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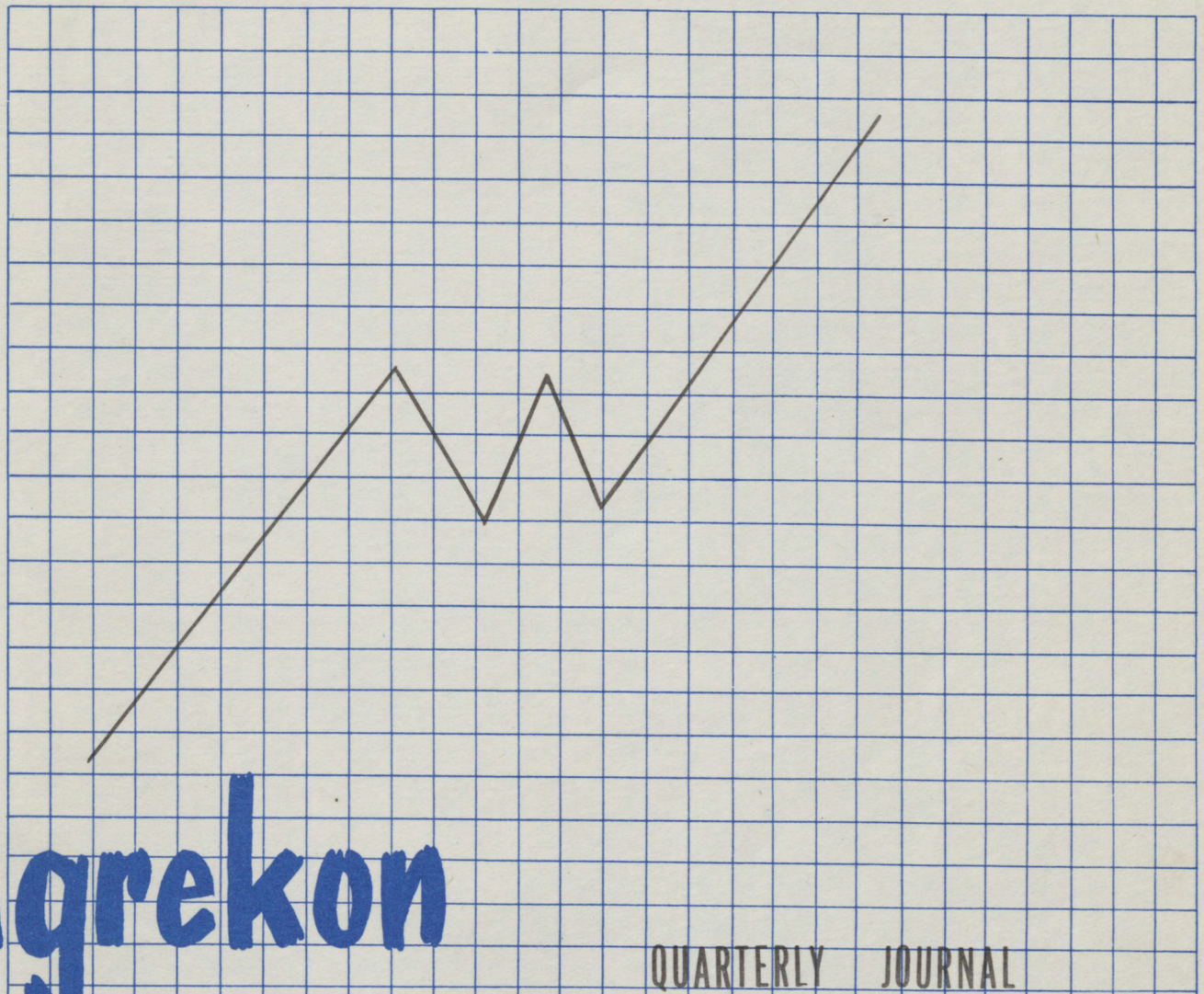

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OPTIMUM ORGANISATION ON DEVELOPED IRRIGATION FARMS IN THE MALELANE-KOMATIPOORT REGION*

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1. INTRODUCTION

It is well known that water is a scarce resource in South Africa. In its second report, the Commission of Inquiry into Agriculture (1970, pp. 63 & 64) expressed the opinion that owing to the importance and scarcity of irrigation water, only farmers with the best agricultural managerial abilities should farm on irrigated lands, and also that serious attempts should be made to utilise irrigated soils as well as irrigation water optimally.

Irrigation areas in South Africa differ radically from each other in many respects such as climate, soil types, relative availability of water and suitable soils, stages of development, etc. This implies that the different irrigation areas should be studied individually.

Along the Crocodile, Komati and Sabie Rivers, approximately 64 000 hectares of land are irrigated, with citrus and subtropical fruit, sugar-cane, vegetables, tobacco and pastures as the most prominent crops (Soil & Irrigation Research Institute, 1974). This region can in itself not be regarded as homogeneous (Brotherton, 1980) and may conveniently be divided into a few subregions. In this article, attention will be given to one such sub-region in the vicinity of Malelane and Komatipoort.

The area is a little over 300 metres above sea-level; its mean highest temperature in the hottest month of the year varies between 37,5 and 40,0 °C and its mean lowest temperature in the coldest month varies between 2,5 and 5,0 °C. The region is warm and generally frost-free, except for low-lying areas along rivers (Ehlers, 1977). The mean annual rainfall is approximately 620 mm and is fairly consistent; over the 15-year period preceding this study it varied between 356 and 950 mm. There is a probability of 0,60 that monthly precipitation in December, January and February will exceed 75 mm. (Ehlers, 1977). Hail is scarce. Soils are deep, of high potential, and suitable for the production of a variety of crops. (Macvicar & Perfect, 1971)

This area is close to national states and to Swaziland. Labour is therefore not a scarce factor. Some farms are more developed than others in the sense that perennial crops (fruit and/or sugar-cane) have been established.

2. RESEARCH PROCEDURE

In this study, standard data as would pertain to farms with above-average management were utilised in the planning of selected actual case study farms. Results pertaining to one particular case study will be presented.

Group conferences were used to obtain data on crops. This information involved physical data, material labour usage and some of the variable costs. In some cases, improved pest control practices recommended by an extension officer were incorporated in the data. Technical constraints on certain crops and practices were also supplied by the extension officers. Standard costs on tractors and machinery, as calculated in Natal by Ortmann (1976), were used. Data on prices of inputs and crops were obtained from co-operatives and wholesalers.

Water requirements of crops were obtained from a joint publication by the Department of Agricultural Technical Services and the Department of Water Affairs. (1973)

Gross margins per hectare of crops were calculated by subtracting variable costs from gross receipts. The following cost items were considered to be variable: seed and plant material, fertiliser, herbicides, pesticides, marketing costs, contract work, crop insurance, packing materials, labour costs and machinery operating costs.[2] A net farm income could eventually be calculated by subtracting the following fixed cost items from the sum of gross margins: costs of fixed improvements; depreciation, tax and insurance on tractors, vehicles and machines; electricity; manager's salary; general overheads, such as telephone, stationery, audit fees, etc.

These data were used in linear programming models to determine optimum organisation.

3. THE LINEAR PROGRAMMING MODEL

The model employed was a profit maximising model, built to maximise the sum of gross margins.

*Based on an M Sc (Agric) thesis by I A Brotherton, University of Pretoria. The study was financed by the Division of Agricultural Production Economics

Three types of activities were included in the objective function:

1) Real activities in the form of hectares of productive enterprises such as Valencias, sugar-cane or tobacco.
2) Purchase activities, to determine how much labour (casual and regular) should be hired, and how much capital should be borrowed.
3) Transfer activities, to tie up monthly labour use to the hiring of the labour, to tie up the use of capital to borrowing, etc.

The real activities involved are shown in Table 1. It may be noted that the table includes more than one activity each for tomatoes, Virginia tobacco, Burley tobacco, cabbage, green beans, cucumbers and gem squash. This is to cater for plantings in different months, which occupy land at different times and should therefore be regarded as different enterprises.

Four types of constraints were used:

1) Real constraints, relating to resource restrictions such as the availability of land, water, tractor hours, etc.
   Tractor hour availability per month was based on tractors existing on the case study farms, and amounted to the number of tractors multiplied by 260. The case study farm of which results will be presented has 224 hectares of irrigated land on which eight tractors, varying from 57 kW to 78 kW, are used. Therefore approximately 2 080 tractor hours are available per month. Water availability was obtained from farmers and pipeline capacities, and was calculated to be 2 540 m^3 per hectare per month.
2) Transfer constraints were used since it was necessary not only to limit labour usage to labour hiring (the purchase activity) but also to allow for a labour transfer in the sense that regular labourers could thus, in times of underutilisation of their time, be used for jobs usually performed by casual labourers.
3) Institutional constraints affected some crops. There are, for example, quota restrictions on sugar-cane. Because of high risk, it was decided to place arbitrary constraints on areas to be planted to cucumbers, gem squash, tomatoes and tobacco. The area for factory tomatoes was limited to contracts readily negotiable.
4) Technical constraints were regarded as necessary because it is also the aim to maintain long-run productivity of the soil. In the case of some crops, there is a danger of accumulation of pests and diseases if they should be in continuous production on the same land.

If tomatoes, for example are grown in monoculture, build-up of the nematode population can be expected. Certain crops, such as tomatoes and tobacco are moreover botanically related, and diseases or pests can often be transferred from one to the other. These technical constraints are shown in Table 2.

The constraints matrix consists of 120 rows and 76 columns

4. EXISTING ORGANISATION AND OPTIMISATION ANALYSES

Different farms have different resource endowments, and different farms are in different financial and credit situations. Their product preferences also differ, and they have different relative preferences between risky revenues and certain, but smaller incomes.

TABLE 1 - Land occupation periods for different crops

Crops	Occupation period
Valencias	All year
Grapefruit	All year
Sugar	All year
Tomatoes (1)	December to June
Tomatoes (2)	January to July
Tamatoes (3)	February to August
Tomatoes (4)	March to September
Tomatoes (5)	April to October
Virginia tobacco (1)	August to February
Virginia tobacco (2)	October to March
Burley tobacco (1)	August to January
Burley tobacco (2)	October to March
Cabbage (1)	January to May
Cabbage (2)	February to July
Cabbage (3)	March to August
Cabbage (4)	April to September
Cabbage (5)	May to October
Green beans (1)	March to August
Green beans (2)	July to December
Cotton	October to May
Factory tomatoes	December to June
Cucumbers (1)	February to June
Cucumbers (2)	April to August
Cucumbers (3)	June to October
Gem squash (1)	February to June
Gem squash (2)	April to August
Gem squash (3)	June to October

TABLE 2 - Maximum allowable area under crops

Crop	Maximum allowed appearance in a crop rotation cycle	Maximum allowable percentage of available ground under the crop per year
Cotton	Plant two out of three years	66,7 %
Green beans	Plant three out of four years	75,0 %
Tomatoes	Plant one out of three years	33,3 %
Burley tobacco	Plant one out of three years	33,3 %
Virginia tobacco	Plant one out of two years	50,0 %

Since, however, the results obtained in the case studies were rather similar, particularly regarding the use of tractors, soil-water relationships and, broadly, also regarding enterprise choices, results of one case study are used to illustrate the salient factors for the region.

The case study farm contained, as mentioned previously, 224 hectares of irrigation land.

In the year preceding the analysis, the following crops were grown:

Valencias	14 hectares	116 hectares of perennial crops
Grapefruit	24 hectares	
Sugar-cane	80 hectares	
Tomatoes	12 hectares	80 hectares of annual crops
Cotton	43 hectares	
Grean beans	25 hectares	

Thus, 52,7 per cent of the irrigation land was planted to perennial crops, and only 75,5 per cent of the rest of the land was used for annual crops. This does not imply that almost 25 per cent of land available for annual crops was permanently idle; rotational cropping was practised, leaving different fields idle during different years.

The fixed costs amounted to R50 456 per annum, the total farm gross margin was R136 408 and the net income was R85 953. The total capital investment was R702 000. Thus, net farm income per R100 investment amounted to R12,24. Net farm income per hectare of irrigated land was R384.

Two linear programming solution sets were obtained:

1) A short-run solution, in which present areas under perennial crops were regarded as given. Neither were annual crops not yet grown considered. The purpose was to obtain a short-run optimum to which the farmer could move within one year without tampering with perennial or new crops.
2) A long-run solution, in which perennial crops were not regarded as fixed. The purpose was to determine in which direction the total organisation should move over a period of time.

5. EMPERICAL RESULTS: SHORT RUN

This analysis involves the primal solution, in which the optimum choice of crops, the optimum resource use and the total gross margin were determined. Net farm income analyses are based on this.

The optimum crop combination appears in Table 3.

One point of interest is the relatively large area to be planted to green beans, which is a crop with a relatively small gross margin. This is due to its short growth period and its time of planting, which puts it in a favourable situation compared to some other crops which have high gross margins but which would necessitate hiring more permanent labourers and borrowing more short-term capital. Green beans also utilise capacity which would otherwise be idle.

A total utilisation of 111,9 per cent of irrigated land indicates that part of the land carries more than one full crop per year.

Table 4 illustrates the use of land, labour, water and tractor hours.

It appears that land is fully used in four months: August, May, October, December. The smallest utilisation (June) is 170 hectares, i.e. 76 per cent of all available land.

Regular labour hours purchased amount to 11 065 hours per month, which is equivalent to employing 50 labourers. These labourers will have some idle time during the first four months of the year, but will be fully occupied for eight months. Large numbers of casual labourers will be required from May to October, mostly for harvesting cotton and sugar-cane.

It also appears that in no month will more than 65 per cent of available water be utilised. This is significant because some farmers often complain that there is not enough water available, whereas extension officers and other technical advisers are of the opinion that soil is being ruined by over-irrigation. These results support the latter view.

It also appears that tractors will be greatly underutilised. The optimum solution never needs more than 54 per cent of tractor capacity available. This again underlines the often remarked upon over-mechanisation and injudicious buying of machinery so prevalent in South African agriculture.

The amount of working capacity needed in each of four 3-month periods is shown in Table 5.

It appears that bank overdrafts and interest payments on such overdrafts will be needed for only limited parts of the year.

Net farm income is calculated as in Table 6.

These results represent a considerable improvement on previous results.

TABLE 3 - Short-run optimum combination of crops

Crops	Land requirements in months	Area (ha)	Percentage of irrigated land	
Valencias	Perennial	14	6,3	
Grapefruit	Perennial	24	10,7	
Sugar	Perennial	100	44,6	
Tomatoes	December to June	5,8	2,6	
Tomatoes	January to July	0,6	0,3	
Tomatoes	February to August	4,5	2,0	8,6
Tomatoes	March to September	2,4	1,1	
Tomatoes	April to October	5,8	2,6	
Green beans	March to July	13,3	5,9	
Green beans	August to December	26,7	11,9	17,8
Cotton	October to May	53,6	23,9	
Total		**250,7**	**111,9**	

TABLE 4 - Short-run solution: Utilisation of land, labour, water and tractor hours

Month	Land (hectares)	Regular labour (hours)	Casual labour (hours)	Water m(³/1 000)	Tractor (hours)
Amount available/ hired	224	11 065	-	569	2 080
January	198	6 497	0	332	299
February	202	4 480	0	290	233
March	218	5 769		298	378
April	224	6 997	0	232	382
May	224	11 065	37 666	189	281
June	170	11 065	38 965	178	245
July	178	11 065	34 688	192	264
August	184	11 065	5 028	202	820
September	173	11 065	5 404	251	820
October	224	11 065	6 928	293	1 121
November	218	11 065	0	323	343
December	224	11 065	0	369	468

TABLE 5 - Short-run cash flow of working capital*

Period	Working capital requirements R	Gross income R	Bank balance** end of period R
January - March	20 691	0	-21 657
April - June	73 420	186 377	91 300
July - September	55 090	139 241	7 149
October - December	48 714	30 957	24 906

* Assuming a bank balance of zero at the start of the year
** Assuming an annual interest rate of 14 %

TABLE 6 - Net farm income: Short-term solution

Sum of gross margins	R169 433
Less fixed costs	50 456
Net farm income	R118 977
NFI per R100 capital	16,94
NFI per hectare irrigated land	531

6. EMPIRICAL ANALYSIS: THE LONG RUN

The long-run solution involved determination of an optimum the farmer should move towards over a longer period such as 10 years. Therefore, the areas under perennial crops were not regarded as fixed; increases or decreases were regarded as possibilities. The long run also involves a sufficient learning period for the farm manager to become acquainted with other crops if he desires to grow these as well. In addition to the crops involved in the short-run analysis, the following have also been included for the long-term solution: Virginia tobacco, Burley tobacco, cucumbers, gem squashes, factory tomatoes and cabbage. These crops are known to have high gross margins and to be suited to the area. In the remainder of this discussion the term "tomatoes" will refer to fresh market tomatoes, and factory tomatoes will be termed as such.

In addition to the real and technical constraints already mentioned, the following were added to the long-run model:

Quotas: Even in the long run the farmer will be limited by quotas. Quota limitations were therefore put on:

Cabbage	20 ha
Green beans	40 ha
Sugar-cane	120 ha

As the factory wants an even supply of cabbage throughout the season, a link was introduced into the model to ensure that the same amount is grown in each of four cabbage-producing periods.

Risk: Upper limit constraints were placed on high risk crops. This pertains largely to crops showing frequent and drastic market price

fluctuations. To try to overcome this problem, a link was placed on these crops so that not all the product would be produced during any period of the year and the risk would be spread over the year.

The following constraints were therefore placed on different crops: Cucumbers and gem squashes were limited to a total of 15 hectares each; no more than 5 hectares may be planted at a time.

Management: Valencias and grapefruit were limited to a total of 60 hectares. This is the maximum area the farmer is prepared to grow since these are long-term crops with uncertain future prices and a low degree of flexibility.

The primal solution will also be followed by post-optimal sensitivity analysis.

The optimal combination of crops is given in Table 7. From this table it is seen that 73,9 per cent of the irrigation land is planted to perennial crops.

The remaining 26,1 per cent is subjected to double working to an extent of 178,4 per cent. Thus, good use is made of the irrigation land. Sugar-cane, cabbages, cucumbers and Burley tobacco appear at the maximum constraint levels.

Crops that did not appear in the optimum solution:
Tomatoes
Factory tomatoes
Virginia tobacco

Table 8 shows the utilisation of land, labour, water and tractor hours as dictated by the long-run solution.

Land is fully utilised in May, August and October. In only 3 months (January, February and September) will more than 10 hectares be idle, which again points to the very efficient use made of this resource.

An optimum number of 10 138 regular labour hours per month, equivalent to 46 labourers, should be employed. According to Table 8, an unusually high utilisation rate will be achieved - full utilisation in 10 months of the year, and utilisation rates of 93 per cent and higher in the remaining two months. Large numbers of casual labourers will have to be recruited between May and July, largely for purposes of harvesting sugar-cane and cotton. The long-run solution calls for the employment of less regular but more casual labour than the short-run solution.

The long-run solution, like the short-run solution, shows that water availability cannot be regarded as restricting. Farmers in this area who complain about availability of water while having the same allocation of water per hectare as in this case study must be guilty of over-irrigation. These results are in contrast to those obtained by Van Rooyen (1973) as well as Hancke and Groenewald (1972). They found water to be more limiting than land in the area below the Hartebeespoort dam, as was also found by Quin (1945) at Zebediela.

At no stage of the year will the present tractor complement be used at more than 65 per cent of available capacity. This means in practice that the owner should not immediately replace tractors when they have to be scrapped.

Table 9 shows working capital requirements. As gross income exceeds requirements in three out of four periods of the year, it may be concluded that expensive short-term credit in the form of bank overdrafts will seldom be needed. Net farm income is shown in Table 10.

7. COMPARING THE LONG-RUN OPTIMUM SOLUTION WITH THE SHORT-RUN OPTIMUM SOLUTION

The short-run solution is intended as a stepping stone which the farmer can use to move towards the long-run solution.

And once the farmer has reached the long-run optimum solution his net farm income will have increased by 20,8 per cent from R118 977 to R143 840 (Table 11).

The most important changes in the crop enterprises are that some new crops will be introduced into the farming system, viz Burley tobacco, cabbage, cucumbers and gem squash. No tomatoes will be grown. Valencias will be

TABLE 7 - Long-run optimum combination of crops

Crop	Land requirements in months	Area (ha)	Percentage of irrigated land	
Valencias	Perennial	35,3	15,8	
Grapefruit	Perennial	10,0	4,5	73,9
Sugar	Perennial	120,0	53,6	
Burley tobacco	August to January	9,9	4,4	8,8
Burley tobacco	October to March	9,9	4,4	
Cabbage	January to June	4,0	1,8	
Cabbage	½ February to July	4,0	1,8	9,0
Cabbage	½ March to August	4,0	1,8	
Cabbage	½ April to September	4,0	1,8	
Cabbage	½ May to October	4,0	1,8	
Green beans	March to July	15,0	6,7	15,3
Green beans	August to December	19,3	8,6	
Cotton	October to May	10,6	4,7	
Cucumbers	½ February to June	5,0	2,2	
Cucumbers	½ April to August	5,0	2,2	6,6
Cucumbers	½ June to October	5,0	2,2	
Gem squashes	½ February to June	5,0	2,2	
Total		**270,0**	**120,5**	

TABLE 8 - Long-run solution: Utilisation of land, labour, water and tractor hours

Month	Land (hectares)	Regular labour (hours)	Casual labour (hours)	Water (m^3/1 000)	Tractor hours
Amount available/hired	224	10 138	-	569	2 080
January	200	10 138	0	331	471
February	197	10 138	0	284	402
March	221	9 446	0	292	364
April	218	9 565	0	246	498
May	224	10 138	53 098	238	259
June	214	10 138	49 105	224	413
July	216	10 138	48 512	224	208
August	224	10 138	0	240	1 350
September	207	10 138	3 389	295	1 067
October	224	10 138	2 328	354	1 178
November	215	10 138	5 765	342	566
December	215	10 138	1 968	374	519

TABLE 9 - Long-run solution: Cash flows of working capital

Period	Working capital requirements R	Gross income R
January-March	22 778	31 978
April-June	77 890	183 245
July-September	52 624	149 556
October-December	41 846	24 655

TABLE 10 - Net farm income: Long-run solution

Sum of gross margins	R205 437
Less: fixed costs	50 456
Net farm income	154 981
NFI per R100 capital investment	22,08
NFI per hectare	692

substantially increased (14 ha to 34,3 ha) and grapefruit will be considerably decreased (24 to 10 ha). Sugar-cane will be increased to its assumed quota of 120 ha, but areas under green beans and cotton will be decreased.

The new combination of enterprises now makes better and more profitable use of all resources; for example land use increases to 120,5 per cent.

All these factors lead to an increase in the net farm income and return per hectare. These increases are rather significant.

A cash flow analysis revealed it to be feasible to move from the short-run to the long-run solution in a period of ten years.

8. POST-OPTIMAL ANALYSIS

The post-optimal analysis will be done in two stages. The first stage involves an analysis of the effect of resource limitations. Resources used fully are listed in Table 12. This table also shows the shadow prices of these scarce and limiting resources, i.e. how much net revenue would increase if one more unit of the resource was available. In another column the limits to which these shadow prices are valid are also shown.

Land is limiting in May, August and October with unit profits of R245; R244 and R109 respectively. These imply maxima of respectively 227 hectares; 227 hectares and 233 hectares. Thus, extra land could be bought at up to R2 500 per hectare. As this refers to purchases of relatively small areas - not more than 9 hectares - this aspect is clearly of no practical importance. The quota constraints on cabbage show rather high shadow prices and it may be worth while to negotiate with the factory for larger quota contracts. An increase in sugar-cane quotas will raise net income by only R53 for every additional hectare up to a total of 150 hectares. The additional R1 590 thus realisable can hardly be described as substantial in the light of the unit's total turnover.

The technical restriction placed on tomatoes and tobacco has a high shadow price of R611 but nothing can be done about it immediately, since it is a necessary rotation practice. It does, however, show that the introduction of alternative methods of nematode control could be very profitable.

Table 13 analyses the sensitivity of the solution to changes in gross margins of those crops included in the optimum program. These changes in gross margins have been expressed in percentages.

In the case of crops at the limit of a quota or similar restriction, the percentages show how much the gross margin has to decline before the area should be reduced. It is understandable that high percentages should be expected for this, as did in fact occur, particularly in the case of cabbage.

A large change in gross margin will also be needed to call for substantial changes in areas under cucumbers and gem squashes.

It must however, be pointed out that these more stable enterprises play a minor role in the overall organisation. The other enterprises tend to be very unstable in the sense that small percentage changes in gross margins of those enterprises would induce changes in optimum organisation. The most unstable crop is Valencias, where a change of 0,3 per cent in the gross margin per hectare will cause the optimum amount of this enterprise to change. If the gross margin of Valencias moved up to R1 168-72 the optimum amount of Valencias to be grown would move up to 39 ha. Accordingly, Valencias are very price-sensitive and a small change in price could have quite a big effect on the number of hectares to be planted in the optimum solution.

TABLE 11 - Summary of long-run and short-run optimum solutions

	Long-run optimum solution		Short-run optimum solution	
Sum of gross margin	194 296		169 433	
Total fixed costs	50 456		50 456	
Net farm income	143 840[2]		118 977[2]	
Crops	**Area (ha)**	**Percentage of irrigated land**	**Area (ha)**	**Percentage of irrigated land**
Valencias	35,3	15,8	14,0	6,3
Grapefruit	10,0	4,5	24,0	10,7
Sugar	120,0	53,6	100,0	44,6
Tomatoes	-	-	19,1	8,6
Burley tobacco	19,8	8,8	x[1])	x[1])
Cabbage	20,0	9,0	x[1])	x[1])
Green beans	34,3	15,3	40,0	17,8
Cotton	10,6	4,7	53,6	23,9
Cucumbers	15,0	6,6	x[1])	x[1])
Gem squash	5,0	2,2	x[1])	x[1])
Total	**270,0**	**120,5**	**250,7**	**111,9**
Regular labour requirements	46 labourers		50 labourers	
Maximum casual labour requirements	241 labourers		177 labourers	
Maximum tractor hour requirements per month	1 350 hours (5,2 tractors)		1 121 hours (4,3 tractors)	

Note: 1) Crops deliberately excluded from the solution
2) Excluding interest on capital

TABLE 12 - Shadow prices of fully utilised resources: Long-run solution

Resource or crop	Type constraint	Limit (ha)	Shadow price (ha)	Upper range limit for shadow price
Land (May)	Availability	224	245	227
Land (August)	Availability	224	244	227
Land (October)	Availability	224	109	233
Cabbage (total)	Factory quota	20	311	20,4
Cabbage (Feb-Jul)	Factory quota	5	348	6,0
Cabbage (May-Aug.)	Factory quota	5	70	5,9
Cabbage (April-Sept)	Factory quota	5	186	5,8
Cabbage (May-Oct)	Factory quota	5	82	6,0
Sugar-cane	Quota	120	53	150
Tomatoes & tobacco	Technical (rotation)	19,8	611	-*

*Variable; depends partly on hectares under perennial crops

TABLE 13 - Sensitivity analysis: Long-run solution

Crop	Area (hectares)	Gross margin (Rand/ha)	Sensitivity (%)
Valencias	35,3	1 165	0,3
Grapefruit	10,0	1 056	1,9
Sugar-cane	120,0	1 003	5,3
Burley tobacco (Aug-Jan)	9,9	1 343	4,2
Burley tobacco (Oct-March)	9,9	1 343	4,2
Cabbage (Jan-May)	4,0	873	21,9
Cabbage (Feb-Jul)	4,0	873	21,9
Cabbage (March-Aug)	4,0	873	21,9
Cabbage (April-Sept)	4,0	873	21,9
Cabbage (May-Oct)	4,0	873	21,9
Green beans (March-Jul)	15,0	428	1,1
Green beans (Aug-Dec.)	19,3	428	1,9
Cotton	10,6	453	3,5
Cucumbers (Feb-Jun)	5,0	722	48,2
Cucumbers (April-Aug)	5,0	722	9,7
Cucumbers (June-Oct)	5,0	722	25,8
Gem squashes	5,0	458	18,0

Grapefruit also exhibit a market price sensitivity, thereby rendering it inadvisable for the farmer to be in a hurry to replace them with other crops. The best policy would probably be to grow 45 hectares of citrus, which would involve slower and smaller establishment of new Valencia orchards than theoretically called for.

Thus, the long-term optimum solution is rather unstable, and as times change, the farmer will not be able to afford to relax his vigilance with regard to price changes. He should not be in too much of a hurry to move to the long-term optimum, particularly as far as new perennial crops are concerned.

9. CONCLUSION

The results obtained in this study may be of interest in the following respects:

1) They highlight the importance of judging every irrigation situation on its own merits and avoiding generalisations. It has, for example, been found that in contrast to some other irrigation areas, this region has abundant water in relation to the availability of other resources. This also renders capital-intensive water saving practices unnecessary and, in fact, wasteful in this particular area.
2) The results tend once again to illustrate the all too prevalent overmechanisation on South African farms. Such overmechanisation represents a waste of capital, which is regarded as one of the scarce resources of South Africa.
3) The last part, involving sensitivity analysis, emphasises the necessity for irrigation farmers to keep abreast of market developments. It also underlines the necessity for the authorities to maintain, and to improve, their information services.

FOOTNOTES

1) Labour, as will be seen later, was regarded as a purchase activity in a linear programming model. It therefore became convenient to include permanent labour as a variable cost item.
2) Full details on income and cost budgets used appear in Brotherton. (1980, pp. 13-17, 234-300)
3) Full details of the matrix appear in Brotherton. (1980, pp. 18-40; 301-309)

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