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THE DEVELOPMENT OF A WHOLE-FARM PLANNING MODEL WITH DYNAMIC LINEAR PROGRAMMING FOR THE LIVESTOCK- SMALLGRAIN-PASTURE AREAS OF THE SOUTHERN CAPE

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ABSTRACT

The ineffectiveness of agricultural extension services in South Africa is characterised by two distinct paradigms i.e. the technical-educative and that of agricultural economics. This situation gives rise to the problem of scientists not being able to present a holistic solution to management problems to farm managers and on agriculture policy to policy makers. As a result the full consequences of management problems or agricultural policies are seldom indicated. The reason is that scientists have failed to solve the problems within the systems framework. In spite of attempts to integrate the two paradigms there is, however, no user-friendly planning model available with a holistic approach (system orientated), that integrates the technical-biological with the economical aspects.

The OPTIMA model has been developed and continuously tested against the original aims that were set. The final result complies, more or less, with all these aims. Even if a model functions mathematically correctly it must be proven valid in practice. Although the validation of a model is subjective, some applications were done to validate the model. The study has indicated that the model can be successfully used on an individual farm level as well as on the impact of agricultural policy on a micro-level.

1. Introduction

The ineffectiveness of agricultural extension services in South Africa is characterised by two distinct paradigms i.e. the technical-educative and that of agricultural economics. This situation gives rise to the problem of scientists not being able to present a holistic solution to management problems to farm managers and on agriculture policy to policy makers. As a result the full consequences of management problems or agricultural policies are seldom indicated. The reason is that scientists have failed to solve the problems within the systems framework. In spite of attempts to improve holistic problem solving, there is, however, no user-friendly planning model available with a holistic approach (system orientated), that integrates the technical-biological with the economical aspects.

The rapid development of computer science and technology has made it possible to develop large scale planning models on a microcomputer. The objective with OPTIMA was to establish a user-friendly holistic farm planning model to contribute to improved farm planning, extension, and the formulation of agricultural policy. The point of departure with this study was to utilise the progress in computer technology to make the dynamic linear programming (DLP) technique user-friendly. The following requirements were set as a goal for the successful development of the model:

(i) The model must be user-friendly enough, within the confinements of a spreadsheet program (like Quattro Pro), to enable someone with limited knowledge of the DLP technique to use the model.
(ii) The analysis period must be limited to the minimum to save time and expense.
(iii) The model must be dynamic. It must be able to handle some stochastic elements within the limitations of DLP.
(iv) The analysis must be presented in an acceptable and interpretable way.
(v) It should be possible to use the model repeatedly without major adjustments.
(vi) To develop more than one model capable of analysing the most common farm systems without the need to make major adjustments.
(vii) To develop a database to include enterprise budgets for the area where the model will be applied.
(viii) The model must be applicable on a project basis (typical farm, case study) as well as on an individual farm level.

2. Resource allocation problems

There are very few people who have never been confronted with the management problem of allocating scarce resources to alternative uses. From an agricultural development point of view this is, after all, what agriculturists do everyday. For instance, there is only a certain amount of capital, labour, land, water, etc. available for the establishment of a nearly unlimited number of small-scale farmers in South Africa. Will the capital investment made out of public or private funds be spent well from an socio-economic point of view?

The Minister of Agriculture, for example, decides to introduce a land tax. In effect this means that the cost of a scarce resource, land, is now higher. The question is whether this policy will harm commercial farmers and at what rate will this harm, if any, take effect? The other important question is whether this tax will cause major structural changes to existing farming practices? The labour unions, for example, put pressure on the government to introduce a minimum wage in agriculture. At what level will this minimum wage start to affect the production of a certain enterprise negatively? Because of world surplus production the wheat/maize price is under pressure. At what level will it be more profitable for farmers to produce alternative products with the same scarce resources? If other alternatives become viable, what will the influence be on resource use and the profitability of farms. A research project to increase the production per hectare (ha) of wheat, costing a specific amount, is being proposed to the government, for example. Will the benefit of funding this research project be higher than the cost?

Farmers, for example, can ask the following questions on micro level: If a farmer introduces a new livestock enterprise on his farm (for example ostriches), what effect will it have on his financial performance, resource use, and the other existing enterprises? Would it be better to sell his grain to the miller or better to feed the grain to his livestock? What strategy should be followed to increase livestock numbers without having to increase farm size? In other words, how can a farmer improve his fodder flow and what is the most economic way to make provision for times of feed shortages? Is it better for a farmer to buy feed or to produce his own feed? How sensitive is a farm to an increase in interest rates? At which rate will it really start to have a negative effect on the financial performance? A farmer buys more land, for example, and wants to know what will be the best way to utilise this land in combination with his existing resources?

3. Development of the Optima Model

Tremendous progress had been made over the last four to five years in computer technology. These advances made it possible to start with the development of a micro-computer model with the capacity not only to do the same job in a matter of days instead of months, but to perform the task much more cheaply and reliably. The technique was also improved to render it sufficiently user-friendly to enable a person with limited knowledge of the technique to make use of it.

Although the DLP technique has been extensively used in other countries, especially the USA and Europe, the problems were and are still the same in South Africa as elsewhere. No user-friendly software is available to use a technique such as DLP without high cost and frustration. The second reason for the development of OPTIMA was the frustration of not being able to provide policy makers as well as farmers, with a holistic (whole farm) answer to the frequently asked questions. It has often happened in the past that the soil scientist, the animal scientist, the economist, etc. have each given the farmer or policy maker their own isolated point of view on development or extension aspects without making them aware of the whole truth.

Although the OPTIMA model is not applicable to all circumstances and is probably far from perfect, the concept has been developed and tested. This model paves the way for the development of similar models where other circumstances exist. The name OPTIMA was derived from the word optimal.

4. Characteristics of the Optima Model

At present the model consists of five different but interrelated parts:

- The budget database.
- Present situation analysis.
- Alternative farm plan analysis.
- A report on the cash flow, capital flow, resource uses, sensitivity analysis, etc., for each alternative plan/analysis.
- The comparison of the alternatives by means of a grouping facility.

The working procedure is as follows:

- Survey of the farm's resources (quantity as well as quality of resources).
- Draw up enterprise budgets for all the crop and livestock enterprises that are biologically adapted to the area and for which there is a market.
- Analyse the present financial situation of the farm.
- Do alternative analyses with OPTIMA.
- Print out the reports and use them to make conclusions.
- Make decisions.

The most time-consuming job is to draw up the enterprise budgets and to verify all the information. Although the procedure of using individual enterprise budgets is very time consuming it has a snowball effect on the generation of norms in a particular area. From an extension point of view this is a very important spin-off. It is important to note that once a large database of enterprise budgets has been built up, the time needed to accommodate a new farmer decreases considerably.

The time needed to do an analysis after the initial information has been gathered is as follows:

- To do the present situation analysis: 1.5 hours.
- To type in the resource information and update all information: 1.5 hours.
- To do an analysis and prepare a report: 30 minutes.

Once all the relative information is captured on the computer the time to do alternative analyses decreases considerably. It will take a minimum of 25 minutes and a maximum of 35 minutes to change any of the data, update the model, rerun the optimiser and to prepare a report of more than 100 pages when all the possible graphs and tables are printed out. It is also possible to prepare only a part of the report, in say 10 to 15 minutes, if all the information is not needed.

The composition of the OPTIMA report is as follows:

- Inventory of all the assets and liabilities of the farm.
- Capital structure summary.
- Balance sheet.
- Present situation analysis up to the level of farm profit.
- Six-year cash flow projection for the farmer's plan.
- OPTIMA plan.
- Projected six-year optimal cash flow.
- Capital flow over six years.
- Present value of the net cash receipts.
- Sensitivity analysis.
- Resource use analysis.
- Feed flow.
- Figures and tables of resource input and activity output.
- The grouping of data to analyse the percentage difference between alternative farm plans.

5. Application possibilities for the Optima Model

Some applications were done to illustrate the application possibilities of the model. It is, of course, not possible to show applications on all the possible questions that could be asked about the farming system. For the purposes of this paper it was decided to divide the applications into two broad categories:

- Applications on an individual farm level (plan an existing farm).

  Small-grain prices have declined on average by 30 percent. The prospects for an increase in prices are not good over the long term. Farmers are forced to change to livestock production as their main source of income. What are the consequences?

  Due to the above-mentioned prospects, farmers want to evaluate the introduction of canola and ostriches as alternatives.

- Applications on the evaluation of the influence of macro-economic factors on agriculture in order to advise policy makers.

  Introduction of a land tax.
  Effect of interest rate changes.
  Effect of product prices changes.
  Effect of changes in yield (management, research, and drought).

The following analyses are purely illustrative of what OPTIMA can be used for. Although the data used are realistic, the assumptions for some of the parameters that were changed are not necessarily defendable.

5.1 Applications on an individual farm level

The farm used for the purpose of the illustration is described in Table 1.

Table 1: Description of case study farm

Total Farm size (ha)	1 496
Dryland (ha)	756.5
Irrigation (ha)	29.5
Veld (ha)	710
Total capital investment (R)	4 139 715
Fixed labourers	7
Casual labourers	5
Small tractors	2
Medium tractors	2
Combine	1
Overhead costs (R)	111 000
Household costs (R)	72 000
Max short term loan (R)	1 241 914 (30% of assets)
Own operating capital (R)	200 000
Interest on short-term loan (%)	19
Interest on savings (%)	16

The first step in the planning of a farm with OPTIMA is to establish what the present plan will bring forth for the next six years. After this, the OPTIMA model is used in search for a better (optimal) plan for the existing activities with a higher financial return over the next six years. The indicator being used to measure the financial performance of a plan over the six-year period is the net present value (NPV) of the net cash receipts over the planning period. The OPTIMA plan compared to the present situation is presented in Table 2.

Table 2: Present plan compared to optimum plan

Present activities	%	Optimal activities	%	Difference
Wheat	33.2	Wheat	27.4	-5.8
Barley	6.6	Barley	22.6	+16.0
Feedgrain	8.3	Feedgrain	20.7	+12.4
Pastures	50.6	Pastures	28.7	-21.9
Other crops	1.3	Other crops	0.6	-0.6
Sheep (LSU)*	254.0	Sheep (LSU)	224.0	-30.0
Milk cattle (LSU)	230.0	Milk cattle (LSU)	150.0	-80.0
NPV (R)	538 676	NPV (R)	1 706 282	1 167 606

**LSU=large stock unit*

The analysis showed that the farm was possibly overstocked and that a better balance between feedgrain and pastures could be a better utilisation of resources. The OPTIMA model also showed that the financial position of this farm measured by the NPV (net present value of the net cash receipts over six years) could be increased considerably by the reallocation of resources.

It is, however, important to note that the optimal answer should be discussed with a multidisciplinary panel to see whether the answer is practical. For the purpose of this presentation this was not done. The assumption was therefore made that the optimal plan was a practical one. Once this combination had been determined the following analysis was done using the above analysis as a control.

In a next scenario everything was kept the same except for a decrease of 30 percent in the prices of all smallgrain, with no prospects in the long term for an improvement. Table 3 shows the effect of the 30 percent decrease in grain prices. The area planted to each crop is the total for the six year planning period.

Table 3: Decrease of 30 percent in grain prices

Control		30% decrease in smallgrain prices		
Activities	Number	Activity	Number	Difference %
Wheat	1 248	Wheat	336	-73.6
Barley	1 030	Barley	79	-92.3
Feedgrain	943	Feedgrain	1 846	+95.6
Pastures	1 308	Pastures	2 043	+56.1
Other crops	30	Other crops	30	0
Sheep	224	Sheep	457	+104.0
Milk cattle	150	Milk cattle	150	0
NPV (R)	1 706 282	NPV (R)	705 289	-58.67

From the analysis it was clear that the optimal plan under these circumstances indicated a structural change towards a livestock farming system. After this analysis the overhead costs was decreased by 50 percent. It was assumed that the overhead costs of a livestock farm are much lower than that of a smallgrain farm. Although the overhead costs would probably not be that much lower, a big incremental change was made just to show the effect clearly for the purpose of the presentation.

From Table 4 it is clear that the optimum combination of activities remained the same, but the NPV was about 61 percent higher with the lower overhead costs. This clearly indicated the importance of adjusting the capital structure of a farm when such a major shift in activities is considered.

Table 4: Decrease of 50 percent in overhead costs

30% decrease: smallgrain prices		50% decrease in overhead costs		
Activity	Number	Activity	Number	Difference %
Wheat	336	Wheat	336	0
Barley	79	Barley	79	0
Feed grain	1 846	Feed grain	1 846	0
Pastures	2 043	Pastures	2 043	0
Other crops	30	Other crops	30	0
Sheep	457	Sheep	457	0
Milk cattle	150	Milk cattle	150	0
NPV (R)	705 289	NPV (R)	1 137 432	+61.3

After this analysis the overhead costs were changed to their original value and a maximum of 70 ha canola was allowed to come into the solution. The results are given in Table 5.

Table 5: Inclusion of 70 ha canola in the solution

30% decrease: smallgrain prices		Max of 70 ha canola: no decrease in overheads		
Activity	Number	Activity	Number	Difference %
Wheat	336	Wheat	358	+6.42
Barley	79	Barley	92	+16.50
Canola	0	Canola	70	+100.00
Feedgrain	1 846	Feedgrain	1 740	+5.70
Pastures	2 043	Pastures	2 025	-0.90
Other crops	30	Other crops	30	0
Sheep	457	Sheep	446	-2.40
Milk cattle	150	Milk cattle	150	0
NPV (R)	705 289	NPV (R)	902 926	+28

The canola could only improve the NPV by about 28 percent. In the next analysis 40 large stock unit (LSU) ostriches, as well as the canola, were allowed to come into the optimal solution and the overhead costs were again reduced by 50 percent. The results are presented in Table 6.

Table 6: Optimum plan including 70 ha canola and 40 LSU ostriches

30% decrease: smallgrain prices		Max. of 70 ha canola and 40 LSU ostriches		
Activity	Number	Activity	Number	Difference %
Wheat	336	Wheat	351	+4.4
Barley	79	Barley	67	-14.8
Canola	0	Canola	70	+100.0
Feedgrain	1 846	Feedgrain	1 556	-15.7
Pastures	2 043	Pastures	1 854	-9.2
Other crops	30	Other crops	30	0
Sheep	457	Sheep	390	-14.5
Milk cattle	150	Milk cattle	150	0
Ostriches	0	Ostriches	40	+100.0
NPV (R)	705 289	NPV (R)	1 292 707	+83

It is clear from Table 6 that ostriches were substituted for sheep. Furthermore, there was a decrease in almost all the other activities except for wheat and canola. This reaction was due to a labour shortage. The ostrich enterprise is very labour intensive and it was therefore decided to add two labourers to the permanent staff and to adjust fixed costs accordingly. The result of the change can be seen in Table 7.

Table 7: Optimum plan including 70 ha canola, 40 LSU ostriches and additional labour

30% decrease: smallgrain prices		Max. of 70 ha canola, 40 LSU ostriches and additional labour		
Activity	Number	Activity	Number	Difference %
Wheat	336	Wheat	366	+8.83
Barley	79	Barley	86	+8.58
Canola	0	Canola	70	+100.00
Feedgrain	1 846	Feedgrain	1 682	-8.86
Pastures	2 043	Pastures	1 955	-4.27
Other crops	30	Other crops	30	0
Sheep	457	Sheep	419	-8.31
Milk cattle	150	Milk cattle	150	0
Ostriches	0	Ostriches	40	+100.00
NPV (R)	705 289	NPV (R)	1 405 906	+99.34

With more labour available it was possible for the farm to increase NPV by increasing sheep numbers by about 29 LSU (174 sheep).

The main conclusion from this analysis was that a more livestock orientated farming system was included in the optimal plan when smallgrain prices were decreased. There should, however, be the necessary adjustments to the capital structure of the farm to ensure high profitability. Another conclusion was that more regular labour could be utilised profitably if ostriches were included in the farm plan as an alternative enterprise. Canola did not make such a big difference in this example, as the area that was suitable for canola on this specific farm was very limited. In other areas this enterprise may have a much bigger impact as an alternative enterprise.

It was also clear that it was possible to develop a farm plan that was almost a 100 percent more profitable than the plan where the smallgrain prices were collapsed. Although the NPV of the livestock plan was still 17.6 percent lower than the optimal plan with the smallgrain as the most important enterprise, there was still the possibility of improving the plan by increasing the number of ostriches, etc. The purpose of these analyses was to show how it is possible to do tactical planning on farm level where the existing farm structure is not profitable anymore.

5.2 *Applications to evaluate the influence of macro-economic factors on agriculture to advise policy makers*

Applications were examined in this section to explain the influence of macro-economic factors on the farm systems.

Table 8: The influence of the introduction of a land tax at different levels

Item	Control	1.0 % tax	1.5% tax	2.0% tax
Wheat	1 249	1 249	1 249	1 249
% change	****	0	0	0
Barley	1 030	1 030	1 030	1 030
% change	****	0	0	0
Canola	0	0	0	0
% change	****	0	0	0
Feedgrains	943	943	943	943
% change	****	0	0	0
Pastures	1 309	1 309	1 309	1 309
% change	****	0	0	0
Other	30	30	30	30
% change	****	0	0	0
Animal (LSU)	374	374	374	374
% change	****	0	0	0
NPV (R)	1 706 282	1 560 969	1 488 218	1 413 881
% change	****	-8.52	-12.78	-17.14
Rand value change (R)	****	145 313	218 064	292 401

It can be seen from Table 8 that it is very important to do a thorough investigation before a policy measure like introducing a land tax is considered. The rate at which a land tax is introduced and the basis on which the rate is calculated are just as important. If a land tax is calculated on the market value of the land it can have quite a dramatic effect on the cash flow of farms. Table 8 shows that with every 0.5 percentage point increase in a land tax there was a decrease of approximately 4.2 to 4.4 percent in the NPV of the farm. In monetary terms this farm would be R145 000, R218 000, and R292 000 worse off over a six-year period at a land tax rate of 1.0, 1.5 and 2.0 percent respectively.

It is also important to note that, with all the calculations, no provision has been made for the payment of personal income tax or for the replacement of capital items such as machinery and implements. If this were also taken into account it could be that this farm would not be economically viable. Even if the farm was economically viable there should still be an economic incentive for any entrepreneur to conduct any business. The return on capital invested in agriculture is already low (approximately 5 percent on average for the country). If land tax erodes the already small return on capital it may lead to a disinvestment in agriculture. The OPTIMA model is a highly effective planning tool to objectively research the influence of most agricultural policy measures on farm level.

The reason for the relatively small changes in the optimum farm plans in Table 9, with different interest rates, was that this farming system became self-sufficient in respect of operating capital from the end of the fourth year. The higher investment rate that accompanied the higher borrowing rate offset the negative effect in that the surplus capital in year five and six were invested at a higher interest rate.

It is important to note that a higher interest rate had a more negative effect on the farm than a lower interest rate had a positive effect.

Table 9: The influence of short-term interest rates

Item	Control	3% increase	3% decrease
Wheat	1 249	1 252	1 249
% change	****	0.3	0
Barley	1 030	1 035	1 030
% change	****	0.4	0
Canola	0	0	0
% change	****	0	0
Feedgrains	943	939	943
% change	****	-0.4	0
Pastures	1 309	1 305	1 309
% change	****	-0.3	0
Other	30	30	30
% change	****	0	0
Animal (LSU)	374	372	374
% change	****	-0.6	0
NPV (R)	1 706 282	1 593 718	1 794 928
% change	****	-6.6	5.2

The influence of changes in product price and in yield of cash crops is presented in Table 10. For these analyses a 10, 20 and 30 percent decrease was made respectively on the price of wheat and thereafter the same changes were made in the yield of wheat. All other prices and yields were kept constant. This would probably never happen in the real world but the analyses were done to indicate that the same incremental decrease in price and yield showed that the variation in yield effected the NPV more negatively than price.

Table 10: **The influence of a variation in the wheat price and yield**

Item	Con-trol	Price -10%	Price -20%	Price -30%	Yield -10%	Yield -20%	Yield -30%
Wheat	1 249	1 237	1 057	962	1 240	1 088	960
% change		-1.0	-15.3	-22.9	-0.7	-12.8	-23.1
Barley	1 030	1 019	839	744	1 022	870	742
% change		-1.2	-18.6	-27.8	-0.8	-15.6	-28.0
Canola	0	0	0	0	0	0	0
% change		0	0	0	0	0	0
Feedgrains	943	955	1 134	1 229	949	1 103	1 221
% change		1.3	20.2	30.3	0.7	17.0	29.5
Pastures	1 309	1 319	1 441	1 521	1 302	1 412	1 517
% change		0.8	10.2	16.2	-0.5	7.9	16.0
Other	30	30	30	30	30	30	30
% change		0	0	0	0	0	0
Animal (LSU)	374	379	381	411	362	369	402
% change		1.3	1.9	9.9	-3.2	-1.3	7.5
NPV (R mil.)	1.706	1.699	1.353	1.205	1.445	1.270	1.115
% change		-0.4	-20.7	-29.4	-15.3	-25.5	-34.6

From the results in Table 10 it is clear that a 10 percent decrease in yield had a 14.9 percent more negative effect than a 10 percent decrease in price, 4.8 percent more negative with a 20 percent decrease, and 5.2 percent more negative with a 30 percent decrease. In both circumstances the 10 and 20 percent decreases, respectively, did not have a significant influence on livestock numbers. The livestock numbers only start to change with a decrease of 30 percent. The analyses also showed that the livestock enterprise was more sensitive for yield changes because it directly influenced the available amount of dry matter. The fact that the yield and price of only the wheat enterprise was changed also indicated the importance of the wheat stubble as part of the fodder flow. As the parameters were varied, it was clear that the loss in stubble from the wheat was compensated for by the increased production of feedgrain and pastures.

6. Conclusion

It was not practical to illustrate all the possible applications of the existing OPTIMA model in this paper. Although DLP is an old technique used for planning, it could not be used on a regular basis as a planning tool in the past because of the user-unfriendly computer software that was available. This model is the first of its kind in South Africa for farm planning and it is now possible to use this technique on a regular basis as part of the tools used by agricultural economists.

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