The Economics of Technology Development for Abiotic Stress in the Cerrado of Brazil and its Potential Use in Other Environments and Cultures

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INTRODUCTION

Tropical acid soils represent 38% of the total land area between the Tropics of Cancer and Capricorn. The inhibition of plant growth in these acid soils has been the objective of agricultural research and development in many countries, with several different approaches. Approximately 20% of Brazil has an acid savanna ecosystem called the cerrado. The cerrado is characterized by poor soil fertility, with chemical impediments that restrict root development and the utilization of the adequate annual water supply, making plants sensitive to short periods water deficiency. Brazil has obtained much experience in the exploration of acid soils for agricultural production during the past two few decades. The successful exploration of the cerrado has been the result of an interesting combination of agricultural research developments and governmental policies.

THE INITIAL OCCUPATION OF THE BRAZILIAN CERRADOS

Prior to the 1970's the Brazilian farmers did not know how to successfully cultivate the cerrado. The extraction of the native vegetation for charcoal production and extensive cattle grazing on native grass pastures were the unique economic activities in the region. This was compatible with the low land prices, low quantity of labor available, low capacity for sustaining agricultural production and deficient transportation infrastructure available at that time. The foremost agricultural exploration was upland rice utilizing the natural fertility of the soils following the extraction of the native vegetation for charcoal production and prior to the formation the grazing land. The rice was sown manually, following the cutting and burning of the native vegetation a labor-intensive sharecropper method of land conversion.

THE DEVELOPMENT OF TECHNOLOGY FOR THE CERRADOS

Since the beginning of the 1950's, the sustainable utilization of the cerrado was a challenge and preoccupation among the scientist that worked in the region. The emphasis of the research and development through the 1960's was on soil aspects. The first attempts were amending the soil with lime from locally available lime rock deposits within the cerrado region. The local availability of the lime and reduced the transportation costs were essential to making this practice viable. The results of soil research generated a set of agricultural practices to rise the soil pH and to increase the availability of phosphorus for the plants. The problem was the large investment necessary for improving the quality of land, reducing the advantage of low land prices. However, during this period, the traditional crop

257

cultivars did not produce a sufficient response to these soil improvements to compensate the necessary investment.

None-the-less, the federal government implemented a set of agricultural policies in the mid 1970's targeted to the cerrado region. This government policy was based on technology and results from the State of Minas Gerais. These policies included agriculture colonization and settlement schemes and subsidized credit for acquiring agricultural machinery and improving soil fertility. Agricultural credit in Brazil in the 1970's was strongly tied with technical assistance. Consequently, it was possible to create and fund a credit program that was supported by technology. The remarkable characteristic of this linkage was that it probably would not have been possible to implement one (technology/credit) in the absence of the other.

A second component fundamental for the initial viability of agriculture production in the cerrado, was the release of the first soybean variety, UFV-1, developed for the cerrado in 1973. The existent soybean varieties, prior to the release of UFV-1, were poorly adapted to the agroecological conditions of the cerrado. UFV-1 proved to be more productive than the traditional varieties, especially with small amounts of inputs, even with little soil fertility improvement. UFV-1's response to increasing doses of phosphorus compensated the use of more phosphorus fertilizer.

The target of the soybean research was very different from that of the upland rice research. In the case of soybeans, a cultivar with adaptation to the conditions of the cerrado was developed, whereas in the case of upland rice, cultivars were developed that responded to improvements to the environment. This was the technological and political scenario that permitted the start of the agricultural occupation and utilization of the Brazilian cerrado. Since then, new technology has continued to be released, making it possible to compensate the withdrawal of the subsidized credit for agricultural production in the cerrado since the early 1990's.

New soybeans varieties have been released that are better adapted for mechanized agricultural production. The advances obtained in the management of biological nitrogen fixation microorganisms, *Rhizobiumm spp*, has permitted the elimination of the use of nitrogen fertilizer in soybeans. A new maize cultivar, BR-201, tolerant to Al toxicity was developed improving its drought resistance. The maize hybrid BR-201 is also very responsive to the use of phosphorus. In 1991 20% of the maize seed sold in the State of Goias and 18% of the maize seed sold in the State of Mato Grosso where of this hybrid. This additional technology permitted an alternative cropping system to the soybean monoculture production system.

The intensification of agricultural production in the cerrado and the use of improved technology have made it possible to improve the utilization and recovery of phosphate fertilizers. After several years of agricultural exploration, it has been possible to rise the level of sustainability utilizing the improved technologies now available.

A synopsis of the important facts that contributed to the occupation and utilization of the cerrado is in the Table 1.

Table 1. Timing of relevant facts leading to the occupation of the Brazilian cerrado.

Activity	Initiation Of Activity	Implementation Of Results
Research on fertility management in cerrado soils	Mid 1950's	Early 1970's
Soybeans breeding	Mid 1960's	1973
Government program to investment in cerrado soil improvements	Mid 1970's	Mid 1970's
Maize breeding	Early 1980's	1989

In summary, the recent increase in the occupation and exploration of the Brazilian cerrado has been the result of several favorable conditions. First was the availability of new cultivars and improved technology for commercial crops like soybeans and maize, improving their yield response to soil quality improvements. Second, the insertion of the Brazilian soybeans into the international market gave support for its prices and allowed its expansion into regions far from the Brazilian ports. The recent trend of increased activities of animal raising in Brazil, principally swine and poultry, has transformed maize into a commercial crop, as opposed to a subsistence crop at the beginning of the 1970's. The fact that both maize and soybeans became commercial crops allowed for the implementation of a governmental program of incentives for improving soil quality. The localization of the lime deposits within the region has also been vital and has helped support the economics of agricultural production in the cerrado since the end of subsidized governmental credit. The improved transportation infrastructure has also provided support for the insertion of local agricultural production into both domestic Brazilian and global markets.

The consequence of this development has been the increase of the area under soybean and maize (crops with potential response to soil improvements) production and a decrease of the importance of upland rice, the crop adapted to the cerrado conditions but poorly responsive to soil improvements (Table 2).

Table 2. Average Area Planted (Percent) and Yield of the Four Agricultural Commodities of the Brazilian cerrado.

	RICE		SOYBEANS		MAIZE		BEANS	
	AREA ('000 ha)	YIELD (kg/ha)	AREA ('000 ha)	YIELD (kg/ha)	AREA ('000 ha)	YIELD (kg/ha)	AREA ('000 ha)	YIELD (kg/ha)
AVERAGE 59/61	562 (58)	1574	0.214 (0)	1379	285 (29)	1534	129 (13)	892
AVERAGE 69/71	1,298 (61)	1188	21 (1)	1234	576 (27)	1493	232 (11)	733
AVERAGE 79/81	2,412 (51)	1105	1,020 (21)	1628	1037 (22)	1995	303 (6)	368
AVERAGE 89/91	977 (15)	1331	3,630 (56)	1972	1,531 (24)	2727	310 (5)	566
AVERAGE 92/94	895 (13)	1537	4,208 (60)	2269	1,713 (24)	3111	238 (3)	865

THE FUTURE OF THE BRAZILIAN CERRADO

Concerns have been raised recently about the sustainability of agriculture production in the cerrado. Current developments show that the occupation of the cerrado saga is far from being over and new developments can considerably change the scenario. Improvements are being made in the transportation system to link the areas of production in the cerrado with ports and industries of the Southeast. Currently, transformation or value added industries of soybeans and maize are moving into the cerrado region. These include both soybean and maize processing industries and modern swine and poultry production enterprises.

On the agricultural research side, the continuos development of new soybean cultivars, more adapted to lower latitudes (nearer the equator), supports the expansion of agricultural activities, in the now more transportation friendly environment of the cerrado region. The development of new maize cultivars adapted to the cerrado increases the opportunity of rotation schemes with soybeans as this crop expands in a northerly direction (closer to the equator) in the cerrado region. In both cases, better adaptation to more mechanized agricultural systems are under pursuit. Characteristics that improve the efficiency of mechanical harvest, more efficient herbicides and improved resistance to pests and diseases is now on the research agenda for these crops in the cerrado.

With improved technology for alleviating the constraints for maize and soybean production now available, a series of other agricultural crops are being developed and planted in the region. Crops like coffee, tropical fruit trees, and vegetables such as sweet corn, carrots and peas are expanding into the region. Also, modern intensive milk and beef cattle production operations, dependent upon silage production, are relocating and developing in the region.

One of the most important changes occurring in the cerrado agriculture scenario is the expansion of the

no-tillage or direct planting systems in the region. This technology is being demand driven by both economic and conservation necessities. As the mechanical operations in no-tillage planting are more efficient, double cropping in becoming predominant in several areas of the cerrado. This system reduces expenditures for fuel and results in a more favorable cash flow for the farmers. More than 1.5 millions hectares are now under the no-tillage systems in the "cerrado." The expansion and adoption of this system is creating new possibilities for crops like sorghum and millet.

APPLICATION OF THE BRAZILIAN EXPERIENCE TO OTHER COUNTRIES

Two complementary forces were important in developing the cerrado for agriculture production, technology and policy. The technology in principal should be applicable to other scenarios with similar crop production constraints. The policy, at least in this case, can be considered more site specific. One specific condition in the case of the cerrado was the location of lime and rock phosphate deposits within the cerrado. This made the use of these inputs more economical than in a scenario where these inputs may be much more expensive due to high transportation costs. In the case of Brazil where mechanization was essential, there was an abundance of farm settlers that had experience with mechanized agriculture.

The research experience in the cerrado and the coupling of research results to agriculture policy formation should be transferable to other scenarios. In the Brazilian case, the research problem was very well defined at the onset. Both physical and human resources were committed to research the problem and produce usable results. The research agenda was linked to the local availability of lime and rock phosphate resources. New production technology evolved that included better adapted crop cultivars and appropriate soil fertility management. In the case of the Brazilian cerrado, adaptation of traditional crops to the cerrado conditions led to the substitution of well adapted, but low yielding upland rice with soybeans and maize. The underlying accomplishment to this transformation was the development of more nutrient efficient cultivars. These new crop cultivars respond better to soil fertility inputs than do traditional cultivars.

The linking of government policy, involving technical assistance and credit, to new technology for exploring the cerrado was a significant factor leading to the successful expansion of agriculture into the cerrado. The accompanying implementation of new commercial activities in the region, such as swine and poultry production and industrial processing of both soybeans and maize, has also been an important component for the expansion of agriculture production in the cerrado.

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