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AGRICULTURAL DEVELOPMENT ON THE BRAZILIAN FRONTIER: SOUTHERN MATO GROSSO

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Agricultural Development on the Brazilian Frontier: Southern Mato Grosso

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Introduction

Brazilian agricultural output performance has been remarkably good in the post-World War II period as supply increases have kept up with demand growth and shifts of demand between commodity groups maintaining real food prices relatively constant. This good performance has been achieved in spite of neglect and even implementation of policies adverse to the agricultural sector.[1/] Most of this output increase has been attributed to the expansion of conventional factors of production, land and labor, rather than the substitution for these conventional factors with "modern inputs," such as fertilizer and machinery.[2/]

These increases in conventional inputs have been primarily achieved with a large-scale reshuffling of the population between states and regions. From 1950 to 1970 the largest rates of inmigration have been to the frontier states of Paraná, Goiás, and Mato Grosso. (See Table 1.) There has also been a more limited and erratic migration into the Northern frontier states of Pará, Amazonas, and Maranhão. The other in-migrant recipient states have been associated with the rapid urban-industrial growth of São Paulo and Rio de Janeiro. Most other states have consistently had net out-migration over these two decades. This includes not only all of the Northeast but also a majority of the states in the South and East. Public investment has facilitated this migration with the construction of infra-structure. From 1952 to 1968 the road network in Brazil more than tripled reaching 940,000 kilometers. Road quality has also been substantially improved with paved roads increasing from 36,000km in the early sixties to 60,000km in 1972.[3/]

This population reshuffling was associated with the rapid expansion of crop area on the frontier. (See Table 2.) The absolute gains in land area, except for Paraná were less in the frontier states than in some of the older agricultural areas; however, the relative gains were much larger. The aggregate crop yields in the frontier have fallen as cultivation has been pushed into more marginal areas especially in the "cerrado" of the Central West frontier.[4/] However, the area expansion has been so rapid in the frontier states that these states have attained the highest crop output growth rates in the country over the last two decades. Only Maranhão, which is also a frontier state, has exceeded the crop output growth rates of Paraná, Goiás, and Mato Grosso. In older agricultural states such as São Paulo, Rio Grande do Sul, and some states in the Northeast aggregate yields have slightly increased.

In spite of falling yields most aggregate crop yields are still higher in the frontier states than in the older agricultural states.[5/]

The shifting systems of cultivation to new crop areas as older areas deplete their soil has been frequently criticized. However, given the relatively elastic supply of virgin land especially on the frontier and the high price of biochemical substitutes for land in the form of fertilizer and fertilizer-responsive varieties, the expansion of conventional inputs is an entirely rational method to increase agricultural output. Moreover, the magnitude of this population reshuffling needs to be emphasized. The net migration to the frontier states from 1950-1970 involved 2.8 million migrants and enabled these states to expand their roles in Brazilian crop production. From 1950 to 1970 Paraná increased its share of total Brazilian crop area from 8.3 to 14.7 percent, Goiás from 2.0 to 5.0 percent, and Mato Grosso from 0.7 to 1.7 percent.[6/]

This paper is concerned with the implications of this large-scale in-migration in Mato Grosso for agricultural development and with the rapid expansion of agricultural mechanization in this frontier area. Little substitution for land with chemical fertilizer has taken place and a final section offers some hypotheses for this.

Crop Shifts from Subsistence to Commercial Crops

As the frontiers in Mato Grosso, Goiás, and Paraná were opened up for settlement in the fifties and sixties with the construction of roads and other infra-structure a shift from subsistence production to market-oriented production would be expected. When farmers obtain the potential to market more of their produce, they generally begin to specialize more in higher value products to sell.

Dichotomizing agricultural production into subsistence and commercial activities is not as easy as it appears. The traditional food crops of Mato Grosso are manioc, rice, beans, and corn; however, rice is not only one of the most important agricultural exports of the state but its importance in commercial production has been increasing. Hence, rice should be classified as a commercial crop. Most of the other commercial crops are relatively easy to identify as they require special non-farm processing before consumption. This group includes cotton, soybeans, and peanuts. Sugar cane is difficult to classify as it has both home consumption and commercial uses. Cane is considered here to be primarily a subsistence crop since the quota share of Mato Grosso in refined sugar has not been expanding rapidly.[7/]

The crop shifts on the frontier are normalized for the relative importance of any given region in the production of the given crop and all crops. The ratio of Mato Grosso's share of Brazilian cotton acreage to its share of Brazilian crop acreage is called a concentration ratio. The primary concern here is in the change in these concentration ratios over time. According to our hypothesis over the period 1950-1970 the importance of subsistence crops will decrease while the commercial crops will increase in importance.

Table 3 indicates a pronounced shift from subsistence to commercial crops. The decline of manioc and cane is very dramatic as is the increasing importance of cotton. The high concentration ratio for rice indicates the importance of this crop as an export for the state. This upland rice is more tolerant of acid soils than most major grains. Hence, it does better than most other crops without fertilization on the acid "cerrado" of the Central Plateau.[8/]

The aggregate data indicate the shift into commercial crops but give no information on the process. Crop shifts generally require new production and marketing technologies. How do farmers on the frontier obtain this information? One hypothesis is that the continuing waves of in-migration make possible these crop shifts. According to this hypothesis the in-migrants bring in the production knowledge of the particular crop from other areas. They need support from the marketing infra-structure to make the production of these commercial crops profitable, but the crop shifts are hypothesized to be associated with this "churning" process from continuing migration as public investment opens up these frontier areas to the major urban markets of Belo Horizonte, São Paulo, and Brasília. To test this hypothesis of the association of in-migrants and new commercial crops, data collected from Terenos and Fátima do Sul in the 1971/72 crop-year were utilized. Chi square contingency tables were used to test the statistical association between migrants and the introduction of new commercial crops. A strong positive correlation was observed in Terenos and in the two areas combined.[9] (See the map and Table 4.)

Thus, we conclude that the crop shift process was a "trial and error" process of proven varieties from other areas being diffused into the frontier by the new migrants. Besides crop-shifts the use of mechanized land preparation has become very important in Terenos and will be considered in the next section.

Mechanization on the Frontier

From 1950-1970 the rates of growth of mechanization were more rapid in the frontier states than in the other Brazilian states, including the capital-intensive agricultural systems of São Paulo and Rio Grande do Sul. (See Table 5.) In Mato Grosso the number of tractors increased from 50 in 1950 to 3,926 in 1970. The most common explanations for mechanization on the frontier are labor shortages and the large power requirement for land preparation, especially in soils with heavier texture. Since large-scale migration of labor has occurred into the frontier states, the labor shortage argument appears to depend upon seasonal shortages or to be a short-run supply inelasticity. In a country with the large underemployed labor force in the Northeast, continuing inter-regional wage differentials, and large-scale inter-regional migration, it does not seem plausible that the long-run supply of labor to the Central West is inelastic. Nevertheless, short-run inelasticities, by encouraging mechanization, could lead to shifts in land use and tenancy, which would only be reversible in the long run.

The second argument of the necessity to mechanize in areas with heavier soil texture and therefore greater power requirements deserves further investigation. It is hypothesized that mechanization will have a high rate of return in these soils and that the use of mechanization will be less in areas of better soils. This section is divided into two parts to test these inter-related hypotheses.

First, farmers' reasons for mechanizing are summarized and the rate of return estimated for a "cerrado" area. Then, a comparison is made between the mechanization levels of two similar agricultural areas with substantial differences in soil quality. Farm interview data from two agricultural colonies in Southern Mato Grosso with similar land-holding systems, size, and cropping patterns were used to evaluate the economics of the farm-level decision to mechanize land preparation.

Of the 66 farmers in Terenos and the surrounding area with an average crop area of 10.9 hectares only four used animal power for land preparation.[10/] The rest used machinery custom rental or their landlord's machinery. Only the land preparation operation was mechanized. In Terenos farmers stated that mechanized land preparation was necessary, due to the difficulty of working the "cerrado" after the long dry season. The planting season is in October-December after five to seven months of dry season. To use animal power at all it was necessary to wait for the first rains. One advantage of mechanical land preparation was that the soil could be broken in anticipation of the first rains and water absorption improved.[11/]

Before using animal power it was necessary to cut or burn the weeds and remove some of the plant roots and clods. Both operations can be avoided by using mechanical power. Moreover, Terenos' farmers claimed that animals with the implements used locally did not plough deeply enough for cotton. For rice, the depth of animal ploughing was sufficient, but germination was reduced by the failure to break the soil adequately. Furthermore, farmers reported that mechanized land preparation reduced the weed problem by turning over and preparing the soil better, especially the disking, so that fewer cultivations were required. This turning and disking was considered to be equal to another cultivation. Finally, farmers reported a risk component to using animals for land preparation. The difficult land preparation activities occurred at the weakest point for the animal stock, immediately after the dry season. Supplementary feeding was not generally given to work animals during the dry season and an overworked, weakened animal could die.

The most striking comparison between mechanical and animal power was the reduction in time required for the basic land preparation operations with mechanical power. Land preparation activities required an average of 5 animal and man-days per hectare or 5 hours of machinery and man-time.[12/] (See Table 6.) The costs of animal power were lower than those of mechanical power for land preparation due to the lower labor and animal rental costs. Mechanical power only became advantageous per hectare when the cost savings from one less cultivation and/or the yield advantage[13/] of mechanized land preparation were also considered.

These effects were combined to estimate the internal rate of return to hiring custom rental services for land preparation. In this analysis the reduced risks were not considered nor was the expansion effect of enabling crop area expansion per worker. The nominal rate of return per hectare for mechanized land preparation was[14/]

$$\frac{C_1 + C_2 + Y - K}{K}$$

where:

C_1 was the cost saving from reduced labor and animal time in land preparation;

C_2 was the cost saving due to the decreased number of cultivations;

Y was the value of the yield difference from mechanization; and

K was the cost of machinery custom rental.

Table 6 indicates that the rate of return per hectare from mechanized land preparation was positive, except for the case in which there were no savings in cultivation costs and a yield differential of 10 percent. Ninety-four percent of the farmers interviewed in Terenos used mechanized land preparation. No one in the sample used fertilizer in the area, hence land preparation was the major cash outlay in the crop operation. Table 6 illustrates that even though production costs went up with mechanized land preparation, gross income increased even faster from the yield effect so that the returns per hectare to mechanized land preparation were positive even with higher per-unit production costs.[15/] Besides the increased yields mechanized land preparation was associated with an increased crop area cultivated. The average crop area of the producers using animal power was 6.5 hectares, while for farmers employing mechanized power it was 11.2 hectares.

In the Fátima do Sul sample of 49, only 16 percent used mechanical power for land preparation.[16/] This group also consisted of small farmers in a colony founded in 1943 in an area of fertile soil ("terra roxa"). Besides having better soil than Terenos there was a wider diversity of crops grown including peanuts, cotton, rice, and soybeans as the principal annuals.

One explanation for the difference between the two areas in the mechanization of land preparation was the substantial difference in the cost of custom rental. The average cost of mechanized land preparation with custom rental was Cr$190 per hectare or more than double the custom rental price of mechanized land preparation in Terenos. Another potential explanation was the difference in land quality (texture) between the two areas. In better soils the land preparation operation is not as power-demanding. Given the better soil texture of the "terra roxa" of Fátima do Sul, there was less necessity for mechanized land preparation.[17/] In Terenos, mechanization by improving the land preparation on "cerrado" appeared to have helped overcome a bottleneck to production increase, hence practically all the farmers utilized tractors for this operation whereas they relied upon animal and human power for all other operations. In Fátima do Sul, mechanization apparently wasn't as necessary and less than one-fifth of the farmers utilized tractors in the land preparation.

In one area of "cerrado" soil mechanization both extended crop area per worker and increased yields. Mechanization levels were much lower in the "terra roxa" soil than in the "cerrado" area. Hence, this analysis supports the hypothesis that mechanization facilitates the cropping of poorer soil areas. Since there is substantial "cerrado" area in Brazil, mechanization is expected to continue at rapid rates, especially in the South and Central West and to hasten the settlement and cropping of these areas. One alternative to the extensive cropping of these marginal soil areas via mechanization is to improve yields in better soil areas through increases in biochemical inputs especially fertilizer and fertilizer-responsive varieties. However, on the Brazilian frontier very little increase in chemical fertilizer consumption has occurred. The next section attempts to explain why.

Barriers to Increased Use of Fertilizer on the Frontier

There appear to be four factors responsible for the slow rates of growth of fertilizer consumption in Mato Grosso. The first is the transportation cost of bringing in agricultural chemicals from outside the state. It is generally necessary to raise the pH of the latosols associated with "cerrado" vegetation,[18] before fertilizing and the lime price is four to five times as high in Terenos than it is outside of the city of São Paulo. Lime deposits are presently being developed in Mato Grosso but it will continue to be necessary to bring in fertilizer. The price of fertilizer should also decrease slightly as improved roads are constructed.

Secondly, an elastic cropland supply, resulting from the availability of virgin land and the potential to shift land use from cattle to crops, could reduce the incentive to substitute for land. With the continuation of present in-migration, increases in land values in the more accessible and better agricultural areas of Southern Mato Grosso will make it more profitable to substitute for land with chemical fertilizers. Already wheat-soybean producers in the Dourados area are using high levels of fertilizers, improved seeds, and lime.[19]

The third constraining factor is the lack of fertilizer-responsive varieties adapted to the area. After exhausting the possibilities for diffusion of available improved varieties from within and outside the region, it will be necessary to adapt or build varieties suited to the local environmental conditions as well as fertilizer-responsive. Some of the variety development can be done by private breeders. However, much of it will have to be done by public research agencies because it is difficult to patent most plant varieties and thus capture the stream of future returns from the investment.[20] One seed breeder in Southern Mato Grosso commented that the price at which he could sell his improved wheat varieties approached the price of all seed wheat within two to three years after its commercial introduction.

The bottlenecks to increased use of biochemical technology appear to have been the high price of agricultural chemicals, an elastic land supply, and the lack of sufficient public research expenditures to adapt or build varieties, which are fertilizer-responsive and resistant to disease, insect, or other specific problems on the frontier. Since two of these limiting factors are presently changing with the construction of new roads, the opening up of lime deposits in Mato Grosso, and continuing in-migration and exploitation of new cropland, it is important to consider why there would be a tendency in Brazil to under-invest in public research facilities to develop new varieties. New variety development requires large initial expenditures in facilities and scientists and generally entails a long delay between the initial investment and the commencement of the stream of returns. If Brazil had experienced rapidly increasing real food prices, there would have been more pressure to make these investments. Without these pressures there was hypothesized to have been little public support or farmer lobbying for experiment station investment. Moreover, a high time discount rate would discourage this type of public investment due to the long lead time required before benefits are obtained.[21]

A final factor which needs further investigation is the rainfall distribution. The returns to fertilizer and fertilizer-responsive varieties are dependent upon the availability of water at critical stages of the development of the plant. The intense but irregular rainfall of the Central Plateau may be a limiting factor to the introduction of biochemical technology.[22/]

Conclusions

With the abundant land resources and the potential to re-shuffle the population between regions with different resource availabilities, there was a high payoff to an extensive agricultural development process. Agricultural development on the frontier was facilitated by infra-structure investment, primarily in roads, enabling agricultural output increases through the expansion of the conventional factors of production, land and labor, plus more recently agricultural mechanization. New crop introduction has been associated with migration into the state. This was a type of in-migrant diffusion process operating through trial and error, labor mobility, and an adequately functioning land market.

Agricultural mechanization of land preparation enabled area expansion per worker and had a high return in one "cerrado" area on the frontier. In another area of small farmers on better soil ("terra roxa"), mechanized land preparation was not as prevalent.[23/] By encouraging mechanization through subsidized credit combined with insufficient funding of experiment station capacity, Brazilian land use may have been biased toward more extensive use of inferior land via mechanization rather than improving yields in the areas with better soils.

Given the high price of chemical substitutes and the supply elasticity of land on the frontier, it was logical to expect little public concern with the adaptation of land substituting, chemical inputs to increase yields. Since private machinery companies were willing to absorb most adaptation and extension[24/] costs, the cost to the public sector of the adaptation of agricultural mechanization to Brazilian conditions was minimal. However, the adaptation costs of biochemical technology will require a substantial public sector commitment.

At some point Brazil will exhaust its frontier. Since there is generally a long lead time necessary to adapt biochemical technology, the implicit time discount rate of public policy-makers may need to be lowered so that when the potential of crop area expansion has been exhausted, Brazil will have fertilizer-responsive, adapted varieties available to substitute for increasingly valuable land. Presently, on the national level there has been recognition of this problem and increased public expenditures for research on variety improvement. Now more interaction between farmers and plant scientists appears to be necessary to identify the desired variety characteristics for various crops by region. Given the irregular rainfall distribution of the Central Plateau, the development and production of high yielding fertilizer-responsive varieties adapted to the insect, disease, and marketing conditions of the area may well be difficult requiring substantial investment in public research capacity and a long payoff period.

TABLE 1

Interstate Migration: Net Number of Migrants and Rates of Migration, 1950-1970

	1950 - 1960 Number of Migrants (Nº)	1950 - 1960 Rates[a] of Migration (%)	1960 - 1970 Number of Migrants (Nº)	1960 - 1970 Rates[a] of Migration (%)
Frontier States:				
Mato Grosso	131,859	23.59	268,517	27.38
Goiás[b]	259,310	21.34	449,076	21.42
Paraná	912,855	43.58	790,169	18.39
South and East:				
Guanabara	372,816	15.68	372,181	11.25
São Paulo	712,706	7.80	993,428	7.66
Rio de Janeiro	195,842	8.53	201,315	5.92
Santa Catarina	- 63,441	- 4.07	- 49,237	- 2.29
Rio Grande do Sul	-162,532	- 3.90	-339,909	- 6.24
Minas Gerais	-593,386	- 7.62	-1,273,746	-12.79
Espírito Santo	44,612	4.66	-227,833	-16.06
Northeast:				
Rio Grande do Norte	-133,723	-13.82	26,171	2.26
Piauí	-157,655	-15.82	-18,858	- 1.49
Ceará	-330,739	-12.27	-82,859	- 2.48
Pernambuco	-372,565	-10.97	-203,231	- 4.91
Bahia	-506,165	-10.47	-366,763	- 6.12
Alagoas	-182,636	-16.71	- 92,917	- 7.31
Paraíba	-256,418	-14.97	-204,418	-10.13
Sergipe	- 99,123	-15.38	- 88,313	-11.62
North:				
Pará	8,638	0.74	89,410	5.52
Amazonas	1,261	0.24	- 17,983	- 2.40
Maranhão	212,231	13.40	-220,542	- 8.85

[a] This was calculated by the global survival method with rates equal to the number of migrants over the base population.

[b] This includes the Federal District.

Source: D.H. Graham and S.B. de Hollanda Filho, Migration, Regional and Urban Growth and Development in Brazil: A Selective Analysis of the Historical Record: 1872-1970, Vol. 1 (Instituto de Pesquisas Econômicas, USP: São Paulo, 1971), p. 80.

TABLE 2

Cropland Expansion and Change in Aggregate Yields in the Brazilian States

	Increase in Cropland 1950 Area (1000 ha)	1960 Percentage (%)	Rate of Change of Crop Area 1947-1965 (%)	Rate of Change of Crop Yields 1947-1965 (%)	Growth Rate of Crop Production 1948/50-1967/69
Frontier States:					
Mato Grosso	229	161	11.8	-0.2	7.9
Goiás	524	113	10.4	-0.5	8.8
Paraná	2,083	153	8.7	-0.1	7.5
South and East:					
São Paulo	510	12	0.0	0.8	1.7
Rio de Janeiro	10	2	2.7	-0.1	2.9
Santa Catarina	323	48	3.4	0.2	4.4
Rio Grande do Sul	1,207	48	4.2	0.1	4.8
Minas Gerais	607	20	2.5	-0.5	1.2
Espírito Santo	150	25	3.7	0.3	1.4
Northeast:					
Rio Grande do Norte	177	40	3.6	0.0	4.6
Piauí	239	106	8.8	0.6	6.6
Ceará	738	89	4.8	0.5	5.4
Pernambuco	398	40	4.2	-0.2	3.9
Bahia	791	58	4.7	-1.1	3.9
Alagoas	148	53	4.3	-0.5	4.0
Paraíba	351	53	3.8	0.4	3.1
Sergipe	43	32	3.6	-0.1	4.7
North:					
Pará	133	82	4.4	-0.2	4.5[a]
Amazonas	42	79	8.3	1.1	
Maranhão	567	172	9.0	1.5	9.1

[a] All the North including the Territories.

Source: L.F. Herrmann, Changes in Agricultural Production in Brazil, 1947-1965, Foreign Agricultural Economic Report No. 79 (Washington, D.C., Economic Research Service, U.S. Department of Agriculture, June 1972), pp. 24, 29, 31.
The crop growth rates were taken from George F. Patrick, "Sources of Growth in Brazilian Agriculture: The Crop Sector," (mimeo, 1974) pp. 6, 7.

TABLE 3

Concentration Ratios for Subsistence and Commercial Crops in Mato Grosso, 1950 - 1970

Year	Subsistence Crops			Commercial Crops	
	Manioc	Beans	Cane	Cotton	Rice
1949-1951	1.87	1.61	1.11	0.19	2.60
1959-1961	1.36	1.39	0.56	0.23	3.58
1968-1970	0.83	1.00	0.37	0.69	3.19

Source: These ratios were calculated from data in Brazil, Anuário Estatístico (Rio de Janeiro: IBGE), 1952, 1962, and 1971 editions.

Note: The ordering of crops by value in 1970 for the Central West region (Mato Grosso, Goiás, and the Federal District) was:

Crop	Value (million Cr$)
Rice	306
Manioc	75
Corn	75
Edible Beans	67
Cotton	35
Sugar Cane	18
Bananas	17
Peanuts	9.7

Source: Beef production was estimated at 208 million Cr$ in 1970 with a stock valued at 2,133 million Cr$. Cattle production in the Central West is still the predominant use of the land. There is a natural rotation of land between pasture and crops which is practiced for both fertility and pest control reasons. See Maria I.A. Schuh, "Some Aspects of Recent Trends in Brazilian Agriculture," (mimeo prepared for EAPA/SUPLAN, March, 1973), pp. 15, 16, 18 for the above data on crop and livestock values.

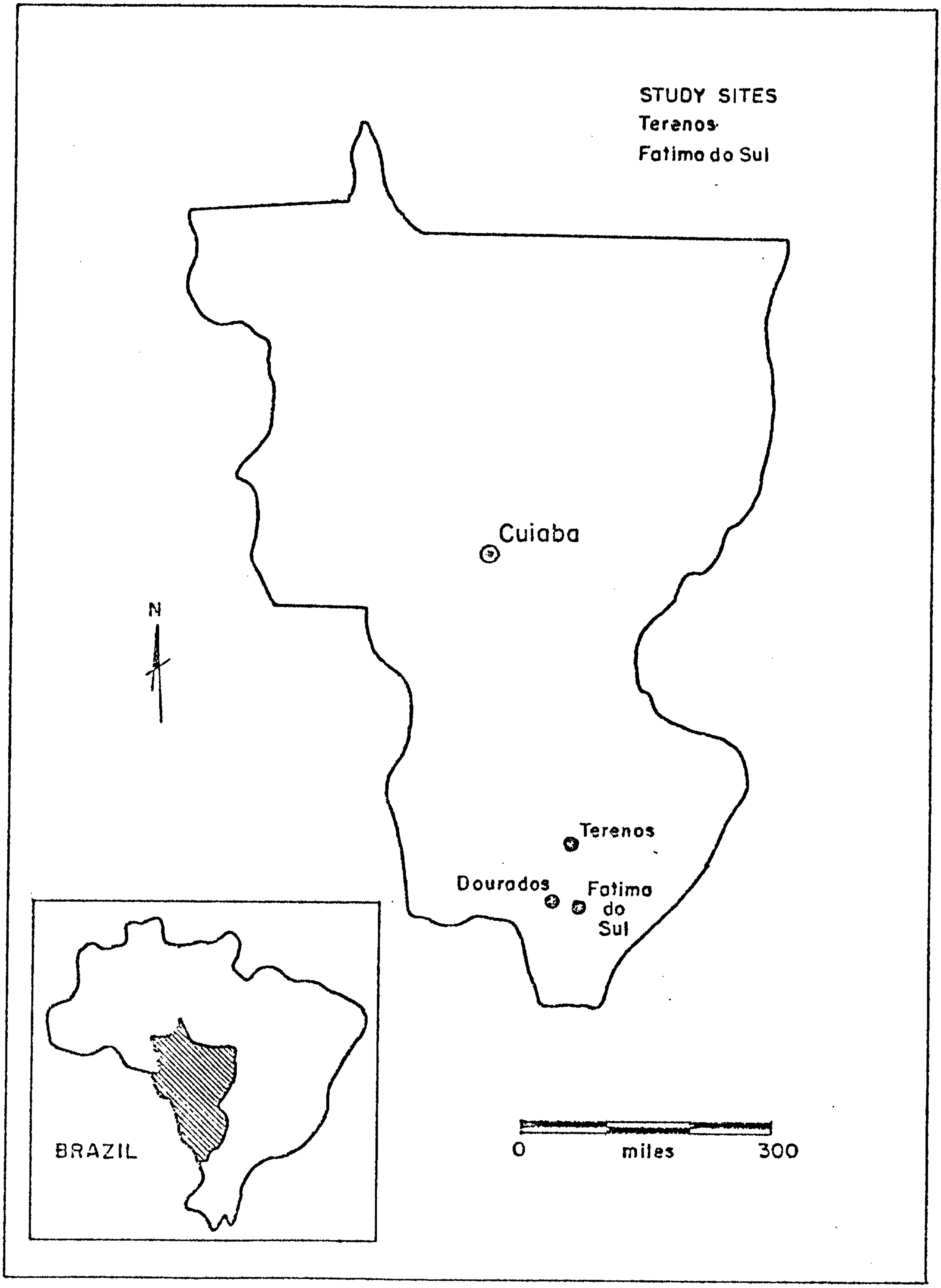

Figure 1: The State of Mato Grosso

TABLE 4

The Relationship Between Migrants and the Introduction of Commercial Crops In Two Areas of Mato Grosso With Rice Considered as a Subsistence Crop

A. Terenos and Fátima do Sul Combined

	Traditional[a] Crops	New Commercial[b] Crops	Total
	------ (Nº of farmers) ------		
Native Farmers	19	6	25
In-Migrant Farmers	21	54	75
Total	40	60	100

$\chi^2 = 18$**

B. Terenos

	Traditional Crops	New Commercial Crops	Total
Native Farmers	18	4	22
In-Migrant Farmers	14	19	33
Total	32	23	55

$\chi^2 = 8.42$**

C. Fátima do Sul

	Traditional Crops	New Commercial Crops	Total
Native Farmers	1	2	3
In-migrant Farmers	7	35	42
Total	8	37	45

$\chi^2 = 0.53$

** Tests A and B were significant at the 99 percent level.

Source: Frederick Bein, "Agricultural Colonization in Southern Mato Grosso", (unpublished Ph.D. diss., University of Florida, ~~in process).~~ 1974.

[a]In this sample area rice was a traditional crop as were manioc, beans, and corn. There was no production of sugar cane. These traditional crops were staples and easy to store, hence the farmer was less dependent upon marketing channels and more insulated from the effects of price fluctuations than in the case of the new commercial crops.

[b]The commercial crops were soybeans, cotton, and peanuts. Note that a farmer producing both traditional and new commercial crops was categorized in the latter group.

TABLE 5

	Frontier States			Capital Intensive Agricultural States	
	Paraná	Goiás	Mato Grosso	S. Paulo	Rio Grande do Sul
1950:					
Number of Tractors	280	89	50	3,819	2,245
Percent of Total Tractors in Brazil	3.3%	1.1%	0.6%	45.6%	26.8%
Tractor/Labor[a] Ratio	0.6	0.3	0.6	2.5	2.1
1960:					
Number of Tractors	5,181	1,356	838	27,176	15,169
Percent of Total Tractors in Brazil	8.4%	2.2%	1.4%	44.3%	24.7%
Tractor/Labor[a] Ratio	4.0	2.7	4.5	15.7	11.4
1970:					
Number of Tractors	17,190	5,523	3,926	65,731	38,317
Percent of Total Tractors in Brazil	11.0%	3.5%	2.5%	42.0%	24.5%
Tractor/Labor[a] Ratio	8.5	9.6	10.3	43.5	26.1

[a]Tractors include all tractors used in agriculture with no weighting by type of tractor. The labor force is the entire agricultural labor force including seasonal labor. The ratio is total agriculture tractors divided by 1,000 agricultural workers. The tractor/labor ratios for the U.S. over the same period are:

	Year	Tractor/Labor Ratio
U.S.	1950	360
	1960	720
	1970	1,205

Source: The data were taken from Brazil, Preliminary Results of the 1970 Agricultural Census (Rio de Janeiro: IBGE, 1972). The U.S. data were taken from 1971: Changes in Farm Production and Efficiency, a Summer Report, Statistical Bulletin No. 233 (Washington: Economic Research Service, U.S. Department of Agriculture, June 1972), pp. 22, 29.

TABLE 6

Rates of Return per Hectare to Mechanized Land Preparation of Upland Rice in Terenos

1971/72 Crop Year

	Animal Power	Mechanized Power
Time Requirements to Prepare one Hectare[a]		
Ploughing	5 days	3 hours
Disking or Breaking		2 hours
Cost of Land Preparation per Hectare[b]	58.60 Cr$	77 Cr$
Value of the Yield Advantage of Mechanized Land Preparation[c]		
10 percent		72 Cr$
15 percent		108 "
20 percent		144 "
Cost of Additional Cultivation[d]	35 Cr$	
Nominal Rate of Return to Mechanized Land Preparation	Yield Effect[f]	Rate of Return
Without the Cost Savings of an Additional Cultivation: Yield Advantage of	10%	-33%
	15	16
	20	63
With the Cost Saving of an Additional Cultivation: Yield Advantage of	10%	15%
	15	62
	20	109

	Yield Effect[f]	Production Cost of Land Preparation[e]
Animal Power		2.42 Cr$/sack
Mechanical Power: Yield Increase of	10%	2.89
	15	2.77
	20	2.65

[a] Furrowing is sometimes also done.

[b] For mechanical power an average of the custom rental price was obtained with 22 observations. The cost of animal power was calculated as the summation of labor, animal, and implement cost. Labor was priced at the minimum wage. The method of calculating animal and implement costs is illustrated in Appendix B. Data for Mato Grosso labor and other costs were provided by IPEAO, Campo Grande, Mato Grosso. The formula for interest and depreciation used was

$$\left(\frac{r}{2} + d\right) C$$

where r is the interest rate, d is the rate of depreciation, and C is the capital cost of the machine.

The interest rate was divided by 2 to allow for the calculation of interest on one-half the value of the principal. For details on this calculation for the daily costs of animal power see Table B - 1 in Appendix B.

[c] For rice production at mean yields and price received. See Table B - 2.

[d] See Table B - 3 for details on this calculation.

[e] The production cost effect of various technologies was calculated by taking the production cost of that particular operation per hectare and dividing by the yields. Average yields from Table B - 2 were used. The effect of reduced cultivation costs was not considered here. A sack is equal to 60 kgs.

[f] These yield effects were taken from the estimates in J.H. Sanders, pp. 239,240. The yield effect varied from 9 to 20 percent depending upon the crop. The data were for São Paulo.

Source: John H. Sanders, "Mechanization and Employment in Brazilian Agriculture, 1950-1971" (Ph.D. diss., University of Minnesota, 1973), pp. 105, 196. The data were obtained from the field interviews of Frederick Bein.

APPENDIX A

The Sampling Method for the Two Agricultural Colonies in Southern Mato Grosso

In the colony of Terenos a universal sample was taken of all farmers. Fifty-five farmers were interviewed. Since the colony of Dourados was much larger and occupied several municipalities, a smaller area had to be selected. In Fátima do Sul there were 2,132 small farm lots averaging approximately 30 hectares. From each block of 80 lots two sites were selected at random without repetition. From blocks of 40 or less only one site was selected at random. Where small continuous blocks occurred they were grouped together forming larger blocks. Fifty-three lots were selected for sampling. Since only lots having tenants for interviewing were included in the sample, eight were thrown out since there were no tenants. Forty-five farmers were interviewed in Fátima do Sul.

A number of farmers outside of the colonies were also interviewed to compare their crop-mix and input use with the two colonies sampled. No significant differences were observed. There was no systematic sampling technique for these farmers.

APPENDIX B

Calculations and Data Employed to Estimate the Private Rate of Return to Mechanized Land Preparation in Terenos

TABLE B-1

Daily Costs of Animal Power for Land Preparation, 1971/1972 Crop Year in Mato Grosso

Labor Cost--including minimum wage and other employee costs paid by the employer	7.53 Cr$
Animal Cost	2.72
Plough Cost	1.47
Total Daily Costs	11.72 Cr$

Calculation of Animal Daily Costs:

Value of new animal	Cr$ 700
Expected work life	15 years
Annual use	180 days

1. Depreciation (straight line) $\frac{700}{15 \cdot 180} = 0.26$
2. Feed
   - (a) Corn 2kg/day • 0.40 Cr/kg = .80
   - (b) Pasture

     Rental of artificial pasture $\frac{\text{11 Cr/cow/month} \cdot \text{12 months}}{180} = .73$
   - (c) Labor costs of feeding and handlings = .35
3. Interest Costs = .58

Total Daily Costs 2.72 Cr$

Source: These data were provided by IPEAO, Campo Grande, Mato Grosso. IPEAO is the federally-supported agricultural experiment station of Mato Grosso.

TABLE B-2

Data Employed to Calculate the Yield Advantage of Mechanized Land Preparation, 1971/1972 Crop Year in Terenos

Number	Crop Area of Farm	Price Received for Rice per sack (1971/72 crop year)	Yields	Gross Income per Hectare
1	20 ha.	30 Cr/sack	15 sacks/ha.	450
2	7	27	35	945
3	20	27	30	810
4	30	31.8	30	954
5	3	37.2	23	856
6	8	30	20	600
7	40	36	35	1,260
8	30	37.2	33	1,223
9	12	37.2	16	592
10	5	37.2	16	595
11	30	36	24	864
12	6	42	39	1,638
13	6	42	50	2,100
14	1/2	for own consumption	6	No sale
15	15	39	15	585
16	10	36	20	720
17	8	39	35	1,365
18	12	39.6	16	634
19	10	40.8	20.4	832
20	6	38.4	6.3	242
	Average	36 Cr$	24.2 sacks/ha	909 Cr$
10% yield increase[a]		36 Cr$ • 2 sacks	=	72 Cr$
15% yield increase[a]		36 Cr$ • 3 sacks	=	108 Cr$
20% yield increase[a]		36 Cr$ • 4 sacks	=	144 Cr$

Source: The data were collected by Frederick Bein in Terenos, in the 1971/72 Crop Year. A sack is 60 kg.

[a] It wasn't possible to separate the effect of mechanization on the average yields above. This average was reduced to 20 sacks to estimate the yield effect.

TABLE B-3

Cost of One Weeding or Cultivation in Terenos Upland

Rice Production, 1971/1972 Crop Year

One animal-man day • 10.82	=	10.82
3.2 man-days with a hoe • 7.53	=	24.10
	Total Daily Costs	Cr$ 34.92
Animal daily cost	=	2.72
Man daily cost	=	7.53
Cultivation daily cost	=	0.57
Animal daily cost		Cr$ 10.82

Note that the above estimate prices family labor at the minimum wage. Hence, for a small farmer this would be expected to overstate the opportunity cost of his family and his own labor. The cultivation process is generally done with animal power and then followed by laborers with hoes. There were four observations of time spent cultivating, with three of the observations using animal power for land preparation. These three used more animal-man days in cultivating than those using mechanized land preparation.

FOOTNOTES

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1/ G. Edward Schuh, "Algumas Observações Sobre o Desenvolvimento Econômico do Brasil," Revista Brasileira de Economia, 26 (Out./Dez. 1972): 207-227.

2/ Lewis F. Herrmann, Changes in Agricultural Production in Brazil, 1947-1965, Foreign Agricultural Economic Report No. 79 (Washington, D.C.: Economic Research Service, U.S. Department of Agriculture, June 1972); William E. Nicholls, "A Agricultura e o Desenvolvimento Econômico do Brasil," Revista Brasileira de Economia, 26 (Out./Dez. 1972): 169-206.

3/ Gordon W. Smith, "Marketing and Economic Development: A Brazilian Case Study, 1930-1970" (mimeo, 1972), p. 18, and Werner Baer, "The Brazilian Boom: 1968-1972, an Explanation and Interpretation" (mimeo, 1973), p. 10.

4/ "Cerrado" is a vegetation type generally associated with a broad category of latosols found in Brazil. These latosols are characterized by low natural fertility especially phosphorous, deficiency, highly acidic, and with high aluminum levels. For a summary of 1,200 soil tests in "cerrado" areas see José Ferreira Mendes, "Características Químicas e Físicas de Alguns Solos sob Cerrado" in Anais da II Reunião Brasileira de Cerrados, 1967 (Sete Lagoas, Minas Gerais: IPEACO; 1972), pp 51-62. Also see the fertilizer articles in this same volume. The Central West frontier includes Goiàs, the Federal District, and Mato Grosso.

5/ In both areas the better soil areas would become exhausted over time and generally be shifted into pasture, thereby reducing aggregate yields. There is a natural decline in fertility in the frontier area with repeated cropping since there is little replacement of nutrients with chemical fertilizers. See Lewis F. Hermann, pp. 32, 33.

6/ Brazil, Anuário Estatístico (Rio de Janeiro: IBGE, 1952, 1962, and 1971 issues).

7/ The commercial utilization of cane is for refined sugar and "aguardente" (distilled cane). There are eight sugar-mills in Mato Grosso, with four for each of the above products. The growth of refined sugar production in Mato Grosso is constrained by the ability of producers to obtain an increased quota. Without this quota or an "aguardente" of sufficient quality to export to other states, sugar cane is primarily used for local consumption as unrefined sugar and for the distilled and undistilled liquid products. This information is based on data from Mato Grosso, Boletim do Acordo de Classificação no Estado de Mato Grosso, 1972. Ano 4, Nº 4 (1973).

8/ Rice is one of the predominant crops in the "cerrado" areas, not only in the Central West frontier but also in São Paulo and Minas Gerais. Rice fits as an intermediate product between the land clearing and the conversion of forests to pasture. This is generally a labor-intensive, sharecropper method of land conversion in which rice is grown in-between the stumps. Frequently, one obligation of the sharecropper is to leave the land in permanent pasture after producing rice for one to three years. See Gerson Pereira Rios, Ricardo José Guazzelli, Aecio Leoni Teixeira, Adelson Freire e José Ferreira Mendes, "Ensaio de Adubação Fosfatada em Arroz" and Erycson P. Coqueiro, Adelson de Barros Freire and João Pereira, "Efeito da Aplicação do Calcário e Enxofre em Cultura de Arroz de Sequeiro," in Anais da IIa Reunião Brasileira dos Cerrados, pp. 71-77, 91-100.

For further discussion of the importance of rice production in the Central Plateau region of Brazil, see P.I. Mandell, "The Development of the Southern Goiás-Brasília Region: Agricultural Development in a Land Rich Economy" (Ph.D. diss., Columbia University, 1969) and P.I. Mandell, "The Rise of the Modern Brazilian Rice Industry: Demand Expansion in a Dynamic Economy," Food Research Institute Studies in Agricultural Economics, Trade, and Development, Vol. 10, Nº 2 (1971): 161-219.

9/ Note that farm size was held constant as the sample was confined to small farmers in two colonies. In Fátima do Sul there were so few native farmers that the test was inadequate. Rice was grouped as a traditional crop because it was one of the first crops introduced in the colonies of Terenos and Fátima do Sul, which were founded in 1924 and 1943 respectively.

10/ Note that only 55 farmers were interviewed in Terenos. However, in-the surrounding area there were also interviews with small producers. See Appendix A for the sampling methodology.

11/ Erosion will also be increased and the benefits from increased water retention have to be weighed against the losses from erosion. Those that prepare the soil in anticipation of the first rains need to employ a second disking to eradicate the weeds, which will spring up after the rains. After this disking, planting can take place.

Another possible cultural operation is to mulch or to plough the plant residues into the soil after harvest in order to improve the structure and water retention capacity of the soil. If the weeds are ploughed under, this early ploughing can have the same effect, although there would be less time for decomposition of the weeds before planting than in the case of ploughing under the post-harvest residues.

12/ Oxen were generally worked only half days after the dry season. Similar time savings were also possible from mechanized cultivation but this was not done by any of the farmers in the sample, including the two owning tractors. Tractor owners had heavier tractors such as the CBT, which were better for breaking the soil but more awkward for other operations.

13/ Substantially lower yields were observed for the animal power users in Terenos with 3 of the 4 having crop failures and the other below-average rice yields. However, the sample is too small and it is unlikely that these disastrous yields can be attributed to the failure to use mechanical power. The yield advantage of mechanical power utilized in Table 6 was based upon the calculations utilizing São Paulo data in John H. Sanders, "Mechanization and Employment in Brazilian Agriculture, 1950-1971" (Ph.D. diss., 1973), University of Minnesota, pp. 239, 240. In this study most other factors affecting yields were held constant especially the use of biochemical inputs. Three yield differentials of 10, 15 and 20 percent were employed in Table 6.

14/ Adjusting for time passed between operations this becomes:

$$C_1 + \frac{C_2}{(1+r)^{0.17}} + \frac{Y}{(1+r)^{0.5}} = K$$

where r is the internal rate of return. The left-hand term includes the discounted benefits of mechanized land preparation and the right-hand term the cost of custom rental. The discounting is based upon the following pattern of activities. The cultivation occurs one-and-a-half to two months after planting and the sale is approximately 6 months after planting. There were substantial variations in the time of sale between observations. Although rice production only takes 3 to 4 months, depending upon the variety, many farmers in Terenos keep their rice covered in the field and wait for the price recovery in the post-harvest season. The simplification of the rate of return calculation used in Table 6 assumes that all costs and returns occur at the same time. Due to the short time period between planting and sale, this simplification should not significantly affect the estimated internal rate of return.

15/The only operation mechanized here was land preparation. In the greater Dourados area on larger farms other operations such as soil preparation, planting and harvesting wheat and soybeans have been mechanized.

Production cost analysis includes the economic costs in the numerator but only the physical yields in the denominator.

The value of the yield increase may be sufficiently great to offset the increased production cost from shifting to mechanical power, thereby justifying the investment even though the per unit production costs increase. See John H. Sanders, 238-250, for a comparative production cost analysis of animal and mechanical power in São Paulo agriculture.

One assumption above is that the individual farmer is a price-taker so that increased production does not affect the price received. In considering the aggregate effects of mechanization, this assumption would have to be modified.

16/ Note that only 45 farmers in this area were interviewed by Bein in his study. Due to incomplete information on power use and costs only 30 of these interviews were utilized here. These 30 were supplemented with another 19 interviews from a random sample done by the Peace Corps in the same colony.

17/ In uncleared areas of higher soil fertility on the frontier it is more difficult to mechanize than in areas of poorer soil. "Mata" or "terra roxa" has denser original growth than "cerrado" or "campo limpo." The original clearing process in good soil generally entails waiting for the large stumps to rot, up to twenty years. In the interim, pasture can be planted or crops with land preparation between the stumps utilizing animal power. The capital investment in labor time, dynamite, or the use of bulldozers was high to remove the large stumps in good soils. The estimated cost of stump removal was Cr$500 per hectare in good soil or an approximate 50 percent increase in the purchase price of the land. This factor of the large investment cost of stump removal in order to mechanize appeared to be important in Fatimado Sul. See F. Bein, op. cit.

In areas of rapid mechanization such as the wheat-soybean planting in the greater Dourados area of Mato Grosso (see the map), in the last three years the in-migrants generally have purchased already cleared and destumped good land or more commonly uncleared, "campo limpo," which is the lower-quality land distinguished by its paucity of original vegetation. The apparent reason for this preference for the poorer soils is to avoid the capital costs of land-clearing on the high-quality, densely vegetated soils.

18/ The mean pH of soil samples for 19 farms in Terenos was 5.3 with a standard deviation of 0.17. Note that the problems of aluminum toxicity and the fixing of phosphorous at a low pH in these soils makes the utilization of lime essential prior to increasing the level of chemical fertilizers. The primary major nutrient deficiency in "cerrado" soils is phosphorous. Generally organic material and potassium were available; however, at increased phosphorous level in two of three cases chemical nitrogen had a significant effect on yields. In three experiments with all three major nutrients, chemical potassium had a negative effect on yields. See the papers on soils and fertilization in Anais da IIa Reunião Brasileira dos Cerrados, especially pp. 79-89 and 147-151.

19/These wheat-soybean operations are generally large farms, completely mechanized, and many are recent migrants from Rio Grande do Sul, Paraná, and São Paulo.

20/This is one apparent reason for the more rapid introduction of mechanical than of biochemical technology into Brazil. Most new agricultural technologies require some adaptation to different climatic and soil conditions. The adaptation necessary for machinery appears to be less than for new seed varieties. Also, it is relatively easy for a private firm to capture the streams of returns from model adaptation, as long as the machine is protected by patent laws or is sufficiently complex so that new firms face entry barriers or high entry and initial costs. Firm entry into many Brazilian industries, including the tractor industry, is controlled by the government.

The future stream of returns from most variety research is more difficult for a private firm to monopolize. Hence, the development of new varieties (non-hybrid) and associated chemicals generally requires a larger public investment than does adaptation of mechanical technology.

Ruttan comments that the failure to make adequate investments in public sector experiment station capacity can lead to an unbalanced growth process in developing countries with the adoption of more mechanical technology and less biochemical technology than would be optimal given the available resources of the country. See Vernon W. Ruttan, "Induced Technical and Institutional Change and the Future of Agriculture," Proceedings of the Fifteenth International Conference of Agricultural Economists (Oxford, England: University of Osford, August 1973), p. 31.

21/ The internal rates of return to variety improvement have been very high in Brazil and the U.S.; however, the initial outlays have been substantial and the time period lengthy. See Harry W. Ayer and G. Edward Schuh, "Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton Research in São Paulo, Brazil," American Journal of Agricultural Economics 54 (November 1973): 557-569; and Zvi Griliches, "Research Costs and Social Returns: Hybrid Corn and Related Innovations," Journal of Political Economy 66 (October 1958): 419-431. For an article reviewing studies of returns to variety research see T.W. Schultz, "The Allocation of Resources to Research" in Resource Allocation in Agricultural Research, ed. W.T. Fishel (Minneapolis: University of Minnesota Press; 1971), pp. 90-120.

22/ Several studies in the Second Annual Conference on problems in "cerrado" soil emphasized the importance of the irregular rainfall distribution. One study attributed the low observed fertilized rice yields to the lack of rain during the flowering stage. See João Pereira, Erycson Pires Coqueiro, e Adelson de Barros Freire, "Adubação Fosfatada em Arroz de Sequeiro em Solos de Vegetação 'Campo-Cerrado';" Anais da IIa Reunião Brasileira dos Cerrados, pp. 61-87 and 137-152, and the other articles on fertilization in this volume.

23/ Heavier texture soil areas have a larger initial power requirement for adequate preparation of the soil. The authors are not suggesting that mechanization will not be found in better soil areas, but are raising the question of whether the land use pattern resulting from rapid mechanization and little introduction of biochemical inputs to raise yields is optimum for Brazil.

Some experimental results of soybean yields in "terra roxa" and "cerrado" areas in Mato Grosso are illustrative. On "terra roxa" the best fertilizer results with all three major nutrients only improved yields by 10 percent from the 51 sacks per hectare of the control plot. With all three nutrients yields were approximately doubled in "cerrado" areas; however, the maximum yield was only 30 sacks per hectare. These fertilizer results were obtained from unpublished data of Viçosa soybean experiments of FAO/ANDA/ABCAR in Dourados in 1972. Lane Hartel of the U.S. Peace Corps carried out the experiments and supplied the data.

24/ Machinery rental agencies have been maintained by the Ministry of Agriculture in Mato Grosso. The services of this agency were available to Terenos farmers in the fifties and early sixties and the price of these rental services was subsidized by the Ministry. Hence, there was some public support for the diffusion of mechanical technology. Agricultural machinery purchases also have been encouraged by low interest loans during the last two decades. See John H. Sanders, pp. 10-38.