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EMBRAPA'S FOOD-FEED-BIO-ENERGY PRODUCTION SYSTEMS:

A Joint Government-Industry Research Venture

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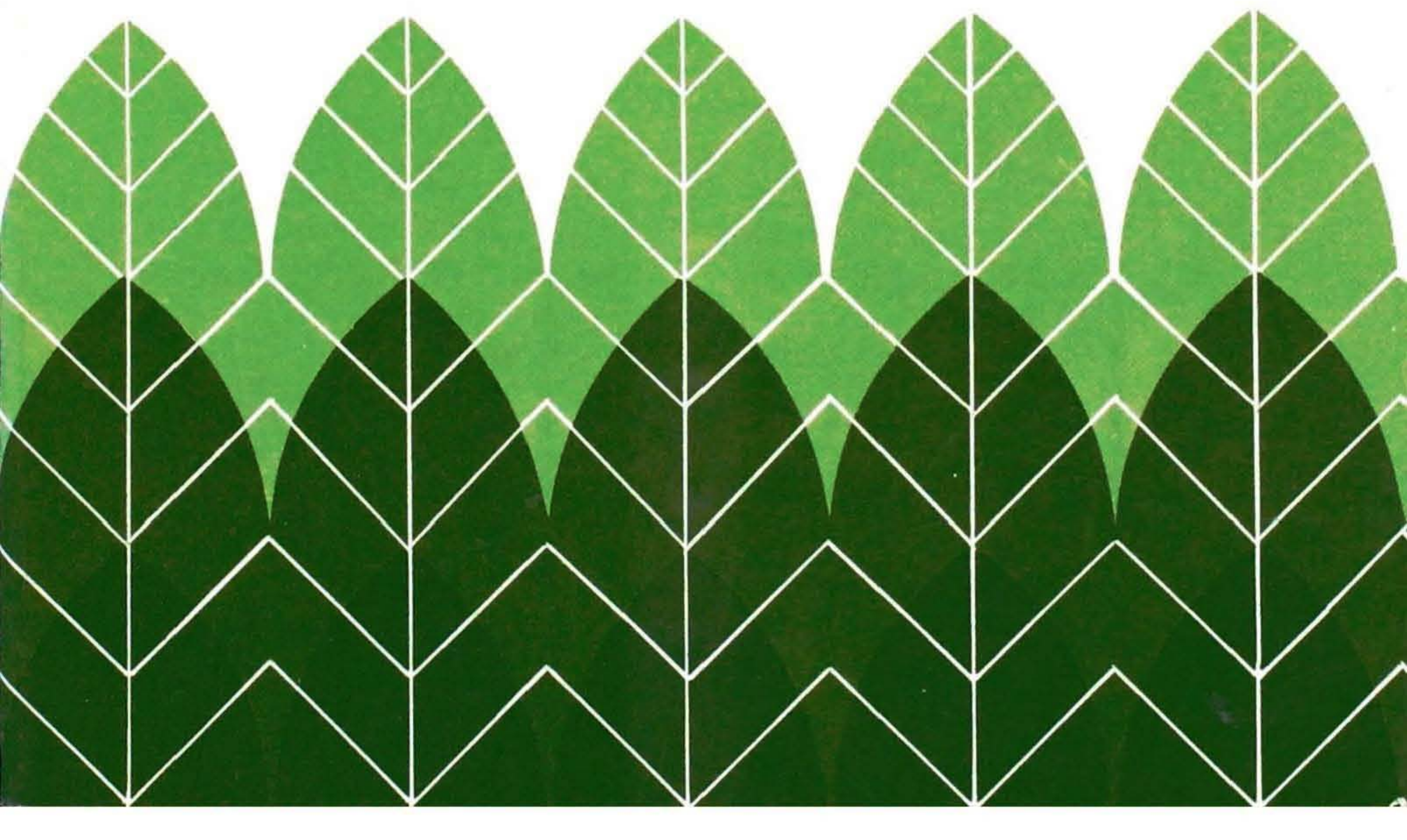

EMBRAPA
BRAZILIAN AGRICULTURAL RESEARCH CORPORATION
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ABSTRACT

This paper presents the preliminary results of decentralized integrated energy-food-feed production systems designed for partial energy self-sufficiency of agricultural production units. These systems constitute an important part of the energy research undertaken by the Brazilian Agricultural Research Corporation-EMBRAPA. In addition to the information and results generated by this public research corporation, this study refers to research and development efforts of private corporations which are actively involved in development testing and marketing of various system components. The major objectives of the program are to avoid competition between food and energy crops, to offer flexibility in shifting from energy crops to food and feed, depending on market conditions and to provide appropriate bio-energy technology for the various ecological conditions existing in different parts of Brazil.

The results indicate that the social costs of unexpected oil price increases of agricultural production units using integrated food-feed-energy systems compared to traditional food-feed system will be significantly lower, justifying the efficiency-flexibility trade-off.

The economic situation which has led to emphasis on alternative bio-energy sources and the institutional setting are discussed. It is shown that both the private and public sectors in Brazil have recently realized that to fulfill their food, feed and energy needs they will have to collaborate in research.

FOREWORD

Despite the fact that agricultural research has become an increasingly important activity in many developing countries, only relatively recently has its management attracted the attention of serious scholars.

This publication is the first of a series to be published by the Brazilian Agricultural Research Corporation, based on experience acquired in the process of building the largest agricultural research system in the developing world.

It is hoped that this experience will be used by other countries who are trying to strengthen their agricultural research institutions.

Victor Palma, Head
Department of Planning Methodology
Brazilian Agricultural Research Corporation

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EMBRAPA'S

FOOD-FEED-BIO-ENERGY PRODUCTION SYSTEMS: Joint Government-Industry Research Venture*

Ägide Gorgatti Netto**
Levon Yeganiantz***

Introduction

The convergence of agriculture and energy relationships will be a key determinant of world affairs in the 1980's and beyond. Against a negative background of spiralling inflation, oil price hikes and low commodity prices on international markets, this "agri-energy interdependence" presents an excellent opportunity for joint private-public research aimed at developing enlightened new technology. The main objective of this technology is to develop energy-efficient and partially self-sufficient food and feed production and processing systems.

The case study presented in this paper covers the preliminary results of an integrated energy-food-feed production system being developed by the Brazilian Agricultural Research Corporation, a federal government agency, in a joint effort with ten private agro-industrial enterprises.

It is shown that both the private and public sectors in Brazil have recently realized that to fulfill their food, feed and energy needs they will have to collaborate in research. The essence of this collaboration is a new research concept which takes a systems approach to food and bioenergy production.

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The Challenge and Response

Toynbee's observation that civilization is the story of challenge and response has seldom been better exemplified than by reaction to the effect on the world economy of the Energy Crisis.

The government of Brazil, for example, has undertaken large-scale production of alcohol, totaling millions of gallons a year. The adaption of a national alcohol fuels program, "Proalcool", was a positive expression of Brazilian determination and resolve to remedy its serious energy problems. As the cost of oil skyrocketed, the Brazilian government became increasingly determined to reduce its dependence on oil imports, using in addition to alcohol other bio-energy alternatives.

Thus, through all the confusion and contradictions of the energy crisis, one important fact is beginning to emerge. Brazil has a good chance to free itself from heavy dependence on foreign oil. A related fact is that in the act of meeting their energy problems, the Brazilians may be starting a new industrial revolution, the most significant and exciting feature of which could be a less centralized and more cooperative and creative way of life.

The energy cycle emerging in Brazil is a process that conciliates scientific creativity with intensive manual labor, combining technological development with creation of employment opportunities for the benefit of a growing population.

Brazilian agriculture has to be guaranteed its basic commercial energy needs and appears ready to exploit its opportunities to use on-farm produced renewable energy instead of that derived from imported fossil fuel sources.

EMBRAPA - The Brazilian Agricultural Research Corporation - has a continuous research program for Integrated Energy-Food-Feed Production Systems which includes technical and economic assessment of production, processing, marketing and financial factors involved in the total operation. The results of these studies have been to provide guidelines for development programs, policy formulation and preliminary estimates of investments needs. In addition, this research has provided a good exemple of a joint research venture between the public and private sectors.

Theoretical Considerations

The principles of interaction of private-public research can best be understood with the help of economic theory.

The Theory of Induced Innovation[1/]. - The theory of induced innovation is a starting point for understanding the nature of the demand for research implicit in the need for technical change. This theory is not new, but was recently revitalized by the energy crisis creating demand for energy-saving innovations.

According to this theory, factor endowments provide the motive power for technical change in agriculture. Relative factor scarcities reflected in relative factor prices induce a search for technical developments that tend to conserve the scarce factors.

The effectiveness of the process by which technical progress is generated along a path induced by relative factor scarcities is conditioned by many circumstances: the state of scientific knowledge, the supply of inputs, the levels of technical and scientific skills embodied in people, market distortions and socio-political circumstances.

Social Interest Groups as Determinants of Research Policy. - Another model which can be seen as a useful intellectual articulation, rather than a theory, has been proposed by De Janvry (1975)[2/], De Janvry views technical change as a circular, commulative process in which socioeconomic and political-bureaucratic structures interact to define the demand for and the supply of new technologies.

The socioeconomic structure defines and is characterized by the land tenure process, product and factor prices, access to institutions, dealing with credit, technical assistance, information etc. It determines the pay-off matrix that shows the economic gains for particular social groups. From the pay-off matrix, the demand for technologies is characterized.

1/ J. HAYAMI and V. RUTTAN. Agricultural Development, an International Perspectives Baltimore: The Johns Hopkins Press, 1971.

2/ ALAIN DE JANVRY. The Organization and Productivity of National Research Systems ADCRTN, Conference on Resource Allocation in National and International Agricultural Research, New York, 1973.

The political bureaucratic structure governs the public research system that will undertake both the basic and the applied research which generates the supply of new technologies.

The key to this model is the pay-off matrix. It is defined by particular interest groups in society: commercial farmers, landed elites, subsistence farmers and consumers who derive income gains from public goods such as research.

Each social group pressures the political administrative structure for research goods to be generated, depending on the particular pay-off it expects.

The relative social power of different groups determines whether and how their demands get translated into the allocation of resources for particular lines of research. The resulting supply of research is filtered through the socioeconomic structure and produces specific pay-offs for social groups.

The extent of basic scientific knowledge determines the area within which technical innovation is possible. The physical characteristics of the innovation in terms of its ability to raise yield or reduce cost, the extent of diffusion of innovation which is conditioned by its suitability to local ecologies and social institutional arrangements and prices which determine the relative profitability of agricultural research determine the pay-off matrix. The pay-off induces further demand for new research.

In both theories, a few elements play key roles. The first emphasizes the natural supply and demand forces showing through factor and product prices the signals of scarcities. De Janvry places emphasis on the socio-economic political structure. Both of them recognize the role of the available scientific knowledge and of the body of trained personnel sense the market orientation or to follow the commandments of the governing structure. The power structure of society plays an important role in De Janvry's model.

According to De JANVRY[1/], agricultural technology is principally

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1/ Alain de Janvry, The Agrarian Question and Reformism in Latin America, Baltimore: the Johns Hopkins University Press, 1981, p. 170.

generated in public research institutions, and its diffusion is regulated by public credit and information institutions and by price and trade policies[1/]. The same author believes it can be divided into two types: mechanical and biochemical. Biochemical technology requires additional research to adapt it to local conditions, while mechanical technology can be directly transplanted without intervention of the state [2/]. Mechanization is labor-saving, promotes economies of scale and reduces management needs. Biochemical technology-best exemplified by the Green Revolution-is land-saving (yield-increasing) and increases both management and labor needs.

The Nature of Technological Innovation

Underlying research and development activities is a unifying concept - the process of technological innovation. Some efforts have been made to explain technological innovation in terms of "technology push" and "demand pull" factors.[3/] As Almarin Phillips puts it: "In a loose sense, the question addressed is whether necessity is the mother of invention (pull) or invention is the mother of necessity (push).[4/]

Technology does not push or force firms to alter their product mix or production processes. It rather offers opportunities to make innovations. Some such opportunities are created internally through the firms own R&D activities. Other opportunities appear from sources not subject to the managerial control of the firm like government research institutions.

Social or cultural acceptability is often a major factor influencing the success or failure of an innovation. Because this is so subjective and

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1/ Alain de Janvry, The Agrarian Question and Reformism in Latin America, Baltimore: the Johns Hopkins University Press, 1981, p. 172.

2/ Ibid. p. 170.

3/ E. Mansfield et al, The Production and Application of New Industrial Technology, New York: N.W. Norton, 1972, pp. 26-28.

4/ Almarin Phillips, Organizational Factors in R&D and Technological Change: Market Failure Considerations (in) Devendra Sahal (ed) Research, Development and Technological Innovation, Lexington, Lexington Books, 1980, p. 112.

ill-defined, there is an obvious temptation to favor the more rational criteria of engineering efficiency or economic viability. The feasibility of widespread adoption of on-the-farm energy producing technology, however, transcends strict economic analysis.

The case presented in this paper represents a situation in which a technological opportunity existed in conjunction with a known market demand. This created a situation in which the private sector, through market forces, recognized a need for alternative fuels resulting in user-dominated "demand pull". At the same time public research institutions in an orderly sequence of related steps, from science through discovery, invention and development of prototypes, created a "technology push" situation. The result was a close association and joint effort of and integrated management between the private and public sectors in partially substituting the use of fossil fuels by renewable biomass energy for the production of a whole series of food and feed joint products and by-products.

In other words, the case study of joint research management between government and private industry is based on convergence of "need pull" and "discovery push" models of innovation.

The social and environmental implications of technology, institutional factors such as the ability to insure and finance the project,assurance of systems reliability and service of the technology, and regulatory and legal decisions influence farm practices. All of these factors are weighed against technology in light of the significance it may have for the overall farming operation. In essence, the perceptions of the people to whom the technology is addressed and those of research workers must be compatible.

Utilization of Appropriate Technology

One of the goals of a decentralized steady-growth economic philosophy is the creation of small to medium size community based businesses that are locally owned and operated. Often these businesses use appropriate technologies (AT) defined as based upon decentralization of technology as well as of many social, political and economic institutions, into small systems controlled by local communities.

An appropriate technology business enterprise could be defined as follows:

. It uses local materials.

. It uses local talent and labor

. It serves a local market

. It is community oriented

. It is small in size

. It tends to be low in capital requirements

. It is ecologically responsible

. It has a management structure that allows maximum employee participation in the decision-making process

. It maximizes the opportunity for contact between the producer and the consumer.

Sometimes it is suggested that developing countries must concentrate on so-called intermediate technologies, leaving the fields of advanced science and technology to industrialized nations. Appropriate technologies do not have to be intermediate technologies as long as they are economically, financially, and ecologically adequate to serve the whole community.

In the past year great attention has been focused on on-farm production of ethanol for use as a pure fuel within the agricultural area in which the alcohol was made. Since ethanol can be used as a pure fuel at lower proof than that needed to blend with gasoline, on-farm production of ethanol is more energy-efficient and ultimately lower in cost. The analysis of small-scale alcohol and biogas plants, in terms of input requirements, capital investment and unit costs shows them to be more economic than large-scale plants.

These small bio-energy systems have a favorable effect on agricultural growth, rural employment and income distribution.

Many economic analysts are looking closely at the long-term viability of large scale-plants vs. small-scale units. Particularly in Brazil, where ethanol production in based predominantly on sugarcane, when food prices rise these large plants with large mortgages become shaky. Under similar circumstances, smaller units can be used when economic conditions are more favorable; low-capital technologies provide more economic options[1/]. Small-scale alcohol fuel plants have the potential to decrease farmer dependence on imported fuel oils and to insure the production of our food and feed supply.

A variety of advantages and disadvantages of small farm alcohol plants as compared to large-scale operations could be considered. Among the advantages are assured fuel supply, a new market for farm commodities, use of off-season labor, direct use of feed by-products for animal nutrition, low transport costs of inputs and outputs, use of waste heat at the production site and the use of low-proof alcohol for farm engines.

The introduction of such seemingly sensible new technologies has failed in the past for want of appropriate management and organizational structures to ensure social participation by persons of various income groups in the successful operations of such community plants.

If agro-energy is to make a real contribution to socio-economic development, it must be based on appropriate technology that would benefit the common man. As far as possible, such technologies should be scientifically up-to-date, economically viable, capital-saving, employment-generating, energy-conserving, environment-protecting, culturally compatible and capable of manufacturing products of the desired quality in the required quantity from indigenous raw materials. Solving the problem of energy generation and self-reliance at the agricultural production-unit level is central to implementation of agricultural developing plans in Brazil.

Unlike fossil fuel deposits, which yield energy in the relatively concentrated and portable forms suitable for large-scale industrial and urban use, the bioenergy is most economically exploited on a small-scale, decentralized basis, and are, thus, well matched to the needs of dispersed rural pupulations.

1/ K. T. Achaya, (ed.), Proceedings of the Workshop on the Management of R&D Institutions in The Area of Food Science and Technology. The United Nations University at the Central Food Technological Research Institute, Mysore. July 17-24, 1979. p. 30.

Energy Crisis and Brasil

The sharp increase in the price of petroleum in 1973 and the steadily rising cost of this commodity since that time had resulted in partial redistribution of wealth in favor of a rather limited number of countries with petroleum deposits. At the same time, non-industrial countries without petroleum deposits were hardest hit since they had to pay high prices both for industrial and petroleum products.

Brazil has generally been referred to as a country with an immense territory (the fifth largest in the world: 8 $\frac{1}{2}$ million square kilometers) with a surpisingly large amount of it still unused. Its rapidly growing population of 125 million and its G.N.P. of 280 billion in 1982 are the world's eighth largest with an enormous potential for development. Brazil is internationally viewed today as one of the most modern and sophisticated newly-industrializing economies now at the middle-level of economic development.

As a result of the energy crisis Brazil was caught between the First and Third Worlds. It was dependent upon the industrial powers for the capital and technology needed for industrialization. At the same time it became dependent upon the OPEC nations for the energy to fuel its modern sector.

The so-called Brazilian economic miracle was characterized by a 11% annual growth rate of the G.N.P. during the 1968-73 period. This rate of growth was cut in half with the increase of world petroleum prices starting in 1974 and decreased to a questionable 1-2% after the second crisis in 1974. This was the result of the lack of local fossil fuels and the need to pay an ever increasing percentage of import earning as payment for petroleum imports.

Table 1 shows the value of imported petroleum as well as value of total exports in the 1972-80 period. The amount of exchange used for importing petroleum went from 10% of export value in 1972 to more than 55% in 1980. Table 2 shows that during the 1974-80 period the foreign debt of Brazil increased from US$ 11.9 to 47.5 billions. The major part of the increase in foreign indebteness was due to the energy bill. As a result, the service payment of foreign debt in 1980 absorbed 64% of export earnings thereby resulting in further indebteness.

TABLE 1

BRASIL'S IMPORTS OF PETROLEUM AND TOTAL EXPORTS (1972-1980)

YEAR	(A) PETROLEUM IMPORT (MILLION US$)	(B) TOTAL EXPORT (MILLION US$)	(A/B)
1972	409.2	3,991.2	0.1025
1973	710.8	6,199.2	0.1147
1974	2,840.1	7,951.0	0.3572
1975	2,875.4	8,669.9	0.3317
1976	3,612.5	10,128.3	0.3567
1977	3,813.9	12,120.2	0.3147
1978	4,195.8	12,658.9	0.3314
1979	6,403.1	15,244.4	0.4200
1980 (*)	11,000.0	20,000.0	0.5500

(*) Estimate

Source: Brazilian Foreign Trade Statistics

Research and the resulting literature on economic and agricultural growth and development in Brazil show that it holds untapped and under-utilized agricultural resources that in time could help it become one of the important bread-baskets to help feed the hungry world. By achieving high growth rates for several years, it has demonstrated a capability to effectively draw some of these resources into production.

Although one must recognize Brazil's potential as a future important supplier of agricultural products, at the same time one should recognize that Brazil as yet has a weak infrastructure to further expand its agriculture. It also has a short supply of qualified farmers and managers to undertake the tremendous task of opening the vast interior to agricultural production.

Although defying easy description, the Brazilian political-economic system may be classified as centrally oriented capitalism with a relatively large public sector.

TABLE 2 - FOREIGN DEBT & REPAYMENTS (in million US$)

Year	Foreign Debt			Repayments			Exports	Net Debt over Export	Repayments over Export
	Gross (A)	International reserves (B)	Net (C=A-B)	Interest (D)	Amortization (E)	Total (F=D+E)	(G)	(C/G)	(F/G)
1974	17,166	5,269	11,897	652	1,920	2,572	7,951	1.50	0.32
1975	21,171	4,040	17,131	1,464	2,120	3,584	8,670	1.98	0.41
1976	25,985	6,544	19,441	1,810	2,992	4,802	10,128	1.92	0.47
1977	32,037	7,256	24,781	2,104	4,060	6,164	12,120	2.04	0.51
1978	43,511	11,895	31,616	2,696	5,324	7,865	12,659	2.50	0.62
1979	49,904	9,689	40,215	4,186	6,540	10,726	15,244	2.64	0.70
1980	54,400	6,911	47,489	5,870	7,000	12,870	20,132	2.36	0.64

Source: Banco Central do Brasil - Boletim e Informativo Mensal (various issues)

The alcohol and other bioenergy programs, whose industrial characteristics do not favor economies of scale, offer ideal structural conditions for the participation of private enterprise on a competitive basis. There is, in fact, no sound argument for direct participation of the State in either the program's industrial portion or in the agricultural part nor can the argument that the sector is "strategic" justify government control since domestic private enterprise is qualified technologically and otherwise to assume a major portion of sectoral investments. Perhaps for this reason, all the interventionist impetus has concentrated on forms of indirect State action, which will be analyzed later in this paper.

The alcohol program for the first time offers conditions for a flourishing multiplicity of private enterprises in such a strategic sector as energy, more and more dominated by government. The atomization of industrial production centers and their articulation with scattered agricultural production centers is expected to generate a new economic structure whose behavior in terms of efficiency gains in the course of time should provide an important basis for comparison with orthodox forms of State performance.

In order to avoid competition between sugarcane, the predominant energy crop, and traditional food crops, the use of alternative raw materials (such as cassava, sweet sorghum, sugarbeet and agricultural plant and animal residues in integrated farm bioenergy pilot demonstration projects) is being implemented. These integrated Food-Bio-Energy Production Systems constitute a step towards decreasing the state and private monopolies in the energy sector.

In terms of potential land use, some areas in Brazil (like the Center-South) are approaching their limit, and it is precisely in those areas that sugarcane expansion is going ahead at full speed.

Table 3 shows the 1980 figures for land use in Brazil, and the potential figures by state:

TABLE 3- Present Land Use and Availability of Suitable Land for Crops (under Modern Management) in 1980.

States	(1) Suitable Land Total (1.000 ha)	(2) Under Cultivation Annual Crops-1980 (1.000 ha)	(3) Total Under Cultivation-1980 (1.000 ha)
NORTH	79,540	754	786
Pará	31,150	336	369
Other	48,390	389	417
NORTHEAST	20,180	4,581	986
Maranhão	55,940	2,763	3,002
Bahia	14,240	1,818	1,984
Piauí	3,690	4,157	7,085
Ceará	8,830	1,000	2,864
Rio Grande do Norte	460	333	770
Paraiba	490	896	1,556
Pernambuco	760	1,160	1,448
Alagoas	920	601	699
Sergipe	230	167	248
CENTER-SOUTH	106,400	31,834	35,557
Minas Gerais	830	3,259	4,159
Espírito Santo	620	322	656
Rio de Janeiro	4,830	307	376
São Paulo	5,600	3,888	5,421
Paraná	9,000	7,995	8,984
Santa Catarina	2,300	2,324	2,348
Rio Grande do Sul	7,900	8,178	8,210
Mato Grosso	49,890	2,843	2,904
Goiás	25,430	2,448	2,509
Brazil	209,810	41,317	48,414

SOURCE: Homem de Mello and da Fonseca (1981).

In rural areas, massive increases in sugarcane production may compete with food production in terms of land use and labor employed, given the seasonal aspects of sugarcane production.

It can be seen that the state of São Paulo, the largest sugarcane producer in Brazil, had a sizable increase in acreage over the last couple of years. Unofficial reports suggest that the pace grew even faster in 1981 and 1982. In order to compare the acreage of sugarcane with other crops in the state of São Paulo. (Table 4).

TABLE 4 - Crop and Pasture Acreages - São Paulo, 1976/1980 (1.000 ha)

Activity	1976	1977	1978	1979	1980	(80-76)	80/76 (%)
Cotton	223	300	345	284	265	++ 42	+ 18.8
Peanuts	230	145	172	203	211	- 19	- 8.3
Rice	606	347	342	300	300	- 306	- 50.5
Coffee	691	637	775	768	805	+ 114	+ 16.5
Sugarcane	723	790	871	948	1,060	+ 337	+ 46.6
Beans	240	350	486	392	449	+ 209	+ 87.1
Oranges	282	286	326	399	427	+ 145	+ 51.4
Castorbeans	23	18	34	21	25	+ 2	+ 8.7
Manioc	30	33	36	28	23	- 7	- 23.3
Corn	1,250	1,134	972	1,055	1,030	- 220	- 17.6
Soyabeans	394	449	559	536	560	+ 166	+ 42.1
Other	222	287	271	363	292	+ 70	
<u>Subtotal</u>	4,914	4,776	5,189	5,297	5,447	+ 533	+ 8.5
Pastures	10,245	10,144	10,092	9,970	9,546	- 699	- 6.8
<u>Total</u>	15,159	14,920	15,281	15,267	14,993	- 166	- 1.1

SOURCE: Homem de Mello e da Fonseca (1981).

Creation of EMBRAPA

Since the early nineteen seventies the expansion of agricultural productivity has been the main objective of Brazilian economic policy. The emphasis that up until then had been largely on growth, has been shifted towards growth with equity.

In 1972, a Task Force was formed to study agricultural policy and propose institutional reforms. As a result of its recommendations, the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) was organized late that same year.

The statutes of EMBRAPA are contained in Law Nº 5,851 of December 7, 1972, which outlines the agency's main functions as follows: (a) direct, control and execute agricultural research activities for the purpose of producing new technology for the development of national agricultural production; (b) assist the Federal executive branch, and its entities, in technical and administrative matters related to the agricultural sector; (c) stimulate and promote the decentralization of research activities to the benefit of state and local interests; (d) provide technical coordination of research projects, the execution of which involves the technical - administrative services of other Federal agencies; (e) maintain close contact and coordination with the Brazilian Technical Assistance and Rural Extension Corporation (EMBRATER) to effectively execute diffusion of research results and technology, and (f) plan, program and budget research activities to reflect the guidelines and policies established by Government.

The public corporation concept means that EMBRAPA operates like a private corporation. It can use all types of financial and human resources and can sell its service to, buy from and collaborate with all kinds of clients.

By 1982 the EMBRAPA research budget was approaching US$ 220 million. In terms of financial resources, this was roughly double the budget of the CGIAR sponsored international agricultural research system. Table 5 shows the growth of EMBRAPA both in terms of financial and human resources.

It is clear that Brazil has been making the most serious effort of any country in Latin America to establish an agricultural research system capable of supporting the transition of Brazilian agriculture from a resource-based to a technology-based industry.

TABLE 5 - Total Budget and Evolution of Number of Research Workers, Support and Administrative Personnel, Brazilian Agricultural Research Corporation 1973-1982 Period.

Year	Total Budget $US 000'	Research Workers	Support Personnel	Administrative Personnel	Total
1973		12	07	47	66
1974	26,333	872	2,125	993	3,990
1975	56,040	1,037	2,356	1,416	4,809
1976	80,829	1,328	2,666	1,709	5,703
1977	98,065	1,311	2,678	1,696	5,685
1978	125,612	1,336	2,954	1,744	6,034
1979	154,122	1,448	3,191	1,935	6,574
1980	157,455	1,553	3,314	1,902	6,669
1981	182,954	1,576	3,340	1,948	6,864
1982	220,000	1,578	3,338	1,996	6,912
(Total)	(1,101,410)				

SOURCE - DRH/EMBRAPA

A new pattern of organization that drew its inspiration from the single-commodity research model that characterized the initial units in the international agricultural research system was adopted. National research centers were established for the major agricultural commodities-wheat, sorghum, corn, beans, soybeans, rice, oil palm, rubber, livestock, and dairy products. Three centers that focused on key resource problems were also established - for the problem soils of the "cerrado", the semiarid Northeast, and the tropical conditions of the Amazon region. Each national center was organized around a major central station plus a series of regional stations, depending on the several agroclimatic regions in which the commodities were produced.

EMBRAPA visualizes the National Centers as primarily applied research institutions. Their mission is to produce technology packages that will have an immediate impact on agricultural production. Explicit feedback mechanisms from producers and the extension services designed to focus research effort on priority production problems have been established. The commodity and resource problem focus of the research centers is viewed as an effective device for achieving multidisciplinary cooperation among researchers and for designing technology packages that take advantage of the interactions among the package elements (crop variety, pest and disease control, fertilization, plant population, and weed control, for example).

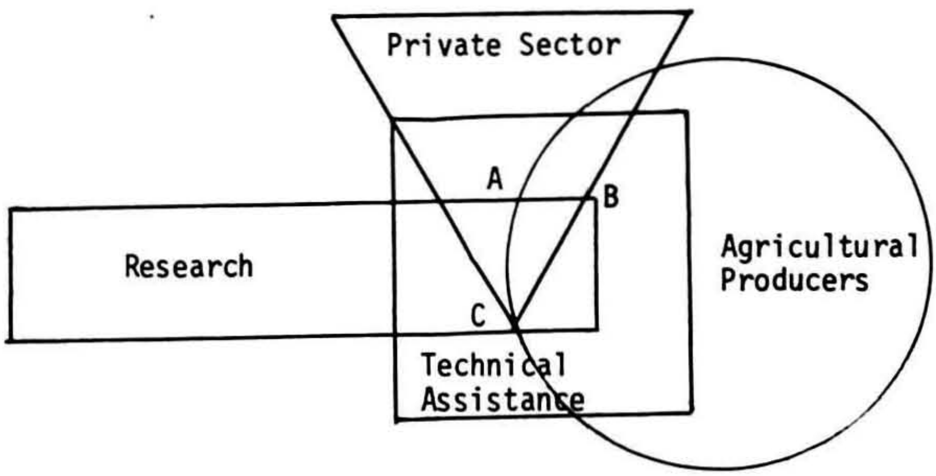
In addition to the reorganization of the Federal research system, a major effort has been made to strengthen the professional capacity of the EMBRAPA staff. Within the first few years, over 2,500 fellowships were granted for graduate study at Brazilian and overseas universities. Salary levels were established at international levels, and an active recruiting effort was undertaken to attract foreign scientists into the Brazilian system. An attempt was made to strengthen the connections among Brazilian and foreign universities and with the international agricultural research centers.

The Circular Model of Research

The programming of agricultural research has as its objective the promotion of a better allocation of human and material resources in such a way that permits the generation of knowledge and production systems able to improve the yield, shorten the time between the generation of knowledge and its utilization by the agricultural producers,as well as to increase the overall generation of knowledge.

To be able to develop an objective programming model of agricutural research,it is absolutely necessary to involve the agricultural researcher together with representatives of all those sectors that in one way or another participate in the production process, including (1) agricultural producers, (2) extension services and (3) modern agricultural inputs and processing industries. This type of interaction constitutes the logic of the so-called circular model. The integration between the various sectors and identification or their common interests constitutes the highest priority of the agricultural research program.

FIG. 1: Interaction System of Research Planning and Programming



The circular programming of research is based on production systems that traditionally have been used. Its identification and description will show clearly the bottlenecks that impede the increase of yields of these traditional production systems. The elimination of these bottlenecks will generate new production systems.

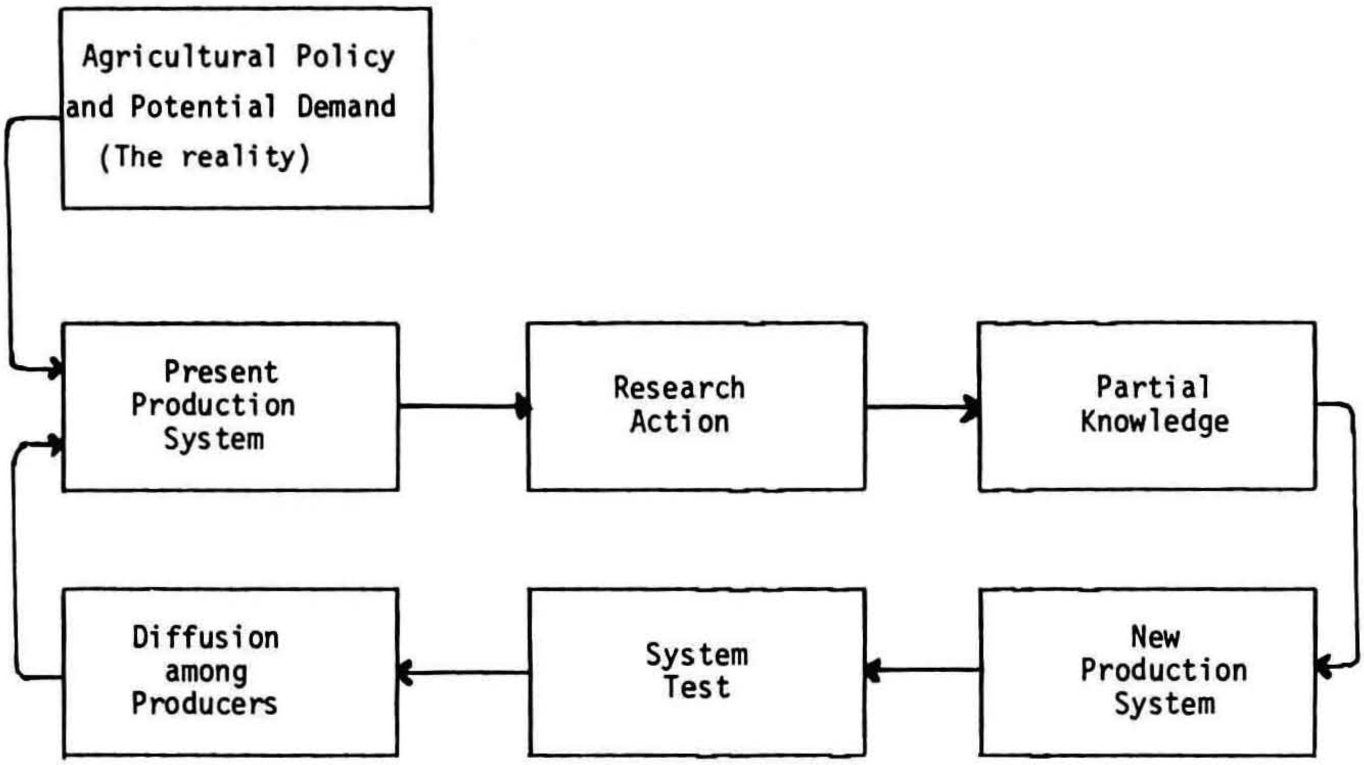
In the above methodology we can see a process of synthesis-analysis-synthesis action of research, which is better called circular programming of research according to RAMALHO1/. In the following graph this idea is better explained.

This circular system is characterized by a strong feedback mechanism while in the linear system this mechanism is absent.

It is more effective in inducing interdisciplinary collaboration than what can be achieved by the exercise of administrative guidelines or authority or a linear chain-of-command type of research management system.

1/ JOSÉ P. RAMALHO. Considerações sobre a programação da pesquisa agropecuária. Brasília, D.F., EMBRAPA, 1979, p. 3.

FIGURE 2: CIRCULAR MODEL OF RESEARCH PROGRAMMING



SOURCE: JOSÉ P. RAMALHO. Considerações sobre a programação da pesquisa agropecuária. Brasília, DF, EMBRAPA, 1979, p. 5.

Interdisciplinary collaboration results in emphasis on impact on yields and earnings rather than contribution to scientific knowledge. It can easily relate the research programs to the particular economic and political environment in which it operates in terms of the ethical and social consequences of technological change.

Selection from among a large number of interesting problems which researchers would like to pursue becomes necessary because of the limitation of resources and management policy to give a specific direction to the various research organisations.

National Research Programs

Taking into consideration the articulation model and circular programming and in accordance with the priorities already fixed by the Ministry of Agriculture, the Board of Directors of EMBRAPA established the National Research Programs to accomplish the major objectives of the system.

Besides a greater objectivity, the definition of research problems through the producers, the researchers, and extension workers may provide other advantages. The participation of the producer in this phase commits him to the process, besides sharpening the expectation for results which can be used in a constructive way to increase the efficiency of the transfer of the technologies obtained through research. These represent the solutions needed by the producer for the problems he helped to define.

Extension and Technical Assistance are essential for this bringing together of researcher and producer and other representatives of the private sector at the time of problem definition. Besides being able to help in problem definition, this group can also identify for the researcher the most represent-tative regions and properties to be used during the "field day". In addition, this approach can yield valuable information as to the extent and variability of the problems as a function of social and ecological differences. Extension has the capability of making the "field days" more efficient and of aiding in the direct communication between researchers and producers, since its personnel is accustomed to the working arrangements employed by the two parties.

The Board of Directors assigns the coordination of each National Research Program to the appropriate research unit of the network. The assigned unit appoints a coordinator of the program, who will then call a meeting of all the units involved with this specific National Research Program and other institutions including representatives of the private sector, in order to elaborate the short and long-term plans of action.

At the present time EMBRAPA has 39 National Research Programs on:

1) Crops including rice, beans, corn, wheat, soybeans, vegetables, cassava, sorghum, cotton, rubber, temperate fruits, citrus, pineapple, banana, mango, African oil palm.

2) Livestock products covering: beef cattle, dairy cattle, sheep and goats, swine and poultry.

3) Evaluation of farming systems and socio-economic studies of the cerrado, semi-arid tropics and humid tropics.

4) Comprehensive programs including forestry, energy, food technology, genetic resources, soil surveys and conservation, viticulture and winemaking, basic seed production and agricultural diversification.

The basic idea behind EMBRAPA's model is that of cooperation and integration between the state governments, universities, technical advisory agencies and the private sector, so as to avoid repetition, while trying to use all available scientific and technological know-how developed in Brazil and abroad. The National Agricultural Research System includes two fundamental lines of action: direct action and coordinating action. Direct action is carried out through the National Centers which do crop research and/or by those specialized centers which develop natural resources and agricultural production systems for humid and semi-arid tropical and "cerrado" areas. These centers have the support of such units as the Soil Survey and Genetic Resources Centers and the State or Territory Research Units directly controlled by EMBRAPA. The coordinating action involves the development of programs and norms for all research projects both at the State controlled agricultural research institution level and EMBRAPA's units.

By the end of 1982 there were forteen state agricultural research corporations using EMBRAPA's institutional model but attached to the Department of Agriculture of each state instead of to the Ministry of Agriculture. States with a long research tradition such as São Paulo, Paraná and Rio Grande do Sul have Integrated Research Programs that are also attached to the state governments. In addition, EMBRAPA has 16 State Agricultural Research Units (UEPAE's and UEPAT's) directly controlled by it and operating in various states and territories. Figure 3 shows the geographic location of various research institutions.

Integrated Food-Bio-Energy Production Systems

When possible, EMBRAPA uses the systems approach in its research, attempting to bring together various components of farm production systems. Fig. 4 represents a simplified self-explanatory flow chart of "Integrated Food-Feed-Bio-Energy Production Systems". (For details see A. G. Netto, 1981).

In order to avoid competition between traditional food crops and sugarcane, the predominant energy crop, the use of alternative raw materials (such as sweet sorghum, cassava, sugarbeet, vegetable oil crops and agricultural plant and animal residues in integrated farm bio-energy pilot demonstration projects) is being encouraged.

It is not expected that all the components presented in the flow chart will be included in the same production unit. EMBRAPA has several systems implanted in various research centers designed to provide energy self-sufficiency for these centers. These systems, in addition to generating part of the fuel needed by the experiment stations, provide detailed data and are used for demonstration purposes. They will also eventually become training grounds for extension personnel and selected farmers. The systems now in operation are:

1) National Center for Corn and Sorghum Research, at Sete Lagoas, Minas Gerais: small still (sugarcane, sweet sorghum), electricity generator, biogas plant, pelletizer, gasogene (poor gas producer), dryers, alcohol-powered farm machinery. Fish production using biofertilizer.

2) Pelotas Experiment Station, at Pelotas, Rio Grande do Sul: small still (sugarbeet, sweet sorghum), confined livestock feeding operation, biogas plant, dryers.

3) National Center for Beef Cattle Research at Campo Grande, Mato Grosso do Sul: small still (sugarcane, sweet sorghum), confined livestock operation, biogas plant, electricity generator, alcohol-powered farm machinery.

4) National Research Center for Cassava and Fruits at Cruz das Almas, Bahia: small still (cassava),biogas plant, confined animal operation.

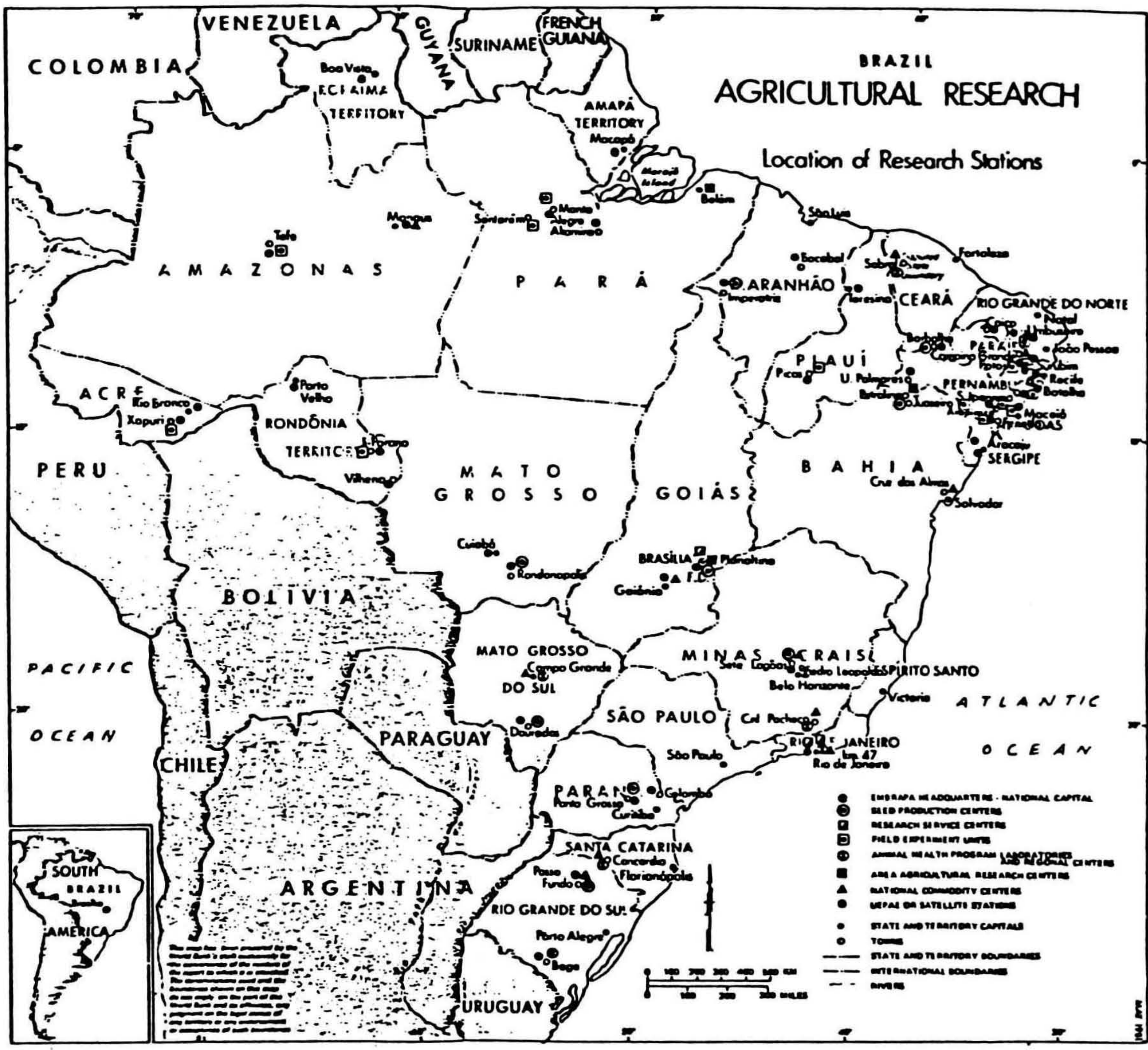


FIGURE 3 - Location of Research Units

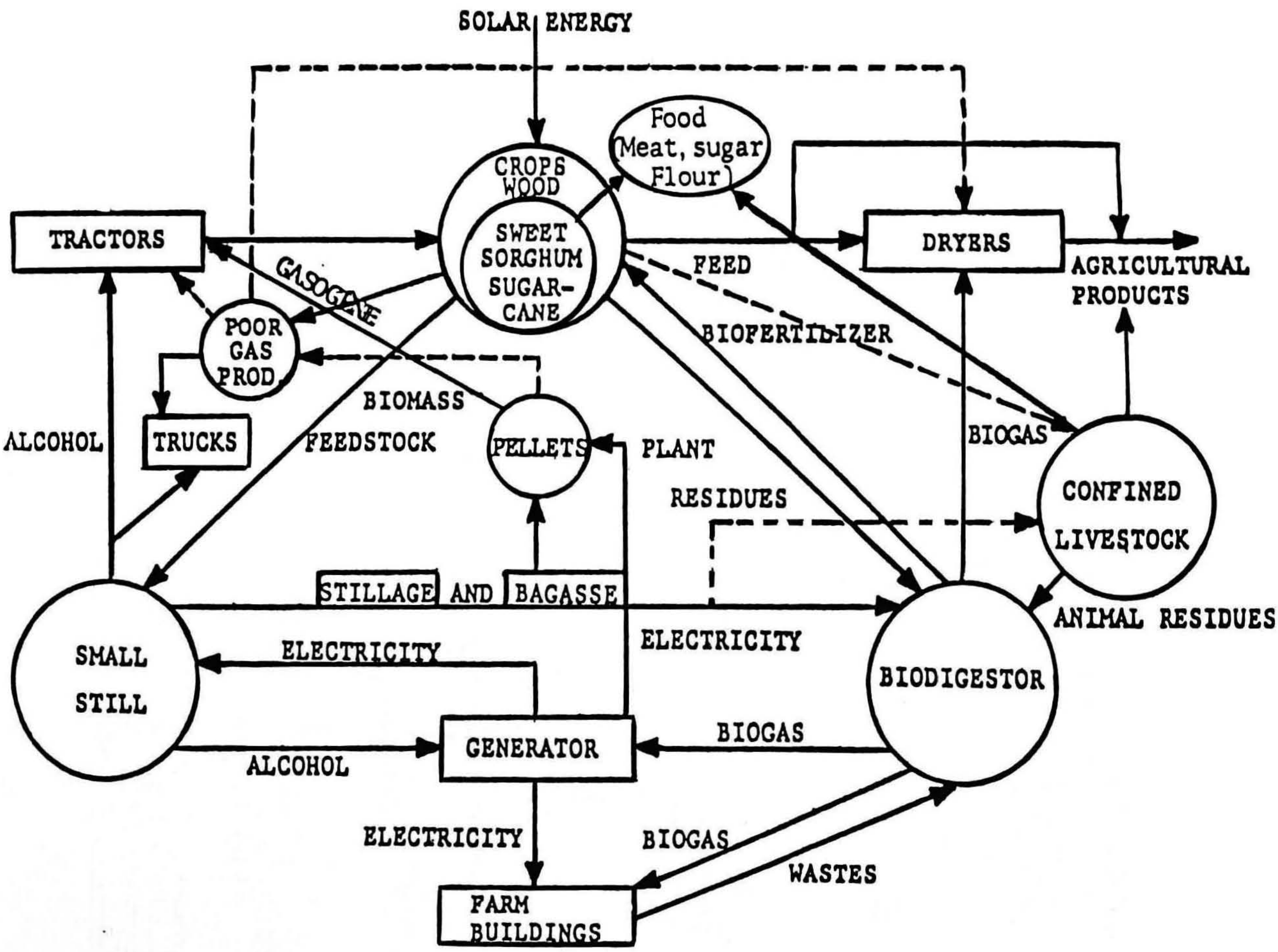


FIGURE 4

EMBRAPA'S Integrated Food-Bio-Energy Production Systems

5) National Center for Dairy Cattle Research at Coronel Pacheco, Minas Gerais; biogas plant, electricity generator, dairy farm using equipment powered by bio-energy.

6) National Research Center for Rice and Beans at Goiânia, Goiás: small still, gasogene-powered farm machinery and irrigation system, alcohol-powered tractors, seed dryers using wood gasifiers, biogas plant using crop residues.

7) National Center for Horticultural Research at Brasilia: small still, gasogene-powered farm machinery.

8) State Agricultural Research Unit at Aracaju, Sergipe: small still, confined livestock, biogas plant electricity generator using biogas, alcohol-powered farm machinery.

Brazilian scientists are working hard on the unsolved problems of producing and conserving energy in agriculture, and on ways of supplying part of the liquid fuel needed by other sectors to keep the country from remaining overly dependent on foreign oil. These scientists know that today's farmer cannot afford a trial-and-error approach to cutting down on fossil fuels and that their research has to provide technically and economically feasible recommendations.

At the same time, scientists at the experiment stations are studying ways of producing sweet sorghum, cassava and sweetpotato and sugarbeet more efficiently for alcohol production. They are optimistic about sweet sorghum as a source of commercially-produced ethanol because of its favorable characteristics.

While it is known that sweet sorghum can be used in ethanol production not enough is known about how best to grow it for this purpose. Agronomists are investigating some of the unanswered questions, such as "When should it be planted? Can two crops a year be produced? Can the harvest be mechanized and extended?".

Since sweet sorghum will ratoon (sprout again) from its own roots, agronomists hope to fund a short-season variety that will mature quickly so that it can be harvested early enough to allow a second crop to grow before the cool season. Usually no additional tillage is needed for this second crop, and neither herbicides nor fertilizers need be applied.

The ultimate aim of this research is to give farmers the know-how to produce two crops of sweet sorghum per year. Since an acre of sweet sorghum can be turned into 200-300 gallons of ethanol by a commercial plant, the results should be beneficial to everyone except petroleum exporters.

The desirable characteristics of sweet sorghum varieties for ethanol production according to Schaffert and Gourley (1982) are: (1) high biomass yield; (2) high percentage of fermentable sugars along with combustible organics; (3) comparatively short growth period; (4) drought tolerance; (5) low fertilizer requirements; (6) production of grain for food or feed use; and (7) the possibility of complete mechanization.

Microdestillery technology for ethanol production from sugarcane can be adapted and utilized to produce ethanol from sweet sorghum.

Scientists are also studying the possibilities of converting sweetpotatoes into alchol. Sweetpotatoes and cassava have a potentially high yield in gallons per acre. Because they can be stored longer than sweet sorghum, they can provide a commercial ethanol plant with a year-round source of fuel alcohol.

An alcohol fuel plant can be considered a separate profit center installed on a farm or it can be integrated with the farming operation in the same fashion as a grain drying bin, a forage chopper or a small feed mixing plant. Thus farms which begin to manufacture alcohol become more diverse and integrated in their own operations while also becoming more tightly integrated with other sectors of the economy. This implies that any farm operation which has the potential for alcohol production needs to make a careful assessment of its entire operation including both physical or operational and fiscal or economic analysis. The most viable operations will be those with maximum flexibility coupled with good marketing and economic planning. The profit may not be maximized, but economic opportunities will be optimized in much the same way that futures hedging can be used to reduce risk to the farmer.

Introduction of biomass technologies in general and alcohol fuel plants in particular should force the farmer to rethink the entire farm operation and to look at the development of totally integrated farm systems.

The introduction of an anaerobic digestor on a farm points out the opportunities for optimizing energy utilization. It is imperative to look carefully at the total farm picture before deciding on the capacity of an alcohol fuel plant. More importantly, it becomes necessary to look at the entire farm operation in order to develop an integrated technical and financial approach to the use of renewable energy systems. It is no longer possible to simply look at the technical and economic feasibility of solutions for a problem such as rising fuel prices or the availability of these fuels in either the short or long terms.A complete analysis is needed to develop systems which optimize both present and future opportunities. The most important need is to make people think in energy terms, then alcohol fuels and other renewable sources of energy will be effectively integrated into farms and communities.

Agriculture used to be mainly a process that converted sunshine into food and fiber. By 1982 agriculture production based on new energy intensive technology was converting a large amount of petroleum and its derivatives into food and fiber.

Energy in agriculture is not only what makes a tractor move; it includes what makes a cow or a hen produce or what makes an irrigation system function. It also turns on the light in the barn, dries the grain, cools the milk, enriches the soil, and kills the corn earworm. In other words petroleum and its derivatives are major ingredients of chemicals and fertilizers as well as of farm fuels.

Collaboration with the Private Sector

The primary rationale for the public sector's investment in agricultural research has been that in many areas incentives for private sector research have not been adequate to induce an optimum level of research investment. In these situations the social rate of return exceeds the private rate of return because a large share of the gains from research are captured by other firms and by consumers rather than by the innovating firm.

In other cases, when the innovating firm can capture some benefits from collaboration between the private and public sectors, joint research becomes feasible.

In 1974 the Ford Motor Company of Brazil accepted EMBRAPA's invitation to discuss the possibility of developing alcohol-powered tractors for use at EMBRAPA's Research Centers. In June, 1979 the first meeting between Ford and EMBRAPA was held in Brasilia and by September Ford engineers were working on their development. In February, 1980 the first 2 prototypes were delivered to EMBRAPA. Shortly thereafter, 7 other tractors entered into service on EMBRAPA's farms and 1 at the Ford Equipment Testing Center at Tatui, SP. These 10 units have now accumulated about 22,000 hours of use.

These tractors up until now have shown good performance in terms of specific fuel consumption per unit area and unit time.

In addition to Ford, other private sector enterprises have been involved in development of various alternative components for Integrated Food-Bioenergy Production Systems. These are:

1) Valmet do Brasil, and Companhia Brasileira de Tratores (C.B.T.); Alcohol-Powered Tractors.

2) Metalúrgica Barbosa Ltda., Deon Hullet, Instituto de Pesquisas Tecnológicas (IPT); Small Stills.

3) Empresa Brasileira de Biodigestores (EMBRABI), and Yanmar-Montgomery and Volkswagen do Brasil: Biogas-Fueled Electric Generator Systems.

4) EMBRABI, Fiat, Volkswagen Truck Division, Siquierolli, Termoquip, Dantas Irrigation Systems and Explo: Poor Gas Producer Systems (gasogene) for Electric Generators, Tractors, Irrigation Systems and Stationary Power Plants.

5) Duratex, Rações Anhanguera and ANFAR (National Association of Feedstock Producers): Feed Production.

6) Piraque and Paty S.A. - Food Products, Sweet Sorghum-based Flour for Mixing with Wheat Flour.

7) Various livestock enterprises using bioenergy by-products and residues as feedstock for animal production.

8) Usina da Barra, Tamoio and others using stillage and biofertilizer on sugarcane and other crops.

EMBRAPA at present is not concerned with the possibility that it may be giving monopoly rights to individual participating firms since any economic or technical innovation resulting from joint efforts will not constitute an exclusive right of any single private enterprise since others will have the right to use the resulting new technology.

The vision of the public sector R & D managers in programming research must encompass the whole national research system and aggregate problems such as the need to make the agricultural sector at least partially self-sufficient in energy without affecting the food and feed supply systems. The participation of private industry was mobilized to design and eventually produce individual components of the system in which each industrial group has a comparative advantage and the chance of being a pioneer innovator in its own field. It is assumed that public research participation will not create monopoly conditions that will prejudice the industry as whole but will lead to healthy competition and to further innovation and technical change. Even though each public research manager may have direct or only partial or indirect responsibility in terms of his collaboration with private industry, the over-all agency research management must be concerned with the national issue of maintenance of capabilities and appropriate levels of balance between its research activities and those of collaborating private industries.

Final Observations

Brazilian agricultural policy aims at achieving self-sufficiency in basic foodstuffs, generating additional foreign exchange earnings through and exports substituting and increasing volume of petroleum with renewable agricultural biomass fuel.

The goal of the Brazilian bioenergy research program is to develop a biomass conversion technology so that the agricultural, forestry, and food processing industries can become at least partial self-sufficient in liquid fuel. Small-scale, decentralized plants are preferred in order to diminish institutional problems and the excessive transportation costs associated with large-scale plants.

The need to keep the rural population on the farms is a primary requirement in strengthing the agrarian system in the country. The supply of energy in the rural areas has as its objective providing the countryman with satisfactory living conditions, improved job opportunities and a rise in agricultural productivity. Decentralized food-feed-bioenergy production system which integrates intermediate technology and renewable sources of energy, has been proposed as an option for power and employment generation in the rural community.

Agricultural energy self-sufficiency, particularly through energy crop production, is an important buffer in the energy supply system, making the agricultural sector less failure prone. This self-reliance makes it possible for an oil-deficient country to insulate its food situation from the oil export policy decisions and actions of other countries.

There must be continuous public-private, non-profit cooperation in agroenergy research which will contribute to building a solid base for a strong agroindustrial economy.

The issue of "Integrated and Decentralized Food-Feed-Bio-Energy Production Systems" developed jointly by public and private sectors is symbolic of a greater issue: the preservation of liberty and social equity by maintaining some independence from the "Big System". According to Lovins:

> "Small energy systems suited to particular niches can mimic the strategy of ecosystem development, adapting and hybridizing in constant coevolution with a broad front of technical and social change. Large systems tend to envolve more linearly like single specialized species (dinosaurs?) with less genotypic diversity and greater phenotypic fragility". 1/

1/ A. Lovins. Scale Centralization and Electrification in Energy System in Future Strategies for Energy Development: A Question of Scale, Oak Rigge: Associated Universities, 1976, p. 7.

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