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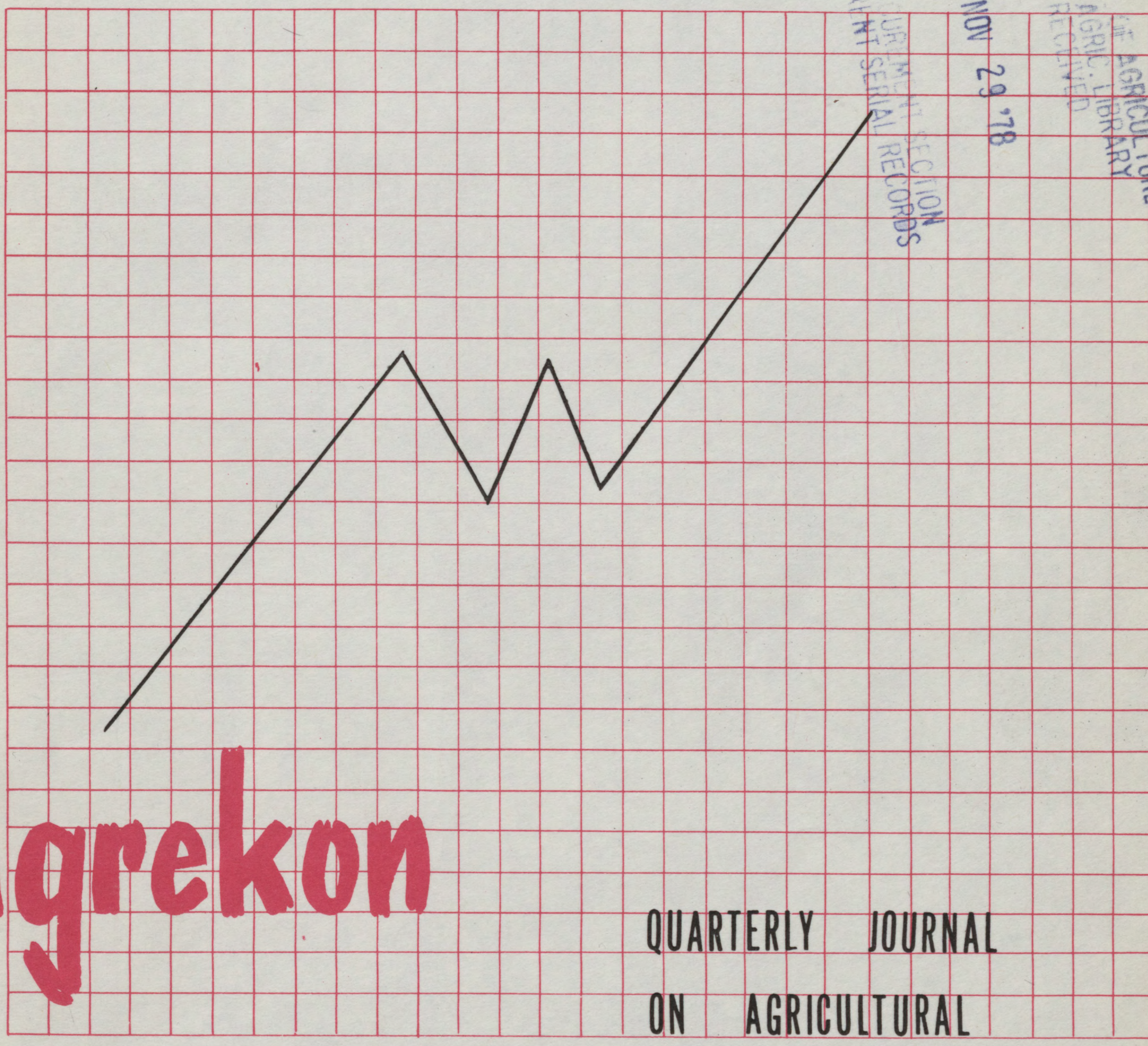

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A STATISTICAL ANALYSIS OF THE SUPPLY OF MAIZE IN THE TRANSVAAL*

by

D.S. LANGLEY
Bophuthatswana National Development Corporation,

and

J.P.F. DU TOIT
University of Pretoria

1. INTRODUCTION

This study is an empirical analysis of the supply of maize in two of the country's most important maize producing regions, namely the Eastern Transvaal Highveld and the Western Transvaal.[1]

A serious lack of knowledge exists as far as the structure of the supply of maize is concerned in South Africa; therefore the annual estimation of the maize crop is still based only on periodic evaluations of production conditions in the various regions.

For effective control it is vital for the Maize Board to know how, and to what extent, farmers respond to certain changes in the price of maize, as well as to changes in other product and input prices. Scientific knowledge regarding the nature of the supply function is therefore of value to the Board for purposes of price determination, planning and formulation of policy in general, whereafter certain policy actions may be evaluated more accurately and the possible consequences of such measures indicated.

The importance of the maize industry is reflected in the average contribution of maize to the gross value of field crop production (46 per cent) and to the total value of agricultural production (20 per cent) during the period 1964/65 to 1974/75.[2]

The value of maize exports in 1975 and 1976 amounted to R302,5 million and R236,5 million, respectively.[3]

The maize industry is, however, characterised by considerable yearly fluctuations in total production which may be ascribed mainly to the variability of weather conditions. This seemingly increasing variability in annual production**, together with rapidly increasing cost of production, emphasises the necessity of research with respect to the supply of maize.[4]

2. CONCEPTUAL AND METHODOLOGICAL CONSIDERATIONS

(a) Conceptual problems associated with the measurement of supply

Theoretically supply represents the relation between the price of a commodity and the quantity offered by the producers or sellers at a particular point in time, while all other factors that could affect this relation are kept constant.[5] Such factors, which are theoretically assumed to be constant, include technology, prices of related products, prices and availability of inputs, etc. A study of supply over a period of time reveals that such functions cannot be regarded as static or constant but rather as curves which shift periodically in consequence of changes in the so-called *ceteris paribus* factors. The various variable factors which are expected to affect the supply of maize will be discussed in paragraph 2 (c).

(b) Choice of production regions

The Eastern Transvaal Highveld represents a fairly stable production area, where relatively stable crop yields can be obtained, even at times when drought conditions persist in many parts of the country. For the purposes of this study, the magisterial districts of Balfour, Delmas, Heidelberg, Nigel, Springs and Standerton were included as representative of the Highveld area. Due to climatic reasons, the Western Transvaal, however, can be regarded as a less stable production area.

In order to obtain a region with relatively homogeneous rainfall, six magisterial districts, namely Coligny, Klerksdorp, Lichtenburg, Potchefstroom, Ventersdorp and Wolmaransstad

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* Based on a M.Sc. (Agric.) thesis by D.S. Langley, University of Pretoria, November 1976.

** The coefficient of variation in the total maize crop from 1968 to 1977 was approximately 30 per cent.

were included to represent the Western Transvaal in this analysis.

(c) Choice of variables

In this analysis it has been attempted to estimate the influence of a number of relevant factors on the following three aspects of the maize supply, viz. area planted (acreage), total production and production per hectare. These three variables will in turn be regarded as dependent variables in the various alternatively specified supply functions.

The area planted with maize serves as a good indication of the production intentions or planned supply of farmers. The total annual production as well as the production per unit area, however, can be viewed as the physical or real supply.

For purposes of estimation of total production as well as yield per hectare, the area planted was also included as independent variable in the supply functions.

It was furthermore assumed that the supply of maize could be regarded as a function of the following independent variables:

(i) Price of maize

Dynamic analyses of supply pose the problem that nobody exactly knows to which prices farmers actually respond. Nerlove[6] and others[7] are of the opinion that farmers do not respond to the previous year's prices, but rather to prices they expect to receive. Owing to this uncertainty with respect to future prices, farmers, however, base their expectations on prices which prevailed in the past, but prices of the more recent past are probably more influential as far as farmers' expectations are concerned.

In this study the lagged price (P_{t-1}) will be considered as the expected price. This implies that the prices of two or more years back (P_{t-2}, P_{t-3}, etc.) do not influence the production planning of the coming season at all. This assumption clearly represents a special case with regard to Nerlove's more general hypothesis in this respect.[8]

The inclusion of the previous year's price as independent variable seemed to be realistic in view of the fact that controlled marketing (single channel fixed-price scheme for maize) succeeded in eliminating large annual price fluctuations or price-uncertainty to a large extent.

(ii) Prices of short-term requisites

The theory of supply offers ample justification for the inclusion of this variable since willingness or ability to produce is directly influenced by cost factors. Prices of variable inputs determine what amount thereof can be used in the production process. With a given price for maize an increase in the prices of inputs will tend to shift the supply curve to the left and *vice versa.* The price index of short-term requisites used in this analysis, was constructed by combining the price indices of two important cost, items, viz. that of fertilizer and fuel, respectively. Due to the fact that the prices of these two commodities are known before they are used, an index based on current prices (period t) was used.

(iii) Prices of alternative crops

Changes in the prices of competitive crops could result in shifts in the supply of maize. For purposes of measuring the magnitude of such possible substitution effects, the prices of grain sorghum, groundnuts, dry beans and sunflower seed have been included individually in the various supply functions. As in the case of the price of maize, lagged prices (period t—1) were used throughout.

(iv) Rainfall

Several problems were encountered in an attempt to calculate satisfactory rainfall figures as an extremely important or most relevant variable in supply equations. Attempts to construct a weather index according to the so-called "experimental plot data approach" suggested by Stallings,[9] were not successful due to the lack of sufficient experimental yield data. Rainfall variables calculated according to a method developed by Houseman[10] also did not yield satisfactory results.

Eventually rainfall variables were calculated by taking average rainfall figures of a number of weather stations located within the areas concerned. The various weather stations were chosen in accordance with Wellding and Havenga's statistical classification of weather stations.[11] Only data of weather stations which proved to be highly correlated (0,65 or more) were used, which also served as a basis for identification of the production regions with relatively homogeneous rainfall characteristics as mentioned earlier. The average monthly quantities of rain measured at these different weather stations were then grouped in combinations in order to obtain seven rainfall variables for each region.

(v) Trend

A trend variable was used as a measure of technological change assuming that technological development took place at a constant rate in the period under review. The effect of technology as embodied in new resource combinations, for example improved cultivars, fertilizers, cultivation and cropping methods, amongst others, could not be ignored in view of the actuality of technological development in the period concerned.

3. DATA USED

Data regarding the areas planted and total production for the period 1946/47 to 1962/63 were obtained from Agricultural Census Reports.[12] Corresponding figures for the period 1963/64 to 1972/73, however, were calculated from data compiled by the Division of Agricultural Marketing Research.

Indices of producer prices for the various crops and of short-term requisites as published in the Abstract of Agricultural Statistics,[13] with 1947/48 to 1949/50 as basis were used throughout.

The price index of short-term requisites was constructed by combining the price indices of fertilizer and fuel in the ratio of 35 to 25 respectively, as suggested by Van Tonder[14]

All the required rainfall data were obtained from the annual reports of the Weather Bureau. The average monthly quantities of rain measured at four Eastern Transvaal and eight Western Transvaal weather stations were used for this purpose.

The small number as well as the uneven geographical distribution of the weather stations finally chosen, undoubtedly reduced the reliability of the calculated rainfall variables. The non-continuity of the data caused by either the closing down or shifting of weather stations resulted in certain shortcomings in the data used. In general, however, the data series seemed to be satisfactory for the purposes of this investigation.

4. MODELS

The hypothesised functional relationships among the variables selected were as follows:

$$OM = f(PM_{t-1}; PK_t; PGS_{t-1}; PGB_{t-1}; PDB_{t-1}; PSB_{t-1}; R; T) \quad (1)$$

$$TP = f(OM; PM_{t-1}; PK_t; PGS_{t-1}; PGB_{t-1}; PDB_{t-1}; PSB_{t-1}; R, T) \quad (2)$$

$$P/h = f(OM; PM_{t-1}; PK_t; PGS_{t-1}; PGB_{t-1}; PDB_{t-1}; PSB_{t-1}; R, T) \quad (3)$$

with

- OM = area planted to maize (ha)
- TP = total production of maize (t)
- P/h = production per hectare (kg)
- PM_{t-1} = price index of maize, lagged one year (period t-1)
- PK_t = current price index of short-term requisites (period t)
- PGS_{t-1} = price index of grain sorghum, lagged one year
- PGB_{t-1} = price index of groundnuts, lagged one year
- PDB_{t-1} = price index of dry beans, lagged one year
- PSB_{t-1} = price index of sunflower seed, lagged one year
- Rsc = rainfall during the months Sept.-Oct. (mm)
- Rsn = rainfall during the months Sept.-Nov. (mm)
- Rsd = rainfall during the months Sept.-Dec. (mm)
- Rnm = rainfall during the months Nov.-March (mm)
- Rdm = rainfall during the months Dec.-March (mm)
- Rjm = rainfall during the months Jan.-March (mm)
- Rsm = rainfall during the months Sept.-March (mm)
- T = trend with 1946/47 = 1; 1947/48 = 2; etc.

5. EMPIRICAL RESULTS

The results of a few regressions which include the final or "best" selections, are presented in Tables 1 and 2. With a few exceptions, the results obtained can be regarded as satisfactory.

In most cases the signs of the estimated coefficients are in step with *a priori* expectations. The calculated t-values indicate that most coefficients of variables included in the final selections are statistically significant, though some proved to be significant at rather low levels of probability. The highly significant F-values and high adjusted coefficients of determination ($\bar{R}^2$) indicate that the data verified the models.

As far as the autocorrelation is concerned, no serious problems were encountered. In some cases, the Durbin-Watson test proved to be inconclusive. In such cases the detrimental influence of serial correlation could neither be proved nor disproved.

Due to high correlations between some independent variables, the reliability of some coefficients was obscured by multicollinearity. In this respect the results of equations 1.1 and 1.2 as well as 2.3 and 2.4 can be regarded as unsatisfactory. The distorting influence of intercorrelation was avoided or rather minimised as far as possible by eliminating highly correlated variables from the final regression runs. For purposes of prediction, this problem can be regarded as less critical.[15]

6. INTERPRETATION

Price of maize: The coefficients of this variable proved to be significant ($p = 0,001$) only with respect to the planned supply (area planted) equations of the Eastern Transvaal. From Table 1 it apppears that a one per cent increase in the price of maize in a particular season can be associated with an increase of between 0,715 per cent and 0,963 per cent in the area planted in the following season — all other factors being constant.

In no other equation, whether for the Eastern or the Western Transvaal, could any significant coefficients be obtained from this particular variable. This finding is, however, contrary to the economic theory of production functions. This result can possibly be ascribed to intercorrelation among prices and other independent variables.

Prices of short-term requisites: This variable seems to have a significant effect ($p = 0,05$) on the area planted to maize in the Eastern Transvaal. The corresponding coefficient for the Western Transvaal differed from zero, though at a low level of probability ($p = 0,20$). The elasticity of supply (area planted) with respect to the price of short-term requisites amounted to -0,908 (equation 1.2) in the Eastern Transvaal area.

This variable does not seem to influence either the area planted or yield per hectare in the period under review. It is, however, known that the real prices of the two inputs (fertilizer and fuel) did not change much during the period covered by this analysis, which made it difficult to measure the influence of this variable in the various models.

Prices of alternative crops: From Table 1 (equations 1.1 and 1.2) for the Eastern Transvaal, it is evident that the coefficient associated with the price of dry beans differed significantly from zero

TABLE 1 - Regression results obtained for the Eastern Transvaal Highveld area over the period 1946/47 to 1972/73

Equation	Dependent variable	Coefficients, t-values[1] and elasticity	Independent variable						Intercept	$\bar{R}^2$	F	D.W.[2]
			OM	PM_{t-1}	PK_t	PDB_{t-1}	Rdm	T				
		Coefficient	x	1 639,1	-1 562,5	408,5	–	949,7				
1.1	OM		x	(529,1)	(645,2)	(157,6)	–	(1 801,7)	137 600	0,7012	14,7***	1,472
		t-value	x	3,10**	- 2,42*	2,59*	–	0,53				
		Coefficient	x	1 217,1	-1 553,3	–	–	4 367,3				
1.2	OM		x	(565,0)	(724,2)	–	–	(1 378,0)	209 656	0,6228	13,8***	1,255
		t-value	x	2,15*	- 2,145*	–	–	3,17**				
		Elasticity	x	0,963	- 0,908	–	–					
		Coefficient	0,1571	–	- 155,0	–	61,9	1 589,5				
1.3	TP		(0,047)	–	(131,8)	–	(13,4)	(192,2)	-28 990	0,0937	50,9***	2,449
		t-value	3,371**	–	- 1,18	–	4,62***	4,05***				
		Coefficient	0,1681	–	–	–	60,7	1 209,1				
1.4	TP		(0,046)	–	–	–	(13,5)	(223,8)	-46 272	0,8916	66,2***	2,251
		t-value	3,65**	–	–	–	4,51***	5,40***				
		Elasticity	1,209	–	–	–	0,747					
		Coefficient	0,0009	–	- 4,8	–	2,2	62,4				
1.5	P/h		(0,0018)	–	(5,0)	–	(0,5)	(14,8)	42	0,8359	31,2***	2,526
		t-value	0,529	–	- 0,959	–	4,452***	4,22***				
		Coefficient	0,0013	–	–	–	2,2	50,7				
1.6	P/h		(0,0017)	–	–	–	(0,5)	(8,3)	- 488	0,8370	41,5***	2,373
		t-value	0,74	–	–	–	4,40***	6,08***				
		Elasticity	1,130	–	–		0,762					

1) Standard errors are shown in brackets and the levels of significance are indicated as follows: p=0,001=***; p=0,01=**; p=0,05=*; p=0,10=a; p=0,20=b
2) Durbin-Watson statistic

TABLE 2 - Regression results obtained for the Western Transvaal area for the period 1946/47 to 1972/73

Equation	Dependent variable	Coefficients, t-values[1)] and elasticities	Independent variable								Intercept	$\bar{R}^2$	F	D.W.[2)]
			OM	PM_{t-1}	PK_t	PGB_{t-1}	PSB_{t-1}	Rsn	Rnm	T				
		Coefficient	x	460,5	-1 781,3	-6 363,6	3 238,4	264,5	–	18 232,0				
2.1	OM		x	(899,1	(1 322,9)	(1 907,5)	(739,8)	(232,8)	–	(2 640,1)	717 903	0,949	73,7***	2,283
		t-value	x	0,512	- 1,35[b]	- 3,336**	4,08***	1,14	–	6,91***				
		Elasticity	x	–	–	- 1,042	0,608		–					
		Coefficient	x	–	-1 322,4	-6 291,8	3 282,2	241,4	–	18 187,0				
2.2	OM		x	–	(955,1)	(1 866,9)	(774,4)	(224,1)	–	(2 589,2)	710 711	0,950	91,8***	2,188
		t-value	x	–	-1,39[b]	-3,37**	4,24***	1,08	–	7,02***				
		Elasticity	x	–	–	-1,030	0,616	–	–	–				
		Coefficient	0,1874	-162,8	172,8	2 312,2	-949,5	–	148,8	3 078,9				
2.3	TP		(0,0951)	(392,3)	(532,8)	(1 075,6)	(462,6)	–	(42,5)	(2 049,2)	-242 359	0,897	26,6***	1,982
		t-value	1,97[a]	-0,42	0,32	2,15*	-2,05[a]	–	3,50***	1,50[b]				
		Coefficient	0,0481	–	–	–	–	–	166,2	4 731,7				
2.4	TP		(0,0677)	–	–	–	–	–	(39,3)	(1 359,0)	-85 687	0,892	66,2***	1 878
		t-value	0,71	–	–	–	–	–	4,23***	3,48**				
		Elasticity		–	–	–	–	–	0,926	–				
		Coefficient	0,0007	-1,15	–	29,49	-18,89	–	2,53	64,41				
2.5	P/h		(0,0013)	(3,99)	–	(13,92)	(6,36)	–	(0,58)	(23,81)	- 1 780	0,844	22,1***	2,011
		t-value	0,58	-0,29	–	2,12*	-2,97**	–	4,35***	2,87**				
		Coefficient	-0,0018	–	–	–	–	–	2,53	92,17				
2.6	P/h		(0,0010)	–	–	–	–	–	(0,60)	(20,89)	- 39	0,797	32,0***	1,685
		t-value	-1,74[a]	–	–	–	–	–	4,19***	4,41***				
		Elasticity		–	–	–	–	–	0,872	–				

1) and 2) See footnotes. Table 1

(p = 0,05) but the positive sign of this coefficient is unacceptable.

The prices of the remaining crops considered probably did not influence total production or yield per unit area in the Eastern Transvaal significantly.

With regard to area planted in the Western Transvaal, the prices of both sunflower seed (p = 0,001) and groundnuts (p = 0,01) yielded significant coefficients. The "wrong" sign of the coefficient associated with the price of sunflower seed can probably be ascribed to a cultivation practice applied in earlier times by many farmers in this area, viz. the cultivation of sunflowers as a row crop between maize. The elasticity of supply (area planted) with respect to the prices of groundnuts and sunflower seed amounted to -1,03 and 0,62 respectively. In view of the unacceptable signs of these two variables in the remaining equations (2.3 and 2.5 in Table 2) these results have been rejected.

Area planted: As expected, the area planted had a significant effect (p = 0,01) on total production in the Eastern Transvaal, but no significant influence on the production per hectare could be found. This could possibly indicate that an increase in the area planted to maize in this area should not necessarily be associated with the cultivation and use of poorer soils, or stated alternatively, that the best soils in this area are not necessarily being reserved for the production of maize.

With reference to the Western Transvaal, this variable yielded a few significant coefficients (equations 2.3 and 2.6) although only at low levels of probability ($p \geqslant 0{,}01$). The results of equation 2.6 indicate that an increase in the area planted is probably accompanied by the utilization of more marginal or sub-marginal soils, which, together with more extensive cultivation practices, affected yields per hectare unfavourably.[16]

Rainfall: In contrast with results obtained for the Eastern Transvaal, the positive rainfall coefficient ($1{,}08 \geqslant t \geqslant 1{,}14$) indicates that the amount of rain during the months September to November appeared to influence the area planted in the Western Transvaal.[17]

The coefficients associated with rainfall during the period December to March for the Eastern Transvaal and those during the period November to March for the Western Transvaal, were both significantly different from zero (p = 0,001) with respect to the total production as well as the yield per hectare equations. The elasticity of total production and yield per hectare with regard to rainfall amounted to 0,93 and 0,87 compared with 0,75 and 0,76 for the Eastern and Western Transvaal respectively. The quantity of rain in this period is of crucial importance since, at this stage of the growing season the maize plant has high moisture requirements and is particularly sensitive to drought conditions.

Trend: In all final selections this variable differed significantly from zero, which implies that the supply of maize shifted to the right or upwards over the period concerned. The annual increase in the area planted (all other factors remaining constant) of approximately 18 000 hectares in the Western Transvaal, is considerably larger than the annual rate of horizontal expansion of just over 4 000 hectares in the Eastern Transvaal Highveld area.

The estimated annual increase in production per hectare in the Western Transvaal of about 70 to 90 kg again exceeded the corresponding trend value of between 50 to 60 kg per hectare in the Eastern Transvaal. These results emphasise the fact that the Western Transvaal has developed from an extensive grazing area into one of the country's most important cropping areas during the period under review.

At this stage, however, it is not clear to what extent this tendency will prevail in future because more and more marginal soils in the Western Transvaal — as in other parts of the country — are being utilized for the production of maize.

The Commission of Inquiry into Agriculture[18] seriously questioned this horizontal expansion on less suitable soils and stated that ......"there is strong doubt whether such soils should ever have been cultivated".

7. SUMMARY

In spite of certain shortcomings, useful results were obtained, especially for the purposes of prediction. Only the area annually planted to maize seems to be influenced significantly by the various price variables. The elasticity of supply (area planted) in the Eastern Transvaal with regard to changes in the price of maize and the price of short-term requisites amounted to 0,963 and -0,908 respectively.

None of the alternative crops included can be regarded as a significant competitor for maize in the Eastern Transvaal area.

Area planted, rainfall and technology seem to be the most important factors which do influence the total production as well as the yield per hectare in both regions.

The results for the Western Transvaal indicate that groundnuts compete strongly with maize for the available cropping area. In the period covered by this analysis, sunflowers were cultivated quite commonly as a row crop between maize and this practice probably explains the "complementary" relation found between maize and sunflower seed. With current cropping practices, sunflower probably represents an important substitute for maize in the Western Transvaal.

Since the end of 1973 prices of short-term requisites have increased sharply. It is therefore reasonable to expect that the current effect of this variable has probably been underestimated by the results of this study.

The estimating technique employed here should be further extended and refined. Supply analyses deserve greater research priority since such knowledge must be regarded essential for the formulation of policy with respect to production planning and adjustments with the passing of time.

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