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# THE AVAILABILITY OF WATER AND LABOUR AS VARIABLE RESOURCES IN PLANNING FOR OPTIMUM ORGANISATION IN IRRIGATION FARMING

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## 1. INTRODUCTION

Optimum farming organisation demands the most efficient use of available resources. Under conditions of "unlimited availability" of resources optimum utilisation occurs when marginal income is equal to marginal costs. In practice, however, especially in the short-term, resources are often so limited that this "maximum profit" is not readily attainable. In this article optimum utilisation of resources under conditions of scarce, but still variable availability of resources is investigated.

Under conditions of scarce, but still variable, availability of resources "the quantity of variable input which maximizes the rate of return on investment in the variable input is perhaps as relevant as the input which maximizes profit in the sense of equating marginal costs and revenues".[2] Using this as a point of departure, the optimum utilisation of irrigation water and labour, both scarce resources, but available in variable quantities, in irrigation farming in the Hartebeespoort Dam Scheme,[3] is determined normatively.

In the following analyses it was also accepted that farm sizes may vary and models for three sizes of irrigation plots were used: 25 hectares; 43 hectares and 60 hectares.

Seasonal labour and short-term capital were also considered as variable resources and were dealt with as purchasing activities according to the methods of Heady and Chandler.[4]

## 2. METHOD OF ANALYSIS

The technique of parametric linear programming was used to maximise incomes from irrigation farming below the Hartbeespoort Dam under conditions of scarce, variable availability of resources.[5] In this method variable resources are incorporated into a linear programming model as parametric variables.[6]

In brief this method[7] amounts to optimum organisation being determined at various levels of availability of scarce, variable inputs. This optimum organisation is determined by investing the variable inputs in those alternative production activities with the largest marginal rate of return. Every unit of the scarce resource therefore gives the highest possible advantage. This procedure is repeated as the availability of the scarce resources changes until the marginal profit rate of these resources is equal to nought*. At this point the net income curve reaches its maximum and the greatest advantage per variable scarce resource is realised.

## 3. IRRIGATION WATER AS A VARIABLE RESOURCE

The annual allocation of irrigation water per farming unit by the Hartbeespoort Dam Irrigation Scheme to a great extent determines the gross margin of the main enterprises.[8] The allocation is traditionally made during October of each year and is based on the amount of water in the dam. The allocated quantity of water is used during the subsequent production year as required by the farming plan. What the situation handled by the simplex model amounts to is that the water not used in October is available for all the other months of the year. In the same way the remaining water not used in November is available for subsequent months, etc.

Mathematically the problem is presented as follows:

*E.g. d gross profit/d labour costs = 0 and gross profit is therefore at a maximum
Because variable costs were built into the model by means of deductions, this at the same time means that marginal income is equal to marginal cost.

$A$ = annual allocation of irrigation water

October irrigation:

$A \geqslant x_1$

$A = x_1 + x_{21}$

where $X_1$ = water used in October;

$x_{21}$ = water not used in October and therefore still available

November irrigation:

$x_{21} \geqslant x_2$

$0 = x_2 - x_{21} + x_{22}$

where $X_2$ = water used in November;

$x_{22}$ = water not used in November and therefore still available

December irrigation:

$x_{22} \geqslant x_3$

$0 = x_3 - x_{22} + x_{23}$

where $X_3$ = water used in December;

$X_{23}$ = water not used in December and therefore still available

The same procedure is followed for all the other months ($x_{21}$, $x_{22}$ and $x_{23}$ are removal activities).

The water consumption for each month is a function of the crops produced ($x_{100}$, $x_{200}$, etc.) and is presented as follows in the model:

$X_1$ = water used in October

$= a_{11}X_{100} + a_{12}X_{200}$

$x_1 = a_{11}x_{100} + a_{12}x_{200}$

$0 = a_{11}x_{100} + a_{12}x_{200}$

$X_2$ = water used in November

$= a_{21}x_{100} + a_{22}x_{200}$

$x_2 = a_{21}x_{100} + a_{22}x_{200}$

$0 = a_{21}x_{100} + a_{22}x_{200} - x_2$

etc.

where $a_{ij}$ ($i = 1,2$ and $j = 1,2$) = coefficients of utilisation of water on production activities $x_{100}$ and $x_{200}$

The simplex model is given in Table 1.

## 4. THE INCORPORATION OF REGULAR LABOUR

In farming both regular and seasonal labour are used. The amount of regular labour ought to be so specified that it can handle the scope of the continuous activities. In some months more regular labour is normally used than in other months. However, regular labourers cannot be dismissed or employed indiscriminately. The month in which most regular labour is used is therefore taken as the basis for employment. This means that during some months regular labour is not fully utilised. For the purposes of this investigation and for practical considerations regular labour is considered a limited resource which can be employed from production year to production year in variable quantities.[9] The optimum farming organisation would therefore depend largely on the amount of regular labour available. Regular labour has been parametrised as a variable resource. According to the technique of variable resource programming, regular labour would therefore continually be "invested" in those production activities where its marginal value product is the greatest, i.e. where an additional labour unit can make the greatest contribution to an increase in the gross profit.

The simplex model must therefore:

(i) Incorporate regular labour as a parametrised variable resource.

(ii) Keep the quantity of available regular labourers the same for different months.

(iii) Indicate the number of regular labourers used monthly.

Regular labour is parametrised by the PARARHS method in the MPS routine.[10]

Mathematically the second requirement is specified as follows:

$X_0$ = regular monthly labour available (quantity parametrised) and $X_{10}$ = regular labour used in October.

$\therefore X_0 \geqslant X_{10}$

$\therefore 0 = x_{10} + x_{50} - x_0$

where $x_{10}$ = regular labour used in October

$x_{50}$ = amount of idle labour available in October ($x_{50}$ is therefore the removal activity)

Therefore also:

$x_0 \geqslant x_{11}$

$0 = x_{11} + x_{51} - x_0$

where $X_{11}$ = regular labour used in November

$X_{51}$ = regular labour idle in November

## 5. WATER AND LABOUR IN THE SIMPLEX MODEL (TABLE 1)

### 5.1 Irrigation water

The -1 in the $x_{21}$ column and $P_2$ row shows that the water not used in October can be carried over for use in November. The -1 in the $x_{22}$ column and $P_3$ row shows the carry-over of water not used in November and available for December, etc. The amount of irrigation water used in October is determined by the utilisation coefficients $a_{11}$ and $a_{12}$. The -1 in the $x_1$ column and $P_{11}$ row and the +1 in the same column and the $P_1$ row ensure that the amount used does not exceed the amount available (A).

By merely changing A the result for different levels of availability of irrigation water may be obtained.

### 5.2 Regular labour

To ensure that an indication is given of the number of labourers active monthly the procedure set out below is followed:

regular labour utilisation October

$$= a_{11}x_{100} + a_{12}x_{200}$$

$$x_{10} = a_{11}x_{100} + a_{12}x_{200}$$

$$0 = a_{11}x_{100} + a_{12}x_{200} - x_{10}$$

where $x_{100}$ and $x_{200}$ represent production activities and $a_{11}$ and $a_{12}$ represent the utilisation coefficients of regular labour for these activities.

The regular labour used during October is now treated as an intermediary activity. $x_{10}$ is therefore determined by the quantities of $x_{100}$ and $x_{200}$ produced. The production of $x_{100}$ and $x_{200}$ is in turn subject to B, the regular monthly labour available. The same procedure is followed for all the remaining months (see simplex table).

## 6. PRODUCTION ACTIVITIES AND LIMITATIONS

For the farming plan the following branches and alternatives were considered:

| | | |
|---|---|---|
| Summer crops | : | Early tobacco |
| | | Late tobacco |
| | | Cotton |
| | | Sunflowers |
| Winter crops | : | Wheat |
| | | Onions |
| | | Potatoes |
| Stock | : | Dairy |
| | | Pigs |
| Fodder crops | : | Maize silage |
| | | Babala silage |
| | | Oats |
| | | Velvet beans |

The maximisation of the farming income takes place within the framework of the following limitations:

| Variable resource | Way in which dealt with in the simplex model |
|---|---|
| Water | Dependent on state of dam (3 m, 6 m, 12 m, and 18 m) |
| Regular labour | Parametrised |
| Seasonal labour | Buying activity |
| Short-term capital | Buying activity |
| Land | Various farm sizes (27 ha, 43 ha and 60 ha) |

| Fixed limitations | |
|---|---|
| Fluctuating cultivation limitations | : Tobacco can be planted only once every three years on the same ground |
| Tractive power | : Only 208,333 tractor hours available per farm |

The complete simplex model consisted of 86 activities and 70 limitations. This was solved on the IBM 70 computer of the University of Pretoria with the aid of the M.P.S. routine and the accompanying PARARHS method.

## 7. RESULTS: OPTIMUM FARMING PLANS

A simplex model was drawn up for three farm sizes and four states of the dam (which determine the allocation of irrigation water). Regular labour was parametrised in variable quantities in each model and the other variable resources and limitations were dealt with as buying activities. In total 12 models were drawn up. Income results are given in Table 3.

**TABLE 3 - Maximum gross profits on various farming units (R)***

| Farm sizes (ha) | Gross incomes according to state of dam 3 m R | 6 m R | 12 m R | 18 m R |
|---|---|---|---|---|
| 25 | 660 | 2 085 | 5 580 | 10 004 |
| 43 | 1 100 | 3 474 | 8 703 | 15 000 |
| 60 | 1 541 | 4 821 | 11 638 | 19 425 |

*1973 values

In order to illustrate the results (optimum farming plans and utilisation of resources and production factors) the situation on a 43 hectare unit with a medium-full dam (state of dam 12 metres) is discussed.

Table 4 and Fig. 1 give the optimum farming plans for various levels of regular labour.

The following deserves mention:

(i) *Labour is used where its marginal return is the greatest*

Regular labour is available in variable amounts, fluctuating between 0 man-hours and 7 000 man-hours. Every basic point (A, B, C, D, E, F, G, H, I, J, K, L) indicates the maximum profit plan for the specified number of man-hours of regular labour. Under each of these basic points regular labour is "invested" in the production activity with the highest marginal return for labour. The maximum profit combination of production activities therefore changes from one basic point to the next. Table 4, for example, shows consecutive basic points.

**TABLE 4 - Optimum plans at various basic points**

| Basic points | H | I |
|---|---|---|
| *Maximum profit plan:* | | |
| Early tobacco | 4,5 ha | 5,3 ha |
| Late tobacco | 9,8 ha | 9,0 ha |
| Wheat | - | 7,8 ha |
| Onions | 2,4 ha | 2,7 ha |
| Potatoes | 3,7 ha | 4,0 ha |
| Maize silage | 1,6 ha | - |
| Babala silage | 1,0 ha | - |
| Lucerne | 2,1 ha | - |
| Oats | 1,9 ha | - |
| Velvet beans | 1,4 ha | - |
| Dairy | 7,5 G.V.E. | - |
| Pigs | 2,7 V.E. | - |
| **Net farming income** | **R5 162,35** | **R5 190,40** |

Between two consecutive base points the same range of marginal rates of substitution of products applies. The maximum profit plans for levels of regular labour between base points can therefore be

**TABLE 1 - The incorporation of regular labour and irrigation water in the simplex model**

| Target function | | -k | O | O | O | O | O | O | O | O | O | O | O | O | +L | +M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Resource limitations | Levels of avail- ability | Regular labour available per month | Regular labour used | | | Irrigation water used | | | Regular labour not used | | | Irrigation water not used | | | Production activities | |
| | | | | | | | | | | | | | | | Tobacco | Wheat |
| | | | Oct | Nov | Dec | Oct | Nov | Dec | Oct | Nov | Dec | Oct | Nov | Dec | | |
| | | XO | X10 | X11 | X12 | X1 | X2 | X3 | X50 | X51 | X52 | X21 | X22 | X23 | X100 | X200 |
| *Regular labour available:* | | | | | | | | | | | | | | | | |
| Per month | B | +1 | | | | | | | | | | | | | | |
| October | O | - 1 | +1 | | | | | | +1 | | | | | | | |
| November | O | - 1 | | +1 | | | | | | +1 | | | | | | |
| December | O | - 1 | | | +1 | | | | | | +1 | | | | | |
| January | | | | | | | | | | | | | | | | |
| *Regular labour used:* | | | | | | | | | | | | | | | | |
| October | O | | - 1 | | | | | | | | | | | | +A11 | +A12 |
| November | O | | | - 1 | | | | | | | | | | | +A21 | +A22 |
| December | O | | | | - 1 | | | | | | | | | | +A31 | +A32 |
| January | O | | | | | | | | | | | | | | | |
| *Irrigation allocation:* | | | | | | | | | | | | | | | | |
| October ($P_1$) | A | | | | | +1 | | | | | | +1 | | | | |
| November ($P_2$) | O | | | | | | +1 | | | | | - 1 | +1 | | | |
| December ($P_3$) | O | | | | | | | +1 | | | | | - 1 | +1 | | |
| January ($P_4$) | | | | | | | | | | | | | | - 1 | | |
| *Irrigation water used:* | | | | | | | | | | | | | | | | |
| October | O | | | | | - 1 | | | | | | | | | +A51 | +A52 |
| November | O | | | | | | - 1 | | | | | | | | +A61 | +A62 |
| December | O | | | | | | | - 1 | | | | | | | +A71 | +A72 |
| January | | | | | | | | | | | | | | | | |

-k = costs per man-hour; + L = gross profit per unit of tobacco; +M = gross per unit of wheat

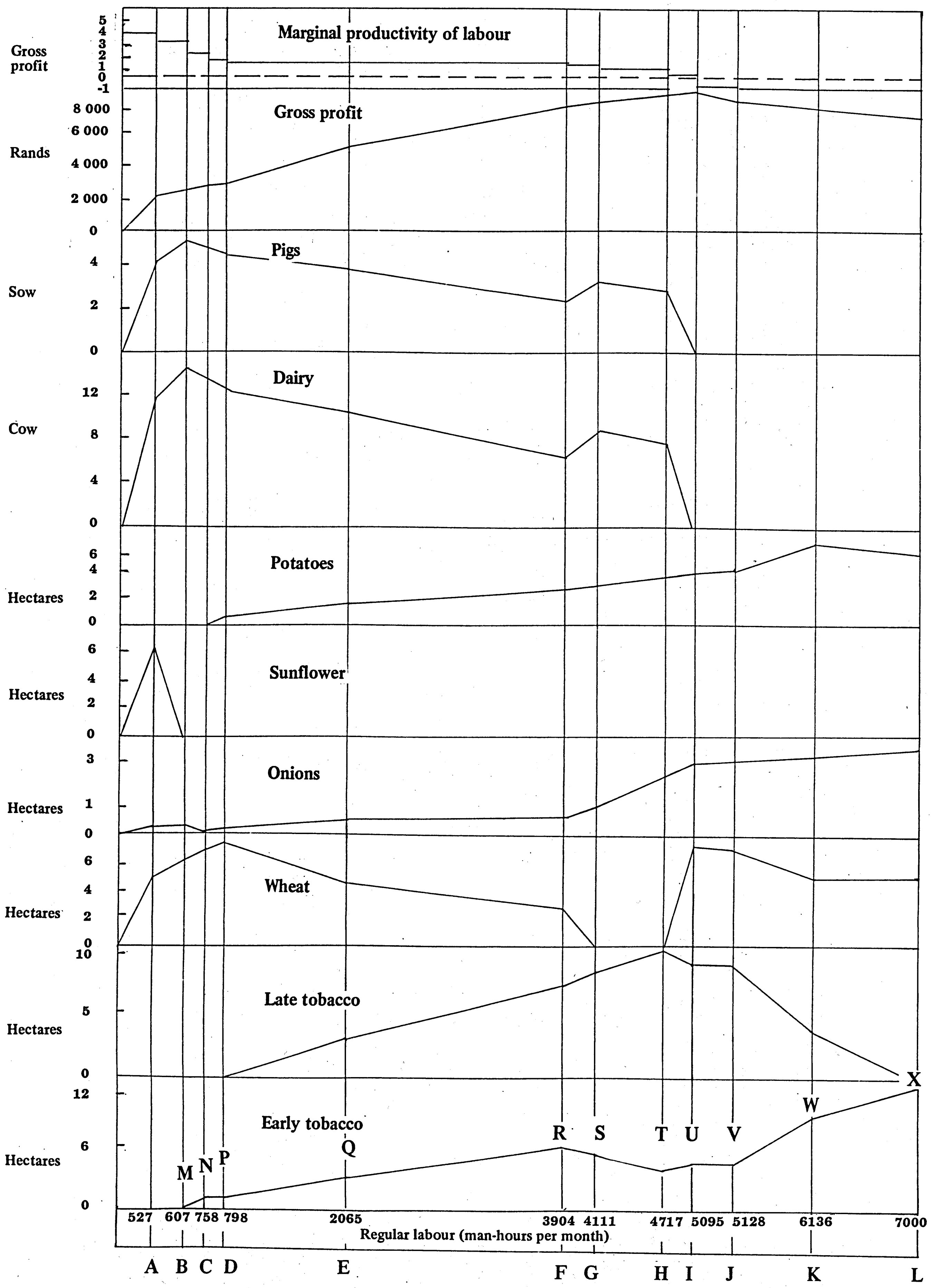


FIG. 1 - Optimum farming plans on 43 hectares: state of dam = 12 metres

**TABLE 2 - Optimum farming plans on 43 hectares: state of dam = 12 metres**

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross profit | R 2 134 | 2 415 | 2 792 | 2 870 | 5 176 | 8 324 | 8 447 | 8 675 | 8 703 | 8 689 | 8 162 | 7 373 |
| Fixed costs | R 3 513 | 3 513 | 3 513 | 3 513 | 3 513 | 3 513 | 3 513 | 3 513 | 3 513 | 3 513 | 3 513 | 3 513 |
| Net income | R-1 378 | -1 096 | - 720 | - 642 | 1 663 | 4 811 | 4 934 | 5 162 | 5 190 | 5 176 | 4 649 | 3 860 |
| Regular labour* hours | 528 | 607 | 758 | 795 | 2 065 | 3 904 | 4 111 | 4 717 | 5 096 | 5 128 | 6 135 | 7 017 |
| Cash capital | R 3 266 | 3 798 | 3 858 | 4 015 | 6 162 | 8 939 | 9 633 | 10 647 | 10 317 | 10 376 | 12 198 | 12 918 |
| Tobacco: Hectares | | | | | | | | | | | | |
| Early: Hectares | | | 1,0 | 9,0 | 3,6 | 7,2 | 6,0 | 4,5 | 5,2 | 5,4 | 10,7 | 14,3 |
| Late: Hectares | - | - | - | - | 2,7 | 7,0 | 8,2 | 9,8 | 9,0 | 8,8 | 3,6 | - |
| Wheat: Hectares | 5,5 | 6,5 | 7,3 | 8,0 | 5,1 | 3,0 | - | - | 7,7 | 7,6 | 5,2 | 5,4 |
| Cotton: Hectares | - | - | - | - | - | - | - | - | - | - | - | - |
| Onions: Hectares | 0,3 | 0,3 | 0,1 | 0,1 | 0,5 | 0,8 | 1,1 | 2,3 | 2,6 | 2,8 | 3,0 | 3,3 |
| Sunflowers: Hectares | 7,3 | - | - | - | - | - | - | - | - | - | - | - |
| Potatoes: Hectares | - | - | - | 0,7 | 1,5 | 2,8 | 2,9 | 3,5 | 4,1 | 4,2 | 5,3 | 5,8 |
| Maize***: Hectares | 2,5 | 3,1 | 2,9 | 2,6 | 2,2 | 1,3 | 1,6 | 1,6 | - | - | - | - |
| Babala***: Hectares | 1,6 | 2,0 | 1,8 | 1,7 | 1,4 | 0,8 | 1,2 | 1,0 | - | - | - | - |
| Lucerne: Hectares | 3,2 | 4,0 | 3,7 | 3,4 | 2,9 | 1,7 | 2,4 | 2,0 | - | - | - | - |
| Oats: Hectares | 2,9 | 3,6 | 3,3 | 3,0 | 2,6 | 1,6 | 2,1 | 1,8 | - | - | - | - |
| Velvet beans: Hectares | 2,1 | 2,6 | 2,4 | 2,2 | 1,9 | 1,1 | 1,5 | 1,3 | - | - | - | - |
| Dairy: Cow | 11,6 | 14,6 | 13,5 | 12,4 | 10,6 | 6,5 | 7,5 | 7,5 | - | - | - | - |
| Pigs: Sow | 4,2 | 5,2 | 4,8 | 4,4 | 3,7 | 2,3 | 2,7 | 2,7 | - | - | - | - |
| Utilisation of land: Hectares | | | | | | | | | | | | |
| October | 16 | 19 | 20 | 20 | 21 | 23 | 23 | 23 | 24 | 24 | 22 | 23 |
| November | 17 | 12 | 12 | 11 | 17 | 22 | 85 | 26 | 21 | 21 | 23 | 23 |
| December | 17 | 12 | 12 | 11 | 17 | 22 | 25 | 26 | 21 | 21 | 23 | 23 |
| January | 20 | 15 | 15 | 15 | 19 | 24 | 27 | 28 | 21 | 21 | 23 | 23 |
| February | 25 | 22 | 22 | 23 | 24 | 27 | 27 | 28 | 29 | 29 | 28 | 28 |
| March | 23 | 20 | 20 | 21 | 23 | 28 | 26 | 27 | 29 | 29 | 28 | 28 |
| April | 21 | 17 | 18 | 19 | 21 | 24 | 24 | 25 | 29 | 29 | 28 | 28 |
| May | 19 | 14 | 14 | 15 | 12 | 9 | 8 | 9 | 14 | 14 | 14 | 14 |
| June | 11 | 14 | 14 | 15 | 12 | 9 | 8 | 9 | 14 | 14 | 14 | 14 |
| July | 13 | 16 | 16 | 16 | 12 | 7 | 6 | 7 | 10 | 10 | 8 | 8 |
| August | 13 | 16 | 16 | 16 | 12 | 7 | 6 | 7 | 10 | 10 | 8 | 8 |
| September | 13 | 16 | 16 | 16 | 12 | 7 | 6 | 7 | 10 | 10 | 8 | 8 |
| Regular labour* hours | | | | | | | | | | | | |
| October | 528 | 607 | 787 | 798 | 2 065 | 3 541 | 3 702 | 4 420 | 5 086 | 5 128 | 6 135 | 7 017 |
| November | 352 | 383 | 563 | 578 | 2 065 | 3 904 | 4 111 | 4 717 | 5 086 | 5 128 | 5 895 | 6 544 |
| December | 208 | 212 | 328 | 312 | 1 455 | 3 143 | 3 397 | 3 674 | 3 441 | 3 406 | 2 521 | 1 889 |
| January | 528 | 456 | 577 | 575 | 1 311 | 2 340 | 2 391 | 2 363 | 2 191 | 2 201 | 2 460 | 2 511 |
| February | 485 | 485 | 742 | 741 | 1 924 | 3 565 | 3 506 | 3 382 | 3 347 | 3 381 | 4 261 | 4 732 |
| March | 528 | 607 | 758 | 788 | 2 065 | 3 904 | 4 111 | 4 351 | 4 188 | 4 168 | 3 839 | 3 400 |
| April | 376 | 438 | 758 | 798 | 2 065 | 3 904 | 3 733 | 3 741 | 4 183 | 4 218 | 4 946 | 5 433 |
| May | 528 | 607 | 758 | 798 | 2 065 | 3 904 | 4 111 | 4 717 | 5 096 | 5 065 | 4 255 | 3 824 |
| June | 208 | 253 | 331 | 798 | 2 065 | 3 904 | 4 111 | 4 717 | 5 096 | 5 128 | 6 135 | 5 523 |
| July | 242 | 292 | 394 | 395 | 926 | 1 678 | 1 881 | 1 784 | 2 931 | 1 934 | 1 994 | 2 090 |
| August | 299 | 360 | 443 | 448 | 1 038 | 1 888 | 1 928 | 2 146 | 2 295 | 2 291 | 2 177 | 2 165 |
| September | 367 | 434 | 445 | 472 | 1 099 | 1 909 | 2 139 | 2 671 | 2 885 | 2 869 | 2 450 | 2 256 |

*Man-hours per month; **Short-term capital; *** Silage

TABLE 2 - (continued)

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seasonal labour* hours | | | | | | | | | | | | |
| October | - | - | - | - | - | - | - | - | - | - | - | - |
| November | 6 | 7 | 136 | 127 | 431 | 862 | 711 | 522 | 624 | 648 | 648 | 1 265 |
| December | 47 | 56 | 139 | 133 | 717 | 1 543 | 1 619 | 1 734 | 1 727 | 1 722 | 1 722 | 1 596 |
| January | 33 | 42 | 291 | 268 | 1 125 | 2 360 | 2 190 | 1 960 | 2 049 | 2 079 | 2 079 | 2 821 |
| February | 187 | 237 | 610 | 563 | 2 141 | 4 410 | 4 288 | 4 078 | 4 073 | 4 101 | 4 101 | 4 803 |
| March | 102 | 119 | 541 | 516 | 2 647 | 5 713 | 5 719 | 5 807 | 5 935 | 5 936 | 5 936 | 6 213 |
| April | 88 | 99 | 459 | 439 | 2 628 | 5 758 | 5 924 | 6 237 | 6 282 | 6 275 | 6 275 | 6 075 |
| May | 162 | 191 | 338 | 332 | 1 928 | 4 179 | 4 551 | 5 136 | 5 068 | 5 032 | 5 032 | 4 112 |
| June | 34 | 36 | 155 | 152 | 1 060 | 2 350 | 2 433 | 2 716 | 2 727 | 2 716 | 2 431 | 2 258 |
| July | - | - | 129 | 120 | 796 | 1 793 | 1 507 | 1 825 | 1 816 | 1 814 | 1 755 | 1 714 |
| August | 68 | 72 | 165 | 170 | 919 | 1 911 | 2 021 | 2 285 | 2 403 | 2 406 | 2 487 | 3 535 |
| September | 153 | 163 | 60 | 95 | 637 | 1 203 | 1 636 | 2 466 | 2 617 | 2 594 | 2 007 | 1 702 |
| Labour** hours | | | | | | | | | | | | |
| Dairy: Cow | 203 | 257 | 235 | 215 | 184 | 112 | 152 | 152 | - | - | - | - |
| Pigs: Sow | 39 | 50 | 45 | 42 | 36 | 22 | 29 | 29 | - | - | - | - |
| Tractor use*** hours | | | | | | | | | | | | |
| October | 32 | 40 | 48 | 51 | 76 | 114 | 106 | 105 | 124 | 125 | 148 | 161 |
| November | 63 | 55 | 52 | 53 | 96 | 141 | 160 | 208 | 208 | 208 | 208 | 208 |
| December | 58 | 21 | 19 | 23 | 47 | 78 | 90 | 107 | 101 | 101 | 96 | 76 |
| January | 26 | 21 | 18 | 27 | 42 | 58 | 67 | 83 | 85 | 86 | 112 | 106 |
| February | 48 | 60 | 58 | 56 | 53 | 46 | 50 | 48 | 36 | 37 | 43 | 48 |
| March | 37 | 45 | 45 | 49 | 51 | 54 | 53 | 62 | 80 | 80 | 81 | 79 |
| April | 44 | 53 | 58 | 61 | 55 | 54 | 41 | 46 | 88 | 87 | 84 | 91 |
| May | 75 | 71 | 79 | 84 | 68 | 63 | 40 | 41 | 100 | 99 | 76 | 74 |
| June | 12 | 16 | 15 | 18 | 29 | 42 | 47 | 52 | 48 | 48 | 57 | 50 |
| July | 6 | 8 | 7 | 6 | 8 | 8 | 10 | 11 | 7 | 6 | 4 | 3 |
| August | 8 | 11 | 9 | 14 | 22 | 30 | 34 | 43 | 45 | 45 | 62 | 60 |
| September | 9 | 11 | 14 | 31 | 62 | 106 | 167 | 118 | 133 | 135 | 203 | 203 |
| Irrigation use**** | | | | | | | | | | | | |
| October | 1 528 | 1 942 | 2 147 | - | 2 623 | 3 341 | 3 212 | 2 508 | 1 784 | 1 855 | 3 651 | 4 880 |
| November | 3 728 | 1 684 | 1 677 | 1 535 | 2 491 | 3 750 | 4 221 | 4 369 | 3 373 | 3 336 | 2 422 | 1 796 |
| December | 948 | 1 204 | 1 246 | 1 141 | 1 694 | 2 383 | 2 551 | 2 456 | 1 844 | 1 845 | 1 873 | 1 892 |
| January | 2 042 | 1 168 | 1 162 | 1 064 | 1 557 | 2 173 | 2 431 | 2 437 | 1 791 | 1 778 | 1 448 | 1 223 |
| February | 1 370 | 694 | 635 | 844 | 1 255 | 1 799 | 2 036 | 2 288 | 2 102 | 2 114 | 2 552 | 2 110 |
| March | 455 | 573 | 529 | 563 | 587 | 562 | 662 | 679 | 450 | 458 | 695 | 634 |
| April | 518 | 658 | 602 | 697 | 791 | 861 | 933 | 1 047 | 834 | 849 | 1 289 | 1 176 |
| May | 3 298 | 4 005 | 4 128 | 4 417 | 3 424 | 2 491 | 1 730 | 2 016 | 4 386 | 4 371 | 3 939 | 3 960 |
| June | 422 | 516 | 503 | 507 | 410 | 268 | 254 | 325 | 470 | 468 | 403 | 431 |
| July | 1 424 | 1 733 | 1 752 | 1 801 | 1 382 | 668 | 630 | 776 | 1 596 | 1 585 | 1 267 | 1 337 |
| August | 1 852 | 2 290 | 2 322 | 2 390 | 1 795 | 1 136 | 801 | 473 | 2 085 | 2 071 | 1 639 | 1 726 |
| September | 4 543 | 5 687 | 5 457 | 5 231 | 4 164 | 2 526 | 2 644 | 2 284 | 1 444 | 1 428 | 980 | 1 004 |

*Woman-hours **Man-hours per month; ***Tractor hours; ****Units in hectares millimetres obtained by combining the various base points of the same production activity. The straight lines MN, NP, PQ, RS, ST, TU, UV, VW and WX in Fig. 1 therefore show the path of expansion of early tobacco if the regular labour available is continually increased.

The gradients of the various extension lines also indicate the product:product ratios of the various production activities. Between base points O and A wheat, sunflowers, onions, dairy produce and pigs complement one another. Between A and B wheat and onions supplement one another, however (onions remain constant with an expansion in wheat); wheat and sunflowers are competitive (sunflowers decrease as wheat production increases); and wheat and dairy produce are still complementary (both production activities are still expanding).

(ii) The highest gross profit of maximum profit plans 1 to 12 is determined at the point where the marginal profit rate on labour drops to zero (see top part of Fig. 1). For this plan 5 096 man-hours of regular labour per month are needed. Above this point an addition in labour will result in larger additional costs than additional income, and the gross profit will therefore drop. This phenomenon is explained by the fact that other resources become scarce at this stage and have a limiting effect on any further extension in activities.

(iii) A labour force providing 5 096 man-hours per month will be fully utilised only during November, May and June and virtually throughout October. During the rest of the year the unused labourers can be used for repair work, development work, etc., and for the replacement of seasonal labour. It would also be a good idea to arrange labourers' leave in such a way that they are absent during the months when least labour is used: December to February and July to September.

(iv) *Scarce resources*

Labour would seem to be a critical resource only up to a level of 5 096 hours per month.

Although 43 ha are available, this quantity of land is not fully utilised during any month. Land therefore cannot be considered under the resource availability levels set out. Available tractor hours and irrigation water, however, limit the further extension of the farming plan.

The available tractor hours (208,3 per month) are fully utilised during November. From a second set of l.p. models in which tractor hours were doubled, it appeared that the purchase of a similar additional tractor would be economically advantageous (increased gross profit = R9 296,32).

The available irrigation water is also fully used. An increase (when the dam is full) would increase the maximum gross profit to R14 999,78.

It therefore seems that under present conditions at the Hartbeespoort Scheme water is a scarce resource; because of the water: area ratios land cannot be considered a scarce resource.

## 8. LONG-TERM PLANNING AND ECONOMIC FARMING UNITS

For farm planning and policies and agricultural development a knowledge of expected long-term net farming incomes is important. With the help of the l.p. models the expectations regarding net farming income for the relevant scheme can be formulated for expected levels of labour employment and water availability.

If it is accepted that as much regular labour can be employed as is necessary for a total maximum profit plan, expectations regarding availability of irrigation water would give an indication of the expected long-term net farming income. From this investigation it appeared that medium full is the most probable state of the dam. The long-term annual net income for the various units was as follows:

25 hectares : R3 389,00
43 hectares : R4 955,00
60 hectares : R6 287,00

Measured at the fixed standard of a net farm income ensuring an existence that is viable and comparable with other sectors, policy decisions concerning economic farming units can be made.

## 9. CONCLUSION

Although a great deal of farming data and surveys are necessary, variable resource programming offers possibilities for planning on the farm and at agricultural policy level. Short-term and long-term planning can be implemented.

By following the variable resource programming approach a great deal of economically relevant information concerning optimum product combinations, resource utilisation, farming units, scarce resources and production factors, product:product and factor:factor ratios, the creation of work opportunities, etc., can be obtained. This type of information is essential for agricultural development of farms, districts and regions.

The techniques of parametric linear programming also lend themselves to the quantification of expectations as regards changes in price, subsidising and stabilising programmes, etc.

Broadly speaking, variable resource programming would seem to be a valuable aid both at micro and macro-economic level.

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