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Programme planning; a practical example

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1. Introduction

The development of programme-planning techniques have led to such questions as — how complex a problem can these techniques solve easily and accurately? This article shows a programme planning method of solving a fairly complex farm planning problem. This problem had already been the subject of an independent linear programming study (WILLEMSEN, 1962), the same basic data are used and the results compared.

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The techniques and principles of gross margin analysis and elements of the mathematics of linear programming are used. In this respect it is similar to the techniques developed by other workers in this field, notably JOHNSON *et al.* (1959) in Sweden and GIAEVER (1961) in Norway. However there are differences in form and application. In this method the "near optimum plan" is calculated, compared with the "optimum" plan when linear programming techniques are used.

2. Nature of the problem

The problem is to find a near optimum plan for the farm from the given data:

2.1. The farm is a mixed farm of 12 ha.

2.2. It is fragmented into three parts, *i.e.* three separate soil types.

2.2.1. Damp sand oil (good soil) 7,2 ha situated near the farmstead.

2.2.2. Old reclaimed soil, 2,4 ha 3,6 km from the farmstead.

2.2.3. Young reclaimed soil, 2,4 ha 3,6 km from the farmstead.

The following conditions and restrictions apply to each soil type.

2.2.1. *Damp sand soil (good soil)*

Of the area of 7,2 ha 0,4 ha are used by the farm horse and removed from the plan, while 0,95 ha is only suitable for permanent grassland. The remaining 5,85 ha are good arable land and may grow permanent grass, oats, barley, early and main crop potatoes and sugar-beet. Only 4,02 ha are suitable for growing sugar-beet, and of this area not more than $^1/_4$ may grow sugar-beet in any one year. Sugar-beet tops may be used for cattle feed if required. Grain crops may be grown on the total arable area. Oats or barley may not individually exceed $^1/_2$ the arable area. In the absence of other arable crops the grain area must be equally divided between oats and barley. The area of potatoes may not exceed $^1/_3$ of the total arable area. The area of sugar-beet + potatoes may not exceed $^1/_2$ the arable area. A catch crop of turnips may be grown after barley and early potatoes. Up to 15,5 cow units may be kept on the farm.

Points:

a. Plannable area = 5,85 ha arable + 0,95 ha permanent grassland.
b. Grain area maximum = 5,85 ha.
c. Barley area maximum = 2,925 ha = $^1/_2$ of the arable land.
d. Oats area maximum = 2,925 ha = $^1/_2$ of the arable land.
e. Potato area maximum = 1,95 ha = $^1/_3$ of the arable land.
f. Sugar-beet area maximum = 1,0 ha = $^1/_4$ of the arable land for s.b.
g. Patato + sugar-beet = 2,925 ha = $^1/_2$ of the arable land.
h. Turnips may be grown after early potatoes and barley.
i. Up to 15,5 cow units may be kept.
j. If only grain crops are grown on arable land, the area must be equally divided between oats and barley.
k. Grassland must be permanent grassland.

2.2.2. *Old reclaimed soil*

An area of 2,4 ha 3,6 km from the farmstead. Rye, oats, maincrop potatoes and leys may be grown. Up to 1,6 ha of 4 year leys may be grown, but must be followed

by 2 years of arable cropping. Since this ground is some way from the farm only young cattle may graze these leys. Therefore the number of cow units kept on this ground may not exceed $^1/_4$ of the total number of cow units kept on the farm. Turnips may follow rye as a catch crop. The yield of turnips is lower than on good soil, 1 ha of old soil yielding the same as 0,64 ha of good soil.

Rotations available per hectare:

1. $^1/_2$ ha rye + $^1/_2$ ha of oats. (Rotation A_1)
2. $^1/_2$ ha rye + $^1/_2$ ha oats + $^1/_2$ ha catch crop turnips after rye. (Rotation A_2)
3. $^1/_3$ ha rye + $^1/_3$ ha oats + $^1/_3$ ha potatoes. (Rotation B_1)
4. $^1/_3$ ha rye + $^1/_3$ ha oats + $^1/_3$ ha potatoes + $^1/_3$ ha of catch crop turnips after rye. (Rotation B_2)
5. $^1/_6$ ha rye + $^1/_6$ ha oats + $^2/_3$ ha leys (1,47 cow units). (Rotation C_1)
6. $^1/_{12}$ ha rye + $^1/_{12}$ ha oats + $^1/_6$ ha potatoes + $^2/_3$ ha leys (1,47 cow units). (Rotation D_1)

2.2.3. *Young reclaimed soil*

An area of 2,4 ha 3,6 km from the farmstead. Only suitable for arable cropping and may grow rye, oats and maincrop potatoes. No catch cropping.

Rotations available per hectare:

1. $^1/_2$ ha rye + $^1/_2$ ha oats. (Rotation A_1)
2. $^1/_3$ ha rye + $^1/_3$ ha oats + $^1/_3$ ha potatoes. (Rotation B_1)

2.3. Contract work and casual labour

Contract work for combining the grain crops is available if required. The net cost is 125 D.fl. per ha. It does however release 4 hours in period 2 and 16 hours in period 3 of the plan per ha.
Casual labour is available for main crop potatoes at a maximum rate of 110 hours per hectare of potatoes in period 4 of the plan. The cost is 1,50 D.fl. per hour.
Casual labour for sugar-beet is available at the maximum rate of 120 hours per hectare in period 1 of the plan. The cost is 2 D.fl. per hour.

2.4. Costs of turnips and sugar-beet tops

A catch crop of turnips after a grain crop or early potatoes has a net cost of 165 D.fl. per ha and requires 18 hours in period 3. On good soil 1 ha of turnips yields 2275 kg of starch equivalent and 490 kg of crude protein.
Sugar-beet tops are also available and are costed at their manurial value of 100 D.fl. per ha if used. The yield per ha amounts to 3000 kg of starch equivalent and 420 kg of crude protein.
They do not require hours in the planning periods. These turnips and sugar-beet tops are fed fresh.

2.5. Cow units

Up to 15,5 cow units may be kept. On this farm own dairy herd replacement are reared. 1 cow unit is taken to be 1 dairy cow.
It has been calculated that 1 cow unit requires 0,45 ha of grassland.
This grassland is treated as follows:

cut for silage in May	45 %
cut for hay in June	25 %
cut for hay in July	30 %
	100 %

After including the normal winter concentrate feed, a cow unit requires 234 kg starch equivalent and 44,5 kg crude protein from catch crops etc.

2.6. Stubble ploughing

Except where a catch crop occurs, stubble ploughing takes place in period 4 of the plan.

2.7. Differences in hours

It is noticeable that the number of hours required for some crops in the calculations differ with soil type. These differences in hours required are due mainly to differences in transport times as the soil types are of unequal distances from the farmstead.

2.8. Limiting time periods

The most limiting time periods on the farm and used in this plan are:

period 1.	20 April—28 June:	540 hours of work available.
period 2.	29 June—26 July:	216 hours of work available.
period 3.	27 July—23 August:	216 hours of work available.
period 4.	24 August—4 October:	324 hours of work available.

The hours required by the horse have been deducted. It is assumed that all land resources must be fully utilized.

3. Theory

The most profitable plan is one which contains the optimum, or in this case near optimum, combination of the most profitable enterprise within the given restrictions of rotational limits, hours of work available, etc. The resources need only be combined within the limits of the hours available in the most restricting period or periods, since the other time periods are less limiting. Therefore only such limiting periods need be included in the plan. Each enterprise frequently requires differing amounts of work in each time period, therefore its profitability in each period is different, *e.g.* the same crop is more profitable in a period requiring few hours of work than in one requiring many hours of work. In order to find the profitability of each enterprise in each restricting time period the revenue per hour is calculated (see TABLE 1, column F, H, J and L). Plans are then calculated combining the most profitable enterprises as shown by their value for gross margin per ha and revenue per hour in each time period. The enterprises are thus combined in relation with their revenue per hour and per ha. From these plans the "near optimum plan" is calculated. The input/output relationships are assumed to be linear in accordance with linear programming theory.

TABLE 1. Work sheet giving enterprise ranks, requirements, returns in D.fl. and yields of starch equivalent and crude protein

Activity	Rotation limits (ha)	Unit of activity (ha)	Gross margin p. unit (D.fl.)	Period 1 540 hrs		Period 2 216 hrs		Period 3 216 hrs		Period 4 324 hrs		Per unit starch (equiv.) SE. (kg)	Per unit crude protein (kg)
				hrs/ unit	reve-nue/hr	hrs/ unit	reve-nue/hr	hrs/ unit	reve-nue/hr	hrs/ unit	reve-nue/hr		
				Good soil 5,85 + 0,95 ha									
A	B	C	D	E	F	G	H	I	J	K	L	M	N
Barley	2,925	1	8807	2	4402	4	2203	39	22,66	10	881	0	0
Barley + contract work	2,925	1	75510	2	377,54	0	0	23	32,84	10	75,53	0	0
Barley + turnips	2,925	1	71511	2	357,55	4	178,84	67	10,78	0	0	+2275	+490
Barley + turnips + contract work	2,925	1	59012	2	2956	0	0	51	11,67	0	0	+2275	+490
Oats	2,925	1	8986	2	4491	4	224,52	35	25,75	14	64,14	0	0
Oats + contract work	2,925	1	7739	2	386,53	0	0	19	40,73	14	55,25	0	0
Potatoes, main crop	1,95	1	12823	35	36,67	5	256,41	0	0	236	5,46	0	0
Potatoes, early	1,95	1	9855	35	28,18	250	3,96	0	0	0	0	0	0
Potatoes, early + turnips	1,95	1	8208	35	23,410	250	3,37	18	45,62	0	0	+2275	+490
Sugar-beet	1	1	13891	320	4,311	0	0	0	0	0	0	0	0
Sugar-beet + tops, fresh	1	1	12892	320	4,012	0	0	0	0	0	0	+3000	+420
Cow units	15,5 units	0,45	12614/ha 573/cow unit	24,3	23,49	12,2	46,15	6,4	89,51	7,5	75,72	—234	—44,5
				Old reclaimed soil 2,4 ha									
Rotation A_1	2,4	1	7207	2	3601	4	1804	43	16,710	15	485	0	0
Rotation A_1 + contract work	2,4	1	59511	2	297,53	0	0	27	227	15	39,76	0	0
Rotation A_2	2,4	1	63710	2	318,52	4	159,36	66	9,712	5	127,41	+732	+158
Rotation A_2 + contract work	2,4	1	51212	2	2564	0	0	50	10,211	5	1022	+732	+158
Rotation B_1	2,4	1	7925	13	615	4,3	1843	28,5	27,76	95,4	8,310	0	0
Rotation B_1 + contract work	2,4	1	7088	13	54,57	1,3	5451	17,6	40,23	95,4	7,412	0	0
Rotation B_2	2,4	1	7746	13	59,56	4,3	1805	44	17,69	88,7	8,79	+488	+105
Rotation B_2 + contract work	2,4	1	6909	13	538	1,3	5312	33	20,98	88,7	7,811	+488	+105
Rotation C_1	2,4	1	10513	42,3	24,79	21,9	47,810	30,8	34,15	17,3	60,33	—346	—65,9
Rotation C_1 + contract work	2,4	1	10094	42,3	23,710	20,9	47,99	25,8	39,14	17,3	57,94	—346	—65,9
Rotation D_1	2,4	1	10871	47,8	22,611	22	49,18	21,9	49,62	59,2	18,27	—346	—65,9
Rotation D_1 + contract work	2,4	1	10662	47,8	22,212	21,5	49,27	19,8	53,81	59,2	17,98	—346	—65,9
				Young reclaimed soil 2,4 ha									
Rotation A_1	2,4	1	7202	2	3601	4	1803	43	16,74	15	481	0	0
Rotation A_1 + contract work	2,4	1	5954	2	297,52	0	0	27	223	15	39,72	0	0
Rotation B_1	2,4	1	7921	13	613	4,3	1842	28,6	27,72	95,4	8,33	0	0
Rotation B_1 + contract work	2,4	1	7083	13	54,54	1,3	5451	17,6	40,21	95,4	7,44	0	0

The indices give the rank value of each enterprise in each time period and for the gross margin per unit.

4. Method

From the basic data of gross margin per unit of each enterprise and hours required per unit of enterprise in each time period, TABLE 1 is constructed.
Columns E, G, I and K of TABLE 1 show the hours required for each enterprise in each time period and on each soil type. Similarly columns F, H, J and L show the revenue per hour and thus the relative profitability of each enterprise in each time period. On the basis of their profitabilities the enterprises are combined in the plans. To assist in this, the gross margin per hectare and revenue per hour figures are given a rank. A figure 1 being the highest rank and denoting the most profitable enterprise. Consequently an enterprise with a high rank is included in the plans to the maximum that the plan will allow. The enterprises of the three soil types are ranked independantly of each other. This is because each set of enterprises is applicable only to its own soil type. Columns M and N show how much each enterprise makes available or needs per unit, of starch equivalent (M) or crude protein (N).
If an enterprise has more than one form each form is treated as a separate enterprise, *e.g.* barley, barley + contract work and barley + catch crop of turnips are three seperate enterprises. They have different gross margins and differing requirements for hours in the time periods. Contract grain harvesting is counted as a separate enterprise since the grain is either combined or not combined, and the inputs are therefore not very variable. Casual labour is different since it may be used in varying quantities up to a certain level per ha. It is therefore handled separately and inserted into the plan at the rate required. The next step is to make some base plans from which the near optimum plan is calculated.

5. Calculation of the base plans

Base plans are calculated combining the enterprises in the ratio of their profitabilities per ha (TABLE 2; Plan A) and per hour in each time period (TABLES 5—8; Plans B, C, D and E respectively).
In many farm problems the area of permanent grassland or arable land is specified. This means that each area, grassland or arable, can be planned relatively independently one of the other. The usual inter-dependencies being the inclusion of arable feed crops on the arable land for animals grazing the grassland. If the grassland is rotational leys, the leys may be treated as a rotational break on the arable land. The total area may then be considered an arable area with leys as a long rotation crop. If either or both these conditions are relevvant to the plan, planning is considerably eased.
In this example, on the good soil arable area, the area of permanent grassland or arable land is not known. In total it may not exceed 5,85 ha. The area of the grassland determines the arable land area and vice versa. The areas of the arable crops are in direct ratio to the total arable area, for rotational reasons. This means that the areas of the arable crops are closely related to the grassland area. Consequently an increase or decrease in the arable or grassland area is shown directly by a proportional change of the arable crops in the plan. This leads to a considerable degree of fluidity which can lead to planning difficulties. Some solutions are offered in plan A. An explanation of plan A will serve as an example of how a base plan is calculated. It is reasonable to assume that it is more profitable to spend time on

TABLE 2. Plan A; base of gross margin per ha in D.fl.

Activity	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha: Needs p. unit (ha)	Total area 11,6 ha: T Total Balance B	Period 1 540 hrs: Needs p. unit (hrs)	Period 1 540 hrs: T Total Balance B	Period 2 216 hrs: Needs p. unit (hrs)	Period 2 216 hrs: T Total Balance B	Period 3 216 hrs: Needs p. unit (hrs)	Period 3 216 hrs: T Total Balance B	Period 4 324 hrs: Needs p. unit (hrs)	Period 4 324 hrs: T Total Balance B
				Good soil	5,85 + 0,95 ha								
I. Sugar-beet	1	1389	1389,0	1	1 T *4,85 + 0,95 B*	320	320 T *220 B*	0	0 T *216 B*	0	0 T 216 B	0	0 T *324 B*
II. Potatoes main crop	1,95	1282	2500,0	1	1,95 T *2,9 +0,95 B*	35	68,3 T *151,7 B*	5	9,8 T *206,2 B*	0	0 T *216 B*	236	460,2 T *—136,2 B*
Casual labour for potatoes	214	—1,5	—321,0	0	0 T *2,9 +0,95 B*	0	0 T *151,7 B*	0	0 T *206,2 B*	0	0 T *216 B*	1	+214 T *77,8 B*
III. Cow units	8,5	573	4870,5	0,45	3,83 T *0 B*	24,3	206,6 T *—54,9 B*	12,2	103,7 T *102,5 B*	6,4	54,4 T *161,6 B*	7,5	63,7 T *14,1 B*
IV. Casual hours for sugar-beet	120	—2	—240,0	0	0 T *0 B*	1	+120 T *65,7 B*	0	0 T *102,5 B*	0	0 T *161,6 B*	0	0 T *14,1 B*

the good soil first and any surplus time on the less good soils. The good soil is then planned first in the base plans. This plan is based on the profitability of the enterprises of their gross margin per ha (TABLE 1, column D).

5.1. Plan A

There are 540 hours for work available in period 1.
216 „ „ „ „ „ „ 2.
216 „ „ „ „ „ „ 3.
324 „ „ „ „ „ „ 4.

Insert good soil into the plan first. This gives 5,85 ha of arable + 0,95 ha of permanent grass to be planned first. Let T = total requirements, B = balance left over.

Selection I. Sugar-beet (rank 1).

The rotational limit of 1 ha is taken leaving a balance of 4,85 + 0,95 B ha in balance. Sugar-beet requires 320 hours per ha in period 1, thus giving 320 × 1 = 320 T for total requirement and leaving a balance of 540 — 320 = 220 B hours for other enterprises. No hours are required in the other periods. Rank 2 sugar-beet + tops is not included in the plan since the rotational limit of sugar-beet has already been met.

Selection II. Potatoes, main crop (rank 3).

The rotational limit of 1,95 ha are taken leaving 2,9 + 0,95 B ha.

Period 1. 35 × 1,95 = 68,3 T leaves 220 — 68,3 = 151,7 B hours.
Period 2. 5 × 1,95 = 9,8 T leaves 216 — 9,8 = 206,2 B hours.
Period 3. 0 × 1,95 = 0 T leaves 216 — 0 = 216 B hours.
Period 4. 236 × 1,95 = 460,2 T leaves 324 — 460,2 = −136,2 B hours.

Casual labour is available in this period at up to rate of 110 hours per ha of potatoes. 1,95 × 110 = 214 T hours, leaving + 77,8 B hours in balance. If no casual labour had been available only $\frac{324}{236}$ = 1,4 ha of potatoes could have been kept. Casual labour costs 1,5 D.fl. per hour.

Selection III. Cow units (rank 4).

Since casual labour is available for sugar-beet in period 1 at a cost of 2 D.fl. per hour, 8,5 cow units may be kept. This exhausts the land resource. The land available is 2,9 + 0,95 = 3,85 ha, cows being able to utilize permanent pasture. One cow unit requires 0,45 ha, therefore $\frac{3{,}85}{0{,}45}$ = 8,5 cow units may be kept.

The inclusion of cows in Selection III means that permanent pasture is included in the plan. This alters the rotational restrictions of sugar-beet and potatoes since the arable area has changed. Two methods of tackling this problem are shown in alternatives I (TABLE 3) and II (TABLE 4). The method of alternative I is prefered since it gives shorter and less complex base plans.

5.1.1. *Plan A. Alternative I*

The ranks, column D, bring the initial choice of enterprises into an arable rotation. Sugar-beet rank 1, and potatoes rank 3 have been chosen. The next choice is cows rank 4. The inclusion of cows brings permanent grassland into an arable rotation.

TABLE 3. Plan A; Alternative I, base of gross margin per ha in D.fl.

Activity	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha: Needs p. unit (ha)	T Total Balance B	Period 1 540 hrs: Needs p. unit (hrs)	T Total Balance B	Period 2 216 hrs: Needs p. unit (hrs)	T Total Balance B	Period 3 216 hrs: Needs p. unit (hrs)	T Total Balance B	Period 4 324 hrs: Needs p. unit (hrs)	T Total Balance B
				Good soil	5,85 + 0,95 ha								
I. Sugar-beet	1	1389	1389,0	1	1 T *4,85 + 0,95 B*	320	320 T *220 B*	0	0 T *216 B*	0	0 T *216 B*	0	0 T *324 B*
II. Potatoes	1,925	1282	2467,9	1	1,925 T *2,925 + 0,95 B*	35	67,4 T *152,6 B*	5	9,6 T *206,4 B*	0	0 T *216 B*	236	454,3 T *—130,3 B*
Casual labour ...	212	—1,5	—318,0	0	0 T *2,925 + 0,95 B*	0	0 T *152,6 B*	0	0 T *206,4 B*	0	0 T *216 B*	1	+212 T *81,7 B*
III. Oats	2,925	898	2626,7	1	2,925 T *0,95 B*	2	5,9 T *146,7 B*	4	11,7 T *194,7 B*	35	102,4 T *113,6 B*	14	40,9 T *40,8 B*
IV. Cow units	2,1	573	1203,3	0,45	0,95 T *0 B*	24,3	51,0 T *95,7 B*	12,2	25,6 T *169,1 B*	6,4	13,4 T *100,2 B*	7,5	15,8 T *25,0 B*
				Old soil	2,4 ha								
I. Rotation D_1	0,6	1087	652,2	1	0,6 T *1,8 B*	47,8	28,7 T *67,0 B*	21,5	12,9 T *156,2 B*	21,9	13,1 T *87,1 B*	59,2	35,5 T *—10,5 B*
Casual labour ...	11	—1,5	—16,5	0	0 T *1,8 B*	0	0 T *67,0 B*	0	0 T *156,2 B*	0	0 T *87,1 B*	1	+11 T *0,5 B*
Total			8004,6	Balance	1,8 ha 2,4 Young soil		67 hrs		156,2 hrs		87,1 hrs		0,5 hrs

TABLE 4. Plan A; Alternative II, base of gross margin per ha in D.fl.

Activity	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha		Period 1 540 hrs		Period 2 216 hrs		Period 3 216 hrs		Period 4 324 hrs	
				Needs p. unit (ha)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B
I. Sugar-beet	0,74	1389	1027,9	1	0,74 T 5,11 + 0,95 B	320	236,8 T *303,2 B*	0	0 T *216 B*	0	0 T *216 B*	0	0 T *324 B*
II. Potatoes main crop	0,74	1282	948,7	1	0,74 T *4,37 + 0,95 B*	35	25,9 T *277,3 B*	5	3,7 T *212,3 B*	0	0 T *216 B*	236	174,6 T *149,4 B*
III. Oats	1,47	898	1320,1	1	1,47 T *2,9 + 0,95 B*	2	2,9 T *274,4 B*	4	5,9 T *206,4 B*	35	51,5 T *164,5 B*	14	20,6 T *128,8 B*
IV. Cows	8,5	573	4870,5	1	3,83 T *0 B*	24,3	206,6 T *67,8 B*	12,2	103,7 T *102,7 B*	6,4	54,4 T *110,1 B*	7,5	63,7 T *65,1 B*
				Old soil	2,4 ha								
Casual labour Sugar-beet	89	—2	—178,0	0	0 T *2,4 B*	1	+89 T *156,8 B*	0	0 T *102,7 B*	0	0 T *110,1 B*	0	0 T *65,1 B*
Potatoes	81	—1,5	—121,5	0	0 T *2,4 B*	0	0 T *156,8 B*	0	0 T *102,7 B*	0	0 T *110,1 B*	1	+81 T *146,1 B*
I. Rotation D_1	2,4	1087	2608,8	1	2,4 T *0 B*	47,8	114,7 T *42,1 B*	22	52,8 T *49,9 B*	21,9	52,6 T *57,5 B*	59,2	142.1 T *4,0 B*
Casual labour for potatoes	43	—1,5	—64,5	0	0 T *0 B*	0	0 T *42,1 B*	0	0 T *49,9 B*	0	0 T *57,5 B*	1	+43 *47 B*
				Young soil	2,4 ha								
I. Rotation B_1	0,8	792	633,6	1	0 T *1,6 B*	13	10,4 T *31,7 B*	4,3	3,4 T *46,5 B*	28,6	22,9 T *34,6 B*	95,4	76,3 T *—29,3 B*
Casual labour for potatoes in the rotation .	30	—1,5	—45,0	0	0 T *1,6 B*	0	0 T *31,7 B*	0	0 T *46,5 B*	0	0 T *34,6 B*	1	+30 T *0,7 B*
Pay back unused casual labour for sugar-beet	31	+2	62	0	0 T *1,6 B*	1	31 T *0,7 B*	0	0 T *46,5 B*	0	0 T *34,6 B*	0	0 T *0,7 B*
Total			11062,6	Balance 1,6 ha			0,7 hrs		46,5 hrs		34,6 hrs		0,7 hrs

Permanent grass is not an arable crop, so the inclusion of cows may not be considered applicable to the arable rotation. Rank 5 early potatoes may not be included in the plan as the rotational limit for potatoes is already included in the plan. Rank 6 oats is included in the plan as Selection III. Cow units may be kept on the 0,95 ha of permanent grassland as Selection IV.
The area of sugar-beet + potatoes may not exceed $^1/_2$ the total arable area of 5,85 ha = 2,925 ha.
1 ha sugar-beet + 1,95 ha potatoes = 2,95 ha.
Potatoes have a lower rank than sugar-beet and are therefore reduced in area to bring their area to 1,925 ha.
Therefore the plan is

Selection I	1	ha sugar-beet	rank 1.
Selection II	1,925	ha potatoes	rank 3.
Selection III	2,925	ha oats	rank 6.
Selection IV	2,1	cow units on the permanent grassland.	

All good soil land resources are fully utilized. Insert 2,4 ha of old soil into the plan. The grassland problems of the good soil are not present in the old soil rotations.

Old soil 2,4 ha:

Selection I. Rotation D_1, rank 1.
Period 4 is the limiting period. 25 hours are available and 59,2 hours per ha are required.
Rotation D_1, contains $^1/_6$ ha of potatoes for which casual labour may be bought at a rate of up to 110 hours per ha. Therefore $\frac{110}{6} = 18$ hours per ha may be bought. The hours required per ha is then 59,2 — 18 = 41,2 hours.
Thus $\frac{25}{41,2} = 0,6$ ha may be kept. 18 × 0,6 = 11 hours of casual labour are bought at a cost of 1,5 D.fl. per hour.
There are no further hours available in period 4. All enterprises require hours in this period, and as none are available they may not be included in the plan. The plan is blocked here and can go no further.

5.1.2. *Plan A. Alternative II*

The inclusion of cows in the arable area of plan A alters the arable area. The rotational restrictions of 1 ha for sugar-beet and 1,95 ha of potatoes are based on an arable area of 5,85 ha. The potatoes and sugar-beet give an arable area of 2,95 ha. This 2,95 ha is then planned for the given rotational restrictions of: sugar-beet $^1/_4$ of arable area, potatoes $^1/_3$ of arable area, sugar-beet + potatoes $^1/_2$ of arable area. Grain crops for the rest with either oats or barley equal to $^1/_2$ of the arable area.

Therefore selections	I	sugar-beet	0,74 ha
	II	potatoes	0,74 ha
	III	oats	1,47 ha
			2,95 ha
	IV	cow units	8,5 as before.

Potatoes having a lower rank than sugar-beet were reduced in area from 0,98 to

0,74 ha to conform with the restriction that potatoes + sugar-beet must not be more than $^1/_2$ the arable area.
The land resources being fully utilized, 2,4 ha of old soil are inserted into the plan.

Old soil 2,4 ha:

Selection I. Rotation D_1, rank 1.

This rotation requires 59,2 hours per ha in period 4 and 47,8 hours per ha in period 1. There are 65,1 hours available in peiod 4 and 67,8 hours in period 1. Therefore hours in these periods, limit the amount of rotation D_1 to be included in the plan. Casual labour is available for the potatoe and sugar-beet enterprises on the good soil in periods 1 and 4.
Casual labour may be used up to a rate of 110 hours per ha for potatoes in periode 4 and of 120 hours per ha for sugar-beet in period 1. Therefore sugar-beet provides 0,74 ha $\times$ 120 = 89 hours of casual labour at a cost of 2 D.fl. per hour in period 1. Potatoes similarly provide 81 hours in period 4 at a cost of 1,5 D.fl. per hour.
2,4 ha of rotation D_1 are taken which utilizes the land resources fully. 1 hectare of rotation D_1 contains $^1/_6$ hectare of potatoes. Therefore $\frac{110}{6} = 18$ hours of casual labour may be bought per ha. In total 2,4 $\times$ 18 = 43 hours may be bought in period 4.

Insert 2,4 ha young soil:

Selection I. Rotation B_1, rank 1.

There are 47 hours available in period 4. Rotation B_1 requires 95,4 hours per ha in period 4. This rotation contains $^1/_3$ ha of potatoes, therefore $\frac{110}{3} = 37$ hours per ha of rotation B_1 may be bought.
The hour requirements in period 4 are 95,4 — 37 = 58,4 hours per ha. Therefore $\frac{47}{58,4} = 0,8$ ha may be taken. Casual labour required is 0,8 $\times$ 37 = 30 hours and costs 1,5 D.fl. per hour.
No further hours are available and as all other enterprises require hours in this period the plan can go no further. Not all the casual labour for sugar-beet is used in period 1 and this is removed from the plan.

5.2. Plans B, C, D and E

Similarly, plans B, C, D and E (TABLES 5—8) are calculated using the method of Plan A. Alternative I.

5.3. Determination of the near optimum plan (Plan F) (TABLE 9)

The plan with the highest total revenue is selected.

Plan	*Total revenue D.fl.*
AI	8004,6
B	5200,7
C	6990,9
D	11164,5
E	5200,7

TABLE 5. Plan B; base of revenue per hour in period 1, in D.fl.

Activity	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha		Period 1 540 hrs		Period 2 216 hrs		Period 3 216 hrs		Period 4 324 hrs	
				Needs p. unit (ha)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B
				Good soil	5,85 + 0,95 ha								
I. Oats	2,925	898	2626,7	1	2,925 T *2,925 + 0,95 B*	2	5,9 T *534,1 B*	4	11,8 T *204,2 B*	35	102,4 T *113,6 B*	14	40,9 T *283,1 B*
II. Barley	2,925	880	2574,0	1	2,925 T *0,95 B*	2	5,9 T *528,2 B*	4	11,8 T *192,4 B*	39	114,1 T *—0,5 B*	10	29,3 T *253,8 B*
Total			5200,7	Balance 0,95 ha			528,2 hrs		192,4 hrs		—0,5 hrs		253,8 hrs

TABLE 6. Plan C; base of revenue per hour in period 2, in D.fl.

Activty	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha: Needs p. unit (ha)	Total area 11,6 ha: T Total Balance B	Period 1 540 hrs: Needs p. unit (hrs)	Period 1 540 hrs: T Total Balance B	Period 2 216 hrs: Needs p. unit (hrs)	Period 2 216 hrs: T Total Balance B	Period 3 216 hrs: Needs p. unit (hrs)	Period 3 216 hrs: T Total Balance B	Period 4 324 hrs: Needs p. unit (hrs)	Period 4 324 hrs: T Total Balance B
				Good soil	5,85 + 0,95 ha								
I. Potatoes main crop	1,95	1282	2499,9	1	1,95 T *3,90 + 0,95 B*	35	68,3 T *471,7 B*	5	9,8 T *206,2 B*	0	0 T *216 B*	236	460,2 T *—136,2 B*
Casual labour	214	—1,5	—321,0	0	0 T *3,90 + 0,95 B*	0	0 T *471,7 B*	0	0 T *206,2 B*	0	0 T *216 B*	1	+214 T *77,8 B*
II. Oats	2,925	898	2626,7	1	2,925 T *0,975 + 0,95 B*	2	5,9 T *465,8 B*	4	11,8 T *194,4 B*	35	102,4 T *113,6 B*	14	41,0 T *36,8 B*
III. Barley	0,975	880	858,0	1	0,975 T *0,95 B*	2	2 T *463,8 B*	4	4 T *190,4 B*	39	38 T *75,6 B*	10	9,8 T *27,0 B*
IV. Cow units	2,1	573	1203,3	0,45	0,95 T *0 B*	24,3	51,0 T *412,8 B*	12,2	25,6 T *164,8 B*	6,4	13,4 T *62,2 B*	7,5	15,8 T *11,2 B*
				Old soil	2,4 ha								
I. Rotation B_1 + contract work	0,19	708	134,5	1	0,19 T *2,21 B*	13	2,5 T *410,3 B*	1,3	0,3 T *164,5 B*	17,6	3,3 T *58,9 B*	95,4	18,1 T *—6,9 B*
Casual labour	7	—1,5	—10,5	0	0 T *2,21 B*	0	0 T *410,3 B*	0	0 T *164,5 B*	0	0 T *58,9 B*	1	+7 *0,1 B*
Total			6990,9	Balance	2,21 ha		410,3 hrs		164,5 hrs		58,9 hrs		0,1 hrs
					2,4 Young soil								

TABLE 7. Plan D; base of revenue per hour in period 3, in D.fl.

Activity	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha: Needs p. unit (ha)	T Total Balance B	Period 1 540 hrs: Needs p. unit (hrs)	T Total Balance B	Period 2 216 hrs: Needs p. unit (hrs)	T Total Balance B	Period 3 216 hrs: Needs p. unit (hrs)	T Total Balance B	Period 4 324 hrs: Needs p. unit (hrs)	T Total Balance B
				Good soil	5,85 + 0,95 ha								
I. Cow units	15,1	573	8652,3	0,45	6,8 T *0 B*	24,3	366,9 T *173,1 B*	12,2	184,2 T *31,8 B*	6,4	96,6 T *119,4 B*	7,5	113,3 T *210,7 B*
				Old soil	2,4 ha								
II. Rotation D_1 + contract work ... (0,4 cow unit)	0,25	1066	266,5	1	0,25 T *2,15 B*	47,8	11,9 T *161,2 B*	21,5	5,4 T *26,4 B*	19,8	5,1 T *114,3 B*	59,2	14,8 T *195,9 B*
III. Rotation B_1 + contract work ...	2,05	708	1451,4	1	2,05 T *0,1 B*	13	26,7 T *134,5 B*	1,3	2,7 T *23,7 B*	17,6	36,1 T *78,2 B*	95,4	195,9 T *0 B*
IV. Casual labour for potatoes in D_1 ..	4,5	—1,5	—6,8	0	0 T *0,1 B*	0	0 T *134,5 B*	0	0 T *23,7 B*	0	0 T *78,2 B*	1	+4,5 T *4,5 B*
V. Casual labour from rotation B_1 for potatoes	75	—1,5	—112,5	0	0 T *0,1 B*	0	0 T *134,5 B*	0	0 T *23,7 B*	0	0 T *78,2 B*	1	+75 T *79,5 B*
VI. Rotation B_1 + contract work ...	0,1	708	70,8	1	0,1 T *0 B*	13	1,3 T *133,2 B*	1,3	0,1 T *23,6 B*	17,6	1,8 T *76,4 B*	95,4	9,5 T *70 B*
Casulal labour ..	3,7	—1,5	—5,6	0	0 T *0 B*	0	0 T *133,2 B*	0	0 T *23,6 B*	0	0 T *76,4 B*	1	+3,7 *73,7 B*
				Young soil	2,4 ha								
Rotation B_1 + contract work	1,3	708	920,4	1	1,3 T *1,1 B*	13	16,9 T *116,3 B*	1,3	1,7 T *21,9 B*	17,6	22,9 T *53,5 B*	95,4	124,0 T *—50,3 B*
Casual labour	48	—1,5	—72,0	0	0 T *1,1 B*	0	0 T *116,3 B*	0	0 T *21,9 B*	0	0 T *53,5 B*	1	+48 T *—2,3 B*
Total			11164,5	Balance	1,1 ha		116,3 hrs		21,9 hrs		53,5 hrs		—2,3 hrs

TABLE 8. Plan E; base of revenue per hour in period 4, in D.fl.

Activity	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha		Period 1 540 hrs		Period 2 216 hrs		Period 3 216 hrs		Period 4 324 hrs	
				Needs p. unit (ha)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B
				Good soil	5,85 + 0,95 ha								
I. Barley	2,925	880	2574,0	1	2,925 T *2,925 + 0,95 B*	2	5,9 T *534,1 B*	4	11,8 T *204,2 B*	39	114,1 T *101,9 B*	10	29,3 T *294,7 B*
II. Oats	2,925	898	2626,7	1	2,925 T *0,95 B*	2	5,9 T *528,2 B*	4	11,8 T *192,4 B*	35	102,4 T *—0,5 B*	14	40,9 T *253,8 B*
Total			5200,7	Balance	0,95 ha		528,2 hrs		192,4 hrs		—0,5 hrs		253,8 hrs
					2,4 Old soil 2,4 Young soil								

TABLE 9. Near optimum plan (Plan F); base of revenue per hour in period 3, in D.fl.

Activity	No. of units taken	Gross margin p. unit	Total revenue (D.fl.)	Total area 11,6 ha		Period 1 540 hrs	
				Needs p. unit (ha)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B
				Young soil	2,4 ha		
I. Rotation B_1 + contract work	2,4	708	1699,2	1	2,4 T *0 B*	13	31,2 T *508,8 B*
				Old soil	2,4 ha		
I. Rotation D_1 + contract work (1,47 cow units/ha) ..	2,4	1066	2558,4	1	2,4 T *0 B*	47,8	114,7 T *394,1 B*
Casual labour for potatoes in period 4 Rotation B_1 2,4 × 37 = 88 Rotation D_1 2,4 × 18 = 43	131	—1,5	—196,5	0	0 T *0 B*	0	0 T *394,1 B*
				Good soil	5,85 + 0,95 ha		
I. Cow units	11	573	6303,0	0,45	4,95 T *1,85 B*	24,3	267,3 T *126,8 B*
II. Potatoes, early + turnips ..	0,1	820	82,0	1	0,1 T *1,75 B*	35	3,5 T *123,3 B*
III. Barley + contract work + turnips	0,92	590	542,8	1	0,92 T *0,83 B*	2	1,8 T *121,5 B*
IV. Sugar-beet + tops	0,38	1289	489,8	1	0,38 T *0,45 B*	320	121,5 T *0 B*
V. Need hours Remove rotation D_1 (above)	$-D_1$		—2558,4				
Insert rotation C_1 + contract work (1,47 cow units/ha) ..	2,4	1009	2421,6				
Change in resources				0	0 T *0,45 B*	1	+13,2 T *13,2 B*
VI. Remove casual labour used in rotation D_1	43	+1,5	64,5	0	0 T *0,45 B*	0	0 T *13,2 B*
VII. Potatoes, main crop	0,45	1282	576,9	1	0,45 T *0 B*	35	15,8 T *—2,6 B*
Casual labour	47	—1,5	—70,5	0	0 T *0 B*	0	0 T *—2,6 B*
VIII. Casual labour for sugar-beet	3	—2	—6,0	0	0 T *0 B*	1	+3 T *0,4 B*
Total			11906,8	Balance	0 ha		0,4 hrs

Period 2 216 hrs		Period 3 216 hrs		Period 4 324 hrs		Starch equivalent		Crude Protein		Balance	
Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	Needs p. unit (hrs)	T Total Balance B	p. unit	Total	p. unit	Total	Starch	Protein
1,3	3,1 T *212,9 B*	17,6	42,2 T *173,8 B*	95,4	229 T *95 B*	0	0	0	0	0	0
21,5	51,6 T *161,3 B*	19,8	47,5 T *126,3 B*	59,2	142,1 T *—47,1 B*	—346	—830,4	—65,9	—158,2	*—830,4*	*—158,2*
0	0 T *161,3 B*	0	0 T *126,3 B*	1	+131 T *83,9 B*	0	0	0	0	*—830,4*	*—158,2*
12,2	134,2 T *27,1 B*	6,4	70,4 T *55,9 B*	7,5	82,5 T *1,4 B*	—234	—2574	—44,5	—489,5	*—3404,4*	*—647,7*
250	25,0 T *2,1 B*	18	1,8 T *54,1 B*	0	0 T *1,4 B*	+2275	+227,5	+490	+49,0	*—3176,9*	*—598,7*
0	0 T *2,1 B*	51	46,9 T *7,2 B*	0	0 T *1,4 B*	+2275	+2093,0	+490	+450,8	*—1083,9*	*—147,9*
0	0 T *2,1 B*	0	0 T *7,2 B*	0	0 T *1,4 B*	+3000	+1140,0	+420	+159,6	*+56,1*	*+11,7*
1	+1,4 T *3,5 B*	1	14,4 T *—7,2 B*	1	+100,6 T *102 B*	0	0	0	0	*+56,1*	*+11,7*
0	0 T *3,5 B*	0	0 T *—7,2 B*	1	43 T *59 B*	0	0	0	0	*+56,1*	*+11,7*
5	2,3 T *1,2 B*	0	0 T *—7,2 B*	236	106 T *—47 B*						
0	0 T *1,2 B*	0	0 T *—7,2 B*	1	+47 T *0 B*	0	0	0	0	*+56,1*	*+11,7*
0	0 T *1,2 B*	0	0 T *—7,2 B*	1	0 T *0 B*	0	0	0	0	*+56,1*	*+11,7*
	1,2 hrs		—7,2 hrs		0 hrs					+56,1 kg	+11,7 kg

Plan D is selected. Plan F is determined using the base period of plan D. This is period 3. The ranks used are those of TABLE 1, column J.

Explanation of plan F (TABLE 9)

The profitability of base plan D (TABLE 7) is primarily due to the high number of cow units that it contains. Cow units may be kept on good and old soil with the smaller proportion on the old soil. The supply of starch and protein for the cows is obviously more easily and cheaply supplied by the enterprises of the good soil, *e.g.* barley + catch crop turnips gives a gross margin of 715 D.fl./ha and supplies + 2275 kg of starch and + 490 kg of protein per ha. Compare this with Rotation A_2 on the old soil supplying 637 D.fl. per ha + 732 kg starch and + 158 kg protein per ha. Consequently it is more likely that protein and starch will be supplied by the good soil with the old soil devoted to a rotation containing cow units. This suggests that most of the difficulties in enterprise allocation will come when planning the good soil. For this reason the young and old soil rotations are planned first (to get them out of the way) and the good soil planned last.

Insert 2,4 ha new soil:

Selection I. Rotation B_1 + contract work, rank 1.

2,4 ha are taken. This gives 2,4 × 1 = 2,4 T ha, leaves 2,4 — 2,4 T OB ha of ground.

Period 1. 13 hours required per ha which gives 13 × 2,4 = 31,2 T leaves 540 — 31,2 T = 508,8 B hours over.

Period 2. 1,3 hours required per ha, which gives 1,3 × 2,4 = 3,1 T leaves 216 — 3,1 T = 212,9 B hours over.

Period 3. 17,6 hours per ha required, which gives 17,6 × 2,4 = 42,2 T leaves 216 — 42,2 T = 173,8 B hours over.

Period 4. 95,4 hours per ha required, gives 95,4 × 2,4 = 229 T leaves 324 — 229 T = 95 B.

No starch or protein is supplied or required by the rotation. Similarly the other rotations and enterprises are calculated in the plan.

The land resources of the new soil are fully used so 2,4 ha of old soil are inserted into the plan.

Insert 2,4 hectares of old soil

Selection I. Rotation D_1 + contract work. Rank 1.

2,4 ha are taken. Rotation D_1 contains $^2/_3$ of a ha of leys per ha, this accomodates 1,47 cow units. Therefore 1,47 × 2,4 = 3,5 cow units are kept. The cow units require starch equivalent and crude protein. 1 ha of rotation D_1 requires 346 kg of starch and 65,9 kg of protein for the cow units. The total starch and protein requirements are:

starch 2,4 × 346 = 830,4 kg (— 830,4)

protein 2,4 × 65,9 = 158,2 kg (— 158,2). A minus figure is used to denote a need for starch and protein.

In period 4 there is a shortage of 47 hours (— 47,1 B). Casual labour is available for the potatoe crops of rotation B_1 on the young soil, and rotation D_1 on the old soil. Rotation B_1 contains $^1/_3$ of a ha of potatoes per ha of the rotation. Rotation D_1 $^1/_6$ of a ha of potatoes per ha of the rotation. Casual labour is available at a rate of up to 110 hours per ha of potatoes.

Rotation B_1 supplies $\frac{110}{3}$ = 37 hours per ha. In total 2,4 × 37 = 88 hours. Rotation D_1 supplies $\frac{110}{6}$ = 18 hours per ha. In total 2,4 × 18 = 43 hours. In all 88 + 43 = 131 hours are bought at a cost of 1,5 D.fl. per hour. This leaves 83,9 hours in balance in period 4.
Old soil land resources are fully used. Insert good soil into the plan.

Insert 5,85 ha arable land + 0,95 ha permanent grassland into the plan

Selection I. Cow units. Rank 1.
Hours in period 4 are limiting. 83,9 hours are available, 7,5 hours are required in this period per cow unit. Therefore $\frac{83,9}{7,5}$ = 11 cow units may be kept. 11 cow units require 11 × 0,45 = 4,95 ha of grassland. This leaves 1,85 ha of arable land in balance.

Selection II. Early potatoes + turnips. Rank 2.
Period 2 is limiting in hours. 27,1 hours are available and 250 hours per ha required. $\frac{27,1}{250}$ = 0,1 ha are taken. No hours are required in period 4.

Selection III. Barley + turnips + contract work. Rank 7.
Enterprises ranking 3, 4, 5 and 6 require hours in period 4, and none are available. They are therefore not included in the plan here.
There are 54,1 hours available in period 3, 51 hours are required per ha for this enterprise. Therefore $\frac{54,1}{51}$ = 1,06 ha could be taken. The barley area may not exceed $^1/_2$ the arable area so only 0,92 ha are taken.

Selection IV. Sugar-beet.
Few hours are available in period 3. Sugar-beet and potatoes, early and maincrop, do not requuire hours in period 3. Maincrop potatoes require hours in period 4 and are therefore excluded. Early potatoes need many hours in period 2 and are therefore excluded. Sugar-beet only requires hours in period 1 and is therefore included. 121,5 hours are available in period 1. Therefore $\frac{121,5}{320}$ = 0,38 ha are taken and contribute 0,38 × 3000 = 1140 kg of starch equivalent and 0,38 × 420 = 159,6 kg of crude protein to the feed requirements of the plan.

Selection V.
There are 0,45 ha in balance; 0 hours in period 1; 2,1 hours in period 2; 7,2 hours in period 3 and 1,4 hours in period 4. Thus the plan needs hours. Can any enterprise be changed to make hours available without altering the number of cows upon which the main profitability of the plan rests? Rotation C_1 + contract work on old soil has the same number of cow units, but requires less hours than Rotation D_1 in periods 1, 2 and 4. Rotation C_1 is exchanged for Rotation D_1 and the change in the number of hours and revenue recorded.

Selection VI.

The casual labour used for potatoes in Rotation D_1 period 4 must be removed from the plan.

There are 0,45 ha in balance; 13,2 hours in period 1; 3,5 hours in period 2; — 7,2 hours in period 3 and 59 hours in period 4. To memove the — 7,2 hours in period 3 barley + contract work + turnips would have to be reduced by $\frac{7,2}{51} =$ 0,14 ha. To utilize the land released from the barley enterprise and replace the starch equivalent and crude protein forgone, the sugar-beet enterprise must be increased by 0,14 ha. The plan would then contain 0,52 ha of sugar-beet. The rotational restriction is $^1/_4$ of the arable area = 0,46 ha. Therefore these — 7,2 hours are not removed from the plan.

Selection VII. Potatoes main crop.

There are 59 hours available in period 4. Casual labour is available for potatoes in period 4 and in period 1 (sugar-beet). 0,45 ha of potatoes main crop are taken and 47 hours of casual labour are used in period 4.

Selection VIII.

Casual labour is required in period 1 and is available for the sugar-beet enterprise. 3 hours are taken at a cost of 2 D.fl. per hour.

There are now 0 ha of land in balance; 0,4 hours in period 1; 1,2 hours in period 2; — 7,2 hours in period 3 and 0 hours in period 4. This is the near optimum plan.

5.4. Comparison of the near optimum plan and optimum plan

Activity	Near optimum plan (Plan F) (ha)		Optimum plan (ha)	
Good soil				
Barley	0,92		0,91	
Potatoes main crop	0,45		0,45	
Early potatoes	0,10		0,07	
Sugar-beet	0,38		0,40	
Permanent grass including 0,95 ha given	4,95		4,97	
Old soil				
Rotation C_1	2,4		2,4	
Young soil				
Rotation B_1	2,4		2,4	
Miscellanious				
Sugar-beet + tops	0,38		0,40	
Turnips	1,02		0,97	
Cow units	14,5	numbers	14,5	numbers
Casual labour period 4	135	hrs	136	hrs
Casual labour period 1	3	hrs	7	hrs
Contract work	3,32	ha	3,31	ha
Total revenue	11906,8	D.fl. (11796,8)	11922,5	D.fl.

The following figures are derived thus:
Contract work

Old soil
Rotation C_1 has $^1/_3$ ha of grain/ha
Young soil
Rotation B_1 has $^2/_3$ ha of grain/ha
} which may be contracted

thus

$B_1 = (2{,}4 \times {}^2/_3) + (2{,}4 \times {}^1/_3)\ C_1 = 2{,}4$ ha
Barley + contract = 0,92 ha
3,32 ha

Turnips catch crop
0,92 (barley) + 0,1 (early potatoes) = 1,02 ha

Cow units
11 on good soil + (2,4 × 1,47 = 3,5) = 14,5 numbers
(Rotation C_1 + contract, *old soil*).

The total revenue of the near optimum plan is very near that of the optimum plan in this example. Other studies have shown total revenues of the near optimum plans within 3 % of the total revenues of the optimum plans. The total revenue in brackets differs from the total revenue of the optimum plan by approximately 1 %.

5.5. Rotational considerations of the arable crops on the good soil

In plan F there are 1,85 ha of arable rotation. $^1/_4$ of this area may be in sugar-beet = 0,46 ha, there are 0,38 ha in the plan. Potato area may equal $^1/_3$ of the area = 0,61 ha, there are 0,55 ha.
Barley may equal $^1/_2$ the area = 0,925 ha, there are 0,92 ha in the plan.
Potatoes and sugar-beet may not be more than $^1/_2$ the arable area = 0,925 ha. Together they are 0,93 ha.
The rotational considerations may be considered satisfied. The removal of the — 7,2 hours in period 3 by increasing the sugar-beet enterprise and reducing the barley enterprise would have given a rotation of : barley 0,78 ha, sugar-beet 0,52 ha and potatoes 0,55 ha. This rotation would not satisfy the rotational restrictions. In practice however, these — 7,2 hours (hours required extra) would present no problem to the farmer.
The total revenue of the plan will be reduced if the — 7,2 hours are removed from the plan by re-combining the enterprises within the rotational restrictions. The marginal value per hour in this period is 15,3 D.fl. (from linear programming matrix). Therefore the total revenue should be reduced by approximately 110 D.fl. The total revenue is then approximately 11796,8 D.fl.

6. Conclusion

The comparison of the near optimum and optimum plan shows that this programme planning technique is accurate enough for this type of empirical work. It can however, lead to difficulties when grassland and arable land enterprises are closely interrelated, as seen in the good soil arable land.

This method, unlike linear programming, does not provide an end matrix which can give an x-ray picture of the farm enterprise relationships. However the planner is able, while planning, to see which enterprises are blocking the plan and where adjustments in the farm policy can be made. In practice many of the restrictions notably hours available and hours required are not rigid. When an enterprise needs many hours in one period and blocks the plan as insufficient hours are available, the planner can decide on the spot if:

a. the enterprise hours can be spread into another time period;
b. to allow minus hours to accumulate. The farmer or planner would then decide if the farmer is prepared to work these extra hours. In linear programming these factors would usually come to light after the plan is finished.

Few farmers are prepared to grow 0,91 ha of barley etc. Therefore the plans, optimum or near optimum, have to be put into a practical form. This means that enterprises are brought into manageable proportions, *e.g.* 1 ha of barley and $^1/_2$ hectare of potatoes etc. The resulting plan is not an optimum plan. Consequently the differences between the optimum and near optimum plan are of little value when the practical plan is given to the farmer.

A further development is "discreet planning". In this method block inputs of the enterprises are used, *e.g.* 1 ha of barley and $^1/_2$ ha of potatoes. The use of block inputs increases the choice element considerably, especially when hours are limiting. The question arises: is it reasonable to increase a high ranking enterprise by another block input of the enterprise and have minus hours in the plan, or not? The answer to such a question relies more on the "discretion" of the planner than on the system. This increases the choice element of the method. Discreet planning is not well suited to solve problems similar to the one in this paper, but can be usefull in solving many farm management problems.

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