OECD DEVELOPMENT CENTRE

Working Paper No. 17

BIOTECHNOLOGY AND DEVELOPING COUNTRY AGRICULTURE: MAIZE IN BRAZIL

by

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Research programme on:
Changing Comparative Advantage in Food and Agriculture

June 1990

OECD OCDE

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RÉSUMÉ

Avec une production annuelle moyenne supérieure à 20 millions de tonnes, le Brésil occupe la deuxième place, après la Chine, parmi les pays en développement producteurs de maïs ; à l'échelle mondiale, il se situe au troisième rang. Cette étude examine la technologie et la recherche qui, au Brésil, ont présidé au développement et à l'extension de cette culture. Fondée sur une approche socio-économique et politico-institutionnelle, elle met l'accent sur les acteurs et les facteurs qui déterminent la recherche et sa mise en application dans la production.

L'étude comporte deux parties. La première traite de la place du maïs dans l'économie brésilienne - principales caractéristiques de sa production, de sa commercialisation et de sa consommation - ; elle aborde également la politique économique qui s'y applique et l'organisation de la production des semences. La seconde partie s'attache, quant à elle, à la recherche et à la technologie relatives au maïs, aux agents de leur développement respectif et aux possibilités d'expansion liées à l'usage des biotechnologies.

On trouvera, en annexe, un aperçu du développement des biotechnologies au Brésil.

De nombreuses personnes ont contribué à l'élaboration de cette étude. Les auteurs tiennent à remercier particulièrement le Centre national de la recherche sur le maïs et le sorgho de l'EMBRAPA et les participants au séminaire de travail préparatoire organisé par le Centre de Développement de l'OCDE en mai 1989.

SUMMARY

With annual production averaging over 20 million metric tons, Brazil is the second largest developing country producer of maize (after China) and the third largest in the world. This report analyses development and dissemination of maize research and technology in Brazil from a socio-economic and politico-institutional perspective. It concentrates therefore on agents and factors which influence development of research and its productive application.

The report is in two parts. First it describes the role of maize in the Brazilian economy - the main characteristics of its production, marketing and consumption, together with relevant sectoral policies and regulation of seed production. Then it analyses the development of maize research and technology in Brazil, identifying the main agents involved and possible future developments in the light of the introduction of biotechnologies.

As an Appendix, the authors review development of biotechnologies in Brazil.

Many people have collaborated in this report and the authors would like especially to thank the researchers at EMBRAPA's National Research Centre on Maize and Sorghum, the Brazilian firm AGROCERES, and the participants in the preparatory workshop organised by the OECD Development Centre in May 1989.

PREFACE

This case study of Brazil has been undertaken as part of a research project on "Biotechnology and Developing Country Agriculture: the Case of Maize", carried out in the context of the Development Centre's research programme on "Changing Comparative Advantages in Food and Agriculture". The project, which assesses the prospects for selected developing countries of incorporating new biotechnologies in maize production and, by implication, enhancing their competitiveness, focuses on the institutional aspects of technological change.

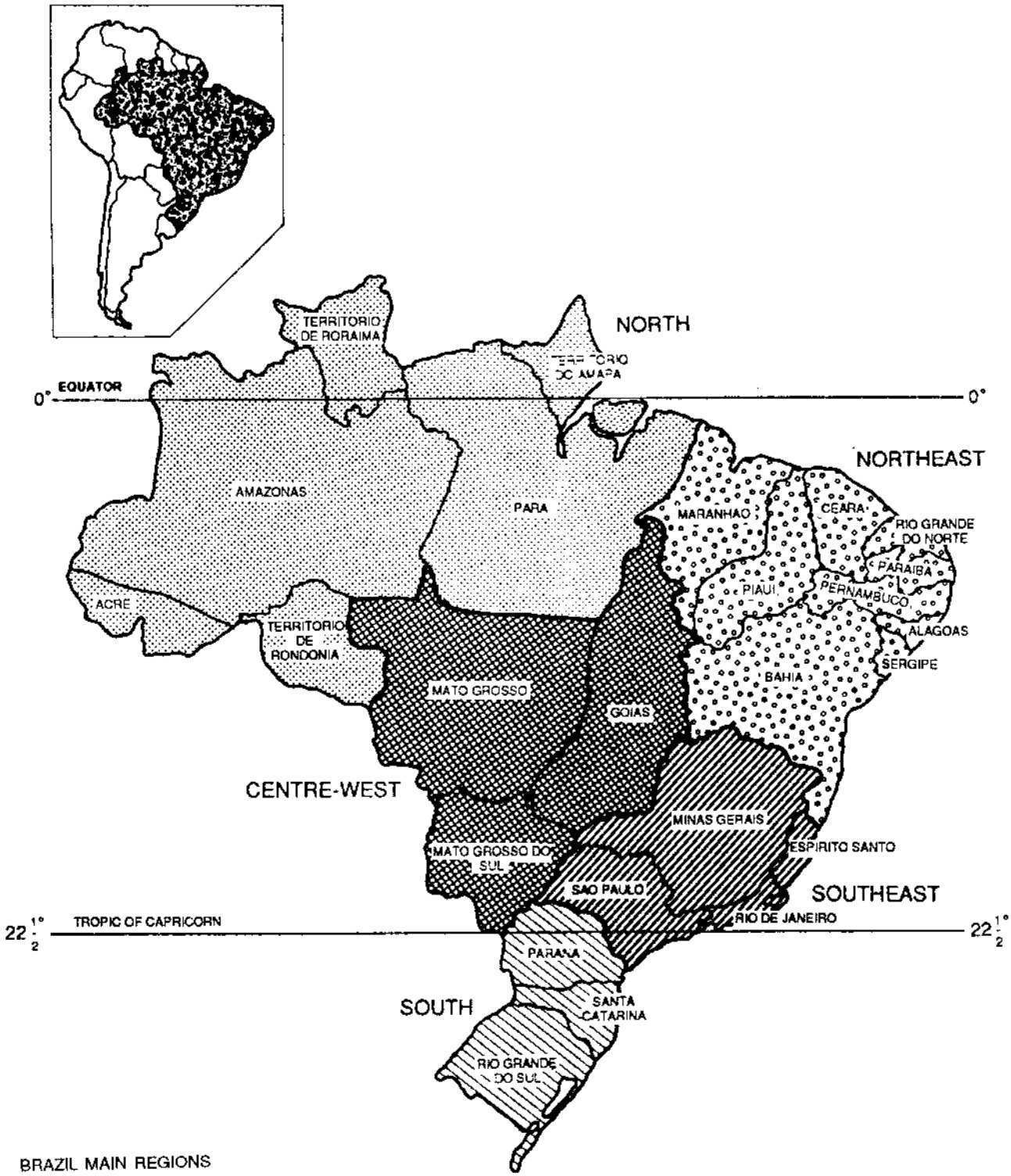
Maize was selected as an eminently suitable subject for examining how new technological developments in industrialised countries "interact" with the situation in developing countries. One of the world's major cereal crops, in many developing countries maize is an important food and/or feed crop for which demand continues to expand, particularly for use as livestock feed. Maize is also a crop on which major biological research effort has been focused. This effort resulted in the innovation of hybridization in the 1930s and shows promise with respect to new biotechnologies.

Drs. Bernardo Sorj and John Wilkinson have contributed this case study of Brazil which traces production and consumption trends, examines Brazil's maize research, technology development and diffusion system and concludes that, in the short term, productivity gains will come from existing technology. In addition to the Brazilian case, the project includes case studies of Indonesia, Mexico and Thailand. It also analyses trends in research on the emerging maize biotechnologies and in the supply, demand and trade of maize internationally. The country studies, together with the analysis of technology trends (entitled "Emerging Maize Biotechnologies and their Potential Impact") are all being published in this Technical Papers series. The conclusions and policy implications to be drawn from the project will be published by the OECD in a separate volume by Carliene Brenner.

Louis Emmerij
President of the OECD Development Centre
May 1990

BRAZIL

STATE AND REGIONAL BOUNDARIES



BRAZIL MAIN REGIONS

North	(Rain Forest)
North-East	(Semi-arid)
Center-West	(Savanna)
South-East	(Tropical and Semi-tropical)
South	(Semi-tropical and Temperate)

Part One

MAIZE IN THE BRAZILIAN AGRO-INDUSTRIAL COMPLEX

Introduction

Before the 1960s, Brazilian agriculture had two sectors: production for the domestic market with little resort to industrial inputs and often based on subsistence farmers, and an export agriculture using significant imported industrial inputs (tractors, fertilizers). This was complemented by a traditional and regionally organised food industry little influenced by packaging, quality control and marketing technologies.

From the end of the 1960s however, a modern agro-industrial complex emerges based on renewed industrial growth - particularly the expansion of the steel, automobile and petrochemical industry - and with multinational companies and state firms jointly responsible for administrative, technological, and marketing modernisation.

This new agro-industrial complex includes the tractor and agricultural machinery industry, fertilizers, animal feed, herbicides/pesticides and veterinary products. Downstream, modern food firms emerge nationally based on marketing technology and industrial quality control. This industry is stimulated by growing urban population, particularly the middle classes, and serviced by supermarkets which dominate retailing in urban centres.

The new complex increases intersectoral industry relations, diminishes the share of farm production in the value added of final food production and alters rural organisational and administrative structures.

Agricultural production for domestic and export markets is transformed. New export products are launched of which Brazil becomes a leading world supplier - soybeans, oranges, and poultry - exploiting the potential of its agro-industrial base.

Many export products are also directed to the domestic market (soybeans and poultry). Typical domestic market products (beans, rice) are not competitive internationally, and export products which have lost their competitivity have been reoriented to the domestic market (sugar). It has been argued that technological innovations have favoured export products which as a result became competitive internationally. This however presupposes the existence of **typical** export products which as we have seen do not exist.

The impact of the agro-industrial complex was to remodel the social structure of Brazilian agriculture, raising the technological threshold of a fraction of farmers and marginalising the rest (see Table 1).

Table 1

AGRICULTURAL PRODUCERS
1980

	Number of Farms (thousands)	Percentage of total
Traditional	3.851	75
Modern	1.306	25
(Total)	5.157	100

Source: CENSO Agropecuario, 1980, Rio de Janeiro, IBGE, v. 2, t. 3, n. 1, 1983-4, G. Muller, *O agrario brasileiro e a medicao do dinamico e do atrasado*, Sao Paulo, CEBRAP, mimeo, 1987.

While small farmers with less than 50 hectares continue to play an important role in production of certain crops, their influence is declining and their share of agricultural production is now around 40 per cent.

Agricultural modernization has spread everywhere, but unevenly. While in the Centre-South many farmers, including small-scale producers, have become integrated into the agro-industrial complex, in the North and the North-East, most small farmers are still marginalised, while the Centre-West is dominated by large mechanised estates.

In the wake of this modernisation, much of the traditional workforce has been proletarianised and urbanised, while the administrative structure of agriculture has been transformed, leading to formation of large producer cooperatives.

Consolidation of the agro-industrial complex received strong support from the state. It was imposed during a military dictatorship when social and labour demands were repressed. So modernisation was strongly biased in favour of large holdings. The state was also the source of subsidised credit which stimulated purchase of industrial inputs and machinery.

The strengthening of federal institutions against the power of the states, as we will see in the second section, benefitted centralised research, extension and inspection bodies which until then had had a largely state character.

Expansion and consolidation of the maize complex in Brazil should be situated in this framework. While hybrid seed production preceded creation of the agro-industrial complex, demand for hybrids soared once the poultry and animal feed industries were established. This poultry complex which set off the expansion of maize is closely associated with foreign capital investment in veterinary products, animal feeds and technology, while the poultry matrices are imported. The large-

scale implantation of foreign seed firms also occurs in this period: Pioneer (1964), Cargill (1965), Continental Grain (1971), Upjohn (1971), Limagrain (1977), DeKalb (1978) and Ciba-Geigy (1979).

In the 1980s, with the agro-industrial complex already consolidated, agriculture continues to expand despite the crisis of the industrial sector (Rezende, 1989). The sector continues to receive incentives from the government, not so much as subsidised credit, but through more realistic pricing. In recent years, increasing fiscal disequilibrium, inflation and economic shocks have strongly affected farming. The Cruzado Plan in 1986 increased internal demand and froze interest, whereas in 1987 price freeing and fall in consumption hit production for the internal market and continued into 1988 and 1989. Nevertheless agriculture remains the major source of Brazil's trading surplus, and therefore of hard currency for repaying interest on the foreign debt.

Meanwhile the fiscal crisis of the state, the difficulty of importing laboratory equipment and a fall in real salaries of public sector researchers begins to affect the country's capacity for agricultural research. In the private sector, economic uncertainty leads to a contraction of investment in research and development and slows down technological modernisation which will influence the sector's future competitivity.

Production

Among agricultural products in Brazil, maize absorbs the most labour, occupies the largest area under production, and comes third in production value after cattle and soybeans. Growth in maize production has been constant since the 1950s, doubling between 1954/58 and 1968/70 and almost doubling again between then and 1986/88 (Table 2).

Brazilian production of commercial maize seeds is around 180 000 tons. Of this, some 20 per cent comes from the public sector (but is marketed by private firms). Overproduction is between 15 to 25 per cent, probably because the main firms want to be ready for extra demand and/or to use it to force prices down if needed.

Maize is produced as a single crop (particularly in Saõ Paulo and Goias), planted together with permanent crops (Minas Gerais) and planted in association with other temporary crops in the North and the North-East. In some states, all three production systems are present (Santa Catarina, Paraná). Productivity is much higher in single crop planting.

Table 2

QUANTITY PRODUCED AND AVERAGE YIELDS OF MAIZE
1960-1985

Year	Area (ha)	Quantity produced (tons)	Average yields (kg/ha)
1960	6 681 165	8 671 952	1 297
1961	6 885 740	9 036 237	1 312
1962	7 347 881	9 587 285	1 304
1963	7 957 633	10 478 267	1 316
1964	8 105 894	9 408 043	1 160
1965	8 771 318	12 111 921	1 380
1966	8 703 169	11 371 455	1 306
1967	9 274 321	12 824 500	1 382
1968	9 584 754	12 813 638	1 336
1969	9 653 757	12 693 435	1 314
1970	9 858 108	14 216 009	1 442
1971	...	...	...
1972	...	...	...
1973	9 923 570	14 185 877	1 429
1974	10 672 450	16 273 227	1 524
1975	10 854 687	16 334 516	1 504
1976	11 117 570	17 751 077	1 596
1977	11 797 411	19 255 936	1 632
1978	11 124 827	13 569 401	1 219
1979	11 318 885	16 306 380	1 440
1980	11 451 297	20 372 072	1 779
1981	11 520 336	21 116 908	1 833
1982	12 619 531	21 842 477	1 731
1983	10 705 979	18 731 216	1 750
1984	12 205 201	21 174 179	1 735
1985	11 801 549	22 019 725	1 874

Sources: Ministry of Agriculture to 1970; IBGE as from 1973; *Agroanalysis*, January 1987.

In the North-East, improved seeds and fertilizers are hardly used and animal traction is common. In the Centre-South, mechanisation is general and 70-85 per cent of farmers use improved seeds and fertilizers. While large-scale production increases rapidly, more than half the national crop is produced on farms of less than 50 hectares.

Although maize is produced throughout the country, most comes from the Centre-South and Southern regions, with the Centre-West the region of fastest growth. Highest productivity is in the South (around 2,500 kg/ha), while in the North-East average productivity is below 500 kg. Here and in the North, maize is generally a subsistence product, using little or no off-farm inputs.

Maize is a typical small farmer product. In Table 3 we see that in the North and North-East, more than 95 per cent comes from farms of less than 50 ha. and more than 80 per cent from properties of less than 10 hectares. In the South-East and Centre-West a larger share of regional production comes from properties of over 100 ha (11.6 and 27 per cent respectively).

Increased maize production during the 1950s and 1960s was largely due to increased area cultivated. In the 1970s, greater productivity became the main factor (Table 4 and 5).

Table 3

QUANTITY OF MAIZE PRODUCED BY DIFFERENT SIZE FARMS
(Percentage)

Area (ha)	REGION				
	North	North-East	South-East	South	Centre-West
10	89.3	82.7	44.9	67.7	37.3
10-50	9.6	13.8	33.3	28.0	24.3
50-100	0.8	1.7	10.2	02.4	11.4
100-200	0.3	0.9	6.6	1.1	12.3
200-500	---	0.5	3.8	0.6	10.0
500	---	0.4	1.2	0.2	4.7

Source: FIBGE, Censo Agropecuario de 1975, in Garcia, Vencovsky, n.d.

Table 4

GROWTH IN MAIZE PRODUCTION
1948-69
(Percentage)

	Rate of production growth (ann.av.)	Area	Yield	Change in location
1948/50 to 1959/61	3.7	92.9	9.6	-2.5
1959/61 to 1967/69	4.3	95.3	2.5	2.2

Source: G.F. Patrick (s.d.), in J.C. Garcia, R. Venkovsky.

Table 5

GROWTH AND SOURCE OF PRODUCTION GROWTH IN MAIZE
1970/72 to 1980/82

Increase in production		6 820 770 t.
Increase due to:		
Addition in area	33.4 %	2 281 390 t.
Addition in yield	66.6 %	4 477 350 t.
Addition in location	0.1 %	62 026 t.

Source: J.C. Garcia and R. Venkovsky, n.d.

The 1986/87 maize harvest, in the wake of the consumer explosion and the frozen interest rates of the Cruzado Plan, reached a record 26.14 million tons. The following year it fell to 24 million, with soybean production in the Centre-South higher than maize. This reflects the severe fluctuations in the Brazilian economy in recent years, with purchasing power falling and difficulties in maintaining export markets for poultry and favourable international prices for soybean. As a result, larger and more modernised farmers have shifted to soybean production.

In the last two decades, maize production has been tied to expansion of the poultry sector. Production increases have therefore been absorbed as animal feed. As shown in Tables 6 and 7, maize is Brazil's most important cereal in volume of production, accounting for almost half the total, followed by soybeans and rice. A sack of soybeans costs twice as much as one of maize, which is the cheapest cereal on the Brazilian market.

Table 6

GRAIN PRODUCTION - 1976/77 to 1986/87
(Millions of 60kg sacks)

(Harvest)	Rice	Beans	Maize	Soya	Wheat	(Total)
1976/77	149.90	38.17	320.93	208.55	34.43	751.98
1977/78	121.60	36.57	226.15	159.02	44.85	588.18
1978/79	126.58	36.43	271.77	170.67	48.78	654.23
1979/80	162.93	32.80	339.53	252.60	45.03	832.90
1980/81	137.03	39.02	351.95	250.12	36.83	815.05
1981/82	162.25	48.38	364.03	213.93	30.45	819.05
1982/83	129.03	26.35	312.18	243.03	37.28	747.88
1983/84	150.45	43.77	352.73	259.02	33.05	839.02
1984/85	150.42	42.48	366.97	304.97	72.00	936.52
1985/86	173.42	36.98	342.35	222.25	93.97	868.97
1986/87	173.70	33.65	446.45	280.23	98.15	1 032.18

Source: IBGE, *Agroanalysis*, July 1988.

Table 7

GRAIN PRODUCTION AT CONSTANT PRICES FOR HARVESTS
1975/76 to 1986/87
(Millions of Cz$)

Harvest	Rice	Beans	Maize	Soya	Wheat	Grains
1975/76	238 952.43	117 394.33	219 895.08	269 904.93	93 578.53	939 725.30
1976/77	220 266.29	146 104.90	238 538.65	300 821.27	60 116.06	965 847.17
1977/78	178 681.66	139 979.98	168 089.48	229 372.31	78 302.18	794 425.61
1978/79	186 004.28	139 469.57	201 994.77	246 176.76	85 169.26	858 814.64
1979/80	239 417.75	125 560.89	252 363.39	364 360.04	78 622.26	1 060 325.13
1980/81	201 506.67	149 358.77	261 592.27	360 778.77	64 306.14	1 037 542.62
1981/82	238 413.65	185 215.08	270 573.39	308 586.41	53 161.68	1 055 950.21
1982/83	189 604.36	100 869.80	232 035.08	350 561.47	65 091.78	938 162.50
1983/84	221 074.47	167 542.13	262 174.49	373 616.51	51 700.94	1 082 108.54
1984/85	221 025.49	162 629.43	272 753.64	439 439.94	125 702.50	1 221 551.00
1985/86	254 822.19	141 575.01	254 456.92	320 582.72	164 053.40	1 135 490.24
1986/87	255 238.52	128 814.76	331 830.85	404 220.32	171 356.95	1 291 461.40

Source: IBGE, *Agroanalysis*, July 1988.

Maize is produced throughout the country but mostly in the Centre-South and the South. From 1975 to 1987, the North-East contained 12 per cent of total area cultivated but only six per cent of total production. As a result, except for 1984-86, the North-East has had to import maize from other regions or from abroad.

Paraná state, the largest producer (about 20 per cent of the total), consumes almost all its production, while other producer states (Saõ Paulo, Rio Grande do Sul, Santa Catarina), as a result of the poultry industry, are net importers depending largely on production from the Centre-West, and particularly Goias state, which has the largest maize surplus.

This situation affects prices through transport costs because of the long distances between main producer and consumer regions and will probably lead to relocation of the poultry industry.

Marketing

Maize in Brazil has traditionally been a domestic market product, with imports and exports only marginal (Table 8). The only exception was during 1986/87 when imports were as high as 15 per cent of domestic consumption.

Table 8

BALANCE IN SUPPLY AND DEMAND OF MAIZE
1980/81 - 1987/88
(Thousands of tons)

Year	Initial Stock (1)	Production (2)	Imports (3)	Total Supply (4) = (1)+(2)+(3)	Internal Consumption (5)	Surplus (6) = (4)-(5)	Exports (7)	Final Stock (8) = (6)-(7)
1980/81	1 180	21 283	0	22 463	21100	1 363	0	1 363
1981/82	1 363	21 604	0	22 967	20 600	2 367	543	1 824
1982/83	1 823	19 014	465	21 302	19 740	1 562	739	823
1983/84	824	21 178	0	22 002	19 700	2 302	1 802	122
1984/85	2 121	21 174	200	23 495	21 053	2 442	0	442
1985/86	600	20 264	2 936	23 800	22 200	1 600	0	1 600
1986/87	1 600	26 770	360	28 730	25 810	2 920	0	2 920
1987/88	2 920	25 031	0	27 951	23 730	4 221	0	4 221

(*) Provisional estimate.
(**) Initial stock for harvest 1985/86 refers to 1/3/86.
Final harvest stock 1984/85 refers to 31/12/85.

Source: I. Wedekin and L.A. Pirazza, 1988.

Brazilian maize is internationally competitive at farm level, but storage and transport costs are prohibitive. This is particularly so in the Centre-West. Even so, "packaged maize" in the form of poultry is highly competitive internationally.

In general, marketing is through traders - 85 per cent in the North-East and 65 per cent in other regions. Most maize producers do not belong to cooperatives.

Inadequate storage is the main cause of losses, especially with less modernised producers. There is no estimate of losses, which occur more during super harvests and cause reduction in nutritional quality, loss in weight and commercial value. Lack of interest in investing in storage is due to lack of incentive for immobilising capital in a sector where the state is quick to intervene with its controlling stocks when prices begin to rise.

Productivity

Temperate and sub-tropical regions are best for maize production in the current state of technology. There is no equivalent of the US "Corn Belt" in Brazil, but there are some areas of higher productivity, as shown in Table 9.

Table 9

CENTRE-SOUTH AND NORTH-NORTH-EAST
EVOLUTION OF MAIZE PRODUCTION
1980/81-1987/88

Year	Centre-South			North-North-East		
	Area (1000ha)	Production (1000t)	Yields kg/ha	Area (1000ha)	Production (1000t)	Yields kg/ha
1980/81	8 960	20 397	2 277	3 185	886	278
1981/82	9 512	20 139	2 117	3 257	1 465	450
1982/83	8 934	18 489	2 070	2 723	525	193
1983/84	9 449	19 375	2 050	2 755	1 802	654
1984/85	8 999	19 473	2 164	2 941	1 701	578
1985/86	9 644	18 074	1 874	3 439	2 190	637
1986/87	10 892	25 629	2 353	3 718	1 130	304
1987/88	9 622	22 542	2 343	3 712	2 489	671

Source: I. Wedekin and L.A. Pinazza, 1988.

However, as Table 10 below shows, the "low-tech" producer predominates in the North-East, whereas elsewhere input use is widespread. Disparities both between regions and within the same region greatly lower productivity. While this has increased in recent years, productivity still lags far behind averages in advanced countries. Only five per cent of farmers use recommended levels of fertilizer, and despite the volume of production, maize accounts for only 10 per cent of fertilizer use in Brazil.

Table 10

PERCENTAGE OF NATIONAL PRODUCTION
PERCENTAGE INCREASE IN PRODUCTION AND YIELDS OBTAINED (kg/ha)
FOR MAIZE IN REGIONS
1970/72 to 1980/82

Regions	Percentage of production		Percentage increase in production	Yields kg/ha 1980/82
	1970/72 (A)	1980/82 (B)		
North	0.4	1.2	361	1 296
North-East	9.5	4.3	-33	381
South-East	34.0	28.8	25	1 997
South	49.9	55.3	63	2 540
Centre-West	6.2	10.4	147	2 016
Brazil	100	100	47	1 777

Source: FIBGE, Garcia, Vencovsky, n.d. CNPMS.

Even so, in some regions productivity approaches the levels of advanced countries. The winner of the national maize productivity competition among the most "high-tech" farmers during the 1987/88 harvest had a per hectare production of 15 077 kilos.

Table 11

MAIZE YIELD IN THE UNITED STATES AND BRAZIL VARIOUS YEARS
(kg/ha)

Period	United States	Brazil	US/Brazil
1916/1917	1 530 (1)	1 690	0.91
1931	1 538 (2)	--[a]	--
1941	1 959 (2)	1 184[b](3)	1.65
1951	2 317 (2)	1 214[c](3)	1.91
1961	3 914 (2)	1 312 (3)	2.98
1971	5 449 (2)	1 339 (3)	4.07
1981	5 898 (4)	1 836 (3)	3.75
1980/1981	6 617 (4)	1 781 (3)	3.72

a no data. b year for 1945. c year for 1952.
1) *source*: Hunnicutt (1924).
2) *source*: Jugenheimer (1976).
3) *source*: FIBGE (v.a.).
4) *source*: USDA (1983); J.C. Garcia and R. Venkowsky, (n.d.).

The generally low productivity indicated in Table 11 reveals great potential for expanding production without resorting to incorporation of new areas. Such an increase is unlikely in the North-East however because of poor technology, because production is largely for on-farm consumption and because ecological conditions do not favour commercial production. Low soil fertility and irregular climate and rainfall discourage investment in commercial inputs. The practice of intercropping in its turn - recommended for such climatic conditions - lowers productivity even further.

Productivity in the region, which averaged 500kg/ha between 1976-88, could be increased with a combination of irrigation policies and production of seeds genetically adapted to the region. Irrigation is the key to production and stable productivity, in addition to full use of modern inputs. However, in the North-East, maize does not seem the best crop for irrigated agriculture. Other crops show greater returns.

Intercropping, as we have seen, is dominant in the North-East (some 90 per cent of total production) but is also present in the Centre-South (about 23 per cent of total production). In general, intercropping declines as production area increases. In the North-East (Table 12 and 13), on-farm consumption is as much as half of total production, whereas some two-thirds is marketed in the Centre-South.

Table 12

NORTH-EAST: COMMERCIAL AND RURAL CONSUMPTION OF MAIZE
1980-1984
(thousand of tons)

	1980	1981	1982	1983	1984
Commercial	712	716	698	710	732
Rural	938	914	962	898	988
(Total)	1 650	1 630	1 660	1 608	1 720

Source: CA, *Agroanalysis*, 87.

Table 13

NORTH-EAST: PRODUCTION AND CONSUMPTION OF MAIZE
1980-87
(thousands of tons)

Item	1980	1981	1982	1983	1984	1985[1]	1986[1]	1987[1]
Production	1 172.6	885.5	1 465.1	525.4	1 802.2	1 700.1	2 174.0	840.2
Consumption	1 650.0	1 630.0	1 660.0	1 608.0	1 720.0	NA	2 055.4	2 155.2
Difference	-477.4	-744.5	-194.9	-1 082.6	82.2	NA	114.6	-1 315.2

Source: CFP, *Agroanalysis*, December 1987.
1) Consumption estimated on basis of global data from North and North-East regions, with 86 per cent participation of the North-East.
n.a.: not available.

The Northern region, with its tropical climate and still-expanding frontier, has a precarious infrastructure. Its population centres are dispersed and population density is low. Maize production here is some 10 per cent of national production. Productivity is between that of the North-East and the Centre-South regions and averages about 1,250 kg/ha. The expanding frontier and constant increase in demand are responsible for a continuous expansion of maize production.

The Centre-South and Centre-West, despite heterogeneity of production systems, have the biggest proportion of capitalised farmers. In the Centre-West especially, large properties predominate. The more capitalised farmers generally buy their hybrid seeds annually, whereas farmers on a lower technological level tend to use a second generation produced on the farm, even though this lowers productivity. For a capitalised producer, hybrid seeds are between two to three per cent of his production costs. It is the second generation (S2) hybrid which is sold in Brazil rather than the S1, which is marketed in the United States. The S1 is more expensive, but more homogeneous and facilitates mechanisation.

The more "high-tech" farmer (responsible for 15-20 per cent of national production) is highly sensitive to price fluctuations and rapidly migrates to other

crops. In recent years, this has led to loss of the most "high-tech" farmers to soybean production.

Consumption

Some 65 per cent of maize produced in Brazil is for animal feed, with 35 per cent for human consumption - fecula, starch, flour, and vegetable oil. There is little difference between different types of maize from the point of view of consumption.

Mainly used for poultry, maize is becoming increasingly important also for pigfeed and cattlefeed (in feed-lots). Between 1973 and 1987, domestic consumption of poultry meat more than tripled (+353 per cent) while pigmeat almost doubled (+174 per cent). The poultry sector has also become a major exporter (Tables 14 and 15).

Until the mid-1960s, pig and poultry production centred on the small farming sector. Towards the end of the 1960s and the early 1970s, the poultry industry began to occupy and expand the market. This involved imported matrices and international technology for large-scale poultry production. The animal feed and veterinary input sectors, based largely on multinational firms, accompanied this expansion. As Table 16 shows, there has been enormous progress in main productivity indicators - average weight, age of slaughter, food conversion and mortality rates.

Table 14

QUANTITY OF MAIZE TRANSFORMED BY THE ANIMAL FEED INDUSTRY
1971-85

Year	Thousands of tons
1971	1 700
1972	2 000
1973	2 500
1974	3 200
1975	3 500
1976	5 766
1977	6 628
1978	7 752
1979	9 742
1980	10 880
1981	9 631
1982	8 500
1983	7 737
1984	7 095
1985	7 307

Source: Agroanalysis, January 1987.

Table 15

POULTRY MEAT
PRODUCTION, EXPORT (QUANTITY, VALUE, AVERAGE PRICE),
INTERNAL AVAILABILITY AND PER CAPITA CONSUMPTION

Year	Production[1] (t)	Exports			Internal Availability (t)	Per Capita Consumption (kg/ano)
		Quantity (t)	Value (US$1 000)	Average Price (US$/FOB)		
1980	1 306 000	168 713	206 690	1 225	1 137 287	9.6
1981	1 490 000	293 933	354 291	1 205	1 196 067	9.8
1982	1 604 000	301 793	285 475	946	1 302 207	10.4
1983	1 584 000	289 301	242 212	837	1 294 699	10.0
1984	1 443 000	287 494	268 976	936	1 155 506	8.8
1985	1 577 000	273 010	238 570	874	1 303 990	9.7

Source: APINCO, ABEF, IBGE, *Agroanalysis*, June 1986.
1) estimate on basis of poultry meat production.

Table 16

COMMERCIAL POULTRY
AVERAGE WEIGHT, SLAUGHTER AGE, RATE OF FOOD CONVERSION, MORTALITY
1934-1994

Year	Average weight (kg)	Slaughter age (day)	Rates of food conversion (kg of animal/ kg of feed weight)	Mortality (%)
1934	1.30	95	4.30	13.0
1944	1.35	84	3.90	10.0
1954	1.40	74	3.00	7.0
1964	1.58	63	2.30	5.5
1974	1.70	59	2.00	5.0
1984	1.89	47	1.96	4.5
1994[(1)]	2.05	42	1.82	4.5

Source: ANFAR.
1) projection.

During this period, the matrices have been entirely imported. Agroceres however has now contracted with Ross Breeders of Scotland for the transfer of genetic lines and their production in Brazil.

Maize is the principal component (about two-thirds) of commercial animal feed and represents 70 per cent of the final cost of poultry and 80 per cent in the case of pigs. Favourable prices for poultry compared with red meat have accounted for the constant increase in demand for it among Brazilians.

In 1988, per capita consumption of red meat in Brazil was 13.5 kilos per year, as against 12.4 kilos in the case of poultry. In the United States, the figures are 33 and 37 kilos respectively. Both countries have shifted towards white meat consumption. In the United States in 1980, the figures were 35 and 28, and in Brazil 15.6 and 9.5 respectively. In the United States, the shift represents changing health habits. In Brazil, it reflects a decline in purchasing power for most of the population during the 1980s (Table 17).

Table 17

SAO PAULO STATE
NOMINAL AND REAL VALUES OF MONTHLY MINIMUM WAGE
NOMINAL AND REAL PRICES OF RED MEAT AND POULTRY
1970-85

	Minimum Wage			Red Meat			Poultry		
	Nominal	Real		Nominal	Real		Nominal	Real	
Year	Cr$	Cr$	1970=100	Cr$/kg	Cr$/kg	1970=100	Cr$/kg	Cr$/kg	1970=100
1970	192	192	100	4.05	4.05	100	4.00	4.00	100
1971	232	193	101	5.02	4.17	103	4.30	3.57	89
1972	292	207	108	5.97	4.23	104	4.96	3.51	88
1973	330	204	106	8.91	5.49	136	6.76	4.17	104
1974	387	185	96	10.97	5.26	130	8.41	4.03	101
1975	525	197	103	13.94	5.22	129	9.49	3.56	89
1976	754	200	96	16.89	4.48	111	13.22	3.51	88
1977	1 086	202	104	22.53	4.19	103	16.95	3.15	79
1978	1 539	206	107	40.61	5.45	135	26.31	3.53	88
1979	2 387	208	108	76.84	6.69	165	43.63	3.80	95
1980	4 500	196	102	140.86	6.13	151	72.66	3.16	79
1981	9 144	190	99	234.48	4.86	120	133.39	2.77	69
1982	18 172	193	101	433 03	4.59	113	227.37	2.41	60
1983	39 524	165	86	1 265.83	5.27	130	686.00	2.86	72
1984	109 268	142	74	3 889.60	5.07	125	2 103.00	2.73	68
1985	372 080	149	78	11 646.00	4.65	115	6 602.00	2.64	66

Source: Banco Central and IEA-SP, *Agroanalysis*, January 1987.
1) corrected by the IGP-DI for 1970.
2) includes the 13th month wage.

Most white meat production is in the South, whence it is exported to other regions and abroad. A sharpening of international competition (from the United States, Europe and more recently Thailand), together with increased domestic production by erstwhile importers (Middle East), has harmed Brazilian exports (Tables 18 and 19). In 1987, Brazil was still the third largest exporter but its share was cut from 17 to 15 per cent. The United States on the other hand increased its share from 21 to 26 per cent. French exports fell from 19 to 17 per cent. While industrialised countries benefit from export subsidies, Brazilian producers have had to face the effects of a fiscal crisis which has reduced direct and indirect subsidies to exporters.

Table 18

POULTRY
EXPORTS (QUANTITY, VALUE AND AVERAGE PRICE)
1975-1985

Year	Quantity (tons)	value ($1 FOB)	Average price ($/ton)	% variation in price
1975	3 469	3 289	950	-
1976	19 636	19 565	1 000	5
1977	32 829	31 572	960	-4
1978	50 805	46 872	920	-4
1979	81 096	81 148	1 000	9
1980	168 713	206 690	1 230	23
1981	293 936	354 291	1 210	-2
1982	295 551	280 657	950	-21
1983	299 231	251 476	840	-12
1984	287 494	268 976	936	12
1985	273 010	238 570	874	-7

Source: ABEF (a producer organisation), *Agroanalysis*, January 1987

However, new export markets have been won - Cuba, for example - and Brazil is developing competitive capacity in high quality markets since its combination of advanced technology and low labour costs allows it to explore the dynamic markets for speciality cuts (e.g. Japan).

Table 19

BRAZIL AND THE UNITED STATES
SALES OF POULTRY TO EGYPT AND IRAQ
1985-1987
(tons)

Origin	Destination	
	Egypt	Iraq
Brazil		
1985	50 019	65 629
1986	5 454	24 985
1987	---	13 333
USA		
1985	6 198	---
1986	25 575	---
1987	26 527	58 479

Source: United States Department of Agriculture (USDA) and ABEF, *Agroanalysis*, May 1988.

So far, non-traditional alternative uses of maize have not been developed nor are they being researched in Brazil. The combination of the sugar lobby and government subsidies has prevented use of maize as an alternative sweetener.

Policies

While there are no individual policies for maize, production is particularly sensitive to overall agricultural policy. Expansion of maize production cannot be dissociated from the subsidised credit which financed consolidation of the poultry industry in the 1970s. The subsidy for wheat over the last two decades (although recently this has declined) affects maize consumption as an alternative component in bread production.

Pressure of debt on hard currency earnings has led the government to support exports, while the struggle against inflation has led to rigid controls and at times freezing of prices of products for the domestic market. Resulting low prices for meat and grains have led farmers to move to soybeans.

Minimum price policies have been the main form of public support in recent years (Rezende, 1989) since storage is risky when the government uses its stocks or imports in the inter-harvest season to control inflationary pressures.

Most important however for maize production are macro-policies determining purchasing power, especially with increased competition in export markets. So production expansion is tied to development of the domestic market.

Public Control and Property Rights

Public controls over seed production are recent and still being consolidated. At first, Saõ Paulo state developed its own system for seed certification. It began in 1936, mainly concerned cotton and was completed in 1968. It involved control over seed origin, the establishment of quality norms, inspection and marketing systems. In this period, the Saõ Paulo state agricultural department was the main seed producer and had a stronger research infrastructure than the Federal Government.

In 1965, the Ministry of Agriculture laid down the first norms for inspection of seed sales, and began studies to define legislation in the area. The National Seed Plan was set up in 1967 as part of a global policy for developing the sector. This policy aimed to strengthen private sector participation while the public sector would continue basic research, quality control and inspection of the marketed product.

PLANASEM, as the national plan was called, distinguished a developed zone in the South and the South-East, and a priority zone in the North, North-East and Centre-West. In the former, private initiative was to be given pride of place. In the second, the state needed to develop infrastructure to enable growth of the private sector.

The law recognises two types of improved seeds: certified seeds with control over genetic origin through multiplication of basic seeds, and inspected seeds whose origin are known but which have not necessarily been multiplied from basic or certified seeds.

While seed inspection is now carried out in all states, certified seeds are still being consolidated in several states and are dominant only in Saõ Paulo.

Seed policy and inspection is carried out by state bodies linked to the federal organ CONASE, the National Seed and Plant Commission, created in 1978. While the latter defines minimum legislation, each state may add its own laws.

Brazilian law does not protect plants and animals. The system of patents is also excluded from the pharmaceutical and food industries both in terms of product and processes.

This may change soon. The new agricultural law being debated in Congress includes an article stipulating that within a year of promulgation, Brazil should regulate intellectual property rights of plant origin. Equally important is consensus in favour of legislation for the area among most of the seed sector and a large part of the public sector research community. In the private sector, there is concern about retaliation by potential importers of Brazilian seeds and plants because of the lack of legal protection. In fact, this has already happened. Equally important however is the need to enter new areas involving transfer of technology which is only possible if there is legal protection. Without such protection, the risk of investing in research into biotechnologies becomes too high since, unlike hybrids, they have no in-built monopoly which would dispense with legislation.

As we shall see, in the public sector, researchers are having to face the impact of fiscal crisis and particularly the effect of inflation on salaries. The possibility of royalties which would benefit researchers and help finance research centres is a major motive for the support by researchers for legislation. Finally there is agreement that in agricultural research, and particularly classical genetics, Brazil already has an internationally competitive capacity.

Part Two

RESEARCH, TECHNOLOGY, DEVELOPMENT AND DIFFUSION

Historical Background - The Shaping of the Public and Private Seed Sectors

While several agronomic centres were established in Brazil over the last century, agricultural research became concentrated in the Campinas Agronomic Institute (IAC) belonging to the state of Saõ Paulo. The Institute was a response to the coffee frontier's shift from the state of Rio, and its early years were devoted to work on this crop. Overproduction of coffee and the subsequent collapse of world prices stimulated agricultural diversification and with it demands for broader agricultural research, with cotton as the main beneficiary.

Interest in improving quality of coffee and cotton fibre led to emphasis on basic research rather than crop practices and field experiments. As a result, the Institute was restructured in the late 1920s to separate applied from basic research activities. Within the latter, a Genetics Section was formed under the Austrian E. Taschdjian. Coffee remained the research priority but the technological frontier in genetics was to favour work on maize.

A year after the restructuring, the agronomist C.A. Krug received a grant to specialise in genetics and citology at Cornell University. He researched into maize and wrote his thesis on the most recent developments in citogenetics and crop improvement as applied to maize.

With the return of Krug in 1932, maize improvement was integrated into the IAC's Genetics Section. This work focused on the controlled self-fertilisation of yellow hard grain Cateto varieties, white hard Cristal, and white-grained Amparo varieties with a view to deriving homogeneous lines for future synthesis of hybrid maize. During the late 1930s and 1940s, Cateto, Armour, and Asteca hybrid maize varieties were launched in Saõ Paulo state.

But there was a basic obstacle. Maize in Brazil is planted at different latitudes to the Corn Belt in the United States. So while the methodology of hybrids was adopted from the United States, resistance factors had to be incorporated from local lines (Cateto).

Maize research was also developed in the 1930s at Viçosa University in the Minas Gerais state, and was similarly directed towards hybrids as a result of training in the United States. The influence of this foreign postgraduate training at a time when the United States was wholly engaged in hybrid research would seem to explain the shift from open pollinated to hybrid research in Brazil. Research on hybrids in Viçosa began in 1937 using 100 North American lines. But only one was successful, and attention was directed to local lines crossed with a Mexican variety.

Close collaboration was maintained with US research, particularly at Purdue University. Developments in Viçosa however took a different direction from that at Campinas. After withdrawal of two leading researchers to form the private firm Agroceres, public research at Viçosa was paralysed. In compensation, Agroceres was to become the leading maize seed company in the Brazilian market.

With the success of the Saõ Paulo public sector in production of varieties, the question of diffusion defined priorities during the 1940s. In 1945, a special farm for hybrid maize production was established by agreement between the department of agriculture and the Saõ Paulo state government. This farm worked in close collaboration with the genetics section of the Campinas Institute, producing simple hybrids for subsequent commercial production of double hybrids. New varieties were launched in the late 1950s incorporating germplasm from Mexico.

By 1950, the Saõ Paulo department of agriculture was distributing over 3,000 tons of hybrid seeds - enough for half of the state's needs. Despite a doubling of the area planted with maize during the 1950s, diffusion of hybrids kept pace and accounted for more than half of Saõ Paulo's maize production.

The success of this integrated seed production system in Saõ Paulo enabled implementation of a Seed Certificate Procedure for hybrid maize in 1957, which implied public control within Saõ Paulo state over genetic origin of seed production in the private sector, in addition to imposition of quality norms and inspection of sales.

The 1960s however saw basic restructuring of public sector research, involving also redefinition of relations with the private seed industry. Three factors can be identified:

i) consolidation of a mature seed industry for hybrid maize
ii) a new national model of agricultural research
iii) expansion of the agricultural frontier to the South and Centre-West.

The seed research and production system in Saõ Paulo had promoted a network of small national firms with no in-house research base which multiplied and marketed public sector basic seeds. Of private firms in the 1950s, only Agroceres marketed its own variety - the AG7. Trials by Agroceres in the late 1940s showed that its hybrids were competitive against both open pollinated varieties and hybrids from the Campinas Institute. The latter's HMD 6999 public sector variety however was widely considered the most competitive. By 1959, the seed firms had joined to form the Saõ Paulo Association of Seed Producers.

Friction between public and private sector grew in the 1960s. The department of agriculture, with eight seed production posts, was able to supply over half the Saõ Paulo market. Its prices were also very close to normal grain prices. Serious over-production resulted and firms were left with large stocks. As a result, strong pressure was exerted to redefine public sector participation in seed markets.

After 1968, the Campinas Institute and other public research centres limited themselves to production of basic seeds and launching of hybrids was halted.

The strong public sector presence in Saõ Paulo led to predominance of small national firms in this state which depended on the Campinas Institute for research and launching of new hybrids. The exception at national level was Agroceres which, as we have seen, emerged from public research and in alliance with the US IBEC Corporation in the mid-1940s. Before the end of the decade it was launching its own varieties. It initially sought agreement with established agro-industrial firms for sales outlets (Anderson Clayton, Serrano), but quickly launched its own network and established decentralised processing units in all zones of future maize expansion. This decentralised presence at national level gave Agroceres a decisive advantage when major foreign firms began to enter the Brazilian market.

Cargill, which was to become the major foreign seed firm, established itself in Campinas in the mid-1960s and Pioneer set up shop in Rio Grande do Sul. The Corn Products Company subsidiary, Refinaçoes de Milho, which dominates maize processing in Brazil, was also active in seeds, marketing material from Funks. An unsuccessful attempt at market expansion however led it to sell out to Ciba-Geigy, which had meanwhile bought out Funks.

So pressure from the emerging private seed industry forced redefinition of the public sector's role and established a new national model. This was first evidenced in the National Seed Inspection Law of 1965 which rejected the genetic control of the Saõ Paulo certificate system in favour of physical controls over quality. This was followed by the National Seed Plan, which implied general redefinition of the public sector's role, limiting it to research and basic seed production. The Plan distinguished two zones - developed and priority - stimulating the private sector in the former (South and South-East) and assuming responsibility for diffusion of improved seeds in the latter (North and North-East).

These changes were part of global restructuring of public sector agricultural research which led in the early 1970s to creation of the Brazilian Agricultural Research Enterprise (EMBRAPA). Heavily influenced by the North American agricultural expert Edward Schuh, research was now organised around individual products rather than disciplines and strongly integrated into the network of International Agricultural Research Centres. Within this framework, the Brazilian National Centre for Maize and Sorghum (CNPMS) was established in 1976.

This consolidation of national research structure reflects expansion of the agricultural frontier away from the Saõ Paulo area. This is true also for maize, which assumes a growing importance as an input for the pig and poultry industry in the states of Paraná and Santa Catarina, stimulated also by growth of soybean production in the southern states. Without the long tradition of the Saõ Paulo public sector, plant improvement research in these states was not accompanied by production and marketing capacity. National policy was therefore to encourage emergence of a private seed industry, welcoming also foreign subsidiaries, since

within the global science and technology policy of this period, agriculture was considered nonstrategic and open to foreign capital.

The National Public Sector Research Structure

Within the restructuring of public sector research, the National Centre for Maize and Sorghum in Minas Gerais, on the edge of the "cerrado" grains frontier region, became responsible for coordinating all maize research included for public financing. Data up to 1985 shows that the National Maize Research Programme comprised 148 projects developed by 31 research institutes (Table 20). As can be seen from the table however, research is very broad with only 43 projects directly concerned with genetic improvement. The CNPMS is itself responsible for 40 projects but only six concern genetic improvement (Table 21).

Table 20

NUMBER OF PROJECTS IN DIFFERENT LINES OF RESEARCH BY REGION IN THE PNP' MAIZE PROGRAMME UNTIL DECEMBER 1985

	Regions				
Evaluation of cultivars	North	North-East	South	Centre-South	Total
Improvement	5	6	3	29	43
Evaluation of cultivars	6	8	3	8	25
Crop practices	1	1	3	12	17
Fertilizer + nutrition	1		2	13	16
Storage pest control	1	2	1	6	10
Weed control		1	1	1	3
Irrigation			2	4	6
Soil treatment			1	2	3
Seed technology	1			1	2
Field pest control			1	6	7
Phytopathology				5	5
Economy				2	2
Mechanisation				2	2
Plant physiology				2	2
Climatology			2		2
Microbiology				1	1
Statistics				1	1
Technology diffusion				1	1
TOTAL	14	19	19	96	148

Source: CNPMS.
1 National Research Programme.

The maize improvement programme is based on work with plant populations or varieties as progenitors of intervarietal hybrids, or extraction of lines for creation of simple, double, triple and/or synthetic hybrids.

The programme's main aims, according to the CNPMS's quinquennial report, were production of modern cultivars with the following characteristics:

i) low size
ii) higher relation of dry material to total grain weight
iii) resistance to the main leaf diseases
iv) good capacity for converting nutrients into grain
v) greater tolerance to drought and mineral stress, especially aluminium
vi) greater efficiency in the use of energy
vii) high quality protein (lysine, triptophane)
viii) improvement of seeds for production of popcorn

Tropical maize populations have abundant foliage, are high in size and have a long cycle. Research in Brazil is increasingly interested in smaller cultivars which allow for greater population density and facilitate mechanical harvesting. Thirty-three populations of smaller cultivars from CIMMYT have been analysed and as a result, maize improvement research can now work with new small-size precocious and intermediary cycle populations.