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THE RISKINESS OF ADOPTING

THE USE OF FERTILIZER

- A BRAZILIAN EXAMPLE

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SUMMARY

Considerable data have been generated from fertilizer experiments on the soils of the Campo Cerrado. These data indicate impressive response of certain crops to some plant nutrients. And preliminary economic analysis has shown that it is profitable to fertilize crops grown on these soils.

Statistical analysis of data collected at Pirassununga, Orlandia, and Matão over four crop seasons for corn, cotton and soybeans showed significant response of corn and cotton to lime, phosphorous, potash and trace nutrients. This response was significantly different among the three locations. But the response of soybeans to fertilizer was statistically non-significant.

The estimated production function, average monthly product prices and fertilizer prices were used to compute the optimum level of fertilizer for corn and cotton at each of the three locations. The optimum level of P_2O_5 ranged from 18 kg/ha on corn at Orlandia to 233 kg/ha on cotton at Pirassununga. The optimum level of K_2O ranged from 83 kg/ha on corn at Matão to 179 kg/ha on cotton at Orlandia.

Considerable variation among replications and over time existed in the yield data. Variation also existed in the product price data. A probable rate of return from fertilizer was computed, taking this variation into account. The average return from a dollar invested in

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a/ The author is an agricultural economist with Battelle's Pacific Northwest Laboratories, Richland, Washington, U. S. A., and received the agronomic data analyzed in this report while on assignment from Purdue University. He is indebted to Dr. Earl W. Kehrberg for his helpful comments and suggestions.

fertilizer varied from $0.78 on corn at Matao to $3.53 on cotton at Orlandia. There is only a 35 percent probability that a farmer will recapture his fertilizer investment on corn at Matão, but a 91 percent probability (i.e., 91 times out of 100) that he will recapture this investment if made on cotton at Orlandia. If he spends a dollar on fertilizer for cotton at Orlandia, the chances are better than 3 to 1 that he will get $4.00 in return.

INTRODUCTION

The potential agricultural productivity of the Campo Cerrado soils in the central plateau of Brazil has long intrigued those interested in increased agricultural production. A considerable amount of scientific study has indicated the agronomic, as well as the economic, feasibility of fertilizing these soils. Feuer[1/] states that the Humic Latosol found in the Campo Cerrado region possesses physical characteristics extremely favorable for cultivation and argues that appropriate modification of unfavorable chemical characteristics will allow a realization of the great agricultural potential. Freitas, McClung and Lott[2/] conducted field trials in Goias during 1958-59 to test the response of crops to fertilizer on the Campo Cerrado soils of that area. McClung, Freitas, Mikkelsen and Lott[3/] based their recommendations for more intensive cultivation of the Campo Cerrado soils at São Paulo on six tests carried out by farmers during 1959-60. Mikkelsen, Freitas and McClung[4/] reported impressive response of selected crops to lime and fertilizer on the Campo Cerrado soils at Orlandia and Pirassununga during 1960-62. Cone[5/] found from his statistical analysis of data generated from seven field trials conducted by Freitas, et al. on the Campo Cerrado soils of northern São Paulo that the within-treatment variation for all but two was so great that statistically significant production coefficients were unobtainable. For the remaining two, when economic analysis was possible, it appeared profitable to use fertilizer. Cone[6/] concluded that if it was profitable to fertilize the alluvial soils of the river basins in the Minas Triangle it was also profitable to clear and fertilize the Campo Cerrado soils.

These studies all point to the physical potential and economic feasibility of fertilizing the soils of the Campo Cerrrado.

Although the farmer is recommended to fertilize the soils of the Campo Cerrado, he has no guide of how much fertilizer to use on specific soil phases when his goal is profit maximization. And he has no idea, other than his own intuition, of how risky an investment it is to fertilize the various crops which might grow on these soils.

In order to give the farmer some idea of the riskiness and optimum use of fertilizer in northern São Paulo, data collected at three locations, over four crop seasons,for three commodities were analyzed.

Production functions were estimated. The optimum level of nutrient use was determined. And the riskiness of the investment in fertilizer was ascertained.

AGRONOMIC DATA

The agronomic data were collected from field trials conducted over the four crop seasons 1960-64 at Orlandia, Matão and Pirassununga. which are all located in the northern part of the State of São Paulo. All three soils were cleared of Campo Cerrado vegetation. The soil at Orlandia is classified as a dark red latosol. This soil is 50 percent clay and the clay fraction is half kaolinite and half gibbsite. The sandy loam at Matão is classified as a red-yellow latosol with 25 percent clay which is primarily kaolinite. The Pirassununga soil is also a sandy loam classified as a deep regosol, with 12 percent clay which is also primarily kaolinite.[4/]

The experiments initially consisted of five blocks (A-E) at each of the three locations. During the first year, Blocks A and B were planted to cotton, C and D to corn, and E to soybeans. Within each block a 3 x 3 x 4 factorial of P_2O_5, K_2O, and lime was established. The phosphorous and potash treatment levels were 0, 90, and 180 kilograms per hectare. The quantities of lime varied among locations, depending on soil pH, to bring the soils on which the greatest amount of lime was applied to a pH of 6.

In 1961 enough lime was added to plots A-D to raise the pH to 6. And nitrogen was substituted for lime in the experiment. The nitrogen treatment levels were 0, 60, 120 and 240 kilograms of nitrogen per hectare. All plots received 60 kilograms of sulfur, 25 of zinc and 20 kilograms of boron per hectare. The same crops were planted in each block.

Blocks A, B, C, and D were split in 1962. One half of each of these blocks were planted to soybeans and one-half to either corn or cotton. Thus, Block A was in corn for the third year, Block D in cotton for the third year, and Blocks B and C were rotated between these two crops. Sixty kilograms of sulfur, five of zinc and two kilograms of borax were applied to the corn and cotton. The factorial design was reduced to a dropout experiment with N, P_2O_5 and K_2O ranging from 0-0-0 to 240-180-180 kilograms per hectare. Block E was abandoned. Soybeans were planted on plots which had been planted to two years of corn, two years of cotton, or a corn-cotton rotation. In addition to the other trace nutrients used on corn and cotton, 0.4 kilograms of molybdenum was applied. No nutrients were applied to a check plot and the maximum application was 360 kilograms of P_2O_5 and K_2O.

The experiment was not changed in 1963. And the investigation was terminated at the close of the 1963-64 production year.

THE PRODUCTION FUNCTIONS

The agronomic data includes 648 observations of corn and cotton yields and 216 observations of soybean yields which were obtained with four different quantities of P_2O_5 and K_2O and five different quantities of N. The fertilizer-yield relationships are described with production functions. An understanding of this physical relationship is paramount to understanding the economic relationships.

Of specific concern is the yield resulting from nitrogen, phosphorous and potash. But variation in yield could also be expected to result from location, lime or pH, and trace nutrients. Zero-one variables were used to separate variation due to location and trace nutrients. The effect of lime on yield was measured in terms of tons per hectare in the case of soybeans, and pH of the soil in the case of cotton and corn. Terms were included to separate the linear, quadratic, and interaction affect of nitrogen, phosphorous and potassium. In addition, the interaction of the three macro nutrients with location was separated because of the difference in chemical composition of the soil at each of the three locations.

The equation of estimation for corn and cotton yield is defined as:

$$\begin{aligned} \hat{Y} = {} & a + b_1\, pH + b_2\, N + b_3\, P + b_4\, K \\ & + b_5\, T_r + b_6\, O + b_7\, M + b_8\, P^2 \\ & + b_9\, K^2 + b_{10}\, NP + b_{11}\, NK + b_{12}\, PK \\ & + b_{13}\, NPK + b_{14}\, NO + b_{15}\, NM + b_{16}\, PO \\ & + b_{17}\, PM + b_{18}\, KO + b_{19}\, KM \end{aligned} \tag{1}$$

where

pH is the pH level of the soil,

N is kilograms of nitrogen per hectare,

P is kilograms of phosphorous per hectare,

K is kilograms of potash per hectare,

T_r is a zero-one variable for trace nutrients,

O is a zero-one variable for location at Orlandia,

M is a zero-one variable for location at Matao.

For soybeans the equation of estimation is defined as:

$$\begin{aligned} \hat{Y} = {} & a + b_1\, L + b_2\, P + b_3\, K + b_4\, O \\ & + b_5\, M + b_6\, P^2 + b_7\, K^2 + b_8\, PK \\ & + b_9\, PO + b_{10}\, PM + b_{11}\, KO + b_{12}\, KM \end{aligned} \tag{2}$$

where

L is tons of lime per hectare and all other variables are as defined in Equation (1).

The estimated coefficients of production are presented in Table I. Much of the variation in corn and cotton yield can be explained by changes in the level of lime, phosphorous, potash and trace nutrients. Location also had a significant effect on corn and cotton yields, both directly and through interaction with phosphorous and potash. Little variation in yield was explained with nitrogen. The coefficient for the nitrogen term was small when compared with coefficients of the linear phosphorous and potash terms, and non-significant by standard statistical levels of significance.

Variation in soybean yields were explained by changes in lime and phosphorous. The location effect was large at Orlandia, as was the interaction of potash with the soils at Matão. However, the level of statistical significance of the coefficients for the phosphorous and potash terms was such that economic interpretation of this production function would have little meaning.

OPTIMUM USE OF PHOSPHOROUS AND POTASH

The estimated production functions presented in Table I are such that it is meaningful to calculate the optimum use of phosphorous and potash on corn and cotton. The optimum use of these inputs is attained when the value of the last unit of output just pays for the last unit of input used. In other words, P_2O_5 and K_2O would be used at optimum levels in the production of corn and cotton when the marginal value of the product is equal to the price of the nutrients. Having estimated the production function, the price of phosphorous and potash, and the price of corn and cotton is needed.

The price of P_2O_5, which was used in this analysis, is $24.24 per 100 kilograms, in the form of <u>Super Fosfato Triplo</u>. The price of K_2O, in the form of <u>Cloreto de Potassio</u> is $12.09 per 100 kilograms. The price of seed

TABLE I

ESTIMATED COEFFICIENTS AND STANDARD ERRORS FOR CORN, COTTON AND SOYBEANS

	Corn	Cotton	Soybeans
Constant term	-1,457.93**	-992.53**	0.12
	(205.29)	(85.21)	(77.41)
pH for corn and cotton	174.59**	125.12**	85.28**
Tons of lime for soybeans	(27.04)	(11.22)	(8.67)
(N) Nitrogen in kgs	1.67	0.02	
	(1.49)	(0.62)	
(P) Phosphorous in kgs	18.85**	4.64**	3.23**
	(2.28)	(0.95)	(1.09)
(K) Potash in kgs	19.02**	8.37**	1.73
	(2.28)	(0.95)	(1.09)
(T_r) Zero-one variable(trace nutrients)	755.11**	453.73**	
	(116.59)	(48.39)	
(O) Zero-one variable (for Orlandia)	3,343.49**	645.56**	1,403.04**
	(197.03)	(81.78)	(99.29)
(M) Zero-one variable (for Matao)	778.96**	825.89**	-11.25
	(197.03)	(81.78)	(97.83)
(P^2) Quadratic Phosphorous term	-0.06**	-0.01**	-0.01
	(0.01)	(0)	(0.01)
(K^2) Quadratic potash term	-0.07**	-0.03**	-0.01
	(0.01)	(0)	(0.01)
(NP) Nitrogen phosphorous interaction	-0.02*	-0.01	
	(0.01)	(0)	
(NK) Nitrogen potash interaction	-0.01	0.01*	
	(0.01)	(0)	
(PK) Phosphorous potash interaction	-0.01	0.01**	0.00
	(0.01)	(0)	(0)
(NPK) Nitrogen,phosphorous potash interaction	0	0 *	
	(0)	(0)	
(NO) Nitrogen Orlandia interaction	-3.99*	-0.62	
	(1.12)	(0.47)	
(NM) Nitrogen Matão interaction	-1.00	-0.45	
	(1.12)	(0.47)	
(PO) Phosphorous Orlandia interaction	-9.01*	-2.13**	-0.82
	(1.22)	(0.51)	(0.66)
(PM) Phosphorous Matão interaction	-4.35*	-1.51**	1.27
	(1.22)	(0.51)	(0.66)
(KO) Potash Orlandia interaction	0.01	2.03**	2.08**
	(1.22)	(0.51)	(0.66)
(KM) Potash Matao interaction	-3.57**	-3.52**	0.05
	(1.22)	(0.51)	(0.66)
R^2	69.14	78.04	89.60
Standard Deviation	956.86	397.15	289.94

Standard errors are in parenthesis.

** indicates 0.01 percent level of significance, and
 * indicates 0.05 percent level of significance.

cotton, paid at the farm gate, averaged \$13.53 per hundred kilograms between May 1965 and May 1968. Corn prices averaged \$3.67 per hundred kilos over the same period.[8/] * Using these input/output price ratios and the appropriate production function, the optimum level of nutrients was calculated and is presented in Table II.

The price of cotton and corn fluctuates. A change in the price of these products could be expected to require a change in the optimum quantity of nutrients. The standard deviation of cotton price, over the three years was \$1.20. And the standard deviation of corn price was \$0.99. Because of the different production functions at each location, a change in the product price may necessitate a different change in the use of fertilizer at each location. For example, as can be seen from Table II, a decrease in the price of cotton from \$13.53 to \$11.16 would mean a 20 percent reduction in the use of phosphorous at Matão, but only a 14 percent reduction at Pirassununga. But the farmer does not always know at planting time what price he can expect at harvest. If he expects \$4.74 for his corn at Matão and applies 72 kilograms of P_2O_5, but the price of corn goes to \$2.50 he will have over fertilized and lost money.

PROBABLE RATE OF RETURN

Of concern to the farmer is the probable rate of return that he can expect from using fertilizer. If he invests a dollar in fertilizer, what are the chances of getting \$1.50 or \$2.00 in return? Yields and product prices vary from year to year. The standard error of the estimated yield of cotton was 397 kilograms and the standard deviation of cotton price was \$1.20. For corn yield, the standard error of the estimate was 957 kilograms and the standard deviation of corn price was \$0.99.

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*These prices were converted from cruzeros to U.S. dollars on the basis of the predominant exchange rate that existed during the month of the transaction. For reasonable interpretation, they can be converted back into cruzeros by using existing exchange rates.

TABLE II

RECOMMENDED LEVELS OF PHOSPHOROUS AND POTASH
FOR DIFFERENT PRICES OF CORN AND COTTON
AT THREE LOCATIONS IN THE STATE OF SÃO PAULO, BRAZIL[a/]

	Pirassununga		Orlandia		Matão	
	Kilograms of P_2O_5/ha.	Kilograms of K_2O/ha.	Kilograms of P_2O_5/ha.	Kilograms of K_2O/ha.	Kilograms of P_2O_5/ha.	Kilograms of K_2O_5/ha.
Corn Price						
$2.50/100 kg	68	100	0	102	34	73
$3.67/100 kg	94	106	18	112	59	83
$4.74/100 kg	107	110	30	116	72	87
Seed Cotton Price						
$11.16/100 kg	201	155	103	173	87	77
$13.53/100 kg	233	162	126	179	109	84
$15.90/100 kg	240	167	141	184	125	89

a/ Price of P_2O_5 is $24.24/100 kg and K_2O $12.09/100 kg.

Using an estimate of the mean values and standard deviations for yields without the use of fertilizer, yields with the use of fertilizer and product prices, it is possible to estimate a probable rate of return. The equation for estimation is:

$$R = [P_Y (Y_F - Y_0)]/C_F \quad (3)$$

where

- R is the rate of return on one dollar invested in fertilizer,
- P_Y is the price of the product,
- Y_F is the yield obtained with some given use of fertilizer,
- Y_0 is the yield obtained without fertilizer, and
- C_F is the cost of the fertilizer.

The fertilizer cost parameter (C_F) is known at planting time and is merely specified as a constant. The product price parameter is assumed to be normally distributed and the mean and standard deviation, calculated from the three years of price data, were used. The mean and standard deviations of the yield variables were calculated from twelve observations of yield at zero level, and the 180 kilogram level of P_2O_5 and K_2O. These values are presented in Table III. Of the various combinations of nitrogen, potash and phosphorous used in the field trials, the 180 kilogram level of phosphorous and potash was closest to recommended levels in Table II. A value for each parameter, and subsequently the value for R, is determined at each of 1,000 iterations by Monte Carlo sampling of the distribution. The probable rates of return are presented in Table IV.

The probable rates of return which can be expected from fertilizing corn and cotton at Pirassununga, Orlandia, and Matão are presented in Table IV. There is generally greater assurance of a profit from fertilizing cotton than corn. This is the case because of variation in yield and variation in price. The variation, measured as a ratio of standard deviation over mean yield, decreased to almost one-half when the fertilizer was applied

TABLE III

MEAN AND STANDARD DEVIATIONS OF YIELD DATA USED IN ESTIMATING PROBABLE RATE-OF-RETURN FROM FERTILIZING CORN AND COTTON, SÃO PAULO, BRAZIL[a/]

	No Fertilizer			180 kg/ha P_2O_5 and K_2O		
	Pirassununga	Orlandia	Matão	Pirassununga	Orlandia	Matão
Cotton						
Mean	47	455	653	1315	2154	1266
Standard Deviation	71	266	384	725	814	559
Ratio of Standard Deviation/Mean	1.51	0.58	0.59	0.55	0.38	0.44
Corn						
Mean	308	2415	1006	2390	4111	1746
Standard Deviation	177	1084	508	1215	1285	1886
Ratio of Standard Deviation/Mean	0.57	0.45	0.50	0.51	0.31	1.08

a/ Based on twelve observations collected at each of the three locations over a period of four crop seasons.

TABLE IV

PROBABLE RATE-OF-RETURN FROM INVESTING A DOLLAR

ON FERTILIZING CORN AND COTTON, SÃO PAULO, BRAZIL

	Average Return	Less Than $1.00	$1.01 - $2.00	$2.01 - $3.00	$3.01 - $4.00	Above $4.00
Cotton						
Pirassununga	$2.69	13%	22%	27%	19%	19%
Orlandia	$3.52	9%	11%	22%	21%	37%
Matão	$1.22	40%	26%	26%	7%	1%
Corn						
Pirrassununga	$1.24	41%	43%	14%	2%	0
Orlandia	$0.99	53%	33%	10%	4%	0
Matão	$0.78	65%	26%	6%	3%	0

to cotton but increased when it was applied to corn. Price variation was considerably higher for corn than it was for cotton.

A farmer has better than a 50 percent chance of making a profit from fertilizing both corn and cotton at Pirassununga. At Matão he has a 60 percent chance of making a profit from fertilizing cotton, but only 35 percent chance in the case of corn. A dollar invested on fertilizing cotton at Orlandia has a far greater chance (91 percent) of returning a profit than a dollar invested on fertilizing corn (47 percent).

CONCLUSIONS

Based on the data analyzed and described in this report, it is profitable to fertilize cotton on the soils of the Campo Cerrado in northern São Paulo. A farmer can profitably use at least 75 kilograms of K_2O and 85 kilograms of P_2O_5, along with enough lime to bring the pH of the soil to six. He can expect a profit from the use of these nutrients at least six times out of ten. A rate of return above 400 percent can be expected almost four times out of ten from applying phosphorous and potassium to the dark red latasols of Orlandia.

It is generally profitable to apply 20 kilograms of P_2O_5 and 75 kilograms of K_2O to corn grown on these soils. But the risk of profit is greater. And there may be only a 35 percent chance of earning a profit from fertilizing corn.

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