





THE SOCIO-ECONOMIC IMPACT OF INVESTMENTS IN RESEARCH BY EMBRAPA:
RESULTS OBTAINED, PROFITABILITY AND FUTURE PROSPECTS

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## FOREWORD

Studies focusing upon socio-economic returns of EMBRAPA's investments in agricultural research have been of major concern by the institution administration. Such studies are mainly oriented to define new directions and future policies regarding to agricultural research. The results of this paper are quite relevant for the institution in justifing the use of public resources as well as support for its research activities coming from the federal government and international financing agencies such as the World Bank and the Interamerican Development Bank.

This study had been discussed during the "XXII Brazilian Congress of Sociology and Agricultural Economics" at Salvador, Brasil (July 1984) and in the "International Seminar on Development and Scientific and Technological Research Effectiveness", at Rip de Janeiro, Brasil (January 1985). Eventhough this study had been published in the proceedings of those Congress and Seminar the quality and opportunity of issues discussed suggested that such study should be published in the EMBRAPA-DEP documents.

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THE AUTHORS

# THE SOCIO-ECONOMIC IMPACT OF INVESTMENTS IN RESEARCH BY EMBRAPA: RESULTS OBTAINED, PROFITABILITY AND FUTURE PROSPECTS\*

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#### ABSTRACT

The main objective of this paper is to analyse the socio-economic impact of EMBRAPA's investments in agricultural research, focusing upon the actual and potential benefits obtained, and on the social rate of return of these investments.

Agricultural research have had a very important role in the performance of the brazilian agriculture during last decades. In the especial case of EMBRAPA, an institution of research relatively young, its contribution refers to the last years. In any way, given the quality of the technologies generated, such contribution has quite expressive.

The results of the evaluation of returns on investments in research developed by EMBRAPA, both at a global level as in the area covered by projects 1249/BR (World Bank) and PROCENSUL I (Inter-american Development Bank), and at the National Agricultural Research Centers for wheat and for soybeans, have showed a high social return. The volume of benefits resulting from the technologies generated by the research has more than compensated for the resources originally invested.

Furthermore, the research work in progress by EMBRAPA's units already presents empirical evidence which allow us to foresee the maintenance of future high social rates of return on investment in agricultural research. This paper stresses that there exists a large number of technologies in the process of generation, whose potential benefits are high. Such benefits, associated with those provided by the adoption of the technologies already generated justify the continuation of financial support for the research program of the Corporation, including obtaining external financial resources.

This paper was based in the document "Rentabilidade dos inveg timentos em pesquisa na EMBRAPA: Resultados alcançados e perg pectivas" prepared by the same authors and submitted by EMBRAPA to the Inter-american Development Bank in partial fulfillment of the requirements of the PROCENSUL II Project.

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# IMPACTOS SOCIOECONOMICOS DOS INVESTIMENTOS EM PESQUISA NA EMBRAPA: RESULTADOS ALCANÇADOS, RENTABILIDADE E PERSPECTIVAS

#### RESUMO

O objetivo principal deste trabalho è analisar os impactos socioeconómicos dos investimentos em pesquisa agropecu ária na EMBRAPA, destacando os beneficios alcançados e potenciais, e a rentabilidade social de tais investimentos.

A pesquisa agropecuária teve um papel muito importante na evolução da agricultura brasileira durante as últimas décadas. No caso particular da EMBRAPA, uma instituição de pesquisa relativamente nova, sua contribuição se restringe aos últimos anos. De qualquer mameira, dada a qualidade das tecnologias geradas, tal contribuição foi bastante expressiva.

Os resultados das avaliações de retorno dos investimentos em pesquisa desenvolvidas na EMBRAPA, tanto a nivel global, como na área dos projetos 1249/BR (BIRD) e PROCENSUL I (BID), e dos Centros Nacionais de Pesquisa de Trigo e Soja, tem mostrado uma alta rentabilidade social. O volume de benefícios, resultantes das tecnologias geradas pela pesquisa, tem mais que compensado os recursos nela investidos.

Outrossim, as pesquisas em desenvolvimento nas unidades da EMBRAPA já apresentam evidências factuais, que permitem antever, também para os próximos anos, a manutenção de altas taxas sociais de retornos para os investimentos em pesquisa agropecuária. Tais beneficios, aliaecorrentes da ampliação da área da adoção das tecnologias já geradas, justificam plenamente a continuação de apoio financeiro á programação de pesquisa da Empresa, inclusive atravês de recur;os externos.

# LES IMPACTS SOCIO-ECONOMIQUES DES INVESTISSEMENTS DE L'EMBRAPA: RESULTATS OBTENUS, RENTABILITE ET PERSPECTIVES

## RESUMÉ

L'objectif principal de ce travail est l'analyse des impacts socio-economiques des investissements de l'EMBRAPA dans la recherche agronomique, en mettant l'accent sur les résultats obtenus et potentiels, et à la rentabilité sociale des ces investissements.

La recherche agronomique a eu un rôle très important dans l'évolution de l'agriculture brésilienne au long des dernières décennies. Dans le cas particulier de l'EMBRAPA, une institution de recherche assez jeune, sa contribution se restreint aux dernières années. De toute façon, compte tenu de la qualité des tecnologies crées, telle contribution à déjá joué un fôle fondamental pour cette évolution.

Toutes les évaluations récemment développées au niveau de l'EMBRAPA ont montré que les investissements ont été très rentables pour la societé bresilienne. Les bénéfices apportés par les technologies développées par la recherche ont atteint un volume de ressources largement supérieur à celui des investissements dans la génération de ces technologies.

Les recherches en cours dans les centres de l'EMBRAPA présentent des évidences qui nous permettent aussi d'espèrer, pour les prochaines années, le maintient de ces taux internes de rentabilité très élavés. Ces bénéfices potentiels, allés à ceux résultants de l'augmentation du taux d'adoption des tecnologies déjà dèveloppées, justifient assez clairement la continuation de l'appui financier à la programmation de recherche de l'Entreprise, y compris les ressources externes.

# THE SOCIO-ECONOMIC IMPACT OF INVESTMENTS IN RESEARCH BY EMBRAPA: RESULTS OBTAINED, PROFITABILITY AND FUTURE PROSPECTS

#### 1. INTRODUCTION

During the last decades, and even in the first two years of the 1980's, the economic growth of Brazil was highly satisfactory. In terms of the Gross Domestic Product (GDP), the official statistics show a growth between the years 1950 and 1980, from 34.7 to 274.3 billion dollars, meaning an average growth rate of about 7% per year. This led Brazil to be among the top ten countries of the world in terms of the size of GDP.

Despite the huge growth of population, which occurred in this period, the country's per capita product increased from an extremely low level of 665 US dollars in 1950 to a more significant one of US 2,303 dollars in 1980.

As jt would be expected, these increases took place with greater intensity in the industrial and services sectors rather than in agriculture. The censuses of Fundação Instituto Brasileiro de Geografia e Estatistica (IBGE), showed that the share of agriculture to the GDP declined from 25% in 1950 to 13% in 1980, while industrial and services sectors grew from 26% to 34%, and from 45% to 53% during the some period respectively.

Regarding the foreign trade of the country, the changes occurred mainly in the last two decades, it is sufficient to say that in 1963—the exports were only about 1.4 billion dollars per year, in which coffee contributed 53% of this total. In 1983, the exports reached 21.9 billion dollars, coffee accounted for 10.6% of the total, and manufactured goods for 52%.

This economic growth was referred to by some authors as the "Brazilian economic miracle", because it was accompanied by deep changes in all sectors of economic and social activity. The country's economic structure was markedly modified in these two decades, with the installed capacity of electricity rising from 6.3 to 36.9 million kilowatts; the production of steel from 2.8 to 14.6 million tons; of motor vehicles increasing from 174,000 to 1.1 million units; of petroleum from 98 to 340 thousand barrels per day, and might reach 550 thousand barrels by the end of 1984. Furthermore, in the period from 1963 to 1979, the amount of federal paved highways rose from 11 to 50 thousand kilometers; the number of telephones increased from 1.2 to 6.2 million; the level of attendance at primary schools increased from 55 to 76%; and the number of recipients of social security benefits rose from 5.7 to 20.6 million, besides many other economic indicators which can be mentioned.

However, in recent years the country has undergone an economic and financial crisis without precedence in its history. This crisis is characterized not only by a large fall in

the levels of output and employment, or by huge increases in the number of bankruptcies and business failures, but also by the prevalence of problems difficult to solve, such as the galloping inflation, the high level of external debt, and also of the internal public debt. The inflation that stood in the 1970's at an annual rate of about 15 to 54%, reached in 1980 100.7%, and in 1983 211%. Therewith, the indexation, which appeared to be economically and socially justifiable became harmful, as it makes the inflation worse. The external debt, which grew to more than 80 billion dollars in 1983, because of the rising level of interest rates in the financial markets became a major The internal public debt, which increases are derived mainly from the government budget deficits, and from decisions made to maintain in the country the implementation of most of the investment projects by the State has currently reached a very high level, pushing the commercial interest rates to a level incompatible with the normal rates of return on economic activitres.

It is difficult to analyse with certainty the underlying causes of this crisis, but one can easily point to some factors which have decisively contributed to this situation. The two world petroleum crises of 1973 and 1979, without any doubt were basic elements in this context, especially because the country's decision-makers did not immediately believe in the permanency of this situation, thus not taking the necessary corrective measures. Over time the Brazilian economy has somehow absorbed these shocks, mainly by obtaining favorable results through intensifying the exploration of petroleum, and from the program for increasing the production of alcohol as a fuel.

The easy access to loans in the international financial market contributed also to increase the Brazilian external debt. The prevalent idea was that for the immediate interest of the country the level of economic growth already achieved should not be reduced, and to proceed with the investment programs in basic projects, which would allow for the attainment of the expected social and economic transformation of the country. Among these projects stand out those devoted to the enlargement of the Iron and steel industry, to the establishment of petrochemical plants, development of the mineral resources of the Carajas, the production of cament and cellulose, re-equipment of ports, of urban transport, production of alcohol, coal, and many other projects. The borrowing of external resources proved to be excessive, but it was basically due to the desire to avoid losing the favorable conditions for economic development known to exist in the country.

The world recession is the other element that has contributed to make the situation difficult, making more difficult the job of selling our products in the foreign markets.

In spite of these difficulties, at the beginning of 1984 the country followed a more rigorous program aimed at

fighting the inflation. The growing monthly balance of trade surpluses obtained at the begining of 1983 and continuing in 1984 is a promising fact which can lead to the hope that the Brazilian economy will enter again a new prosperous phase.

In this difficult economic context at a national level any analysis of the agricultural sector, even a superficial one, will show that such a sector has great possibilities of helping to provide a solution for this economic crisis.

In principle, there is no doubt that agriculture is the economic sector which can best make the most rapid contribution to overcoming the country's economic and financial difficulties. The increase in the agricultural output brings several benefits to the economy. If the expansion is for agricultural exports it will bring improvements to the balance of trude, and if it is on products consumed domestically will effectively help to reduce the inflation. Moreover, as the activity is relatively labor-intensive, any growth of its production will help to bring about a fall in unemployment, and also as the production process requires a small amount of imported goods, its expansion does not place great pressure on the balance of payments. Besides that, as the programs in the agricultural sector are of short maturity, they put little pressure on the demand for consumer goods, and thus on the rate of inflation.

The question which arises then is whether Brazil reckons upon the factors which allow for sizeable increases in the agriculture output. In this sense, the possibilities are particularly favorable for reasons that should be mentioned.

In the last 10 to 15 years Brazilian agriculture has shown great dynamism, with a satisfactory growth of production, widespread occupation of new agricultural lands, outstanding diversification of products and intensive adoption of modern technologies. It is worth to point out some of the factors that have contributed to this recent change in Brazilian agriculture, and to assess the chances of the level of output achieved to be maintained at an even larger scale.

Regarding the technological modernization of agriculture it should be remembered that this has occurred late, when compared with other countries. This is so because Brazil had in the past abundant reserves of forests, and of fertile soils. The land occupation was based upon a technologically traditional agriculture without using modern inputs which made some farmers with a short-sighted economic vision of the problem to abandon their crops as soon as the crop land got damaged molands, and repeating this pattern whenever necessary. This has happened mainly with the crops of coffee, cotton, corn and rice in a socially expensive itinerant agriculture, leaving behind eroded land and unproductive pastures.

Later, with the settlement of the last available areas of forests and fertile lands in the Center-South Region of the country, the farmers have to adopt modern technology in recovering ancient crop lands. With this need has increased markedly the use of machines, fertilizers, and inseticides, and on those old agricultural areas have expanded the cultivation of new modern crops producing high yields per hectare, especially those of sugar cane, coffee, orange, cotton, soybean, and other crops.

Concerning the expansion of the agricultural frontier in this period of great dynamism of Brazilian agriculture, stands out the intense settlement of "cerrado" agriculture (savannah areas). The total area of cerrado is estimated as being 189 million hectares, and in a certain way separates the fertile lands of the Center-South from those of the rest of the country, that is from the Amazon and Northeast regions. It is important to say that one of the main reasons why the occupation of this area has not been done earlier was the lack of adequate technological knowledge. It was known that by burning the the brushwood, rice could be manually cuitivated for two years, and after that pastureland could be established, although with a low capacity of supporting livestock per hectare. That was the known technology which allowed for the economic utilization of the area. Thus the occupation of the cerrado land proceeded slowly.

With the creation of new technologies adequate to the conditions of the cerrado areas was confirmed that those lands whenever mechanically prepared, and with an adequate application of fertilizers could exhibit high yields per hectare, yet with reduced risks owing to the regularity of rainfall in the region, despite it being concentrated in a relatively short period of the year, and the occasional occurrence of drought ("veranicos").

Therefore, in recent times the agricultural occupation of these areas has reached an increased pace, based upon a commercial agriculture with the employment of a modern technology, and the intensive use of capital.

Also as a feature of the recent change in Brazilian agriculture, we have a large number of agricultural producers coming from rural families and tenant-farmers of the south of the country, that emerged in the frontier areas as new entrepeneurs enjoying a successful commercial agriculture and a high level of technology.

It must be emphasized that the country still has at its disposal abundant resources, similar to those which were used in the recent expansion of agricultural production. In the Center-south region there still exists extensive areas of land, long ago occupied by agriculture which can be recovered. In the cerrado regions the land occupied by modern agriculture is small

compared to the total area that can be utilized. It is enormous the number of entrepreneurs mainly among the population of countrymen and tenant-farmers who have managerial capacity, and are eager to start agricultural activities on a larger-scale and more technical basis.

The existence of resources still not utilized is one guarantee that in principle new increases of production can be obtained. But one might have to consider the economics of the matter. As the possibilities for expanding production are always attached to the adoption of modern technologies, and as this adoption is particularly expensive requiring from farmers large investments and high costs, it is vital that favorable prospects of profits can be foreseen, as without that farmers do not have sufficient incentives to change agriculture and to expand their production.

It is important to mention that the farmers have had in the last 10 to 15 years abundant highly subsidized credit for investment, so that their costs of production reflected low expenditures on interest and repayment of loans in real terms. Based on this it must be supposed that they might have profited from their farming, and also might have enjoyed favorable profit outlook to expand their activities.

At present, there is a policy of withdrawing subsidies for agriculture in the country. This implies to a marked degree a raising of production costs, and consequently a reduction in the prospective returns. Therefore, it cannot be expected that the farmer can maintain the dynamism experienced by agriculture during the recent past.

To counteract this difficulty, without claiming changes in the prices of inputs and of products, which are complex issues and of uncertain solutions it is necessary to obtain with the utilization of modern agricultural technology, a larger reduction of cost and higher returns per hectare (increased productivity).

This means to work much more intensively in the research for more efficient low cost methods to combat pests and diseases, and also to generate new crop varieties more productive and resistant. With this, improved yields per hectare can be achieved for both crops and cattle breeding at lower costs.

The intensification of research and the expansion of the technical assistance services and rural extension activities are consequently the ways to provide new favorable profit perspectives for Brazilian agriculture, in order that it can maintain its dynamism, supplying increased production of foodstuffs and raw materials.

#### 2. THE SOCIO-ECONOMIC IMPACTS OF EMBRAPA'S RESEARCH

#### 2.1. Theoretical Aspects

The evaluation of the socio-economic benefits of agricultural research has ultimately received very special attention from researchers, and social scientists. Nevertheless, as already has been pointed out by Griliches (1979), given the nature of the research benefits, this evaluation has constituted an extremely complex task.

The knowledge, which is the final product of research can be expressed through an enrichment of the initial level of knowledge on new techniques, and/or methods of production, in improving the quality of life, advancement of professional competence, and further through other results such as a betterment of status or prestige, or the arrival of new ideas on certain research topics.

Biven this wide range of the research product, the issue of which unit of measurement to use for evaluating such a benefit becomes crucial. If knowledge is considered the final product of research, in what way can it be measured, if this is generated in unmeasurable units. Similarly, despite that knowledge has an economic value there does not exist a defined market for it, thus there do not exist mechanisms which can give a direct measure of this knowledge to society.

The researchers who have tried to evaluate agricultural research have utilized different methods for measuring the product of research. The most frequently ones used are the following: a) that considering the number of, and the circulation of technical and scientific publications produced in a given period and; b) the one which measures the findings of the research in terms of its effect on agricultural productivity.

The quantity of publications taken as an indicator of the research returns presents difficulties (Evenson & Kislev, 1975). It is evident that the quantity of knowledge transmitted through a publication varies too much from case to case, and the assessment of the relative value of publications constitutes a very hard task, and is subject to controversy. Besides that, the use of the amount of publications as an index of the productivity of research may result in damage to the institution's reputation in the long-term, since the researchers can play the "publications game", where the quality of research plays a secondary role.

To assess the contribution of research to agricultural productivity, as was the case of the majority of attempts at measuring the benefits from research in the 1970's, "the variable research expenditures" was much used, and in some studies also the number of researchers working in agricultural research or in research and technical assistance.

As the main contribution of agricultural research does not always render an improvement in productivity, as is the case for example of the research contribution to the reduction of production costs (nitrogen biological fixation, integrated pest-management etc) or even to an expansion of the agriculture frontier (soybeans in the tropics), such an alternative can lead to an underestimate of the research benefits.

Recently, Cruz et al. (1982) introduced a new indicator of research contribution. Such a measure comprises the evaluation of research contribution to the increased net income of the farmers, and in this case both the increased productivity achieved and the reduction in costs were taken into account, besides the net earnings obtained through an expansion of cultivated land. Therefore, the range of possibilities of underestimating the research impacts was reduced.

However, it should be emphasized that one institution working on agricultural research generally generates various types of research, and the results achieved cannot always be measured in terms of the producers earnings.

Another aspect which should be considered when dealing with the issue of measurement of research benefits is that referring to the effects of the transfer of technology (that is, the "spill-in" and "spill-over" effects). Such effects result from the imitation of firms within the same industry, from the transfer (legal and illegal) of ideas, processes innovations between different sectors and regions, and even between countries. In the case of agricultural research, which product is generally not patented, the stock of knowledge created in universities, public and private research institutions moves to and from one source to another. This is where stands out the difficulty of establishing what proportion of benefits should be attributed to a specific source. This difficult task becomes still bigger when the participation of a certain institution occurred in the past (e.g. starting the process of research work), and even when this was located in another country. When this happens, as has been stated in the literature, some authors considered the stock of knowledge which preceded the research of the institution being evaluated (that is, the stock of knowledge already existing) as a "free good". This was the case, for example of Ayer & Schuh (1982), when evaluating the research with cotton undertaken by the Instituto Agronomico de Campinas (IAC) -Agronomy Institute of Campinas, where the costs of creation of the basic varieties imported from the United States were not taken into account.

In the case of communication between researchers, the issue of measuring costs and benefits become still more complex. Generally speaking, the treatment given to the problem by the authors is to consider it as a "free good", however, such

a procedure can lead to an overestimate of the rate of return. Regarding this point, it is worthwhile to mention that some evaluation studies of the impact of agriculture research at a national level have shown that the important contributory role resulting from close communication between researchers of national systems and international research centers (CIMMYT, IRRI, CIAT, etc.) has not been sufficiently analysed.

Regarding the definition of "inputs" of a research program, another important aspect is that of research developed at the level of universities and agricultural colleges. A considerable number of research topics, especially at a basic level is carried out there. The communication between researchers and professors can produce a large amount of knowledge, which is "free" to the research program of experimental research units. The question which is put forward is how to take this fact into account, when the net benefits from research of a specific institution are measured. On the other hand, it should be considered that part of the benefits from education represents also a contribution from research institutions, since they are complementary to the education systems.

Besides the aspects related to the process of meeasuring costs and benefits, the evaluation of returns on investments in research requires special attention due to the time-lag occurring between investments in research and the effects of it on production, although there is a variation between technologies with regard to the process of adoption, Evenson (1981) argues that this time-lag is of at least three years. The average time-lag between the publication of research results and its adoption by producers is estimated as being seven years. On the other hand, it should be emphasized that the research benefits tend to last long, and this duration of benefits more than compensates for the cost of generating the knowledge.

Finally, some issues related to the economic policy should be discussed, since they can in many ways affect the returns on agricultural research. Basically economic policy can alter the relative prices through policy measures which affect the prices of agricultural products, and/or of the inputs. Therefore it can make economically viable or not the adoption of determined technologies generated by research. As long as the economic policy changes the prices ratio (as through subsidies, prices control, export quotas, surcharges, etc) the social benefit of a given research program can be under or overestimated depending upon the direction of change. On the one hand such aspects show the important role of the economic policy in the process of evaluation of agricultural research, and on the other hand stress further the complexity of su

#### 2.2. Results Obtained

Brazil has been heavily investing in agriculture research since the establishment of EMBRAPA in 1973. Table 1 presents the research expenditures during the period 1974/83, which amounts to resources of about 1.2 billion US dollars.

Table 1 - Research Expenditures by EMBRAPA, 1974/83

year	turrent values (Er\$ millions)	Real terms* values (Cr\$ million)	Value in US\$dollars** (million)
1974	151	34,594	22.2
1975	411	73,635	50.6
1976	807	102,368	75.6
1977	1.277	113,551	90.3
1978	2,028	130.015	112.3
1979	3.988	166,100	148.4
1980	8,004	166.483	151.9
1981	16.386	162.385	176.2
1982	41.716	211,500	232.5
1983	74.559	148,372	129.4

Source: DRO - EMBRAPA

\* At February 1984 prices, corrected by the General Prices Index - Domestic Supply (Getullo Vargas Foundation)

\*\* Prices corrected by the annual average value of the US dollar

In reply to this huge financial support for its research activities EMBRAPA has given in recent years progressive evidence of efficient use of the resources allocated to research Owing to the innumerable technologies created in its 38 research units located throughout the country, involving 1,597 researchers\*, the share of the corporation in the recent expansion of Brazilian agriculture has been significant.

Table 2 indicates for a given year some of the technologies produced by EMBRAPA in recent years, their main effects, the additional returns achieved and the effective

<sup>\*</sup> Among EMBRAPA researchers, 323 have a university degree, 989 have a Master's degree, and 285 a Ph.D (based on April 1984 data).

adoption of each of them in terms of cultivated land, or benefits for livestock. Among the technologies presented in Table 2 several of them shall be described next, almed at offering a better vision of the results obtained, and of the amount of resulting benefits.

The integrated management of soybean pests is one of the technologies produced by EMBRAPA, which impact has been impressive. This technology was developed in the first years of the functioning of the corporation, and permits the producers to reduce their use of inseticides to the minimum level necessary. The correct utilization of this technology has reduced the use of inseticides in the soybean crop to only once or twice, while they used to do it on average five times per harvest.

Such a technology consists basically of the systematic follow-up with the appearance of pests, and its spreading to the crops. This monitoring, together with the producers awareness of the level of damage caused by the pests and of the potentiality of biological control represented by diseases, parasites and predators, enables them to determine precisely the real needs for the use of inseticides. Recent estimates show that the reduction in costs resulting from a smaller number of inseticides applications is Cr\$ 23,000/ha, which in 1984 should mean a total savings of about 35.2 billion cruzeins\*\*.

Another great impact technology is related to the reduction in harvesting losses of soybeans. This technology comprises a set of agricultural practices, including the soil preparation, the right time for sowing, use of new varieties adapted to mechanized harvesting, spacing and plants density, manuring, time of harvesting, and correct regulators of combined harvesters.

A survey undertaken during 1978/79 harvest in the State of Parana showed that the average loss of soybeans was about 3.1 sacks or 60 kg per hectars. Due to the adoption of the technology developed by research work, It has been possible to achieve a reduction of at least 50% of these losses. In 1984 the resulting benefits from the adoption of this technology should reach about Cr\$ 33 billion\*\*.

Besides that, the research work in soil biology done by EMBRAPA has shown high rates of return. For soybeans, the nitrogen biological fixation by selected inoculation enabled the total substitution of nitrogen fertilizers for the crop. The savings from this substitution was estimated at about Cr\$ 450 billion in 1983\*\*.

<sup>\*\*</sup> At February 1984 prices

Table 2 - Results achieved by EADRAPA in some selected research work

Types	Main Effects	Additional Bainst	Effective adoption: Area/livestock - year
Management of Soybeans pests Reduction in Marvesting Cosses of	. Reduction in costs	Crf 23 thousand/ba	1.4 million ha - 1983
sogheams Development of new varieties of souheams adapted to low latitudes	. Increased productivity	Crt 25 thousand/ha	895 thousand ba - 1983
("trapical" variety) fielegical control of cateraillars	. Cultivated area	-	14.5 thousand ha - 1984
in sombeans Biological control of aphids in	. Reduction In casts	Cr# 17 thousand/ba	49.7 thousand ha - 1983
wheat crops Sogbeams cultivation using wheat	. Reduction in costs	Crt thousand/ha	728 thousand ba - 1983
straws  Bevelopment of new wheat varieties	<ul> <li>Reduction in the toss of phosphorus and potassiva</li> <li>Increased productivity</li> </ul>	Crt 31 thousand/ba	400 thousand ba - 1943 342 thousand ba - 1983
Hitragen biological fixation in supersons areas	. Mitrogen manuring	CF3 28 (NO42484/NA	245 28082546 44 - 1192
•	substitution, and import substitution	tel 50 thousand/ba	9 million ha - 1983
Creation of the Brasilia carrot variety	. Reduction in costs . Increased productivity	Cri 277 thousand/ha 12 tons/ha	680 ha - 1763 400 ha - 1983 ·
Production of yeas in the "cerrados"	. Increased cultivated	12 Mb3/84	67 ha - 1981
Efficient diet for breeding sous Reduction in raw protein level (141	. Reduction in costs	Cri 21 thousand/pig	3.5 million pigs - 1984
in feedstuff for fattening pigs) Treatment of atrophic rhioitis in	. Reduction in costs	Cr3 2.3 thorsand/pig	t4 million pigs - 1984
swines	. Reduction in costs	Crt 1.8 thousand/pig	FO thousand animals for breeding
feriad of sheep breeding Introduction of auazon quiculo hay	. Increased number of weaming sheeps . Increased ratio of	100 per cent/year	1,7 million sheep - 198
	support for livestock per hectare, and thus of neat production/hectare	Cri f.S thousand/ha	500 thousand ba - 1912
Introduction of "buffel" hay in the	. Increased productivity	Cri 50 thorsand/ha	100 thousand ha - 1982
froduction of beans in winter (3rd barwast)	. Increased production	Crs 19.7 thousand/ha	20 thousand ha - 1982
Rice extra fertilization with zinc Virus - free strauberry young plants	. Increased productivity . Increased productivity	Cri 15.2 thousand/ha Cri 4.2 million/ke	900 thousand ha - 1982 425 ha - 1984
Hew varieties of irrigated rice (BA/ IRGA - 429 and BA/IRGA)	. Increased productivity	Crt 50 thousand/ba	330 thousand ha - 1983

E like mometary figures refer to cruzeiros at February of 1984 prices. Source: Irias et al. (1984)

Regarding the wheat crops, stands out the development of technology for biological control of aphids, allowing for a substantial reduction in the costs of production, due to the reduction by up to 90% in the use of inseticides. In 1983 the adoption of this control in an area of 720,000 hectares meant savings of about Cr\$ i3 billion, considering one application of inseticides against aphids instead of two.

The atrophic rhinitis in swines is well-known since the beginning of XIX century. In flocks affected by the disease the animals show frequently persistent nasal discharge, sneezing, watering of the eyes, deviation of the snout, and losses in the feed conversion and on the daily increase in weight. These losses of swine are estimated at between 5% to 25%.

Research work carried out by EMBRAPA enabled the development of a vaccine for the treatment of atrophic rhinitis, which substitutes advantageously the chemotheraphy traditionally used by breeders of swines. Recently, the additional gains occurring from the use of vaccines against rhinitis were estimated at Cr\$ 1,800 per head, which in 1983 meant a total benefit of about Cr\$ 60 million.

Another technology developed which must be mentioned deals with the correct time period for sheep breeding. Studies have shown that a delay in the time of sheep breeding allows for an average increase of 10% in the number of weaned lambs. This is so, because this technology helps to increase the birth rates, and to reduce the mortality rates of lambs. In the State of Rio Grande do Sul the major producer of sheeps in Brazil, this technology might permit an increase in sheep production of about 170 thousand lambs in 1984.

Besides the examples of technologies produced above mentioned, a huge number of others could be shown and their benefits stressed. However, given the aims of this report the quoted instances are more than sufficient to give evidence of the large socio-economic impact of the research developed by EMBRAPA.

#### 2.3. Social Returns

The impact of the results achieved by EMBRAPA stressed under the previous heading was measured in terms of the social returns on investments by Cruz et al. (1982). At that time the authors estimated the rates of return on total investments and on physical capital, based upon the benefits from the technology developed up to 1981, measured at a farmer level.

The rate of return on EMBRAPA's total investments in research during the period 1974/92 (including ten years of potential benefits, based upon the technology already adopted during 1981/82) was estimated as being 42.8%. This figure indicates a high level of return on investments, when compared

with the rates obtained in other studies of research evatuation undertaken in Brazil (Table 3).

On the other hand, when the average rate of return on investments in physical capital was estimated, taking into account both the net revenue of 1981 (total benefits minus current expenditures and depreciation) and the stock of physical capital available at the start of that year, a rate of return of 52,3% was obtained. Such a value is equivalent to more than twice the return estimated by Langoni (1974) for other sectors of Brazilian economy (e.g. electric power 19.1%; printing and publishing 17.9%; the Chemical sector 17.2%; and the construction industry 16.0%).

The estimate of high rates of return by using two distinct procedures confirms that the research carried out by EMBRAPA has generated enormous economic and social benefits to Brazilian society, thereby providing in a relatively short period of time an excellent return to the financial support received since its establishment in 1973.

Cruz & Avila (1983), using the same methodology of the study mentioned above, estimated the rate of return on investments in research for the areas covered by Project 1249-BR, completed in 1982 and partially financed by the Interamerican Bank of Reconstruction and Development (IBRO). The results confirmed the high returns of EMBRAPA research, as the gures varied between 19.5% and 37.8%, depending upon the different assumptions made. Such values are above the standards accepted by Development Banks as giving adequate return to investments. The IBRD itself requires on average an annual rate of return of 10% on its loans.

Following this same line of evaluation, it should be mentioned a recent study done by Avila et al. (1983), on the formation of human capital and returns on investment in manpower training by EMBRAPA. The Graduate and Continuous Training Programs carried out by the Corporation soon after its establishment were evaluated.

The Graduate Program has contributed substantially to the changes observed in the composition of the technical and scientific occupational groups during the period of analysis (1974/82). In 1974, only 17% of EMBRAPA's research staff had master's degree and/or Ph.D. while at the end of 1982 this percentage figure increased to 75%\*. Moreover, the Continuous Training Program is playing an important role in avoiding the depreciation of the investment already done in human capital.

It must be mentioned that several researchers who joined EMBRAPA during this period had aleady got a Master's degree, or a doctorate.

Table 3 - Social Rates of Return on Investment In Agricultural Research in Brazil

Authors	Products/ Institutions		Internal Rates of Return(*) .(%)
Ayer & Schuh	Cotton	1924/67	77-110
Monteiro	Cocoa: - Total period Period under - CEPLAC's administration	1923/74	16-18(R+T)
	administration	1954/74	60-79(R+T)
Fonseca	Coffee	1933/75	23-26 17-22(R+T)
Moricochi	Citrus fruit	1933/78	18-28
Avila	IRGA/RS: - Irrigated rice	1959/77 ,	87-119 83-114(R+D)
Cruz, Palma & Avila	EMBRAPA: - Physical capital - Total Investments on Research	1981	53
	on Research	1974/92	22-43
Cruz & Avila	EMBRAPA/IRBD I: - Total investments	1377/82	20 38
Avila, Borges-Andra de, Irias & Guirino	EMBRAPA: - Human capital	1974/96	22-30
Pinazza, Gement % Matsuoka	PLANALSUCAR: - Sugar cane	1972/82	35
Roessing	Embrapa/CNPS: - Soybeans	1975/95	45 59-62
Ambrosi & Cruz	EMBRAPA/CNPT:(**) - wheat (TI) - wheat (PC)	1974/82 1974/90 1982	59 74 40
Avila, Irias & Veloso	SCPA/IDB(***) Total investments	1977/96	27

<sup>(\*)</sup> The Monograms R + T mean that the estimates of the return rates include investments in both research and technical assistance.

<sup>(\*\*)</sup> II = Total investments, and PC = Physical capital

<sup>(\*\*\*)</sup> SCPA stands for the Co-operative System of Agricultural Research of the Center-South Region/PROCENSUL I Project.

Despite the high amount of resources invested by Brazilian society in manpower training for agricultural research (Cr\$ 38.4 billion at 1982 prices, during the period 1974/82), the study by Avila et al. showed that such an investment was highly productive. The social rate of return on manpower training was estimated at 22.2%, which reflected a high level return even when compared with any alternative investment whether private or public, whether in Brazil or abroad. It should be stressed that this high rate of return was obtained by taking into account the direct net benefits for farmers resulting from technologies developed by those researchers benefitting from the training programs.

The Indirect net social returns on manpower training were also analysed in that study and present an additional relevant support for the policy of investment in human resources adopted by EMBRAPA. The level of benefits achieved was discussed from three different viewpoints: the individual, the organization, and society.

From the individual viewpoint, the main benefits comes from new options open in the labor market, a concern with the need for a permanent updating of knowledge, which can be achieved through acquiring more training, or by more intensive communication with professors and fellow scie the organization, the training of its staff enlarges the possibilities of their performing other functions, besides that of increasing their capacity to provide services in different ways, and strengthening its credibility with society and other institutions. For society the training brings many unmeasured benefits, such as: an increase in the diffusion of knowledge, an influence on the definition of the terms of reference of both research and teaching in agriculture at the university level and of national research institutions, and even for those outside the country; allows also for the trainee's family new experiences, especially valuable for widening their aspirations levels and performance ability.

Roessing (1984), assessed the return on research investments at the National Agricultural Research Center for Soybeans located in Londrina in Parana. The author estimated an annual stream of net beneifits from research works carried out at the CNPSoybeans, taking into account on the one hand, the benefits from its main developed technologies (integrated management of pests, control of harvesting losses, rational use of manure, application of herbicides in narrow rows, new varieties adapted for low latitudes, and the biological control of caterpillars), and on the other hand all costs borne by the Center in the period 1975/82. The internal rate of return obtained was 45%, under the assumption that the level of net benefits achieved in 1982 will be maintained within the next ten years. Under more optimistic assumptions the rate of return obtained laid between 59% and 62%.

The return on resources allocated to research in wheat was estimated by Ambrosi & Cruz (1984), based on results obtained at the National Agricultural Research Center for Wheat - CNPT of EMBRAPA. The internal rate of return estimated by those authors for the total investments of CNPT stayed at about 59% (for the period 1974/82), and 74% (during the period 1974/80), while the average rate of return on the CNPT's physical capital was estimated at 40%, taking 1982 as the base year.

Recently, Avila et al. (1984) assessed the socioeconomic impact of PROCENSUL I, a project implemented during the period 1977/83, and partially financed by the Inter-American Development Bank (IDB), under the co-ordination of EMBRAPA. The rate of return on investments done by the Co-operative System of Agricultural Research - SCPA) in the Center-South region of Brazil through PROCENSUL was estimated at 27%.

It should be stressed that the rate of return estimated could have been higher, and thus closer to the estimated figure for EMBRAPA (42%), and for research undertaken for specific products (soybeans 45-60%, and wheat 59-74%), if the time-period of implementation of that project had not been relatively recent.

Many of the benefits from the research financed by PROCENSUL are still to be generated, especially within the next five years, given the time-lag between investments in research and the adoption of research results by farmers.

#### 2.4. Other Socio-economic Impacts

When evaluating PROCENSUL I Avila et al. (1984) aggregated the technologies produced by SCPA in the Center-South region into categories more or less related, and analysed the socio-economic impacts of the categories of technologies obtaining very relevant results. In this section those results shall be briefly discussed, taking for a base the data shown in Table 4, referring to 1983 and 1984.

Of the technologies produced within the area covered by PROCENSUL I and used for the evaluation study, 44% were oriented towards the production of foodstuffs surplus (rice, beans, corn, manioc (cassava), beef, milk, potatoes, wheat, tomatoes, garlic, and onions), while 27% of those technologies were aimed at reducing and/or saving modern imputs (inseticides, pesticides, fertilizers, etc.); those orientated towards the generation of surplus for export accounted only for 11% of all those studied.

Another interesting aspect of the study refers to the share of each category in the overall quantified benefits. Of total benefits, 40% represents the contribution of technologies aimed at generating a food production surplus, 34% of the technologies related to export crops (coffee, soybeans and cotton), and 25% of technologies planned to save inputs.

Table 4 - Net Benefits of Research Produced by SCPA in the Center-South region, according to groups of related technologies, 1983 and 1984.

	_			Crs millio	ns#
Category of	Number of Technologies	1983		1984	
Technologies		Cr\$	US\$	Cr\$	US\$
Generating production surplus of foodstuffs	44	74,984	59	89,583	71
Generating surplus of export goods	11	68,533	54	72,522	57
Saving modern imputs	27	49,604	39	56,148	44
Other technologies	18	3,762	3	4.544	4
TOTAL	100	196,885	155	222,807	176

<sup>\*</sup> The figures in cruzeiros refer to March 1984, corrected by the General Price Index ~ Domestic Supply, of Getulio Vargas Foundation. The exchange rate in March 1984 was Cr\$ 1,265.45 = US\$ 1.

Source: Avila et al. (1984), EMBRAPA.

Another result deserves to be stressed regarding that group of technologies aimed at saving modern inputs. Starting from a figure of 28 million US dollars in 1981, this category of technology shall produce in 1984 net benefits of 44 million US dollars, meaning an increase of 60% during the period. Assuming that such technologies generally economize in the use of account inputs, especially those imported, its multiplier effects are very important for the trade balance through a reduction of imports.

In the category of technologies generating surplus of export goods it is important to notice that the net benefits obtained represents 0.6% of the total value of Brazilian agricultural exports in 1983.

### 3. FUTURE PROSPECTS FOR EMBRAPA'S RESEARCH

For this decade EMBRAPA thrent units intends to continue investigating several research topics. As well as to undertake new specific research projects. One of the main objectives of this programing shall be to expand and to improve the quality of research work.

In order to show the potential research benefits, the authors called for collaboration from all EMBRAPA units aiming at the measurement of the prospective results. The working hypotheses for estimating future benefits were based upon past experiences, and also on the future outlook of the results, taking into account the knowledge and the experience acquired by the corporation's research staff. In some cases, the difficulties associated with specific research topics did not enable us to estimate the benefits with some certainty. In these cases only qualitative statements were asserted. Due to lack of time and space, and even because of the huge amount of research work being carried out; the authors do not claim to present here an exhaustive discussion of the expected results from the research. It shall be mentioned only some examples of EMBRAPA research related to the Center-South region, going into a greater detail for some topics.

The expected results are depicted in Table 5, and refer to some research in progress within EMBRAPA's units in the Center-South region. In this table the topic of research work is identified with its main effects in terms of objectives and aims of the agricultural activities, and an estimate of its expected results. In this part of the table is shown the additional benefits per hectare gained with the adoption of these results, and the actual potentialities for the extension of the resulting technology. It should be stressed that, although some results can be obtained in the short and medium term, other results shall only be achieved in the long term.

The great dependence of Brazil upon the foreign production of wheat (about 65% of domestic consumption is imported) makes investments in wheat research wimed at raising both production and productivity extremely important. The continuity of research work for wheat is of vital importance for the attainment of the proposed objectives, especially considering that according to the current state of the arts it takes from ten to twelve years of research to produce a new variety. It should be added also that the new wheat varieties have a productive period very short, owing to genetic and environmental factors. This fact has compelled the breeders to work hard on the creation of new varieties. Besides the development of new varieties, the main research topics with wheat include the preservation of genetic resources (Active Banks of Germoplasma), and biological control.

Table 5 - Expected Results of Some Selected Research work Included in PROCENSUL 11

Types	Main Effects	Additional	Adoption/ Potential Benefits	
Selection and animal cross-breeding, carcass analysis, introduction and evaluation of new hay varieties, namagement of soil and fodder, amimal nutrition, substitution of mineral phosphorous, management of amimal breeding and diseases control of cows and calves	. Reduction in age for slaughtering, increase in the weight of carcasses, and improvement in the quality			
	of meat from bultocks . Increase in the weight of carcasses, and improvements in	Crf 55 (bowsand/head	5.7 million head	
	the quality of neat from cous . Increase in the rate of birth	Crs 39 thousand/head	2.6 million head	
	of calves	Cr\$ 50 thousand/bead	2.9 alltion head	
	<ul> <li>Redution in the mortality rate of calves</li> </ul>	Crf 50 thousand/head	4.2 million head	
Introduction of aixed flour in the manufacturing of bread, biscuits,				
and pastry	. Import substitution . Disinfection of pastures from	Us# 230 million/year	-	
	parasites	Cr\$ 500/head	It million head	
Evaluation of dairy cattle, and the development of mongrel cattle				
for tropical regions	<ul> <li>Increased productivity and production</li> </ul>	Crt 176/liter	1.3 billion liter	
Control of the itch of appte-trees in Rio Grande do Sul	. Reduction in costs	Cr\$ 150 thousand/ba	5 thousand ha	
Integrated control of pests in apple-trees in Rio Grande do Sul Bevelopment of new soubeans	. Reduction in costs	Crf 214 thousand/ha	5 thousand ha	
varieties for distinct ecological regions and production systems Development of early and late	. Increased productivity	175 tg/ha	9 million ha	
sogbeans varieties	. Increased production	1750 kg/ha	500 thousand ha	
Preparation of soil, decompressing the soils for soybeans Biological control of weeds in	. Increased productivity	437 kg/ba	6.5 million ba	
sogkeans	. Reduction in costs	Erf 20 thousand/ha	8.5 million ha	
Biological control of Bedhugs in saybeans Purification of virus for the	. Reduction in costs	Cr\$ 20 thousand/ha	6.5 million ba	
biological control of soybeans caterpillar	. Reduction in costs and import substitution	Cr\$ 28 thousand/ha	4 million ha	

continues...

Table 5 - Expected Results of Some Selected Research work (included in PROCEMSEL II (cont.)

Types	Main Effects	fainst	fotential femefils	
Atmospheric mitrogen fixation and solubility of phosphate for the			AA 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	
biological process of growing beans	. Reduction in costs, and import substitution	US\$ 44/ha	4 million ha	
· Development of new potato varieties	. Inport substitution of potatu seed	US\$ 5 million/year	-	
Development of hybrids of cabbages, Development of hybrids of cucumber	. Import substitution of seeds	HSS 613 thousand/gear	-	
for salad	. Increased produtivity and	Fal. 1/A - []] (as buse		
	quality . Import substitution	Cri 168 million/year OSi 116/wear		
Development of new varieties of melon	. Incorporation of resistance to viruses	6-4 (4 b)[])(		
Development of hybrids of saisons	. Tuport substitution of seeds	Gr\$ 18 billion/year US\$ 828 thousand/year	:	
Introduction of varieties of tonato	. (sport substitution of seeds	USI 446 thousand/year	_	
Intraduction of genetic material,		•		
and selection of new types of fouts Identification and selection of	, Import substitution	BSO & aillion/year		
black scacia	. Increase the proportion in tanning of the busts	BSS 388/producer	22,800 producers	
Production systems and forms of		•••		
growing Erva Mate	. Increased freductivity	321	40 thousand tons (198)	
conditions	. Increased Productivity	Crf 7.5 billion/gear	-	
of corn	. Increased Productivity . Increased Productivity and	Cr\$ 12 billions/year	-	
	ia brix	Cr\$ 665 thousand/ha	150 ha (3o. year)	
Selection of yeast for wine production	. lopart substitution	ES\$ 44/kg .	3 thousand by (30, yes	
Carbon maceration of red wimes	. Reduction of time for maturing of the wine	Cri Mi/Liter	3.5 million liters	

t when in cruzeiros the values refers to february 1984

Source: fries et al. (1984), EMIRAPA.

It should also be stressed the expected research results for wheat in the cerrado areas. The new varieties developed for this region not only has enabled the expansion of the cultivated wheat area, but also has allowed gains of productivity, besides the possibility of obtaining two harvests per year. The second harvest during the drought period is obtained by irrigation, and with a variety adapted to this practice.

The analysis of the Brazilian cattle breeding shows a scenario of a low productivity level, if considered in aggregate terms. The birth rate is very low (50 to 55%), the mortality rate is high (15%), and the age for slaughtering is relatively late (4 or more years). The yields rate has varied around 12. In the central region of Brazil, comprising the states of Minas Gerais, Goiás, Mato Grosso do Sul, São Paulo, Mato Grosso, Espírito Santo, and Rio de Janeiro are located about 58% of the Brazilian cattle herds. This region includes the Pantanal region, covering an area of approximately 138,000 square kilometers with an extensive cattle breeding amounting to about 4 million animals.

Among the research topics undertaken for beef cattle in the Central part of Brazil stand out those referring to: (a) selection and cross-breeding of animals; (b) development analysis for the carcass; (c) introduction and evaluation of οf new hay varieties; (d) management of the soil and feed crops adapted for tropical pasture land; (e) utilization of alternative sources of phosphorous in the mineral mixtures of the land (f) control of parasites (ecto, emo and hecto), and of diseases affecting calves. These research topics will enable huge improvements in the returns from cattle breeding. The expected economic returns will be significant due to the size of the cattle herds, and the low levels of current yields. If for instance the research results are applied to the actual population of bullocks slaughtered, only a reduction in the age of slaughter to 3 years, and an increase in the average carcass weight to 240 kilograms, with some qualitative improvement of the meat could lead to an expected gross benefit of about 30 billion cruzeiros, even considering that only 10% of the animal were covered by the improved technology. A similar simulation can be done to measure other prospective benefits from these research The prospective results seen in this context are extremely encouraging.

The research in the field of agrobusiness technology has had in the last few years a remarkable growth in importance in the social and economic context of Brazil, especially with regard to the food processing industry, due to the desire to use it to improve the dietary levels of the Brazilian population. The introduction of mixed flours in the manufacturing of breads, biscuits and pastries, the cenclogical research into the selection of yeasts and carbon maceration of red wines, the studies of essential oils from gartic and onions,

as well as obtaining natural colorants, comprise the main research proposals in the area of agrobusiness technology.

The dependence upon the imports of wheat meeting domestic consumption has greatly encouraged efforts towards viable alternatives of other flours for the manufacture of bread and pastries. The results already achieved have Identified as an alternative the use of non-fatty corn flow, besides the flour of soybeans, sorghum, manioc and triticale in the partial substitution of wheat flour. Besides continuing the studies mentioned the research proposals are directed towards the optimization of some parameters in the production process with these flours, such as determining the fermentation time temperatures for cooking and drying, and adjustment of the equipment used by the industry, with the objective of improving the efficiency in the quality of the final product. The simple substitution of 20% of the wheat flour by other flours would represent savings of foreign exchange of about 230 million US dollars per year, through the reduction in wheat imports. of the pure triticale flour by the utilization manufacturing industry would save another 90 million US dollars per year. Among the other results of this substitution are the increase of domestic production of alternative raw-materials, improvement of nutritional conditions of the population given the advantages in terms of quality of these flours compared to wheat flour, and the reduction of the idle capacity of the flour milling industry.

the national socio-economic context, soybeans complex (grains, meals, and oil) has played an important role. For the domestic market it has a strategic role, be it as a foodstuff, or in the form of edible vegetable oil, and as a primary product export, soybeans and its derivatives share the largest volume of foreign exchange. The research results have greatly contributed to this performance. To support research of vital importance to achieve increases in production productivity. expansion of the agricultural frontier and Improvements in the farmers net income through a rational use of imputs. Among the several research works carried out for soubeans stand out the following: the introduction of new varieties adapted to several ecological regions and to different production systems, the creation of early and late varieties, the preparation and decompressing of soils, the biological control of weeds and bedbugs, and the purification of the virus for the biological control of caterpillars.

With the introduction of new varieties of soybeans according to ecological regions and production systems, it is intended to meet the intrinsic characteristics of regions considered as traditional producers (such as Rio Grande do Sul, Santa Catarina, Parana, and São Paulo), aimed at besides increasing their productivity also achieving the stability of production through developing resistance to insects, diseases, nematoides, and tolerance to acidity and droughts. For the

expanding frontier regions (Mato Grosso do Sul, Mato Grosso, Golás, Minas Gerais, Bahia, and Maranhão) the new varieties shall represent the best options for cultivation. 1,134 varieties have already been selected for an assessment of their productivity levels, and adaptation to the diverse regions and production systems. Considering that the new varieties help to improve by at least 10% the current average yields, which is about 1,750 kilograms per hectare, an additional increase of 175 kilograms per hectare shall be obtained. The research benefits could thereby be represented by the additional gains in production of about 157.5 thousand tons, assuming that of the current 9 million hectares planted with soybeans, only 10% adopt the new varieties. In minetary terms, these benefits would produce annual additional gains of 52 billion cruzeiros.

The results already obtained suggest a wide range of possibilities for the introduction of new early and late varieties, with sowing periods before and after the traditionally recommended season. As the alm is to offer to farmers within the next 5 years new varieties exhibiting such characteristics, it is estimated that in 1990 at least 5% of the land cultivated with soybeans might be adopting this technology. This adoption shall mean an additional utilization of 500 thousand hectares, which is equivalent to approximately an additional production of 875 thousand tons, or of 288.7 billion cruzeiros at current prices.

Research work at an experimental level showed that adequate soil preparation, including the decompressing of soils, can raise the southeast yields by even 25%. In the south region of Brazil, especially in the States of São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul, a large proportion of cultivated land with southeast shows a problem of the compacting of the soils. A research effort which provides adequate alternatives for the soil preparation can brits of great impact, in view of the fact that the area susceptible to that problem amounts to 6.5 million hectares.

With the objective of reducing costs of production but also to have a remarkable effect in ecological terms, there great expectations in the research proposals aimed at establishing through the biological control ways to combat weeds, bedbugs and caterpillars in the soybeans crop. Preliminary studies have already identified a highly promising fungus to be used as biological herbicide in combating the main weed found in nearly all the regions producing soybeans in the south of Brazil. It is intended to control the infestation to a level below the economic losses for the crop, by an integrated management of pests, using the biological herbicides together with mechanical and chemical methods. It is estimated that this practice could reduce the costs of production of soybeans by about Cr\$ 20,000 per hectare, which will lead to direct benefits to farmers valued at 13 billion cruzeiros annually, even if only 10% of the cultivated land with soybeans came to adopt this technology in the south of Brazil. Regarding the combatting of bedbugs, which is one of the pests causing the most damage to the crop, leading to a fall in yields by up to 80%, the studies already undertaken show a promising result in the combat of these pests through natural parasites. With the identification and improvement of these parasites it is expected to reduce the applications of chemical insectides in controlling bugs, and therefore reducing the costs of production by at least Cr\$ 20,000 per hectare.

In the case of the soybean caterpillar, biological already been used, through the poliedrose virus, which has shown to be as efficient as chemical control. The research seeks to examine in the next few years a procedure for purifying the virus in a liquid form to provide it to farmers, in order to make easier both its application and the storage. present the farmer should apply the initial inoculation of the virus, and later on to collect the dead caterpillars and to store them in a refrigerator. For a new application the only thing to is to macerate the caterpillars, to strain the liquid and to mix it with water (in the pulverizator), and to spread it over the plants. With the help of the purification of the virus in it is expected to double the levels of adoption liquid form, attained and to reach 1990 with a coverage of adoption of this technology of about 4.2 million hectares, providing an additional social benefit of 80 billion cruzeiros per harvest season, at current values. In Rio Grande do Sul the hydromorphic soils cover an area of approximately 3 million hectares, of which only 600 thousand are cropped annually with irrigated rice, owing to the impractibility of planting this crop in sucessive years, in the same area. The remaining area is used for an extensive cattle raising, showing low productivity meat/hectare/year. The best use of this area with dry crops (soybeans, sorghum, and others) rotation with irrigated rice is currently very difficult, due to the dificiency in the drainage of hydromorphic soils, to the hydraulic "stress" during the soil preparation, and also to the cycle of the dry crops themselves. To those problems it must added the low performance of machines and agricultur agricultural implements, which are generally speaking projected to meet the needs of highlands, and also the deficiency of the new varieties developed and adapted to the climate and hydromorphic soils of the region, preventing a better utilization of this type of soil.

With the development by research of adequate techniques of irrigation, drainage, and systematization of soils it is possible to make suitable for dry crops about one million out of three million hectares of hydromophic soils of the region. It is also possible to recover for the planting of irrigated rice about 400 thousand hectares of flooded land, and up to now underdeveloped, which shall increase the area cultivated annually with irrigated rice to approximately 750 thousand hectares. With the recovery of the hydromorphic soils and the development of agricultural research under the PROCENSUL II program, through new varieties more adaptable and productive, besides new cultivation practices, the production of grains can be expanded in the region to about three million and five hundred thousand tons per year.

The constant increases of petroleum prices at the beginning at the 1970's decade, and its harmful effects on country's economy, required an intensification of the search for substitute industrialized fertilizers alternatives tō utilizing biological resources. The results already achieved by research in the biology of the soil allows for the total substitution of chemical nitrogen manure in soybeans, through selected inoculants which can yield a saving of 500 million US dollars per year. Another important advancement in the biological production of nitrogen was obtained with the identification of a specific inoculant for the beans crop. It is also important to mention that it was found out the existence of suitable inoculants, which will enable an extension of the biological fixation of nitrogen for the corn crops and other gramineous plants. Biological processes are also promising in the solubility of phosphate through micorrizicos fungi.

Regarding the cultivation of beans, for example, to raise the average yields in Brazil from 600 to 1,200 kilograms per hectare, it should be required to apply 40 kilograms of nitrogen and 80 kilograms of P2 O5 per hectare, in terms of chemical manure. Experiments already carried out showed that the adoption of selected new varieties, which are innoculated and do not use nitrogen fertilizers, can attain the targeted level of 1,200 kg/ha, or in some cases even more compared with those using 40 kilograms of nitrogen per hectare. The prospects for obtaining a substitution of fertilizers by biological processes are promising. This substitution, even partially would result in the case of beans savings of fertilizers of 60 US dollars per hectare, or about 24 million dollars annually, If this technology was extended to cover 10% of the area cultivated with this crop which is about 4 million hectares. Taking into account the expected potential benefits foreseen, the costs of 2 US dollars for using inoculants at producers level appears quite small.

The technologies generated by research in horticulture are still much below the needs of the sector, thus Brazilian horticulture is still highly dependent upon other countries, utilizing hybrid varieties developed for climatic conditions and consumer habits distinct from those of Brazil. Among the research proposals for the next few years can be mentioned the studies aimed at developing new varieties and vegetable hybrids, especially those intended to provide national seeds for substituting the imported ones. It should be stressed the importance of research work aimed at producing new varieties of potatoes and melons, hybrids of cabbage, hybrids of cucumber for salads, and varieties of tomatoes for processing.

In the specific case of the potato it is expected to obtain a saving of foreign currency of about 5 million US dollars annually, only with the import substitution of potato seeds. It should be pointed out the relevance of the technical

work undertaken by a national network of experimental units which has provided basic subsidies for the identification of new varieties suitable for the distinct geographical regions of Brazil, as well as the import policy for potato seeds.

The research on melons is basically orientated towards incorporating a resistance to viruses, and also for the production of hybrids. The continuity of research work on melon in the areas traditionally producing this fruit is threatened (in Pernambuco, and Para) by the mosaic virus of Paulo, watermelon. The affected fruits lose their commercial value. recent survey of this virus disease carried out in the region of São Francisco river area has shown a high incidence of the disease. In a great number of farms, nearly all the plants were The research work in progress seeks to resistance to the virus by the main varieties used, by using for breeding purposes the varieties Amarelo and Prince. Experimental data already confirms this possibility, therefore, through the retro-crossing of varieties it will be attempted to recover some of the characteristics of production and quality of the Amarelo variety. The direct benefits resulting from this technology shall be at a farmer level approximately 18 billion cruzeiros per year.

The socio-economic importance of the development of poultry activity in Brazil as a supplier of basic protein for the population, and as a source of foreign exchange - Brazil is the second largest exporter of chickens in the world - has imposed a task on the research walk in terms of the heavu expectations regarding the discovery of new technologies. Special prominence should be given to the work the genetic improvement of the fowls. Generally speaking, the poultry industry in Brazil is totally dependent upon the imports of foreign species. In 1983 of the total number of companies currently operating in the sales of chicken for breeding purposes, only one used national genetic material. The research proposals alm at the establishment of a basic population of great genetic potential for selecting and obtaining Brazilian species specializing in the production of meat and eggs, enabling the country to substitute the import of eggs. It is expected within a few years to achieve through a well directed research effort to meet the total needs of the market with national species, meaning savings of foreign currency of about 8 million US dollars annually.

The results expected only from research work developed for the great Center-south region have been analysed in this section, it can be anticipated that the social benefits obtained more than compensate for the investments made. Added to the examples mentioned and analysed should be other research proposals certainly as important as those quoted here. Some are instrumental to the achievement of specific objectives at the agricultural producer level. For others the current level of knowledge does not enable an estimate of expected results within a range of reasonable possibilities. Regarding these prospects for agricultural research it should be added the resulting

benefits from an enlargement of the degree of adoption of the technologies already produced by the corporation.

So it is expected that within the next few years the high rates of return on investment in agricultural research shall be maintained, justifying also the maintenance of a continuous flow of financial resources to the research activities of EMBRAPA.

#### 4: SYNTHESIS AND CONCLUSIONS

In this study it was intended to show the economic and social viability of investments in agricultural research co-ordinated by EMBRAPA. The research benefits were characterized within the context of the economic development experienced by the country in recent years, emphasizing the contribution obtained by farmers from new agricultural technologies.

Brazilian agriculture has shown great dynamism, with a satisfactory growth of output. For such growth agricultural research has played important contribution through the creation of several technological innovations, which have allowed increases in the productivity levels. The research results have also remarkably contributed to the reduction in the costs of production, as well as to the occupation of new land areas.

The role of EMBRAPA in the advancement of the national agriculture sector has been impressive. Its technologies have achieved high social rates of return. The rates of return estimated were 43% for the total investment, and 22% for the return on the manpouer training programs of EMBRAPA. Specific studies analysing the investments in research for the area included under the EMBRAPA/World Bank Project, and for research programs of the corporation for the crops of soybeans and wheat have also shown high rates of return. Regarding the project undertaken jointly with the World Bank the rates of return were between 20 and 38%, and for research in soybeans and wheat they varied between 45 and 74%. These figures are significant as they are above the rates of return obtained for other alternative investments by Brazilian society.

The experience of the corporation acquired in its first ten years of existence has provided the researchers with new knowledge and empirical evidence, which gave the boundaries for the estimate of future benefits of the research proposals. The future prospects for this research, particularly for the Center-South region of the country, are also very encouraging. Among other research results, it is expected to achieve high increases in the yields of cattle raising in the central region of Brazil; the partial substitution of wheat flour in the manufacture of bread, biscults and pastries, through the utilization of corn flour, of triticale, soybeans and manion

flour; and also to generate new varieties of soybeans, wheat, grape vines, corn, potatoes, and melon; and to control through the biological process weeds, bedbugs, and caterpillars affecting soybeans crops; to extend the biological nitrogen fixation to the crop of beans; and to establish a basic poultry population with large genetic potential for selecting and obtaining Brazilian species for the production of meat and eggs.

The expected results from these new technologies measured at the producer level will more than compensate for the investments to be undertaken. It should be also added the benefits resulting from the extension of the degree of adoption of technologies already produced by the corporation. Therefore it is believed that within the next few years the rate of return on investments in agricultural research will be maintained, which justifies the provision of continuous flows of financial resources to the activities of the corporation.

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