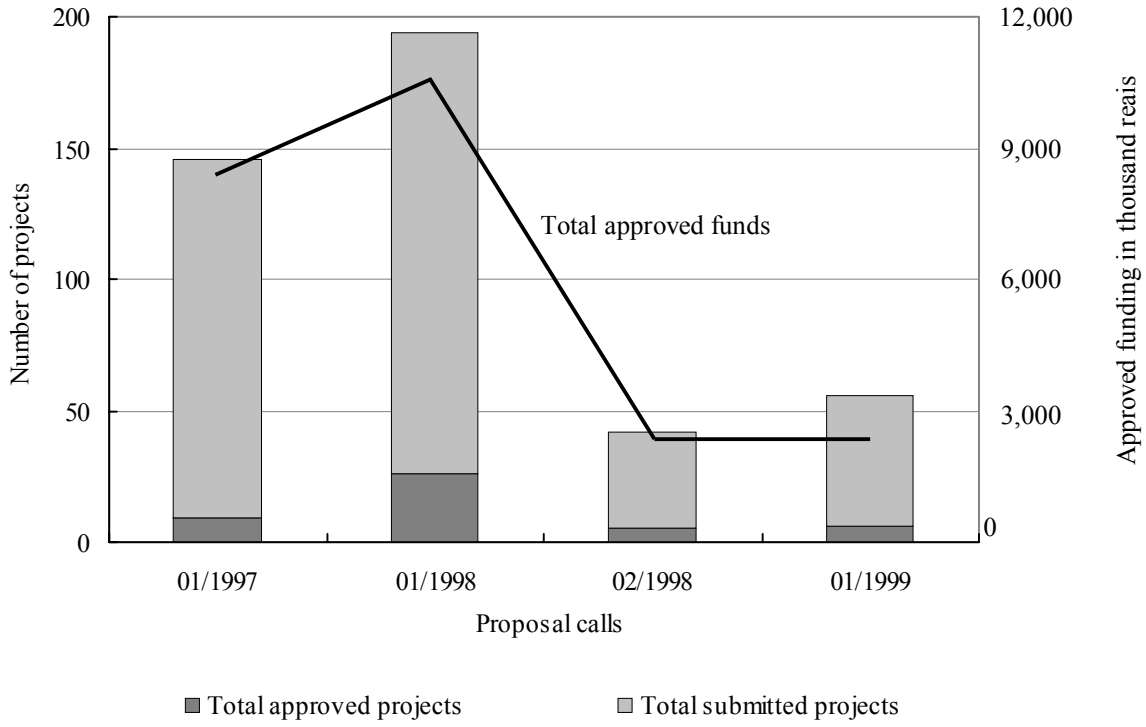
[29] These conditions are published in a *User's Operational Manual* (Embrapa 1998).

[30] Submissions from faculties or departments within one university or various departments/units within Embrapa or a state agency are allowed, but these are not seen as multi-institutional (Embrapa 1998).

counterpart funding, the shares of which must range between 25 and 55 percent depending upon the relevant priority area (Embrapa 1998).

By the end of 2000, four calls for proposals had been made to date—one in 1997, two in 1998, and one in 1999—resulting in 392 proposal submissions, of which 46 were approved (12 percent). The total approved funding from the four rounds of submission was 23.6 million reais or $21.8 million in 1993 international prices (Figure 2).

Figure 2—*Projects Submitted to and Approved by PRODETAB, 1997–99*

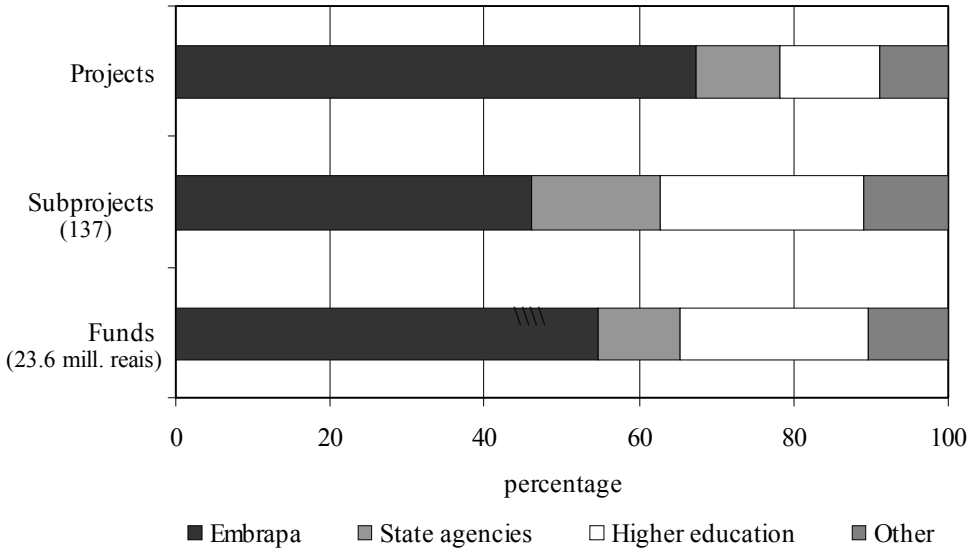


Source: Embrapa (1999b).

Each approved project has an average of 3.2 subprojects, reflecting the aim—and hence structure—of this funding mechanism to promote collaborative research. Embrapa dominates as the executing agency, accounting for two-thirds of the projects (Figure 3a) and almost half of the 137 subprojects (Figure 3b). The balance is shared among higher

education, state government, and various other agencies (13, 11, and 9 percent of the total projects respectively).

Figure 3—*Executing Agencies for PRODETAB Funds, 1997–99*



Source: Embrapa (1999b).

The approved projects were distributed fairly evenly throughout the country, with the exception of the southeast region where over a third of the approved projects or 45 percent of the total funds was earmarked (Embrapa 1999a). Research on small-scale farmers, advanced technology, and natural resources each accounted for more than 25 percent of the 43 approved projects. Only five projects were approved for research on agribusinesses, but the average size of these projects was $1 million reais, more than twice that of the projects from the other four priority areas (Embrapa 1999a).

The competitive funding mechanism, PRODETAB, represents a new approach to disbursing research funds in Embrapa, and Brazil more generally, but block funding still predominates. Annual disbursals from the World Bank component of PRODETAB

average $12 million over the five-year duration of the project, just 2 percent of Embrapa's total annual budget and around 1 percent of Brazil's total agricultural R&D expenditures. The PRODETAB funds made available to Embrapa during 1997–99 represented only 1 percent of the agency's total funding for that same period.

4. HUMAN AND FINANCIAL RESOURCES

4.1 AGRICULTURAL R&D STAFFING TRENDS

In contrast to some other Latin American countries such as Colombia and Uruguay, the majority of the agricultural researchers in Brazil work for government agencies. In 1996, a total of 4,707 full-time equivalent (fte) researchers were employed in the 68 Brazilian agricultural R&D agencies in our sample—Embrapa employed 44 percent of this total, the state agencies 37 percent (Table 5).[31] CEPEC, the five nonprofit institutions, and private enterprises each accounted for about 2 percent of the total.

In the mid 1990s, the 11 firms included in Appendix Table B.1 conducted research in Brazil, employing an estimated total of 88 fte scientists. It is our sense that the 27 entries in Appendix Table B.3 include most of the remaining firms engaged in agriculturally related research in Brazil. Many of these firms provide input technologies or technical services to production agriculture, and some are involved in postharvest (mainly food processing) activities, but a sizable share of the relevant technologies is

[31] See Appendix Table B.1 for a list of the agricultural R&D agencies in our sample.

developed outside of Brazil.[32] We suspect that the 11 private companies in our sample accounted for about half the total fte researchers working in the private sector in 1996.

We received completed surveys from (or used secondary sources for) 28 higher education agencies that employed 559 fte researchers in 1996, about 12 percent of the total fte researchers in our 68-agency sample. Most of the important higher education agencies regarding agricultural research were included in our 28–agency sample, but we suspect we missed about one third of the total fte agricultural researchers working in Brazil's higher education sector.

Scaling up our sample totals to account for missing data for the higher education agencies and private enterprises brings the total fte agricultural researchers to 5,070, increasing the share of the higher education agencies and private enterprises to 17 and 4 percent, respectively, and decreasing the shares of Embrapa and the state government agencies to 41 and 35 percent of the 1996 total, respectively (Table 5, column 3). This 5,070 fte total is still likely to be an undercount, as the coverage of fisheries research in our sample was low.

[32] Roseboom (1999) supports our own impressions that comparatively little private food processing and agricultural machinery research takes place in Brazil, and that much of the agrochemical research conducted by multinational companies is done elsewhere.

Table 5—*Institutional Deployment of Brazilian Agricultural Researchers 1996*

Type of Agency	Number of Researchers	Share		Number of Agencies[a]
		Total	Adjusted Total	
	(*fte's*)	(*percentage*)		
Federal government agencies				
Embrapa	2,092.0	44.4	41.3	1
CEPEC	89.0	1.9	1.8	1
State government agencies[b]	1,762.4	37.4	34.8	22
Nonprofit institutions	117.0	2.5	2.3	5
Higher education agencies	559.2	11.9	16.7	28
Subtotal	*4,619.6*	*98.1*	*96.8*	*57*
Private enterprises				
National	70.5	1.5		8
Multinational	17.0	0.4		3
Subtotal	*87.5*	*1.9*	*3.5*	*11*
Total	*4,707.1*	*100*		*68*
Adjusted total for omitted higher education agencies and private enterprises[c]	*5,070.0*		*100*	

Source: Compiled by authors from IFPRI/Embrapa survey, Albuquerque and Salles-Filho (1997), Embrapa-DAP (1999), and IAC (2000). Data for some higher education agencies are from other secondary sources (see also Appendix Table B.1).

a. Number of agencies covered in our sample (see also Appendix Table B.1.).
b. IB is excluded in this sample due to lack of data.
c. We estimate that our sample included about two thirds of the fte research staff at higher education agencies and half of the fte research staff at private enterprises.

During the period 1976–96, total agricultural research staff in a 45-agency sample, excluding private enterprises, increased at an average rate of 2.3 percent per year. This overall rate masks differences among institutional categories and subperiods (Table 6). It appears that the growth in the number of researchers stalled in the early 1990s, and, based on 1997–98 data for Embrapa and the majority of the state agencies, declined in more recent years. Embrapa grew fastest, at 2.8 percent per year, but this increase

occurred primarily in two spurts, one in the late 1970s and the other in the late 1980s. Embrapa's research staff decreased slightly between 1991 and 1998, with the exception of 1995 when numbers rose by about 100 researchers and then fell again in 1996. This explains the positive, but very low annual growth rate of 0.4 percent for the period 1991–96. The large one-year increase in 1995 was evenly distributed among most Embrapa research centers. The 1996 decline in total research staff was the result of a large voluntary retirement program within Embrapa.

Table 6—*Trends in Brazilian Agricultural Researchers, 1976–99*

	Government agencies			Nonprofit Institutions	Higher Education Agencies	Subtotal	Private Enterprises		Total
	Embrapa	CEPEC	State				National	Multinational	
					(*number*)				
Number of agencies in sample	1	1	22[a]	4[b]	17	45	8	3	*56*
Researchers					*(fte's per year)*				
1976–80	1,395.2	111.6	1,296.2	38.2	276.1	3,117.2	na	na	*na*
1981–85	1,610.4	115.2	1,641.5	50.0	315.5	3,732.6	na	na	*na*
1986–90	1,963.4	135.6	1,785.3	52.2	349.6	4,286.1	na	na	*na*
1991–95	2,111.8	115.6	1,824.9	48.6	364.2	4,465.1	74.5	15.4	*4,555.1*
1996	2,092.0	89.0	1,762.4	57.0	374.3	4,374.6	70.5	17.0	*4,462.1*
1998	2,063.0	na	1,547.5[c]	na	na	na	na	na	*na*
1999	2,064.0	na	na	na	na	na	na	na	*na*
Annual growth rate[d]					*(percentage)*				
1976–81	4.2	4.8	4.5	4.0	3.2	4.3	na	na	*na*
1981–86	1.6	–0.3	3.0	3.3	1.6	2.2	na	na	*na*
1986–91	4.5	1.1	0.2	–1.6	1.2	2.2	na	na	*na*
1991–96	0.4	–6.9	0.5	1.9	1.5	0.3	–1.4	2.6	*0.3*
1976–96	2.8	0.1	2.1	1.5	1.8	2.3	na	na	*na*

Source: Compiled by authors from IFPRI/Embrapa survey, Embrapa (1993), IICA and IDB (1993), Queiroz (1994), Albuquerque and Salles-Filho (1997), Embrapa-DAP (1999), and IAC (2000).

Note: Data from 1976 to 1995 are presented as five-year averages.

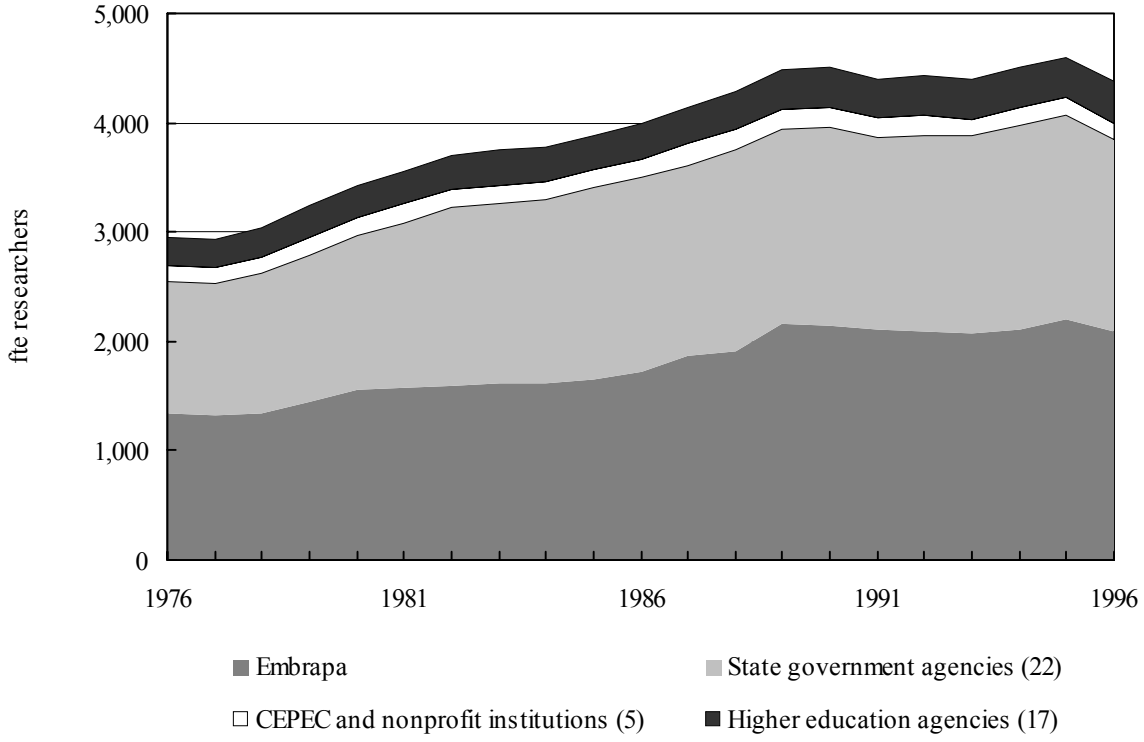
a. IB is excluded from this sample.
b. COOPERSUCAR is excluded from this sample.
c. Data for six of the 22 state agencies (accounting for 15 percent of total fte research staff at state agencies in 1996) were estimated using the trend from 1996 to 1998 for the 16 agencies for which data were available.
d. Least squares growth rates.

The state government agencies grew at an average rate of 2.1 percent per year, with most of this growth occurring in the late 1970s and early 1980s. And, like Embrapa, the number of researchers working for state agencies grew slowly during the 1990s, averaging only 0.5 percent per year. The staff numbers for 19 of the 22 state government agencies in our sample remained constant or contracted from 1995-1996, a decline of 9 percent or 111 fte researchers for that year alone. More recent data for 16 state agencies (one of which one was closed in 1998) show that the overall decline continued during 1997–98, but with substantial differences among the state agencies. Among the comparatively large state agencies, the number of fte researchers at EPAMIG, for example, increased by 20 percent between 1996 and 1998 and EMEPA by 10 percent, but a large number of state agencies (specifically IAPAR, IP, IPA, and ITAL) shrank by more than 10 percent. EPEAL, located in the state of Alagoas, contracted most, by 28 percent from 1996 to 1998. Taking the overall trend of the 16 agencies in our sample to be representative of the trend for the group inclusive of the six state agencies not in our sample, we estimated that total fte research staff at the state agencies decreased by more than 200 from 1996 to 1998. CEPEC and the 8 national private enterprises also lost researchers during the 1991–96 period, while the number of fte researchers increased on average for the nonprofit institutions and the multinational private enterprises.

There has been comparatively little change in the institutional composition of agricultural researchers in Brazil since the mid 1970s, in contrast with some other countries in the region (like Colombia) where the higher education sector and other (often

nongovernment) agencies now employ a significantly larger share of the agricultural researchers (Figure 4).[33]

Figure 4—*Institutional Structure of Brazilian Agricultural Researchers, 1976–96*



Source: See Table 6.
Note: Number of agencies in sample is within brackets.

The Embrapa data include Embrapa researchers outposted to state government agencies, the numbers of which have decreased over recent years as well. In the late 1980s around 150 Embrapa researchers were outposted, while in 1998 the total was only 92. Most of these researchers were outposted to state agencies in the northeastern region.

[33] Recall we have less than complete coverage of higher education agencies, but this is unlikely to affect our perspectives on the institutional composition of Brazilian agricultural researchers.

Degree Status

In 1996, more than half the 4,685 fte researchers in our 63-agency sample were trained to the MSc level, and close to a third held a doctorate degree (Table 7). These shares are higher than those in other Latin American countries in the same year. For example, in Colombia around half the agricultural researchers were trained to the postgraduate level with one fifth of those (that is, 11 percent of the total) holding doctorate degrees (Beintema et al. 2000a); only 7 percent of Uruguay's agricultural researchers held PhD degrees, 27 percent had MSc degrees (Beintema et al. 2000b). These postgraduate shares for agriculture are in line with those for total S&T staff, although the share of agricultural PhDs is considerable lower than the share across all sectors. In 1993, 51 percent of all scientific staff held a doctorate degree, with 31 and 18 percent of these holding MSc and BSc degrees, respectively (MCT-CNPQ 1996).

The share of research staff with doctorate degrees at Embrapa was 8 percent higher than the sample average, while for the 23 higher education agencies in our sample an average of half the research staff held a doctorate degree. The state government agencies and other institutional categories all had fewer researchers with postgraduate degrees than the sample average, and of those researchers with postgraduate degrees relatively fewer held a doctorate degree.

Table 7—*Degree Status of Brazilian Researchers, 1996*

Type of Agency	Number of Researchers				Shares			Number of Agencies
	PhD	MSc	BSc	Total	PhD	MSc	BSc	
	(fte researchers)				*(percentages)*			
Federal government agencies								
Embrapa	793.0	1,143.0	156.0	2,092.0	37.9	54.6	7.5	1
CEPEC	25.0	39.0	25.0	89.0	28.1	43.8	28.1	1
State government agencies	340.9	912.1	509.4	1,762.4	19.3	51.8	28.9	22
Nonprofit institutions	9.0	50.0	58.0	117.0	7.7	42.7	49.6	5
Higher education agencies	279.3	206.8	56.6	542.7	51.5	38.1	10.4	23
Subtotal	*1,447.2*	*2,350.9*	*805.0*	*4,603.1*	*31.4*	*51.1*	*17.5*	*52*
Private enterprises								
National	11.0	39.5	19.9	70.5	15.6	56.1	28.3	8
Multinational	5.0	6.0	6.0	17.0	29.4	35.3	35.3	3
Total	*1,462.3*	*2,394.4*	*827.9*	*4,684.5*	*31.2*	*51.1*	*17.7*	*63*

Source: Compiled by authors from IFPRI/Embrapa survey, Embrapa-DAP (1999), and IAC (2000).

This 1996 picture is very different from that of several decades earlier. In 1976 only a quarter of the research staff in our 38-agency sample, which excludes the private sector, held postgraduate degrees and only 6 percent were trained to the doctorate level (Figures 5a and 5b). Ten years later, the average share of researchers with postgraduate degrees had increased to 71 percent, and to 84 percent by 1996.[34] In the early 1960s, few agricultural researchers held postgraduate degrees: only one government institute had one researcher with a doctorate degree and only three institutes had some staff trained to the MSc level (Schuh 1970). This

[34] The 1996 shares in Figures 5a and 5b differ slightly from those in Table 7, because timeseries data on educational attainment were only available for a smaller sample.

situation began changing from 1963, largely as a consequence of the USAID-supported programs to the Brazilian universities described in section 2.1. A large number of university faculty staff was sent to the United States for graduate training (Sanders et al. 1989). By 1976, 41 percent of the researchers at the 16 higher education agencies in our sample held PhDs and 29 percent held MSc degrees. The share of researchers with doctorate degrees continued to increase in more recent years. For example, in 1999, 46 percent of Embrapa's research staff held a doctorate degree, 49 percent had MSc degrees, and only 4 percent had BSc degrees. The 15 state agencies for which recent degree data were available show similar trends. In 1998 the share of research staff from state agencies with doctorate and MSc degrees was 25 and 54 percent respectively.

Figure 5a—*Share of Postgraduates in Total Research Staff by Institutional Category, 1976–96*

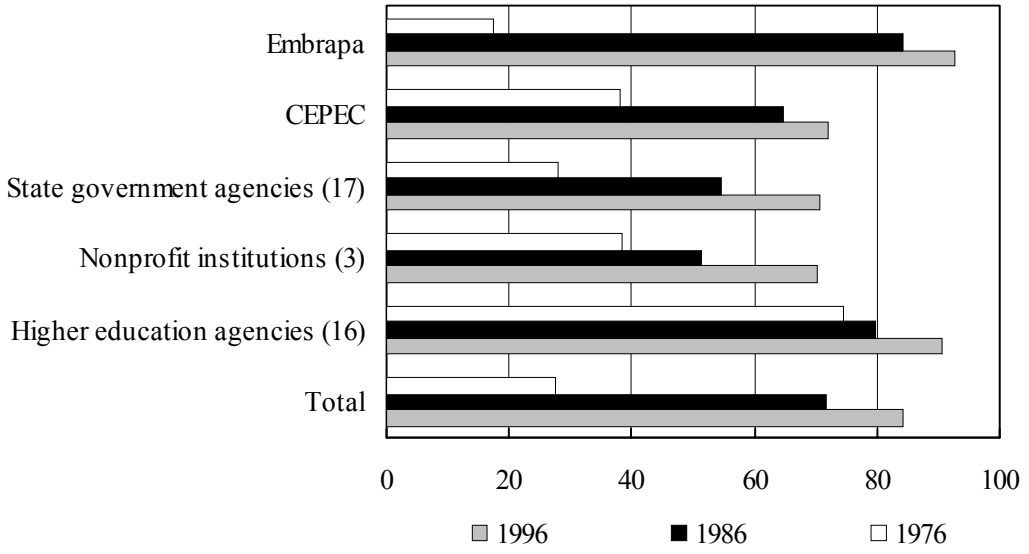
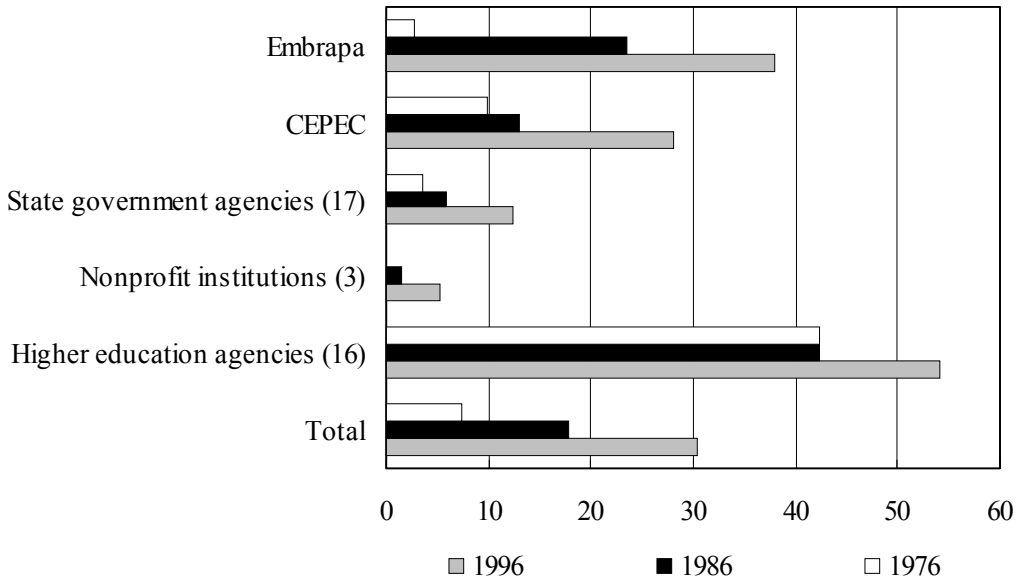


Figure 5b—*Share of PhDs in Total Research Staff by Institutional Category, 1976–96*



Source: Compiled by authors from IFPRI/Embrapa survey, Embrapa (1993), Embrapa-DAP (1999), and IAC (2000).

Note: Number of agencies in sample shown in brackets.

Embrapa has invested heavily in training its research staff and has received considerable support for this from agencies such as the IDB and the World Bank via their respective loans. Mainly as a result of these extensive investments in human capital development, the share of agency's researchers trained to the postgraduate level increased from 17 percent in 1976, lower than the sample average in that year, to 93 percent in 1996. Staff holding a doctorate degree increased from 3 to 38 percent during the same period. In recent years Embrapa has continued to invest in training its research staff with financial support from the World Bank via PRODETAB. By 1999, 96 percent of Embrapa's research staff held postgraduate degrees and 46 percent had doctorate degrees. However, Embrapa will need to continue investing heavily in human capital to maintain the quality of its

research staff as fully one third of the 1998 research staff (that is, 750 researchers) will retire before 2008 (Embrapa 1999a).

Beginning in the late 1970s and throughout the 1980s Embrapa had an annual average of more than 300 researchers enrolled in postgraduate training (Table 8). In 1998, a total of 2,077 Embrapa researchers had completed MSc or PhD studies (Embrapa 1999a). As mentioned earlier, Brazilian universities began offering postgraduate courses much earlier than many other countries in Latin America with the result that most Embrapa researchers seeking MSc degrees now do so in Brazil. In 1976, for example, 76 percent of the 422 Embrapa researchers enrolled in MSc programs were studying at Brazilian universities. By the 1990s only a small (and decreasing) share of the MSc training was undertaken abroad. For doctorate training, most Embrapa researchers were sent to universities abroad in the late 1970s, but since the mid 1980s—by which time many local universities had established PhD programs—more than half of the researchers undertaking doctorate-level training were enrolled in Brazilian universities.[35] Also many researchers from other Latin American countries were enrolled for postgraduate training at Brazilian universities.

[35] The number of undergraduate courses in agricultural sciences at Brazilian higher education agencies increased from 17 in 1950, to 96 in 1986, and 172 in 1998. In 1998 Brazil had 156 MSc and 54 doctorate courses compared with 118 and 25 courses a decade earlier (Alves and Contini n.d.).

Table 8—*Embrapa Research Staff Studying in Brazil and Abroad, 1976-98*

Type of Agency	Embrapa Researchers Studying					Shares				
	1976–80	1981–85	1986–90	1991–95	1996–98	1976–80	1981–85	1986–90	1991–95	1996–98
	(*number per year*)					(*percentage*)				
Post PhD										
Brazil	0	0.2	0.2	0.2	1.0	–	100	2.3	0.8	10.7
Abroad	0	0	8.6	23.4	8.3	–	–	97.7	99.2	89.3
Total	*0*	*0.2*	*8.8*	*23.6*	*9.3*	*–*	*100*	*100*	*100*	*100*
PhD										
Brazil	20.8	64.2	110.6	128.6	53.0	21.1	35.2	53.1	59.9	48.3
Abroad	77.8	118.4	97.8	86.0	56.7	78.9	64.8	46.9	40.1	51.7
Total	*98.6*	*182.6*	*208.4*	*214.6*	*109.7*	*100*	*100*	*100*	*100*	*100*
MSc										
Brazil	231.6	120.6	103.8	105.6	24.0	77.4	90.3	94.4	91.2	97.3
Abroad	67.6	13.0	6.2	10.2	0.7	22.6	9.7	5.6	8.8	2.7
Total	*299.2*	*133.6*	*110.0*	*115.8*	*24.7*	*100*	*100*	*100*	*100*	*100*
Total										
Brazil	252.4	185.0	214.6	234.4	78.0	63.4	58.5	65.6	66.2	54.3
Abroad	145.4	131.4	112.6	119.6	65.7	36.6	41.5	34.4	33.8	45.7
Total	*397.8*	*316.4*	*327.2*	*354.0*	*143.7*	*100*	*100*	*100*	*100*	*100*

Source: Embrapa-DAP (1999).

Note: Data are presented as five-year averages for all but the last period, which is the average of three years.

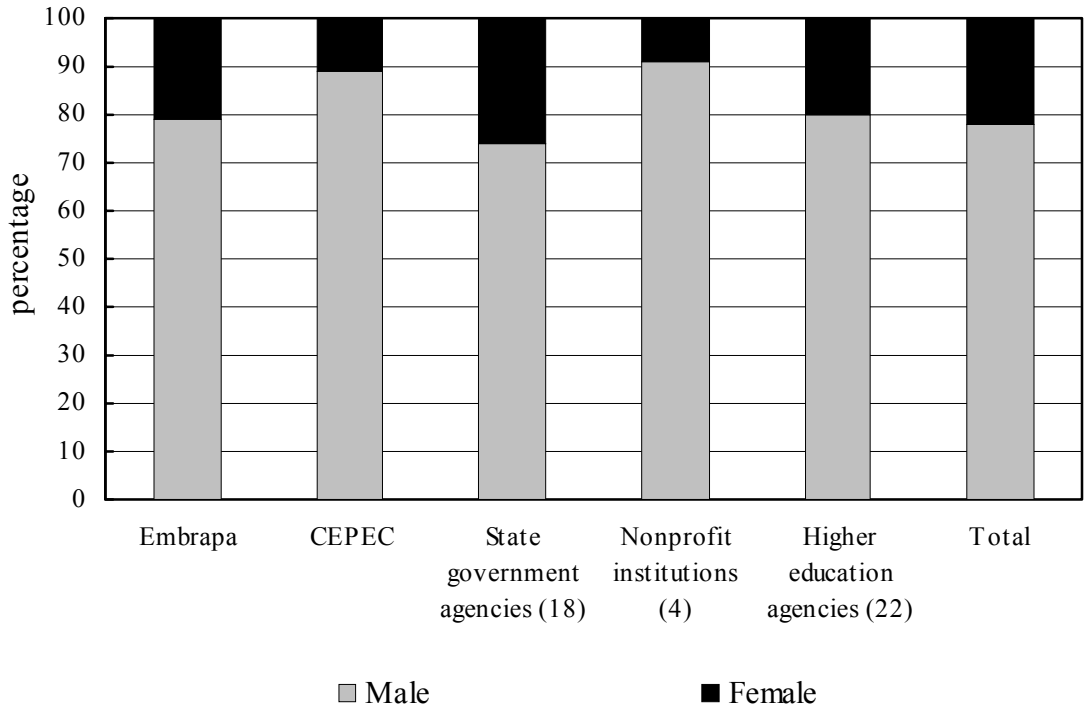
The number of Embrapa researchers receiving postgraduate training decreased substantially in recent years from 374 researchers in 1996 to 132 in 1998. This decline occurred mainly in the number of researchers enrolled in Brazil; those enrolled at universities abroad declined only marginally. These trends are a consequence of the high proportion of Embrapa researchers that have now received postgraduate degrees, combined with the fact that many of Embrapa's new hires already hold higher degrees.

Data for IAC for the 1995–98 period show that around 90 percent of the research staff studying for a doctorate degree were doing so at Brazilian universities (in contrast to Embrapa were a sizeable share still studies abroad), as were all those studying for an MSc degree (IAC 2000).

Gender

For a sample of 46 agencies in 1996, an average of 22 percent of the researchers were female (Figure 6). About one fifth of Embrapa's total researchers were female, but there were significant differences among the 37 Embrapa centers. Three quarters of the centers had between 10 and 20 percent of female scientists, with two centers (CENARGEN and CTAA) employing slightly more female researchers than male ones. Embrapa's share of female research staff increased slowly from 15 percent in 1986 to 21 percent in 1995 and has changed little since then.

Figure 6—*Gender of Research Staff, 1996*



Source: Compiled by authors from IFPRI/Embrapa survey.

Note: Number of agencies in sample shown in brackets.

As a group, the 18 state-government agencies in our sample had the highest share of female research staff, but again with significant differences among agencies, ranging from 7 percent for EPAGRI to 62 percent for ITAL. Shares for the nonprofit organizations and CEPEC were 9 and 11 percent respectively. Notably, the share of female agricultural researchers is much lower than the share of female scientists in Brazil more generally. RICYT (2000) reports that 39 percent of all Brazilian scientists were female in 1996 compared with 22 percent in agriculture.

4.2 PUBLIC AND PRIVATE R&D EXPENDITURE TRENDS[36]

The institutional structure of agricultural R&D expenditures in our 68-agency sample differed somewhat from the breakdown of fte researchers in Table 5. In 1996, Embrapa accounted for 61 percent of total agricultural R&D expenditures compared with 44 percent of total fte research staff (Table 9), while state agencies had 22 percent of the expenditures and 37 percent of the fte researchers. This reflects Embrapa's generally stronger financial situation compared with state agencies and a 1996 spike in funds forthcoming to Embrapa.

Compiling expenditure data for higher education agencies proved difficult. The little data that were obtained often included only the explicit expenditures earmarked for research—such as the operational costs associated with university research or project funds received from external sources—rather than a comprehensive accounting of the costs including salaries, rent, and utilities appropriately prorated to reflect the share of total faculty time spent on research. To redress these problems, an estimate of total expenditures for the higher education sector was calculated using the average expenditures per researcher for government agencies and nonprofit institutions scaled by the total fte researchers employed by the higher education agencies in our sample.

[36] Converting the time-series expenditure data to 1993 international dollars was complicated by bouts of hyperinflation and episodic (and large) currency devaluations. Brazil's national currency was devaluated or renamed a total of five times during 1976–98, the last time being July 1994. We sought data in current local currency units so that a standardized method of deflation and currency conversion could be used to express the series in base-year prices and international (or U.S.) dollar currency units. Other country reports in this series use 1993 as the base year, but exceptionally high inflation during the 1993–94 period (an average of 2,000 percent per year for these years) made basing the local currency time-series on 1993 problematic, so we chose 1996 as the base period instead. Some agencies supplied data in constant reais or some prior currency unit. For some other agencies we derived 1993 (and some 1994) estimates by interpolation to skirt some currency conversion and deflation problems.

Table 9—*Composition of Brazilian Agricultural Research Expenditures, 1996*

Type of Agency	Spending		Share		Number of Agencies[a]
	1996 Reais	International Dollars	Total	Adjusted Total	
Federal government agencies	(*millions*)		(*percentages*)		(*number*)
Embrapa	565.2	580.3	60.9	56.7	1
CEPEC	17.0	17.5	1.8	1.7	1
State government agencies[b]	204.6	210.0	22.0	20.5	22
Nonprofit institutions	26.3	27.0	2.8	2.6	5
Higher education agencies[c]	95.8	98.4	10.3	14.6	28
Subtotal	*908.9*	*933.2*	*98.0*	*96.2*	*57*
Private enterprises[d]					
National	14.9	15.3	1.6		8
Multinational	4.1	4.2	0.4		3
Subtotal	*18.9*	*19.5*		*3.8*	*11*
Total	*927.9*	*952.6*	*100*		*68*
Adjusted total for missing higher education agencies and private enterprises[e]	*996.2*	*1,022.7*		*100*	

Source: Compiled by authors from IFPRI/Embrapa survey, UNICAMP (1997), Albuquerque and Salles-Filho (1997), Embrapa-DAF (1999), and IAC (2000).

a. Number of agencies covered in sample (see also Appendix Table B.1.).
b. IB is excluded due to lack of data.
c. Expenditures for the higher education agencies were estimated based on the average expenditures per researcher for government agencies and nonprofit institutions. Embrapa data for 1995 were used as a basis for the calculation to sidestep the spike in Embrapa's 1996 expenditures.
d. Five of the 11 private enterprises in our sample provided data in nominal U.S. dollars, while six used nominal local currencies. The U.S. dollar series were first deflated to base year 1993 using the World Bank (2000) GDP deflator for the United States, and then converted to international dollars using the World Bank's (2000) PPP index for 1993.
e. We estimate that our sample included about two thirds of the fte research staff at higher education agencies and possibly half of the fte research staff employed by private enterprises.

After adjusting these total expenditure estimates for missing data for the higher education and private, for-profit sectors (see discussion above), we estimate that in 1996 the total investment in agricultural R&D (that is, public and private) in Brazil was $1,023 million (1993 international prices), or 996 million 1996 reais. Our adjustment for missing data increases the higher education and private-enterprise shares in total expenditures to 15 and 4

percent, respectively, and reduces the shares of Embrapa and state government spending to 57 and 21 percent, respectively. The extraordinary costs associated with an early retirement scheme made available to Embrapa's staff in 1996 meant that data for that particular year is not especially representative of Embrapa's spending pattern around this time. However, excluding the one-off costs to pay out the retirement packages (that is, $25 million reais) reduces Embrapa's share of total Brazilian expenditures by only 1 percent in 1996.

Agricultural R&D investments for a sample of 45 agencies (excluding the private sector) grew substantially in the late 1970s at an average rate of 9.9 percent per year. During the early 1980s total R&D investments declined slightly, but grew again during the late 1980s and early 1990s at rates of 4.6 and 2.8 percent per year respectively, well below the rate witnessed during the late 1970s (Table 10).

Table 10—*Trends in Brazilian Agricultural Research Expenditures, 1976–99*

	Government Agencies			Nonprofit Institutions	Higher Education Agencies[c]	Subtotal	Private Enterprises[d]		Total
	Embrapa[a]	CEPEC[b]	State				National	Multinational	
Number of agencies					*(number)*				
in sample	1	1	22[e]	4[e]	17	45	8	3	*56*
Expenditures in constant local currencies				(*million 1996 reais per year*)					
1976–80	239.5	13.6	138.5	3.6	38.3	433.4	na	na	*na*
1981–85	322.0	17.2	164.5	5.7	47.0	556.4	na	na	*na*
1986–90	340.0	17.7	207.9	4.9	50.7	621.2	na	na	*na*
1991–95	434.7	18.2	229.5	4.9	61.0	748.3	14.8	4.0	*767.1*
1996	565.2	17.0	204.6	6.9	64.1	857.9	14.9	4.1	*876.8*
1998	478.7	na	188.4[f]	na	na	na	na	na	*na*
1999	444.4	na	na	na	na	na	na	na	*na*
Expenditures in constant international dollars				(*million 1993 international dollars per year*)					
1976–80	245.9	13.9	142.2	3.6	39.4	445.0	na	na	*na*
1981–85	330.6	17.7	168.9	5.9	48.3	571.3	na	na	*na*
1986–90	349.1	18.2	213.4	5.0	52.0	637.8	na	na	*na*
1991–95	446.3	18.7	235.7	5.0	62.7	768.3	15.2	4.1	*787.6*
1996	580.3	17.5	210.0	7.1	65.8	880.7	15.3	4.2	*900.2*
1998	491.5	na	193.4[f]	na	na	na	na	na	*na*
1999	456.3	na	na	na	na	na	na	na	*na*
Annual growth rate[g]					(*percentage*)				
1976–81	12.6	17.8	4.7	12.9	8.8	9.9	na	na	*na*
1981–86	–2.9	–5.1	4.1	0.9	–1.2	–0.7	na	na	*na*
1986–91	8.1	4.6	–1.1	–6.0	3.6	4.6	na	na	*na*
1991–96	4.8	–3.0	–0.9	12.3	2.0	2.8	0.4	0.3	*2.7*
1976–96	4.1	1.8	3.1	2.2	3.0	3.6	na	na	*na*

Source: Compiled by authors from IFPRI/Embrapa survey, Embrapa (1993), Albuquerque et al. (1986), UNICAMP (1997), Albuquerque and Salles-Filho (1997), Embrapa-DAF (1999), and IAC (2000).

Note: Data from 1976 to 1995 are presented as five-year averages.

a. Embrapa expenditures exclude pass through funds that were transferred to the state institutes.

b. CEPEC expenditures for some years have been interpolated.

c. Higher education agencies expenditures were estimated using average expenditures per researcher for the government agencies and nonprofit institutions.

d. Five private companies provided expenditure data in U.S. dollars, which we converted to constant local currencies (see Table 9 footnote d).

e. See Table 5.

f. Data for 6 of the 22 state agencies (accounting for 13 percent of total fte research expenditures at state agencies in 1996) were estimated using the trend from 1996 to 1998 for the 16 agencies for which data were available.

g. Least squares growth rates.

Embrapa's total expenditures more than doubled from an average of $246 million per year (1993 international prices) or 240 million 1996 reais in the late 1970s to $456 million or 444 million reais by 1998. Given its large (but shrinking) share of total Brazilian expenditures, the period-to-period pattern observed for Embrapa mirrors the pattern described above for overall expenditures. Embrapa's annual expenditures peaked in 1996; after adjusting for inflation total spending in 1999 was 17 percent lower than the 1996 level (even after abstracting from the one-time additional cost of the 1996 voluntary retirement program).[37] CNPS is the only Embrapa center to have increased its total spending in recent years. Expenditures of all other Embrapa centers have declined dramatically, with a few centers—CNPGL, CNPTIA, CPACT, CPAMN, and CPAP—down by more than 35 percent between 1996 and 1998.

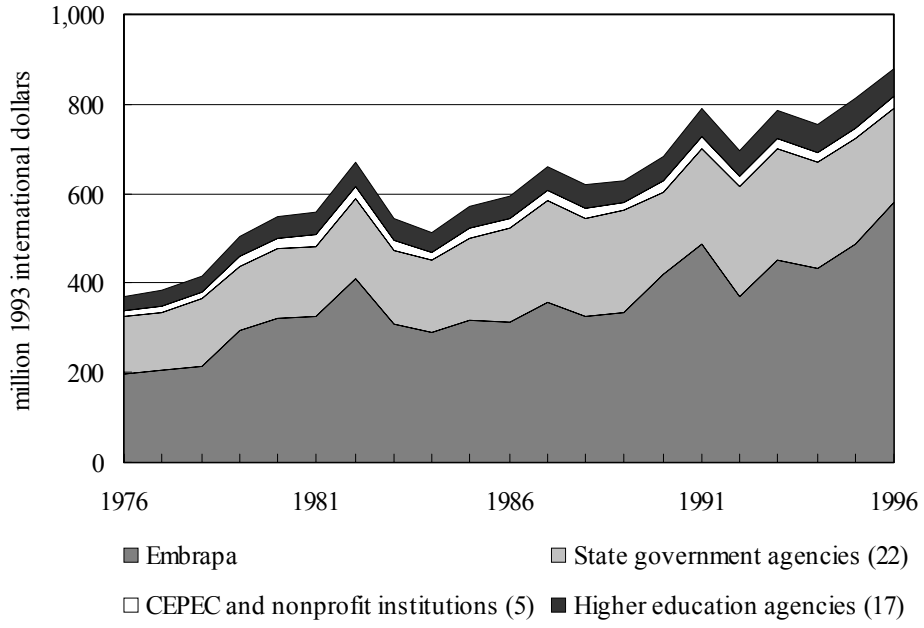
Over the 1976-96 period spending by state agencies grew by 3.1 percent per year compared with Embrapa's annual rate of 4.1 percent. Spending by the 16 state agencies (of which one was closed in 1998) during the 1996 to 1998 period also contracted by 8 percent.[38] However, this average masks substantial differences among the agencies. For example, expenditures by the comparatively large state agencies, EPAMIG and ITAL declined by around 20 percent between 1996 and 1998, with more dramatic declines by EPEAL and EBDA (31 and 48 percent respectively). In contrast, EPAGRI, IAPAR, and PESAGRO substantially increased their expenditures by 26, 31, and 46 percent, respectively, during the

[37] These expenses for the 1996 voluntary retirement program accounted for seven percent of Embrapa's total salary costs and five percent of total expenditures.

[38] No quantitative information on total expenditures was available for the years following 1998 but it appears to have continued to decline.

same period. The annual growth rates reported in Table 10 are five-year averages and hide the year-to-year variation revealed by the plot of annual data in Figure 7.

Figure 7—*Long-term Composition of Brazilian Agricultural Research Expenditures (Excluding Private Enterprises), 1976–96*



Source: See Table 10.

Note: Number of agencies in sample shown in brackets.

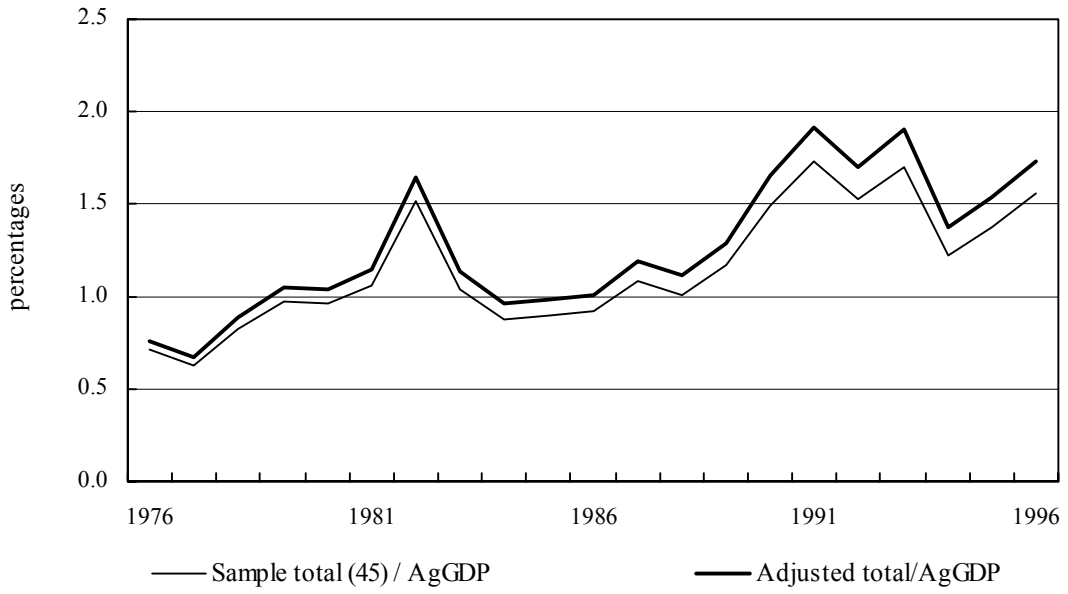
Intensity Ratios

Total public spending as a percentage of agricultural output (AgGDP) is a common research investment indicator that helps place a country's agricultural R&D spending in an internationally comparable context (Figure 8). According to our adjusted estimates the public-sector intensity ratio more than doubled from 0.8 percent in 1976 to 1.7 percent in 1996.[39] The

[39] We used the data in Tables 9 and 10 along with other information to scale up the estimates for the 17 higher education agencies for which timeseries data were available, adjusting the scaling factor over time to reflect the fact that many of the significant faculties engaged in agricultural R&D were only constituted during the 1980s and early 1990s.

growth in intensity has been uneven, with two significant spikes in 1982 and 1991–93 (Figure 8). Notably, the intensity with which Brazil invested in agricultural research in 1996 was considerably higher than other countries in the region (for example, Beintema et al. [2000a] found a 1996 intensity ratio of 0.5 for Colombia). The Brazilian ratio is moving closer to the lower end of the range observed for developed countries, and is comparable to countries such as Ireland, Italy, Portugal, and Spain (Pardey and Beintema 2001).

Figure 8—*Public Agricultural R&D Spending Relative to AgGDP, 1976–96*



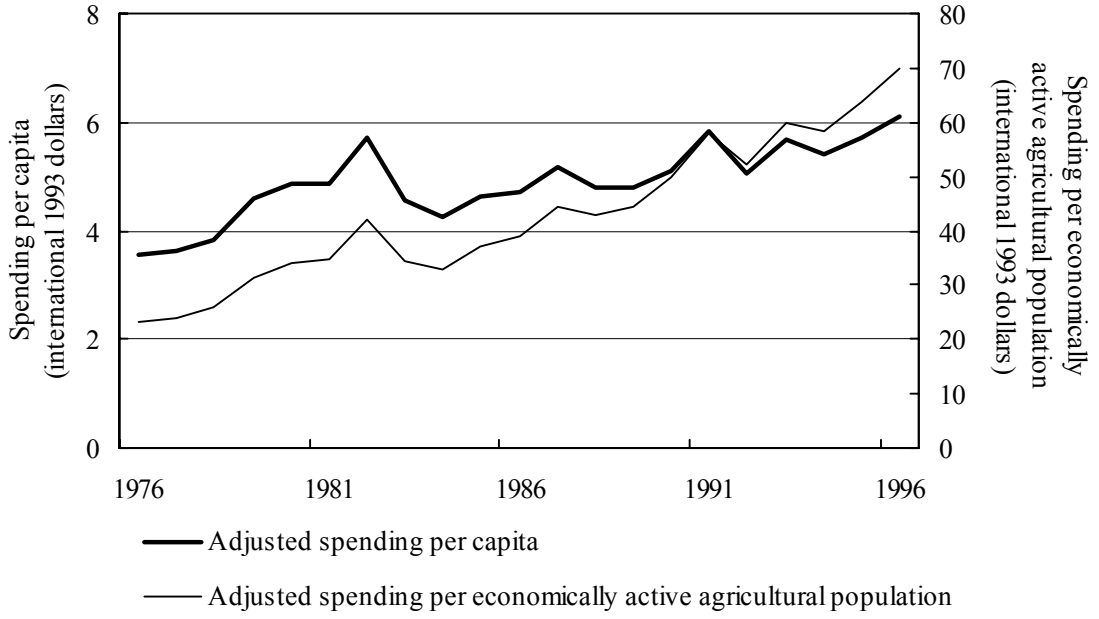
Source: Data underlying Table 10 for R&D expenditures. AgGDP from World Bank (2000).

Since 1996, the intensity ratio has no doubt declined given the drop in spending by Embrapa and the state agencies, which combined represent the lion's share of public agricultural R&D expenditures in Brazil. Assuming expenditures by the other public agencies (such as CEPEC, the nonprofit institutions and the higher education agencies) were unchanged from those of 1996, the 1998 intensity ratio would have declined to 1.5. But in

reality it was likely lower, given that spending by most public agencies has probably been curtailed because of Brazil's generally poor economic performance in recent years.

The trends for agricultural R&D spending per capita and per economically active agricultural population paralleled those for research spending as a percentage of agricultural GDP (Figure 9). Agricultural R&D spending per capita (adjusted for expenditures deemed missing from our sample) increased from $3.6 per capita in 1976 to $6.1 in 1996 (1993 international prices). Spending per economically active agricultural population increased more than spending per capita, which is not surprising given the declining share of farmers in the total population. Agricultural R&D spending per economically active agricultural population was $69.9 in 1996 compared with only $23.1 in 1976 (1993 international prices). By way of comparison, in 1996 Colombia spent $5.1 per capita and $53.2 per economically active agricultural population on agricultural R&D, slightly less than the corresponding Brazilian figures (Beintema et al. 2000a).

Figure 9—*Spending per Capita and per Economically Active Agricultural Population, 1971–96*



Source: Data underlying Table 10 for R&D expenditures. Population and economically active agricultural population from FAO (1999).

Note See Figure 8.

Cost Structures

In 1996, 72 percent of Embrapa's expenditures were for salaries, one percent higher than the average for the 15 state government agencies in our sample (Table 11). These shares are considerable higher than some other Latin American countries such as Colombia for example, whose agricultural R&D institutions (excluding higher education agencies and private enterprises) spent 59 percent of their total expenditures on salaries (Beintema et al. 2000a).

Table 11—*Total Costs by Various Cost-Categories, 1976–98*

	Embrapa				State Government Agencies			
	Personnel	Operational	Capital	Total	Personnel	Operational	Capital	Total
Number of agencies in sample				*(number)*				
		1				15		
Expenditures in constant local currencies				*(million 1996 reais per year)*				
1976–80	136.4	76.6	26.5	239.5	82.2	28.3	7.4	118.0
1981–85	177.7	98.4	45.9	322.0	98.8	29.1	11.1	139.0
1986–90	226.6	77.3	36.1	340.0	115.5	40.6	17.2	173.3
1991–95	322.2	77.3	35.3	434.7	123.7	42.6	13.1	179.3
1996	406.9	99.3	59.1	565.2	119.2	34.3	14.5	167.9
1998	328.6	127.5	22.6	478.7	na	na	na	na
1999	299.8	121.8	22.8	444.4	na	na	na	na
Expenditures in constant international dollars				*(million 1993 international dollars per year)*				
1976–80	140.1	78.6	27.2	245.9	84.4	29.1	7.6	121.1
1981–85	182.4	101.0	47.2	330.6	101.4	29.8	11.4	142.7
1986–90	232.7	79.3	37.1	349.1	118.6	41.7	17.7	177.9
1991–95	330.8	79.3	36.2	446.3	127.0	43.7	13.4	184.1
1996	417.7	101.9	60.7	580.3	122.4	35.2	14.8	172.4
1998	337.4	130.9	23.2	491.5	na	na	na	na
1999	307.8	125.1	23.4	456.3	na	na	na	na
Shares				(*percentages*)				
1976–80	57.0	32.0	11.1	100	69.7	24.0	6.3	100
1981–85	55.2	30.6	14.3	100	71.1	20.9	8.0	100
1986–90	66.7	22.7	10.6	100	66.6	23.4	9.9	100
1991–95	74.1	17.8	8.1	100	69.0	23.7	7.3	100
1996	72.0	17.6	10.5	100	71.0	20.4	8.6	100
1998	68.6	26.6	4.7	100	75.1[b]	20.8[b]	4.2[b]	100[b]
1999	67.5	27.4	5.1	100	na	na	na	na

Source: Compiled by authors from IFPRI/Embrapa survey, Embrapa (1993); UNICAMP (1997), Embrapa-DAF (1999), and IAC (2000).

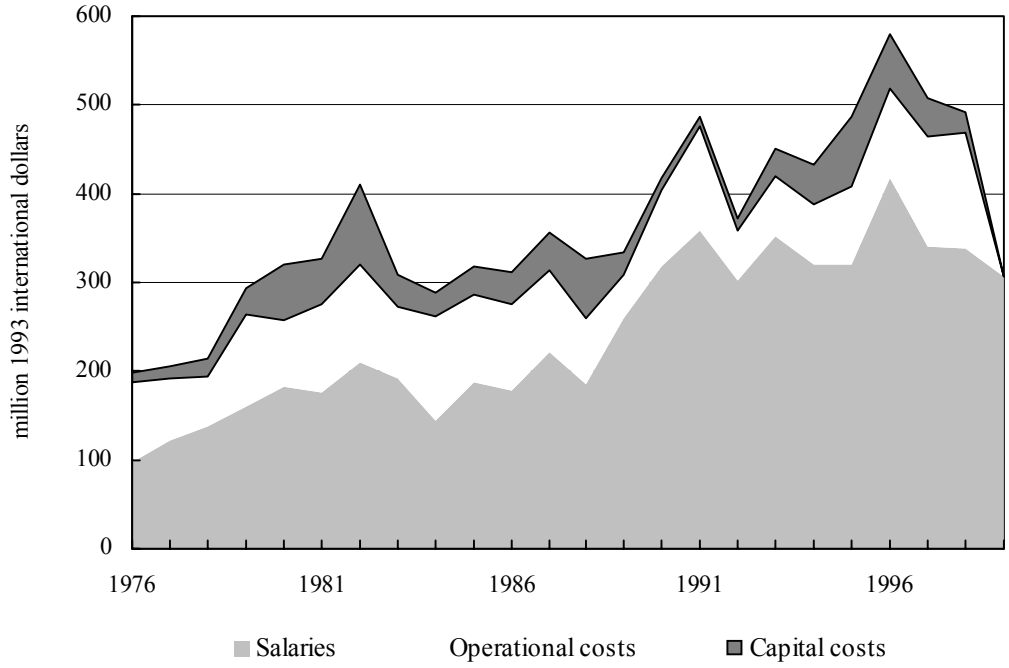
Note: Data from 1976 to 1995 are presented as five-year averages.

a. Embrapa expenditures exclude funds that were transferred to the state institutes.
b. Shares are based on expenditure data for 12 of the 15 state agencies in our sample.

The cost structures for state government agencies were comparatively stable over the 1976–96 period, but for Embrapa, salaries as a share of total spending increased (from 57 percent in the late 1970s to 68 percent in 1999), with a commensurate decline in the share of operational and capital expenses (Figure 10). The relatively low salary shares in the late 1970s and early 1980s reflects the substantial capital investments made by Embrapa during its formative years. In 1992, salaries claimed 82 percent of total spending, a consequence of the 25 percent reduction in total spending in that year compared with the previous one.

Coincident with the decline in funding for Embrapa and most state agencies in recent years is a cutback in capital expenditures and a reduction in the share of capital in total costs from 11 percent in 1996 to 5 percent in 1998. The 12 state agencies in our sample (for which we had more recent data) reduced their capital cost shares from 9 to 4 percent over the same period. Notably, Embrapa has managed to preserve and even increase the share of costs committed to operational expenses, squeezing salary (as well as capital) cost shares as total funding has declined in recent years.

Figure 10—*Embrapa's Expenditures by Cost Category, 1976–99*



Source: Embrapa-DAF (1999).

5. RESOURCES PER RESEARCHER

5.1. SUPPORT STAFF RATIOS

In 1996, the average number of support staff per scientist in our 44–agency sample was 3.9—comprising 0.7 fte technicians, 0.9 fte administrative personnel, and 2.3 other support staff such as laborers, guards, drivers, and so on (Table 12). This represents a considerably higher level of support than we observed for Colombia (where the corresponding support-staff-to-scientist ratio was 2.7 [Beintema et al. 2000a]). In 1996, Embrapa had 3.3 support staff per scientist, well below the 5.0 ratio for the 16 state government agencies in our sample, although the preponderance of support staff in the state

agencies consisted of laborers, guards, drivers, and so on. Higher education agencies had only 2.0 support staff per scientist, a pattern that is evident throughout much of Latin America.

Table 12—S*upport-Staff-to-Scientist Ratios, 1986–98*

	Government Agencies			Nonprofit Institutions	Higher Education Agencies	Total
	Embrapa	CEPEC	State			
				(*number*)		
Number of agencies in sample	1	1	16	3	23	44
Technicians per researcher						
1986	0.34	na	na	na	na	*na*
1991–95[a]	0.57	1.32	1.10	0.62	na	*na*
1996	0.59	1.76	0.91	0.57	0.55	*0.72*
Administrative support staff per researcher						
1986	0.68	na	na	na	na	*na*
1991–95[a]	0.84	0.94	1.31	0.55	na	*na*
1996	0.77	1.08	1.09	0.53	0.64	*0.87*
Other support staff per researcher						
1986	2.85	na	na	na	na	*na*
1991–95[a]	2.20	5.40	3.33	3.24	na	*na*
1996	1.98	7.02	2.95	3.14	1.00	*2.33*
Total support staff per researcher						
1986	3.88	na	na	na	na	*na*
1991–95[a]	3.61	7.66	5.74	4.41	na	*na*
1996	3.35	9.87	4.95	4.24	1.95	*3.90*
1998	3.20	na	na	na	na	*na*

Source: Compiled by IFPRI/Embrapa survey. Embrapa data from Embrapa-DAP (1999).

Note: Data exclude private enterprises.

a. Data from 1991 to 1995 are presented as five-year averages.

From 1991 to 1998 the number of support staff at Embrapa declined at a faster rate than total number of research staff so that the support-staff-per-scientist ratio fell from 3.7 to 3.1. Notably, most of the decline involved nontechnical support staff such that the ratio of technical support staff per scientist remained fairly constant. Moreover there was little variation in the ratios of technical and administrative support staff per scientist among Embrapa centers, but the other-support-to-scientist ratios varied considerably from center to center. For example, in 1996 CPAMN and CNPAF had other-support-to-scientist ratios twice those of the Embrapa average of 2.0, while the ratios for CNPDIA, CNPTIA, and NMA were far less than one tenth of the Embrapa average.

5.2. SPENDING PER SCIENTIST

Agricultural R&D expenditures per researcher in Brazil for our 45-agency sample (excluding private enterprises) increased at an average annual rate of 1.3 percent from $143,000 in the late 1970s to $202,000 in 1996 (in 1993 international dollars) or, in 1996 reais, 139,000 and 196,000 respectively (Table 13). Embrapa's expenditures per researcher were considerably higher than for their colleagues at other agricultural R&D agencies during 1976–96 (Figure 13). For example, Embrapa's expenditure per researcher of $277,000 in 1996 (in 1993 international dollars) was more than twice the comparable figure for the state government agencies.[40]

[40] Excluding additional expenditures for the voluntary retirement program, Embrapa's 1996 expenditure per researcher was $264,000, still more than twice the corresponding figure for the state agencies.

Table 13—*Trends in Spending per Scientist, 1976-99*

	Government Agencies			Nonprofit Institutions	Higher Education Agencies[a]	Subtotal	Private Enterprises[a]		Total
	Embrapa[a]	CEPEC[a]	State				National	Multinational	
Number of agencies					(*number*)				
in sample	1	1	22[a]	4[b]	17	45	8	3	*56*
Expenditures per researcher in constant									
local currencies					(*thousand 1996 reais per year)*				
1976–80	171.7	121.4	106.8	93.0	138.9	139.0	na	na	*na*
1981–85	199.9	149.5	100.2	114.0	149.0	149.1	na	na	*na*
1986–90	173.2	130.9	116.4	94.1	145.0	144.9	na	na	*na*
1991–95	205.8	157.3	125.8	100.4	167.6	167.6	187.0	260.9	*168.2*
1996	270.2	191.2	116.1	121.3	171.4	196.1	199.1	239.2	*196.3*
1998	232.1	na	121.7[c]	na	na	na	na	na	*na*
1999	215.3	na	na	na	na	na	na	na	*na*
Expenditures per researcher in constant									
international dollars					(*thousand 1993 international dollars per year)*				
1976–80	176.2	124.7	109.7	95.5	142.6	142.7	na	na	*na*
1981–85	205.3	153.5	102.9	117.1	153.0	153.0	na	na	*na*
1986–90	177.8	134.3	119.5	96.6	148.8	148.8	na	na	*na*
1991–95	211.3	161.5	129.1	103.1	172.0	172.1	191.9	267.9	*172.7*
1996	277.4	196.3	119.2	124.5	175.9	201.3	204.4	245.6	*201.5*
1998	238.2	na	125.0	na	na	na	na	na	*na*
1999	221.1	na	na	na	na	na	na	na	*na*
Annual growth rate[d]					(*percentages)*				
1976–81	8.0	12.4	0.2	8.7	5.4	5.4	na	na	*na*
1981–86	–4.5	–4.9	1.1	–2.3	–2.8	–2.8	na	na	*na*
1986–91	3.4	3.4	–1.2	–4.4	2.3	2.3	na	na	*na*
1991–96	4.4	4.2	–1.4	10.2	0.5	2.4	1.8	–2.2	*2.4*
1976–96	1.3	1.7	1.1	0.6	1.1	1.3	na	na	*na*

Source: Tables 6 and 10.

Note: Data are presented in five-year averages.

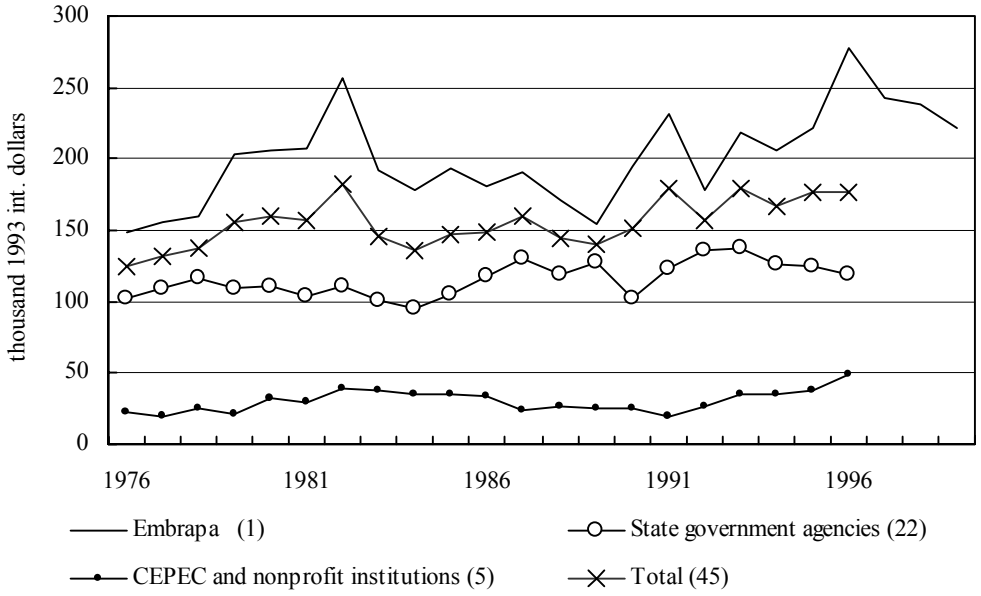
a. See Table 9.

b. Excluded from the sample is COPERSUCAR, which had considerably higher expenditures per researcher than the four agency average reported here.

c. Data for 5 of the 22 state agencies (accounting for 13 percent of total fte research expenditures at state agencies in 1996) were estimated using the trend from 1996 to 1998 for the 17 agencies for which data were available.

d. Least squares growth rates.

Figure 11—*Trends in spending per researcher by institutional category and total average, 1976-98*



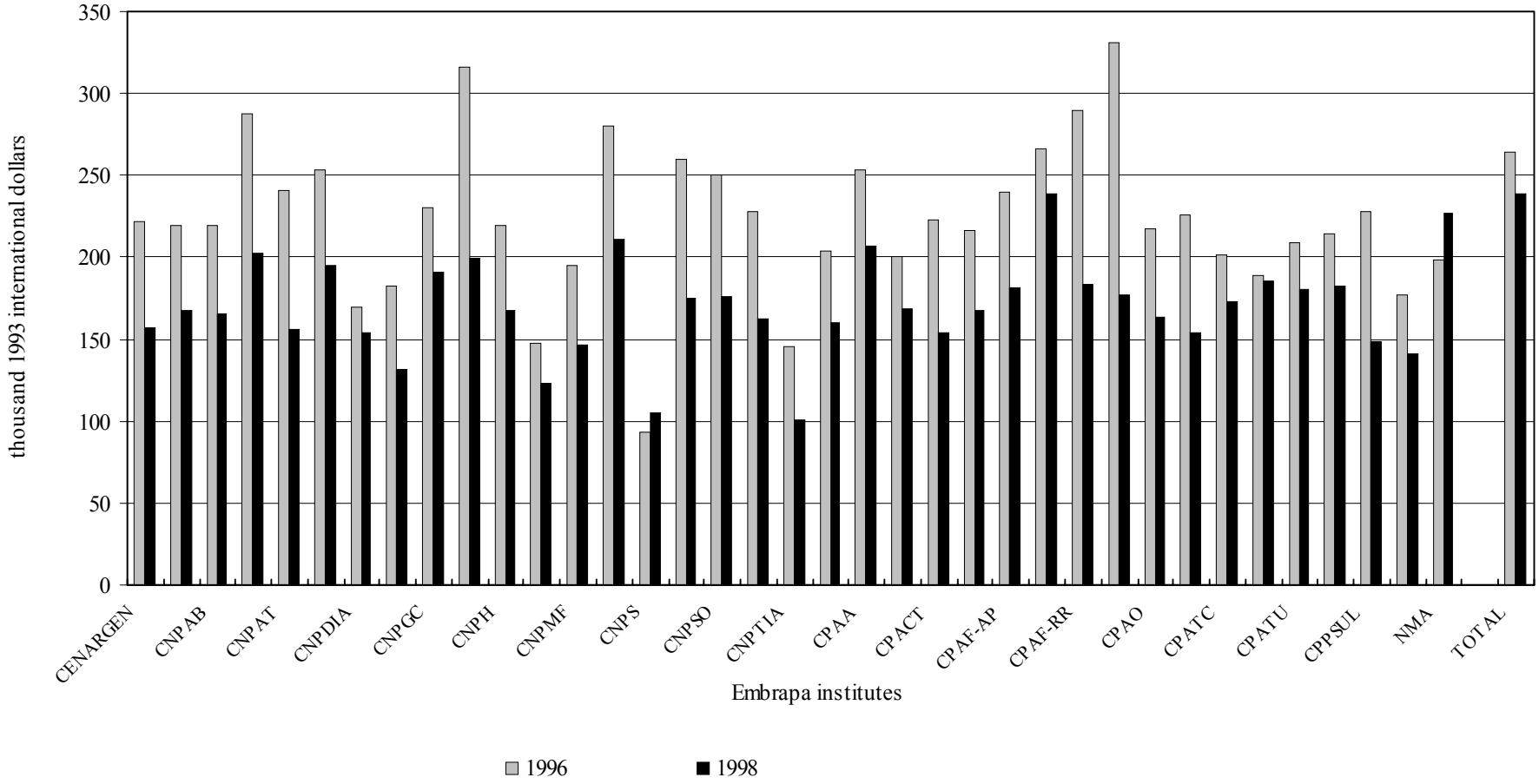
Source: Table 13.

Even after adjusting for the one-time charges resulting from Embrapa's voluntary retirement program in 1996, there were large differences in spending per scientist among the Embrapa centers, ranging from $114,000 for CNPS to $343,000 CPAMN (in international 1993 prices) (Figure 12a). More recent data show that expenditures per researcher for Embrapa as a whole declined to $221,000 in 1999.[41] Moreover, there is a good deal of volatility in these spending per scientist figures among Embrapa centers. In general, centers with comparatively high 1996 spending ratios experienced larger declines than those with lower initial ratios, so that spending per scientist ratios became more uniform across Embrapa centers (Figure 12a). There was no discernable pattern when comparing the 1996

[41] The decline in Embrapa's expenditures was greater than the decline in total research staff over this period (see sections 4.1 and 4.2).

spending per scientist estimated for state government agencies and nonprofit institutions in our sample with the corresponding 1998 figures (Figure 12b). The eight national private enterprises in our sample for which we had data had average expenditures per researcher of $204,000, less than the $246,000 per scientist incurred for the local operations of the three multinational enterprises in our sample (Table 13).

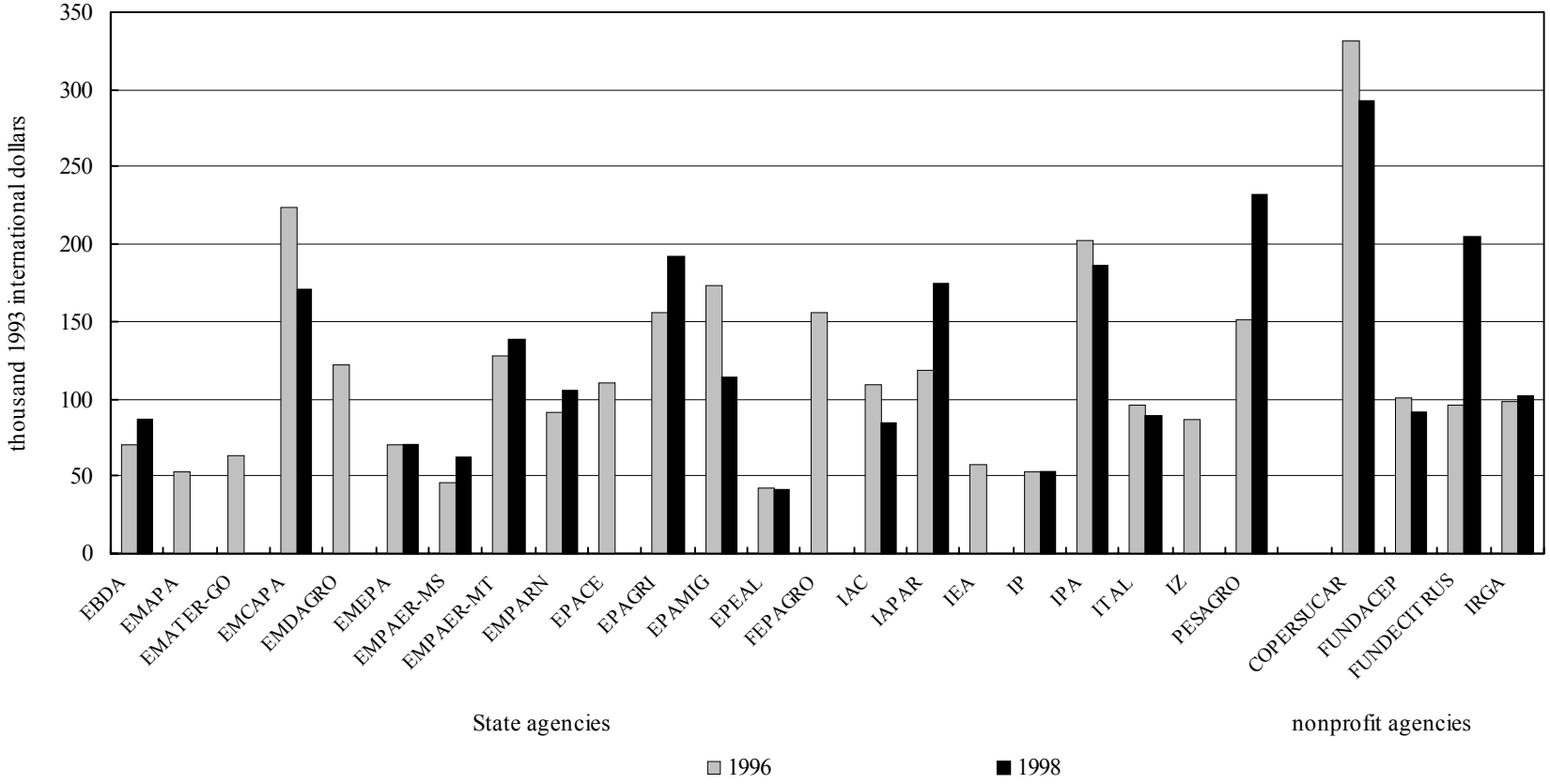
Figure 12a—*Differences among Embrapa Centers' Spending per Scientist, 1996 and 1998*



Source: Embrapa-DAP (1999).

Note: The total includes headquarters and other unspecified Embrapa units. The one-time salary expenditures incurred under the 1996 voluntary retirement program have been excluded to make the data for that year more comparable with the 1998 figures.

Figure 12b—*Differences among State Agencies and Nonprofit Institutions' Spending per Scientist, 1996 and 1998*



Source: Compiled by authors from IFPRI/Embrapa survey, Alburquerque (1997), and IAC (2000).

Note: For complete institutional names and additional information see Appendix Table B.1. EMAPA and EPACE were closed in 1998/99.

Salary Structures

Remuneration packages include salaries, and various monetary and nonmonetary fringe benefits, the composition of which varies markedly among agencies and over time, making it difficult to measure and meaningfully interpret these types of data. Mindful of these problems, we present evidence of the average salary structures of 23 Brazilian agricultural R&D agencies. In 1996, Embrapa's researchers were paid considerably more than their counterparts at the 19 state government agencies in our sample (Table 14). Embrapa's senior researchers were paid slightly higher salaries than their colleagues at the three nonprofit institutions in our sample, but junior researchers at Embrapa were paid less than their counterparts at the nonprofit institutions. The salaries paid to Embrapa's support staff were considerably higher than the average salaries received by their colleagues at the state agencies and nonprofit institutions.

Embrapa's researcher salaries are comparable with those paid to scientists working at the National Institute of Agricultural Research (INIA) in nearby Uruguay: senior researchers working at Embrapa receive a slightly lower salary, on average, than their colleagues at INIA, but junior researchers at Embrapa earn about 20 percent more than those working at INIA (Beintema et al. 2000b).

Table 14—*Average Monthly Salaries, 1996*

	Government Agencies		Nonprofit Institutions	Average
	Embrapa	State		
Number of agencies in sample	1	(*number*) 19	3	23
Salaries in local currencies		(*current reais*)		
Senior researcher	3,498[a]	2,267	3,373	2,465
Junior researcher	2,490	1,527	2,792	1,734
Technical support	2,503	1,253[b]	1,653	1,364[c]
Secretary	1,468	614[b]	997	705[c]
Laborer	826	304	433	344
Salaries in constant international dollars		(*1993 international dollars*)		
Senior researcher	3,591[a]	2,328	3,463	2,531
Junior researcher	2,556	1,568	2,867	1,780
Technical support	2,570	1,286[b]	1,697	1,400[c]
Secretary	1,507	630[b]	1,023	723[c]
Laborer	848	312	444	353

Source: Compiled by authors from IFPRI/Embrapa survey; Embrapa data from Embrapa-DAF (1999).

Note: Include fringe benefits.

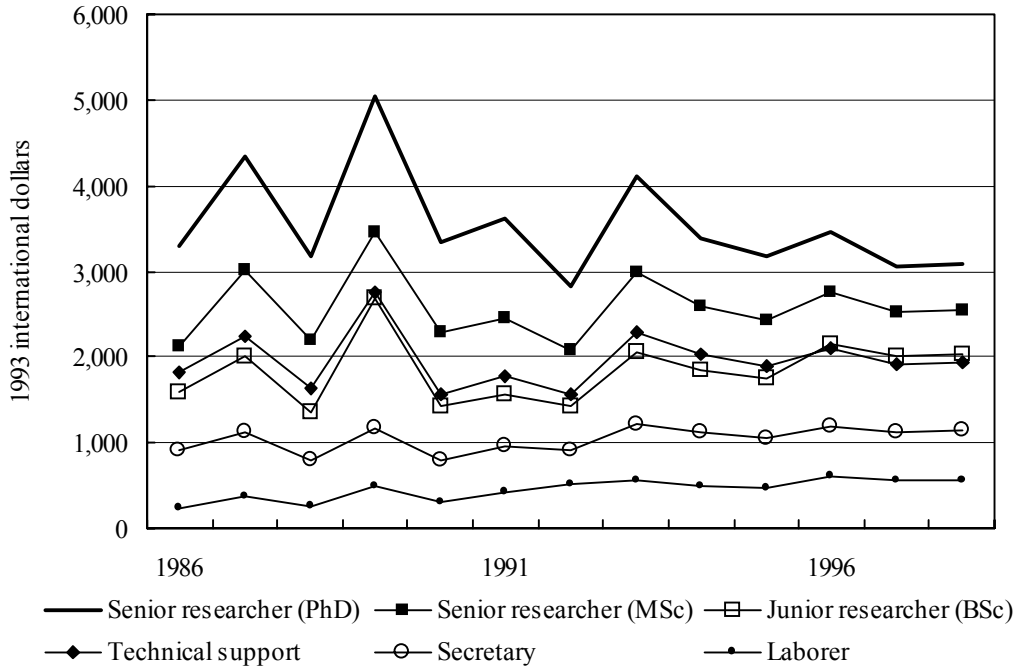
a. Average for researchers with MSc and PhD degrees.
b. Average for 18 agencies.
c. Average for 23 agencies.

After adjusting for inflation, average Embrapa salaries have been fairly erratic over the years (Figure 13).[42] Salaries for most staff categories increased only marginally since 1986, with little or no growth since 1996. An exception to this longer-run pattern of slow growth is the salaries paid to senior researchers whose average monthly salary declined from $3,294 in 1986 to $3,080 in 1998 (in 1993 international prices and excluding fringe benefits). Average salaries paid to junior researchers were lower than those paid to technical support staff during the late 1980s, but subsequently grew at a

[42] There is some spatial variation in the salaries paid to Embrapa scientists of similar qualifications and experience. Personnel working in the Northern region (with the exception of the research center in Pará) receive a 25 percent salary supplement reflecting the higher costs of living in this region.

faster rate so that they are now above those of technical staff. Starting from a very low base, the salaries received by laborers more than doubled from 1986 to 1998.

Figure 13—*Salary Trends for Embrapa Staff, 1986-98*



Source: Embrapa-DAF (1999).

Note: Data exclude fringe benefits.

6. RESEARCH ORIENTATION

The allocation of resources among various lines of research is a significant policy decision, and so detailed information was collected on the number of fte-researchers working on specific commodity and thematic areas.

6.1 COMMODITY FOCUS

More than one half of the 4,061 fte researchers in our sample of 85 agencies conducted crops research in 1996 (Table 15) of which 907 were located at one of the 37

Embrapa centers. Livestock accounted for 18 percent of the total while 8 percent was involved in research related to natural resources. The overall research orientation of Embrapa, the state government agencies, and the higher education agencies were generally in line with our sample averages, an exception being forestry research where Embrapa and the universities have a higher intensity of effort than the state agencies. The four nonprofit institutions and the three multinational private enterprises were only engaged in crop research. The share of fisheries research in total fte research staff in our 85-agency sample was only 4 percent in 1996 (a slight underestimate of the relevant share given that our sample omits IBAMA and a several other agencies known to undertake some fisheries research).

Table 15—*Commodity Orientation of Brazilian Researchers, 1996*

	Government Agencies			Nonprofit	Higher Education		Private Enterprises		
	Embrapa Centers	CEPEC	State	Institutions	Agencies	Subtotal	National	Multinational	Total
Number of agencies in sample	37	1	21	4	10	74	8	3	85
Number of researchers					(*fte researchers*)				
Crops	906.7	73.9	871.5	102.0	109.5	2,063.6	38.0	17.0	2,118.6
Livestock	322.2	4.5	339.4	–	53.2	719.4	18.1	–	737.4
Forestry	104.0	–	27.5	–	15.0	146.4	18.4	–	164.8
Fisheries	10.0	–	86.3	–	1.9	98.2	–	–	98.2
Postharvest	81.6	10.7	112.9	15.0	13.5	233.7	–	–	233.7
Natural resources	201.7	–	128.1	–	11.9	341.6	0.5	–	342.1
Other	196.8	–	163.6	–	6.1	366.5	–	–	366.5
Total	*1,823.0*	*89.0*	*1,729.4*	*117.0*	*211.0*	*3,969.4*	*75.0*	*17.0*	*4,061.4*
Shares by commodity					*(percentage)*				
Crops	49.7	83.0	50.4	87.2	51.9	52.0	50.6	100	52.2
Livestock	17.7	5.0	19.6	–	25.2	18.1	24.1	–	18.2
Forestry	5.7	–	1.6	–	7.1	3.7	24.5	–	4.1
Fisheries	0.6	–	5.0	–	0.9	2.5	–	–	2.4
Postharvest	4.5	12.0	6.5	12.8	6.4	5.9	–	–	5.8
Natural resources	11.1	–	7.4	–	5.6	8.6	0.7	–	8.4
Other	10.8	–	9.5	–	2.9	9.2	–	–	9.0
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
Shares by institutional category					*(percentage)*				
Crops	42.8	3.5	41.1	4.8	5.2	97.4	1.8	0.8	100
Livestock	43.7	0.6	46.0	–	7.2	97.5	2.5	–	100
Forestry	63.1	–	16.7	–	9.1	88.8	11.2	–	100
Fisheries	10.2	–	87.9	–	1.9	100	–	–	100
Post-harvest	34.9	4.6	48.3	6.4	5.8	100	–	–	100
Natural resources	58.9	–	37.4	–	3.5	99.8	0.2	–	100
Other	53.7	–	44.6	–	1.7	100	–	–	100
Total	44.9	2.2	42.6	2.9	5.2	97.7	1.8	0.4	100

Source: Compiled by authors from IFPRI/Embrapa survey.

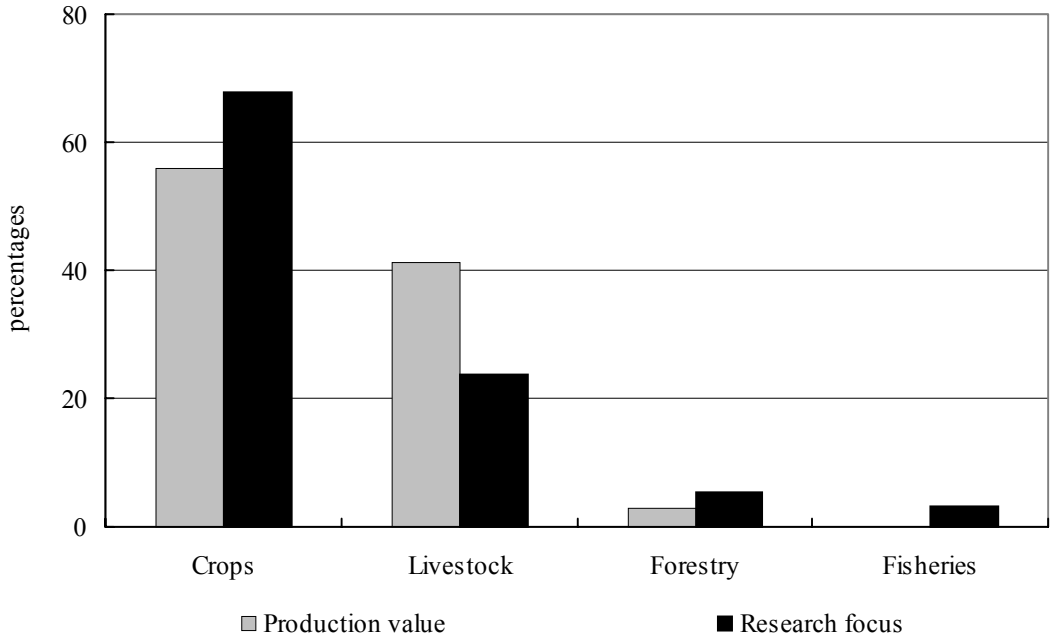
The congruency or parity model is a commonly used method of assessing the allocation of research resources. This usually involves allocating funds (or, in this instance research personnel) among research areas in proportion to their corresponding contribution to the value of agricultural production. For example, if the value of rice output were twice that of corn, then congruence would be achieved if research on rice were to receive twice as much funding (or, say, employ twice as many scientists) as corn. The model assumes that an additional dollar spent on research would yield a higher return if spent in areas with a relatively low ratio of research funding to output value, therefore funds should flow toward programs with relatively low research intensities and from those with high research intensities. If research spending or scientist shares were congruent with the corresponding value of output for a particular commodity then the congruency ratio for that commodity—measuring the commodity share of researchers to the corresponding share of output—would be equal to 1.0.

It is important to note, as Alston et al. (1998) describe, that the model overlooks key factors affecting the payoff to R&D, such as the differences in probability of research success, likely adoption rates, and the likely extent of research-induced productivity gains. It also does not account for the spill-in of technologies from other countries or differences in the costs per scientists among different areas of R&D. So, while the congruence rule is a useful tool for allocating resources, and a distinct improvement over precedence and some other shortcut methods, congruency ratios that differ from 1.0 are not necessarily a cause for concern.

Figure 14 shows the shares of crops, livestock, fisheries, and forestry in gross value of agricultural production with the corresponding share of research staff in these

areas. In 1996, 68 percent of the 3,119 researchers in this sample undertook crops research—considerably higher than the share of crops in the total value of production—resulting in a congruency ratio of 1.2. The congruency ratios for fisheries and forestry were also higher than 1.0. In contrast, the share of livestock research was 18 percent lower than the corresponding share in total value of production the same year, resulting in a congruency ratio of 0.6.

Figure 14—*Congruence between Crop and Livestock R&D and Production Value, 1996*

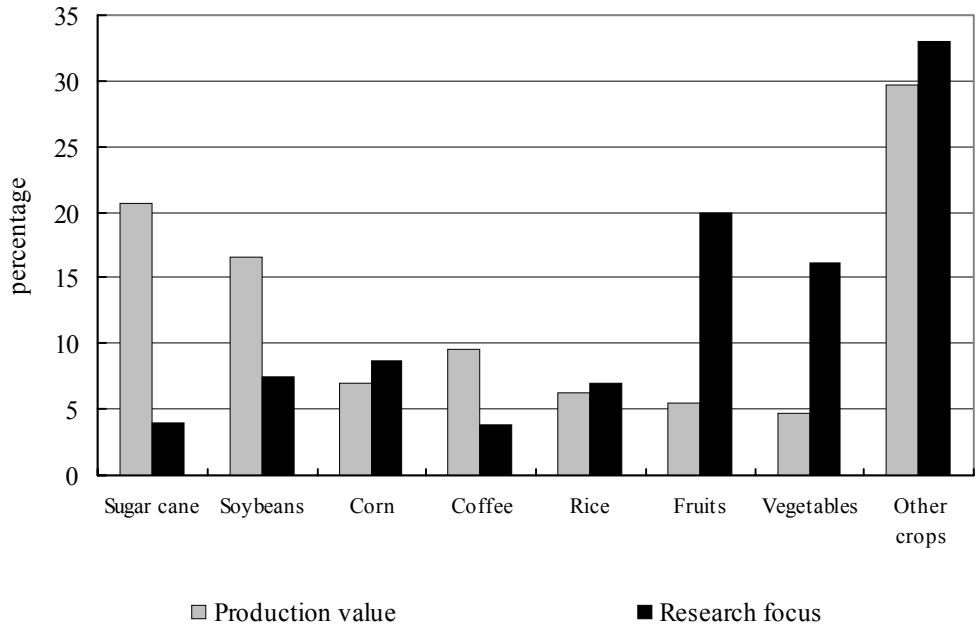


Source: Compiled by authors from IFPRI/Embrapa survey. 1996 production value from IBGE (1999b).

There were major incongruencies between the shares of researchers and output values revealed at the level of an individual crop (Figure 15a). Sugarcane, for example, accounted for 21 percent of the total value of crop production in 1996 but only 4 percent of the 2,119 fte crop researchers in the sample conducted sugarcane research (the congruency ratio was 0.2). Congruence ratios for soybeans and coffee were also

comparatively low at 0.5 and 0.4 respectively. For other crops like corn, rice, and, especially, fruits and vegetables the congruency ratios were above 1.0, indicating a more intensive research effort than a consideration of crop values alone would justify.

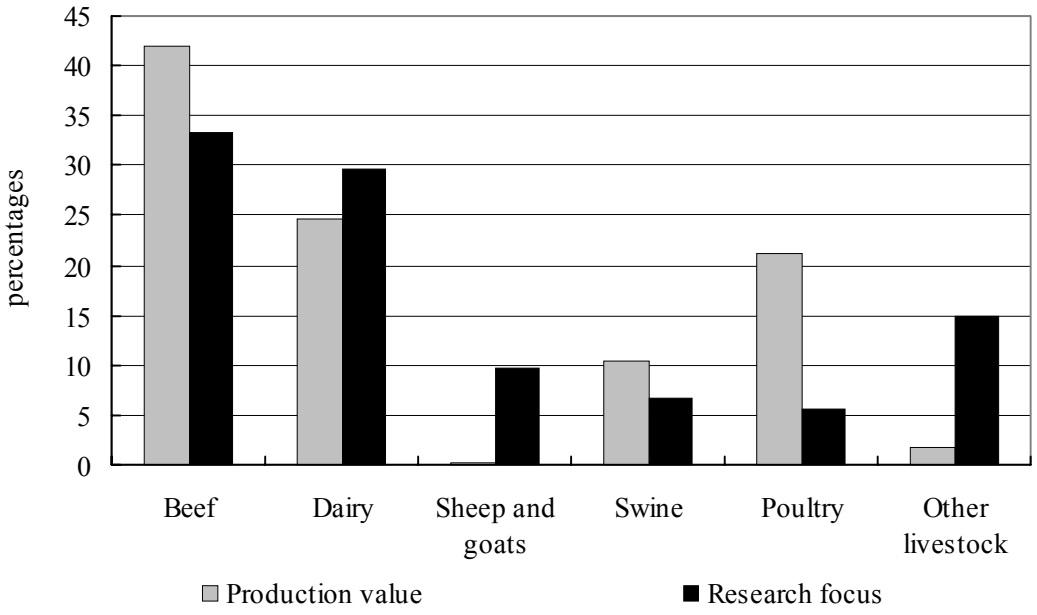
Figure 15a—*Congruence between Crop R&D and Production Value, 1996*



Source: Compiled by authors from IFPRI/Embrapa survey. 1996 production value from IBGE (1999b).

There were also significant incongruencies between fte researcher and value-of-output shares for particular lines at total fte livestock researchers in 1996. With the exception of dairy (ratio of 1.2), none of the specified livestock items had congruency ratios close to 1.0 (Figure 15b). The shares of beef and poultry research were considerably smaller than their corresponding shares of total value of livestock production. In contrast, the share of sheep and goat production in total value of livestock production was negligible or nonexistent (0.1 percent) while 73 (that is, 10 percent) of the 733 fte livestock researchers in the sample were involved in sheep and goat research.

Figure 15b—*Congruence between Livestock R&D and Production Value, 1996*



Source: Compiled by authors from IPFRI/Embrapa survey. 1996 production value from IBGE (1999b).

6.2 THEMATIC FOCUS

In 1996, 17 percent of the 4,059 fte researchers in our 86-agency sample were working on crop genetic improvement research and 23 percent on other crop themes (excluding pest and disease control) (Table 16). The data in Table 16 reinforce the importance of Embrapa and state government agencies in total Brazilian agricultural R&D. Together these agencies accounted for between 85 and 93 percent of the research in most themes, with the exception of livestock pest and disease control where the higher education agencies accounted for a comparatively large share of the 21 percent of total fte researchers working on this theme. Embrapa accounted for more than two thirds of the total fte research staff working on water and other natural resources issues.

Table 16—*Thematic Orientation of Brazilian Researchers, 1996*

	Government Agencies			Nonprofit Institutions	Higher Education Agencies	Subtotal	Private Enterprises		Total
	Embrapa Centers	CEPEC	State				National	Multinational	
					(*number*)				
Number of agencies in sample	36	1	21	5	12	75	8	3	86
Number of researchers					(*fte researchers*)				
Crop genetic improvement	294.1	9.2	266.4	50.5	17.5	637.6	34.8	7.4	679.9
Crop pest and disease control	193.6	20.6	131.8	16.2	13.4	375.6	5.7	9.2	390.5
Other crop	370.3	21.7	452.1	20.7	37.8	902.6	10.3	0.5	913.3
Livestock genetic improvement	56.7	–	71.9	–	16.8	145.4	10.9	–	156.3
Livestock pest and disease control	26.2	–	87.7	–	27.5	141.5	4.3	–	145.8
Other livestock	207.3	4.3	217.1	–	53.6	482.3	2.6	–	484.8
Soil	121.5	6.6	86.4	3.2	17.7	235.5	1.4	–	236.9
Water	48.3	1.1	16.7	2.6	3.9	72.6	–	–	72.6
Other natural resources	107.1	6.6	49.7	–	3.1	166.5	1.3	–	167.8
Postharvest	90.1	6.6	121.0	17.3	10.3	245.2	0.3	–	245.5
Other	288.9	12.5	228.5	6.6	25.5	561.9	3.4	–	565.3
Total	*1,804.0*	*89.0*	*1,729.4*	*117.0*	*227.2*	*3,966.6*	*75.0*	*17.0*	*4,058.6*
Shares by research theme					(*percentage*)				
Crop genetic improvement	16.3	10.3	15.4	43.1	7.7	16.1	46.4	43.5	16.8
Crop pest and disease control	10.7	23.1	7.6	13.8	5.9	9.5	7.6	53.8	9.6
Other crop	20.5	24.4	26.1	17.7	16.7	22.8	13.7	2.6	22.5
Livestock genetic improvement	3.1	–	4.2	–	7.4	3.7	14.5	–	3.9
Livestock pest and disease control	1.5	–	5.1	–	12.1	3.6	5.8	–	3.6
Other livestock	11.5	4.8	12.6	–	23.6	12.2	3.4	–	11.9
Soil	6.7	7.4	5.0	2.7	7.8	5.9	1.9	–	5.8
Water	2.7	1.2	1.0	2.2	1.7	1.8	–	–	1.8
Other natural resources	5.9	7.4	2.9	–	1.4	4.2	1.7	–	4.1
Postharvest	5.0	7.4	7.0	14.8	4.5	6.2	0.4	–	6.0
Other	16.0	14.0	13.2	5.6	11.2	14.2	4.6	–	13.9
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
Shares by institutional category					(*percentage*)				
Crop genetic improvement	43.3	1.3	39.2	7.4	2.6	93.8	5.1	1.1	100
Crop pest and disease control	49.6	5.3	33.8	4.1	3.4	96.2	1.5	2.3	100
Other crop	40.5	2.4	49.5	2.3	4.1	98.8	1.1	0.0	100
Livestock genetic improvement	36.3	–	46.0	–	10.7	93.0	7.0	–	100
Livestock pest and disease control	18.0	–	60.2	–	18.9	97.0	3.0	–	100
Other livestock	42.8	0.9	44.8	–	11.0	99.5	0.5	–	100
Soil	51.3	2.8	36.5	1.4	7.5	99.4	0.6	–	100
Water	66.5	1.5	23.0	3.6	5.4	100	–	–	100
Other natural resources	63.8	3.9	29.7	–	1.9	99.2	0.8	–	100
Postharvest	36.7	2.7	49.3	7.0	4.2	99.9	0.1	–	100
Other	51.1	2.2	40.4	1.2	4.5	99.4	0.6	–	100
Total	44.4	2.2	42.6	2.9	5.6	97.7	1.8	0.4	100

Source: Compiled by authors from IFPRI/Embrapa survey.

6.3. REGIONAL ASPECTS

Brazil's agricultural R&D resources are not equally distributed among the five geographical regions identified in Table 17. In 1996 only 7 percent of the 3,999 fte researchers in a 80-agency sample (excluding higher education and private enterprises) were located in the northern region, while the Southeast, which includes the state of São Paulo, accounted for 35 percent of the total. Embrapa's research staff were more equally spread among the five regions than the state government agencies. None of the seven states in the Northern region—where most of Brazil's forestry resources and biodiversity is located—support a state government research agency although Embrapa maintains centers in six of the seven states. In 1996 close to one half of the fte researchers working for the state government agencies were located in the Southeastern region. This region also accounted for 74 percent of the fte researchers working at the 11 private enterprises for which we had data and more than half of the fte researchers at the five nonprofit institutions in our sample. Embrapa's share in total fte research staff was also high in the Center-West region, where 416 of the regional total of 519 fte researchers were employed at one of the seven Embrapa centers. Embrapa's presence in this region is even stronger if its headquarter staff were considered.

Table 17—*Research Staff and Expenditures by Institutional Category and Region, 1996*

	North	Center West	South	Northeast	Southeast	Total
			(number)			
Number of agencies in sample[a]	6	10	16	16	32[b, c]	80
Researchers			*(fte's)*			
Embrapa centers	282.0	416.0	353.0	339.0	436.0	1,826.0
CEPEC	–	–	–	89.0	–	89.0
State government agencies	–	99.6	422.0	447.0	793.8	1,762.4
Embrapa to state agencies[d]	–	3.0	10.0	77.0	27.0	117.0
Nonprofit institutions	–	–	51.0	–	66.0	117.0
Private enterprises	–	–	21.5	–	66.0	87.5
Regional total	*282.0*	*518.6*	*857.5*	*952.0*	*1,388.8*	*3,998.9*
Research expenditures			*(in million 1993 international dollars)*			
Embrapa centers	68.2	98.5	84.2	79.6	92.6	423.2
CEPEC	–	–	–	17.5		17.5
State government agencies	–	6.6	60.0	48.8	94.7	210.0
Embrapa to state agencies[d]	–	0.9	1.4	13.5	4.6	20.4
Nonprofit institutions	–	–	6.5	–	20.5	27.0
Private enterprises	–	–	7.2	–	13.1	20.3
Regional total	*68.2*	*106.0*	*159.3*	*159.4*	*225.4*	*718.4*
Expenditures per researcher			*(in thousands 1993 international dollars)*			
Embrapa centers	241.8	236.7	238.5	234.9	212.5	231.7
CEPEC	–	–	–	196.3	–	196.3
State government agencies	–	66.7	142.1	109.1	119.3	119.2
Embrapa to state agencies[d]	–	307.8	141.2	175.8	168.8	174.6
Nonprofit institutions	–	–	127.9	–	310.2	230.7
Private enterprises	–	–	336.9	–	198.1	232.2
Regional total	*241.8*	*204.5*	*185.8*	*167.4*	*162.3*	*179.7*

Source: Compiled by authors from IFPRI/Embrapa survey; Embrapa data from Embrapa-DAF (1999) and Embrapa-DAF (1999).

Notes: See note Appendix Table B.1 for a listing of Brazilian states for each region. Data exclude higher education agencies, IB, and Embrapa headquarters' research staff and expenditures.

a. Embrapa 37 centers are counted individually (see Appendix Table B.1).
b. Excludes IB.
c. AGROCERES' five research entities are counted individually (see Appendix Table B.1).
d. Refers to Embrapa researchers outposted to state agencies and related personal expenditures.

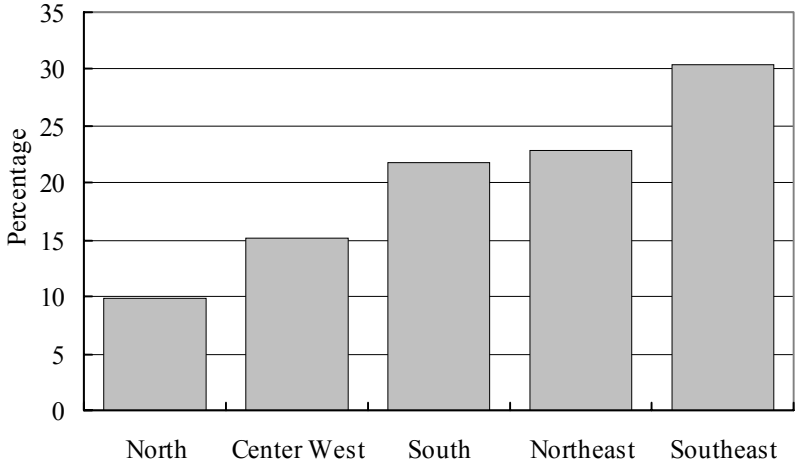
Expenditures per researcher are highest in the Northern region because Embrapa—with its comparatively higher spending-per-scientist ratios—is the only agency with researchers in this region. Expenditures per researcher in the Center-West region are also higher than the country average, again, the result of a strong Embrapa presence in this region.

Our incomplete sample of universities, made it impractical for us to assess the regional distribution of university-based research effort. However, Reifschneider and Lele (1998) provide evidence of large regional disparities in the distribution of professors engaged in postgraduate agricultural science courses in 1993. Only 2 percent of the professors were located in the Northern region and 3 percent in the Center-west regions, with the Southeastern region alone accounting for two thirds of the total.

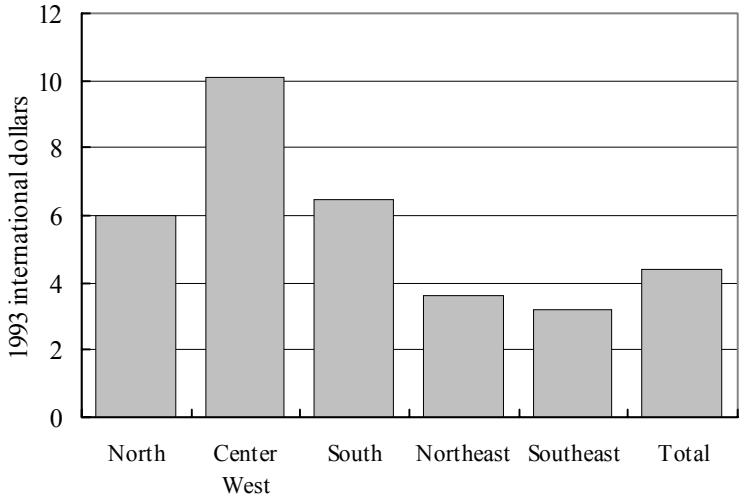
Although it is important to acknowledge the regional differences of Brazilian agricultural R&D expenditures and research staff, it would make more sense to look at regional differences in indicators such as agricultural R&D expenditures as a percentage of regional value of agricultural production or per capita and per total economically active agricultural population (Figure 16, panels a to d). The Southeastern region had the highest share of nonacademic public agricultural R&D expenditures in 1996 (panel a), but the lowest expenditures per capita of all five regions (panel b). This was because the Southeastern region was home to 67 million people, about 43 percent of Brazil's total population in 1996. The Center-West region, which includes the Federal District, had the highest expenditures per capita in 1996. Panels c and d provide another perspective on the spatial pattern of spending, panel c reporting expenditures per farmer and panel d expenditures as a share of agricultural gross value added.

Figure 16a-d—*Regional Indicators of Nonacademic Agricultural R&D, 1996*

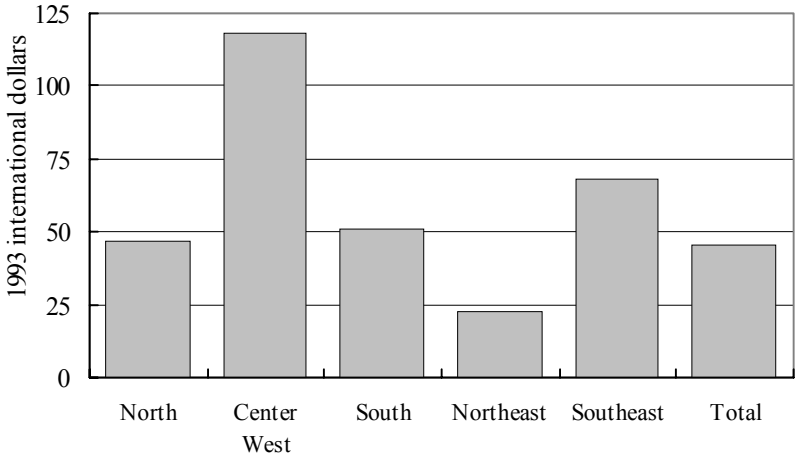
Panel a: *Share of total expenditures by region, 1996*



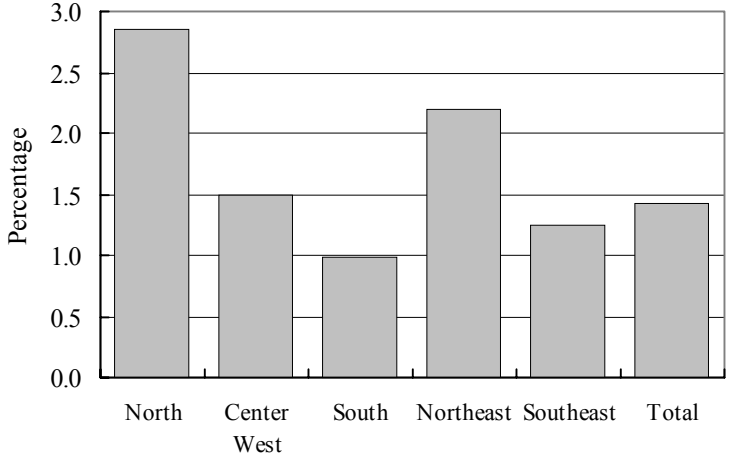
Panel b: *Total expenditures per capita by region, 1996*



Panel c: *Total expenditures per farmer by region, 1996*



Panel d: *Total expenditures as a percentage of gross value added by region, 1996*



Source: Compiled by authors from IFPRI/Embrapa survey. Value of agricultural production, total population, and number of farmers from IBGE (1996 and 1999b).

Note: Excludes Embrapa headquarter, higher education agencies, and private enterprises. Population data from IBGE differ slightly from FAO series used in Figure 9.

Comparisons of local expenditures on research to local agricultural production and population provide indications of the local intensity agricultural research, but do not account for issues such as spill-ins of research done elsewhere. For example, many Embrapa centers focus on specific commodities and their research is intended to effect crop production nationally, in contrast with the state agencies that focus on state-level research problems.

7. CONCLUSION

Brazil accounts for about half of the total agricultural R&D investments in Latin America and the Caribbean (Pardey and Beintema 2001) and employs the third largest number of agricultural scientists in the developing world. In 1996, Brazil employed more than 5,000 fte researchers and invested more than $1 billion (1993 international dollars) in agricultural R&D.

The organization of agricultural R&D in Brazil is complex with numerous federal and state government agencies, higher education agencies, nonprofit institutions, and private enterprises. Nonetheless, Brazilian agricultural R&D is still predominantly a public sector affair—by our estimates government agencies accounted for 79 percent of the country's agricultural R&D expenditures in 1996. There seems to be an increasing amount of agricultural technology provided by the private sector, but comparatively little of the private research to generate these technologies is conducted in Brazil. Among the government agencies, Embrapa dominates. It accounts for 72 percent of government agricultural R&D spending, and spending per scientist for the state agencies is about half the comparable Embrapa figure. Both Embrapa and the state government agencies are

still heavily reliant on government sources of support. In 1996, government provided about four fifths of the funds going to Embrapa as well as the state research agencies. Funding for Brazilian agricultural R&D tends to rise and fall with the general state of the economy. Although funding has trended upwards since the mid 1970s, the economic downturns of the early 1980s and the late 1990s saw a commensurate cutback in funding for agricultural R&D.

In terms of the intensity of investment in agricultural R&D Brazil is now looking more like a developed country, albeit at the lower end of the developed-country range. In 1996, Brazil invested $1.70 for every $100 of agricultural output, more than double the 1976 figure and well above the intensity of investment of most other Latin American countries.

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APPENDIX A

Definitions and Concepts

Measuring National Agricultural R&D Effort

The construction of quantitative and internationally comparable expenditure, personnel, and related measures of national agricultural research activities requires a precise idea of what, in fact, is being measured. Since these activities are open to a variety of interpretations, it is necessary to define rather precisely the concepts used in this paper. Our approach adheres, wherever possible, to the internationally accepted statistical procedures and definitions developed by the OECD and UNESCO for compiling R&D statistics (OECD 1994 and UNESCO 1984). For statistical purposes we used the following norms:

National. The concept of "national" research used in this report refers to all research conducted by all public and private agencies that have a domestic orientation. Research activities of supranational agencies are excluded.

Agricultural. Agricultural research, as defined here, includes research on crops, livestock, forestry, fisheries, natural resources, and the socioeconomic aspects of primary agricultural production. Also included is research on pre- and post-farm aspects such as input supply and postharvest or food-processing research. Ideally, pre-, on-, and post-farm oriented research should be itemized separately to aid analysis and understanding, but the realities are that it is often difficult to identify research at this level of detail.

Research. Research is often performed in conjunction with other activities such as technology transfer, extension, education, and production. To the extent possible, research activities (in terms of expenditures and staff) are differentiated from these other activities. However, for practical reasons, if nonresearch activities are an integral part of an institute's research activities and account for less than 20 percent of the resources of the institute, it was expedient to classify all the activities of the institute as being research-related. Occasional or ad-hoc research activities by agencies without a clear research mandate are excluded.

Institutional Classification

The Frascati Manual (OECD 1994) identifies five institutional categories related to the conduct of research, of which the following three are relevant for this paper:[43]

[43] The two institutional categories not included here are “private nonprofit” and “abroad.” In the 1993 version of the Frascati Manual the scope of the private nonprofit category was reduced substantially compared with earlier versions of the manual and now only includes: (a) nonmarket, private nonprofit institutions serving households; and (b) private individuals and households. Research agencies that are not directly controlled by but receive more than 50 percent of their funding from government, universities, or business enterprises should be assigned accordingly. Consequently the private nonprofit category has become almost negligible as a research-executing category, although it still plays some role as a source of support for research. By restricting our survey to “national” research, the institutional category “abroad” is not relevant.

(1) Government agencies. This category includes all agencies that are controlled and mainly financed by the government. Agencies that are not directly controlled, but are mainly financed by the government are also classified as government agencies.

(2) Higher education agencies. This category includes all public and private universities, colleges of technology, and other higher education institutes. Also included are all research institutes and experimental stations that are controlled directly, administered, or associated with higher education agencies.

(3) Business enterprises. This category comprises the following three subcategories: (3a) public enterprises; (3b) private enterprises; and (3c) nonprofit institutions. The nonprofit subcategory covers research undertaken on the collective behalf of business enterprises and which they control and mainly finance—for example, research controlled and mainly financed by commodity boards and farmer organizations. A further distinction among private enterprises is that of national versus multinational, the latter considered being private enterprises with at least 50 percent of foreign ownership.

Full-Time Equivalent (fte)

A full-time-equivalent researcher year is taken to be a person who holds a full-time position as a researcher during the whole year. Adjustments to full-time equivalents have only been made when: (a) a research position was part-time; (b) a research position was not filled for the whole year; and (c) the position explicitly involved tasks other than agricultural research. In the latter case an estimate was made of the time spent on agricultural research. No adjustments were made, however, for vacation or sick leave, nor for time spent on administration, meetings, travel, or other activities that form part of the normal duties required to support research. Following this line of reasoning, professional staff in management positions was classified as research staff. Also, research staff that were on study leave, but fully supported in terms of salaries and benefits, were included.

The degree status of researchers is determined on the following basis: 3–4 years full-time university education (BSc), 5–6 years (MSc), and more than 6 years plus doctorate thesis (PhD).

Deflators and Exchange Rates

All expenditure figures were first compiled in current local currency units. To facilitate comparisons over time and across countries, these figures were deflated with a local GDP deflator to the base year 1993, and then converted to a common currency (U.S. dollars) using the 1993 Purchasing Power Parity (PPP) over GDP. PPPs are synthetic exchange rates that attempt to reflect the purchasing power of a country's currency. The PPPs used here are derived from the 2000 World Development Indicators (World Bank 2000). For additional information on currency conversion methods in this context see Pardey, Roseboom, and Craig (1992).

Nomenclature for Tables in Text

A zero indicates an actual observation of zero; a dash indicates an observation is not relevant (due to institutional mergers, closures, and so on), while "na" indicates an observation that is not available. In the text we note any marked deviations from these data compilation norms and include points of clarification if warranted.

APPENDIX B

Overview of Agricultural R&D Agencies in Brazil

Table B.1—*Overview of Agricultural R&D Agencies in Brazil, 1996*

Supervising Agency	Executing Agency			Research Focus (major commodities)	State[b]	Number of Researchers	
	Name (Portuguese)[a]	Name (English)	Acronym			Total	fte's
Government agencies, federal							
Ministério da Agricultura e do Abastecimento (MAA), Empresa Brasiliera de Pesquisa Agropecuária (Embrapa)	Centro Nacional de Pesquisa de Recursos Genéticos e Biotecnologia (1974)	National Center for Research on Genetic Resources and Biotechnology	CENARGEN	genetic resources, biotechnology	DF	114	114.0
	Centro Nacional de Pesquisa de Algodão (1975)	National Center for Research on Cotton	CNPA	cotton	PB	39	39.0
	Centro Nacional de Pesquisa Agrobiologia (1989/1992)	National Center for Research on Agrobiology	CNPAB	agrobiology, soils, ecology	RJ	32	32.0
	Centro Nacional de Pesquisa de Arroz e Feijão (1974)	National Center for Research on Rice and Beans	CNPAF	upland rice, beans	GO	52	52.0
	Centro Nacional de Pesquisa de Agroindústria Tropical (19??)	National Center for Research on Tropical Agroindustry	CNPAT	tropical agroindustry, nuts, drinks, fruits, vegetables, ornamental plants, flowers	CE	51	51.0
	Centro Nacional de Pesquisa de Caprinos (1975)	National Center for Research on Goats	CNPC	sheep, goats, pastures	CE	27	27.0
	Centro Nacional de Pesquisa a Desenvolvimento de Instrumentação Agropecuária (1985)	National Center for Research on Agricultural Instrumentation	CNPDIA	instrumentation, biotechnology, agroindustry	SP	19	19.0
	Centro Nacional de Pesquisa de Florestas (1984)	National Center for Forest Research	CNPF	forestry	PR	52	52.0
	Centro Nacional de Pesquisa Gado de Corte (1974)	National Center for Research on Beef Cattle	CNPGC	beef, cattle, pastures	MS	48	48.0
	Centro Nacional de Pesquisa de Gado de Leite (1974)	National Center for Research on Dairy Cattle	CNPGL	dairy	MG	65	65.0
	Centro Nacional de Pesquisa de Hortaliças (1981)	National Center for Research on Vegetables	CNPH	vegetables, postharvest, biotechnology	DF	50	50.0
	Centro Nacional de Pesquisa de Monitoramento e Avaliação de Impacto Ambiental (1982)	National Center for Research on Monitoring and Evaluating Environmental Impact	CNPMA	environment, monitoring, evaluation	SP	60	60.0
	Centro Nacional de Pesquisa de Mandioca e Fruticultura Tropical (1975)	National Center for Research on Cassava and Tropical Fruit Culture	CNPMF	cassava, tropical fruit, cocoa	BA	58	58.0

Supervising Agency	Executing Agency			Research Focus (major commodities)	State[b]	Number of Researchers	
	Name (Portuguese)[a]	Name (English)	Acronym			Total	fte's
	Centro Nacional de Pesquisa de Milho e Sorgo (1976)	National Center for Research on Corn and Sorghum	CNPMS	corn, sorghum, biotechnology	MG	70	70.0
	Centro Nacional de Pesquisa de Solos (1993)	National Center for Research on Soils	CNPS	soils, environment	RJ	58	58.0
	Centro Nacional de Pesquisa de Suínos e Aves (1975)	National Center for Research on Swine and Poultry	CNPSA	swine, poultry	SC	41	41.0
	Centro Nacional de Pesquisa de Soja (1975)	National Center for Research on Soybean	CNPSO	soybeans, sunflower	PR	61	61.0
	Centro Nacional de Pesquisa de Trigo (1974)	National Center for Research on Wheat	CNPT	wheat, barley, oats, soybeans, biotechnology	RS	55	55.0
	Centro Nacional de Pesquisa Tecnológica em Informática para a Agricultura (1995)	National Center for Technological Research on Agricultural Information	CNPTIA	agricultural information	SP	40	40.0
	Centro Nacional de Pesquisa de Uva e Vinho (1975)	National Center for Research on Grapes and Wine	CNPUV	grapes, wine, temperate fruit, soils	RS	27	27.0
	Centro de Pesquisa Agroflorestal de Amazônia Ocidental (1989)	Center for Agroforestry Research of the Western Amazon	CPAA	agroforestry	AM	57	57.0
	Centro de Pesquisa Agropecuária dos Cerrados (1975)	Center for Agricultural Research on the Savannas	CPAC	savannas, beef, fruits, grains	DF	93	93.0
	Centro de Pesquisa Agropecuária de Clima Temperado (1993)	Center for Temperate Climate Agricultural Research	CPACT	irrigated rice, dairy, biotechnology, natural resources	RS	92	92.0
	Centro de Pesquisa Agroflorestal do Acre (1976)	Center for Agroforestry Research of Acre	CPAF-AC	agroforestry	AC	28	28.0
	Centro de Pesquisa Agroflorestal do Amapá (1980)	Center for Agroforestry Research of Amapá	CPAF-AP	agroforestry,	AP	16	16.0
	Centro de Pesquisa Agroflorestal do Rondônia (1975)	Center for Agroforestry Research of Rondônia	CPAF-RO	agroforestry, pastures	RO	30	30.0
	Centro de Pesquisa Agroflorestal do Roraima (1991)	Center for Agroforestry Research of Roraima	CPAF-RR	agroforestry	RR	16	16.0
	Centro de Pesquisa Agropecuária do Meio Norte (1993)	Center for Agricultural Research of the Mid-North	CPAMN	irrigation, fruit, grains	PI	42	42.0
	Centro de Pesquisa Agropecuária do Oeste (1975)	Center for Agricultural Research of the West	CPAO	natural resources, grains	MS	26	26.0
	Centro de Pesquisa Agropecuária do Pantanal (1984)	Center for Agricultural Research of the Pantanal	CPAP	livestock, fisheries, environmental sciences	MS	36	36.0
	Centro de Pesquisa Agropecuária do Tabuleiros Costeiros (1993)	Center for Agricultural Research of the Coastal Tablelands	CPATC	animal production, sugar, soils, cocoa, fruits	SE	37	37.0
	Centro de Pesquisa Agropecuária do Trópico Semi-Árido (1975)	Center for Agricultural Research of the Semi-Arid Tropics	CPATSA	natural resources, irrigation, animal production, biotechnology	PE	79	79.0

Supervising Agency	Executing Agency			Research Focus (major commodities)	State[b]	Number of Researchers	
	Name (Portuguese)[a]	Name (English)	Acronym			Total	fte's
	Centro de Pesquisa Agroflorestal da Amazônia Oriental (1975)	Center for Agroforestry Research of the Eastern Amazon	CPATU	agroforestry, natural resources, environment, agroindustry	PA	135	135.0
	Centro de Pesquisa de Pecuária do Sudeste (1995)	Center for Cattle Research of the Southeast	CPPSE	dairy, beef, cattle, pastures	SP	34	34.0
	Centro de Pesquisa de Pecuária dos Campos Sul Brasileiros (19??)	Center for Cattle Research of the Southern Brazilian Grasslands	CPPSUL	dairy, beef, pastures	RS	25	25.0
	Centro Nacional de Pesquisa de Tecnologia Agroindustrial de Alimentos (1971)	Center for Research on Agroindustrial Food Technology	CTAA	food technology	RJ	48	48.0
	Núcleo de Monitoramento Ambiental e de Recursos Naturais por Satélite (1989)	Environmental and Natural Resource Remote Sensing Unit	NMA	agroecology, natural resources	SP	10	10.0
	Embrapa headquarters					269	269.0
Ministério da Agricultura e do Abastecimento (MAA), Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC)	Centro de Pesquisa do Cacau (1957)	Cocoa Research Center	CEPEC	cocoa; natural resources, fruits, rubber	BA	89	89.0
Ministério de Medio Ambiente (MMA)	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis	Brazilian Institute for the Environment and Renewable Natural Resources	IBAMA	fisheries, forestry, natural resources, environmental sciences	—	na	na
Government agencies, state[c]							
Secretaria de Agricultura, Bahia	Empresa Baiana de Desenvolvimento Agrícola S.A. (1981)[d]	Agricultural Development Company of the State of Bahia	EBDA	crops, livestock, natural resources	BA	89	89.0
Secretaria de Ciência e Tecnologia, Maranhão	Empresa Maranhense de Pesquisa Agropecuária (1975)[e]	Agricultural Research Corporation of the State of Maranhão	EMAPA	crops	MA	31	31.0
Secretaria de Agricultura, Goiás	Empresa de Assistência Técnica e Extensão Rural do Estado de Goiás (1973)[d]	Technical Assistance and Rural Extension Enterprise for the State of Goiás	EMATER-GO	crops, beef, diary, natural resources	GO	65	65.0
Secretaria de Agricultura, Espírito Santo	Empresa Capixaba de Pesquisa Agropecuária (1973)[d]	Agricultural Research Corporation of the State of Espírito Santo	EMCAPA	coffee, fruits, other crops, dairy, natural resources	ES	57	57.0
Secretaria de Agricultura, Abastecimento e Irrigação, Sergipe	Empresa de Desenvolvimento Agropecuário de Sergipe (1987)[d]	Agricultural Development Corporation of the State of Sergipe	EMDAGRO	vegetables, fruits	SE	7	7.0
Secretaria de Agricultura, Irrigação e Abastecimento, Paraíba	Empresa Estadual de Pesquisa Agropecuária da Paraíba (1978)	Agricultural Research Corporation of State of Paraíba	EMEPA	crops, livestock	PB	68	68.0
Secretaria de Meio Ambiente e Desenvolvimento Sustentável, Mato Grosso do Sul	Empresa de Pesquisa Agropecuária, Assistência Tecnica e Extensão Rural de Mato Grosso do Sul (1979)[d]	Corporation for Agricultural Research, Technical Assistance, and Rural Extension of the State of Mato Grosso do Sul	EMPAER-MS	crops, dairy, natural resources	MS	23	23.0

Supervising Agency	Executing Agency			Research Focus (major commodities)	State[b]	Number of Researchers	
	Name (Portuguese)[a]	Name (English)	Acronym			Total	fte's
Secretaria da Agricultura e Assuntos Fundiários, Mato Grosso	Empresa de Pesquisa Agropecuária, Assistência Tecnica e Extensão Rural de Mato Grosso (1979)[d]	Corporation for Agricultural Research, Technical Assistance, and Rural Extension of the State of Mato Grosso	EMPAER-MT	crops, forestry	MT	39	11.6
Secretaria de Agricultura, Rio Grande do Norte	Empresa de Pesquisa Agropecuária do Rio Grande do Norte (1979)	Agricultural Research Corporation of the State of Rio Grando do Norte	EMPARN	crops, livestock, forestry, natural resources	RN	44	44.0
Secretaria de Ciência e Tecnologia, Ceará	Empresa de Pesquisa Agropecuária do Ceará (1975)[e]	Agricultural Research Corporation of the State of Ceará State	EPACE	crops, livestock	CE	57	57.0
Secretaria de Desenvolvimento Rural e de Agricultura, Santa Catarina	Empresa de Pesquisa Agropecuária e Difusão de Tecnologia de Santa Catarina S/A (1975)[d]	Agricultural Research and Rural Extension Corporation of the State of Santa Catarina	EPAGRI	crops, beef, dairy, forestry, fisheries, natural resources	SC	178	178.0
Secretaria de Agricultura, Pecuária e Abastecimento, Minas Gerais	Empresa de Pesquisa Agropecuária de Minas Gerais (1974)	Agriculture and Livestock Research Corporation of the State of Minas Gerais	EPAMIG	coffee, vegetables, fruits, other crops, livestock	MG	140	140.0
Secretaria de Agricultura, Alagoas	Empresa de Pesquisa Agropecuária do Estado de Alagoas (1979)	Agricultural Research Corporation of the State of Alagoas	EPEAL	na	AL	36	36.0
Secretaria de Ciência e Tecnologia, Rio Grande do Sul	Fundação Estadual de Pesquisa Agropecuária (1994)	State Agricultural Research Foundation	FEPAGRO	crops, livestock, forestry, fisheries, natural resources	RS	92	92.0
Secretaria de Agricultura e Abastecimento, Paraná	Instituto Agronômico do Paraná (1972)	Agronomic Institute of the State of Paraná	IAPAR	crops, livestock, forsestry, natural resources	PR	152	152.0
Secretaria de Agricultura, Pernambuco	Empresa Pernambucana de Pesquisa Agropecuária (1935)	Agricultural Research Institute for the State of Pernambucan	IPA	livestock	PE	115	115.0
Secretaria de Agricultura e Abastecimento, São Paulo	Instituto Agronômico de Campinas (1887)	Agronomic Institute of Campinas	IAC	crops, natural resources	SP	234	234.0
	Instituto de Economia Agrícola (1968)	Agricultural Economics Institute	IEA	agricultural economics	SP	75	75.0
	Instituto de Tecnologia de Alimentos (1969)	Food Technology Institute	ITAL	food technology	SP	99	99.0
	Instituto de Zootecnia (1970)	Zootechnical Institute	IZ	zootechnics	SP	106	31.8
	Instituto Biológico (1927)	Biological Institute	IB	na	SP	na	na
	Instituto de Pesca (1960)	Fisheries Institute	IP	fisheries	SP	83	83.0
Secretaria de Agricultura e Abastecimento, Rio de Janeiro	Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro (1975)	Agricultural Research Corporation of Rio de Janeiro State	PESAGRO	crops, livestock, natural resources	RJ	74	74.0
Nonprofit institutions							
Cooperative dos Produtores de Cana, Açúcar e Álcool do Estado de São Paulo Ltda.	Centro de Tecnolgia Copersucar (1979)	Technology Center Copersucar	COPERSUCAR	sugarcane, postharvest	SP	107	60
Organização das Cooperativas do Estado do Paraná (OCEPAR)	Cooperativa Central Agropecuária de Desenvolvimento Tecnológico e Econômico Ltda. (1971/1974)	Central Agricultural Cooperative ofTechnology Development and Economics	COODETEC	soybeans, cotton, corn, wheat	PR	12	12.0

Supervising Agency	Executing Agency			Research Focus (major commodities)	State[b]	Number of Researchers	
	Name (Portuguese)[a]	Name (English)	Acronym			Total	fte's
Federação das Cooperativas de Trigo do Rio Grande do Sul (FECOTRIGO)	Fundação Centro de Experimentação e Pesquisa Fecotrigo	Foundation Center for Wheat Experimentation and Research	FUNDACEP	soybeans, corn, wheat	RS	16	16.0
Fundo de Defesa da Citricultura	Centro de Pesquisas Citrícolas (1994)	Citrus Research Center	FUNDECITRUS	citrus fruits	SP	6	6.0
Secreatria de Agricultura do Rio Grande do Sul	Instituto Rio Grandense do Arroz (1939)	Rice Institute of Rio Grande	IRGA	rice	RS	23	23.0
Higher education agencies[f]							
—	Faculdade de Agronomia "Dr. Francisco Maeda" (1987)	Faculty of Agronomy "Dr. Francisco Maeda"	FAFRAM	na	SP	37	11.1
—	Faculdade de Agronomia e Zootecnia de Uberaba (19??)	Faculty of Agronomy and Zootechnology of Uberaba	FAZU	crops, livestock	MG	43	4.3
—	Faculdade de Ciências Agrárias do Pará (1945)	Faculty of Agricultural Science of the State of Pará	FCAP	na	PA	122	33.6
—	Fundação Faculdade de Agronomia "Luiz Meneghel"	Foundation Facultyof Agronomy "Luiz Meneghel"	FFALM	na		51[g]	12.6
Fundação de Ensino "Octávio Bastos"	Faculdade de Medicina Veterinária "Octávio Bastos" (1992)	Faculty of Veterinary Medicine "Octávio Bastos"	FMV/FEOB	veterinary medicine	SP	52	12.6
Universidade do Estado de Santa Catarina	Centro de Ciências Agroveterinárias (19??)	Center of Agro-Veterinary Sciences	CAV/UDESC	crops, veterinary medicine	SC	91	27.3
	Escola de Medicina Veterinária (1951)	School of Veterinary Medicine	EMV/UFBA	veterinary medicine	BA	21	5.3
Universidade Federal de Goiás	Escola de Agronomia (1963, 81)	School of Agronomy	EA/UFGO	crops		59[g]	11.7
	Escola de Veterinária (1963, 81)	School of Veterinary	EV/UFGO	veterinary medicine	GO	52	15.6
—	Universidade Federal de Lavras (1908)	Federal University of Lavras	UFLA	crops, livestock	MG	197	59.1
Universidade Federal de Mato Grosso	Faculdade de Engenharia Florestal (1975)	Faculty of Forestry Engineering	FEF/UFMG	forestry, water	MT	18	5.4
Universidade Federal da Paraíba	Centro de Ciências Agrárias (1936)	Center of Agricultural Sciences	CCA/UFPB	crops, livestock, postharvest	PB	51	9.0
	Departamento de Engenharia Florestal, Centro de Saúde e Tecnologia Rural (1979)	Department of Forestry Engineering, Center for Health and Rural Technology	DEF/CSTR/UFPB	forestry	PB	32	9.6
Universidade Federal de Pelotas	Faculdade de Agronomia "Eliseu Maciel" (1883)	Faculty of Agronomy "Eliseu Maciel"	FAEM/UFPEL	crops, livestock, postharvest	RS	95	28.5
Universidade Federal do Rio Grande do Sul	Faculdade de Agronomia	Faculty of Agronomy	FA/UFGRS	na	RS	65[g]	12.9
	Faculdade de Veterinária	Faculty of Veterinary	FV/UFGRS	veterinary medicine	RS	54	13.5
Universidade Federal Rural do Rio de Janeiro	Instituto de Agronomia (1911)	Institute of Agronomy	IA/UFRRJ	crops	RJ	32	9.6
Universidade Federal de Santa Catarina	Centro de Ciências Agrárias	Center of Agricultural Sciences	CCA/UFSC	na	SC	75[g]	15.0

Supervising Agency	Executing Agency			Research Focus (major commodities)	State[b]	Number of Researchers	
	Name (Portuguese)[a]	Name (English)	Acronym			Total	fte's
Universidad Federal de São Carlos	Centro de Ciências Agrárias (1961)	Center of Agricultural Sciences	CCA/UFSCAR	crops, livestock, water, soils	SP	40	10.0
Universidad Federal de Santa Maria	Centro de Ciências Rurais	Center of Rural Sciences	CCR/UFSM	crops, livestock, forestry	RS	142	42.6
Universidade Federal de Viçosa	Centro de Ciências Agrárias	Center of Agricultural Sciences	CCA/UFV	na	MG	219	65.7
Universidade de Brasília	Faculdade de Agronomia e Medicina Veterinária (1997)	Faculty of Agronomy and Veterinary Medicine	FAV/UNB	crops, livestock, postharvest, soils, natural resources	DF	23	6.9
Unidade de Ensino Descentralizada de Pato Branco	Curso de Agronomía, Centro Federal de Educação Tecnológica do Parana (1992)	Agronomy Course, Federal Center for Technical Education of the State of Parana	CEFET/UNED-PB	crops, natural resources	PR	22	6.6
Universidade Estadual Paulista,	Faculdade de Ciências Agrárias e Veterinárias, Campus de Jaboticabal (1964)	Faculty of Agricultural and Veterinary Sciences	FCAVJ/UNESP	crops, livestock, veterinary medicine	SP	na	na
	Faculdade de Engenharia de Ilha Solteira (19??)	Faculty of Engineering of Ilha Solteira	FEIS/UNESP	agricultural engineering	SP	60	15.0
	Faculdade de Medicina Veterinária e Zootecnia (1976)	Faculty of Veterinary Medicine and Zootechnology	FMVZ/UNESP	livestock, veterinary medicine	SP	83	24.9
Universidade Estadual de Campinas	Faculdade de Engenharia Agrícola (1985)	Faculty of Agricultural Engineering	FEA/UNICAMP	agricultural engineering	SP	na	na
Universidade do Sul de Santa Catarina	Centro de Ciências Tecnológicas, Agrárias e das Engenharias (1992)	Center of Technology, Agricultural, and Engineering Sciences	CCTAE/UNISUL	agriculture	SC	31	6.2
Universidade de São Paulo	Escuela Superior de Agricultural "Luiz de Queiroz" (1901)	Higher School of Agriculture "Luiz de Queiroz"	ESALQ/USP	agriculture	SP	227	68.1
	Faculdade de Medicina Veterinária e Zootecnia	Faculty of Veterinary Medicine and Zootechnology	FMVZ/USP	livestock, veterinary medicine	SP	55	16.5
Private enterprises, national[h]							
Agroceres	Departamento de Pesquisa e Desenvolvimento de Milho (1945)[i]	Research and Development Department for Corn	AGROCERES-Milho	corn	SP	17	17.0
	Centro de Pesquisa de Hortaliças (1991)[i]	Research Center for Vegetables	AGROCERES-Horta.	vegetables	SP	4	4.0
	Departamento de Pesquisa e Desenvolvimento Sorgo (1970)[i]	Research and Development Department for Sorghum	AGROCERES-Sorgo	sorghum	SP	3	3.0
	Pic Suínos Biotecnologia e Nutrição Animal, S.A. (1978)	Swine Biotechnology and Animal Production	AGROCERES-PIC	Pigs	MG	4	2.0
	Ross Melhoramento Genético de Aves, S.A (1989)	Poultry Genetic Improvement	AGROCERES-ROSS	poultry	SP	2	2.0
Agroflora S.A. Reflorestamento e Agropecuária	Estação Experimental de Bragança Paulista (1968)	Experimental Station of Bragança Paulista	AGROFLORA	vegetables	SP	7	7.0

Supervising Agency	Executing Agency			Research Focus (major commodities)	State[b]	Number of Researchers	
	Name (Portuguese)[a]	Name (English)	Acronym			Total	fte's
Duraflora S.A.	Gerência de Engenharia e Meio Ambiente (1971)	Engineering and Environmental Center	DURAFLORA	forestry	SP	9	9.0
	Indústria e Comércio de Sementes Ltda (1977)	Industry and Commerce of Seeds	INDUSEM	soybeans, wheat, corn	PR	5	0.5
Indústrias Klabin de Papel e Celulose S.A.	Gerência de Pesquisa Florestal (1943)	Forestry Research Center	IKPC	forestry	PR	7	7.0
Sementes Mogiana Ltda	Mitla Pesquisa Agrícola Ltda (1952)	Mitla Agricultural Research	MOGIANA	corn, sorghum	SP	2	2.0
Florestas Rio Doce S.A.	Gerência de Tecnologia e Programação (1970)	Office of Technology and Programming	RIODOCE	forestry, natural resources, pastures	MG	6	3.0
	Sadia Concórdia S.A. Ind e Com (1974)	Sadia Concórdia Industry and Commerce	SADIA	pigs, poultry	SC	14	14.0
Private enterprises, multinational[h]							
DeKalb, United States[i]	Braskalb Agropecuária Brasileira Ltda (1978/84)	Braskalb Brazilian Agriculture	BRASKALB	corn, sorghum	SP	3	3.0
Novartis Seeds Ltda, Switzerland	Centro de Pesquisas Biogenéticas de Uberlândia + Centro de Pesquisas Biogenéticas de Cascavel (1977)	Biogenetic Research Center of Uberlândia + Biogenetic Research Center of Cascavel	NOVARSEEDS	corn		5	5.0
Rhodia, France	Rhodia Agro Ltda (1961)	Rhodia Agro	RHODIA	crops	SP	9	9.0
Total						*6,356*	*4,707.1*

Source: Compiled by authors from survey responses. Research focus for Embrapa from survey responses and Embrapa (1999c).

a. Establishment dates, if available, are given in brackets. For the semipublic and private companies the dates signifies the year that research activities were initiated.
b. State acronyms: North: AC:= Acre; AM = Amazonas; RO = Rondônia; RR = Roraima; PA = Pará; AP = Amapá; Center West: GO = Goiás; MT = Mato Grosso; MS = Mato Grosso do Sul; DF = Distrito Federal; South: PR = Paraná; SC = Santa Catarina; RS = Rio Grande do Sul; Northeast: MA = Maranhão; PI = Piauí; CE = Ceará; RN = Rio Grande do Norte; PB = Paraíba; PE = Pernambuco; AL = Alagoas; SE = Sergipe; BA = Bahia; Southeast: MG = Minas Gerais; ES = Espírito Santo; RJ = Rio de Janeiro; SP = São Paulo.
c. See Appendix Table B.2 for additional details.
d. Agency is responsible for the state's agricultural research and extension.
e. State agency was closed after 1996.
f. Only those higher education agencies for which we had data are listed in this table.
g. Number of full-time professors for 1996 was estimated using 1994 data from IICA and FAO (1997) and, if available, data from the faculties' web pages. Time spent on research was estimated to be 20 percent.
h. Only those national and multinational private enterprises for which survey responses were received are listed in this table. For additional private enterprises see Table B.3.
i. These three departments formed Sementes Agroceres, which was taken over by Monsanto in 1996.
j. Braskalb was taken over by Monsanto in 1998.

Table B.2—*State Government Agricultural Research Agencies*

Region and State	Institute(s) (1996)	Mandate	Developments
North			
Acre	—		)
Amazonas	—		)
Rondônia	—		) no state-government agricultural research agencies
Roraima	—		)
Pará	—		)
Amapá	—		)
Center-West			
Goiás	EMATER-GO	research and extension	Research agency (EMGOPA) established separately in 1973; incorporated into extension agency (EMATER-GO) in 1995; merged with two other nonresearch state agencies (IDAGRO and IDAP) in 1999 and renamed Agencia Goiana de Desenvolvimento Rural e Fundiário
Mato Grosso	EMPAER-MT	research and extension	Established in 1979 as research agency (EMPA-MT), merged with state extension and promotion agencies (EMATER-MT and CODEAGRI) in 1992
Mato Grosso do Sul	EMPAER-MS	research and extension	Established in 1979 as research agency only, later merged with state extension service; the agency was incorporated into the Instituto de Desenvolvimento Agrário e Extensão Rural do Mato Grosso do Sul (IDATERRA) in October 2000.
Distrito Federal	—		
South			
Paraná	IAPAR	research	Established in 1972; no major reorganizations
Santa Catarina	EPAGRI	research and extension	Research agency (EMPASC) established separately in 1975; merged with extension agency (EMATER-SC) in 1991 and renamed EPAGRI
Rio Grande do Sul	FEPAGRO	research	Previously as under state Secretariat of Agriculture of Rio Grande do Sul as three separate research agencies (IPAGRO, IPZFO, and IPRNR); obtained current name in 1994
Northeast			
Maranhão	EMAPA	research	Established in 1975; no major reorganizations; closed in 1999
Piauí	—		
Ceará	EPACE	research	Established in 1975; no major reorganizations; closed in 1998
Rio Grande do Norte	EMPARN	research	Established in 1979; no major reorganizations
Paraíba	EMEPA	research	Established in 1979; no major reorganizations; incorporated two Embrapa research stations in 1997
Pernambuco	IPA	research	Established in 1935 as IPA, renamed in 1975 as Empresa Pernambucana de Pesquisa Agropecuária, but kept same acronym; no major reorganizations since then
Alagoas	EPEAL	research	Established in 1979; agency is currently not operational due to financial problems and is in the process of liquidation and being replaced by a research department at the secretary of agriculture of the state.

Region and State	Institute(s) (1996)	Mandate	Developments
Sergipe	EMDAGRO	research & extension	Research agency established separately in 1987 and incorporated into the extension agency (EMATER-SE) in 1991 and renamed EMDAGRO
Bahia	EBDA	research & extension	Research agency Empresa de Pesquisa Agropecuária da Bahia, S.A. (EPABA) was established separately in 1981; merged with extension agency Empresa de Assistência Técnica e Extensão Rural da Bahia (EMATER-BA) in 1991 and renamed EBDA
Southeast			
Minas Gerais	EPAMIG	research	Established in 1974; no major reorganizations
Espírito Santo	EMCAPA	research & extension	Research agency (EMCAPA) established separately in 1973; merged with extension agency in 1999 and renamed EMCAPER
Rio de Janeiro	PESAGRO	research	Established in 1976; no major reorganizations
São Paulo	IAC; IB; IEA; IP; ITAL; IZ	research	IAC was created in 1887 and IB in 1927; IP was established from the Division of Fisheries and the Protection of Forestry and Animal Production in 1960; IEA was established from the Economic Rural Division in 1969; ITAL was created in 1968 from IAC's Division of Soils, Agricultural Machinery, and Technology; IZ was created in 1970 from the Department of Animal Production (created in 1942). São Paulo's agricultural research activities are currently being reorganized

Source: Based on information provided in survey responses, Albuquerque and Salles-Filho (1996), and other sources of information.

Table B.3—*Private Enterprises Possibly Undertaking Research in Brazil*

Supervising Agency[a]	Name (Portuguese)[a]	State	Main Agricultural Research Focus	Other Activities	Main Products
National					
—	Agristar do Brasil Ltda	RJ	crop breeding (fruits, vegetables)	na	improved varieties
—	Biovet	SP	animal health (bovine, equine, poultry, small animals, swine)	—	vaccines
Companhia Industrial Agricola Ometto (Iracema)	Omtek Industria e Comercio Ltda (1990)	SP	animal and aquaculture production and nutrition, agroindustry, sugar	—	additives, yeasts for fermentation
—	Genomic Engenharia Molecular Ltda (1991)	SP	animal production	human health, information and technical assistance	breeding lines, diagnosis, technology development and adaptation, certification
—	Geratec S.A. Biotecnologia Aplicada (1988)	RS	plant production and nutrition	—	inoculants and biopesticides
—	Industria de Bio Soja de Inoculantes Ltda (1971)	SP	plant production and nutrition	—	inoculants
—	Instituto Rio Grandense de Febre Aftosa Ltda (1953)	RS	plant and animal production and nutrition	—	vaccines , parasiticides and inoculants
Lagoa da Serra	Lagoa da Serra Inseminação Artificial Ltda (1971)	SP	animal production	information, training and technical assistance	bovine semen, certification, improved breeding lines, bovine embryos; technical assistance in animal reproduction technologies
—	Nitral - Industria e Comércio de Inoculantes e Produtos Agropecuários (1971)	PR	plant production and nutrition	—	inoculants, fertilizers, and biopesticides
—	OR Sementes	RS	wheat	na	na
—	Perdigao	SC	swine	na	na
—	Solofix Biotecnologia Agricola Ltda (1991)	PR	plant production and nutrition	quality control, training and technical assistance	inoculants
—	Tortuga		animal health (bovine, poultry, swine)		
—	Turfal, Industria e Comercio de Produtos Bologicos e Agronomicos (1970)	PR	plant production and nutrition, environmental protection	—	inoculants, compost

Supervising Agency[a]	Name (Portuguese)[a]	State	Main Agricultural Research Focus	Other Activities	Main Products
Multinational					
American Cynamid Company, United States[b]	Cyanimid Quimica do Brasil (1957)	SP, RJ	animal and plant protection	human health	herbicides and insecticides
Aventis, Germany[c]	Aventis CropScience Brasil Ltda	SP, MG	chemicals, crop improvement, animal health	na	na
British American Tobacco, United States	Souza Cruz	PR	tobacco	na	na
Holding Dedini, Italy	Codistil S.A. Dedini (1943)	SP	support technology, environmental protection, alcohol research	technical assistance	machinery for agroindustry, anaerobic processes
Monsanto, United States[d]	FT Sementes	PR	crop breeding (corn, soybeans, edible beans)	na	improved varieties
Pioneer Hi-Bred International, United States[e]	Pioneer Sementes Sementes Ltda (1972)	various	plant and animal production and nutrition	—	corn, sorghum, and alfafa seeds, additives
Profigen, United States	Profigen	RS	crop breeding	na	na
RJR Nabisco Inc, United States (1931)	Produtos Alimentícios Fleishmann e Royal Ltda	RJ	agroindustry	—	yeasts for fermentation
	Companhia Florestal Monte Dourado (1948)	RJ, PA	plant production and nutrition	—	eucalyptus plants, buffalo semen
Seminis Vegetable Seeds, Mexico	SVS do Brasil -Asgrow	na	vegetables	na	improved varieties
	SVS do Brasil-Horticeres	MG, RS	vegetables	na	improved varieties
	SVS do Brasil-Petoseed	na	vegetables	na	improved varieties
	SVS do Brasil –Royal Sluis	na	vegetables	na	improved varieties
Yakult Honsha Company, Ltda, Japan (1955)	Yakult S/A Industria e Comercio (1968)	SP	agroindustry , livestock, aquaculture and fishery	immunology	dairy products, food, embryos, fish, mollusks

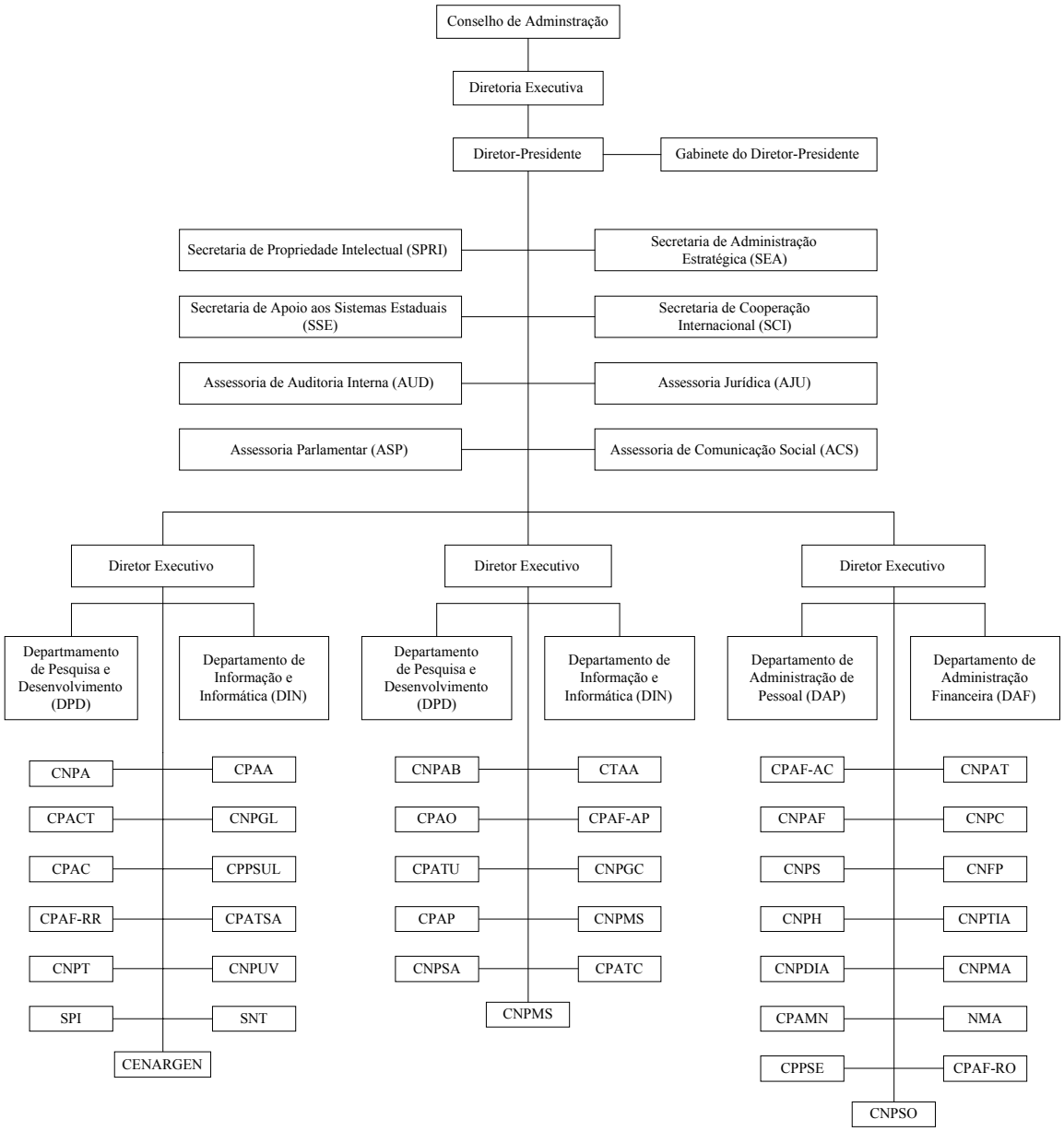
Source: BDT (2001) and various other unpublished sources.

a. Establishment dates, if available, are given in brackets.
b. Purchased by BASF in 2000.
c. Recently purchashed the Brazilian companies Sementes Riberal Ltda, Sementes Fartura, and Mitla Pesquisa Agricola.
d. Now part of Dupont.
e. Now part of Pharmacia based in New Jersey.

APPENDIX C

Embrapa's Institutional Details

Figure C.1. *Embrapa's Organizational Structure, January 2001*



Note: The acronyms of Embrapa centers are provided in Appendix Table B.1; SCT is the *Serviço Comunicação para Transferência de Tecnologia* and SNT is the *Serviço de Negócios para Transferência de Tecnologia*.

Table C.1. *Embrapa's Programs and Subprojects, 1998*

Programs	Number of Subprojects
R&D programs	
Natural resources	190
Genetic resources	169
Basic biotechnology research	91
Grain production	351
Fruit production and horticulture	321
Animal production	186
Raw material production	110
Forestry and Agroforestry production	91
Family farming	50
Harvest/extraction, post-harvest and conservation of agricultural products	66
Environmental quality protection and evaluation	58
Agricultural automation	50
Rural and regional development	170
Subtotal	*1903*
Institutional development programs	
Information production and exchange	107
State agricultural research systems	7
Institutional development and administration	500
Subtotal	*614*
Total	*2517*

Source: Embrapa (1999a).

Note: Embrapa's research now encompasses three additional programs: the technology transfer program, and communication and business program—both previously part of the rural and regional development program—and the formerly fruit production and horticulture program was split into the coffee and fruits program and horticulture program.