MODELLING FERTILISER USE IN THE GRAIN CROP AND OILSEED SECTORS OF SOUTH AFRICA

M.C. Breitenbach[1] and N.G. Meyer[2]

A Partial Equilibrium (PE) model is developed to model fertiliser use in the grain crop and oilseed sectors to assess the impact of changes in the physical and economic environment on production and fertiliser use.

Since the adoption of a policy of trade liberalisation and the shift towards a free market for agricultural products, the actual cropping patterns of grain crops have moved closer to the expected optimum production pattern. It is shown that the total area cultivated will decrease by 2,4 percent. Results show that except for the area under sunflower (that remains unchanged) and yellow maize that increases, the area utilised by other crops will decrease.

Fertiliser use is directly correlated with production patterns in the provinces. A comparison of the base-case scenario and optimum solution revealed that the movement from a base to an optimum solution results in a drop in total area cultivated, production and exports. Fertiliser use correspondingly decreases.

MODELLERING VAN KENNISVERBRUIK IN DIE GRAAN EN OLIESADE SEKTORE VAN SUID-AFRIKA

'n Parsiële Ewewigsmodel is ontwikkel om kunsmisverbruik in die graan en oliesade sektore te modelleer en om die impak van veranderinge in die fisiese en ekonomiese omgewings op produksie en kunsmisverbruik te bepaal.

Sedert die aanvarding en implementering van 'n beleid van handelsliberalisering en 'n vryemark vir landbouprodukte het die werklike produksiepatrone nader beweeg na die verwagte optimum produksiepatroon. Resultate toon dat die totale area onder bewerking met 2.4 persent sal daal, en dat behalwe vir sonneblomproduksie waar die area benut word onveranderd sal bly, dat dié van geelmielies sal toeneem en dat die area benut deur ander gewasse sal afneem.

Kunsmisverbruik is direk gekorreleerd met produksiepatrone in die provinsies. 'n Vergelyking van die basisgeval scenario en die optimale oplossing toon aan dat 'n beweging vanaf die basis na 'n optimale oplossing 'n daling in die totale area onder bewerking, produksie en uitvoere sal veroorsaak. Kunsmisverbruik sal dienooreenkomstig afneem.

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1 *Department of Economics, Vista University, Pretoria.*
2 *Department of Agricultural Economics, University of the Free State, Bloemfontein.*

1. INTRODUCTION

Over the next two decades, the agricultural sector, both at national and global levels, will face major structural changes. This is primarily due to global shifts in production and changes in production costs and demand patterns. In the aggregate, the sector may well find ways to adjust to the structural changes, but in individual countries and industry segments the effects may be strong, and involve serious operational and policy problems.

A Partial Equilibrium (PE) model was developed to model fertiliser use in the grain crop and oilseed sectors (hereinafter only referred to as the grain crop sector) to assess the impact of changes in the physical and economic environment on production and fertiliser use. It is also important to gain an understanding of the variables and how they interact. More specifically, the aim is to formulate a model that can assist decision-makers in their decision on how much fertiliser to buy and mix and how to mix and distribute optimally.

Studying the issues at a macro and provincial level one can derive specific and clear policy guidelines and recommendations. The Partial Equilibrium (PE) model developed was a result of a need to address policy issues in a spatial context using actual figures for specific years.

2. THEORETICAL CONSIDERATIONS

The structure of the model is organised according to the following activities, *viz.*

- supply activities;
- linking activities;
- demand activities; and
- risk activities.

Figure 1 depicts a simplified demand and supply structure of the PE model and is self-explanatory. In balancing the food equation, it is important to include imports, carry-in stocks and domestic production of food on the supply side and domestic consumption and exports on the demand side while the processing and distribution system performs the link between demand and supply.

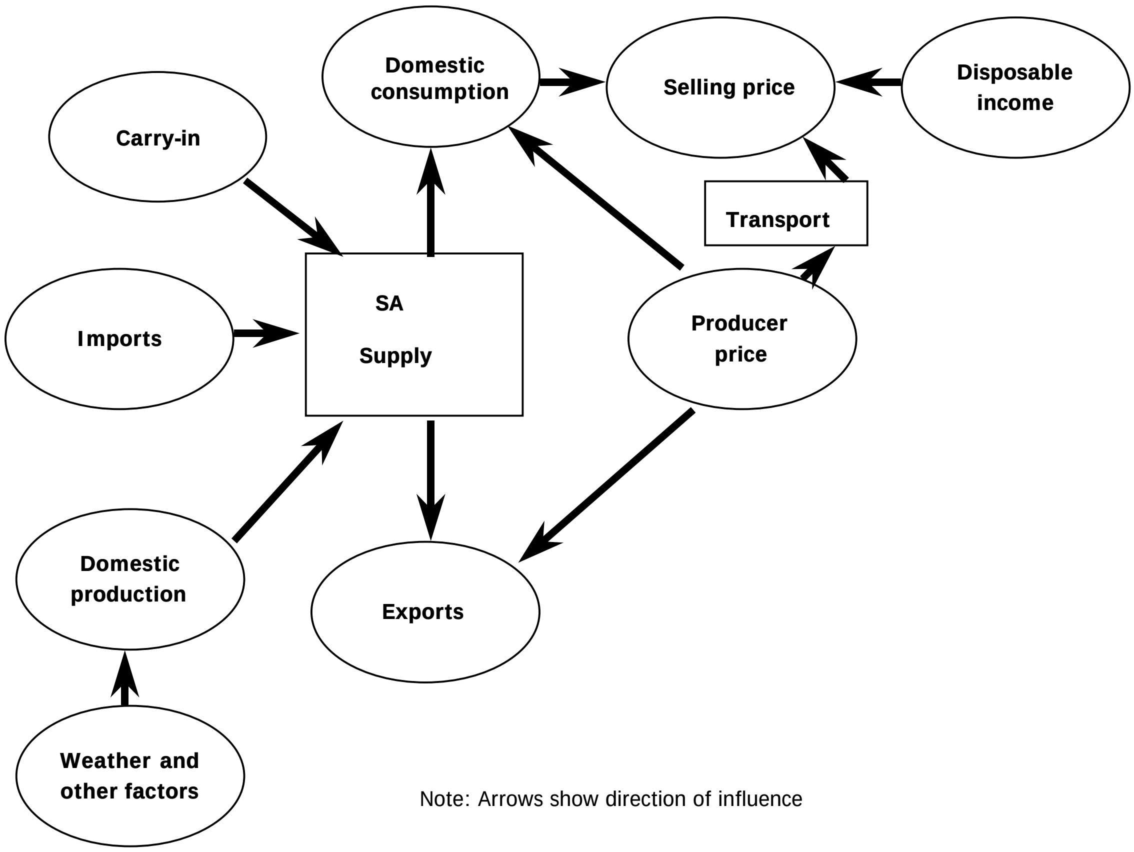

Figure 1: The demand and supply structure of the PE model

Source: *Meyer, 1998 – as adapted*

2.1 Supply activities

2.1.1 Farm type classes

Within the provinces two types of land-use categories were distinguished for the four commodities identified, i.e. maize, sorghum, wheat and sunflower. The land-use categories are irrigated production and non-irrigated production. This naturally implies the application of different technologies, yields and production costs by farm type classes and farmer typologies. In this case, the farmer typology refers to the commercial farming sector.

2.1.2 Homogeneous farming regions

In a perfect model, each farm is modelled independently with its own unique set of production conditions. However, when production conditions over an area are similar, then that area can be treated as one activity (farm, where production conditions are thus assumed homogenous). The first problem, therefore, is to identify homogeneous regions, i.e., areas of similar yields and costs per hectare. In this model, South Africa was divided into two relatively homogeneous regions, *viz.* the Free State and Rest of South Africa with the assumption that the statistics used represent an average for all farming units within the province.

One import/export 'region' was also included, namely Durban harbour. The designations according to provinces were strongly circumscribed by the availability of data.

2.1.3 The land constraint

The next step in the construction of the PE model is to tabulate the resource endowments and specifically the land constraint (Table 1).

Table 1: Area cultivated by main crop (ha), 1997

Product	Landuse	Western Cape (ha)	Free State (ha)	Rest of RSA (ha)	Total (ha)
Wheat	Dryland	403 000	668 408	38 612	1 110 020
	Irrigation		33 592	150 188	183 780
	Total	403 000	702 000	188 800	1 293 800
White maize	Dryland		673 084	1 171 000	1 844 084
	Irrigation	0	9 916	50 000	59 916
	Total	0	683 000	1 221 000	1 904 000
Yellow maize	Dryland		415 084	931 156	1 346 240
	Irrigation	0	9 916	46 844	56 760
	Total	0	425 000	978 000	1 403 000
Sorghum	Dryland		87 000	87 000	174 000
	Irrigation	0	0	0	0
	Total	0	87 000	87 000	174 000
Sunflowers	Dryland		239 002	368 998	608 000
	Irrigation	0	0	0	0
	Total	0	239 002	368 998	608 000

Source: *Data was collected from various sources, viz. National Department of Agriculture, Development Bank of Southern Africa, Agricultural Research Council (Small Grains Institute) and Grain Producers Organisation.*

Note: *1997 was chosen for the study because it was the last normal production year for the selected crops.*

Because there is a constraint for arable land, i.e. both dryland and irrigated land, in each province, the model generates shadow prices for land if all the land is utilised. *Farmers employ a resource until its marginal revenue equals its price.* Therefore, the shadow price of land in the model is its measure of the value of land. This serves as a check on the model because these shadow prices can be compared with the actual rental value of land.

Equation (1) depicts the potential available land constraint by activity and type of land-use.

$$\sum A_{ij} X_j \leq B_i \quad \text{(for all i = 1,2,....n)} \tag{1}$$

where:

i	=	1,2,...,n constraints
j	=	1,2,...,n enterprises
A_{ij}	=	the resource requirement of good 'j' activity for constraint 'i'
X_j	=	the producing activity for good 'j'
B_i	=	the constraint level of constraint 'i'

2.1.4 Factor supply

As with the land constraint, fertiliser as input is a scarce resource. The demand for fertiliser can be derived from the production (supply) functions and is positively correlated with the nature and extent of production activities. In this model, fertiliser prices were fixed. In the case of product markets, the demand functions were implicit in the model's structure. For factor markets, the reverse holds: the factor supply functions are specified beforehand, and the corresponding demand functions are implicit in the production activities of the model.

The supply functions of many factors are simple, being either perfectly inelastic of perfectly elastic. For the sector as a whole, or for regions within the sector, land is a factor that typically is perfectly elastic in the long run. Fertilisers are usually perfectly elastic in supply, at the given price. For an input that has a perfectly elastic supply, their cost is subtracted from the objective function in the model and there is no restriction on their availability.

Fertiliser buying options were introduced into the sector model to provide for the buying of fertiliser. In this case, the nutritional requirements of the crops could be met from alternative types of fertiliser and additional equations were added to the model to enter nutrient requirements and to include buying activities for each type of fertiliser. The available raw materials (fertilisers) are LAN (28 percent of nitrogen), Ureum (46 percent of nitrogen), Superphoshate (10,5 percent of phosphate) and Potassium Chloride (50 percent of potash). The equations were included in the model as follows:

	Maize	Buy LAN	Buy Ureum	Buy Supers	Buy KCl	RHS
Objective function (R)	1500	-P1	-P2	-P3	-P4	
Nitrogen (N)	41	-0.28	-0.46			<=0
Phosphate (P)	13			-0.105		<=0
Potash (K)	4				-0.5	<=0

Source: *Compiled from operational information obtained from FSSA, 1999*

The application rate of fertiliser can be determined by chemical analysis of soil samples. Soil analysis is the only accurate basis for fertiliser and lime recommendations and therefore also for the prevention of soil chemical restrictions for plant production. Leaf analysis is a further valuable aid for the diagnosis of element deficiencies or toxicity. Nutrient concentrations are strongly influenced by climate, cultivars and growth stages, and threshold values are therefore not absolute in this regard. Nitrogen (N) is absorbed by the plant in the inorganic form i.e. ammonium and nitrate nitrogen while Phosphorus (P) is absorbed by the plant in the form of phosphate compound.

Fertiliser application rates for the Free State and the Rest of South Africa were based on assumptions regarding soil conditions and yield targets as summarised in fertilisation application guideline documents compiled by the Small Grain Institute of the Agricultural Research Council. These assumptions as verified with experts are depicted in Table 2.

2.1.5 Alternative crops

The crops selected for the PE model were those regarded as most important from a food security point of view. It was important to identify those crops that compete for land and other resources so that the alternatives that face the farmer are also specified in the PE computer model. In this way, substitution in supply is included in the PE model. As stated earlier four commodities, viz. white and yellow maize, wheat, sorghum, and sunflower were used as alternative crops in this particular application. The model allows for the inclusion of any number of crops. Equation (2) is merely a transfer row where production, on a per hectare basis, is transferred by the yield to a per tonne basis for the selling activity.

$$-Y_j X_j + Q_j \leq 0 \text{ (for all j=1,2,....n)} \quad (2)$$

where:

Y_j = the yield of activity 'j'
X_j = the producing activity for good 'j'
Q_j = the selling activity for good 'j'

Table 2: Assumed fertiliser application rate by region, 1997

	Landuse	Yield (t/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Western Cape					
Wheat	Dryland	2.00	20	9	15
	Irrigation	-	-	-	-
Free State					
Maize	Dryland	2.83	45	13	8
	Irrigation	5.00	95	29	11
Wheat	Dryland	1.63	20	9	15
	Irrigation	4.28	80-120	24-30	25
Sorghum	Dryland	2.51	30	13	0
	Irrigation	-	-	-	-
Sunflowers	Dryland	1.29	22	9	9
	Irrigation	-	-	-	-
Rest of SA					
Maize	Dryland	2.81	45	13	8
	Irrigation	5.93	95	29	11
Wheat	Dryland	1.77	25-30	9	15
	Irrigation	4.30	80-120	24-30	25
Sorghum	Dryland	2.60	30	13	0
	Irrigation	-	-	-	-
Sunflowers	Dryland	1.21	22	9	9
	Irrigation	-	-	-	-

Source: *Small Grain Institute, 1999 (as adapted)*

2.2 Linking activities

Linking activities and equations refer to the transport of agricultural commodities linking any of the two supply points to two consumption points and the one export/import harbour.

Linking activities also include s*upply-demand balances* for the agricultural commodities specified at both national and provincial levels. Balances are required in order to equate supply and demand of agricultural commodities where the quantities are endogenous to the system.

2.3 Demand activities

In theory, the inclusion of demand in the model to enable the endogenous generation of equilibrium prices requires the inclusion of stepped demand functions (equations 3 to 5).

The model is therefore changed as follows (Duloy & Norton, 1973):

$$\sum_{k=1}^{n} \sum_{k=1}^{n} W_{kj} \; V_{kj} - C_j X_J - \phi\sigma = MAX\,! \tag{3}$$

such that:

$$- Q_j + \sum_{k=1}^{n} q_{kj} \; V_{kj} \leq 0 \text{ (for all j=1,2,.......n)} \tag{4}$$

$$\sum_{k=1}^{n} V_{kj} \leq 1 \text{ (for all j=1,2,.......n)} \tag{5}$$

where:

k	=	1,2,...,u segments in the welfare function
W_{kj}	=	the area beneath the demand curve between q_o and q_k
V_{kj}	=	are the activities which linearise the areas beneath each of the k steps in the demand function for good 'j'
q_{kj}	=	the quantity of good 'j' on segment 'k' of the demand function
C_j	=	the cost of producing 1ton of good 'j'
X_j	=	the producing activity of good 'j'
Ø	=	risk aversion coefficient
σ	=	the activity which transfers the standard deviation into the objective function.

The first two terms of Equation (3) measure total welfare (producer plus consumer surplus) since W_j is the area beneath the demand function and C_jX_j is the area beneath the supply function. Equation (4) directs the total quantity produced into the demand activities and ensures that the markets are cleared, i.e., what is produced is consumed. Equation (5) is known as the "convexity constraint". It ensures that only one segment or a fraction of two segments of each demand function enters the solution.

The use of this technique depends on the availability of elasticity estimates for each crop for each of its uses (e.g. animal demand, human demand and export demand), and the current mean quantity consumed and the price are the data requirements of the model.

2.4 Risk activities

Evidence suggests that farmers behave in a risk-averse manner (Hazell, 1982:348 and Young, 1979:1065). Neglect of risk in planning models can lead to considerable overstatements in the size of risky enterprises. Other consequences may be specialised cropping patterns, biased estimates of the supply elasticity of individual commodities, overestimation of the value of certain resources, such as land and irrigation water, and the incorrect prediction of technology choices (Hazell, 1982:384).

There are three main sources of risk:

- yield uncertainty;
- price uncertainty; and
- cost uncertainty.

In this study, gross income variations deflated by the producer price indices (PPI) were used as a measure of risk because of the lack of time series cost data. Risk can be considered as a cost, namely the additional expected return that farmers want as compensation for taking risk (Barry & Fraser, 1976:288). The inclusion of risk means that the marginal cost or supply curve shifts to the left.

3. THE DATA SET

The data requirement of the model is quite formidable and data are not necessarily collected or published in the required format. The data used in the model was largely extracted from the Development Bank of Southern Africa (DBSA) information base.

Production data:

- Input-output coefficients for production by product, technology, region and farm type for each of the nine provinces

- Resource endowments, i.e. land available for cultivation by province
- Base-period quantities produced and marketed
- Quantities and price, and tariffs, taxes, and subsidies, for imports and exports
- Input prices
- A time series on price quantity by product and region, for the risk matrix

Risk data:

Yield variations during the six-year period 1990/91 to 1995/96 were used to model the production risk associated with grain crop cultivation. Provincial time series data from the Directorate Agricultural Statistics and Management Information at the National Department of Agriculture were used.

4. MODEL VALIDATION AND CALIBRATION

Validation begins with a series of comparisons of model results with the reported actual values of the variables. Although several validation tests are relevant, only the production variable was used.

Production is the variable most commonly used in validation tests and for a number of agricultural models, there are reported validation results for production. Typically, there is considerable variation over products in the closeness of the fit to the historical data, and the model-builder may be willing to accept greater deviations in minor products if the predictions are good for the major products. There is no consensus on the statistics to be used in evaluating the fit, but in most cases simple measures such as the mean absolute deviation (MAD) or the percentage absolute deviation (PAD) was used. The price test is identical to the production test, except that it is performed on product prices.

The model was tested by imposing all of the policies that were in operation in 1995/96 in order to see how well it simulates the current situation. The better the current situation is represented by the model, the more reliable the model. According to the results, the values generated by the model correspond fairly well with the actual values if, as a general rule of thumb (as suggested by Hazell & Norton, 1986) a deviation of 15 percent is deemed acceptable for the model. All deviations, national and provincial, are within one percent of the actual values and are within acceptable limits. A PAD of less than one percent across all provinces is obtained. This is a particularly good result for this type of model. The model can thus be accepted as being relatively accurate and can be used for simulating the effects of policy changes with confidence.

5. RESULTS

Various types of scenarios were modelled to demonstrate the working of the model and to illustrate the effects of policy changes on production and fertiliser use of the products selected. The scenarios are modelled under the assumption of a free market for agricultural products. The objective of the model is to maximise expected income from production, imports, exports and consumption of the selected products subject to the availability of resources and the satisfaction of risk and consumption constraints.

The model results discussed here refer specifically to the base-case scenario (scenario A) and the optimal scenario (scenario B).

Under scenario A, the base-case scenario is simulated and provides a standard for comparison with other scenarios. The base-case scenario correlates strongly with the actual production pattern realised in 1995/96. Under scenario B, the optimal solution, the model is allowed to find an optimal production pattern. This is done by allowing the upper and lower boundary of the land constraint to vary by a maximum of 20 and 10 percent respectively. The estimated crop production pattern by region is presented in Table 3.

Crop production patterns show no major shift in production and the areas cultivated, indicating that since the adoption of a policy of trade liberalisation and the shift towards a free market for agricultural products, the actual cropping patterns of grain crops have moved closer to the expected optimum production pattern. Table 3 shows that the total area cultivated will decrease by 2,4 percent. This trend is confirmed by trend analysis performed on time series production data. Results show that except for the area under sunflower (that remains unchanged) and yellow maize that increases, the area utilised by other crops will decrease.

The markets for various field crops are intertwined with one another and with the market for animal products. Production will shift to areas of comparative advantage reflecting relative distances from these markets. For instance, it was found that the major yellow maize consumption areas for South Africa exist in the coastal areas. However, trade liberalisation will result in different regional maize prices in South Africa. Producer prices for coastal regions could in future be determined by the world price. It is expected that maize producers in the

Table 3: Area utilised under scenario A and B (hectares), 1997

	Western Cape	Free State	Rest of RSA	Total
Base-case solution:				
Wheat	403 000	702 000	188 800	1 293 800
White maize		683 000	1 221 000	1 904 000
Yellow maize		425 000	978 000	1 403 000
Sorghum		87 000	87 000	174 000
Sunflower		239 002	368 998	608 000
Total	403 000	2 136 002	2 843 798	5 382 800
Optimal solution:				
Wheat	362 700	682 816	169 920	1 215 436
White maize		614 700	1 098 900	1 713 600
Yellow maize		461 936	1 043 230	1 505 166
Sorghum		84 403	7 800	92 203
Sunflower		286 802	442 797	729 599
Total	362 700	2 130 657	2 762 647	5 256 004
Percent change:				
Wheat	-10.0%	-2.7%	-10.0%	-6.1%
White maize		-10.0%	-10.0%	-10.0%
Yellow maize		8.7%	6.7%	7.3%
Sorghum		-3.0%	-91.0%	-47.0%
Sunflower		20.0%	20.0%	20.0%
Total	-10.0%	-0.3%	-2.9%	-2.4%

Source: *Reproduced from PE Model*

region will increasingly be subjected to international competition and it will therefore be necessary for producers to increase productivity to ensure their comparative advantage.

Maize producers in the western areas (Free State and Northwest) may, for instance, find it more profitable to shift from white maize to yellow maize and expand their livestock industries. Table 3 shows that this is indeed happening – the total area under white maize will decrease with 10 percent and the area under yellow maize will increase by 7,3 percent. The market for white maize in Africa is also limited. In the long run, the shift from white maize to wheat can be expected, following the gradual substitution of wheat products for white maize products in the market place.

As far as *wheat* is concerned, deregulation has benefited the wheat producers in the Free State relative to their counterparts in the south due to a transport cost advantage as they are closer to the major consumption areas and further away from the import harbours. The area under wheat in the Western Cape shows a decrease of 10 percent from the base-case scenario to the optimal solution, as was expected.

Sorghum production will decrease at a rate of 4,5 percent per annum. This decrease is especially prevalent in the Rest of RSA where it will decrease at a rate of 6,2 percent per annum. The model results under scenario B confirm this trend. The area under sorghum will decrease by 47 percent from 174 000 to 92 203 ha. This trend can be attributed to trends in the market for feed grain and malt. As summer cereal, sorghum competes with maize and sunflower for land and in the stockfeed market the price and availability of competitive grain affects the demand for sorghum.

Cropping patterns of *sunflower* show and increase in area under cultivation and production. The model predicts that the area under sunflowers will increase by 20 percent in both the Free State and the Rest of RSA from 608 000 to 729 000, indicating that production will increase to meet the expected total demand. Fluctuating production caused by rainfall patterns, however, necessitates imports on a net average basis. It is predicted that South Africa will become more self-sufficient in the production of sunflower as sunflower replaces maize in the marginal production areas.

Results also clearly show that South Africa is not only self-sufficient in the production of these crops but will in a normal year produce small surpluses for export. Under the optimal scenario, exports will decrease significantly (Table 4). Figure 2 depicts the expected optimum cropping pattern of the selected crops in a normal year.

5.1 Fertiliser use

Fertiliser use will be directly correlated with production patterns in the provinces. A comparison of the base-case scenario and optimum solution has revealed the following results. The movement from a base to an optimum solution results in a drop in total area cultivated, production and exports. Raw materials used will correspondingly decrease as follows: LAN by 2,39 percent, Superphosphate by 2,23 percent and KCl by 0,15 percent. Table 5 is self-explanatory, summarising the use of raw material by product and by province. explanatory, summarising the use of raw material by product and by province.

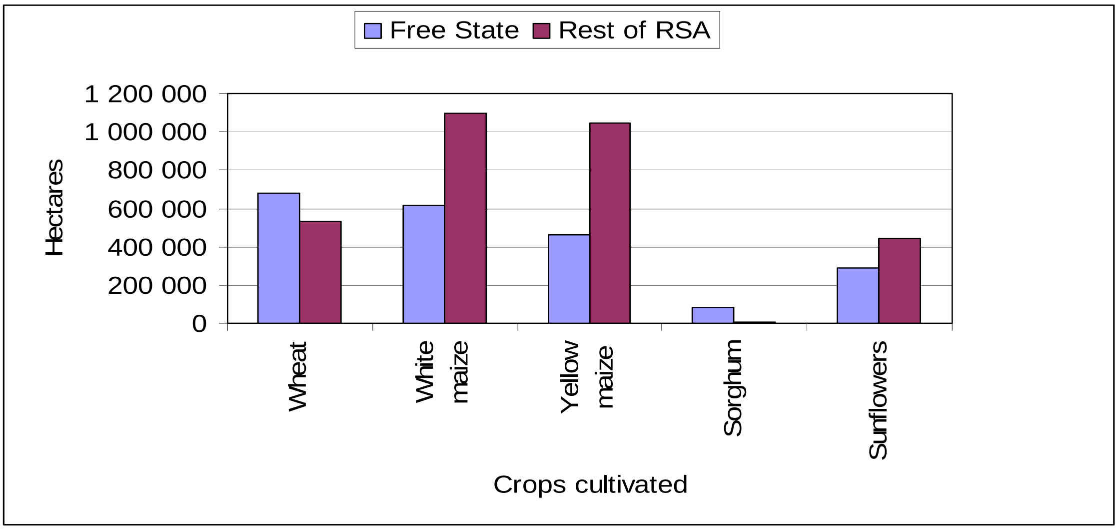

Figure 2: Expected optimum cropping patterns

Source: *Own database*

These results can now be converted to actual N, P and K utilisation by crop and province to simulate changes resulting from the different scenarios. It can be compared with actual fertiliser sales and the model fertiliser application assumptions can be calibrated to simulate actual fertiliser sales by province.

6. CONCLUSIONS

It should be noted that the model has some important limitations. Firstly, the model is only as good as its data. However, simulation of the current situation provides a rigorous test for data, even though it only tests the origins of the underlying functions. Data on nutrient requirement of plants and the soil status need to verified and researched in more detail. Secondly, costs and therefore the economies of scale are assumed as constant. Similarly, stepped demand and welfare functions were not used in order to simplify the model. In theory, the inclusion of demand in the model to enable the endogenous generation of equilibrium prices requires the inclusion of stepped demand functions.

Despite these limitations the results of the PE model highlight the areas of comparative advantage and recommended growth in agricultural production for the Free State and the Rest of South Africa.

Table 4: Food balance situation

	Base-case Scenario	Optimal solution	Per cent change
Area cultivated:	(ha)	(ha)	
Wheat	1 293 800	1 215 436	-6.06
White maize	1 904 000	1 713 600	-10.00
Yellow maize	1 403 000	1 505 166	7.28
Sorghum	174 000	92 293	-47.01
Sunflowers	719 599	729 599	0.00
Total	5 504 399	5 256 004	-4.51
Production:	(metric tons)	(metric tons)	
Wheat	2 702 211	2 515 148	-6.92
White maize	5 287 753	4 758 816	-10.00
Yellow maize	4 293 165	4 621 371	7.64
Sorghum	479 370	447 913	-6.56
Sunflowers	682 300	818 760	20.00
Exports:			
Wheat	187 063	0	0.00
White maize	1 803 423	1 274 666	-29.32
Yellow maize	399 078	727 284	82.24
Sorghum	31 457	0	0.00
Sunflowers	7 997	144 457	1706.39
Consumption:			
Human consumption			
Wheat	2 515 148	2 515 148	
White maize	3 484 150	3 484 150	
Yellow maize	614 850	614 850	
Sorghum	77 913	77 913	
Sunflowers	119 000	119 000	
Animal consumption			
Wheat			
White maize			
Yellow maize	3 279 237	3 279 237	
Sorghum	370 000	370 000	
Sunflowers	555 303	555 303	

Source: *Reproduced from PE Model*

Table 5: Growth rates in the use of fertiliser raw materials (Scenario A & B) (kg)

		Wheat	White maize	Yellow maize	Sorghum	Sunflowers	Total
Optimum solution:							
LAN	.Wcape	51 814 286					51 814 286
LAN	.FreeS	57 410 579	91 730 777	69 361 849	9 043 254	22 534 474	250 080 934
LAN	.RSA	51 377 464	215 010 000	207 394 469	10 067 143	34 791 240	518 640 316
	Total	160 602 329	306 740 777	276 756 318	19 110 397	57 325 714	820 535 535
	%	19.57	37.78	33.73	2.33	6.99	
Supers	.Wcape	69 085 714					69 085 714
Supers	.FreeS	132 075 883	77 465 623	58 552 058	10 449 982	24 583 063	303 126 609
Supers	.RSA	41 376 994	112 800 000	109 527 116	5 965 714	37 954 080	307 623 905
	Total	242 538 592	190 538 592	168 079 174	16 415 497	62 537 143	679 836 228
	%	35.68	27.99	24.72	2.41	9.20	
KCL	.Wcape	3 627 000					3 627 000
KCL	.FreeS	21 089 163	267 732	196 337		5 162 443	26 715 675
KCL	.RSA	7 800 984	10 681 200	10 706 781	469 800	7 970 357	37 629 122
	Total	32 517 147	10 948 932	10 903 118	469 800	13 132 800	67 971 797
	%	47.84	16.11	16.04	0.69	19.32	
Base-case solution:							
LAN	.Wcape	57 571 429					57 571 429
LAN	.FreeS	59 740 571	101 923 086	64 144 514	9 321 429	18 778 729	253 908 329
LAN	.RSA	57 086 071	238 900 000	193 004 971	11 185 714	28 992 700	529 169 457
	Total	174 398 071	340 823 086	257 149 486	20 507 143	47 771 429	840 649 214
	%	20.75	40.54	30.59	2.44	5.68	

Table 5: (continued)

		Wheat	White maize	Yellow maize	Sorghum	Sunflowers	Total
Supers	.Wcape	76 761 905					76 761 905
Supers	.FreeS	135 953 752	86 072 914	54 130 057	10 771 429	20 485 886	307 414 038
Supers	.RSA	45 974 438	125 333 333	101 619 391	6 628 571	31 628 400	311 184 133
	Total	258 690 095	211 406 248	155 749 448	17 400 000	52 114 286	695 360 076
	%	37.20	30.40	22.40	2.50	7.49	
KCL	.Wcape	4 030 000					4 030 000
KCL	.FreeS	21 731 840	297 480	218 152		4 302 036	26 549 508
KCL	.RSA	8 667 760	11 868 000	9 791 448	522 000	6 641 964	37 491 172
	Total	34 429 600	12 165 480	10 009 600	522 000	10 944 000	68 070 680
	%	50.58	17.87	14.70	0.77	16.08	
Per cent change:							
LAN	.Wcape	-10.00%					
LAN	.FreeS	-3.90%	-10.00%	8.13%	-2.98%	20.00%	-1.51%
LAN	.RSA	-10.00%	-10.00%	7.45%	-10.00%	20.00%	-1.99%
	Total	-7.81%	-10.00%	7.62%	-6.81%	20.00%	-2.39%
Supers	.Wcape	-10.00%					-10.00%
Supers	.FreeS	-2.85%	-10.00%	8.17%	-2.98%	20.00%	-1.39%
Supers	.RSA	-10.00%	-10.00%	7.78%	-10.00%	20.00%	-1.14%
	Total	-6.24%	-10.00%	7.92%	-5.69%	20.00%	-2.23%
KCL	.Wcape	-10.00%					-10.00%
KCL	.FreeS	-2.96%	-10.00%	-10.00%		20.00%	-.63%
KCL	.RSA	-10.00%	-10.00%	9.35%	-10.00%	20.00%	0.37%
	Total	-5.55%	-10.00%	8.93%	-10.00%	20.00%	-0.15%

Source: *Reproduced from PE Model*

Table 6: Fertiliser use by crop (kg), 1997

	Wheat (kg)	White maize (kg)	Yellow maize (kg)	Sorghum (kg)	Sunflowers (kg)	Total (kg)
Optimum						
N	44 968 652	85 887 418	77 491 769	5 350 911	16 051 200	229 749 950
P	25 466 552	19 977 890	17 648 313	1 723 648	6 566 400	71 382 804
K	16 258 574	5 474 466	5 451 559	234 900	6 566 400	33 985 898
Base-case						
N	48 831 460	95 430 464	72 001 856	5 742 000	13 376 000	235 381 780
P	27 162 460	22 197 656	16 353 692	1 827 000	5 472 000	73 012 808
K	17 214 800	6 082 740	5 004 800	261 000	5 472 000	34 035 340
Percent change						
N	-7.9%	-10.0%	7.6%	-6.8%	20.0%	-2.4%
P	-6.2%	-10.0%	7.9%	-5.7%	20.0%	-2.2%
K	-5.6%	-10.0%	8.9%	-10.0%	20.0%	-0.1%

Source: *Calculated from PE Model*

The model, having been calibrated to simulate changes in production patterns under certain scenarios, is a useful tool in predicting fertiliser use in a product- and region-specific context and the results generated by the model proved to be adequate given the limitations.

Decision making at all levels should be based on full and timely information. With correct information the PE model as developed and applied could prove to be a useful tool to analyse the impact of various policies at a provincial level.

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