AGRICULTURAL
ECONOMICS
RESEARCH UNIT

Lincoln College

PROGRAMMING A CANTERBURY MIXED FARM

by

J. D. STEWART and P. NUTHALL

Publication No. 7

THE AGRICULTURAL ECONOMICS RESEARCH UNIT

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PROGRAMMING A CANTERBURY MIXED FARM

Analysis of Alternative Cropping and Livestock Systems on a Canterbury Plains' Arable Farm

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P R E F A C E

Most farm management problems are concerned with the choice between alternative production plans with a view to maximising income, minimising costs, or achieving some other defined farming objective.

These problems can often be solved by the well tried and simple method of comparing budgets for various alternative plans to establish which plan comes nearest to attaining the objective. But when the number of possible alternatives becomes large, it is necessary to use a more complicated technique such as linear programming with which we can explore the implications of a whole range of budgets in a speedy and systematic way.

In this paper, Dr J.D. Stewart and Mr P. Nuthall of the Farm Management Department at Lincoln College, present the results of using linear programming to analyse the outcome of alternative cropping and livestock systems on the Lincoln College mixed cropping unit.

The paper does not give a detailed description of the methods of linear programming. The aim is rather to present the results, for it is felt that these will be of interest to farm advisory officers and others concerned with farm management problems for whom the paper has been expressly written.

Lincoln College
4 August 1964

B. P. Philpott

PROGRAMMING A CANTERBURY MIXED FARM

ANALYSIS OF ALTERNATIVE CROPPING AND LIVESTOCK SYSTEMS ON A CANTERBURY PLAINS' ARABLE FARM

Farms on the medium and medium-heavy soils of the Canterbury Plains are very versatile. They are capable of growing a profitable range of cereal and pulse crops including wheat, oats, barley, ryecorn, garden and partridge peas. In specific areas brassica seed production is reliable and generally remunerative. Small seeds production is also characteristic of the area, with ryegrass and white clover predominant, but with cocksfoot and other special purpose seed stands being favoured in some areas. Potatoes provide additional flexibility and intensity where the soil type is suitable.

The livestock system is generally based on fat lamb production from Corriedale, Three-quarter bred, or Romney ewes. These flocks are usually maintained by purchase of hill-country cast-for-age or cull two-tooth ewes, or occasionally ewe hoggets. The breeding of replacement ewes is not common on this class of property, as it is generally considered that this results in a loss of flexibility in overall

management. Additional versatility in sheep management is conferred by the capacity of the farmer to vary his disposal policy. He may for example sell ewes in-lamb in the early spring, or ewes and lambs all-counted, or he may carry the lambs through to export weights. He may also attempt to get his dry ewes, and his early weaned ewes killed early, giving increased scope for small seeds production. This complementary relationship between small seeds and sheep may be further exploited by the wintering of wether-hoggets, and their disposal fat off-shears in the late spring.

The possible combinations of these enterprises are innumerable, and that the choice problem confronting the farmer on this class of property is of considerable significance. In making this choice he will be influenced by a number of criteria, which may include:-

1. the maximization of short term profits;
2. the availability of labour, machinery, and operating capital;
3. the maintenance of the long-run fertility and productivity of the farm, including the control of disease, pests and weeds;
4. the compatibility of the programme with managerial capacity and personal preferences.

In the farm study which follows, the maximization of profits has been taken as the primary objective. The maintenance of fertility and productivity is assured by limiting the alternative systems considered to only those which will satisfy this objective. Furthermore it is assumed that the supply of managerial ability, of machinery and operating capital is sufficient for any feasible programme. The question of labour availability is reviewed later in the paper.

The Farm

The programmed farm is the Lincoln College mixed-cropping unit. The area of this property is 400 acres, of which 394 are effectively farmed. There are three fairly distinctive soil types which, in general farm management terminology, are classified as heavy (58 acres), medium-heavy (202 acres) and medium (134 acres).(1) In general these soils have the same cropping capacity, and may be farmed under similar cropping systems, the basic differences being in yields and in cultivation techniques. For the purposes of this study these land classes have been designated (1), (2) and (3) respectively. The

(1) Heavy. Temuka silt loam
Medium-heavy. Wakanui silt loam
Medium. Templeton silt loam.

property which is all ploughable is subdivided into 23 paddocks ranging in area from 10 to 25 acres. It is in a high state of fertility and is free from serious perennial weeds. The fences and water supply are good.

The labour force is a working manager, a general farm-hand, and a youth over the summer period. Casual labour is hired occasionally, at rush periods. There is an adequate range of machinery for the current farming programme, but the plant is not geared to any substantial expansion in the area of potatoes.

Costs and Returns from Individual Enterprises

Before we can analyse alternative cropping and livestock systems it is necessary to examine the prospective costs and returns from the individual enterprises which will make up these systems. We assume here that the only relevant costs are the direct or variable costs which can be assigned to these enterprises. In the short term, fixed costs such as depreciation, interest, rates, insurance and fixed labour and machinery charges are irrelevant. They will remain the same within the bounds of the alternative systems under consideration.(2) The difference

(2) For a fuller discussion see J.D. Stewart "Planning for Profit". Proc. Lincoln College Farmers' Conference 1963.

between the prospective gross returns per acre of a crop and the direct costs involved in producing it, is the amount which this crop contributes to the meeting of the overhead costs and to true profit.

Gross returns less direct costs is called the "gross margin", or the "net revenue". We shall use the former term. It is clear that if we maximise this amount, we maximise profits (or minimise losses), in the short run.

An example of the calculation of the gross margin for an individual enterprise is now given. This is for garden peas on the medium soil type of the farm under study.

Garden peas (ex old pasture)

Gross revenue (per acre)

35 bus. at 18/-		£31 10 0
Direct costs		
5 hours cultivation at 3/-	15 0	
Seed, 4 bus. at 23/6	4 14 0	
Fertiliser 1¼ cwt at 9/8	12 1	
Spraying	1 6 0	
Harvesting	7 0	
Sacks	12 6	
Cartage	16 8	
Sundry	3 0	9 6 3
Gross margin per acre(nearest shg.)		£22 4 0

The costs and prices used are those ruling in mid 1963. It should be kept clearly in mind that

the cultivation, spraying and harvesting costs do not include any allowance for the overheads on the equipment, or for the fixed labour operating it. The direct costs are not the "costs of production". They are the costs which the farm would not incur if this acre of peas was not grown.

An example of the calculation of the gross margin of a sheep enterprise is as follows:-

2 year fat-lamb ewe flock(1)

Gross revenue per ewe (lambing 115%)			
Lambs 115 at 38/- net	£2 3 8		
Wool 10 lbs at 38d net	1 11 8		
Cull ewe ½ at 20/-	10 0	4 5 4	
Direct Costs			
Ewe replacement ½ + .05 (death rate 5%) at 45/-	1 4 9		
Shearing at £7.10s/100	1 6		
Crutching at £3.10s/100	8		
Vaccination, dipping etc.	1 0		
Ram replacement	1 0		
Cartage	1 3		
Sundry	3 0	1 13 1	
Gross margin per ewe (nearest shg.)		£ 2 12 0	

It will be noted that there are no feed costs charged against the sheep enterprise. These costs (e.g. pasture, lucerne, hay) are accounted for in an

(1) These figures were estimated prior to the 1963/4 lamb and wool selling season. However this is not a great disadvantage to the study, as a central part of it has been to explore the effect of variations in the prices used. Thus, provided the starting point is reasonable, we can take price variation into account.

indirect way, which will become clear as we proceed. The basic procedure is to calculate the direct costs of producing the feed and then specify the feed requirements which become an indirect charge against the sheep.

The results of the costs and returns estimates for individual enterprises are given in Appendix 1.

Grouping of Enterprises

There are physical and biological inter-relationships between individual crops on the arable farm. This often makes it difficult, and sometimes illogical to consider these enterprises independently. For example, consider the practice of undersowing wheat crops with white clover, to produce a white clover seed crop in the succeeding year. There are some costs involved in this practice which are obviously joint costs. They can not be assigned completely to either the wheat or white clover. Cultivation and fertiliser costs come into this category.

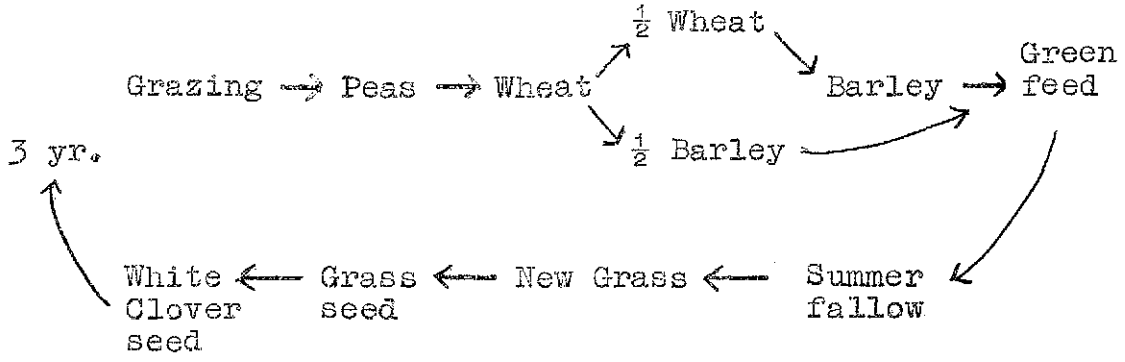
Similarly, when we consider a rotation of pasture and crops there are generally residual effects in respect of plant nutrients, cultivation requirements, and perhaps weeds and pests.

Because of these interrelationships it is

necessary to study enterprise combination problems from the standpoint of groups of interrelated enterprises, rather than the individual enterprises themselves. In other words we want to find which combination of enterprises will yield the greatest profit.

A practical way to group different enterprises is to work them out on the basis of feasible cropping rotations. A rotation then has its own land use system, and one may compare this and its related livestock programme, with other alternatives.

An example of a rotation and its corresponding land use system is as follows:



Assuming 203 acres of land, and 20 acres being ploughed out of grass each year this would give the following land utilization:-

Winter		Summer	
20 acs.	ploughed	20 acs.	peas
30 "	wheat	30 "	wheat
30 "	barley	30 "	barley
20 "	greenfeed	20 "	summer fallow
20 "	new grass	20 "	grass seed
80 "	grazing	20 "	white clover seed
		60 "	grazing

We thus calculate the feed provided by this system and work out a sheep programme to fit it. We then have the basis of a budget, which can be compared with the results derived from an alternative system.

Method of Analysis

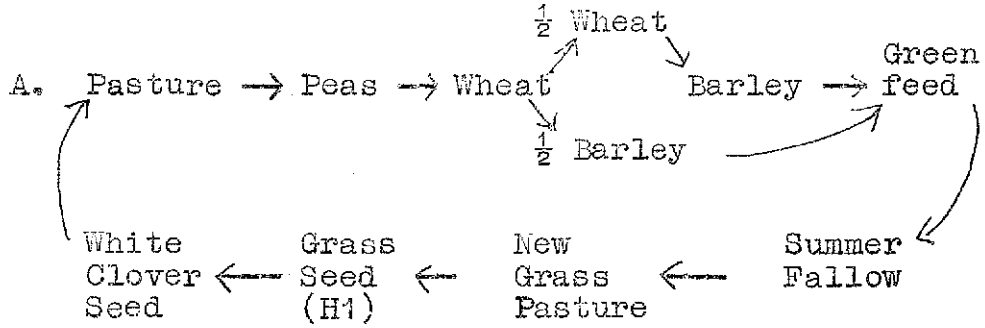
The normal technique in farm management analysis for this kind of problem is comparative budgeting. In most general farm management work this method is adequate, particularly where the alternatives to be considered are few. It is clear however, that under the farming conditions we are considering there are a very large number of possible cropping systems. In addition there are a number of alternative sheep management systems. Therefore if we wish to carry out a thorough exploration of the economics of this large number of alternatives, comparative budgeting would be extremely arduous.

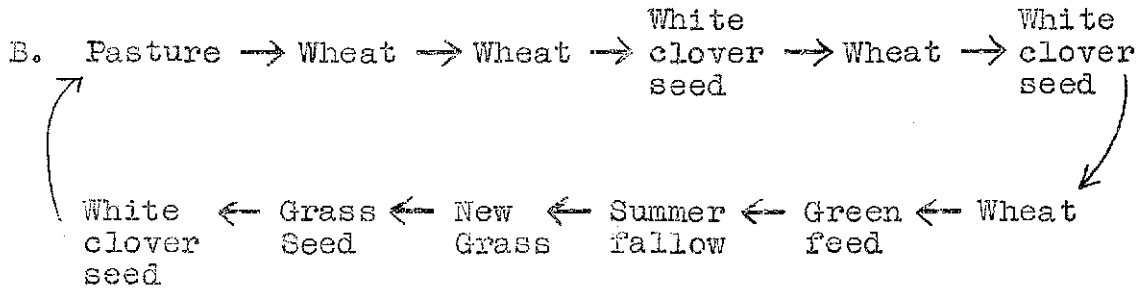
The technique of linear programming permits us to carry out this comparative budgeting procedure very quickly, particularly with the aid of an electronic computer. Furthermore, once the alternatives are defined, and their requirement of limiting factors accurately specified, the linear programming routine will sort out the one solution which satisfies our objective, the maximization of profits. We shall also see that it provides some useful additional information.

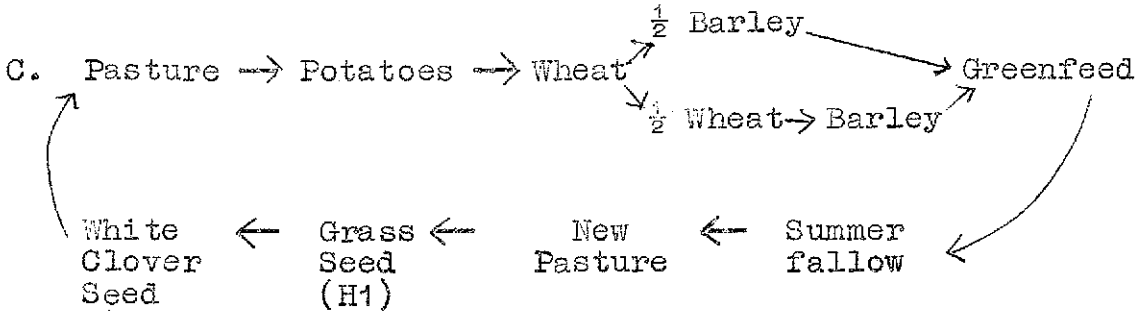
Even electronic computers, however, are limited in the size of the problem they can solve. They are limited by the capacity of their "memory". Therefore it was necessary to do some preliminary choosing of the alternative rotations which were to be studied. In doing this we chose rotations which are representative of the principal methods under which the property can be farmed. Thus, even electronic programming does not make commonsense and judgement redundant.

Alternative Land Use Systems

The following four basic rotations were studied:-







D. Pasture → Swedes → Summer fallow → New pasture

Rotation A. is a conventional Canterbury sequence of crops, which permits a fairly intensive level of cropping and small seeds production. It ensures fertility maintenance and weed control by the provision

of a greenfeed crop, three or four years of summer grazing, and a summer fallow.

Rotation B. is an intensive wheat-white clover rotation, in which there is a good deal of interest at present. These "specialist" white clover seed crops are undersown in the wheat, grazed in the winter and spring following harvest of the wheat and closed for clover seed in October or November. Yields of white clover have tended to be high and reliable under this sytem, because of the absence of grass competition. Also the nitrogen build up is beneficial to the subsequent crop of wheat.

Rotation C. is similar to A., but potatoes take the place of peas as the first crop after old pasture.

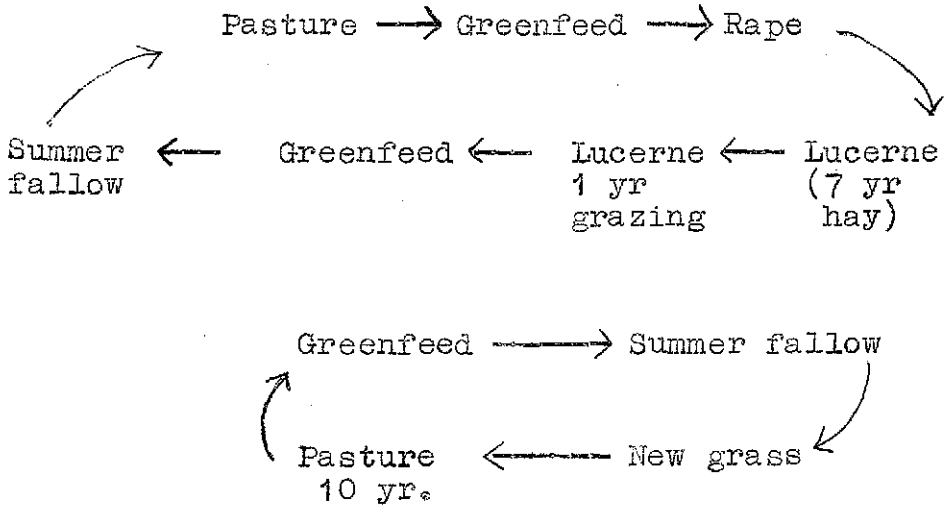
Rotation D. is a simple forage cropping system, suitable with a complete sheep farming programme. Although commonsense dictates that such a programme would not budget well against a cash cropping programme at present prices it was included in order to study alternative prices under which it might compete.

We also examined the role of lucerne in the farm economy. A small lucerne and lucerne renewal programme was therefore superimposed on these rotations. But this was confined only to land classes (2) and (3), the medium heavy and medium soils, for the heavy soils of class (1) are generally considered too wet in the

winter for the maintenance of good lucerne stands.

Additionally it was thought important to examine an alternative forage cropping system, (E). This did not include a root crop, but used lucerne hay for winter feeding with an intensive grazing system.

Rotation E.



The remaining system of land use included in the study was cocksfoot seed production (Rotation F).

This gives six possible basic rotational systems. We superimposed on these different levels of intensity of crop production. We did this by assuming varying acreages being ploughed out of old pasture to enter the rotations.

For example, if 20 acres were ploughed out of grass on the medium-heavy land block (class 2) and put through Rotation A, this would provide the following

land use pattern.

Peas	20 acs
Wheat	30
Barley	20
Greenfeed to summer fallow	20
H1 seed	20
White Clover seed	20
Lucerne	$7\frac{1}{2}$
Pasture	$64\frac{1}{2}$
	202

This gives a cropping capacity of half the total acreage in cash crop, while a quarter is in white straw crops. If less were ploughed out of grass we should have a larger area of pastures, and correspondingly less cropping.

To examine the influence of cropping intensity, we defined three levels. These levels have been designated x, y and z. The respective levels of crop production are:-

x = 5/12 cash crop, $\frac{1}{3}$ white straw crop (Heavy cropping intensity)

y = $\frac{1}{3}$ " " $\frac{1}{4}$ " " " (Med-heavy cropping intensity)

z = $\frac{1}{4}$ " " 1/5 " " " (Medium cropping intensity)

For Rotation A we now have defined the following variants:-

A_{1x}	Rotation	A	on	class	(1)	land	under	heavy cropping
A_{1y}	"	"	"	"	"	"	"	med-heavy "
A_{1z}	"	"	"	"	"	"	"	medium "
A_{2x}	"	"	"	"	(2)	"	"	heavy "
A_{2y}	"	"	"	"	"	"	"	med-heavy "
A_{2z}	"	"	"	"	"	"	"	medium "
A_{3x}	"	"	"	"	(3)	"	"	heavy "
A_{3y}	"	"	"	"	"	"	"	med-heavy "
A_{3z}	"	"	"	"	"	"	"	medium "

Similarly for Rotations B and C nine possibilities are defined. Further variants of Rotations A, B and C on class 2 and 3 land involved the exclusion of the lucerne components. This gives another six possibilities, designated HA_{2x} etc., which implies, Rotation A on class 2 land, under heavy cropping, with lucerne omitted.

The forage cropping rotations D, E are programmed at only one level while cocksfoot seed production, F, is trestricted to classes 1 and 2 land. This gives an additional 8 variables, and brings the total number of land-use alternatives to 41. These are detailed in Appendix 2.

Alternative Sheep Policies

Five possible sheep policies were considered. These were:-

S1. Fat-lamb flock, Romney or Three-quarter bred, maintained by purchase of 4 year old ewes, replacing half the flock each year.

S2. Fat lamb flock, breeding replacements.

S3. Fat lamb flock, maintained by purchase of 2-th ewes.

S4. Wintering of one-year ewes with the sale of ewes and lambs all-counted in the spring.

S5. Wintering of wether hoggets, and selling them fat off shears in the late spring.

The details of the costs and prices associated with these enterprises are given in Appendix 3.

These alternatives permit the examination of three types of replacement programme. The most widely practised system on this class of farm is the purchase of four or five year old ewes, which are retained for two lambings. Breeding is not widely practised because it tends to lessen flexibility, which is rather important, particularly where there is a substantial small seeds programme. The two wintering alternatives - ewes and lambs all counted

and fattening hoggets are quite common, and both are complementary to small seeds production.

While provision was made in the rotational system for lucerne, it was also decided to allow for the possibility of buying lucerne hay. For it is possible that under some circumstances this may be a more profitable thing to do than to grow it.

Thus, with 41 possible land use systems over the three land classes, five possible sheep enterprises and the possible purchase of hay, we have 47 alternative activities on the farm. This by no means exhausts the total possibilities, which are very great. But, because we have included five rotational systems which are indicative of different, important, basic policies, and because we have allowed three levels of cropping intensity within these rotations, this represents a fairly thorough exploration of the production possibilities.

Limitations

The production possibilities of a farm are limited by the available resources - basically by the land, labour and capital. In this study we have assumed that adequate capital, both fixed and operating capital, is available to meet the requirements of any feasible programme. Feasibility is to a large extent determined

by the nature of the alternatives we are programming. For example, the machinery available for handling potatoes is limited and a large area could not be incorporated without capital investment in plant.

The problems involved in incorporating reliable labour coefficients in a linear programming model for this type of farm are very great. The actual labour force on the farm consists of a working manager, a general farm hand and a youth over the summer period. Thus the only crop likely to generate a labour bottle-neck is potatoes, and as pointed out this is already limited to an acreage which can be handled by the existing resources, through the defined rotations.

If however our knowledge of the labour requirements of the various enterprises was more precise and reliable, then the study would be greatly enhanced. But in the meantime it is not possible to determine satisfactory labour coefficients with the degree of precision demanded by linear programming. We are thus led to the expedient of programming the farm independently of the labour constraint and then relying on our judgement when examining the programmed solutions. This after all is the basis we tend to use in budgeting, and in practical farm management.

The limitations included in the analysis were as follows:-

(1)	Land (Class 1 Heavy)	58 acres
(2)	Land (Class 2 Med-Heavy)	202
(3)	Land (Class 3 Medium)	134
(4)	Winter feed	
(5)	Lambing feed	
(6)	Spring-summer feed	
(7)	Maximum Cocksfoot	40
(8)	Maximum fattening hoggets	500

The feed limitations were expressed in terms of stock-units. All the stock were converted to standard stock-units, and the feed provided by the various rotations in winter and spring-summer were expressed in the same terms. Details are provided in Appendix 4.

The limitation of 40 acres on cocksfoot was imposed because of a subjective risk factor. The restriction of 500 on the number of hoggets to be wintered results from the experience that once numbers of this class of stock exceed this density management and thrift problems tend to arise.

We now have the boundaries of our farm management problem - a number of possible rotational systems on the three classes of land, each at various levels of cropping intensity, a range of possible sheep management

systems, and the specified limitations at which these enterprises may be carried on. The aim is to combine these enterprises in the most profitable way, compatible with the limitations imposed. The most profitable way is that which maximises total gross margins, which we have defined as the revenue in excess of those costs which are variable and which can be directly assigned to the specified alternatives.

Programmed Solutions

Before they can be used as a positive prescription for adjustments to existing management, farm programmes produced by budgeting or linear programming must fulfil a number of conditions. In the first place the prospective increase in profit must be significant. Further, any increase in risk, or in work load must be acceptable to the farmer. Similarly any increase in the complexity of management must be compatible with the managerial skill available. If sufficient data on the riskiness of various crops were available it would be possible to include this risk element in a modified programming model, and to provide solutions which were compatible with only prescribed levels of risk. But at present data of this nature is not procurable. We must therefore treat our risk factor in a less refined way, either by including appropriate constraints on

risky enterprises at the outset as we have done for cocksfoot seed production, or by examining programmed solutions for acceptable levels of risk. Often we may need to do both, for it is not always possible to formulate completely all the limits we may wish to impose initially.

The farm programme representative of recent years is as follows:

Peas	40 acres
Potatoes	6
Wheat	88
Barley	-
Grass-seed	37
White clover seed	33
Greenfeed to summer fallow	51
Lucerne	13
Grazing	126
	394 acres

Sheep 850 4 & 5 yr old breeding ewes
500 wether hoggets wintered.

Using the costs and revenues outlined in the appendix the above programme would produce a total gross margin of £7100.

This is the figure with which we must compare any programmed solution, keeping in mind that net farming

profit is derived from this by deducting fixed costs. Thus if fixed costs amount to £3,000, giving a net profit of £4,000, then an increase of £1,000 in total gross margin from £7,000 to £8,000 would be equivalent to a 25% increase in net profit, i.e. £1,000 on £4,000.

The primary optimal solution was as follows*:-

Class 1 Land (Heavy)	
Rotation B_x	58 acres
Class 2 Land (Med-Heavy)	
Rotation B_x	202 "
Class 3 Land (Medium)	
Rotation B_x	134 "
	394 "
Stock	
Basic ewe flock 530 ewes	530 ewes
(Breeding replacements)	
Wintering ewes and selling ewes and lambs "all counted"	390 ewes
Wintering hoggets	500 hoggets
Purchase Hay	900 bales
Total Gross Margin	£7,920

* To nearest acre, and to nearest 10 sheep, 10 bales hay and £10.

Rotation B_x, it will be recalled, is the intensive wheat "specialist" white clover rotation carried on at the most intensive level. This rotation on each of the land classes would result in the following overall summer land utilisation.

	acres	acres
Wheat (ex white clover or old grass)	33	
Wheat (ex wheat)	98	131
White clover seed (ex wheat)	66	
White clover seed (pasture)	31	97
Ryegrass seed		31
Lucerne		15
Grazing		89
Summer fallow to new grass		31
		394

With the heavy small seeds programme the stock policy is based on a heavy wintering programme involving the maximum number of wether hoggets wintered, as well as 390 ewes for disposal with lambs at foot, in addition to the basic flock of 530 ewes and replacement hoggets. The 15 acres of lucerne hay grown, and the available area of winter grazing is supplemented by the purchase of 900 bales of hay. In the spring-summer period with available grazing restricted to 89 acres after the white clover is closed, sheep numbers are restricted to the basic ewes and replacements. The white clover

areas however do make a contribution to the fattening of lambs, through its relatively late closing time. Examination of the feeding coefficients in Appendix 4 will show that the programmed rotations and stock numbers are reconcilable.

Before we discuss the practical side of this solution, we can make the following additional notes about it.

(1) The programmed total gross margin is £800 higher than that for the existing policy. Bearing in mind the constant fixed costs, and the conservation of our yield and price estimates, this must be regarded as significant.

(2) The stock policy, with high winter carrying, and summer destocking is feasible. Had the restriction on hogget numbers not been included, there would have been additional numbers of these, instead of the ewes sold with lambs, all-counted.

(3) The breeding of replacements for a small flock of 500 ewes on a property of this nature is not general. But in fact, if we accept the costs and prices used, and the feeding coefficients, the breeding policy budgets out slightly better than buying in. However the reduction in profit

if the policy of buying in were substituted, because of its additional flexibility, would be 6/- per ewe, that is about £160.

(4) The purchase of hay would remain an economic thing to do if its price rose from the programmed figure of 6/- per bale to 7/6 per bale. If it were higher than this then the programme would be readjusted.

(5) In respect of the price of wheat, the programme would remain optimal if its price were to fall from 13/6 to 10/9 per bushel, all other prices remaining the same. But no further increase in the price of wheat would induce higher production, for it is already at the highest level compatible with the rotational constraints.

(6) In respect of the price of white clover, the solution would remain optimal for a reduction in price from 3/- to approximately 2/9 per pound.

Our conclusion can only be that if this were an entirely acceptable system of farming the property, it would result in significantly higher profits, and these would be reasonably stable. But the system is fairly revolutionary, and subject to a degree of

technical uncertainty, which may not be very widely acceptable. Although there is considerable interest in the intensive wheat-white clover rotation at present, it is doubtful whether there are farmers who would push it to the levels prescribed in the linear programming solution. There are problems of weed and pest control, and aspects of fertility maintenance which, at the time of writing, have not been fully explored.

With this in mind the farm was re-programmed with the intensive wheat-white clover rotations restricted allowing only the low (Z) levels. The solution was as follows*:-

Class 1 Land (Heavy)		
Rotation B_z		58 acres
Class 2 Land (Medium Heavy)		
Rotation C_y		202 "
Class 3 Land (Medium)		
Rotation B_z	78 acres	
Rotation C_y	56 "	134 "
		394 "
Stock		
Basic flock (breeding replacements)		866 ewes
(Breeding replacements		130 ewe hoggets)
Wintering hoggets		500 hoggets
Total Gross Margin		£7,248

* A few bales of purchased hay were in the solution but were considered insignificant.

Thus the low intensity wheat-white clover rotation (B_2) comes in on the heavy land and as a proportion of the medium land. The total land-use with this programme would be

Wheat	65	acres
Barley	26	"
Potatoes	25	"
White Clover seed (undersown)	14	"
White Clover seed (pasture)	30	"
Grass seed	30	"
Green feed and summer fallow	30	"
Lucerne	15	"
Grazing	159	"
	394	"

Reference to the basic rotations will indicate that Rotation C contains potatoes as the first crop after grass rather than peas and it is clear that if the labour and equipment is available to handle potatoes, total gross margin is somewhat higher with this crop included.

Apart from this we find that the overall system of management in the revised solution does not differ greatly in principle from the existing pattern of management. About 30 more acres are devoted to

grazing in the spring-summer period, approximately the same number of ewes are carried but in the programmed solution additional ewe hoggets are run*. The difference in total gross margin, £7,248 against £7,100, may hardly be regarded as significant. Indeed examination of the solution matrix for this programme reveals that only marginal changes in revenue accompany quite a range of possible adjustments in the cropping programme. For example the programmed loss in revenue from forcing the conventional (A) rotations into the solution would amount to 12/- to 16/- per acre over a large range. Similarly cocksfoot seed production on class (1) land would not reduce programmed revenue very substantially.

Thus, our conclusion from the analysis to this stage is that should experience show an intensive wheat-white clover rotation (B_x) to be practicable, from the husbandry point of view, it would result in a significant increase in profits on this class of property. But if we exclude this sytem, then considerable flexibility in the cropping system is possible with little sacrifice of prospective revenue.

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* The programmed loss in revenue if bought 4 year old ewes are substituted would be 3/- per ewe.

The wintering of hoggets is clearly a highly stable element in the optimum programme. Analysis of the solution shows that the margin could fall to as low as 12/- per hogget and it would still be profitable to run them. However it is also evident that if the restraint of 500 on hogget numbers was released, it would be necessary to buy hay (or reduce ewes) and the margin would decline somewhat. Nevertheless, with selenium and thiabenzole drenching having such pronounced effects on hogget thrift, limitations on hogget numbers for this reason could be critically looked at. The strength of the hogget enterprise is its complementary relationship with the cropping and small seeds programme, whereas the basic ewe flock is competitive. Substantial reductions in income would result from forcing the forage cropping rotations (D) and (E) into the programme. The solution shows that this cost would be £4 to £5 per acre, and that this would rise fairly sharply.

A final test of the economic stability of this balanced cash cropping, small seeds, sheep system was carried out by bringing the gross margins for the sheep enterprises into line with the high prices ruling in the 1963/4 season for wool and lamb. For example the wool price was increased from 38d net to

48d, and the lamb price from 38/- net to 45/-. But this failed to bring about a significant adjustment in the overall programme, even though it was programmed again without the intensive wheat-white clover rotations. This implies that even very high wool prices will not result in an intensive sheep system being economically competitive with a balanced cropping system, where the yields of crops are as high, and as reliable as they are in the class of country studied.

APPENDIX 1

COSTS AND RETURNS FOR INDIVIDUAL ENTERPRISES

(September 1963 Prices & Costs)

SOIL TYPE I

HEAVY CROPPING (x)

Enterprise	Peas ex O.G.	Potatoes ex O.G.	Wheat ex Peas or Potatoes	Wheat ex Wheat	Barley ex Wheat	Rye Seed (Pasture)	White Cl. Seed Pasture
Yield	35 bu.	7 t.table 4 t.seed	55 bu.	50 bu.	60 bu.	40 bu.	210 lbs
Price	20/-	Table £13 Seed £20	13/6	13/6	8/6	12/6	3/-
Total Revenue p/ac	£35 0 0	171 0 0	37 2 6	33 15 0	25 10 0	25 0 0	31 10 0
Direct Costs "	£ 9 18 11	146 7 11	6 7 11	6 16 4	5 15 4	14 7 0	7 5 7
Gross Margin "	£25 1 0	24 12 0	30 15 0	26 19 0	19 15 0	10 13 0	24 4 0

MEDIUM-HEAVY CROPPING (y)

Yield	40 bu.	8 t.table 4 t.seed	60 bu.	55 bu.	65 bu.	45 bu.	210 lbs
Price	20/-	Table £13 Seed £20	13/6	13/6	8/6	12/6	3/-
Total Revenue p/ac	£40 0 0	184 0 0	40 10 0	37 2 6	27 12 6	28 2 6	31 10 0
Direct Costs "	£ 9 18 11	153 6 8	6 10 7	7 1 6	5 17 9	15 9 3	7 5 7
Gross Margins "	£30 1 0	30 13 0	33 19 0	30 1 0	21 15 0	12 13 0	24 4 0

SOIL TYPE I (Cont'd)

HEAVY CROPPING (x) (Cont'd)

Enterprise	Specialist W.C. (ex Wheat)	Cocksfoot	GF.SF.NG.	Pasture Maintenance
Yield	300 lbs	350 lbs		
Price	3/-	2/-		
Total Revenue p/ac	£45 0 0	35 0 0		
Direct Costs "	£10 1 5	15 11 0	9 19 0	1 2 0
Gross Margin "	£34 19 0	19 9 0		

MEDIUM-HEAVY CROPPING (y) (Cont'd)

Yield	300 lbs	350 lbs		
Price	3/-	2/-		
Total Revenue p/ac	£45 0 0	35 0 0		
Direct Costs "	£10 1 5	15 11 0	9 19 0	*1 7 0 1 2 0
Gross Margins "	£34 19 0	19 9 0		

*Rotation B.

SOIL TYPE I (Cont'd)

MEDIUM CROPPING (z)

Enterprise	Peas ex O.G.	Potatoes ex O.G.	Wheat ex Peas or Potatoes	Wheat ex Wheat	Barley ex Wheat	Rye Seed (Pasture)
Yield	46 bu.	9 t.table 4 t.seed	60 bu.	55 bu.	68 bu.	50 bu.
Price	22/6	Table £13 Seed £20	13/6	13/6	8/6	12/6
Total Revenue p/ac	£51 15 0	197 0 0	40 10 0	37 2 6	28 18 0	31 5 0
Direct Costs p/ac	£10 19 5	162 19 5	6 10 7	7 1 6	6 0 0	16 11 6
Gross Margins p/ac	£40 16 0	34 1 0	33 19 0	30 1 0	22 18 0	14 13 0

SOIL TYPE II

HEAVY CROPPING (x)

Yield	30 bu.	7 t.table 4 t.seed	50 bu.	45 bu.	50 bu.	35 bu.
Price	18/-	Table £13 Seed £20	13/6	13/6	8/6	12/6
Total Revenue p/ac	£27 0 0	171 0 0	33 15 0	30 7 6	21 5 0	21 17 6
Direct Costs p/ac	£ 9 6 3	146 7 11	6 2 9	6 11 2	5 8 5	13 7 10
Gross Margins p/ac	£17 14 0	24 12 0	27 12 0	23 16 0	15 17 0	8 10 0

SOIL TYPE I (Cont'd)

MEDIUM CROPPING (z) (Cont'd)

Enterprise	White Cl. Seed Pasture	Specialist W.C. (ex Wheat)	GF.SF.NG.	Pasture Maintenance	Cocksfoot
Yield	210 lbs	300 lbs			350 lbs
Price	3/-	3/-			2/-
Total Revenue (p/ac)	£31 10 0	45 0 0			35 0 0
Direct Costs "	£7 5 7	10 1 5	9 19 0	1 8 0	15 11 0
Gross Margins "	£24 4 0	34 19 0			19 9 0

SOIL TYPE II (Cont'd)

HEAVY CROPPING (x) (Cont'd)

Enterprise	White Cl. Seed Pasture	Specialist W.C. (ex Wheat)	Lucerne for Hay	Make Lucerne Hay bales	GF.SF. NG.	Pasture Maint-enance	Cocksfoot
Yield	180 lbs	250 lbs		150			250 lbs
Price	3/-	3/-					2/-
Total Revenue p/ac	£27 0 0	37 10 0					25 0 0
Direct Costs "	£6 9 0	8 14 10	3 5 0	2 15 0	9 19 0	1 2 0	12 16 6
Gross Margins "	£20 11 0	28 15 0					12 3 0

SOIL TYPE II (Cont'd)

MEDIUM-HEAVY CROPPING (y)

Enterprise	Peas ex O.G.	Potatoes ex O.G.	Wheat ex Peas or Potatoes	Wheat ex Wheat	Barley ex Wheat	Rye Seed (Pasture)	White Cl. Seed Pasture
Yield	35 bu.	8 t.table 4 t.seed	55 bu.	50 bu.	55 bu.	40 bu.	180 lbs
Price	18/-	Table £13 Seed £20	13/6	13/6	8/6	12/6	3/-
Total Revenue p/ac	£31 10 0	184 0 0	37 2 6	33 15 0	23 7 6	25 0 0	27 0 0
Direct Costs "	£ 9 6 3	153 6 8	6 7 11	6 16 4	5 10 10	14 7 0	6 9 0
Gross Margins "	£22 4 0	30 13 0	30 15 0	26 19 0	17 17 0	10 13 0	20 11 0

MEDIUM CROPPING (z)

Yield	38/-	9 t.table 4 t.seed	55 bu.	50 bu.	58 bu.	45 bu.	180 lbs
Price	20/-	Table £13 Seed £20	13/6	13/6	8/6	12/6	3/-
Total Revenue p/ac	£38 0 0	197 0 0	37 2 6	33 15 0	24 13 6	28 2 6	27 0 0
Direct Costs "	£10 1 2	162 19 5	6 7 11	6 16 4	5 13 1	15 9 3	6 9 0
Gross Margins "	£27 19 0	34 1 0	30 15 0	26 19 0	19 0 0	12 13 0	20 11 0

SOIL TYPE II (Cont'd)

MEDIUM-HEAVY CROPPING (y) (Cont'd)

Enterprise	Specialist W.C. (ex Wheat)	Lucerne for Hay	Make Lucerne Hay Bales	GF.SF. NG.	Pasture Maint-enance	Cocksfoot
Yield	250 lbs		150			250 lbs
Price	3/-					2/-
Total Revenue(p/ac)	£37 10 0					25 0 0
Direct Costs "	£ 8 14 10	3 5 0	2 15 0	9 19 0	*1 7 0 1 2 0	12 16 6
Gross Margins "	£28 15 0					12 3 0

*Rotation B.

MEDIUM CROPPING (z) (Cont'd)

Yield	250 lbs		150 Bales			250 lbs
Price	3/-					2/-
Total Revenue(p/ac)	£37 10 0					25 0 0
Direct Costs "	£ 8 14 10	3 5 0	2 15 0	9 19 0	1 8 0	12 16 6
Gross Margins "	£28 15 0					12 3 0

SOIL TYPE III

HEAVY CROPPING (x)

Enterprise	Peas ex O.G.	Potatoes ex O.G.	Wheat ex Peas or Potatoes	Wheat ex Wheat	Barley ex Wheat	Rye Seed (Pasture)	White Cl. Seed (Pasture)
Yield	35 bu.	55 t.table 3.5t.seed	45 bu.	40 bu.	45 bu.	30 bu.	120 lbs
Price	12/6	Table £13 Seed £20	13/6	13/6	8/6	12/6	3/-
Total Revenue p/ac	£21 17 6	141 10 0	30 7 6	27 0 0	19 2 6	18 15 0	18 0 0
Direct Costs "	£ 8 4 3	125 3 5	6 11 2	6 8 4	5 3 9	13 1 6	4 17 6
Gross Margins "	£13 13 0	16 7 0	23 16 0	20 12 0	13 19 0	5 13 0	13 2 0

MEDIUM-HEAVY CROPPING (y)

Enterprise	Peas ex O.G.	Potatoes ex O.G.	Wheat ex Peas or Potatoes	Wheat ex Wheat	Barley ex Wheat	Rye Seed (Pasture)	White Cl. Seed (Pasture)
Yield	40 bu.	6 t.table 4 t.seed	50 bu.	45 bu.	50 bu.	35 bu.	120 lbs
Price	12/6	Table £13 Seed £20	13/6	13/6	8/6	12/6	3/-
Total Revenue p/ac	£25 0 0	158 0 0	33 15 0	30 7 6	21 5 0	21 17 6	18 0 0
Direct Costs "	£ 8 8 11	134 1 2	6 2 9	6 11 2	5 8 5	13 7 10	4 17 6
Gross Margins "	£16 11 0	23 19 0	27 12 0	23 16 0	15 17 0	8 10 0	13 2 0

SOIL TYPE III (Cont'd)

HEAVY CROPPING (x)(Cont'd)

Enterprise	Specialist W.C. (ex Wheat)	GF.SF.NG.	Pasture Maintenance	Lucerne for Hay	Make Lucerne Hay
Yield	170 lbs				Bales 120
Price	3/-				
Total Revenue(p/ac)	£25 10 0				
Direct Costs "	£ 6 12 9	9 19 0	1 2 0	3 5 0	2 7 0
Gross Margins "	£18 17 0				

MEDIUM-HEAVY CROPPING (y) (Cont'd)

Yield	170 lbs				Bales 120
Price	3/-				
Total Revenue(p/ac)	£25 10 0				
Direct Costs "	£ 6 12 9	9 19 0	*1 7 0 1 2 0	3 5 0	2 7 0
Gross Margins "	£18 17 0				

*Rotation B.

SOIL TYPE III (Cont'd)

MEDIUM CROPPING (z)

Enterprise	Peas ex O.G.	Potatoes ex O.G.	Wheat ex Peas or Potatoes	Wheat ex Wheat	Barley ex Wheat	Rye Seed Pasture
Yield	40 bu.	7 t.table 4 t.seed	50 bu.	45 bu.	53 bu.	40 bu.
Price	16/-	Table £15 Seed £20	13/6	13/6	8/6	12/6
Total Revenue(p/ae)	£32 0 0	171 0 0	33 15 0	30 7 6	22 10 6	25 0 0
Direct Costs "	£ 9 7 7	143 13 11	6 2 9	6 11 2	5 8 5	14 7 0
Gross Margins "	£22 12 0	27 6 0	27 12 0	23 16 0	17 2 0	10 13 0

FEED ROTATION ENTERPRISES

SOIL TYPE I, II & III

Enterprise	Swedes	SF.NG.	Pasture + Maintenance	G.Feed	Rape
Direct Costs (per acre)	£4 7 0	7 1 0	1 7 0	3 2 0	1 15 0

+ For swede production rotation

SOIL TYPE III (Cont'd)

MEDIUM CROPPING (a)(Cont'd)

Enterprise	White Cl. Seed Pasture	Specialist W.C. (ex Wheat)	GF.SF. NG.	Pasture Maintenance	Lucerne for Hay	Make Lucerne for Hay
Yield	120 lbs	170 lbs				Bales 120
Price	3/-	3/-				
Total Revenue(p/ac)	£18 0 0	25 10 0				
Direct Costs "	£4 17 6	6 12 9	9 19 0	1 8 0	3 5 0	2 7 0
Gross Margins "	£13 2 0	18 17 0				

FEED ROTATION ENTERPRISES

SOIL TYPE I, II & III

Enterprise	Lucerne	Lucerne Hay	Pasture* Maintenance	GF.SF.NG.	Lucerne Hay Soil (3)
Direct Costs (per acre)	£3 5 0	2 15 0	1 8 0	10 5 0	2 7 0

* For hay production rotation

APPENDIX 2

LAND USE SYSTEMS

ROTATION A.

No.	27	28	29	36	37	1	2	3	18	19	20
Code	A1x	A2x	A3x	HA2x	HA3x	A1y	A2y	A3y	A1z	A2z	A3z
	acs	acs	acs	acs	acs	acs	acs	acs	acs	acs	acs
Peas	7	24	16	24	16	6	20	13	5	16	11
Wheat ex Peas	7	24	16	24	16	6	20	13	5	16	11
Wheat ex Wheat	3	12	8	12	8	3	10	7	2	8	5
Barley ex Wheat	7	24	16	24	16	6	20	13	5	16	11
GF.SF.NG.	7	23	15	24	16	6	19	12	5	15	10
Rye Seed	7	23	15	24	16	6	19	12	5	15	10
W.C. Seed	7	23	15	24	16	6	19	12	5	15	10
Pasture	13	41	25	46	30	19	67	44	26	93	58
Lucerne		8	8				8	8		8	8
Total	58	202	134	202	134	58	202	134	58	202	134
GM/acre	£13/7	10/8	7/17	10/14	8/4	12/8	10/0	7/10	10/15	8/5	6/9

ROTATION B.

No.	30	31	32	38	39	4	5	6	21	22	23
Code	B1x	B2x	B3x	HB2x	HB3x	B1y	B2y	B3y	B1z	B2z	B3z
	acs	acs	acs	acs	acs	acs	acs	acs	acs	acs	acs
Wheat ex O.G.	5	17	11	17	11	4	13	8	3	10	7
Wheat ex Wheat	14	50	33	50	33	11	38	25	9	30	20
W.C.(specialist)	10	34	22	34	22	7	25	17	6	20	13
GF.SF.NG.	5	16	10	17	11	4	12	7	3	9	6
Rye Seed	5	16	10	17	11	4	12	7	3	9	6
W.C.(Pasture)	5	16	10	17	11	4	12	7	3	9	6
Pasture	14	45	30	50	35	24	82	55	31	107	68
Lucerne		8	8				8	8		8	8
Total	58	202	134	202	134	58	202	134	58	202	134
GM/acre	£16/19	14/1	10/8	14/14	11/1	13/4	11/2	8/6	10/9	8/10	6/8

ROTATION C.

No.	33	34	35	40	41	7	8	9	24	25	26
Code	C1x	C2x	C3x	HC2x	HC3x	C1y	C2y	C3y	C1z	C2z	C3z
	acs	acs	acs	acs	acs	acs	acs	acs	acs	acs	acs
Potatoes ex O.G.	7	24	16	24	16	6	20	13	5	16	11
Wheat ex Potatoes	7	24	16	24	16	6	20	13	5	16	11
Wheat ex Wheat	3	12	8	12	8	3	10	7	2	8	5
Barley ex Wheat	7	24	16	24	16	6	20	13	5	16	11
GF.SF.NG.	7	23	15	24	16	6	19	12	5	15	10
Rye Seed	7	23	15	24	16	6	19	12	5	15	10
W.C.(Pasture)	7	23	15	24	16	6	19	12	5	15	10
Pasture	13	41	25	46	30	19	67	44	26	93	58
Lucerne		8	8				8	8		8	8
Total	58	202	134	202	134	58	202	134	58	202	134
GM/acre	£13/5	11/5	8/3	11/10	8/11	12/9	10/16	8/5	10/4	8/15	6/17

ROTATIONS D, E & F.

No.	10	11	12	13	14	15	16	17
Code	D1	D2	D3	E1	E2	E3	F1	F2
	acs	acs	acs	acs	acs	acs		
Swedes	7	25	17					
SF.NG.	7	25	17					
Pasture	44	143	91	44	151	101		
Lucerne		8	8	7	25	17		
Rape		1	1	1	4	2		
G.Feed				1	4	2		
GF.SF.NG.				5	18	12		
Total	58	202	134	58	202	134		
GM/acre £	-2/6	-2/12	-2/13	-2/17	-2/16	-2/15	19/19	12/3

Note: Class F - cocksfoot - was worked out on the basis of one acre - stand lasting 8 years and using renewal rotation of OG ⟶ GF.SF. ⟶ New cocksfoot and white clover.

APPENDIX 3

SHEEP ENTERPRISES

Enterprise	2 yr Ewe Flock	Breeding Replacement Flock	Buying 2 th Replacement Flock	Wintering Only Selling Ewes and Lambs all Counted	Hoggets
Lambing	115% S.to S.	110% S.toS.	110% S.toS.	110% S.to S.	
Price	38/- net	38/- net	38/- net	30/-	
Wool	10 lbs	11.7 lbs	10½ lbs		6 lbs
Price	3/2 net	3/2 net	3/2 net		3/2 net
Stock sold of c.f.a.	½	0.15	1/5	1	1
Price	20/-	20/-	20/-	30/-	55/- net
Total Revenue (per ewe)	£4 5 4	£3 13 11	£3 19 1	£3 3 0	£3 14 0
Direct Costs (per ewe)	£1 13 2	£0 7 11	£1 16 9	£1 18 6	£2 7 9
Gross Margins (per ewe)	£2 12 0	£3 6 0	£2 12 0	£1 4 0	£1 6 0

APPENDIX 4

STOCK UNITS BASIS OF FEED RECONCILIATION

Feed Provided Soil Types:-	1.	2.	3.
Available Summer Grazing	7 S.U./acre	6 S.U./acre	5 S.U./acre
White Clover (summer before closing)	1 "	1 "	1 "
Autumn saved pasture (lambing)	6.5 acres/100 ewes	7 acres/100 ewes	7.5 acres/100 ewes
New Grass → grass-seed (lambing)	5.5 acres/100 ewes	6 acres/100 ewes	6.5 acres/100 ewes
New Grass (lambing)	4.5 acres/100 ewes	5 acres/100 ewes	5.5 acres/100 ewes
Green Feed (lambing)	5.5 acres/100 ewes	6 acres/100 ewes	6.5 acres/100 ewes
Autumn saved pasture (winter)	5.5 S.U./acre	5 S.U./acre	4.5 S.U./acre
Pasture (winter)	1.5 S.U./acre	1.5 S.U./acre	1.5 S.U./acre
Swedes (winter)	35 S.U./acre	30 S.U./acre	25 S.U./acre

Lucerne Hay (winter) 3 bales/S Unit.

The above figures are for the y level of cropping. x and z levels have slightly different stock units basis.

Amount of Autumn Saved Pasture - 50% of pasture (Pasture for W.C. and Rye Seed not considered in "pasture" here).

Stock Requirements

2 yr Ewe flock	1.014 S.U./ewe	
Breeding Ewe flock	1.154 "	
Buying 2th replacement flock	1.014 "	
Selling Ewes and lambs all counted	1.014 "	(winter & lambing requirements)
		0.014 (summer requirements)
Wintering hoggets	0.66	(winter only)

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