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A POSSIBLE USE OF COMPUTERS IN ANIMAL PRODUCTION

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SUMMARY

A computer can be programmed in such a way as to make tentative feasibility studies on the economics of beef production.

The model considered is that animals of 300 lb liveweight are put into feed yards and over a period of 360 days fed either freshly cut grass, silage from previously cut grass or concentrate feed brought in from outside the farm.

Given feed requirements, costs of such operations as grass-cutting silage making etc., the computer is then programmed to calculate the method of feeding which will give maximum profit per acre.

The calculations are made over a range of values for such variables as average liveweight increase per day, appetite restriction, feed requirements, etc.

One of the most interesting conclusions is that the maximum profit per acre is largely independent of the rate of growth over a range of 2.0 to 2.6 lb L.W.I./day.

THE PURPOSE of this paper is to show how a computer can assist in certain types of problems in animal production. The particular problem discussed is that of making preliminary feasibility studies of rearing beef cattle in New Zealand in feed-lots.

It is assumed that it is possible to take animals of 300 lb liveweight into the feed-lots and raise them to a finished liveweight of about 1,000 to 1,200 lb liveweight (lb L.W.) in 12 months or less and then dispose of them for slaughter.

THE PROBLEM

In making a theoretical investigation of this type, one has to envisage various practical ways in which to undertake the operation. In this particular investigation, the method chosen of achieving the result was as follows:

(1) A fixed number of animals are kept in a feed-lot.

(2) Associated with the feed-lot is an area of pasture (the size of which has to be later calculated) which is used to provide feed for the animals.

(3) The feeding process to raise the animals from 300 lb L.W. to the required finish weight must not last longer than 12 months.

(4) Three types of feed and these only are available at any one time:

  (a) Freshly cut grass is fed directly to the animals.

  (b) Silage (or some other form of stored grass) can be fed. This silage must have been made from grass cut at some earlier time.

  (c) Concentrate feed brought into the farm from some external source of supply.

The concentrate is the only feed allowed to be brought into the farm from outside. All grass and silage had to be home grown.

At any one time any combination of the three feeds could be fed.

The problem now resolves into the following steps:

(1) To find some reasonable estimates of costs, such as the cost of cutting grass, or making silage.

(2) To obtain estimates of seasonal pasture production and its feed values. In this study, feed values have been expressed in terms of starch equivalents (S.E.) as a percentage of the dry matter of the relevant feed.

(3) To assemble data on the feed requirements necessary to enable an animal to have a given liveweight increase per day (L.W.I./day) at various body weights (over the range of body weights of, say, 250–1,250 lb L.W.).

(4) To make an estimate of the capital cost (land and equipment) of such a project.

(5) To estimate the initial cost of the animals and their final selling price.

(6) When the above information has been obtained, to calculate the most profitable way of achieving the target. A moment's reflection will show that costs of achieving the target could vary greatly.

If the feeding process started in the spring, 40 acres of land could support, say, 200 animals during the spring and allow them to grow at a rate of 2.5 lb L.W.I./day, leaving no grass to be made into silage. In the winter, however, the greatly reduced pasture production would then have to be considerably supplemented by costly concentrate. This cost of concentrate could well be offset by starting with fewer animals in the spring and using silage made in the spring to feed in winter rather than the much more expensive concentrates.

THE COST ESTIMATES OF LABOUR, FEED AND CAPITAL

The cost estimates were derived from a variety of sources. Most of them were obtained from the Department of Agriculture. In this study, the tendency has been, as a general rule, to be conservative—*i.e.*, to make the costs a little too high.

(1) The cost of cutting grass was taken as 12s. per ton (all tons are long tons, 2,240 lb) of green weight of grass.

(2) The cost of making silage, £1 per ton of green weight of grass fed into the silo. The costs were based on vacuum-packed silage. A loss of dry matter of 20% in the silage making was assumed. This loss was deliberately made a little high.
Note: The above costs do not include the costs of feeding the grass or silage to the animals in the feed-lots. These are included in a later figure.

(3) The capital costs (land and equipment) are taken as £250 per acre. These have been amortized over ten years. Thus, the annual capital charge per acre has been taken as £25. This figure is, quite frankly, barely more than an inspired "guesstimate".

(4) It is necessary at a later stage to make some estimate of the cost of labour, veterinary services, losses due to wastage, electricity, etc. Unfortunately, there are no local data whatever to make any reliable estimate at all of these costs. Data from the United Kingdom and U.S.A. would suggest that these would be somewhere between £4 and £6 per year for each animal in the feed-lot.

(5) By averaging the price of various locally available concentrate feeds, the cost of concentrates was taken as 3d. per lb or £28 per long ton.

PASTURE PRODUCTION

The Department of Agriculture kindly made available the results of mowing and grazing measurements of pasture production made at a few selected experimental areas. The figures used in this report are the results (averaged over several years) from experimental areas at Marton and Dargaville. The data are set out in Table 1.

TABLE 1: AVERAGE PASTURE PRODUCTION (PER ACRE) AT MARTON AND DARGAVILLE EXPERIMENTAL AREAS

Marton

Season	Green Wt (lb)	% D.M.	Total D.M.	S.E.* as % D.M.
Spring	 24,300	16	3,887	75
Summer	 4,290	60	2,573	50
Autumn	 10,050	20	2,010	70
Winter	 3,134	29	1,097	60
Total:	41,774		9,567	

Dargaville

Season	Green Wt (lb)	% D.M.	Total D.M.	S.E.* as % D.M.
Spring	 29,370	16	4,700	75
Summer	 10,710	60	5,353	50
Autumn	 19,300	20	3,859	70
Winter	 6,780	35	2,372	60
Total:	66,160		16,284	

*Starch equivalent values from Coop (1949).

FEED REQUIREMENTS

Because of lack of local data, feed requirements for beef rearing in feed yards in Great Britain have been used (Boden, 1959). Feed requirements have been expressed in terms of pounds of starch equivalents required for maintenance and liveweight increases per day. An abridged version of these feed requirements is set out in Table 2.

TABLE 2: SOME VALUES FOR FEED REQUIREMENTS FOR DIFFERENT RATES OF GROWTH, USED IN BEEF PRODUCTION PROGRAMMES

Liveweight (lb)	Starch Equivalents (lb) required for: Maintenance	M. + 1 lb L.W.I./day	M. + 2 lb L.W.I./day
200	2.8 (2.78)	3.7 (3.89)	4.9 (5.05)
400	4.0 (3.92)	5.5 (5.26)	6.7 (6.78)
600	4.9 (4.84)	6.5 (6.53)	8.4 (8.39)
800	5.6 (5.55)	7.5 (7.59)	9.8 (9.81)
1,000	6.0 (6.05)	8.4 (8.43)	11.2 (10.99)

In order to insert these values in the computer, it was necessary to find a mathematical formula to describe them. This was done by least squares. If $100x$ represents the liveweight of the animal and y the L.W.I. (lb.)/day, then these starch equivalent requirements may be represented by the equation:

$$\text{S.E.} = 1.422 + 0.731x - 0.0268x^2 + 0.557y + 0.090y^2 + 0.173xy.$$

The numbers in parentheses in Table 2 give the starch equivalent requirements as calculated from the above equation. It will be seen that the fit is adequate over the range of values used in the examples to be discussed.

Two important points regarding feed requirements must be stressed.

The first is that there is an upper limit to the daily rate of growth that an animal, or a group of animals, can be expected to achieve and maintain over a period of several months. This limit, for a group, is most unlikely to exceed 3.0 lb L.W.I./day.

The second point is that of appetite restriction. In this paper, the three different types of feed, fresh grass, silage and concentrate, have been given the same appetite restriction, in terms of daily intake of dry matter as a percentage of the liveweight of the animal. Values of 2.3%, 2.5% and 2.7% have been taken in different examples.

METHOD OF SOLUTION

Two major programmes were written for the computer.

In the first programme (P1) the initial liveweight of the animal was given and also the average daily rate of growth in each season. This means that the final liveweight of the animal was fixed in advance. The computer then has to work out, for each season, the daily amount of cut grass to be fed fresh to the animal, the amount of cut grass to be made into silage, the amount of silage to be fed, and the amount of concentrate. When it has done these calculations, it can then work out the total feed cost.

The second programme (P2) is more complicated and more general. In this programme the computer is given an upper limit of, say, 3.0 lb L.W.I./day, of daily growth rate and is required to work out not only the feeding regime (the amount of grass fed, etc.) in each season, but also the daily growth rate in each season and hence the final liveweight to be attained in order to give maximum profit per acre.

SOLUTIONS

Because P2 is more complicated, it was used to evaluate only a few possible cases. In this paper only three sets of results from using P2 are reported.

In each of these three examples, an appetite restriction of 2.5% has been assumed and the seasonal pasture production pattern at Marton has been used. All animals commenced at 300 lb L.W.

In the first two examples, daily growth rates have been restricted to a maximum of 2.5 lb L.W.I./day, and the selling price, as in all examples, taken as £4 per 100 lb L.W. The only difference between the first two examples is that in one the animals were put into the feed yards in the spring and, for the other, in the summer. These can be called the spring and summer solutions respectively.

In the third example, the conditions are the same as in the spring solution, except that the daily growth rates are not allowed to exceed 3.0 lb.

The results of these three examples are set out in Table 3.

In this table, the variable z denotes the initial cost of the animal at 300 lb L.W. plus the costs of labour, veterinary services, losses due to wastage, electricity, etc. It is thought that z would be about £20 per animal in most practical situations.

TABLE 3: RESULTS FROM USE OF GENERALIZED PROGRAMME (P2), FOR BEEF PRODUCTION

Appetite Restriction 2.5%

Growth rate	Spring L.W.I. max. (3.0 lb)	Spring L.W.I. max. (2.5 lb)	Summer L.W.I. max. (2.5 lb)
Spring	2.7	2.5	2.5
Summer	1.7	1.6	1.0
Autumn	3.0	2.5	2.5
Winter	3.0	2.5	2.0
Final Weight	1,232 lb	1,120 lb	1,020 lb
Animals/acre at 10,000 lb D.M./yr	1.37	1.52	1.73 (fed concentrate in summer)
Profit/acre	£$(54.5–1.37z)x$	£$(57.5–1.52z)x$	£$(56.6–1.73z)x$
Profit/acre ($z = 20$)	£27.1x	£27.1x	£22.0x

The variable x denotes the annual production of dry matter per acre, the unit of x being 10,000 lb dry matter per year.

The profit per acre is gross profit—*i.e.*, profit before capital charges and tax. At first sight it might appear strange that an annual capital charge of £25 per acre was programmed into the computer but that the results are expressed in profits before capital costs and tax. The reasons for this procedure are two-fold. First, in order to obtain sensible solutions, it is necessary to put some value on the price of land, otherwise the cost of growing grass (as distinct from cutting it) would be zero and thus it would never pay to feed concentrate in any circumstances. On the other hand, once any reasonable value is put on the price of land, the amount of concentrate to be fed is relatively independent of the exact land value used. The second reason is the difficulty, at this stage, of obtaining any reliable estimate of capital charges.

Two points emerge very clearly from Table 3. The first is that, under the conditions of the model, the profit per acre is virtually independent of the maximum permissible rate of growth over the range 2.5 to 3.0 lb L.W.I./day. The second point is that there is an appreciable drop in profit per acre if the feeding commences at the beginning of summer rather than at the beginning of spring.

FACTORIAL INVESTIGATION

In the three examples already discussed, specific data have had to be assumed for such variables as appetite restriction and feed values. While all reasonable care has been taken to see that these were the best obtainable, it must be admitted that not all of these data are known to any high degree of accuracy.

Hence it can be of considerable value to see what effect changes in these data have on the profit per acre.

To do this, runs were made on the computer in the form of a factorially designed experiment.

The following variables, and their values, were used in this factorial design:

A_2 Appetite restriction 2.7%.

A_1 Appetite restriction 2.3%.

S_1 N.A.A.S. feed requirements reduced by 15%.

S_2 N.A.A.S. feed requirements as published.

S_3 N.A.A.S. feed requirements increased by 15%.

L_1 Uniform L.W.I. 2 lb/day. Final weight 1,020 lb. Selling price £40.8.

L_2 Uniform L.W.I. 2.6 lb/day. Final weight 1,236 lb. Selling price £49.44.

D Seasonal pasture production pattern at Dargaville.

M Seasonal pasture production pattern at Marton.

Sp Feeding starts at the beginning of spring.

Su Feeding starts at the beginning of summer.

There are 48 combinations of variables in this design (essentially a factorial design of order $2^4 3$) and the results are set out in Table 4.

To illustrate the meaning of the results set out in this table, consider the entry in the bottom right-hand corner. This entry gives the feeding cost and area per animal in the case where feeding commenced at the beginning of summer, the pasture production pattern (10,000 lb D.M./acre) was of the Dargaville type, the uniform L.W.I./day

TABLE 4: EFFECT OF VARIATION IN FACTORS OF PRODUCTION (SEE TEXT) ON PROFIT FROM BEEF PRODUCTION

	L_1						L_2					
	A_1			A_2			A_1			A_2		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Sp.M												
Feeding cost/animal (£)	7.68	12.87	30.36	6.38	9.09	14.30	11.42	25.49	N.S.	7.97	13.46	27.05
Acres/animal	0.50	0.58	0.53	0.50	0.58	0.67	0.62	0.65	N.S.	0.62	0.73	0.77
Sp.D												
Feeding cost/animal (£)	7.08	12.16	29.12	5.78	8.37	13.47	10.67	24.40	N.S.	7.21	12.57	25.83
Acres/animal	0.53	0.62	0.55	0.53	0.62	0.72	0.66	0.68	N.S.	0.66	0.77	0.80
Su.M												
Feeding cost/animal (£)	10.12	15.05	24.82	7.53	11.95	16.40	14.12	21.74	N.S.	11.34	16.63	24.00
Acres/animal	0.50	0.58	0.54	0.50	0.59	0.68	0.63	0.67	N.S.	0.63	0.74	0.79
Su.D												
Feeding cost/animal (£)	9.59	14.21	24.03	7.00	11.33	15.64	13.45	20.76	N.S.	10.68	15.84	22.84
Acres/animal	0.54	0.62	0.59	0.54	0.63	0.73	0.67	0.73	N.S.	0.67	0.79	0.86

was 2.6 lb, the appetite restriction 2.7%, and the feed requirements were taken as 15% greater than those published by the N.A.A.S.

The entry, N.S., which occurs in all examples involving A_1, L_2 and S_3, simply means that in these cases it is impossible to find a solution which will satisfy each of the requirements of A_1, L_2 and S_3 simultaneously. Nutritionally, this simply means than an animal having the low appetite restriction of 2.3% and the 15% higher feed requirements just cannot consume enough dry matter per day to enable it to achieve and maintain a uniform growth rate of 2.6 lb/day throughout the 360 days.

Because solutions are not possible for the cases involving A_1, L_2 and S_3, it is not possible to analyse the results easily as in the conventional factorial design. Hence in the results that follow, all data involving S_3 have been omitted, thus changing the original design from a $2^4 3$ type of factorial design to the simplier 2^5 type.

The main effects and first order interactions are set out in Tables 5 and 6, respectively.

Higher order interactions have not been calculated as it is believed that they would be an unnecessary refinement and, also, that most of them would not permit of any very meaningful or practicable interpretation.

The main point of interest in the results is that the profit per acre is largely independent of the daily growth

TABLE 5: SUMMARY OF PROFITABILITY OF BEEF PRODUCTION

Main Effect	Gross Profit/Acre (£)	Gross Profit/Acre when $z = 20$ (£)
D	$52.51—1.585z$	20.80
M	$54.14—1.698z$	20.15
$M—D$	$1.63—0.113z$	—0.65
S_1	$62.33—1.749z$	27.35
S_2	$44.32—1.534z$	13.64
$S_1—S_2$	$18.01—0.215z$	13.71
L_1	$56.18—1.799z$	20.20
L_2	$50.47—1.484z$	20.79
$L_2—L_1$	$—5.71+0.315z$	0.59
A_1	$50.94—1.658z$	17.78
A_2	$55.70—1.626z$	23.18
$A_2—A_1$	$4.76+0.032z$	5.40
Sp	$54.94—1.659z$	21.76
Su	$51.71—1.624z$	19.23
$Sp—Su$	$3.23—0.035z$	2.53
Average overall results	$53.325—1.6416z$	20.493

TABLE 6: INTERACTION EFFECTS ON PROFITABILITY OF BEEF PRODUCTION

Interactions (*First Order*)	Gross Profit/Acre (£)	Gross Profit/Acre when $z = 20$
$(S_1—S_2)$ $(M—D)$	$2.83+0.009z$	3.01
$(S_1—S_2)$ $(Sp—Su)$	$—4.08+0.016z$	—3.76
$(A_2—A_1)$ $(M—D)$	$—1.28+0.006z$	—1.16
$(A_2—A_1)$ $(Sp—Su)$	$1.18+0.006z$	1.30
$(L_2—L_1)$ $(M—D)$	$—2.12+0.019z$	—1.74
$(L_2—L_1)$ $(Sp—Su)$	$—2.28+0.036z$	—1.96
$(M—D)$ $(Sp—Su)$	$—1.95—0.009z$	—2.13
$(S_1—S_2)$ $(L_2—L_1)$	$2.45—0.136z$	—0.27
$(S_1—S_2)$ $(A_2—A_1)$	$—0.4\ +0.064z$	0.88
$(A_2—A_1)$ $(L_2—L_1)$	$0.05+0.049z$	1.03

rate over the range 2.0 lb to 2.6 lb per day. This simply means that the greater selling price of the heavier animals is materially offset by their extra feeding costs and the need for more land to grow their extra feed requirements.

The small difference in profits between the two patterns of pasture production is understandable, as the total dry matter production is the same for each.

The biggest difference, and this is only to be expected, comes from the two different values of the feed requirements. The differences are proportionately much greater than the differences found in the case of the two appetite restrictions.

The differences in feed requirements can be interpreted in two ways. Provided the combination of feed requirements, appetite restriction, and uniform daily growth rate is such that a solution can be obtained, then the difference in feed requirements is really a difference in the total costs of feeding. Identical results will be obtained for the case where the actual amount of feed required for a certain growth rate has increased by, say, 15%, while the cost of the feed per pound weight has remained unchanged, or, conversely, in the case where the amount of feed required remains unaltered but its cost per pound has increased 15%.

Because of the size of these differences due to different feed requirements (or values), the main effects of S_1, S_2 and S_3 have been calculated over all the cases where the appetite restriction is 2.7%. The results are:

S_1: $= £64.08 - 1.808z = £27.92$ $(z = 20)$
S_2: $= £46.88 - 1.488z = £17.12$ $(z = 20)$
S_3: $= £33.00 - 1.334z = £6.32$ $(z = 20)$

The most significant feature of the interactions is that the largest ones generally arise when one considers the effect of seasons, either for patterns of pasture production or the times at which feeding commences.

GENERAL DISCUSSION

The results reported in this paper show quite clearly that it is possible to develop a programme for the feeding system and that the programme will lead to meaningful results. Certain points, however, must be stressed.

(1) A schematic model of the proposed feeding system must be prepared and this can be done, as a general rule, only by intimate collaboration between well-trained computer programmers and experts in animal husbandry.

The programmes used in this study are essentially ones of moderate complexity dealing with linear programming and require the services of a computer of reasonable storage capacity and speed.

(2) A very valuable by-product of this type of feasibility study is the way in which it highlights any inadequacies in data or methods of husbandry. For example, best estimates of appetite restriction and of feed requirements had to be made. There was very little firm information on these points for the case of beef production under New Zealand conditions.

(3) It is often argued that the results obtained from a computer are only as good as the data supplied to it. This is undoubtedly correct, but it must be remembered that decisions frequently have to be made on the basis of inadequate data and that the speed and power of modern computers make it possible to examine the possible outcomes of a proposed course of action when different possible values of a number of variables are taken into account. For example, this study shows quite clearly that, for the type of feeding system considered, there is no great extra profit to be made on a per acre basis by trying to reach as high a finished liveweight as possible at the end of twelve months. This finding is correct over a wide range of values of appetite restriction, feed requirements and the other variables.

Without a computer, the effort to find this conclusion would have been, if not prohibitive, then, at least, almost soul-destroying, because each run, which took only a few minutes on the computer, would have required something of the order of 20 hours on a desk-calculator. Offsetting this factor, of course, is the time required to develop the computer programme, a not inconsiderable amount of work, but not to be compared with the tribulations of most other possible procedures.

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