Farm business analysis

PLANNING PROFITABLE FARMING SYSTEMS

Five Examples of the use of Linear Programming

by

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F O R E W O R D

The use of linear programming for farm management is no longer a novelty. Many, however, whilst aware that it is associated with electronic computors, have only vague ideas about what can actually be achieved with it. On the other hand some have been so intrigued by its possibilities and by those of the use of computors that they have seen it as the answer to all problems of farm organisation. It is hoped that the account given in this report of the application of linear programming on 5 Yorkshire farms and the following commentary, will both illustrate how linear programming can be used and also what its advantages and limitations are for this class of work.

It should also serve another purpose. Considerable numbers of farm programmes are now being run through computors by different persons and organisations but few of the results are published. Yet programming a farm is a complicated procedure and the would-be programmer can learn much from the methods developed by others. Those followed in this study are explained in detail in the hope that they will provide some assistance to workers who may be experimenting with linear programming for the first time. The procedures used in the five examples presented here are not without their defects - indeed if the investigator were to tackle these farms again he would undoubtedly revise certain of the procedures. It is hoped nevertheless that they will be of value to those who will be developing their own procedures for linear programming farms.

This report would not have been possible without the co-operation of the five farmers whose farms have been used to illustrate the application of linear programming. Their help both in providing the basic data and later in permitting publication of the sections on their farms is very warmly acknowledged. The help given by other members of the Agricultural Economics Section, by Mr.R.Holliday and by the staff of the Electronic Computing Laboratory must also be acknowledged here.

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C O N T E N T S

PLANNING PROFITABLE FARMING SYSTEMS
(5 Examples of the Use of Linear Programming)

1. INTRODUCTION

There are wide variations in the profits achieved by farmers even among those who are occupying farms of a similar size and potential. Partly these variations spring from the fact that some farmers are better than others at the technical jobs of growing good crops, managing livestock efficiently and at marketing. They are however, also a reflection of the many different combinations of stock and crops found on different farms. While it is true that farming systems can be classified into broad general types, it is rare indeed to find even two farmers who are adopting a pattern of cropping and stocking which is identical in all respects. Some systems however, undoubtedly make a more profitable use of the available resources than do others but the problem of identifying these profitable systems for adoption on a particular farm is difficult.

It is not sufficient to locate the farms where high profits are being made and then set these up as examples to be followed, for the opportunities open to individual farmers are not the same, nor are their personal aims. It is admissable in most circumstances, to regard the maximising of the farm profits as the paramount goal of the farmer but it is important to recognise the narrow context within which this goal is sought. The farmer's attitude to risk, breadth of experience, level of education, willingness to depart from traditional methods and other subjective factors all limit the bounds within which he is likely to develop production on his farm, quite apart from the restrictions arising from the availability or otherwise of capital, buildings, equipment and other tangible factors. Once a farmer is established his future plans are likely moreover to be highly influenced by his current system of farming. In spite of these narrow bounds, the choices facing the average farmer when he makes decisions on the crops to grow and the stock to keep are numerous and while the value of ad hoc reasoning should not be minimised, the use of some form of systematic approach to locating the combination likely to be most profitable would seem advantageous.

One such systematic approach is represented by linear programming, a mathematical technique which has found widespread application in economic problems involving the allocation of scarce resources. In using linear programming the assumption is made that there are a limited number of possible enterprises or activities each with a specified unit revenue, which can be considered for inclusion in the system to be adopted on any particular farm. The choice of these activities and their respective levels will be restricted both by the limited resources of that farm and by specific restrictions introduced to ensure a feasible and acceptable plan. Within these bounds there

will be a unique optimum combination which maximises the revenue obtained. The revenue function to be maximised, is normally expressed in terms of gross margins. These represent the gross income less the variable costs which are costs directly linked with the scale of output and include expenditure on items such as purchased feedingstuffs, seeds and fertilisers. Other costs fall into the category of fixed costs and are unlikely to vary significantly in the short run whatever combination of activities is adopted. Such fixed or common costs include regular labour, implement depreciation, rent and the sundry items such as car expenses coming under the heading of general farm expenses. For planning purposes it would be wrong to allocate the fixed costs to specific activities as their magnitude will not by definition be related directly with either the particular combination of activities chosen or by the levels at which such activities are carried on.

The problem to be solved by linear programming is initially set out in the form of a table or matrix such as that given below.

		Barley	Potatoes	Cattle
Gross Margin per Unit	£	32	85	25
Restrictions				
Arable Land	100 acres	1	1	.2
Grass	20 "	0	0	.5
Max.Potatoes	15 "	0	1	0
Labour	5000 hours	11	80	20

This, of course, represents a very simplified example. Here there are three activities to choose from, barley, potatoes and cattle with gross margins per unit of £32, £85 and £25 respectively. There are four restrictions relating to the areas of arable and grassland, potato quota and labour availability, which limit the number of feasible combinations of the three activities. The unit requirements of each activity in terms of the restrictions are set out in the three columns on the right of the table. The data in the table is used as a basis for the calculations which eventually lead to the best solution which is feasible within the restrictions. This maximises the aggregate gross margin.

In actual farm problems the number of rows and columns of data in the initial table is normally considerable and a very large amount of computation is required to reach the optimum solution. For this reason recourse must be had to a high speed electronic computor.

So far in this discussion the term activity has been used synonymously with enterprise but this is not correct. An activity is a specific way of producing a certain commodity resulting in a stated gross margin. Thus a barley activity will refer to barley

grown and harvested by prescribed methods resulting in a specified labour input per acre, and a given expenditure on fertiliser, seed and sprays. Similarly the yield and price received must also be specified. The commodity produced by an activity need not however be something such as barley which is sold off the farm, it can be a product which will enable the scale of another activity to be increased. In the problem set out in the table above, under no circumstances could more than 40 units of the cattle activity enter the final plan since there are only 20 acres of grassland available and each cattle unit utilises half an acre of this. If however a ley activity is introduced as an additional possibility, the cattle limit can be raised by using some of the arable land for leys in order to augment the area of grass. A revised table including the ley activity is given below -

		Barley	Potatoes	Cattle	Ley
Gross Margin per Unit £		32	85	25	- 4
Restrictions					
Arable Land	100 acres	1	1	.2	1
Grass	20 "	0	0	.5	- 1
Max.Potatoes	15 "	0	1	0	0
Labour	5000 hours	11	80	20	2

It will be noted that the ley activity has a negative gross margin of -£4. There is no income from the ley as such so that the gross margin is simply £0 less the variable costs, £4 per acre in this instance. The 1 in the ley column on the arable land row indicates that one unit of ley requires one acre of arable land while the -1 on the grass row indicates that each unit of ley increases the grass area by one acre. The absolute limit on cattle numbers is no longer 40 but 240 as by putting all the arable land down as a ley, the total area of grass can be pushed up from 20 to 120 acres. This of course will not happen unless such a plan results in the highest attainable level of gross margins which would be unlikely.

The concept of setting out in tabular form the constituents of the problem which faces a farmer who has to decide on the form and scale of production and then allowing an electronic computor to take over has an undoubted attraction but it is not without hazard. Once the computor has produced an optimum solution from the data fed to it, there is the temptation to regard this solution as absolute and to forget the imperfections of the data from which it has been derived. It is easy to ignore the many inter-relationships between different forms of farm production and as a result arrive at a false optimum. Elements of risk and uncertainty particularly those due to market fluctuations and variations in weather conditions are hard to resolve. The pace of development in agriculture can rapidly date a plan. Perhaps above all there is the difficulty of setting the initial restrictions so that the

optimum plan is in all respects acceptable to the farmer whose problems it aims at resolving. Setting out the production possibilities of a farm in such a way that linear programming will lead to an optimum profit maximising plan which is both valid and acceptable to the farmer is not easy. The extent to which it can be adequately done must however determine whether this method is in fact of practical value for increasing farm profits.

It was partly with the aim of studying further the problems involved in constructing appropriate linear programming models that a project was started in 1962 involving the application of linear programming as a tool for indicating the means of increasing profits on 5 Yorkshire farms. These farms are all located broadly within the bounds of the Plain of York and while they differ appreciably in area and in soil type, the range of production possible is fairly similar in each case. Corn and potatoes are grown on all five farms and sugar beet on four of them. All have both beef cattle and pigs and on one a dairy herd is run as well. There are sheep on four out of the five farms. These farms were selected for this project partly because good financial records were available and the farmers were thought likely to be sufficiently interested to be willing to give a certain amount of assistance in the task of data preparation. The profits recorded in recent years on four of the farms had been satisfactory. On the fifth the profit record gave some cause for concern although a certain improvement was evident in the most recent year. Generally the farmers did not have the incentive to make any very radical changes to improve their profits. The fact that they were farming successfully however represented something of a challenge to discover how they could do still better.

Computational Facilities

Before describing the application of linear programming on each of the five farms, reference should be made to the computational facilities used. All the programming was done on the University's Ferranti Pegasus computor using the Simfix (Mark 6) order programme. With this programme, the computor prints out the linear programming solution showing the level of the activities coming into the solution and the extent to which restrictions have not been fully taken up. It then prints the d row (z-c or index row) which indicates the extent to which the gross margins of those activities which have not entered the solution would have to be increased to bring them in, and also the marginal return or marginal value products to the fully utilised restrictions. Facilities were not available when most of the programming was undertaken for determining the extent to which the gross margins of activities entering the solution can be varied without altering their levels. An addition to the Simfix programme has now however been devised by D.J.Battye of the University's Electronic Computing Laboratory for this purpose.* (Library programmes for parametric and variable price programming were not available)

* The ranges could be determined by manual computation after extracting the solution matrix from the computor. This however is a slow and cumbersome process.

2. APPLICATIONS TO INDIVIDUAL FARMS

FARM A. General Features Farm A is a farm of 232 acres situated on medium loam. In 1961 the cropping was as follows:-

	Acres
Wheat	20
Barley	57½
Oats	25
Potatoes	15
Sugar Beet	3
Swedes	13
Mangolds	5
Kale	1
1 Year Ley for Hay	20
Permanent Grass	72½
	232

Crop yields have been very satisfactory with four year averages of 35 cwts per acre of wheat, 34½ cwts of barley, 11½ tons of potatoes and 14 tons of sugar beet. On the stock side an average of about 90 cattle are carried and this includes calves reared both on the bucket and on nurse cows for carrying through to slaughter weight and also older stores purchased in the autumn for winter feeding. A flock of 65 ewes is used for the production of fat lambs, some of which are sold off grass in the summer and some off beet tops in the autumn. It is also the practice to buy in store lambs to be run over the tops and swedes during the winter. Pig-keeping is rather restricted by a lack of accommodation but up to 180 weaners a year are purchased for fattening. There is a small poultry enterprise consisting of 200 hens in a deep litter house.

Five regular men are employed. The farmer considers this staff to be rather larger than is strictly necessary but since all the men have worked on this farm for a number of years he has not been anxious to dispense with any of them.

The farm is well equipped and the machinery complement includes a combine, baler and corn drier.

The methods used in the application of linear programming to this farm are described in detail in the following pages since they are also illustrative of the general approach adopted on the other four farms included in this study.

Range of Activities Considered In deciding to apply linear programming to the particular situation existing on this farm, one of the first questions to settle was what enterprises should be considered for inclusion in any new plan aimed at increasing profits? As there seemed little opportunity for extending the range of cash crops beyond the corn, potatoes, and sugar beet already grown, attention was confined to these crops. Each crop was represented by a single activity based on the present production methods with all

the grain harvested by combine, the potatoes harvested by hand with the help of a casual gang and the sugar beet and other root crops hoed by the farm staff. Provision was made however for the inclusion of an extra activity to allow for the mechanical harvesting of sugar beet by a contractor's machine, instead of by hand as at present, if such a change could be justified.

It seemed reasonable to base the cash crop activities on existing methods since these had given good results in the past and on the whole represented the use of up-to-date techniques. With stock however the arguments were less straightforward. There are many alternative systems of stock production and the choice of activities could be made very wide. One has only to think of the variety of methods for both rearing and feeding cattle and of the many combinations that can be made of these not to mention the scope for buying and feeding store cattle. To include all possible methods would make a very unwieldy problem and in fact the data are not available to allow this to be done. The availability of adequate input-output data is particularly crucial to the handling of the stock enterprises. The variation in the results recorded in cost surveys indicates the danger of assuming that results obtained on one farm will necessarily be achieved in a different context. This variability largely derives from the complex nature of stock production depending as it does, not only on the skilled choice and treatment of the stock themselves but also on the level of efficiency in fodder production. Because of these uncertainties, the choice of livestock activities has in the main been confined to activities representing the systems currently followed on the farms under study. For these at least, farm records provide an indication of performance in the recent past, which is probably the best basis on which to estimate the level of achievement in the near future.

Beef production on farm A could be divided into at least two separate activities - the rearing of calves for subsequent fattening and the purchases of stores for yard feeding. The financial accounts however were insufficiently detailed to permit a breakdown of the returns for the two activities and it was decided to use only a single activity which would cover the combined systems. A similar problem arose with sheep as it is was not possible to isolate the returns for the breeding and production of home-bred sheep from the fattening of purchased stores and a single activity was again used to cover the two systems. It did seem however at least possible that the existing sheep enterprise with its emphasis on winter folding over roots was not the most profitable and it was decided to widen the choice by including another sheep activity to represent a ewe flock run solely on grass for summer fat lamb production. This is a fairly standardised system and good data for it is available from an up-to-date survey covering flocks on nearby farms.

Pigs were represented by a single activity related to the existing practice of buying weaners for feeding to bacon weight. The farmer had no experience of breeding pigs and was not particularly anxious to introduce them. A poultry activity based on existing production in the deep litter house completes the list of activities related to the farm enterprises but it was desired to test whether there would be any advantage in substituting the feeding of silage for the fodder roots. For this purpose two silage activities were included, one to replace swedes and the other to replace mangolds.

Restrictions With the main activities defined, it was next necessary to list the various factors which could limit the feasible combinations of these. The most obvious restriction is, of course, the area of land available, 223 acres in this instance. Out of this total 39 acres of permanent grass was regarded as unsuitable for arable cropping partly because of drainage problems. This left only 193 acres available for cropping. The uncroppable 39 acres were taken as forming the area of grass which would initially be available for the cattle and sheep activities but to have restricted these activities solely to this grass would not have been appropriate, particularly as these stock were currently making use of 72 acres of grass. A ley activity similar to that described on page 5 was therefore introduced to allow an extension of the grass area on the land classed as suitable for cropping. It was arbitrarily assumed that the output of the leys would be one-third above that of permanent grass so that every acre of ley would add the equivalent of 1.33 acres to the grass area.

The quota acreages of 19 acres and 3 acres were obvious restrictions on potatoes and sugar beet respectively. The sugar beet quota was only a small one as a few years ago it had been decided, perhaps mistakenly, to cut back on this crop and concentrate on potatoes.

Availability of buildings is normally an important factor in limiting the number and type of stock which can be kept and on Farm A it appeared that these would not permit of an increase of cattle numbers above the present level. The maximum throughput of pigs was put at 220 a year and it was decided not to raise poultry numbers above the 200 hen capacity of the existing deep litter house.

The need to ensure that the combined labour requirements of final plan could be dealt with by the farm labour force required the use of a series of restrictions relating to the availability of labour at key periods throughout the year. Periods when work on crops is relatively slack have however been ignored since with relatively constant requirements for stock, labour availability in such periods is never likely to be an effective restriction.

The key periods have been defined to correspond so far as is possible with the periods during which certain operations are undertaken. These periods together with the operations falling within them are listed below:-

Period	Principal Operations
March 8 - 31	Drill spring corn, plough for potatoes
April 1 - 15(includes Easter)	Plant potatoes, drill beet & grass seeds
April 1 - 30	as above plus cultivating for & drilling fodder roots
May 21 - June 5(includes Whitsun)	Spray spring corn, single beet and other roots
	Inter-row work on potatoes and beet, 1st silage cut
June 15 - 30	Continue hoeing and inter-row work on potatoes and roots, haymaking.
Aug.20 - Sept.30	Corn harvest
May 1 - Sept.30	As above, plus leading out F.Y.M. and one week's holiday per man.
Oct 1 - Nov.30	Lift potatoes, beet & mangolds, drill winter wheat
Oct 1 - Mar.31	As above including work in 1st period, plus winter ploughing, potato riddling.

(work on cattle, sheep, pigs & poultry occurs in all periods)

It will be noted that certain of the periods overlap. This is in order to cover both jobs which have been done within a critical period and those for which a wider range is permissible. Thus clearing out of the F.Y.M. from the cattle yards can be done at any time during the summer as opportunity arises but sugar beet must be singled within a period of two to three weeks in May or June. Holidays can be taken during the summer as work allows.

Bad weather can, of course, all too easily throw a tightly defined schedule out of gear and even in an average year conditions on some days are likely to be such as to prevent the specified tasks being undertaken. Any attempt to determine the probable frequency of such days raises very difficult problems and there is some discussion of these in a later section. To some extent however, the relatively short periods allowed for the more critical tasks provide a safeguard against an over-optimistic plan - spring corn for instance will often be sown before March 8th or after March 31st. Corn harvesting is probably the operation most dependent on weather conditions but in this instance we know that an $8\frac{1}{2}$ foot cut self-propelled combine such as is possessed on this farm, has the capacity to handle over 200 acres of corn annually as against the 193 acres which is the maximum area available for cropping.

In addition to the seasonal restrictions, a restriction was placed on the total labour available over the year for productive work. This was assessed at only 75 per cent of the hours actually contributed by the 5 men so ensuring that 25 per cent would be available for non-allocatable jobs. This provided a further hedge against the over-taxing of the labour resources. In calculating the hours available in the seasonal periods and over the year, no account was taken of the farmer's contribution and any jobs normally done by him alone were excluded from the activity requirements. In practice of course, his contribution is likely to vary very much according to the needs of the farm at any particular time.

To allow of the possibility of overtime working during the spring and summer, five overtime activities corresponding to the seasonal labour restrictions were introduced. Each had a negative gross margin of 5/8d per extra hour worked, the then current statutory rate. In order to prevent excessive overtime being worked, each of these activities had its own restriction as to its maximum level which was based on the assumption that not more than one additional hour per day would be worked in March and April and not more than two hours during the summer months.

Restrictions on tractor hours were unnecessary as the four operational tractors on the farm would be sufficient for any plan within the capacity of the five man staff.

It was necessary to restrict the acreage of certain crops to ensure that the combination of crops appearing in the final plan was capable of being fitted into a satisfactory rotation. While potatoes and sugar beet are restricted by their quotas to relatively small proportions of the total area, corn crops could be expanded to well above their present levels. Successive crops of spring barley appear to incur little disease risk if adequately fertilised but eyespot in particular can become serious if winter wheat is grown too frequently while oats are liable to cereal root eelworm. Because of the eyespot risk winter wheat is commonly grown only as the first cereal crop after a root or grass break. A second wheat crop however can be grown with reasonable safety provided it is a resistant variety such as Cappelle and that a break of at least two years from both wheat and barley precedes the first crop. With this need for an adequate break, the maximum area of wheat becomes dependent on the area of the other crops grown, apart from barley. This linkage was covered by a wheat restriction set initially at zero, but built up at the rate of two-thirds of an acre for each acre of potatoes, sugar beet, fodder roots and oats coming into the plan[*]. Leys also contributed but at only half this rate in their first year since they do not provide an altogether satisfactory break at that stage owing to the possible presence of rogue corn.

[*] With a two-year break permitting two wheat crops, an acre for acre build-up of the wheat restriction could have been justified but such a high proportion might well be too risky in the long term.

To guard against the risk of cereal root eelworm, oats were restricted in a similar manner to one-third of the acreage of other crops, apart from barley.

Corn after corn needs more fertiliser than the first crop if yields are to be maintained and to take account of this, a "first corn crop" restriction was used and this like the wheat and oats restrictions was initially set at zero and then built up as the non corn crops entered the plan. It could also be augmented by bringing a "second corn crop" activity into the solution. This activity with a negative gross margin of 21/- per unit representing the cost of the extra fertiliser, simply added one acre per unit to the "first corn crop" restriction.

Most arable farmers in Yorkshire strongly favour the use of a dressing of F.Y.M. for potatoes and would be reluctant to grow this crop without such a dressing. Recent work on experimental husbandry and other farms does not however in general give much support to the view that F.Y.M. has effects other than those directly attributable to its N.P.K. content in which case its absence can be made good by extra fertilisers. However, the position especially in relation to varying soil types is not yet fully defined and to produce acceptable plans it may be necessary to respect farmers' beliefs whether proven or not. On farm A, sugar beet and fodder roots, as well as potatoes, were receiving F.Y.M. and a plan that included potatoes without sufficient stock to produce the F.Y.M. for them seemed unlikely to be accepted. A restriction related to the quantity of F.Y.M. available was therefore used to ensure that the numbers of cattle and pigs would be at least sufficient to provide for the requirements of the potatoes if these were included in the plan.

Finally there were a number of restrictions relating to the availability of fodder. The grass restriction has been discussed but there were further restrictions on the quantities of swedes and mangolds available. These quantities were of course zero until the corresponding swede or mangold activities or their silage equivalents came into the plan.

Hay requirements were incorporated directly as part of the cattle and sheep activities with the assumption that the hay would be produced from a one-year clover ley as is common in the district. The aftermaths of such leys are frequently used for sheep grazing and provision was made for an aftermath grazing restriction linked to the area clover leys and available only for sheep grazing. However, so as not to tie sheep numbers to this restriction a special activity was used to permit the transfer of some of the grass capacity to the aftermath grazing. This activity had a zero gross margin as no cost attached to the transfer.

No restrictions were placed on the use of capital. This may cause comment. It would have been feasible to use capital restrictions but to have done so would considerably have complicated the issue. Two problems in particular would have needed to be resolved. Firstly the determination of the capital available and secondly the devising of a satisfactory scheme for handling the varying seasonal requirements of the different activities. It should be appreciated that the concern here is with working rather than fixed capital. The indivisibility of fixed capital items makes their incorporation into ordinary simplex linear programming models impossible and comparisons can only be made by comparing solutions with and without such items.*

The working capital possessed by a person about to set up in farming can be assessed fairly readily but the position becomes much more complex when an established farmer is considering a change from one system to another. The timing of the changes then becomes of great importance. The possibility of delaying payments or securing advances may need to be taken into account and this in its turn can require consideration of interest both earned and paid. Such elaboration is probably unnecessary when, as on Farm A and in the later examples, the range of both activities and restrictions will prevent too radical a departure from the existing system and make it unlikely that the plans formulated will be beyond the financial resources of the farmers concerned.

For Farm A there were in all 29 restrictions and 24 activities (excluding disposal activities) in the initial table or matrix. These are listed in the Appendix 2 in full.

Derivation of the Data Unit gross margins and unit requirements in terms of each of the 29 restrictions had to be derived for each activity. Many of these coefficients were readily obtained, it being quite obvious for example that an acre of the wheat activity uses one acre of arable land or that only the poultry activity has other than a zero in the poultry restriction row. Other coefficients however caused more trouble and in this category can be placed the gross margins of the productive activities, their unit labour requirements and the fodder inputs for stock.

To turn to gross margins first - the general procedure used in calculating these has been to base the crop gross outputs on the average yields obtained over the preceding four years weighted by the prices received in the most recent year . Variable costs were calculated at current prices and the difference between the calculated gross output and the variable costs then equalled the gross margin. In the case of potatoes and sugar beet, the gross output was calculated directly from returns in each of

* They can however be dealt with by "integer programming"

the four years with no account taken of physical yields. Four years is, of course, a short period to form a basis for arriving at normalised yields but going further back may be to discount the yield increases obtained in recent years while records were not always available. In one or two instances some adjustment was made to the average to correct the distorting effect of an exceptional yield in one of the four years.

Gross outputs for the livestock activities have generally to be related to specific feed inputs and for this reason were normally based on the results obtained in the most recent year only.

The variable costs included expenditure on purchased feedingstuffs and home grown grain, fertilisers, sprays, veterinary items, machinery repairs, fuel costs, casual labour, certain special payments to regular workers and a number of small sundry items. These were generally apportioned on basis of both information obtained in discussion with the farmer and of data extracted from the farm's accounts.

Feed costs not surprisingly caused most difficulty since with one exception full records were not available of the disposal of either purchased feeds or of home-produced grain. Reference to invoices, however, helped to establish the utilisation of purchased feed and farmers' estimates of the daily consumption of different stock provided some indication of the uses of the home-produced grain. The balancing of grain with fixed proportions of purchased supplement was a useful guide in two instances. If a satisfactory estimate of consumption by the smaller users of concentrated feed such as cattle or sheep is obtained, the consumption of the major users, say, pigs, can then be derived by subtraction.

The homegrown grain fed was costed at the same realisation price as that assumed in calculating the gross margins of the cereal activities. It seemed almost certain that at least sufficient grain would be grown to meet the needs of the livestock and use of different prices for buying and selling was therefore unnecessary.

Fertilisers and sprays were apportioned according to the farmer's statements on the quantities used on different crops and the aggregated totals then checked against the actual expenditure.

Average rates derived from farm surveys were used to assess the per acre repair and fuel costs on expensive machines such as combines, pick-up balers and beet harvesters. Those on tractors and less complicated machinery were covered on Farm A by an addition of 5/0d per estimated tractor hour - this gave an aggregated total approximately equal to the overall expenditure in a normal year.

In addition to the casual labour costs which on Farm A were only incurred for potato lifting, any overtime directly attributable to specific activities has been classed as a variable cost. This includes weekend and holiday work with stock, a certain amount of unavoidable late working during harvest and the premium inherent in the piece-rates paid to the regular staff for hoeing and the lambing bonus paid to the shepherd.

After all the activity gross margins had been calculated, a check was made by applying these to the 1961/62 crop acreages and stock numbers and comparing the aggregated totals with the actual figures shown in the accounts. After taking account of yield differences and any abnormal items of revenue or expenditure, close agreement was obtained.

The assessment of the unit labour requirements depended very much on the farmer's co-operation. For crops the first step was to obtain from the farmer a fairly complete description of the techniques and machinery used in the production of the various crops. A schedule of operations could then be drawn up to which standard working rates usually derived from enterprise cost studies but occasionally direct from the farmer, could be applied to give the requirements in hours per acre. Stock requirements could be derived more easily since time spent varies little from day to day, apart from the reduction at the end of the winter feeding period. No account was taken of such tasks as the daily inspection of the sheep and grazing cattle since this was normally done by the farmer himself. It was an advantage to be able to ignore this work since the time taken on it is not directly proportional to the numbers of stock and so does not comply with the linearity assumptions of linear programming. The time spent removing and spreading F.Y.M. has been allocated to the cattle and pigs rather than to the crops.

Ad hoc methods varying from farm to farm were used for the allocation of the grass and forage crops. On Farm A, the breeding ewes were summered on an 11 acre grass field going on the aftermaths as these became available. They spent the period from December to February folded on roots and this left about four months of the year when they would be on other grasses. A reasonable allowance for this period appeared to be the equivalent of a full season's use of another 4 acres of grass over and above the 11 acres used in the summer. All the remaining grassland was allocated to cattle.

As it was the practice on Farm A to pull two out of every three rows of swedes so leaving one for the folded sheep, the division of this crop was easy. For mangolds however, it was necessary to calculate the tonnage consumed by sheep, the lesser users, on the basis of the length of feeding period

and normal daily consumption and then convert this into acreage terms on the basis of farmers' estimate of the yield per acre. The remaining acreage was allocated to cattle. This was not a very satisfactory procedure owing to the likelihood of errors in the estimates of yield - the farmer had no accurate yardstick on which to base these. The likelihood of these errors also becomes an important factor when the relationships between the mangold and swede activities and those for silage are considered. Even if both the yield of silage and the weight of it required to replace a given quantity of swedes or mangolds are known, determination of acreage needed per head of stock is still dependent on a knowledge of weight of roots currently fed. In practice only a rough guess could be made of the probable yield of silage as it had not been produced previously on the farm and although a substitution rate of silage for roots was calculated on the basis of starch equivalent values, the validity of this calculation is somewhat doubtful, particularly in view of the variations in the feeding values of different silages. However, it was assumed that 9 tons per acre of silage would be obtained in two cuts and that 3 lbs of silage would replace 4 lbs of roots. The unsatisfactory nature of the data would require that any plan which included the silage activities should be examined with particular care, especially as their introduction would represent a radical departure from current practice.

The Optimum Plan

Once the activity data had been assembled, it was possible to process the material through the computor and obtain the optimum plan maximising profits within the limits of the stated restrictions and choice of activities. The details of this optimum plan are given below together with the actual figures for 1961/62 as a comparison. While the proposed plan itself is not without interest, attention inevitably focuses on its effect on the farm profit. This raises the problem of measurement. A simple comparison of the calculated profit from the new plan with that actually revealed in the most recent accounts would be misleading owing to differences between prices and yields actually realised and those used as a basis for planning. To obtain a figure which is comparable, it is necessary to apply the unit gross margins used for planning to the current crop acreages and stock numbers to give an aggregated total which is referred to here as "the standard gross margin". Fixed costs could be deducted from this to give a standard profit but since the fixed costs by definition will not vary, the difference between the standard gross margin of the present system and that of the optimum plan, in itself gives an accurate indication of the anticipated increase in profits. On Farm A this increase amounted to £1,532 equivalent to £6.12s per acre. Out of this however, £515 can be attributed to the raising of pig and poultry numbers to their maximum levels and there is also some gain from increasing potatoes up to their full quota.

F A R M. A.

Cropping	Actual 1961/62 Acres	Optimum Plan Acres
Wheat	20	31.7 ⁂
Barley	57½	106.0
Oats	25	-
	(102½)	(137.7)
Potatoes	15	19.0 ⁂
Sugar Beet	3	3.0 ⁂
Mangolds	5	3.9
Swedes	13	7.8
Kale	1	-
Grazing Ley	-	9.1
Mowing Ley (1 year)	20	12.5
Permanent Grass	72½	39.0
	232	232.0
Stock		
Cattle (Annual gross output)	£4,000	£3,590
Ewes(plus followers and purchased lambs) Nos.	62	
Pigs Fattened "	66	220 ⁂
Hens "	100	200 ⁂
Standard Gross Margin	£7,913	£9,445
Gain over 1961/62		£1,532

⁂ Maximum allowed

(Pig turnover in 1961/62 was low owing to disease)

To turn now to the details of the plan itself - perhaps the most marked difference between it and the existing system is the absence of sheep. This absence, together with a slight reduction in the size of the cattle enterprise permits the area under grass and clover to fall by 32 acres and that under fodder roots by 7 acres. The area released is taken up by the corn crops, particularly barley. Oats with identical requirements to barley but a 4½ cwt per acre lower yield do not enter the plan. The permitted 3 acres of sugar beet comes into the plan and it is of interest that this will still

be pulled by hand. There is sufficient labour available in the autumn for this job and there would thus be no point in paying a contractor to do it. In fact, spare labour is available in each of the periods covered by a restriction, apart from the first fortnight in April, and even at this period the overtime worked is less than the permitted maximum. Rather surprisingly in view of the relatively large staff, total labour available over the year is fully taken up and thus becomes an effective determinant of the plan.

The option of feeding silage to the cattle instead of roots is not taken up.

As was noted on page 6 , the computor besides printing out the solution to the linear programming problem as represented by the optimum plan, also prints out the values in the d or z-c row. These are of considerable interest as indicating the extent to which aggregate gross margin would be increased if additional units of the fully used restrictions were available. Thus for Farm A, this row shows that every additional acre of arable land made available over and above the existing 193 acres would add £31.2s. to the aggregate gross margin for the optimum plan. The figure of £31.2s. is relevant for the addition of up to 25 acres after which the increase would be smaller. The high marginal return or marginal value product is a measure of the value of extra land on farms such as this, which are already well staffed and equipped.

A very high marginal return of £48.18s. per acre is indicated for the potato quota but that for the sugar beet quota is only £1.2s. Even if the gross returns from potatoes fell by £48.18s. per acre bringing them down to £88.12s. per acre, the full quota acreage would still come into the optimum plan. The position of sugar beet is however much less assured.

The marginal return to total labour was only 1/0d per hour, a low figure which suggests that this restriction while effective in determining the shape of the plan, was only limiting gross margins to a very limited degree. Indeed, further computations using adjusted figures which assumed the employment of only four regular men, gave a gross margin of £9,224, only £221 less than the original optimum. This reduction would be more than offset by the saving in wages - in fact the employment of the fifth man was reducing the potential profit by about £300 annually. A further reduction to only three men would not however have been justified since the gross margin then falls by a further £879 which is well over the annual cost of a man.

The main differences between the original plan and that calculated on the four man assumption, are that sugar beet is excluded and the cattle numbers are reduced by nearly half with silage replacing the feeding of roots. Corn goes up still further to a total of 160 acres, all except 15 acres of which is barley. Potatoes, pigs and poultry remain at the maximum levels.

In addition to indicating the marginal returns to effective restrictions, the d row also shows the extent to which the gross margins of the activities which have been excluded from the plan would need to be raised so as to justify their inclusion. On Farm A, the only productive activities excluded are those for sheep (both existing system and summer fat lambs) and oats. The increases required to bring these activities into the plan are £1.13s. per ewe for sheep on the existing system, £3.8s. per ewe for a summer fat lamb system and £2.9s. per acre for oats.

FARM B.

General Features Farm B which is situated on rather lighter soil than Farm A, consists of 160 acres. The cropping for 1961 which is given below shows that cash roots - potatoes and sugar beet, are relatively more important on this farm and account for 17½ per cent of the total area. The proportion of permanent grass is however lower. Some of the potatoes grown are lifted as earlies at the end of July.

	Acres
Wheat	7
Barley	52
Oats	10
Potatoes	13½
Sugar Beet	15
Fodder Beet	3½
Swedes	4
1 Year ley for hay	22
Lucerne	3
Permanent Grass	30
	160

The cattle enterprise is based on the purchase of store bullocks for fattening both in yards and on grass and there is annual turnover of nearly 90 beasts a year. There are now no sheep but until recently hoggs had been bought for finishing on beet tops. Both silage and roots are fed to the cattle; the silage being made until this year off lucerne and from aftermaths, while the roots consist of fodder beet and swedes. Fodder beet is grown in preference to mangolds as it can be lifted with the sugar beet harvester.

A substantial pig enterprise centres on a herd of between 15 and 20 sows whose progeny are carried through to bacon weight. About 1,200 hens are run on intensive systems.

High crop yields have been obtained and in the four years up to 1961, the following averages were achieved - wheat 37 cwts per acre, barley 35 cwts, potatoes 9½ tons and sugar beet 16 tons per acre.

The regular staff consists of three men and the available machinery includes a combine, beet harvester and lorry. There is however no grain drier.

Range of Activities Considered

Although a rather larger number of separate activities were defined for Farm B as compared with Farm A, the range of crops and stock covered was broadly similar. Each of the corn crops, winter wheat, barley and oats was covered by a separate activity with an additional activity for the growing of barley for sale as seed. The farmer had obtained substantial premiums on seed barley but the amount that he could grow was limited by the need to follow a non-corn crop.

Two activities were included for sugar beet, one being based on hoeing by the farm men and the other on letting this by piece to casual workers. Similar duplications were made for the swede and fodder beet activities and for the former the possibility of letting the pulling and topping was also taken into account so giving a total of four swede activities. Currently the greater part of the hoeing is let but it seemed worthwhile testing whether by some re-arrangement, the cost of this could not be saved.

Separate activities were required for early and maincrop potatoes, if only on account of the differences in seasonal labour demands. Gross margins per acre are also likely to vary but only overall returns were available for the potato crop. Discussion however brought out the fact that while returns from both the early and maincrop vary widely, the expectation was that over the years there would be little difference between the two. In the absence of other information it was therefore decided to use the same gross margins for both activities so making selection between them solely dependent on labour relationships.

The cattle enterprise on Farm B was more clearly defined than that on Farm A, there being in effect three distinct systems operated. These included the purchase of store bullocks in October for fattening in yards, the purchase of smaller stores in December to be run on before turning out to be finished on grass and finally purchases in April purely for grass feeding. Fortunately, cattle kept under each system could be fairly successfully identified in the accounts and as a result gross margins were determined for three separate activities covering the three systems.

A separation of the pig enterprise into rearing and fattening activities was not feasible since there was no information available on the division of feed costs. A combined activity was therefore used.

An activity was not included to cover the recently discontinued practice of buying in hoggs for fattening on beet tops as the margins obtained in the past appeared inadequate even to cover the variable costs which were rather high owing to heavy supplementary concentrate feeding. A summer fat lamb activity was included however as the farmer expressed interest in this possibility and as mentioned in connection with Farm A, the system is fairly standardised with good data available for it.

Although a flock of over 1,000 layers is carried, no poultry activity was included. On this farm the poultry are managed by two part-time workers employed solely for this purpose. The birds receive no farm produce, apart from grain, so that for all intents and purposes they can be regarded as quite independent of the rest of the farm and their contribution to the farm profit can be assessed simply on the basis of an enterprise profit and loss account.

Apart from the swede and fodder beet activities mentioned above, there were three silage activities. These represented silage made from lucerne, silage from an arable crop of oats and vetches and silage off the aftermaths. Arable silage is not very popular nowadays, but the farmer considered that the harvesting of this crop in July was a means of avoiding the clash between hoeing and silage-making and in 1962 he grew this crop in place of lucerne.

The duplication of each silage activity according to whether it was to replace swedes or fodder beet was avoided by expressing the silage output in terms of the equivalent area of swedes only. Silage in excess of the swede requirements could be transferred to replace fodder beet by means of a special activity with a zero gross margin for converting swedes to an equivalent acre of fodder beet.(1)

As on Farm A, a ley activity permitted an extension of the grass area.

Restrictions The form of the restrictions was very similar to that on Farm A, with the farm area again divided into the part suitable for cropping, 146 acres in this instance, and the uncroppable permanent grass, 14 acres. Potatoes and sugar beet were limited to their quotas of 16 and 15 acres respectively. Restrictions on wheat and oats as before were initially set at zero and built up as the other crops entered the solution. A new restriction was that on barley for seed, related to the area of non-corn crops. To prevent the use of the same break in the rotation by both winter wheat and barley for seed, it was necessary to have a positive co-efficient for the barley for seed activity in the wheat restriction row. Cattle and pig restrictions were related to the available housing. The layout of the cattle yards required the use of two restrictions, one on the total number of cattle wintered, and the other on the number of December purchased stores for running on. The latter can only use one of the three yards on the farm since only this has direct access to the land allowing the cattle to move in and out at will.

Potatoes were restricted as in the previous example by the need to produce enough F.Y.M. to give the whole crop a dressing. Considerable emphasis has been put on the use of F.Y.M. on Farm B with most of the sugar beet and fodder roots currently being dressed in addition to the potatoes.

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(1) The transfer had to be made from swedes to fodder beet and not vice versa, since swedes are more expensive to grow per unit of food value and allowing transfers from fodder beet to swedes would automatically have excluded swedes from the solution.

The available man hours were calculated on the assumption that the present staff of three men would be retained. It could be argued that it is at least possible that a two-man system would be more profitable. Against this, however, must be set the fact that several of the major field operations, particularly those for harvesting the various crops, would be difficult to organise with a gang of less than three men, unless radical changes were made in the methods and tackle used.

As on Farm A, the available man hours were divided into a number of periods corresponding with the timing of the crop operations. The ten seasonal restrictions are listed below. In addition there was again a restriction on total labour available over the year calculated on the basis of a 25 per cent deduction for unallocated work.

Period	Principal Operations
March 8 - 31	Drill spring corn, arable silage, part of sugar beet. Riddle potatoes, plant early potatoes.
April 1-15(Easter)	Plant maincrop potatoes, drill remainder sugar beet, fodder beet, grass seeds.
May 1 - 15	Spray wheat, single beet, inter-row work on potatoes and beet.
May 16-31(Whitsun)	Single beet, inter-row work, spray spring corn, 1st cut lucerne silage.
June 1-15	Complete beet hoeing and work on early potatoes, hoe swedes.
July 16-Aug.7 (Bank Holiday)	Lift early potatoes, arable silage cut and made.
Aug 8-Sept.20	Corn harvest, 3rd cut lucerne silage.
Oct.1-Nov.30	Lift potatoes, 2/3 rds sugar beet, ½ swedes, riddle potatoes, drill wheat.
Dec.1 - Dec.31	Lift remaining beet and swedes, riddle potatoes.
Dec.1 - Mar.7	as above plus winter ploughing, spreading F.Y.M. chitting potato sets.

Derivation of the Data The activity co-efficients for Farm B were formulated for the most part on the same lines as those for Farm A, with the gross margins based on average crop yields over the previous four years weighted by the prices obtained in the most recent accounting year. The gross margins of the cattle activities relate to the average increases in value of the fat cattle over the store prices obtained in the three preceding years, accounts not being available for a longer period. The variable cost items such as purchased foods, fertilisers, machinery costs, casual labour and overtime work were apportioned as previously.

The data on fodder supplies was rather more satisfactory on this farm than was the case on Farm A. Measurement of the clamps gave at least an objective measure of silage yields and with sugar beet for comparison the estimated yield of fodder beet should have been of the right magnitude. Substitution of silage for roots should permit a reduction in the proportion of protein in the concentrate ration of the cattle which contained 30 per cent of ground nut cake. Allowance for such a saving was credited in calculating the gross margins (negative), of the silage activities.

Labour requirements were again assessed following discussion with the farmer and using standard operation times where appropriate. A point concerning the requirements of the silage activities may be mentioned. The location of the silage clamps is such that the cattle yards have to be cleaned out before the silage can be got in. To ensure that this will be possible the seasonal requirements for this job have been allocated to the silage activities. A result of this is that lucerne silage has a high labour requirement in the first fortnight of May, the only period available for removing the F.Y.M. between turning the cattle out and bringing the silage in. For the <u>total</u> requirements over the year however, removal of F.Y.M. is set against the cattle rather than the silage since there is no guarantee that the latter will come into the plan.

<u>Optimum Plan</u> The optimum plan (plan 1) and comparable details of the existing system are set out below. The calculated increase obtained in the aggregate gross margin amounts to £1,599 equivalent to £10 per acre, representing a very substantial addition to profits. The changes proposed include the growing of an extra 48 acres of corn with the emphasis on wheat rather than barley, a reduction in permanent grass down to the 14 acres which are unfit for cropping and a sharp fall in the number of bullocks fattened. Potatoes and sugar beet acreages are maintained or brought up to the full quota. Most of the beet is to be hoed by the farm staff rather than by casuals as previously. This is possible because elimination of the lucerne silage and the swedes plus a reduction in the area of fodder beet eases the labour position in the early summer. With fewer cattle less fodder beet is needed and sugar beet tops will replace swede feeding. Some silage is to be made off the aftermaths. Sufficient labour is available for lifting all the potatoes either as earlies or as maincrop and given the assumption of identical gross margins. There is no particular advantage in splitting the potato acreage either one way or another between the two activities.

Tests were made on the stability of the optimum plan shown below, with regard to the effects of changes in the activity gross margins. These tests revealed that with other prices remaining the same, a mere 2.2 per cent fall in corn prices would result in

this plan no longer being the most profitable obtainable. It was decided, therefore, to compute a new optimum on the assumption that corn prices would fall by 5 per cent in order to indicate the extent of the changes necessitated by such a fall. The revised plan - plan 2 - shows a fall of 15 acres in the corn area coupled with the elimination of barley and an increase in the number of summer fattened bullocks from 1 to 31 which is permitted by the inclusion of 15 acres of 3 year ley. *

F A R M B.	Actual 1961/62	Optimum Plan (Plan 1)	Plan 2
Crops	Acres	Acres	Acres
Wheat	7	41.3 **	56.2 **
Barley	52	39.8	-
Oats	10	26.5 **	36.5
	(69)	(107.6)	(92.7) **
Potatoes	13½	16.0 **	16.0 **
Sugar Beet own hoe	1	14.0) **	15.0 **
casual hoe	14	1.0)	-
Fodder Beet	3½	1.5	1.5
Swedes	4	-	-
1 Year Ley for hay	22	5.9	5.9
3 Year Grazing Ley	-	-	14.9
Lucerne	3	-	-
Permanent Grass	30	14.0	14.0
	160	160.0	160.0.
Stock	Nos.	Nos.	Nos.
Bullocks (a) Winter Fed	30	9.1	9.1
(b) Dec. purchased Runners on	12	20.0 **	20.0 **
(c) Grass fed	41	1.0	30.7
Sows (plus followers)	20	20.0	20.0
Standard Gross Margin	£5,564	£7,163	£6,941 ***
Gain over 1961/62		£1,599	£1,377

* The summer fattening activity assumes a short feeding period coupled with a high rate of stocking.

** maximum allowed.

*** at reduced corn price.

The elimination of barley here raised an interesting point. The gross margins per acre of the corn crops as originally stated were:-

	£
Wheat	41.8
Barley(feeding)	33.4
Oats	33.0

The advantage of wheat over the other two crops is clear but its area is limited by its specific restriction. Barley has a slightly higher gross margin than oats but against this oats is a clear crop for eyespot whereas barley is not, and every $1\frac{1}{2}$ acres of oats permits another acre of wheat to be grown. A combination of $1\frac{1}{2}$ acres of oats and 1 acre of wheat gives a gross margin of £91.3 as against £83.5 from $2\frac{1}{2}$ acres of barley, a difference equivalent to £3.1 per acre so making the wheat/oats combination more profitable than barley alone. In plan 1 the operation of restriction on oats prevented this combination occupying all the corn land but in plan 2 with the addition of the area under ley more oats can be grown and there is no need for barley. It may be noted that on Farm A, the differences in gross margins were such that barley alone was more profitable than a wheat/oats combination so that the optimum plan for that farm did not include oats. In practice the proportion of wheat in Plan 2 is likely to be regarded as rather high although growing this proportion would not necessarily be completely infeasible.

In both plans 1 and 2, only two of the general restrictions were fully used up although a number of activities such as those for potatoes, wheat and pigs came in to the limit of their specific restrictions. The effective general restrictions were the area of arable land, and labour available in the period May 16th to 31st, the peak for root hoeing. In plan 1 full use is made of both the regular labour and the overtime capacity available during this period, but in plan 2 only 45 out of the potential hours of overtime are worked then as the reduction in spring corn reduces the time spent on spraying.

The marginal returns per unit of certain of the effective restrictions are shown below:-

Restriction	Unit	Marginal Return per Unit	
		Plan 1	Plan 2
		£	£
Arable Crops	Acres	33.2	31.5
Potato Quota	"	26.6	32.7
Sugar Beet Quota	"	47.7	54.2
F.Y.M.	"	- 20.6	- 15.2
Dec.Purchased Bullocks	Beasts	1.5	1.7
Labour May 16 - 31	Hours	0.7	0.3
Pigs	Sows	32.4	30.7

As on Farm A, the marginal return per arable acre is high with an extra acre adding over £30 to the aggregate gross margin. In plan 1 labour in the May 16 - 31 period has a marginal return of 14/- per hour, but in Plan 2 with overtime capacity to spare this falls to the overtime rate of 5/9d per hour. ¤ The high figures attributable to the potato and sugar beet quotas are indicative of the value of these two crops and of the extent to which their gross margins per acre could fall before they become unprofitable - the respective levels being a gross return of £84 per acre for potatoes and £65 for sugar beet. ¤¤ It should be emphasised that the unit marginal returns shown here are only applicable for a relatively small expansion in the areas of potatoes or beet - they would fall as soon as other labour restrictions became effective.

The negative figure against the F.Y.M. restriction is a measure of the cost of insisting on its use for potatoes. It represents the extra profit that could be attained were it not for the necessity of including 9 winter fed bullocks in order to make F.Y.M. supplies just sufficient for the 16 acres of potatoes, taking account of that made also by the December purchased bullocks and the pigs. The low marginal return of 30/- to 34/- per head to the restriction on December purchased bullocks shows that a small change in the gross margin of this activity would suffice to alter the numbers of such bullocks in the plans. The linkage with potatoes expressed through the F.Y.M. restriction also means that altered assumptions concerning the amount of manure produced per bullock or a change in the potato gross margin could effect the position of these bullocks. The summer fat lamb activity was the only productive activity apart from the variants representing the use of casual labour for roots, which did not appear in the optimum plans. The d row indicates that the gross margin per ewe would need to be raised by 19/- per ewe in Plan 1 and by 13/6d per ewe in plan 2 to warrant the inclusion of sheep. Increases of this order are certainly within the range of possibility, although even the achievement of these would not bring in the sheep on a significant scale. Moreover, the figure of £11.15.0d. taken as return per ewe from the sale of lambs and wool was chosen with some care as being a reasonable indication of the average results that might be obtained over a period of years.

¤ The marginal return of 14/0d per hour in Plan 1 would only apply for the relatively small increase in May 16 - 31 labour needed to eliminate the single acre of casual hoed sugar beet with beet hoed by the farm staff. The figure of 14/0d per hour represents the total cost of casual hoeing £11 per acre, divided by the 15½ hours of hoeing per acre which are assumed to fall within the May 16-31 period.

¤¤ "Unprofitable" is used here in the sense that given the assumption of a three man staff, the best plan would still include the maximum acreages of potatoes and beet even if returns fell to the levels indicated.

F A R M C.

General Features Farm C is larger than either Farm A or Farm B. It is situated on light sandy soil which with a relatively high water table, is well suited to the growing of root crops, and advantage has been taken of this to develop an intensive system of arable cropping with substantial acreages of potatoes, sugar beet and carrots. These three crops in fact account for 41 per cent of the total farm area. Adding in the fodder roots, swedes and mangolds, brings the area under root crops up to 45 per cent of the total, or 53 per cent of the tillage area. Apart from the cash roots, barley is now the only other sale crop grown. The potatoes, sugar beet and carrots are all machine lifted and their harvesting together with that of the fodder roots provides constant employment for the regular staff of 9 men from July when early potatoes are lifted until the carrots are finished with in January. With hoeing occupying the men in early summer, there are relatively few slack periods. Corn is harvested by a contractor's combine but the farmer has his own baler for handling the straw.

Livestock play a relatively minor role in the farm economy and account for less than a quarter of the total output. Cattle are looked upon primarily as suppliers of F.Y.M. which again on this farm is regarded as a necessity for the potato crop. with perhaps rather more justification in view of the lightness of the soil. The system of production is rather similar to that on Farm B with store bullocks purchased in late summer and autumn for finishing either out of yards or on grass during the following summer.

A flock of around 100 ewes is carried mainly for the production of summer fat lambs. The acreage requirements of this flock are kept to a minimum by making use of catch crops such as kale after early potatoes, or rye sown on the stubbles. In addition to the ewe flock, between 200 and 300 store lambs are bought each autumn for finishing on beet tops.

Up to 30 sows are maintained for the production of weaner pigs but a lack of suitable accommodation has so far precluded fattening. There are no poultry.

Range of Activities Considered

The activities considered on this farm were, as in the previous examples, mainly those already forming part of the present system. Barley was chosen as the sole corn activity since a long-term comparison showed that on this farm it out-yielded wheat by $6\frac{1}{2}$ cwts and oats by $7\frac{1}{2}$ cwts per acre - differences of such magnitude as to make it apparent that neither crop would replace it in the optimum plan. The employment of casual labour was not

considered for either hoeing or lifting the root crops as such labour is difficult to obtain on account of the location of the farm. This disregard of the possibility of employing casual labour meant that in contrast to Farm B, single activities were sufficient for sugar beet, carrots, swedes and mangolds. Three separate potato activities were included however to cover first early, second early and main crop production. In the absence of other data, these were again assumed to have similar gross margins.

Single activities represented the production of weaner pigs and the fattening of lambs on beet tops but there were two activities to cover the ewe flock. Both of these were based on the current methods, but in one the feeding of kale grown as a catch crop after early potatoes was included while in the other swedes replaced kale. Without the second activity the introduction of the ewes would have been dependent on early potatoes coming into the plan.

The cattle enterprise was run more flexibly than that on Farm B, a fact which prevented a breakdown between winter and summer fattening and made necessary the use of a combined activity to cover both. Consideration of such a combined cattle activity alone would make the introduction of cattle and on account of the F.Y.M. requirement, potatoes as well, dependent on the availability of sufficient grass for the summer feeding. It seemed possible, however, that an elimination of cattle grazing and a concentration on yard feeding would be more profitable. It was decided therefore to include a purely yard-feeding activity as well as the activity based on present practice. The data for this activity was based on a costing on a rather similar farm chosen from a number investigated during a recent survey.

In view of the already large area of cash roots, it seemed possible that cutting out the fodder roots might appreciably improve the labour balance. Two methods of replacing these roots were considered. The first was by the production of silage and the second by increased grain feeding. Two activities, one for swede replacement and one for mangold replacement, were used for each of these two alternatives.

As before the hay requirements were directly incorporated in the stock activities with the assumption that these would be met from one year clover leys. The kale and other catch crops were similarly handled as part of the ewe activities. A ley activity permitted an extension of the grass area.

Restrictions

Only 6 acres of the permanent grass on this farm is considered completely unsuitable for cropping so the basic restriction on the area of arable crops was the total farm area less 6 acres. Potatoes and sugar beet were limited by their respective quotas and the farmer thought it would be unwise to expand the present area of carrots owing to possibility of yields deteriorating. Parts of the farm are not suitable for growing this crop. Cattle numbers were restricted by the available yard space to 80 head wintered and sow numbers were also limited by the buildings to a maximum of 30.

Restrictions relating to the available quantities of swedes and mangolds were necessary. That for swedes could be built up from its initial zero value not only by the swede and swede replacement activities for silage and grain but also by the sugar beet and carrot activities coming into the plan. The former provides a substitute in the form of beet tops and the latter as reject carrots.

The restriction that sufficient F.Y.M. should be produced to meet the needs of the potato crop was again retained.

The plans for Farms A and B are based on the continued employment of the existing staffs and as has already been explained there were good reasons for working on this basis. On Farm C with more men employed, a different situation existed and there was no reason to assume in advance that the farm could be most profitably run with present 9 paid workers. The most profitable plan might need either more or fewer men to operate it, depending on the point at which the increase in gross margins achieved from having extra labour available was balanced by the cost of that labour. The argument advanced with regard to Farm B, that any reduction in the size of farm staff would leave too small a team for certain operations would not be valid in this instance. It was thus desirable to regard the size of the regular labour force as a variable factor, although account would have to be taken of the need to employ this force round the year.

One way of discovering what is the optimum size of the labour force is the computation of several plans based on different assumptions as to the number of men employed as was in fact done latterly for Farm A. On a large farm this is somewhat cumbersome and an alternative approach has been preferred. Initially the labour restrictions have been based on the hours contributed only by a basic force of three men who might be regarded as the skilled nucleus including the foreman and head stockman. This initial supply of labour could be augmented by bringing in a "regular labour" activity, one unit of which would add an extra hour of labour on each working day throughout the year. This activity has a negative gross margin of approximately £60 per unit, representing the cost of this extra labour when the basic wages and insurances for a regular man run out at £10 per week. To illustrate the operation of the regular labour activity, a situation may be envisaged where owing to a peak demand extra hours are required in a period of say, 10 working days in June. Each extra hour in this period would then use 1/10 or 0.1 units of the regular labour activity with a cost, or negative gross margin of £60 x 0.1 = £6 per hour. The marginal return per hour in the peak period would have to be at least this amount if the regular labour activity was to come into operation.

The level of the regular labour activity in the solution printed out from the computor is shown as a certain number of hours and part hours taken to four places of decimals. Division of this figure by the average number of hours worked per day gives the answer in terms of men but still with so many decimal parts. To say the least, this appears unrealistic at first sight. Yet on a farm where several men are employed is such an answer in fact greatly less realistic than one in round figures? The turnover among staff and the fact that there is often a gap between one man leaving and his replacement being found means that employment over the full year is not necessarily provided for a constant number of men. The employment of youths is a possible means of meeting labour requirements if the cost of an adult man's wage is not justified and the farmer's own contribution in terms of physical labour can be highly elastic. The more men employed the less, of course, will be effect of rounding decimal solutions to whole numbers. ¤

The seasonal labour restrictions for Farm C which are listed below, resemble those used on the previous two farms. An addition, however, is a specific restriction on the hours available for harvesting corn. In this case the use of a contractor's combine removed combine capacity as a guide to the maximum area could be dealt with. Labour requirements for the corn harvest were nevertheless appreciable as the farmer provided one man to work on the combine and his men also had to lead in the grain in bags, as well as baling and carting the straw. The time available for the grain harvest work was estimated at 102 hours per man, excluding overtime. This is derived from the assumption that the equivalent of three weeks will be available when conditions are suitable and that work will not commence before 10.30.am each day. This assumption is related to the accepted figures for the capacity of combines and to their working speeds.

Period	Principal Operations
March 21 - 31	Plant early potatoes
April 1 - 21(Easter)	Plant 2nd early & maincrop potatoes, drill grass seeds.
March 21 - April 21	As above plus drilling sugar beet
May 8-31 (Whitsun)	Hoeing Sugar beet and mangolds,inter-row work on potatoes and roots, drilling swedes, 1st silage cut.
June 1-30	Hoeing & inter-row work on roots and potatoes, haymaking.
July 16-Aug.7 (Bank Holiday)	Lift early potatoes. Final hoeing & inter-row work on carrots.
Aug.8 - Sept.30	Corn harvest, lift 2nd early potatoes, 2nd silage cut.
May 8 - Sept.30	as above plus leading out F.Y.M. and one week's holiday per man.
Oct.1 - 31	Lift maincrop potatoes and ½ of sugar beet, stubble cultivation & sowing of catch crops.

¤ If integer programming facilities were available a solution could be reached which gave employment to a labour force expressed in round numbers.

(cont'd)

Period	Principal Operations
Nov.1 - Dec.31.	Lift remaining sugar beet, mangolds, 1/3rd of swedes, 2/3rds of carrots.
Nov.1 - March 31.	As above plus lift remaining carrots and swedes, riddle potatoes, chit potato sets, winter ploughing and drill barley.

Derivation of the Data

The approach to the construction of the activity data was similar to that adopted for Farms A and B but two factors simplified the task. Firstly the farmer had co-operated in a number of the University's enterprise cost programmes in recent years and the records from these provided valuable data, particularly on labour requirements. Secondly the utilisation of feed by the various classes of stock was such that allocation was relatively straightforward. For instance, apart from a known 4 tons of cake fed to the ewes, all purchased foods other than sugar beet pulp were consumed by pigs. Beet pulp was the mainstay of the cattle rations with only a small offtake for sheep. Less than 20 tons of homegrown barley was fed and the farmer was able to estimate that the proportion fed to pigs was two-thirds.

Gross margins as on the other farms were based on four-year average yields weighted by current prices, although for the three cash root crops use was made of the actual cash output over the preceding four years.

Optimum Plan The optimum plan for Farm C raised the aggregate gross margin by £842 above the standardised figure for the existing system in 1961/62. In this instance however, a simple comparison of the gross margin levels no longer gives a true measure of the improvement achieved owing to the treatment of regular labour as a variable factor. It is necessary now to take into account not only the gross margins but also the variation in the level of fixed costs resulting from changes in the number of men employed. ¤ The optimum plan allows for only 7.5 men compared with the 9 men employed at present and this represents a cost saving of £777. This combined with the higher gross margins gives the total benefit accruing from the plan as £1,619 - this is the amount by which the farm profit would be raised. The figures are set out in tabular form below:-

¤ The value in the objective function of the computor solution represents the aggregate gross margin of all the activities in this solution, including where applicable a deduction for the cost of additional labour contributed by the regular labour activity. However, to avoid confusion, the gross margin totals quoted here are based on the conventional treatment of all regular labour as a fixed cost.

	1961/62	Optimum Plan
	£	£
Standard Gross Margin	14,662	15,504
plus Saving on Labour	-	777
Total	14,662	16,281
Gain over 1961/62		1,619

On a per acre basis, the improvement is rather less than that suggested for Farms A and B but profits per acre on Farm C have been appreciably higher than on either of the other two farms. In practice close adjustment of the labour force to the planned figure would not be possible and the exact figures shown above therefore conceal a range of variation as to the possible improvement in the farm profit.

A 61 per cent increase in the area of barley represents the main difference between the optimum plan and the system followed in 1961/62. This substantial increase is achieved by eliminating all the fodder roots and all the permanent grass except the 6 acres defined as uncroppable.

Potatoes, sugar beet and carrots are all in at their maximum levels. The potatoes are divided entirely between first and second earlies with approximately equal proportions of each. This is a marked departure from the policy adopted in the past of planting the major part of the potato break to the maincrop. The exclusion of maincrop potatoes results from the full utilisation in the plan of the total labour available over the year. Maincrop potatoes have to be riddled out of the store and as a result have considerably higher total labour requirements than earlies. Similar gross margins per acre have been assumed for all the potato activities, so that inevitably the return per total hour from the maincrop is below that of the earlies and results in their exclusion in spite of an adequate supply of labour at the seasonal peaks including that of lifting. The validity of this exclusion on the grounds of relative returns per total labour hour is discussed in a wider context later. A shift is envisaged in the plan from the present system of cattle fattening to yard feeding only, without any grazing. No roots will be used for these bullocks since their requirements in terms of swedes can be met by the use of beet tops and those in terms of mangolds by heavier grain feeding.

The sheep flock is reduced to 29 ewes, the number which should be carried on the 6 acres of permanent grass supplemented by the clover aftermaths and catch crops. It is questionable however whether the 6 acres of permanent grass could provide satisfactory summering for the 29 ewes on a continuing basis from year to year as opposed to a single year's intensive management. The fattening of lambs on beet tops does not appear in the optimum plan, although after allowing for the tops consumed by the

bullocks, sufficient remain to carry about 130 lambs. However the use of a certain area of croppable land to provide the requirements for hay coupled with a low margin per head, has resulted in their exclusion from the plan.

The production of weaner pigs features in the plan at the maximum level of a 30 sow herd.

When consideration is given to the restrictions which effectively determine the shape of the optimum plan, it is interesting to discover that none of the seasonal restrictions on labour are fully taken up. ⁎ Total labour after allowing for the 25 per cent deduction is, however, as already explained, completely used.

The area suitable for arable crops is again, not unexpectedly, an important restriction but the marginal return at £23.8s. per acre is appreciably below that on Farms A and B. The lower figure results from the changed treatment of regular labour - with this allowed to vary, the supplies of land and labour can be brought into a better equilibrium.

High marginal returns to the restrictions on the three cash root crops indicate that these fully justify their dominant position. Of the three, carrots appear to be most rewarding and sugar beet the least but the latter crop, of course, scores as regards stability of returns.

	Marginal Return per Acre
	£
Potato quota	45.9
Sugar beet quota	20.5
Carrot Limit	49.7

As on Farm B, the proviso that potatoes could not be grown without F.Y.M. could only be met by bringing in sufficient livestock at the cost of an apparent reduction in total gross margin in this case of £6.8s. per acre manured. On Farm C, the F.Y.M. restriction not only forced the cattle into the optimum plan but was also instrumental in bringing in the pigs, since the gross margin per sow would otherwise have been insufficient to have covered the marginal cost of employing extra labour to meet the relatively high requirement of 62 hours per sow per year, including manure disposal.

Turning to the excluded activities, an increase of 10/6d per head in the gross margin would be necessary to bring the fattening of lambs on beet tops into the plan on a substantial scale. The margin between the buying and selling prices of these lambs on the basis of past experience was taken as £2.9s. per head, which is probably rather above average and a further increase of 10/6d per head seems improbable.

⁎ This is not entirely correct as all the labour available in the July 16-Aug.7th period is in fact used. However, a shift from first to second early potatoes would permit some labour to go slack in this period. Such a shift could be made without loss of income as there is labour to spare in the following period, Aug.8-Sept.30th when the second earlies are lifted. The marginal return to labour in the July 16th-Aug.7th period is nil and the overtime activity does not operate then.

An increase of £4.7s. per bullock would be required to bring in the activity for cattle on the current mixed system of summer and winter feeding. The figure is related not only to the increases in value obtained during fattening but also on the estimates made of the relative amounts of F.Y.M. made by these cattle and those in the winter feeding activity.

FARM D.

General Features Farm D is a farm of 265 acres. Its situation compares rather unfavourably with those of the three farms discussed so far. The soil which is relatively shallow, overlies sandstone and has a lower inherent fertility than that on the other farms, while the rather undulating nature of the ground increases cultivation problems. Nevertheless with skilful management the land is capable of yielding satisfactory crops and on Farm D arable cropping has been combined with a number of livestock enterprises to produce what has been a fairly profitable system of farming.

In contrast to Farm C, livestock account for almost 60 per cent of the total output and it is appropriate to describe the livestock enterprises first before turning to the cropping system which is closely linked with these. The livestock enterprises include a dairy herd of just over 30 cows managed on a yard and parlour system, a flock of 95 ewes for the production of summer fat lambs, a pig unit with 27 sows and their progeny carried on for sale as baconers and a flock of 600 hens on deep litter. All the calves from the dairy herd are retained - the steers to be sold fat out of yards at about 18 to 20 months old and the heifers for herd replacement or for sale as breeders. About one-fifth of the milk produced is sold through a retail outlet and this involves some extra work by the cowman.

A special feature of the system on this farm is the intensive use of grass with the emphasis on short duration heavily fertilised leys. An area adjoining the buildings in which the cows are housed is reserved for cow grazing leys and the kale and cabbage grown as fodder for them; no other crops are grown here. Where the fields are adequately fenced and watered, two-year leys feature in the arable rotation and are used both for grazing and for silage production. On the remaining arable amounting to about 75 acres, one year leys are put down and used solely for conservation. The 45 acres of permanent grass is mainly on steep slopes which could not easily be ploughed. It provides useful wintering for the sheep as well as grazing for the young stock.

The cropping details given below show that the various types of grass take up in all just about half the farm area. On the remainder wheat and potatoes are the dominant crops. No sugar beet is grown but peas for pulling green are a useful breakcrop.

	Acres
Wheat	59
Barley	19
Oats	5½
Potatoes	33
Peas	15
Kale and Cabbage	2½
Mangolds	2
Leys 1 Year	15
2 Year	30
Cow block	30
Long duration	9
Permanent Grass	45
	265

The regular staff includes 7 men amongst whom there is a certain amount of specialisation including both a full-time cowman and a pigman. Although a contractor is employed to combine the barley, the wheat and oats are cut by binder and stocked. Casual labour is employed for potatoe. lifting while the merchant who buys the peas on a share basis provides a gang for pulling these.

Range of Activities Considered The activity list in this instance covered all the saleable crops at present grown - winter wheat, barley, oats, potatoes and peas, plus the five livestock activities, dairy herd, fattening of steer calves, ewe flock, pigs and poultry. The rearing of heifers was incorporated in the dairy herd activity and similarly the poultry activity included pullet rearing. The pig activity covered both breeding and fattening since there was no adequate data available in which to make a separation. Two ewe flock activities were used, one being based on entirely current practices, whereas the other permitted the feeding of purchased rather than homegrown mangolds. At present two acres of mangolds are grown primarily for the ewes but the hoeing of these clashes with silage-making and it seemed possible that the ewes might be excluded from the optimum plan solely on this account, whereas the substitution of purchased mangolds at an assumed price of £4 per ton would be a possible means of avoiding the clash.

Three ley activities were used to differentiate between the one, two and three year leys. The one and two year leys are heavily fertilised receiving typically 4 cwt per acre of compound fertiliser and 6 cwts of Nitro-chalk per acre annually. The treatment of three year leys is more akin to that of the permanent grass with considerably lower nitrogen dressings resulting in a rather lower output per acre. To balance this however, the establishment costs borne annually are lower and are moreover offset by the ploughing out grant. The output per acre from the one and two year leys was assumed to be

identical and this made it unlikely that the one year leys would feature in the plan since these incur higher charges for establishment. The need to provide grazing for the sheep on the first year of ley, which was regarded as an essential feature of the intensive system followed on this farm, could however conceivably make their use necessary.

The fodder requirements in the form of silage, hay, kale, cabbage and mangolds were in this instance all incorporated with the appropriate livestock activities and a similar treatment was used for the special leys reserved solely for cow grazing.

Restrictions The restrictions were again similar in general form to those on the preceding farms. There are 220 acres of arable land available after deducting the 45 acres of permanent grass. The potato quota is 35 acres, and it was felt desirable to limit the peas to 20 acres on account of uncertainty as to whether the merchant who purchased these would be willing to give a contract for additional acreage. A wheat restriction was linked with the acreage of eyespot clear crops as on farms A and B, and an additional restriction limited the total cereals here to four-fifths of the arable area. A restriction was also used to ensure that a sufficient area of barley or oats was available for under-sowing with ley mixtures.

While the F.Y.M. supply formed one of the restrictions, an attempt was made to express the F.Y.M. requirements of potatoes less rigidly than before. Instead of stating that potatoes could only be grown if sufficient F.Y.M. was available, the option was now permitted of growing potatoes without F.Y.M. but at the expense of losing 1½ tons yield per acre. ¤ This option involved the use of two potato activities, one with F.Y.M. applied and one without.

The size of the dairy herd was limited both by the capacity of the cow yard and by the farmer's desire to restrict the cow grazing area to a block of land adjacent to the buildings. Additional buildings cannot be converted for use by the cows owing to their distance from the milking parlour but it would be possible to use the cow yard for beef cattle. In addition to the restriction on cow numbers, a combined cattle housing restriction was therefore necessary. This permitted the fattening of up to 65 bullocks yearly or, alternatively, a combination of cows (plus replacements) and bullocks up to this number. It should be noted that this restriction allows the beef enterprise to be expanded well beyond the supply of homebred calves from the dairy herd on the assumption that suitable calves could be purchased at the same figure as that placed on the home-reared calves.

¤ It may be questioned whether the loss in yield will be as great as this especially if extra quantities of fertiliser are applied to compensate for the absence of F.Y.M. The figure of 1½ tons per acre is in fact based on the results of a particular ten year trial but other experiments have shown much lower responses. The growing of potatoes without F.Y.M. however, represents a break from local tradition and the advantage, if any, of doing this needs to be conclusively demonstrated.

The labour force on Farm D seemed of sufficient size to again justify the treatment of regular labour as a variable factor using a regular labour activity to augment the hours contributed by a basic three-man staff. The seasonal labour restrictions are listed below.

Period	Principal Operations
March 7 - 31	Drill spring corn, fertiliser on grass, riddle potatoes
March 24 - April 14	Plant potatoes, sow grass seeds
March 7 - April 14	All operations above
May 21 - June 6	Spray spring corn and peas 1st silage cut
Aug.20 - Sept.30	Corn harvest, 3rd silage cut
Oct.1 - Nov.10	Lift potatoes, thresh wheat for potato clamps ... drill winter wheat

In addition there was a restriction relating to the hours available for corn harvesting as on Farm D.

Derivation of the Data The allocation of the area of grass used both for grazing and for silage to the different classes of stock in order to give the requirements per head proved to be the most difficult problem in arriving at the data for this farm. While specific cuts of silage could be fairly readily allocated as individual clamps were made to meet the needs of different groups of stock, there was no easy way of assessing the demands of the silage cuts relative to the grazing requirements of the sheep and young cattle (cow grazing was restricted to a specific area). How for instance could winter grazing by the ewes be equated with silage cuts in the summer? It was in fact difficult to find any alternative to making arbitrary divisions in consultation with the farmer. On the basis of these divisions, comparisons were made of the relative productivities of the short leys and of the permanent grass on a stock unit week basis. ¤ These led to the conclusion that the output per acre from the short leys was approximately 50 per cent greater than that from the permanent grass. The output of the long duration ley was equated with that of permanent grass as both received similar treatment.

The farmer is in the habit of recording the division of his expenditure on feedingstuffs among the different classes of stock and this of course very much simplified the allocation. No homegrown corn is fed to the sheep, pigs or poultry and records were available of the quantity fed to the dairy herd so leaving only the problem of splitting the remainder between the bullocks and young heifers. This was done on the basis of the estimated daily rations per head.

The gross outputs of the crop activities were, as previously, based on average yields in the preceding four years but an exception here was made with regard to barley where it seemed that the recent use of higher nitrogen dressings was giving yields above those obtained in earlier years. The yield figure was therefore revised upwards.

¤ For an explanation of the stock unit week system used see Appendix A, Farmers' Report No.156. "Economic Aspects of Sheep Production on the Lowland Farm". (University of Leeds, Agricultural Economics Section)

Detailed records for the labour inputs on the fodder crops were available as a result of the farmer's participation in the University's Milk Cost Scheme and these were naturally of considerable value in the calculation of the labour co-efficients.

Although there was no difficulty in ascertaining the magnitude of the labour inputs on milk production in relation to the existing cow numbers, a problem did arise in calculating the per head requirements. The relationship between herd size and labour requirements per cow is usually thought of as being non-linear since certain jobs such as bringing the herd in and cleaning up the parlour and utensils may be expected to take much the same line however many cows are in the herd. Such a non-linear relationship could not be handled directly. Instead it was dealt with by deducting a fixed requirement estimated at one hour per day from the available labour hours and then including only the variable element in the dairy herd activity co-efficients. If the optimum plan excluded the dairy herd a further solution would have to be computed after adding back this hour per day.

Optimum Plan

Plan 1 given below, represents the optimum plan first calculated for Farm D. After allowing for the slight decrease of £75 in labour costs, which in fact is unlikely to be realised, the improvement over the standard gross margin for 1961/2 is put at £1,165. The deviations made from the system followed then are relatively small, the main difference being the exclusion of sheep, which, together with a slight fall in the number of bullocks, permits an expansion of 25 acres in the area of corn. The wheat acreage falls however since the reduction in the area of leys means that there are fewer break crops available. Part of the increased gross margin can, of course, be credited to the inclusion of the dairy cows, pigs, potatoes and peas at the maximum levels permitted which are higher than those in 1961/62. The labour required for Plan 1 is to all intents and purposes the same as that now employed.

Farmers with even quite small corn acreages are nowadays dispensing with the binder and harvesting all their corn by combine. On Farm D, however, over 60 acres were still being cut by binder. It seemed a fairly obvious step to test whether profits would not be improved here by a changeover to more mechanised methods. Discussion brought out the fact that such a changeover was unlikely to be made unless the dairy herd was also dispensed with. The reasons for linking these two changes were that the cowyard was the most suitable building for conversion to a grain store and that disposal of the cows would be a convenient means of financing the purchase of grain harvesting machinery. In order to test the possible advantages which would accrue from such changes, a further plan, Plan 2, was computed with the co-efficients of the corn activities revised on the assumption that harvesting would be fully mechanised and the dairy herd completely excluded.

FARM D.	Actual 1961/62	Optimum Plans Plan 1	Plan 2
Crops	Acres	Acres	Acres
Wheat	59	47.7	36.7
Barley	19	60.4	128.3
Oats	5½	-	-
	(83½)	(108.1)	(165.0)
Potatoes with FYM	33	35.0 *	12.4
without FYM	-	-	22.6 *
Peas	15	20.0 *	20.0 *
Kale and Cabbage	2½	3.5	-
Mangolds	2	-	-
2 Year Ley	30	22.2	-
Cow Block & other leys	54	31.2	-
Permanent grass	45	45.0	45.0
	265	265.0	265.0
Stock			
Cows (+ replacement heifers)	32	35.0 *	-
Bullocks Fattened	15	11.6	31.5
Sows (+ progeny)	20	25.0	25.0
Ewes	95	-	-
Hens	600	750	750
Regular Men	7	6.8	5.3
	£	£	£
Standard Gross Margin	9,457	10,547	10,359
Saving on Labour	-	75	902
Total	9,457	10,622	11,261
Gain over 1961/62		1,165	1,804

* Maximum allowed

Plan 2 involves a more substantial reduction in the size of the regular labour force than does Plan 1 and the saving resulting from this when added to total gross margin gives a net improvement of £639 over Plan 1. However, no account has been taken of depreciation charges on the new equipment or of higher interest charges resulting from a possible increase in total capital investment. The extent to which the additional charges would cancel out this improvement would depend on the farmer's choice of equipment and the degree of mechanisation he considered desirable. It would also be up to him to decide whether the anticipated improvement in his profits was sufficient to justify the radical changes involved. It is perhaps relevant to note here that barley is more highly subsidised than milk.

In Plan 2, three-quarters of the corn area falls under barley since wheat is now severely restricted by the lack of break crops. There are no leys and the rearing of bullocks comes in only to the limit imposed by the potential of the 45 acres of permanent grass. With the relatively small number of cattle, F.Y.M. supplies are sufficient for only 12½ acres of potatoes, nevertheless the plan includes the full quota of 35 acres since the lower yielding potatoes without F.Y.M. activity, takes up the remaining 22½ acres. Peas are in at their maximum level as also are the numbers of pigs and poultry.

The marginal returns to the effective restrictions in the two plans are given below. Once again high figures are indicated to the restriction on arable crops and to the potato quota. There is also a high marginal return to the pea limit suggesting that the peas on this farm are a highly profitable crop. Returns from this crop admittedly fluctuate widely as between years but gross returns per acre could fall from the assumed average level of £44 to £27 per acre (£29 in Plan B), without requiring any alteration to the optimum plan. An advantage of the crop is that it has low variable costs and low labour requirements per acre - harvesting is not the farmer's concern.

Restriction	Unit	Marginal Return per Unit	
		Plan 1	Plan 2
		£	£
Arable Crops	Acres	22.3	25.3
Potato Quota	"	24.5	23.6
Pea Limit	"	17.2	15.0
Cow Block	"	9.3	-
Total Labour	Hours	.3	.3
Labour Aug.20 - Sept.30	"	.0	.1
Poultry	50 hens	.4	.7
Pigs	Sows	14.0	15.2

Total labour was a determinant of both Plans 1 and 2, but only in the latter, was a seasonal restriction, that for August 20th, September 30th effective, and then only to very minor degree as is indicated by the low marginal return per hour.

The marginal return to the limit imposed by the available poultry housing was very low for both plans at only 7/6d and 14/0d respectively per 50 birds. This activity obviously makes little contribution to the farm profit and dropping it might be justified in the interests of simplification. The position as regards pigs appears more satisfactory.

The d row indicates that the gross margin per ewe would need to be increased by 28/- before sheep came into Plan 1 and by 34/- to bring them into Plan 2.

FARM E.

General Features Farm E adjoins Farm D but is considerably larger in area extending to 436 acres and a greater emphasis has been put on the arable as opposed to the livestock enterprises. In 1961 there were about 200 acres of corn, 44 acres of potatoes, 35 acres of pulling peas and 10 acres of sugar beet, a comparatively recent introduction. The beef enterprise was primarily based on a herd of 20 cows for single suckling but the beasts reared from these were supplemented by the purchase of additional bullocks for yard fattening. Some dairy heifers were also being reared. There was a flock of nearly 200 ewes kept primarily for the production of store lambs to be finished on the farm on swedes and these also were supplemented by purchases. The pig enterprise based on the fattening of purchased weaners was an important feature of the farm, having a turnover of nearly 500 pigs a year. The regular staff consisted of 9 men. Grain harvesting had been fully merchanised with adequate drying and storage facilities installed.

The system as described above was in a state of flux when the question of applying linear programming was first raised owing to the recent transfer of the management to the owner's sons. In some ways this was a particularly appropriate juncture at which to use linear programming but the ensuing changes in production methods hindered both the derivation of appropriate technical co-efficients and the evaluation of the improvement which could be expected in the level of anticipated profits. Partly on this account and partly because many of the methods used have already been described, the description of the use of linear programming on this farm will be kept relatively brief.

Activities and Restrictions The activities, as on the other farms, related mainly to the components of the system currently practised with, as on Farms C and D, a regular labour activity to permit variation in the size of the labour force. The breeding of weaner pigs in addition to fattening had been under consideration and an activity was introduced to cover pig breeding as well as fattening. Another possibility which had not been considered elsewhere was selling straw off the farm either as left by the combine at 25/0d per acre or alternatively in bales at £3 per ton. Scope was also provided for extending the corn area beyond the capacity of the present combine by an activity for the hiring of a contractor's machine at a cost of £4 per acre.

Restrictions took the same form as those used in the earlier examples relating to both physical features such as the area of land for arable cropping, available stock-housing and hours of labour, and to the limits on specified crops. The alternative uses for straw made a restriction on the quantity of straw necessary to ensure that the amounts sold, plus those used for cattle and pig bedding, did not exceed the quantity produced.

The co-efficients for this restriction could however be only crudely estimated. Another restriction was on the combined numbers of cattle and sows. It was envisaged that the dry sows would be housed in the cattle yards but this would not be practicable unless cattle numbers were reduced and on the basis of space requirements one sow was equated to 0.4 of a beast. The maximum number of sows was put at 60 which was the capacity of the building it was proposed to convert into a piggery for sows and litters.

The activity co-efficients were obtained by the methods described previously. The accurate recording on this farm of the foods consumed by the pig herd was of particular value in the calculation of the gross margin for the pig fattening activity.

Optimum Plan The optimum plan differs markedly from the pattern followed in 1961/62. The corn area is increased from 200 to over 300 acres, sheep are totally excluded and the cattle much reduced, but a big expansion is envisaged in pig production. Both potatoes and peas are at their maximum levels but there is only 1.3 acres of sugar beet as against a quota of 15 acres and such a small area is probably best disregarded. Only the 10 acres of grass regarded as unploughable remain in the plan and these in theory, just meet the hay requirements of the winter fed bullocks which, in conjunction with the pigs, provide sufficient F.Y.M. for all but 2.6 acres of potatoes. With relatively few cattle, most of the straw can be sold with preference given to sale loose in the field. A contractor will be required to deal with 84 acres of corn. Employment is provided for 6.8 men as against the existing 9. The combined effect of all these changes is to raise the anticipated gross margin by £5,212 per year - nearly £12 per acre. Part of this gain however comes from the proposed expansion of the pig herd and in this sense cannot be attributed to the planning process. No deduction has been made for extra fixed charges resulting from the conversion of existing buildings to form additional piggeries.

The effective limits on the plan include the area of arable land with a marginal revenue of £24.6 per acre, total labour and labour in October although the restriction on overtime is not in fact fully taken up.

On this farm as on Farm B, wheat and oats in combination give a higher average gross margin per acre than barley alone and for this reason the plan includes the maximum permissible area of oats.

FARM E.

Crops	Actual 1961/62 Acres	Optimum Plan Acres
Wheat	80½	106.0 *
Barley	98	162.0
Oats	24	66.3 *
	(202½)	(334.3)
Potatoes with F.Y.M.	44½	47.4) *
without F.Y.M.	-	2.6)
Peas	29	35.0 *
Sugar Beet	10	1.4
Mangolds	5	1.4
Swedes	22	3.9
Kale and Cabbage	14	-
Leys	56½	-
Permanent Grass	52½	10.0
(Straw sold)	-	(238)
	436	436
Stock		
Cattle	Mixed system with 20 suckler cows, approx.110 cattle in all.	34.5 bullocks winter fattened
Ewes	177	-
Hoggs on Swedes	234	-
Sows	-	60.0 *
Fat Pigs sold	471	900.0 *
Regular Men	9	6.7
	£	£
Standard Gross Margin	14,655	18,658
plus Saving on Labour	-	1,209
Total	14,655	19,867
Gain over 1961/62		5,212

* Maximum allowed

A Second Approach For various reasons several months elapsed between the initial discussions with the partners who are now running the farm and the computation of the optimum plan. During this period an additional 131 acres of land were acquired and it was suggested that the plan might be re-computed to allow for this extra acreage. This was agreed but first of all various modifications were made to the original data in the light of a discussion on the farm of the results given in the original plan.

It was thought for instance, that the value of oats as a break crop for wheat was more than balanced by the problems arising at harvest time through having three rather than two corn crops to deal with and that oats should not be included as a possible crop. Heavier dressings of nitrogen were being used on the wheat and barley and these had led to an increase in yields. It was now suggested that 35 cwts and 32 cwts per acre were more appropriate figures for these two crops than the previous ones of 30 and 28½ cwts. Another point concerned the response of potatoes to F.Y.M.dressings. The present partners were by no means convinced that F.Y.M. would give higher yields than would otherwise be obtained, provided fertiliser dressings were adequate. It was therefore decided to ignore any possible interaction between F.Y.M. and potato yields. Modifications had been made to the system of sheep management in order to advance the dates when the lambs were sold thus eliminating the need for folding on swedes. The figures for the sheep flock were revised to take account of these modifcations. The proposal to remove the sheep entirely turned out to be rather unwelcome and it was decided to introduce the proviso that any new plan must include a flock of at least 200 ewes.

Adjustments were made to the labour co-efficients for potato lifting following the adoption of a stillage system and the opportunity was taken to revise the gross margins for both potatoes and peas in the light of a further year's results. Quotas for potatoes and sugar beet were adjusted upwards and the figure for the combine capacity raised in the light of additional experience from 250 to 300 acres. Duplicate activities were used for all the crops likely to be grown on the newly acquired land with the labour co-efficients for these raised by 10 per cent to allow for the extra time spent in travelling from the farmstead.

The plan computed following these changes includes the maximum numbers of both sows and fattening pigs and the 200 ewes which had been insisted upon. Apart from 40 acres of fodder crops and leys for the sheep, all the land was to be under cash crops including potatoes, peas and sugar beet at their maximum levels of 50, 35 and 15 acres respectively. The 401 acres of corn is split between 115 acres of wheat and 286 acres of barley. The labour required is 8.4 regular men, 1.6 more than were needed for the previous plan on the basis area of 436 acres. After adjusting for the larger labour force, the gross margin obtained with the new plan is £3,790 larger than that obtained with the first plan but rather over £1000 of this can be attributed to higher yields and other changes in the initial assumptions. The remainder would not all accrue as a higher profit as some increase in fixed costs would be bound to occur as a result of the increase in farm size although initially this might be relatively small.

3. A SUMMARY OF THE RESULTS

The plans computed for the five farms indicate that in each instance, profits could be substantially improved with a new combination of enterprises giving a better use of the available resources. The increase in profits on four of the farms was put at between £1,500 and £1,800 per year. On the fifth, Farm E, where there were special factors such as the change in management and the proposed extension in pig housing, the increase was expected to be substantially larger. In relation to current net income calculated on a standard basis, the percentage improvement ranged from 24 per cent to 210 per cent and averaged 93 per cent. These figures are however, in all probability over-optimistic since it is most unlikely that the plans either would or could be implemented exactly. For instance, crop areas would almost certainly be adjusted to fit more appropriately with field boundaries while it is likely to be hard in practice to achieve the full use of the available stock-housing capacity where this has been assumed in the plans. Almost invariably there would be a need to make short-term adjustments in the light of prevailing conditions. The adjustments should however to some extent compensate each other and the reduction in the aggregate gross margins would not necessarily be very large.

Any forecasting of the anticipated results from a given plan is bound to be very hazardous and it is not claimed that even exact implementation would be likely to give a realised profit at all close to the predicted figure since all the three components of gross margins - yields, costs and prices - are likely to vary. ¤ Nevertheless the results as calculated on the basis of standard gross margins represent as satisfactory criteria as any on which to base a judgement on the value of the plans. Using these criteria there can be little doubt that the computed plans represent a substantial improvement on existing practice.

The extent to which the adjustments proposed for each of the five farms are similar is obviously of interest. Comparison of the optimum plans does in fact show that there are certain common features. The most obvious is that in every instance, the area under corn is to be substantially increased while that under grass is to be reduced. None of the plans apart from that for Farm C includes sheep and even on Farm C the sheep come in only as a residual activity using the small area of permanent grass. Pig numbers are always at the maximum level as also are poultry, where these have been considered. The marginal returns indicate that the position of these activities would, in most cases, be maintained even when their gross margins dropped to low levels.

¤ For a very full discussion of this point see Renborg.Ü. "Studies on the Planning Environment of the Agricultural Firm". Uppsala. 1962.

The inclusion of beef cattle tends to be dependant on the proviso that F.Y.M. is necessary for potatoes. On farms B and C, this proviso can only be met by a substantial reduction in the potential gross margins obtainable from the other activities. On farm A however, the plans include more cattle than are needed for the requirements of the potato crop. On farm D and initially on farm E, a differential of 1½ tons per acre has been assumed for the yield of potatoes with and without F.Y.M. This is sufficient to bring in enough cattle to manure nearly all the potatoes on farm E but not on farm D once the dairy herd is excluded. On farm E however the very large number of pigs would provide much of the F.Y.M, and cattle only come in to the extent permitted by the small area of permanent grass. The position of the potatoes themselves is clear cut, with the quota always fully taken up and high marginal returns from £23 to £49 per acre, shown. Sugar beet was only considered in relation to four of the farms and on two of these (B & C), it came up to its limit and the marginal return was high. On the other two (A & E), where the acreage grown was in any case smaller, its position was less certain and it was either included with only a small marginal return or excluded altogether.

On each of the three farms (C, D and E) where a regular labour activity permitted variation in the size of the labour force, the plans indicated that profits would be maximised with rather fewer men than at present employed. It was also apparent on farm A that the employment of one less man would raise the profit potential.

4. THE PLANNING CRITERIA

With knowledge of the effective restrictions and of the relative gross margins per unit of these restrictions, it is not difficult to comprehend in broad terms, the criteria which have led to the derivation of the optimum plans. It would be tedious to describe these for each plan but the tables below indicate some of the more important factors. Table 1 gives the gross margins per arable acre for the main activities, although some selection has been necessary for reasons of space and certain variants, particularly with regard to cattle feeding methods and the employment of outside labour for root crops, have been excluded. Table 2 lists the gross margins per total hour for the activities in Table 1 with the addition of those for pigs and poultry.

Potatoes invariably returned the highest gross margins per arable acre with sugar beet generally coming next, although for this crop there was a marked difference between the levels on farms B and C, and those on farms A and E. On the latter two farms with relatively low gross margin, beet only entered the plans marginally. The gross margins from the corn crops fell mainly within the range £25 to £35 per arable acre, with winter wheat always returning the highest figure. The cattle activities show considerable variation but for the most part the gross margins are below those of the corn activities. The figures for sheep are remarkably consistent

Table 1. Gross Margins per Arable Acre

	FARM A	B	C	D	E
	£	£	£	£	£
Potatoes	87.6	71.3	88.5	82.0	79.2
Sugar Beet(no casual)	40.7	75.3	64.5	-	45.2
Wheat	38.9	41.8	-	31.0	33.5
Barley	33.3	33.4	27.5	25.1	27.3
Oats	26.6	33.0	-	21.0	24.6
Ewes	26.7	21.9	25.2	25.6	27.5
Fattening Sheep		-	44.3	-	20.0
Beef - stores winter fattened	-	10.3	20.3	-	49.2
rearing and fattening	32.8	-	-	32.7	-
summer fattening	-	25.9	-	-	-
Dairying	-	-	-	36.8	-

Table 2. Gross Margins per Total Hour

	FARM A	B	C	D	E
	£	£	£	£	£
Potatoes early	-	1.56	.69	-	-
maincrop	1.04	.93	.83	1.23	1.14
Sugar Beet(no casual)	.34 +	.79	.98	-	.51
Wheat	3.70	3.84	-	1.75 ⁂	4.0
Barley	3.03	3.33	2.27	2.70	2.94
Oats	2.44	3.23	-	1.10 ⁂	2.70
Ewes	.68	.74	2.00	1.01	.74
Fattening Sheep			.34		.40
Beef Cattle - Stores winter fattened	-	.22	.64		.64
fattening & rearing	.68	-	-	.51	-
summer fattening	-	No labour	-		-
Dairying	-	-	-	.67	
Pigs	.44	.66	.27	.47	.67
Hens	.74	-	-	.31	-

\+ Hand lifted

⁂ Harvested by binder

(Figures for beef cattle based on the feeding of swedes and mangolds)

at between £22 and £27 per acre - a relatively low level. The only exception was the fattening of store lambs on beet tops on farm C.

Total hours available over the year were an effective restriction on all the farms apart from farm B, and it is immediately apparent from Table 2 that by far the highest gross margins per total hour were obtained from the corn crops which, with mechanised harvesting have low labour requirements per acre. Potatoes and sugar beet use labour less profitably and the gross margin per hour is generally between a third and a half that of corn. The cattle and sheep figures show considerable variation with some very low gross margins per hour. For the most part the return from these activities is below that from potatoes and sugar beet. Pigs and poultry both show relatively low returns to labour.

Comparison of the figures in the two tables with the optimum plans shows clearly that selection has been based to a marked extent on the relative gross margins per arable acre rather than those per hour. This is illustrated particularly by the invariable inclusion of potatoes to the maximum level and the almost equally invariable rejection of sheep. In fact the normal position appears to be that potatoes and sugar beet are selected to their respective limits while the remaining arable area is used for corn with the preference given, so far as is possible, to wheat. The availability of labour in the autumn was not however an effective restriction in any of the cases dealt with; if it had been the selection of either potatoes or sugar beet to the quota limits might have been less automatic.

The existence on each farm of an area of uncroppable permanent grass rather complicates the issue as regards cattle and sheep since so long as these stock are utilising this area, their demands on the potential arable area will be relatively low and gross margins per arable acre correspondingly high. The figures in Table 1 are, however, based on the assumption that the cattle or sheep are grazing leys on the arable area.

Cattle enter the plans to meet the F.Y.M. requirements and go beyond this on farm A and also on farm D where milk production is an option on both farms the gross margins per arable acre are at a similar level to those for corn. Summer fattening of bullocks comes into the second plan for farm B although the gross margin per arable acre is only £25.9 compared with a revised figure of £31.2 for barley. Here, however, the inclusion of leys for bullock fattening raises the average corn gross margin per acre by permitting a bigger proportion of wheat to be grown while with the barley out, some of the labour previously needed for spraying can be diverted to replace casuals for beet hoeing.

Pigs and poultry make no direct use of the arable land so they can be regarded as having an infinite gross margin per arable acre which makes their inclusion into the plans hardly surprising in spite of the fact that gross margins per hour are relatively low.

Attention has been focused here on the returns to land and labour rather than on the other restrictions since in this context with capital excluded, it is only these restrictions which are effective on all or nearly all of the activities. It is not surprising that out of these two it is the return to land which is dominant. On the first two farms (A and B) to all intents and purposes sufficient labour was available to meet the needs of programmes maximising returns per acre and on the other three where labour was allowed to vary, the same end could be achieved provided the marginal return per hour was greater than its cost. The cost of adding one extra hour of total labour by means of a regular labour activity is £0.31 (6/2d) per hour which is appreciably below the gross margins per hour derived from most of the activities. ¤ It is less than one-third of the potato figures and barely a tenth of those for corn.

5. POSSIBLE CRITICISMS OF THE PLANNING EXAMPLES

Some may query the whole concept of objective planning which has formed the basis of this work while others are certainly not fully convinced of the merits of the gross margin as an economic criterion. These points are argued elsewhere and it is not proposed to examine them again. There are, however, less fundamental, but nevertheless important, aspects of the planning examples quoted above, which are open to criticism and an attempt will be made to discuss the more important of these. Many of the arguments put forward in this section are relevant not only to the use of linear programming but also to the use of the simpler techniques such as programme planning and gross margin analysis.

It may be argued that the optimum plans have been over-circumscribed by limiting the choice of activities very largely to those which were part of the current systems. Alternative methods of cattle feeding (silage or corn substituting for roots), were in fact considered on farms A, B and C, and also the introduction of sheep on farm B and that of breeding pigs on farm E. The choices could however obviously have been made very much wider particularly on the livestock side. It would for instance, have been possible to contrast the early mid season and late production of lambs combined with various methods of ewe wintering instead of using a single ewe flock activity, while on the crop side more attention might have been given to the potential for further mechanisation.

The introduction of such additional choices however raises one of the more difficult problems of advisory work, namely that of assessing the likely performance rates on a particular farm in the absence of past records. This becomes an especially acute problem in relation to new or recently introduced techniques. Once a practice has been fairly widely adopted, surveys can be made to

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¤ Pigs on farm C have a gross margin per hour of only £0.27 but come into the optimum plan on account of their value in providing F.Y.M. for the potatoes.

ascertain both the mean level of performance and the ranges. The need however may be to evaluate a technique, within the context of conditions on the farm, before it has been widely adopted. Even with well established techniques it is not always easy to predict the results likely on a particular farm - enterprise cost studies invariably show a wide range of inter-farm variation although their annual basis may rather exaggerate this. The problem is most acute with cattle and sheep owing to the need to consider both the production and conversion of a wide range of forage crops as well as the stock themselves. Cash crops are more easily dealt with and pigs and poultry can often be treated outside the main area of planning.

Although a farmers first preferance may be to continue mainly on the basis of his current activities, the need to consider activities new to the farm is likely to arise frequently. There seems however to be no ready answer as to how his likely performance with the new activities can be evaluated. More determined efforts to record new techniques on a survey basis, coupled with the rapid publication of results, might help but in general little can be said apart from a warning on the need for circumspection when drawing up the coefficients for new activities on the basis of the very limited amount of data which is so often all that is available.

The planning co-efficients used in this study assume that current performance levels will remain unaltered in the future. The crop yields, for instance, are taken as the average of the previous four years and labour figures relate specifically to current methods. An alternative approach which has been propounded is the use of standard figures based on technically acceptable practices. The implication is that the farmers existing methods should be evaluated and steps taken where necessary to improve them before planning is undertaken. This however, would seem to assume firstly that a thorough review, enterprise by enterprise, is always possible; and secondly that the farmer will both adopt all the recommendations and achieve the desired results. This seems rather dangerous ground, for communication between adviser and farmer may be less than perfect. The farmer may well have reasons for not adopting all the recommendations and it cannot be guaranteed that if he does he will achieve the desired results. It would seem safer to plan initially on the basis of current performance, while recognising that as on farm E, future improvement may justify further planning computations within a relatively short period. The same sort of argument may be applied with regard to the possible changes in the gross margins arising from price alterations. The use here of current prices as a basis for planning may be regarded as too static an approach. Some adjustments might have been made to these prices in the light of current trends, but forecasting is hazardous and in any case with the present system of guarantees, the changes occuring within the next year or two are unlikely to be of such magnitude as to markedly alter the balance of the optimum plans. Even if plans

become non-optimum within this period, the discrepancy between the income produced by these and the current optimum plans should not be large. Over the longer term, technical changes may have as much effect on gross margins as those in prices, and re-programming may again be justified.

If the changes envisaged require additional long-term investment the problem becomes more complicated. Probably the best that can be done, having regard to future uncertainties, is to test the ranges over which the gross margins can vary without altering the optimum plans, so as to ensure that the plan adopted is relatively stable to possible price changes. * Variable price programming, which gives all the optimum plans for variations within a specified range of the prices of either one or two commodities, represents a rather similar approach. An objection to the stability tests is that the effects of changes in the gross margin of one activity is measured only on the assumption that the gross margins of the other activities will remain unchanged. To some extent the use of selling activities each covering a broad range of products such as all types of beef cattle or all types of corn, offers a means of widening the scope of the tests. The use of several alternative sets of gross margins, as illustrated in recent example, offers another way of locating stable plans. **

Relative gross margins per acre are the dominating factors in shaping the optimum plans on each of the five farms but the fact that certain labour restrictions are also effective implies that the definition of these restrictions will have had some influence on the form of the optimum plans. The correctness or otherwise of such definitions therefore requires careful consideration.

Total hours of labour available over the year were an effective restriction in four out of the five examples, but the need for a restriction on these can be queried on the grounds that if the seasonal restrictions are met there is no need for the double check. It will be recalled however that the total labour available was assessed as only 75 per cent of that actually contributed by the regular staff thus allowing 25 per cent for unallocated work, mainly coming under the heading of maintenance. This is a high percentage compared with the commonly used figure of 13 per cent (equivalent to 15 per cent of the assessed requirements), which is supported by the results of at least one investigation. ***

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* The question of stability is fully treated by Renborg. op.cit.

** Fletcher, A. Hales A.W. and Simpson I.G. "Linear Programming and Uncertain Prices in Horticulture" Jour: of Agricultural Economics XV.4.

*** Mathieson M.C. "The Use of Labour in Yorkshire Farming" University of Leeds, Farmers' Report No.130 (1956).

However, checks made on the five example farms showed that the current requirements of crops and stock as assessed accounted for an average of only 74 per cent of the estimated available labour hours with the figures for four out of the five falling between 71 and 80 per cent. It is not possible to generalise from this small sample, but it could be that with faster working implements the total time actually spent on productive work is less than formerly. An investigation in 1960/61, in South West England showed that on average 20 per cent of the total labour input was used on maintenance work but this was on predominantly livestock farms. ¤ Fresh investigations to determine the current position on arable farms would be valuable.

The requirement that a fairly high proportion of the total available labour should be unallocated serves as a hedge against plans which would overtax the available staff, particularly in difficult seasons. It is debatable whether it would in fact have been better to have relied solely on the seasonal restrictions, in the anticipation that sufficient labour would in any case be left slack, to make the plans workable. A plan computed for farm C without a total labour restriction raised the total gross margin by £450. The labour force was reduced from 7.5 to 5.8 men but only 3 per cent of the total labour was unallocated. The only significant change in the pattern of cropping and stocking was a fall of 15 per cent in the area of sugar beet. The relatively small gain in income would seem insufficient to balance the greater risks attendant on the very full employment of labour. Plans for farm D calculated without a total labour restriction, also resulted in a very full labour utilisation with only 5.5 per cent unallocated while gains in the gross margins were relatively modest - £624 where a dairy herd was included and £356 without one. However, the form of the plans was affected to a greater extent than on farm C, with a substantial shift from corn to leys and either the addition of more bullocks or the introduction of sheep to use the extra grass.

The tight restrictions on total labour available used in these examples have resulted in few of the seasonal restrictions on labour being fully taken up. This will not always be the case, indeed the importance of total labour restrictions here is in part a reflection of the type of farming studied - arable with cash roots - which makes substantial demands on labour at all seasons. Where there is less diversification, seasonal restrictions would have a greater importance, as they would also have where shortage of labour made it necessary to operate with a staff of less than optimum size.

¤ Davies E.T. "A Study of Labour Utilisation on a Sample of Farms in South West England 1960/61". University of Exeter. Report No.143 (1963).

Definition of these seasonal restrictions poses considerable problems. Subdivision has, in the past, often been made on the basis of calendar months but this is not very realistic. In this study flexible periods of varying lengths are used, but their determination has been entirely empirical following discussion with the farmers. A more exact approach would seem desirable.

There are really two problems involved. The first is to define the period during which a particular operation may be performed and the second is to determine the number of days within that period when weather conditions are likely to be such as to permit the operation to be undertaken. Defining the periods when certain operations can be performed may mean introducing rigidity where in fact none exists. For example, the ideal period for planting maincrop potatoes is probably the first fortnight in April and later plantings are likely to result in lower yields. Potato planting might be restricted to the first fortnight in the planning calculations but to do so would be to ignore both the possibility that the lower yielding later planted crop could still be profitable to grow, and the likelihood that weather conditions in some seasons will prevent potatoes being planted at the optimum time. The alternative of allowing a fairly wide spread in the possible dates for potato planting therefore seems preferable, but the use of long period labour restrictions can lead to solutions which are incapable of fulfilment unless additional checks are provided. If for instance, it was estimated that conditions were suitable for planting potatoes on only 10 days in April, the use of 26 working day restriction covering the whole month could easily give rise to an infeasible solution, unless some other restriction such as the potato quota, effectively limited potato planting to 10 days or less. Even then the situation would not be fully covered since a solution could still be obtained in which all the available labour was allocated to potato planting on the 10 suitable days leaving the requirements of the other crops and the livestock to be met on the remaining 16 working days. As livestock need daily attention and the other crops may clash with potatoes this would not be workable. Derivation of realistic plans may thus require the use of a fairly complex set of overlapping labour restrictiotions. The fact that labour availability is likely to be critical at only certain times of the year should limit the number of such restrictions which have to be entered into the matrix. Once certain restrictions have been found to be effective limitations on the plans, it may be necessary to re-examine them and possibly re-programme, after allowing for some relaxation of the initial premises.

Meteorological records could be used to estimate the number of days within any period when conditions are likely to be suitable for carrying out particular field operations, and a report from Ohio provides an example of this procedure. ¤ The variation

¤ "The Effect of the Weather on the Days Available to do Selected Operations - Central Ohio 1938-1957". Mimeo.Bulletin A.E.313. Dept.of Agricultural Economics and Rural Sociology. The Ohio State University.

in both soil types and local climate would however seem to limit its use in British conditions. A more practical but less refined approach would be to derive the days or hours available from the capacities of key implements and their working rates. This was in fact done in determining the available hours for corn harvesting on Farms C and D. The capacity of a particular machine might be determined either by observation of the performances achieved within a group of farms or perhaps by simply asking the farmer how much extra acreage he could handle with his existing machines.

With linear programming it is, at least in theory, possible to find the most economical methods of feeding livestock, having regard to the alternative production possibilities on the farm. The computation by linear programming of least-cost concentrate rations for pigs and poultry lies rather outside the main area of planning. Cattle and sheep however normally make use of farm produced forage crops and the choice of these, together with the extent to which they should be balanced by concentrates, will obviously affect the cropping plan, as also will the numbers of stock kept. Logical decisions on these points can only be made after a cost has been placed on the various forages. This cost should be the opportunity cost - that is, the cost which the farmer incurs by feeding these crops rather than by following an alternative course of action. The more bulky fodders are not normally grown for sale and may, as in the case of silage, be in such a form as to make sale difficult. The appropriate opportunity cost is not therefore their sale value as it is with home produced grain, but rather the loss incurred by growing these crops rather than alternatives for direct sale. The linear programming process automatically balances these opportunity costs against the revenue obtained through the use of extra forage to extend the scale of the livestock activities and in the optimum solution the marginal revenue from the livestock is equated with the opportunity cost of producing extra forage crops. We thus select the combination of forage crops which leads to maximum profits, not from the livestock enterprises by themselves, but from the farm as a whole. The ability of linear programming to correctly price forage crops in the context of alternative resource uses is of great potential value.

There are however difficult problems to overcome before this potential can be fully realised. Some of these have been discussed in connection with the derivation of the data for the silage activities introduced as possible substitutes for roots on farm A. Reference was made to the lack of data on the relative yields of fodder crops and their respective feeding values and to the uncertainty over substitution rates. The premises on which the co-efficients were based in this instance might be regarded as being in fact so shaky as to make the exercise of little practical value. One might argue with this were it not that to do so would be to leave untouched a large area of the farm economy. Decisions have to be made in this area and even with poor data, the use of a logical method would seem preferable to intuition and possible faulty reasoning.

There is a strong case for more effort being made at the farm level to obtain reliable estimates of fodder crop yields, either by sampling or the measurement of the stored produce. Without such estimates, preferably backed by analysis of the feeding value, the use of any system of feeding standards must be severely limited.

It is becoming increasingly clear that the rates of substitution between different feeds are a good deal more complex than the simple linear relationships implied by the starch equivalent system. Although improved feeding standard systems are likely to be evolved, the goal of precise prediction has not yet been achieved. It may be that, at this stage, it is safer to confine our attention to forage - forage substitutions where there is perhaps less danger in using the conventional standards rather than forage - concentrate substitutions.* From this angle the possibility of substituting corn for roots permitted on farm C is more open to criticism than the roots - silage substitutions.

Some criticism may be levelled at the arbitrary nature of the figures given in the plans for crop areas and livestock numbers. It may be said that the crop areas bear no relationship to field sizes, that the combinations suggested could not be worked into a rotation and that decimal parts of livestock are not practical possibilities. The last point is readily conceded! Adjustments to round numbers will however have little effect on the anticipated profits. Part cropping of some fields as well as certain adjustments to the specified acreages may be necessary, but this again should not greatly affect the results. The potato and sugar beet quotas tie these crops to the areas currently grown which presumably bear some relation to field size. These quotas, together with the restrictions on wheat and oats, ensure that the proposed crop combination can be worked into satisfactory crop rotations, although in some instances these will have rather a large number of courses including several successive courses of corn (see examples in Appendix 1). The small areas of grazing leys on farms A and B, 9 and 15 areas respectively, might be difficult to handle in the general rotation, and it would perhaps have been better for this reason to have ignored the ley breaks when calculating the maximum area of wheat permissible.

* K.L.Blaxter writes " for usual rations existing feeding systems give very reasonable results. Discrepancies arise, however, as soon as gross departures are made from existing practices"
The Energy Metabolism of Ruminants, Chapter 18.

6. THE PRACTICAL VALUE OF THE PLANS

Planning the individual farm must lose much of its purpose if the resulting plans are not taken up by the farmer and it may justifiably be asked whether the five farmers whose farms have been used as examples, are following the optimum plans computed for them. In fact none are doing so, or are likely to do so, to the extent of trying either to grow the exact crop areas suggested or to keep the recommended numbers of stock. The plans are however likely to have some influence on future policy on most of the farms. It should be remembered that the need for an improved organisation was not used as a basis for the selection of the farms and that financial results on four of them were such as to make the need for any change far from imperative. Nevertheless it is doubtful whether this fully explains why the plans are not now being exploited.

The opportunity was taken to visit all five farmers after they had been sent copies of the computor derived plans and it is partly in the light of the ensuing discussions that these further reasons are advanced. Firstly it is undoubtedly difficult for a person such as the writer, who has a not very intimate knowledge of the districts where the farms are located, to be convincing on some of the technical aspects of the plans. A local adviser should of course be able to handle these more effectively. A second reason why the plans have not been fully accepted probably follows from the necessity of carrying out the processing of the data and the actual computation away from the farm. This means that the farmer has no part in the planning process after the initial discussions, so that he has to accept that the data has been correctly processed and the right answer given by the computor. By budgeting out the optimum plans, it may be possible to give them a greater validity in the farmer's eyes, but he must still put considerable trust in both the human programmer and in the "black box" represented by the computor and this must inevitably be something of a barrier. A third reason which also relates to the lack of direct participation by the farmer, is the difficulty of assessing correctly the restrictions within which a farmer chooses to operate. Even with the most careful questioning, wrong judgements can still be made concerning such questions as the balance a farmer wishes to keep between crops and livestock, or what new activities he would be prepared to adopt. The restrictions, or perhaps qualifications is a better word here which a farmer has concerning his future plans are not normally positively expressed in the rigid terms required for mathematical computation. Indeed he may only become aware of them when certain plans are presented to him. This is perhaps particularly true when there is a choice between several courses, each of which involves varying degrees of uncertainty.

The first point raised above, that of convincing the farmer of the technical aspects of the plans can probably be dealt with through close co-operation between programmers and local advisers or, even better, the training of the advisers in programming techniques. The second and third points relating to the lack of farmer participation may however prove insurmountable barriers to the widespread use of linear programming as a farm planning tool of general application. If this is so, we must look to alternative methods which, while still embodying a systematic approach, can be used by farmers either alone or working closely with advisers.

Inevitably attention turns to the systematic farm planning techniques such as programme planning and gross margin analysis developed in recent years. ¤ In the development of these techniques the aim has been to move away from the mathematical complexities and rigidities of linear programming whilst still retaining the concept of the maximisation of gross margins within the bounds set by the farm resources. The basis of activity selection is primarily the comparison of gross margins per unit of the limiting restrictions with particular emphasis usually given to that of the relative gross margins per acre. In some cases after a primary selection on this basis, the budgeting of alternative plans may be resorted to, using the unit gross margins merely as a convenient means of evaluation. In other cases systematic selection on the basis of relative gross margins is carried further, and the relative returns to other limiting restrictions considered. As regards maximising aggregate gross margins absolutely, this is obviously desirable, but the additional complexity must be weighed against it.

In the linear programming examples described here about 30 restrictions were included in the initial matrices but by no means all were fully taken up in the optimum plans and the majority of those which were related only to specific activities - the restrictions on stock numbers and certain crops fall into this class. The number of general restrictions which were effective on all or many of the productive activities was small, including only the area of arable land, area of grass (effective only on cattle and sheep) and not more than two labour restrictions, although a larger number could be expected if labour was in very short supply. This small number of effective general restrictions simplifies the planning problem since the specific restrictions are easily handled.

¤ See McFarquahar A.M.M. "Research in Farm Planning Methods in Northern Europe" Journal of Agricultural Economics XV.1. May 1962. for a valuable summary of these.

An account of the Gross Margin Analysis system is given in:-

Wallace.D.B. and Burr.H."Planning on the Farm" University of Cambridge, Farm Economics Branch, Report No.60. 1963.

Nevertheless difficulties are likely to arise when attempts are made to select rigorously on the basis of gross margins per unit of the restrictions. It is, for instance, difficult to cope with more than two general restrictions. The co-ordination of activities such as has been attempted in the linear programming examples by linking the area of potatoes to the amount of F.Y.M. produced by the stock activities or tying wheat to the area of break crops, greatly multiplies the amount of calculation. Areas of uncroppable permanent grass complicate the straightforward comparison of gross margins per acre for cattle and sheep as it becomes necessary to consider both the gross margins per acre of the basic area of permanent grass and those per acre of arable, assuming that some arable is needed for fodder crops. There will further be a difference in the gross margins per arable acre according to whether permanent or temporary grass is grazed. The need to work in terms of a common unit, normally acres, may involve considerable preliminary calculation in preparing the data for the livestock activities, which have to be aggregated to include both the direct requirements of the stock and also those for the fodder crops. It is not possible to treat the latter as independent activities, as can be done with linear programming, to give the optimum livestock-fodder combinations within the general framework of planning.

These difficulties may hinder farmer participation in the planning process as effectively as the more refined mathematics of linear programming. It may therefore be necessary to rely on the simpler approach of using gross margins to budget alternative plans rather than full-scale programme planning. Nevertheless in drawing up these plans use can be made of programme planning principles with the emphasis initially on selection according to relative gross margins per acre, but turning to comparisons of the gross margins per unit of other restrictions particularly those for seasonal labour as these become bottlenecks. ¤ Even on this basis the calculations needed can still be considerable, particularly for deriving the activity data and back checking on the feasibility of the plans. This however will be reduced if there is foreknowledge of the restrictions which are likely to be effective. The careful definition of the seasonal labour restrictions recommended [illegible] needs to be followed to ensure that the plans really are feasible.

¤ Even where labour or other factors are likely to be more restricting than the supply of land, it is probably desirable to start with a comparison of gross margins per acre as this is an easily understood concept. Even if labour is the scarcest factor, the effective seasonal restrictions will not necessarily be known in advance.

The budgeted plans may fall considerably short of the linear programming optimums but this could be balanced by their greater realism and ensuing chance of acceptance. * The many uncertainties make the differences between the true optimum plans and those budgeted perhaps of less importance than would otherwise be the case.

This emphasis on a relatively unrefined approach to the general problem of planning on the farm should not be taken as meaning that linear programming is of little use in this context. The use of linear programming to study in detail the management problems on farms in different localities should be of considerable assistance when using more approximate methods and the concept of management objectives recently advanced by C.S.Barnard deserves following up. ** The subsidiary information derived through linear programming on marginal returns and the ranges in unit gross margins for which the plans remain stable may be as useful as the optimum solutions themselves. It is important however to be clear as to broad criteria which have led to the derivation of a particular plan.

The description of the applications of linear programming given here should simplify planning on other similar farms. Among the particular points which have emerged are:-

i) The high marginal returns per arable acre and the over-riding importance of gross margins per arable acre as criteria.

ii) The key positions of the corn and potato crops.

iii) The high penalties which may be incurred by insisting on the use of F.Y.M. for potatoes.

iv) The uncompetitive position of sheep even when efficiently managed.

v) The frequent scope for economy in the numbers of men employed.

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* It is difficult in most cases to make an exact comparison of the results obtained by using linear programming and those obtained by other methods on account of the contrast between the rigid treatment of restrictions required by linear programming and the more flexible approach of the other methods. Even comparison of plans derived independently by two persons would not be entirely satisfactory as they may put different interpretations on the restrictions pertaining to the particular farm.

** Barnard C.S. Farm Models, Management Objectives and the Bounded Planning Environment.

Journal of Agricultural Economics XV.4.

In spite of the points made here concerning the difficulty of securing farmer participation in the process of planning there will be circumstances where linear programming is in fact the best technique for planning the individual farm. Such circumstances are likely to occur where the production opportunities are particularly wide or where, as in a large-scale enterprise, the need for delegation enhances the attraction of rigidly defined plans.

.....

S U M M A R Y

1) Identification of the system of farming which will be the most profitable on a particular farm having regard both to the resources available and to the bounds imposed by the farmer's own attitudes, is not easy. The use of some form of systematic approach to the problem seems desirable. In this report, a description of the use of one such approach, linear programming, is given with reference to five arable farms. The aim was to construct plans which while maximising profits would be practical and acceptable to the farmers concerned. The methods used in each application are described in detail.

2) Attention has been mainly confined to seeking new combinations of the activities already operated on the farms but in some instances, the choice was widened by permitting the use of alternative production methods including substitution of livestock feeds.

3) The optimum plans in every case indicate a substantial increase in gross margin levels and consequently in profits as compared with the existing systems. All show a substantial increase in the area of corn coupled with a decrease in that under grass. Cash roots especially potatoes are usually maintained at their full quota levels. The inclusion of beef cattle tends to be linked with the F.Y.M. requirements of the potatoes. Pigs and poultry are at their maximum levels but the plans normally exclude sheep. In several instances, a reduction in the regular staff is envisaged. Relative gross margins per arable acre appear to have been of over-riding importance in determining the shape of the optimum plans.

4) In the discussion on these applications, reference is made to the problems involved in handling activities which are new to the farm and also to the effects of price fluctuations and technical developments. Attention is given to the problems involved in defining labour restrictions and use of the capacity of key implements as a guide in this context is suggested. The potential value of linear programming as providing a means of correctly evaluating forage crops in terms of their opportunity costs is stressed, but difficulties in assessing yields as well as those in assessing relative feeding values are likely to limit the use that can be made of this potential.

5) The optimum plans have for a variety of reasons, not been implemented as such. Probably the major drawback to the use of linear programming on individual farms is the lack of participation by the farmer in the planning process. Without this participation it is difficult to identify the qualifications which limit the number of acceptable plans. For this reason, it may well be necessary to rely on relatively simple planning methods which, while using relative gross margins per unit of scarce resources in the selection of activities, do not attach over-riding importance to absolute profit maximisation. Nevertheless, linear programming is a valuable tool which can do much that the simpler methods cannot and its continued use on farms of varying types should be of considerable help to the users of the latter methods.

APPENDIX.1. Possible Rotations to Fit Cropping in the Optimum Plans

FARM.A.

← 15 acres barley		4 acres ley
1 year ley		ley
sugar beet and fodder roots		ley
potatoes		potatoes
wheat		wheat
wheat		barley
barley		
barley		
barley		
barley		

FARM.B. (Plan 1)

← 16½ acres sugar and fodder beet		← 5½ acres oats
oats		oats
potatoes		seeds
wheat		
wheat		
barley		
barley		

FARM.C. The cropping in the optimum plan for farm C can be based on alternating barley with root crops or 1 year leys.

FARM.D. (Plan 1)

11 acres	ley	20 acres	peas
	ley		potatoes
	potatoes		wheat
	wheat		wheat
	barley		barley
	barley		barley

Plus 35 acres for cow block including leys, and kale and cabbage. On the 20 acre block peas and potatoes might be transposed to ease the drilling of the first wheat crop.

FARM.E. (Original optimum)

35 acres	Oats	35 acres	Peas
	Potatoes		Potatoes(15)Oats(20)
	Wheat		Wheat
	Wheat		Barley
	Barley		Barley
	Barley(25)Oats(10)		Barley

APPENDIX.2. Lists of Activities and Restrictions Used in the Planning Examples

FARM.A.

Restrictions

Available Labour Hours
- March 8-31
- April 1-15
- May 21-June 5
- June 15-June 30
- Aug.20-Sept.30
- May 1-Sept.30
- Oct.1-Nov.30
- Oct.1 - Mch.31
- Total

Maximum Overtime:
- March 8-31
- Apl 1 - 15
- May 21-June 5
- June 15-June 30
- Aug.20-Sept.30

Maximum Arable
- " Potatoes
- " Sugar Beet
- " Wheat
- " Oats
- " Pigs
- " Poultry

Available F.Y.M.
- " Swedes
- " Mangolds
- " Grass
- " Aftermath Grazing
- " Corn for Sale
- " Area for 1st Corn Crops

Activities

- Winter Wheat
- Barley
- Oats
- 2nd Crop Cereals
- Potatoes (maincrop)
- Sugar Beet(hand pulled)
- " " (contract lifted)
- Cattle(existing system)
- Sheep (" ")
- Sheep(summer fat lambs)
- Pigs
- Poultry
- Swedes
- Mangolds
- Silage for Swedes
- Silage for Mangolds
- 3 Year Ley
- Convert Grass to Aftermath
- Corn Sell
- Overtime: March 8 - 31
  Apl. 1 - 15
  May 21-June 5
  June 15-June 30
  Aug.20-Sept.30

FARM.B.

Restrictions		Activities
Available Labour Hours:		
	March 8 - 31	Winter Wheat
	April 1-15	Barley
	May 1-15	Barley for Seed
	May 16-31	Oats
	June 1-15	Sugar Beet(hoe by own men)
	July 16-Aug.7	" " (hoe by casuals)
	Aug.8-Sept.20	Early Potatoes
	Oct.1-Nov.30	Maincrop Potatoes
	Dec.1-Dec.31	Fodder Beet(hoe by own men)
	Dec.1-Mch 7	" " (hoe by casuals)
	Total	Swedes(hoe & lift by own men)
Maximum Overtime:		
	March 8-31	Swedes(hoe by own men,lift by casuals)
	April 1-15	Swedes(hoe by casuals, lift by own men)
	May 1-15	Swedes(hoe & lift by casuals)
	May 16-31	Lucerne Silage
	June 1-15	Arable Silage
	July 16-Aug.7	Aftermath Silage
	Aug.8 - Sept.20	3 Year Ley
Maximum Arable		Convert Swedes to Fodder Beet
" Potatoes		Cattle(October purchased stores)
" Sugar Beet		" (December " ")
" Wheat		" (Spring " ")
" Oats		Sheep (summer fat lambs)
" Barley for Seed		Pigs
" Wintered Cattle		Corn Sell
" Dec.Purchased Bullocks		Potato Sell
Available F.Y.M.		Overtime: March 8 - 31
" Swedes		April 1 - 15
" Fodder Beet		May 1 - 15
" Grass		May 16 - 31
" Aftermath		June 1 - 15
" Corn for Sale		July 16-Aug.7
" Potatoes for Sale		Aug.8- Sept.20

FARM.C.

Restrictions	Activities
Available Labour Hours:	Barley
March 21 - 31	1st Early Potatoes
April 1 - 21	2nd " "
March 21 - April 21	Maincrop "
May 8 - 31	Sugar Beet
June 1 - 30	Carrots
July 16 - Aug.7	Swedes
Aug.8 - Sept.30	Mangolds
Harvest Period	
May 8 - Sept.30	
Oct. 1 - 31	
Nov.1 - Dec.31	
Nov.1 - Mch 31.	
Total	
Maximum Overtime:	
March 21 - 31	Silage for Swedes
April 1 - 21	Silage for Mangolds
May 8 - 31	Grain for Swedes
June 1 - 30	Grain for Mangolds
July 16 - Aug.7	
Harvest Period	
Maximum Arable	3 Year Ley
Potatoes	Beet Tops to replace Swedes
Sugar Beet	Convert Grass to Aftermath
Carrots	2nd crop cereals
Cattle Wintered	Cattle(existing system)
Pigs	" (winter fattening only)
Available F.Y.M.	Fatten Lambs on Beet Tops
Grass	Ewe Flock
Aftermath Grazing	Pigs
Sugar Beet Tops	Regular Labour
Swedes	Overtime: March 21-31
Mangolds	April 1-21
Area for Kale	May 8-31
Area for 1st Corn Crops	June 1-30
Potatoes for Sale	July 16-Aug.7
	Harvest Period

FARM.D.

Restrictions	Activities
Labour Hours Available:	Winter Wheat
March 7-31	Barley
March 24-April 14	Oats
March 7-April 14	Potatoes(Maincrop with FYM)
May 21-June 6	" (maincrop without FYM)
Aug.20 - Sept.30	Peas
Harvest Period	1 Year Ley
Oct.1 - Nov.10	2 Year Ley
Total	
Maximum Overtime:	
March 7 -31	3 Year Ley
March 24-April 14	Extend Permanent Grass
May 21-June 6	Dairy Herd
Aug.20-Sept.20	Rear & Fatten Bullocks
Oct.1 - Nov.10	Ewe Flock (existing system)
Maximum Arable	" " (purchased mangolds)
" Potatoes	Pigs
" Wheat	Poultry
" Peas	Potato Sell
" Cereals	Regular Labour
" Pigs	Overtime: March 7-31
" Poultry	March 24-April 14
" Cows	May 21-June 6
" Total Cattle	Aug.20 - Sept.20
	Oct.1 - Nov.10.
Available F.Y.M.	
" Grass	
" Corn for Undersowing	
" 1st Year Ley for Sheep	
" Potatoes for Sale	

FARM.E. (1st Application)

Restrictions		Activities	
Labour Hours Available:			
	March 7 - 31	Winter Wheat	
	March 24-April 14	Barley	
	March 7 - April 14	Oats	
	May 2 - June 5	Peas	
	June 6 - Aug.1	Potatoes(maincrop with FYM)	
	Aug.20 - Sept.30	" (maincrop without FYM)	
	Oct.1 - 31	Sugar Beet	
	Nov.1 - Dec.31	Ewe Flock (on Swedes)	
	Total	Ewe Flock (on beet tops)	
		Fatten Lambs on Roots	
Maximum Overtime:			
	March 7 - 31	Breed Pigs	
	March 24-April 14	Fatten Pigs	
	May 2 - June 5	Cattle(existing system)	
	June 6 - Aug.1	(heifer rearing)	
	Aug.20 - Sept.30	(winter fattening only)	
Maximum	Arable	1 Year Ley	
"	Wheat	2 Year Ley	
"	Oats	3 Year Ley	
"	Potatoes	Beet Tops to replace Swedes	
"	Peas	Let Grass for Summer Grazing	
"	Sugar Beet	Sell Straw in Field	
"	Corn	" " " Bales	
"	Pigs Fattened	Hire Combine	
"	Sows		
"	Cattle + Sows		
Available	F.Y.M.	Regular Labour	
"	Grass	Overtime:	March 7 -31
"	Corn for Undersowing		March 24-April 14
"	Straw		May 2-June 5
"	Combine Capacity		June 6 - Aug.1
"	Sugar Beet Tops		Aug.20 - Sept.30.
	Potential for Use		
"	of Beet Tops		
"	Corn for Undersowing		
"	1st Year Ley for		
"	Sheep		