Study of an Intensive System of Hill Sheep Management and some Nutritional Implications.

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Thesis presented for the degree of Doctor of Philosophy in the Faculty of Science in the University of Edinburgh.

1970.

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PREFACE

On the basis of recent increased productivity the position of Hill Sheep farming in Britain relative to the rest of the Agricultural industry in general, is poor. While the rest of the Agricultural industry has continued to increase productivity by the use of improved techniques and a more efficient use of labour and machinery, hill sheep farming has remained almost static and has continued to be tied to a traditional system of farming which does not lend itself to the establishment of new methods without capital expenditure and radical changes in hill sheep husbandry methods.

In Scotland, out of a total of 16½ million acres, 10 million acres are taken up with hill and upland farming and can account for some 30% of the Agricultural output from Scotland. In Britain as a whole the contribution from the 'hills' has been estimated by Davidson (1956) to be 4% of the National Agricultural Product. Thus in Britain, and in particular, Scotland the farming of the hill areas is an important part of the Agricultural industry.

As a system of farming the management of hill sheep in Scotland has remained unchanged during the last 150 years with the notable exception of disease control. Productive hill sheep farming commenced with the arrival of the monks at Kelso and other Border monastries. It has been primarily based on two breeds of sheep, the Cheviot and the Blackface. While there have been periods when the Cheviot has been more popular than the Blackface, the position that now exists is that the Blackface tends to predominate in regions of higher altitude and poorer quality hill pastures while the Cheviot populates the lower lying grassy hill pastures.

The two breeds fit into a long established pattern of production stratification in which they play a major part in the supply of crossbred dams for crossing with Down rams to produce finished lambs from lowland and upland stock-rearing farms.

While some hill farms may specialise in the production of pedigree breeding stock, the majority are chiefly concerned with the production of store and finished lambs, wool and cast ewes. The number of finished lambs tends to be low, the majority being sold as stores.

Traditional hill sheep farming relies much on the efficiency of a shepherd. His ability and skill can have a considerable affect on output. In a system which relies on set stocking on a large acreage of pasture, of varying quality and on open hill country, the ability of the ewe to survive, produce, and rear a lamb, depends on how effectively the flock is driven on to productive grazing during the spring, and how well they are kept off certain hill pastures which are conserved for the less productive winter months. Of recent years labour has been increasingly difficult to obtain and the position is not likely to improve quickly, thus the very nature of traditional hill sheep farming may well need to change as labour availability dictates.

Ewe mortality can vary from 5-10% being greater in years of severe weather. Lamb mortality can be as high as 20 per cent, many lambs dying within a few hours of birth. Lambs reared per ewe varies considerably from 0.70 to 1.10. Low numbers of lambs reared make flock replacement difficult and can result in a lowering of the quality and type of stock and for breeding purposes.

in late pregnancy for optimal foetal nutrition is dependent upon the body condition of the ewe.

In an experiment in which the use of F.F.A. glucose and ketone levels were used as indices of undernourishment Russel, Doney and Reid (1967) found that F.F.A. and ketone levels of twin bearing ewes were slightly but consistently higher than those of the corresponding single bearing ewes and presumed that these differences reflected the greater glucose requirements of twin foetuses and because feed adjustments during pregnancy were made relative to prescribed levels of F.F.A. and ketone concentrations and not on the number of foetuses a ewe was thought to have, these adjustments were slightly and consistently less efficient in twin bearing ewes. Also biochemical measurement was taken at a time when differences between single and twin bearing foetuses were likely to be greater. In making comparisons of foetal development between the treatment groups (I. fed to constant intake but adequately nourished throughout the period of study, II. fed to produce a moderate degree of undernourishment during the last 6 weeks of pregnancy equivalent to F.F.A. level of 750 u equiv/l and III. fed to produce a relatively severe degree of undernourishment, characterised by plasma ketone levels of 8-10 mg %), however, it was nevertheless apparent that within the two undernourished groups the birthweight of twin lambs was reduced by the same extent as that of singles. In assessing the technique the workers conclude that a moderate degree of undernourishment, where little or no elevation of ketone levels is expected, may be controlled successfully by the use of F.F.A. levels, but where the object is a more than moderate degree of undernourishment ketone levels provide a useful criterian for feed adjustments.

For Blackface ewes on the hill it has been suggested, with qualifications, that undernourishment which occurs in hill ewes with single foetuses may be expected to reduce lamb birthweight by 10 per cent compared with that which may be expected from a ewe under conditions of optimum nutrient intake. The difference in twin birthweights was estimated to be 25 per cent.

In calculating the foetal requirement in terms of D.O.M. for the last 10 days of gestation (Russel, Doney and Reid (1967b)) use the foetal growth curve of Cloete (1939) in estimating growth rate. In applying this correction on the regressions of mean daily intake (days 6-15 prepartum) expressed as a g/DOM/kg foetus on birthweight, an estimate of the foetal energy requirement is given as 100 g DOM/kg foetus which is approximately equivalent to 400 kcal ME/kg foetus. Graham (1964) has shown the heat increment of pregnancy to be 90 kcal/kg/day. Thus, using this as an estimate of foetal maintenance requirement Russel et al (1967b) have concluded that there will be 310 kcal/ME/kg/day left for foetal growth.

In a recent paper Langlands and Sutherland (1968) derived a number of relationships between the composition of the gravid uterus less the composition of the uterus taken from non pregnant sheep, and time from conception. The rate of nutrient deposition was subsequently calculated and estimates were made of the nutrients utilised for pregnant Merino sheep. From their model of a pregnant ewe losing no maternal body tissue and producing a single foetus (4.4 kg) they have estimated a foetal requirement at term of 812 kcal ME or 184 kcal/kg which is approximately 50 per cent of the value calculated by Russel et al (1967b). In deriving their relationship of energy utilisation, however, they made the assumption that energy was stored in extra-uterine tissue with similar efficiences by both pregnant and non-pregnant sheep and there is no information by which this assumption may be justified.

Protein Requirement for Maintenance

The most direct way in which the maintenance requirement for protein can be determined is by performing a balance trial which may also be carried out during a basal metabolism study. The result of such a trial is frequently termed the apparent biological value of the protein, an expression which can be stated thus:-

$$Bv = \frac{\text{N intake - faecal N + urinary N}}{\text{N intake - factal N}}$$

It has long been recognised, however, that urinary nitrogen loss includes material resulting from the degradation and replacement of protein structures and of simple nitrogenous components of the tissues in irreversible reactions typified by the dehydration of creatine to creatinine (ARC 1965). One of the early attempts to measure endogenous urinary nitrogen was made by Smuts (1935) who obtained a value of 2 mg endogenous nitrogen /kcal basal metabolism for rats, guinea pigs and rabbits and pigs. Since then many more determinations have been made on both sheep and cattle and are listed by A.R.C. (1965) defining endogenous nitrogen as being equal to the minimum level of urinary nitrogen excretion after an animal has been kept for some time upon a diet containing little, or no protein but adequate in other respects. It is notable that estimates of endogenous urinary N loss from measurements of fasting metabolism studies should be doubled in the case of the animals Smuts studied. It is evident, however, that for cattle and sheep, this is inaccurate.

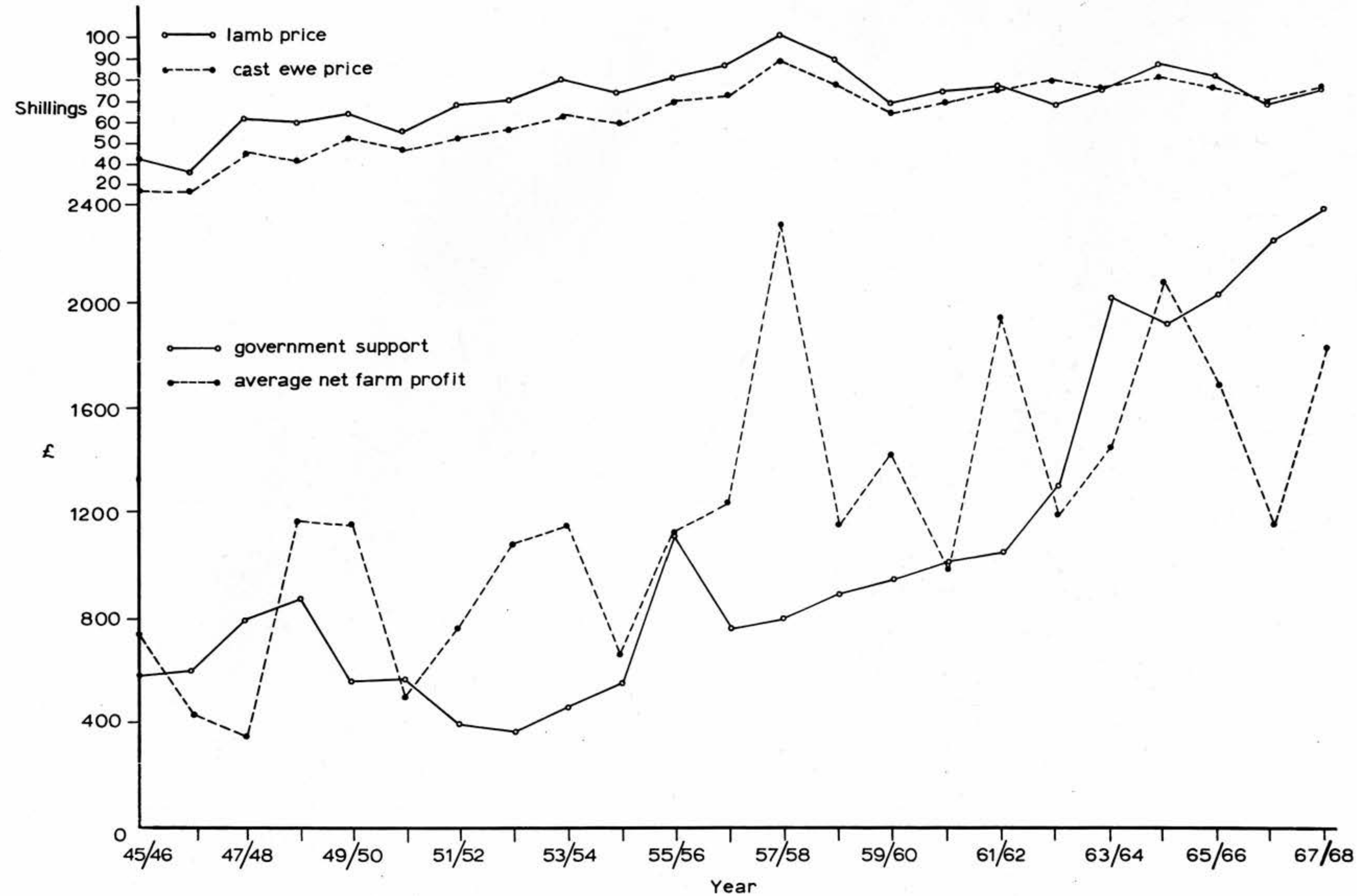
While some of the early workers (Brody (1945); Smuts (1935)) attempted to estimate protein requirements direct from endogenous urinary N loss the difficulties of calculating its value from fasting metabolism studies or its determination from feeding N free diets and the conversion of this value into terms of digestible crude protein, greatly reduce the credibility of the values obtained.

A number of experiments aimed at measuring the N balance of animals have been carried out and information regarding these can be used in estimating N maintenance requirement. Harris and Mitchell (1941) investigating the effects of feeding nitrogen in the form of urea and casein found that the absolute requirement for N to maintain equilibrium was 161 and 202 mg N/kg body weight for casein and urea respectively the requirement for maintenance being 61 mg and 76 mg N/kg/day (casein and urea were 38.0 and 37.7% digestible respectively) and expressed in terms of body weight $^{0.73}$ values of 0.99 and 1.23 g digestible protein are obtained for maintenance.

Harris and Mitchell (1941) quote work of Klein Schmid et al (1939) in which they found that 410 mg digestible protein/kg body weight was required for N equilibrium which expressed in terms of body weight is 1.18 g/kg $W^{0.73}$/day.

Elliott and Topps (1964) have more recently carried out N balance studies on African sheep in an effort to establish protein requirements. These workers have estimated the maintenance requirement for digestible N by calculating regression equations of digestible N intake on urinary N and from these estimate the point at which digestible N intake was equal to urinary N. The pooled estimate, from all values, was 2.10 $\pm$ 0.55 g digestible N daily for a sheep of average weight - 30.7 kg. This is equivalent to a value of 1.08 g digestible protein per kg $W^{0.73}$.

One aspect of Elliott and Topps (1964) work deserves particular attention. They found that maintenance requirement increased by 0.25 $\pm$ 0.06 g N/day per unit increase in the ratio of roughage to concentrate. Robinson (1966)



lamb price
cast ewe price
government support
average net farm profit
Shillings
100
90
80
70
60
50
40
20
2400
2000
1600
1200
800
400
0
£
45/46
47/48
49/50
51/52
53/54
55/56
57/58
59/60
61/62
63/64
65/66
67/68
Year

Figure 1.

suggests that since ruminants at maintenance are often fed a roughage diet only, these findings are of practical importance. He suggests that the higher requirement for protein of ruminants offered a high roughage diet may be related to the higher rumen acetic acid production which in turn increases urinary N excretion as shown by Armstrong, Blaxter and Graham (1957).

A.R.C. (1965) have adopted a factorial method of calculating protein requirements. They recognise that, as in the urine, the faeces also contains a component of endogenous loss which they term metabolic faecal nitrogen. The amounts excreted are usually quoted in terms of g N excreted per kg of D.M. even though there is evidence to suggest that MFN loss is not necessarily constantly related to dry matter intakes.

Thus the original equation from which biological value may be calculated can be expanded and modified.

$$\text{Bv} = \frac{\text{N intake} - (\text{faecal N} - \text{MFN}) - (\text{urinary N} - \text{EVN} \times 100)}{\text{N intake} - (\text{faecal N} - \text{MFN})}$$

$$\text{or} = \frac{\text{N balance} + \text{MFN} + \text{EVN} \times 100}{\text{Apparently dig N} + \text{MFN}} \quad \text{(ARC 1965)}$$

Many measurements of faecal nitrogen have been obtained and are summarised by A.R.C. (1965).

Other losses of N which are particularly applicable to maintenance are those due to fleece growth. Simmonds (1955) found the nitrogen content of clean scoured Merino wool to be $16.35 \pm 0.12\%$, that is to say it may be considered to consist entirely of protein. A.R.C. (1965) give details of N retention/day in grams for the various breeds.

In combining the factors together for the calculation of maintenance requirement A.R.C. (1965) give the following equation:

$$\text{AP} = (\text{EVN} + \text{S}) \times 6.25 \times \frac{100}{\text{Bv}}$$

where AP is the available protein which is independent of MFN loss and therefor of dry matter intake BV has been estimated to be 68% for sheep.

For the conversion of AP to DCP, AP is multiplied by a factor of 16.8D (sheep) where D is the dry matter intake in kg/day.

Summary: Protein for Maintenance.

	DCP g/kg $W^{0.73}$		
Harris and Mitchell (1941)	1.24 (urea)		0.99 (casein)
Klein Schmid Studt and Mullen (quoted by Harris & Mitchell)	1.18		
Elliot and Topps (1964)	1.08		
Robinson (1966)	1.16	&	0.93
N.R.C. (1957)	3.30		
U.K. Evans (1960)	1.63		
Breirem (Thomson & Aitken 1959)	2.80		

Protein Requirement for Pregnancy

As in the case of energy requirement it can be expected that the greatest demand for protein will occur in the last third of gestation. The chemical composition of the products of conception indicate that the percentage of protein is high. Wallace (1948), Langlands and Sutherland (1968), analysed the carcasses of two sets of twin lambs just after birth and found that the mean N content was 2.85 per cent of the fresh weight or 103 g. This gives a total deposition of N up to term for twins of 206 g.

Graham (1964) gave values of 84.3, 88.2, 116.6 and 103.7 g total N in each of the Merino conceptures he analysed. Thus it is likely that the total N requirement for the foetus and its associated tissues could vary from

100 to over 200 g of N.

Mousgaard (1959) has estimated a 57 per cent utilisation efficiency of digestible N for reproductive purposes. If this is so an extra 334 g N could be required, which is equivalent to 2087 g DCP. If 70 per cent of this is utilised in the last 6 weeks of gestation this would indicate an approximate daily intake of DCP for reproduction of 35 g DCP/day. (Robinson 1966)

Nitrogen balance has also been used as a technique in estimating protein requirement during pregnancy.

Klostermann et al (1951) gave pregnant ewes 1.05 g DCP/kg $W^{0.73}$ and they remained in positive N balance retaining 1.5 g N daily. The workers reported that this low protein intake, compared to NRC recommendations had no adverse effect on lamb production. In the same series of experiments there were no consistent differences in lamb production parameters as a result of feeding ewes diets equal in the energy fed but which varied from 6.8 to 11.0 per cent crude protein.

In a second series of experiments Klostermann et al (1953) in which groups of pregnant ewes were fed diets containing 0.26, 0.16 and 0.06 lb DCP per day they show that as gestation proceeded there was a marked increase in the N retained on the high level of protein feeding, while on the lower protein levels the ewes were in negative balance in early gestation but were in positive balance in mid and late gestation. This was due in part to an increased feed intake. In larger groups of ewes on similar treatments there were no significant differences in birthweight of lambs or weight of lambs at 30 days old. Ewes fed the lower levels of nitrogen tended to have lighter fleeces and their twin lambs weighed slightly less at 30 days. The death loss of ewes was somewhat higher on the low protein rations.

In N balance experiments concerning the utilisation of casein Chalmers et al (1954) found that Cheviot hill ewes fed on a low energy and protein intake (0.06 lb DCP) and supplemented with casein to the extent of 0.09 lb DCP by mouth, runinal fistula and anodinal fistula, in late pregnancy used the supplementary protein ineffectively and all remained in negative nitrogen balance irrespective of whether they were carrying singles, twins or triplets. On the other hand these workers report on a similar ewe receiving a high energy, high protein (0.14 lb DCP) diet which was supplemented in late pregnancy with 0.09 lb DCP as casein by mouth and was in nitrogen balance to the extent of storing N at a rate of 4.49 g N/day an increase of 3.18 g N/day from the basal diet. This would indicate that at this stage of pregnancy (5-6 weeks prepartum) 0.14 lb DCP would be adequate for the development of the foetus, and in this case the ewe was carrying twins.

The report of N balance studies carried out by Graham (1964) in which two levels of protein intake were given to Merino ewes of similar liveweight and carrying single foetuses (0.10 and 0.15 lb DCP per day) indicates that even at the low level of intake the ewe remained in positive balance to a substantial degree (2.8 g N/day retained).

The evidence from feeding trials, as for those reported for differences in energy intakes, are difficult to interpret though are helpful to some extent in measuring mortality effects since larger numbers are involved.

Van Horn, Burkett, Payne and Hughes and Wilson (1950) fed four groups of 250 ewes grazing pasture pelleted supplements containing 10.4, 18.2, 27.1 and 37.0 per cwt crude protein. They report that sheep on the highest protein level maintained their weight better than those fed lower levels and there was little difference in fleece weights. Lambs born from ewes on higher protein levels were slightly heavier at birth but weaning weights were practically the same. Whiting and Slen (1950) report on a trial in which they fed groups of 27 ewes 7%, 10% and 13% CP in individual pens. Feed intakes up to six weeks before lambing were similar. Birthweights were 9.4 lb, 11.4 lb and 10.6 lb (twins) and 7.6 lb, 8.6 lb and 8.8 lb (singles) respectively. Eight week weights and percentage lambs for ewes mated, were respectively 34.2 lb (56%), 42.2 (89%) and 42.0 (108%). The fleece weights from ewes were 4.8 lb 5.6 lb and 5.7 lb respectively. They conclude that 7% CP in the ration is insufficient for optimum lamb growth and wool production but there was little advantage in feeding more than 10% CP if the ewes receive adequate energy.

On a fuller report of the same trial Slen and Whiting (1952) show that differences between the 7% CP fed ewes and the 10 and 13% fed ewes in the parameters measured were all significant. During the last six weeks there was some reduction in the feed intake of the ewes on the low protein diet though this was slight. DCP intake for the three groups of ewes was given as 0.13, 0.23 and 0.29 lb respectively during the last six weeks of gestation. From the weight gains of the ewes these workers conclude that in early pregnancy the recommended allowances for DCP (NRC) are higher than required and are also probably too high in the last 6 weeks.

These latter results would seem to be at variance with those of Whiting and Slen (1950). The differences may be due to an interaction of energy intake since it would seem that although levels between treatments were similar those ewes of Slen and Whiting (1953) were given 1.7 - 1.9 lb TDN those of Klostermann et al (1951) were given 2.4 - 2.5 lb TDN. It is of interest that Klostermann et al (1951) report on a group of ewes similar to those used in the experiments referred to in which they fed 1.7 lb TDN and 0.10 lb DCP and obtained a birthweight of twins almost 1.5 lb less than ewes fed at 2.5 lb TDN and varying protein levels of 0.15 - 0.34 lb DCP/day.

It must be concluded from these experiments that protein levels as low as 0.15 lb, i.e. lower than those recommended by NRC (1957), will not affect lamb birthweight as long as energy levels are adequate.

From a further experiment, Slen and Whiting (1952) report that ewes fed 7.7% CP throughout gestation gave birth to significantly lighter lambs than ewes either fed 10.5% CP throughout gestation or fed 7.7% CP up to six weeks before lambing, then 10.5% CP in the six weeks. Lamb survival was poorest among those born from low protein fed ewes i.e. those fed 7.7% CP throughout gestation. The same pattern in lamb weights was evident at six weeks of age and at weaning.

Jordan, Klostermann and Wilson first reported on experiments conducted to investigate the effect of level and source of protein in pregnant ewe rations or ewe productivity in 1949. There was no significant differences in fleece weights, vitality of the lamb at birth or daily gain of the lamb but there were highly significant differences in the liveweight gains of ewes during gestation and the "condition" of the lambs at birth.

In a fuller report Klostermann et al (1951) confirmed these earlier findings and show that there were no consistent differences in the birthweight of lambs from the various treatment groups though there was a trend for twins to be lighter from low protein fed groups (0.18 - 0.12 lb DCP). The highest level of protein fed was 0.54 lb DCP/day.

Robinson and Forbes (1967) suggest that for a 150 lb level a daily intake of 0.17 lb DCP was required during late pregnancy for maximum efficiency of utilisation and that a level of 0.21 lb is required for maximum efficiency of energy utilisation.

'The effect of feeding regime on
the performance of Blackface
'group fed' ewes.'

The effect of feeding regime on the performance of Blackface 'group fed' ewes

Introduction

There are a number of alternative feedingstuffs available for the feeding of ewes and in these series of studies it was intended to evaluate the feasibility of using some of these in practical terms (acceptibility, consumption and cost) and ascertain their effect on the ewe while housed and its subsequent performance on the hill.

Hay has long been accepted as a roughage for hill ewes during times of storm and during other periods of nutritional stress though it is known that even under such stress some hill ewes will not eat any form of conserved feed.

Silage has also been used in some hill farming situations where there has been a limited acreage of arable land. The application of silage feeding on most hill farms is likely to be very limited.

The acreage of cereals in Britain has increased and may increase further giving rise to large quantities of straw. The use of barley straw as a cattle feed has been investigated by a number of workers (Burt, 1966; Lamming et al, 1967) but there is little information on barley straw being fed to sheep. If supplies were relatively cheap and production costs were low the feeding of straw could have real implication and therefore requires some assessment as to its feasibility for use in group feeding systems and as to its nutritional value in terms of metabolisable energy and digestible crude protein.

In situations in which an animal is to have its total feed supply given in the form of conserved products an additional supplement to the roughage part of the diet must be given. In these experiments proprietary supplements were used which included protein, minerals and vitamins and also other feed by-products which were given additional mineral and vitamin supplementation.

Clearly the level of protein included in the supplement will greatly affect its cost. From the results of recent experiments carried out by Robinson and Forbes (1967) the levels of protein recommended for pregnant ewes have been brought into question. Some of the group feeding trials therefore include comparisons of different levels of protein and different sources of protein.

EXPERIMENTAL 1964-65

In the first year the investigations were concerned with evaluating three basic diets.

1. Complete ground and pelleted barley straw, protein, mineral and vitamin supplemented diet.
2. 50% hay + 50% straw + protein supplement.
3. Hay + protein supplement.

The composition of the protein supplement used for diets 2 and 3 is given in Table 1.

TABLE 1 : Composition of Protein Supplement

	%
Extracted Groundnut	64½
Extracted Soya	10
Maize	4
Molasses	8
Tallow	1½
Di Calcium Phosphate	2
Lime	6
Salt	4
Vit. A	7 m.i.u.
D_3	1½ m.i.u.
E	50,000 mg.

Because of its extensive nature, remoteness at relatively high altitudes, poor pasture quality, and climatic extremes traditional hill sheep farming incurs considerable economic risk.

It can be seen from Figure 1, which is taken from the data of Duthie (1968 and 1970) how average net farm income for a group of some 20 hill farms in the East of Scotland Agricultural College Area has varied since 1945 and how Government financial support has increased dramatically since 1958.

From 1945 a gradual increase in net farm income took place up to 1957/58, in response to an increase in lamb prices from 45 shillings to 100 shillings and a gradual increase in Government support. This took place against a background of increased costs, £0.85/ewe for labour and £1.87/ewe for other costs.

Since 1957/58, the economic fortunes of hill farming have been less promising and annual net farm incomes have been erratic for this group of farms.

The demand for store lambs fell, as lowland farmers increased their acreages of arable cropping, and as a consequence lamb prices fell, and with them net farm income up to 1960/61. There was a substantial increase in net farm income in 1961/62 due to a heavy lamb crop(100% c.f. 90%) and a rise in lamb and cast ewe prices. It fell again in 1962/3 due to a fall in lamb price and then increased to a high level in 1964/65 during which time Government Support per farm almost doubled (from £1000 to £2000).

From 1964/65 net income fell by £1000 per farm due, in the main, to a fall in lamb and cast ewe prices but despite a further increase in Government Support. The 1966/67 lamb crop was below average and net farm

Six groups of 40 ewes were selected as far as possible on the basis of age and weight, three of the groups being predominantly gimmers. Two groups, one of aged ewes and the other of gimmers were fed on each of the diets.

The ewes on diets 1 and 2 were bedded on straw, those on diet 3 on sawdust.

Feeding was weighed into feeding boxes and anything remaining 'weighed out' the following day.

Details of the amounts of each diet fed are given in Table 2.

TABLE 2 : Diets given 1965

	lb fresh	gms fresh	Feed	ME(Kcals)	D.C.P.(g)
Treatment 1					
14 to 17 Feb	2.18	990	Straw Pellet	1515	61
28 Feb to 6 Mar	2.27	1013	Straw Pellet	1577	62
7 Mar to 21 Apr	2.50	1135	Straw Pellet	1737	70
	0.28	127	Protein Pellets	282	46
				2019	116
Treatment 2					
10 to 27 Feb	0.5	227	Protein Pellet	473	77
	0.56	254	Straw	345	-
	0.75	341	Hay	590	8
				1439	85
28 Feb to 6 Mar	0.47	213	Protein Pellet	473	77
	0.78	413	Straw	481	
	0.75	341	Hay	590	8
				1544	85

TABLE 2 contd.

	lb fresh	gms fresh	Feed	ME(Kcals)	D.C.P.(g)
Treatment 2 contd.					
7 to 13 Mar	0.73	336	Protein Pellet	746	121
	0.84	381	Straw	518	
	0.72	327	Hay	566	8
				1830	129
14 to 20 Mar	0.72	327	Protein Pellet	726	118
	0.78	354	Straw	481	
	0.97	440	Hay	761	11
				1968	129
21 to 24 Apr	0.71	322	Protein Pellet	715	116
	0.62	281	Straw	382	
	1.18	536	Hay	927	13
				2024	129
Treatment 3					
10 to 27 Feb	0.38	173	Protein Pellet	384	62
	1.55	704	Hay	1218	16
				1602	78
28 Feb to 6 Mar	0.41	186	Protein Pellet	413	67
	1.59	722	Hay	1249	17
				1662	84
7 to 10 Apr	0.61	277	Protein Pellet	615	100
	1.78	808	Hay	1398	19
				2013	119

Digestibility studies were carried out on all the feeds used in the diets except the protein pellet, the metabolisable energy content of which was estimated from the values of the individual constituents. Each feed and each diet was fed to 3 pregnant ewes during a period beginning some 30 days after conception. The ewes were introduced to the feed or diet to be examined and fed for 21 days. Feed recording then began, together with faecal and urine collection over 10 days, the interval between feeding and faecal collection being 48 hours.

Statistical Analysis

The method used was the same as that adopted in the previous section. Full data, was corrected to a 5 year old ewe, with a male single lamb, on the basis of the within year data. Lamb data was corrected to a male single from a 5 year old ewe.

RESULTS

Ewe Feeding

No difficulty was found in obtaining the required feed intakes on diet 3. Both the ewes and gimmers ate the hay and protein pellets as specified.

There was some difficulty, however, in obtaining the required straw intake necessary for maintenance with diet 2. The actual energy intake on this diet was below that of the other two groups by some 150 Kcals ME/day, during the period up to six weeks before lambing.

The intake of metabolisable energy of ewes given diet 1 was approximately 50 Kcals ME/day lower than that required for maintenance due to a low estimate of the M.E. value. This was not corrected until the metabolism studies had been completed. Three ewes on this diet failed to eat it and were taken out of the treatment groups temporarily and given rumen inoculations. After six to seven days the ewes were feeding normally and were then returned to their respective treatment groups.

Protein levels would appear high in Treatment 2 (Table 2). This is because the straw used had a negative D.C.P. value and from digestibility studies done on the straw and protein alone it appeared that the combined D.C.P. value was much lower than estimated by direct incremental calculation.

During the last 6 weeks of housing all groups were given equal amounts of metabolisable energy and digestible crude protein.

Metabolism Studies

A full summary of the results are given in Table 2a.

The metabolisable energy of the hay used was 2.10 Kcals/g D.M. and of the barley straw used was 1.64 Kcals/g D.M. The ground straw pellets with supplementary protein was also 1.64 Kcals/g D.M. The digestible crude protein contents of the hay, barley straw and ground straw pellet were respectively 2.9%, -0.8% and 6.6% of the dry matter.

Ewe Weight and Condition

The effect of a lower energy intake among ewes given diet 2 was reflected in a slight loss in weight from the beginning of February to the beginning of March. A similar loss was observed among ewes given diet 1. The ewes on diet 3 gained slightly during this period (Table 3).

There were no observable differences between the ewes on the 3 diets in condition over this same period.

The differences in weight gain during the last 6 weeks of housing (i.e. up to the point of lambing) between ewes fed diet 1 was significantly less ($p \leq 0.05$) than the weight gains on diets 2 and 3. This difference in weight may be due to a difference in "gut fill" at the time of weighing since the rate of passage of the ground barley straw through the gut of the ewe was

TABLE 2a : Digestibility Results

D = % Digestibility. DN = % Digestible Nutrients

			Barley Straw		Straw Pellets		Protein Pellets		*Hay+Protein Pellets		(1) **Straw+Protein Pellets		(2) ***Straw+Protein Pellets	
	D	DN	D	DN	D	DN	D	DN	D	DN	D	DN	D	DN
Dry matter	61.2		45.8		47.2				68.6		55.8		63.1	
Organic matter	62.6	58.5	47.1	45.1	48.6	44.7			70.3	64.2	57.2	52.9	65.9	60.2
Crude protein	40.0	2.9	-28.5	-0.8	59.1	6.6			68.8	10.3	67.0	9.0	70.9	12.1
Ether extract	31.4	0.4	15.4	0.3	59.9	1.0			48.2	0.7	38.4	0.7	43.1	0.8
Crude fibre	58.0	17.1	57.0	26.6	42.7	13.8			64.6	15.6	58.6	20.9	67.3	21.7
N.F.E.	68.6	38.1	44.1	19.8	49.7	23.3			74.1	37.6	53.7	22.4	63.6	25.7
S.E.		41.6		19.1		26.5				50.2		32.3		41.5
T.D.N.		59.0		46.1		46.0				65.0		53.8		61.2
M.E. Kcals/g(D.M.)		2.10		1.64		1.64		2.44		2.31		1.91		2.18
(In fresh)		1.73		1.36		1.53		2.22						

* 579 g Hay D.M. + 153 g Protein Pellet D.M. per day.

** (1) 598 g Straw D.M. + 206 g Protein Pellet D.M. per day.

*** (2) 408 g Straw D.M. + 206 g Protein Pellet D.M. per day.

likely to be more rapid than was the case with diets 2 and 3. Even though care was taken to weigh the groups in the same order, some 4 hours after feeding, there may also have been a differential rate of passage effect due to an increasing size of foetus.

At marking and clipping the hay fed ewes were significantly ($p \leq 0.05$) heavier than the ewes given straw pellets. There were no differences between the groups at weaning.

Wool Production

The ewes given the hay + protein supplemented diet yield significantly ($p \leq 0.05$) more wool than those on the other 2 diets. (Table 4)

The ewes given the ground straw pellet diet ceased to ruminate after 1 to 2 days, and it is presumed as a consequence began to 'pick' each others fleeces which resulted in a considerable wool loss.

Wool picking was not such a problem, however, among ewes given the long straw/hay diet yet they also yielded significantly less wool, some form of dietary défficiency associated with the feeding of straw, therefore, cannot be disregarded.

TABLE 3 : Corrected ewe liveweights and liveweight gains and losses in treatment groups (1965) lb.

Diet		Nov	Jan	Feb	Mar	Apr	Marking	Clipping	Weaning
		Liveweight							
1	Straw Pellet	130.5	124.0	117.6	115.8	121.6	104.7	118.6	119.6
2	Hay/Straw	130.7	124.0	117.2	115.8	125.7	106.9	121.5	123.1
3	Hay	130.5	124.2	117.9	118.8	129.6	109.7	125.3	123.3
		Liveweight differences							
1		-6.4	-6.4	-1.9	5.8	-16.9	13.9	1.0	
2		-6.7	-6.7	-1.4	9.9	-18.8	14.6	1.6	
3		-6.3	-6.3	0.9	10.8	-19.9	15.6	-2.0	

TABLE 4 : Corrected wool weight 1965 (lb)

Diet	1	2	3
	Straw Pellet	Hay/Straw	Hay
	2.3	2.2	2.7

Lamb Production and Performance

There was no statistically significant difference in the mean lamb birthweights of the 3 groups. (Table 5)

TABLE 5 : Corrected male single lamb birthweights, 35, 84 and 140 day liveweights 1965 (lb)

Diet	Birthweight	35	84	140
1	9.8	32.0	56.2	76.6
2	10.0	31.2	55.8	76.3
3	9.7	31.0	54.1	74.1

TABLE 6 : Lamb Mortality

No. Ewe	No. Lamb	Sex	Date Birth	Death	Age Days	Single or Twin	Wt. at Birth	Cause
377	-)	E	7.4	7.4	0	T	4.)	Weakness
377	)	E	7.4	7.4	0	T	4.5)	"
342	301	M	7.4	7.4	10	S	8.0	Acute abomasitis
134	-	-	14.4	14.4	0	T	8.5)	Hanged
"	-	-	14.4	14.4	0	T	7.0)	
108	304	M	14.4	21.4	7	T	5.5	Coliform
132	154	M	15.4	23.4	8	S	8.5	Bumble foot - slaughtered
147	313)	M	16.4	16.4	0	T	3.0)	Weakness
"	314)	F	16.4	16.4	0	T	4.0)	
124	319	F	17.4	18.4	1	T	5.5	Smothered when "Twinned" to 147
346	17	M	16.4	16.4	0	T	5.0	Smothered
300	562	M	18.4	23.4	5	T	7.0	Exposure
195	-	F	19.4	19.4	0	T	10.5	Strangled
297	190	M	22.4	1.6	9	T	8.5	Starvation - not mothered
154	195	F	22.4	27.4	5	S	11.0	Joint ill
268	46	M	22.4	29.4	7	T	7.0	Necrobacillus
384	51	E	23.4	30.4	7	S	7.0	Joint ill
307	350	M	23.4	24.4	1	T	8.5	No P.M.
209	-	F	-	-	1		4.0	Weakness
239	61	M	25.4	27.4	2	?	9.5	Coliform infection
194	594	M	28.4	4.5	6	?	9.0	Joint ill
343	371)	F	28.4	10.5	12	T	6.0)	Starvation-Ewe, short thick
	372)	F	28.4	30.4	2	T	5.0)	teats
164	80)	M	29.4	30.4	1	T	9.0	Starvation - weak
	79)	M	29.4	21.5	22	T	8.0	Joint ill
322	241	F	29.5	30.4	1	S	7.5	General weakness
190	244)	F	30.4	1.5	1	T	6.5)	Starvation - ewe no milk
	245)	F	30.4	1.5	1	T	6.25)	
219	608	M	21.5	22.5	1	T	8.0	General weakness

EXPERIMENTAL 1965-66

In the second year 3 different diets were given, 2 being based on barley straw and one on hay. They were as follows:-

1. Long barley straw

   + pelleted milled barley

   + protein pellet

2. Long barley straw

   + pelleted milled barley

   + protein pellet (20% N as urea)

3. Hay

   + protein pellet

   + pelleted milled barley in last 6 weeks of gestation.

The composition of the protein pellets was the same as in 1965 (Table 1) with a urea substitution in diet 2.

Six groups of approximately 50 ewes were selected according to weight, age and previous treatment, 2 groups being fed each diet. Gimmers were not grouped together, they were divided throughout the groups.

All stock were on slats.

Feed recording was carried out as in the previous years investigations.

Details of the amounts fed are given in Table 6a.

The energy levels given in this year were less than those fed in 1964-65. This was done to establish whether a reduction in feed intake would affect ewe performances. The level used for the period up to 6 weeks before lambing was 1300 Kcals M.E. and 0.11 lb D.C.P. Energy and protein intake was then stepped up at 14 day intervals as follows:

TABLE 6a : Calculated Rations

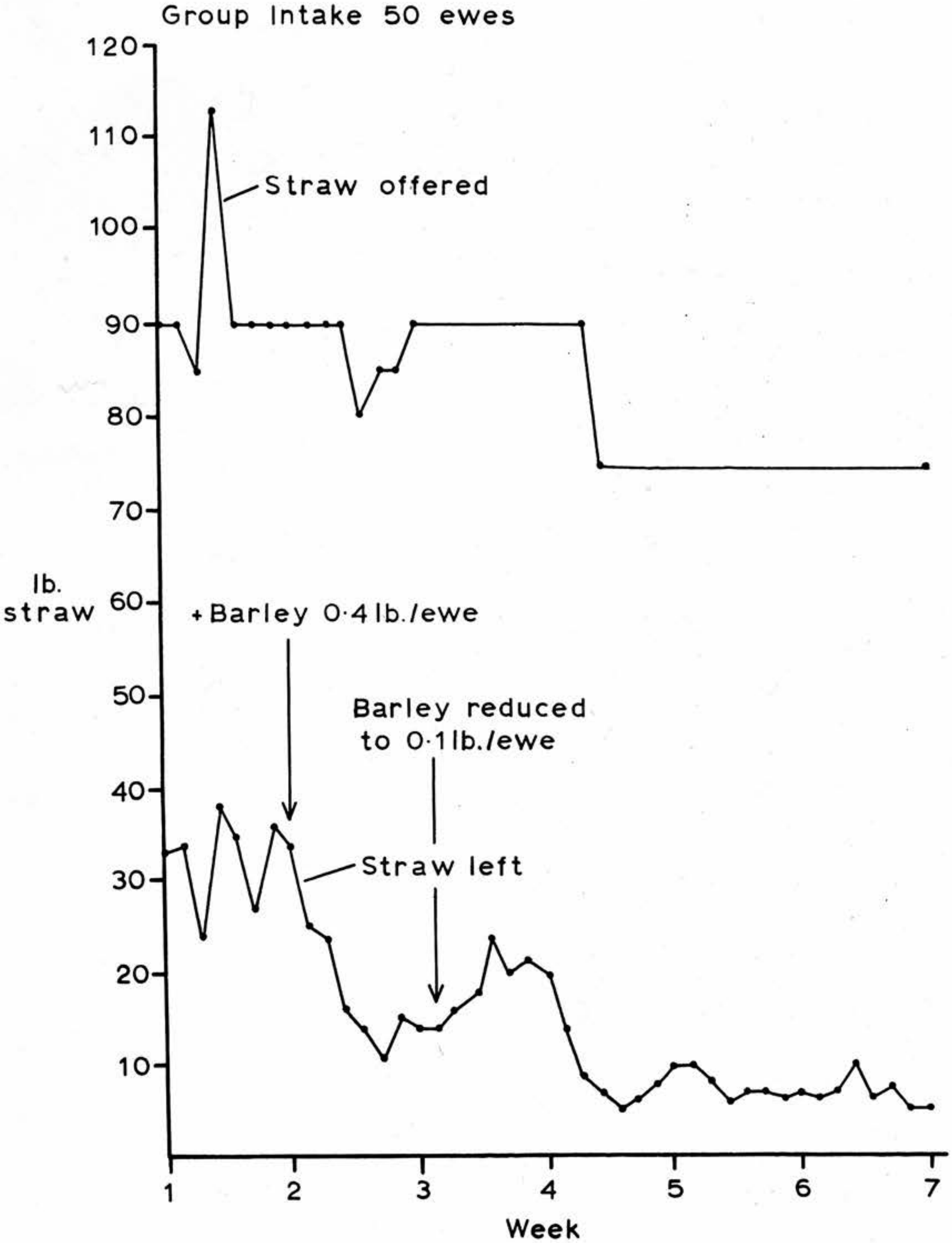
	lb fresh	gms fresh	Feed	Kcals	D.C.P.(g)
	A. Straw fed groups				
I	1.4	635	Straw	839	
	0.08	36	Barley	92	
	0.34	154	Protein	321	
				1252	54.48
II	1.4	635	Straw	839	
	0.35	158	Barley	413	10.72
	0.37	166	Protein	346	61.90
				1598	72.62
III	1.4	635	Straw	839	
	0.44	200	Barley	524	13.60
	0.46	209	Protein	437	78.26
				1800	91.86
IV	1.4	635	Straw	839	
	0.53	241	Barley	633	16.4
	0.56	253	Protein	528	94.6
				2000	111.0
	B. Hay fed groups				
I	1.7	757	Hay	1248	35.10
	0.07	32	Protein	67	12.04
				1315	47.14
II	1.7	757	Hay	1248	35.10
	0.16	73	Barley	191	4.96
	0.18	82	Protein	170	30.53
				1609	70.59
III	1.7	757	Hay	1248	35.10
	0.25	113	Barley	296	7.68
	0.28	127	Protein	264	47.30
				1808	90.08
IV	1.7	757	Hay	1248	35.10
	0.34	153	Barley	400	10.40
	0.38	173	Protein	360	64.50
				2008	110.00

Period I Jan. 2 – Mar. 2

Period II Mar. 2 – Mar. 16

Period III Mar. 21 – Apr. 4

Period IV Apr. 4 – Apr. 15 onwards (i.e. Apr. 30th)



Group Intake 50 ewes
120
110
100
90
80
70
60
50
40
30
20
10
lb.
straw
Straw offered
+Barley 0·4 lb./ewe
Barley reduced
to 0·1 lb./ewe
Straw left
1
2
3
4
5
6
7
Week

Figure 1.

1. 1600 Kcals M.E. and 0.18 lb D.C.P./day

2. 1800 Kcals M.E. and 0.23 lb D.C.P./day

3. 2000 Kcals M.E. and 0.28 lb D.C.P./day

Digestibility studies were carried out on the hay and straw and on the 3 diets used in a similar manner to that described previously (Experimental 1964-65).

RESULTS

Ewe Feeding

As in the previous year no difficulty was encountered in feeding hay, (diet 3). It became apparent, however, that feeding a small quantity of protein daily was not satisfactory since some ewes had an ability to eat the pellets quickly and consequently consumed greater quantities than others. In an effort to even out the distribution of intakes the pellets were fed in larger quantities twice weekly.

In diets 1 and 2 considerable difficulty was found in obtaining the level of straw intake desired. To achieve a mean intake of 1.5 lb at least double that quantity of straw had to be offered, an arrangement which on slats is impractical, though with straw bedding it might have been acceptable. An increase in intake was associated with the feeding of a small quantity of barley which was introduced in the second week of the feeding period. At the same time as intake was increased wastage became less and the amount of straw offered was reduced.

Figure 1 shows how the amount of straw offered varied with the amount left during initial stages of the inwintering period for one of the straw fed groups; the other groups performed in a similar manner.

There was no appreciable difference in the intake of straw between the groups of ewes given different protein supplements.

Metabolism Studies

A full summary of the results are given in Table 7 with individual feed analysis.

The metabolisable energy of the hay used was 2.01 Kcals/g D.M. and of the barley straw used was 1.61 Kcals/g D.M. The metabolisable energy of the 3 diets used and their D.C.P. values are given in Table 8.

TABLE 8 : Energy and D.C.P. Values of Diets

	Kcals M.E./g D.M.	D.C.P. % D.M.
Barley straw, Barley + Protein Pellet	1.81	6.9
Barley straw, Barley + Protein/Urea Pellet	1.87	7.1
Hay + Protein Pellet	2.20	7.2

The nitrogen balance results, Table 9, show that even where protein was added to the roughage part of the diet one animal in each of the groups (three animals per group) had a negative nitrogen balance. These ewes were in-lamb and being given 1300 Kcals M.E. and 47 g D.C.P. per day at about the 4 th week of gestation.

The results suggest that the level of protein given at this level of energy would be inadequate to maintain a positive N balance for a proportion of ewes.

Ewe Weight and Condition

Table 10 shows how the mean liveweights of the groups varied during the inwintering period and the rest of the year. During the period from the beginning of February to the beginning of March there was a loss in mean

TABLE 7 : Digestibility Trial Results

D = % Digestibility. D.N. = % Digestible Nutrients

	Hay 65/11		Straw 66/2		Protein Pellets 109 & 140		Barley		65/12 Hay + Protein 109		66/3 Straw + Barley + Protein 109		66/4 Straw + Barley + Protein 140	
	D	D.N.	D	D.N.	D	D.N.	D	D.N.	D	D.N.	D	D.N.	D	D.N.
Dry Matter	59.6		45.59						65.3		54.4		52.8	
Organic Matter	61.3	55.9	46.99	44.9					67.3	61.6	55.7	52.0	53.9	50.3
Crude Protein	55.5	5.7	-28.37	-1.0					62.0	7.2	62.7	7.1	62.8	6.9
Ether Extract	28.9	0.5	25.90	0.6					40.7	0.6	42.6	0.6	41.2	0.5
Crude Fibre	67.1	22.1	57.40	26.3					71.8	22.5	48.5	16.4	46.7	15.9
N.F.E.	59.5	27.6	42.48	18.8					66.4	31.3	59.6	28.0	57.3	26.9
S.E.		36.8		18.7						43.5		32.4		30.5
T.D.N.		56.5		45.3						62.4		52.7		50.9
M.E. Kcals/g (D.M.)		2.01		1.61		2.44				2.20		1.87		1.81
M.E. Kcals/g (Fresh)		1.64		1.31		2.14								

65/12 758 gms Hay D.M. + 35 gms Protein 109 D.M. per day

66/3 700 gms Straw D.M. + 170 gms Protein 109 D.M. + 76 gms Barley D.M. per day

66/4 700 gms Straw D.M. + 130 gms Protein 140 D.M. + 76 gms Barley D.M. per day liveweight in all the groups. The hay fed ewes lost significantly ($p \leq 0.05$) less weight than those fed straw. During the last 6 weeks of gestation the weight gain of the hay fed ewes was significantly greater ($p \leq 0.05$) than the weight gain of the straw fed groups, this resulted in the hay fed ewes being significantly greater in weight when taken out of the house ($p \leq 0.05$).

The condition of all the ewes and their udder development was poor. There was, however, a considerable variation in the condition of the ewes fed straw even though this was not reflected in a wide variation in liveweight, the standard errors of the three treatment groups being $\pm$ 2.11, $\pm$ 2.04, $\pm$ 2.07 respectively.

There was no difference in the mean liveweight of the groups at marking, there was, however, a significant difference ($p \leq 0.05$) in the mean liveweight losses during the period between being put out of the house and marking, the hay group having lost 19.5 lb compared to 13.5 lb (ewes given straw and protein supplement) and 12.5 lb (ewes given straw and protein/urea supplement).

There were no differences in liveweight at clipping and weaning.

Wool Production

There was no significant differences in yield of wool per ewe from the three treatment groups. Table 11.

Lamb Production and Performance

As might have been expected from the weights of the ewes pre-lambing, the mean birthweight of the lambs from the ewes given hay diet (3) was greater than that obtained from the straw diets, the difference, however, was only significant ($p \leq 0.05$) in the case of the straw/protein diet (1). Table 12.

TABLE 9 : Nitrogen Balances

Treatment	Sheep No.	Initial L.Wt.	Final L.Wt.	Nitrogen Fed	Nitrogen Urine	Nitrogen Faeces	Total Nitrogen Excreted	Body Prot. Broken down	Protein Witheld
		lb	lb	gms	gms	gms	gms	gms/day	gms/day
	4	106	101	17.8	26.8	24.2	51.0	20.75	
Straw	5	96	93	23.8	21.6	33.3	54.9	19.44	
	6	87	84	19.0	19.1	29.7	48.8	18.63	
Straw	4	106	107	110.0	82.0	36.5	118.5	5.31	
Barley	5	95	95	117.9	72.6	43.5	116.1		1.13
Protein	6	111	113	115.0	63.0	48.4	111.4		2.25
Straw	4	107.	111	111.9	78.5	35.1	113.6	1.06	
Barley	5	-	-	114.1	67.5	44.4	111.9		1.38
Urea/Prot.	6	113	111	113.8	61.6	47.1	108.7		3.19
	1	103	103	104.7	52.1	44.8	96.9		4.88
Hay	2	102	103	104.6	68.5	44.3	112.8	5.13	
	3	118	118	105.2	58.5	50.8	109.3	2.56	
	1	101	101	117.4	58.3	47.2	105.5		7.44
Hay	2	102	101	118.8	75.7	44.9	120.6	1.06	
Protein	3	116	115	118.5	53.7	42.7	96.4		7.56

TABLE 10 : Corrected ewe liveweights and liveweight gains and losses in treatment groups 1966 (lb)

Liveweight

Diet		Nov	Jan	Feb	Mar	Apr	Marking	Cropping	Weaning
1	Barley Straw	131.9	116.7	122.7	117.7	120.9	107.4	118.1	127.3
2	Barley Straw/Urea	131.7	116.3	122.6	116.9	120.2	107.8	116.9	125.6
3	Hay	135.4	116.4	123.0	119.8	129.0	109.4	117.1	127.1

Liveweight differences

-15.1	+5.9	-5.0	+3.2	-13.5	10.8	9.2
-15.4	+6.3	-5.6	+3.3	-12.5	9.1	8.7
-15.0	+6.7	-3.2	+9.1	-19.5	8.2	9.4

TABLE II : Corrected Wool Weight 1966 (lb)

Diet	1	2	3
	Barley Straw	Barley Straw/Urea	Hay
	3.2	3.2	3.0

TABLE 12 : Corrected male single birthweight, 35, 84 and 140 day liveweights 1966 (lb)

Diet	Birthweight	35	84	140
1	9.1	30.2	51.6	72.4
2	9.3	28.6	49.2	70.7
3	9.7	30.7	51.3	72.8

The differences in mean wight of the lambs at 35, 84 and 140 days were not significant.

Ewe Mortality

A full analysis of ewe mortality is given in Table 13. Mortality from ewes given the straw/protein diet (1) was 12%, from ewes given the straw/protein/urea diet (2), 7.3%, and from ewes given the hay diet (3), 3.8%. Most deaths occurred from pneumonia; of 23 deaths, 16 died of pneumonia, 1 of epizootic adenomatosis, 3 of enterotoxoemia, 1 with a ruptured uterus and 1 with a borken leg (slaughtered). Diagnosed disease is given in Table 13a.

TABLE 13 : Ewe Mortality

Date	Ewe No.	Treatment	Cause of Death
Jan. 8th	322	A2	Enterotoxaemia
Jan. 10th	654	C2	Enterotoxaemia
Jan. 30th	427	B1	Enterotoxaemia
Feb. 25th	330	A2	Epizootic Adenomatosis
Mar. 8th	451	A2	Ruptured Uterus
Mar. 9th	222	B1	Pneumonia
Mar. 20th	302	C2	Pneumonia
Mar. 21st	349	B2	Pneumonia
Apr. 2nd	649	B1	Pneumonia
Apr. 6th	310	A1	Pneumonia
Apr. 18th	328	B2	Pneumonia
Apr. 18th	211	C2	
Apr. 20th	308	A1	Hypomagnesaemia/Pneumonia
Apr. 20th	342	A2	
Apr. 20th	314	A2	
Apr. 27th	419Y	A1	Pneumonia (Moredun)
Apr. 27th	306	B1	
May 9th	105	A2	
May 12th	639	B2	'Couped'
May 15th	619	A2	Pneumonia
June 2nd	326	C2	Pneumonia
June 7th	610	A1	Broken Leg (Slaughtered)
July 28th	304	A2	Pneumonia

TABLE 13a : Diagnosed Diseases - Number of Ewes

Dietary Treatment	1 Straw/Protein	2 Straw/Protein/Urea	3 Hay/Protein
Pneumonia	8	8	7
Abortions	8	5	2
Pneumonia & Abortions	2	3	-

It was thought that many of the abortions occurred due to a rapid rise in ewe body temperature similar to that observed in ewes with pneumonia. After abortion many of these ewes made a full recovery.

It was clear that the health of the ewes given hay was in general better than those given straw.

Lamb Mortality

Lamb mortality was greater among those nursed by ewes given straw (33.7% - diet 1 and 27.8% diet 2) than those given hay (22.8%) it was, however, higher than usual from all groups. Many of the losses were due to pneumonia the most of the remaining losses being due to starvation. 75% of all lambs lost were one of a twin pair. As indicated ewe condition was poor and many had not enough milk to suckle two lambs. A summary of lambs mortality is given in Table 14.

Percentage distribution of Scottish hill farms according to net income. 1965 — 1967.

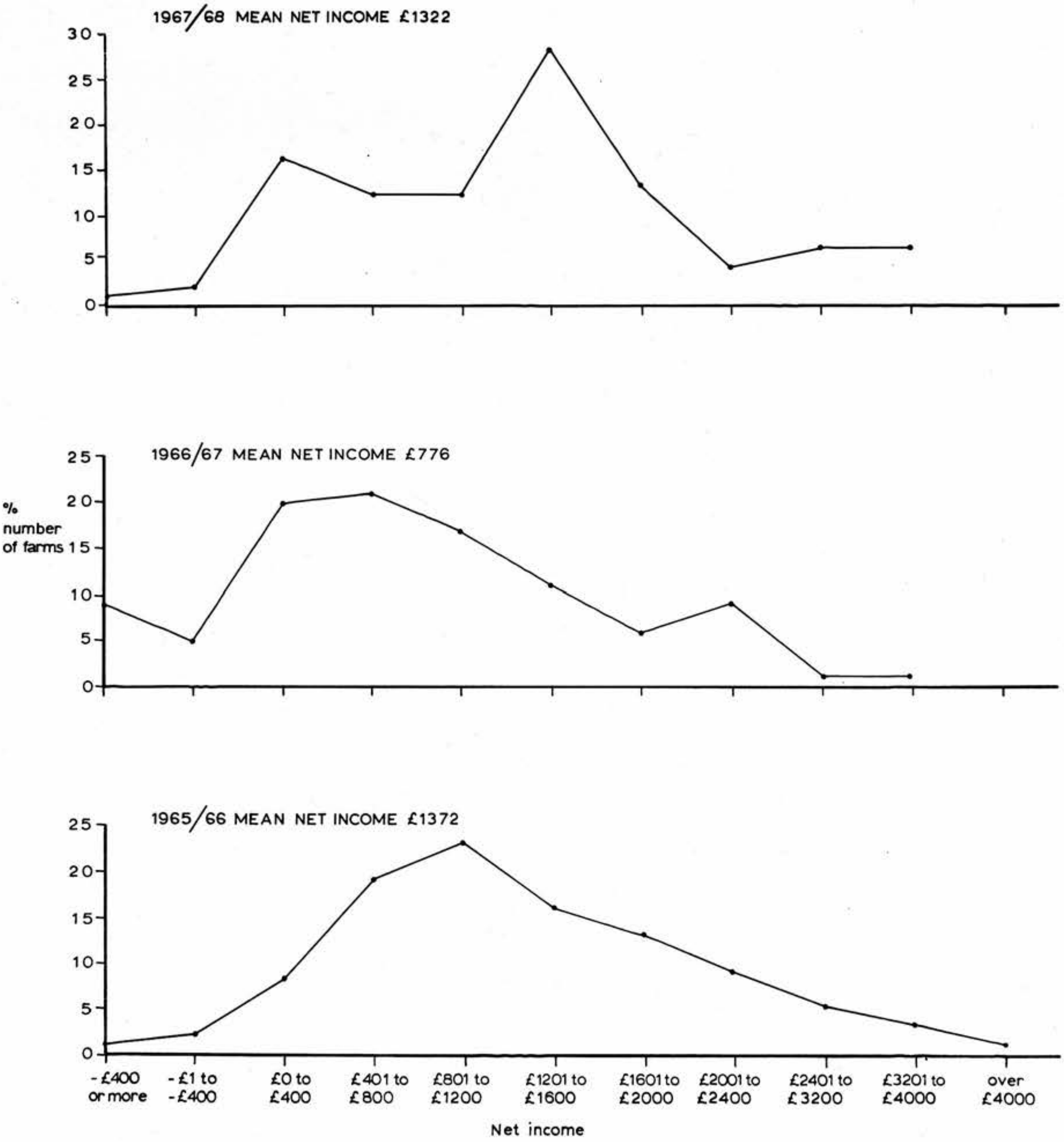


Figure 2.

TABLE 14 : Summary of Lamb Mortality

Cause of Death	**Nos. Died**
Caught in slats	1
Crushed	5
Starvation	21
Pneumonia	42
	69
Location	
Pens	21
Hill or Field	43
Stell	2
Shed	1
Steading	2
Weights at Birth (lamb deaths up to 6th June)	
Lambs under 6 lb	29
Lambs under 4 lb	9
Bottle fed before death	10
Ewes without milk	At least 6

EXPERIMENTAL 1966-67

A. Effect of incremental increases in energy during the last 6 weeks of gestation

Two treatments were:-

1. A group of aged ewes (3-5 year olds), (50), and a group of gimmers with a small number of 6 year olds (total of 50 ewes in group), were given the following:-

   1670 Kcals M.E./ewe/day and 0.10 lb D.C.P./ewe/day up to 6 weeks before lambing then 2000 Kcals M.E./ewe/day and 0.26 lb D.C.P./ewe/day.

2. A group of aged ewes (3-5 year olds) (25) and a group of gimmers with a small number of 6 year olds (total of 25 ewes in group) were given the following:-

   1670 Kcals M.E./ewe/day and 0.10 lb D.C.P./ewe/day up to 6 weeks before lambing then for 14 days 1800 Kcals M.E./ewe/day and 0.21 lb D.C.P./ewe/day and then for the next 14 days 2000 Kcals M.E/ewe/day and 0.26 lb D.C.P./ewe/day and for the final 14 days 2200 Kcals M.E./ ewe/day and 0.33 lb D.C.P./ewe/day.

These levels of energy and protein were given as indicated in Table 15 by diets 1 and 2.

TABLE 15 : Calculated Rations

Diet I

Expt.	Treat-ment	Period	lb fresh	gms fresh	Feed	Kcals	D.C.P. gms
			Hay fed groups				
A&B	I	I	1.85	839	Hay	1137	21.1
			0.53	239	Brewers Grains	545	26.5
						1682	47.6
		II	2.00	908	Hay	1244	23.0
			0.75	340	Protein '305'	747	98.1
						1991	121.1

Diet 2

Expt.	Treat-ment	Period	lb fresh	gms fresh	Feed	Kcals	D.C.P. gms
			Hay fed/increment energy groups				
A	2	I	1.85	839	Hay	1137	21.1
			0.53	239	Brewers Grains	545	26.5
						1682	47.6
		II	2.00	908	Hay	1244	23.0
			0.56	253	Protein '305'	556	72.8
						1800	95.8
		III	2.00	908	Hay	1244	23.0
			0.75	340	Protein '305'	747	98.1
						1991	121.1
		IV	2.00	908	Hay	1244	23.0
			0.96	435	Protein '305'	956	125.0
						2200	148.0

Diet 3

Expt.	Treat-ment	Period	lb fresh	gms fresh	Feed	Kcals	D.C.P. gms
			Hay and Straw fed groups				
B	3	I	0.25	113	Straw	150	
			1.75	796	Hay	1082	19.9
			0.53	239	Brewers Grains	545	26.5
						1777	46.4

TABLE 15 contd.

Expt.	Treat- ment	Period	lb fresh	gms fresh	Feed	Kcals	D.C.P. gms
Diet 4 and 5							
			Hay fed/different protein levels				
		I	1.85	839	Hay	1137	21.1
			0.53	239	Brewers Grains	545	26.5
						1682	47.6
Diet 4							
C	4	II, III	1.85	839	Hay	1137	21.1
		& IV	0.88	380	Brewers Grains	863	42.1
						2000	63.2
Diet 5							
C	5	II, III	1.85	839	Hay	1137	21.1
		& IV	0.86	392	Protein '305'	863	112.9
						2000	134.0

Period	I	27th January to 3rd March
	II	4th March to 17th March
	III	18th March to 31st March
	IV	1st April to 14th April

B. Use of Straw

Treatment I in the above comparison was also used as a comparison of performance with a group of aged ewes (3-5 year olds) (50) and a group of gimmers with a small number of 6 year olds which were given identical energy and protein levels but were given diet 3 (Table 15) which included straw, designated treatment 3.

C. The effect of different levels of protein in the last 6 weeks of gestation

Two further nutritional treatments were compared (viz Treatment 4 and Treatment 5).

Treatment 4 comprised 25 ewes which were given 1670 Kcals M.E./ewe/day and 0.10 lb D.C.P. up to 6 weeks before lambing and then 2000 Kcals M.E./ewe/day and 0.14 lb D.C.P./ewe/day. These levels were provided by diet 4 (Table 15)

Treatment 5 comprised 25 ewes which were given 1670 Kcals M.E./ewe/day and 0.10 lb D.C.P. up to 6 weeks before lambing and then 2000 Kcals M.E./ewe/day and 0.30 lb D.C.P./ewe/day. These levels were provided by Diet 5 (Table15).

In the period up to 6 weeks before lambing dried brewers grains was used as the protein supplement, it was thereafter used only in Treatment 4.

A metabolism study was carried out on the hay used.

RESULTS

Ewe Feeding

All the diets fed were accepted. In treatment 3 in which long barley straw was given the quantity eaten was small and due to variations in the daily intake of the group the mean energy of the treatment was slightly less than treatment 1 (60 Kcals M.E./ewe/day) in the last 6 weeks.

Even though the brewers grains were dry, particularly so after the addition of minerals and vitamins, they were quite acceptable.

Metabolism Studies

The hay had a metabolisable energy value of 1.67 Kcals/g D.M. and a D.C.P. value of 3.1% D.M. (Table 16).

The analysis of the hay, brewers grains and protein supplement is given in Table 17.

TABLE 16 : Digestibility Trial Results on Hay 1967

	Digestibility (%)	Digestible Nutrients (%)
Dry Matter	81.6	
Organic Matter	52.2	49.7
Crude Protein	40.8	3.1
Ether Extract	15.1	0.2
Crude Fibre	58.2	20.7
N.F.E.	52.4	25.7

	Estimate from Digestibility Trial	Bomb Calorimeter
M.E. Kcals/g (D.M.)	1.78	1.67
M.E. Kcals/g (Fresh)	1.45	1.36

TABLE 17 : Feed Analysis 1967

	Hay	Brewers Grains
Dry Matter	81.20	95.16
Organic Matter	94.30	96.02
Crude Protein	8.27	16.70
Ether Extract	1.35	6.04
Crude Fibre	35.65	19.14
N.F.E.	49.05	54.14
Ash	5.68	3.98

Treatment 1 and Treatment 2 (Expt. A)

Ewe weight and condition (Table 18)

While no difference in condition was apparent the ewes on treatment 2 (incremental increases in energy and protein in last 6 weeks) gained significantly (p 0.05) more weight than those on treatment 1 during the last 6 weeks housed up to lambing. The liveweight loss between mid April and marking was not significantly different but was greatest for ewes on treatment 2. These differences were not reflected in differences in lamb birthweight or weight at marking. Ewe liveweight at clipping and weaning of the two treatments was similar.

TABLE 18 : Corrected ewe liveweights and liveweight gains and losses in treatment groups 1967 (lb)

	Liveweight							
Treatment	Nov	Jan	Feb	Mar	Apr	Marking	Clipping	Weaning
1	136.8	127.4	122.8	133.4	143.0	124.1	126.6	124.9
2	130.3	121.6	128.2	130.8	146.0	123.8	127.2	126.9
3	138.3	129.3	124.2	130.5	141.5	126.0	129.9	128.6
4	128.7	125.7	128.7	132.8	145.9	127.5	130.5	127.7
5	132.0	124.8	125.8	132.9	143.0	122.0	125.0	124.4

	Liveweight differences						
1	-9.4	-4.5	+10.0	+ 9.6	-18.9	+2.5	-1.7
2	-8.4	+6.6	+ 2.5	+15.3	-22.2	+3.4	-0.4
3	-9.1	-5.0	+ 6.3	+10.9	-15.5	+3.9	-1.3
4	-3.0	+3.0	+ 4.1	+13.0	-18.3	+2.9	-2.8
5	-7.2	+1.0	+ 7.1	+10.0	-21.0	+3.0	-0.6

Wool production

The mean weight of the wool clip from ewes on treatment 2 (3.9 lb) was significantly ($p \leq 0.05$) greater than that obtained from ewes on treatment 1 (3.4 lb). It is not clear why this difference occurred, but it is suggested that lack of nutritional stress in last 6 weeks might have influenced this.

Lamb production and performance

There was no significant difference in lamb birthweight, weight at 35, 84 or 140 days, between the two treatments.

Treatment 1 and Treatment 3 (Expt. B)

Ewe weight and condition

There were not significant differences in the mean liveweight of the two treatments at any time during the inwintering period or during the summer. The ewes given straw (Treatment 3) gained more weight during the last 6 weeks of housing but the difference just failed to be significant, ($p \lesssim 0.05$).

Wool production

The ewes given straw gave slightly more wool but the difference was not significant.

Lamb production and performance

There was no significant difference in lamb birthweight, weight at 35, 84 or 140 days, between the two treatments.

Treatment 4 and Treatment 5 (Expt. C)

Ewe weight and condition

When the differential protein levels were started 6 weeks before lambing both groups were of similar liveweight and though during the last 6 weeks of housing up to lambing the ewes on treatment 5 gained on average 2.9 lb less than those on treatment 4 (low protein) this difference was not significant. The ewes on treatment 5 however, lost more weight between mid April and marking (-21.0 lb compared to -18.3 lb).

Wool production

The ewes given the high protein diet (Treatment 5) gave significantly ($p \leq 0.05$) less wool than those on the low protein diet. It is possible that the ewes given the low protein diet also had a higher fibre diet than the ewes on the high protein diet since the former were given dried brewers grains. Because of this the amount of wool 'picking' may have been reduced in treatment 4. Otherwise no other explanation can be offered.

Lamb production and performance

The ewes on the high protein diet produced heavier lambs at birth but the difference was not significant. The mean liveweights of the lambs at 35, 84 and 140 days were not significantly different. Though numbers involved were small, lamb mortality was greatest for ewes on the low protein diet being some 5% greater.

Ewe Mortality

Ewe health was good and mortality was low 3.6%. No ewes died of pneumonia and no one treatment was specifically involved in any cause of disease or mortality. Enterotoxaemia was the cause of at least two of the twelve ewes that died. Other causes were not specific.

Lamb Mortality

Lamb mortality was also low (7.8%). Greatest cause ofloss was mis-mothering which seemed to be the result of lambing at high stocking rates (8-10 ewes per acre). At least 50% of the lambs dying were twins.

TABLE 19 : Corrected Wool Weight 1967 (lb/ewe)

Treatment	1	2	3	4	5
	3.4	3.9	3.6	4.2	3.5

TABLE 20 : Corrected male single birthweight, 35, 84 and 140 day liveweight 1967 (lb)

Treatment	Birthweight	35	84	140
1	9.6	37.4	61.6	80.1
2	9.4	36.2	60.2	78.1
3	9.7	37.0	61.6	80.1
4	9.5	36.6	59.9	81.1
5	10.0	37.5	61.0	79.0

EXPERIMENTAL 1967-68

In an effort to verify the results obtained in 1966-67 regarding the effect of level of protein given during the last 6 weeks of gestation on performance, 4 groups of 50 ewes were used, 2 groups given a level of 0.15 lb D.C.P. and 2 groups given a level of 0.24 lb D.C.P. During this period all the ewes were given 2100 Kcal M.E.

Up to six weeks before lambing all the ewes were given 1800 Kcals M.E. and 0.13 lb D.C.P.

The diets given were as follows:-

1. Hay and protein supplement containing

   28% Oats
   28% Barley
   20% Maize
   20% Groundnut Cake
   6% Molasses

   (low protein diet)

2. Hay and protein supplement containing

30% Oats
30% Barley
25% Fish meal
10% Groundnut Cake
5% Molassine Meal

(high protein diet)

Both were supplemented with minerals and vitamins as in 1965.

Details of the amount fed are given in Table 21.

TABLE 21 : Diets given 1968

lb fresh	gms fresh	Feed	M.E. (Kcals)	D.C.P. (g)
Up to six weeks before lambing				
1.75	795	Hay	1300	29.1
0.46	209	Protein Nut	528	30.6
			1828	59.7
Last six weeks gestation				
High protein				
1.75	795	Hay	1300	29.1
0.75	341	High Protein Nut	856	80.5
			2156	109.6
Low protein				
2.00	908	Hay	1489	33.3
0.52	236	Low Protein Nut	600	34.8
			2089	68.1

A metabolism study was made on the hay.

RESULTS

Ewe feeding

No difficulty was found in obtaining the required feed intakes. The amount of energy given during the period up to 6 weeks before lambing was greater than that used in previous year.

Metabolism Study

A summary of the results are given in Table 22.

TABLE 22 : Digestibility Trial Results on Hay 1966

	Digestibility (%)	Digestible Nutrients (%)
Dry Matter	81.2	
Organic Matter	60.6	56.9
Crude Protein	50.4	4.53
Ether Extract	27.6	0.34
Crude Fibre	61.2	19.7
N.F.E.	62.7	32.3
SE		38.3
T.D.N.		57.4
M.E. Kcal/g (D.M.)		2.04
M.E. Kcal/g (Fresh)		1.66

The metabolisable energy of the hay used was 1.61 Kcals M.E./g D.M. and the digestible crude protein was 4.53% of the dry matter.

The metabolisable energy value of the protein supplement was estimated at 2.90 Kcals M.E./g D.M. the low protein diet containing 16.8% D.C.P. in the D.M. and the high protein diet containing 27.3% D.C.P. in the D.M.

Ewe Weight and Condition

Due to an unbalanced selection the ewes subsequently given the high protein diet were significantly greater in weight than those given the low protein diet when housed. Both groups received identical energy and protein intakes up to 6 weeks before lambing and during this period there was no significant difference between the groups in the mean liveweight change of the ewes.

During the last 6 weeks when differential protein levels were given the ewes given the high protein diet gained significantly ($p \leq 0.01$) greater weight than those given the low protein diet (Table 23).

TABLE 23 : Corrected ewe liveweights and liveweight gains and losses in treatment groups 1968 (lb)

Liveweight

Treatment	Nov	Jan	Feb	Mar	Apr	Marking	Clipping	Weaning
1 High Protein	120.8	110.7	112.2	120.0	133.9	115.4	121.9	118.1
2 Low Protein	128.2	119.1	119.3	126.4	135.4	117.7	124.1	122.8

Liveweight differences

-10.0	+1.5	+7.8	+13.9	-18.4	+6.4	-3.8
- 9.0	+0.2	+7.1	+ 9.0	-17.7	+6.4	-1.4

There was no significant difference in the weight of the ewes at marking or at clipping though the difference at weaning was just significant ($p \leq 0.05$) the ewes given the low protein diet being greater.

There were no significant differences in the rate of change of weight between the groups from mid April to marking.

Wool Production

The ewes given the high protein diet yielded 0.40 lb more wool than those given the low protein diet, this difference was significant ($p \leq 0.05$) (Table 24).

TABLE 24 : Corrected Wool Weight (lb/ewe)

Treatment	1	2
	4.2	3.5

Lamb Production and Performance

The mean birthweight of the lambs from both treatments was identical and the small differences in liveweight at 35, 84 and 140 days were not significant. Growth rates were 0.70 lb/day from birth to 35 days, 0.52 lb from 35 to 84 days and 0.25 lb from 84 days to 140 days (Table 25).

TABLE 25 : Corrected male single birthweight 35, 84 and 140 day liveweight 1968 (lb)

Treatment	Birthweight	35	84	140
1	10.1	34.8	60.2	74.5
2	10.1	34.2	59.7	73.8

Ewe Mortality

The health of the flock was very good throughout the year and mortality was low (3.7%) there being no difference between the ewes given the low protein diet and those given the high protein diet.

Lamb Mortality

Lamb mortality was also low being 4.2% up to 35 days. The lamb count at marking was 7 less than that at 35 days. Total lamb mortality could therefore have been 5.8%.

DISCUSSION

In general the use of hay as the main source of the bulk feed has given no problems. Hay was accepted by all animals and, as far as can be ascertained in a group feeding regime, intakes between animals did not vary unduly, if variation in condition and/or weight change can be taken as giving some indication of relative differences in intake. The relative even quality of hay as a bulk feed has considerable advantage. If protein content is high, supplementation will be low. In 1966, the quality of the hay was such that concentrate feed requirement was very low and in this case the supplement was fed twice weekly in order to even out individual ewe consumption. This arrangement appeared to work satisfactorily. By feeding more hay in some years it would have been possible to provide the ewe with its maintenance requirement in energy and protein but mineral requirement would not have been met. Thus, even when the energy and protein content of a hay is high a supplement will be required to meet the mineral and vitamin requirement of a housed in-lamb ewe.

In practice hay is frequently fed on an ad libitum basis to sheep. It would appear, within the context of this investigation that this would have been wasteful in relation to the nutritional requirement of the animal. It is true, however, that the contentment and more placid animals were those that had access to some form of roughage for most of the day. The feeding of straw in conjunction with hay, as is discussed later, would seem sensible where ewes are housed on slats or sawdust.

The use of long barley straw as a bulk feed did have problems. In 1965, the intakes necessary to provide maintenance could not be attained and an increasing amount of hay was offered to offset these deficiences. Given in conjunction with hay the diet as a whole appeared to give a satisfactory performance. The ewes seemed to be more placid, possibly by virtue of the fact that they always had roughage in the feeding boxes. This was also true of the ewes given a small quantity of straw with hay in 1967.

In 1966 when long barley straw was offered as the only source of roughage the mean intake of straw was 1.5 lb which was achieved during a period of some 21 days and after the concentrate energy part of the ration had been increased by offering barley in addition to the protein supplement. There appeared to be considerable variation in individual ewe intakes and this was reflected in variation in liveweight gains and losses and differences in condition.

There is no reported data available for the feeding of long barley straw to ewes or to sheep in general. This may well be a reflection of the difficulty of obtaining a reasonable intake. Intakes which supply a considerable proportion of the nutrients in diets for cattle can be achieved but straw is only used when the performance requirement is not high e.g. storing cattle through the winter and suckler cow wintering. The variation in straw quality has a considerable affect on intake. From observations straw which was brittle, and well dried was less acceptable than a softer type. Late harvested oat straw was quite unacceptable to ewes. Early harvested barley straw which contained undersown first year grass as hay was much more acceptable.

The digestibility results indicate that both in 1965 and 1966 the straw used had a negative digestible crude protein value, contrary to the accepted analysis in some text books and Bulletin 48. Even when a protein supplement was offered at the rate of 130 to 170 g per head along with 76 g barley, the N balance results indicated that two out of the six ewes on the digestibility trial were in negative balance. The D.C.P. intake as calculated from the apparent digestibility of the diet, however was 66.2 g which would appear from the literature, (McClelland and Forbes, 1968), adequate for a Blackface ewe of 110 lb liveweight.

The use of urea as a source of protein, (comprising 20% of the total nitrogen in the diet), did not appear to increase straw intake in the early stages of feeding to any greater extent than a protein supplement containing only vegetable protein. The performance of the ewes and lambs did not differ significantly from that of the ewes given the long barley straw, vegetable protein diet. The saving in cost was negligible; 5 pence per ewe over the wintering period. Thus, the results would confirm the generally held view that the use of urea in systems of once-a-day feeding, is likely to have little or no advantage over a protein supplement which is of vegetable content.

In 1965, a complete diet, comprising 65% ground barley straw, pelleted with a protein supplement, was used. The performance of the ewes on this diet was comparable to that of ewes given a hay protein supplemented diet. The ewes on the complete diet, however, did not ruminate after one to two days on the feed. The extent to which this affected the digestibility of the diet is not known but it is clear that a reduction could be expected.

After pelleting ground roughage, the dry matter digestibility has been shown by a few workers to increase but by far the majority show that it is depressed, (Minsen, 1963). There are indications however, that the net energy value of pelleted and unpelleted feeds will tend to remain constant by virtue of the fact that high faecal energy loss will be compensated by low losses of energy as heat and methane when feeding pellets, (Blaxter and Graham, 1956). The apparent dry matter digestibility of the ground barley straw pellet was 47.2% compared to that of 45.8% for the long barley straw and 61.2% for the hay used in 1965. While the source of the barley straw was different, it is significant that the M.E. value of the long barley straw was identical to that of the complete pellet. The fact that the straw was ground and pelleted, however, made it possible for the ewe to consume up to 738 g straw supplying 1737 kcals M.E. whereas a maximum of 381 g of long straw was consumed in 1965, (518 kcals M.E.), and 635 g in 1966, (839 kcals M.E.). It is clear, therefore, that straw, if ground and pelleted, can make a considerable contribution to the total diet of a pregnant ewe which is dependent upon its total nutritional intake being supplied. The feeding of long barley straw has proved difficult and by virtue of the considerable variation in intake that is experienced with sheep it is a nutritionally unreliable feed, particularly if of poor or varying quality. The poor performance of the ewes given the long barley straw diets in 1966 would confirm this view.

The cost of transporting and the processing of straw, in order to make it a more nutritionally reliable feed, both in terms of intake and quality, would appear to be too high in relation to other feed alternatives. For example, when used in 1965, the cost per ewe on the complete pelleted straw diet was more than double the cost of the ewes given the hay, protein supplemented diet, (52s. compared to 25s.). Methods which would improve the efficiency of harvesting straw into smaller bulk would also reduce transport costs appreciably, but whether it will be possible to reduce processing costs will depend on the development of more efficient machinery.

It is probably unnecessary, however, that straw must be ground and pelleted to render it useful as a sheep feed. The author has investigated the use of a chopped straw, energy and protein supplemented diet, for both lambs and ewes. In the case of lambs the straw was chopped to a mean length of $\frac{5}{8}$" and compressed with the other dietry constituents into a'flake'. For ewes the straw was chopped to a mean length of 1" and compounded into a 1" pellet. The ewes given this diet were individually fed and variation in daily intake was low but the speed of completing their daily ration varied considerably which would suggest that it might not be a good feed to use in a group feeding system at the rate of straw inclusion used here, (60%). The highest inclusion rate used for lambs was 40%; used for ewes, the intakes of this diet would be low if equated with practical nutritional requirements. This again would tend to be undesirable since it would be likely that group fed animals would inevitably have variable feed intakes dependent upon differences in speed of eating and whether an animal is an aggressive or a placid member of the group.

Nevertheless methods by which straw can be chopped and included at higher rates, (60-70%), in a complete diet would seem necessary if straw is to be widely used in systems of feeding in which intake is controlled. It would seem that the costs of chopping and inclusion are likely to be less than grinding and pelleting.

The total cost of feeding of the ewe during the winter period is influenced by the amount of energy and/or protein supplement required to provide a balanced diet. More particularly the amount of protein required will influence the price of the diet chosen. The fact that the diet is ground and pelleted will also increase the cost of the diet.

The level of protein supplementation in a diet will be determined to a great extent on the quality of the bulk feed in respect of protein. As has already been mentioned the supplementation of a good quality hay is likely to be low and in general it is desirable to make or buy a better quality roughage feed in order to avoid the purchase of large amounts of protein concentrate though this will depend on the increase in the price of the hay relative to the increase in its D.C.P.

In this series of investigations proprietary protein supplements were primarily used. These were ground feeds, mixed and pelleted and apart from the one year in 1966, when one of the treatments included urea, they contained only vegetable sources of protein. Pelleted feeds compounded on the farm were also based on vegetable protein.

In 1967, however, brewer's grains, a by-product of the brewing industry were used. These with the addition of a mineral supplement, provided a satisfactory diet at a less cost than would have obtained by using a more conventional form of supplement. Though high in fibre and dry matter they were palatable and accepted by the ewes. It was probable that there was a more even distribution in intake due to the nature of the feed. It was notable that the ewes given the brewer's grains were slower to finish feeding than those on proprietry pellets.

In a system of hill sheep management which is highly sensitive to variable costs, due in the main to high feed costs, it is important to use feeds which are cheap, yet palatable and unvarying in quality. Many of the by-products available from the brewing and distilling industries are suitable as sheep feeds and could be used to advantage where sheep are housed. They are not suitable for outdoor feeding due to their lightness and dryness.

A preliminary investigation using a small number of ewes, in 1967, to test different protein levels given on a group feeding basis, gave results which suggested that for the two levels used there was no difference in the performance of ewes, in terms of weight change during gestation, lamb birth-weights and early lamb growth rates. In the last six weeks of gestation 0.14 lb D.C.P./ewe/day was given to the low protein group and 0.30 lb/ewe/day to the high protein group.

These results were largely confirmed in 1968 when the level of protein intake under test were 0.15 lb D.C.P. and 0.24 lb D.C.P. There was a significantly greater liveweight gain among ewes on the high protein diet but this did not result in any greater lamb birthweights or liveweight gains during early lactation. The amount of wool produced from the high protein group was significantly greater than from the low protein fed group, which is in direct contrast to the results obtained in 1967. It is felt that little confidence can be put on the total wool clip results since wool loss due to rubbing on feed boxes and wool 'picking' was variable among groups. Wool 'picking' may be related to the level and type of fibre in the diet. As was observed there was a considerable amount of wool 'picking' in the ground barley straw fed ewes in 1965 which was attributed to the fact that the ewes no longer ruminated on this diet. Regardless of diet wool 'picking' may well be the result of boredom.

In regard to crude fibre level in the diets used for the protein level experiment in 1967, the protein concentrate used on the high level had a crude fibre content of 6.5% while the low protein concentrate (brewer's grains), had a crude fibre content of 19.1%. The crude fibre level in the diet may have affected the extent to which wool 'picking' took place and it may also have affected the actual D.C.P. requirement of the ewe, since Elliott and Topps (1964), found that maintenance requirement increased by 0.25 $\pm$ 0.06 g N per day per unit increase in the ratio of roughage to concentrate.

The fact that no appreciable difference occurred in the performance of pregnant ewes on widely different protein levels is in general agreement with Whiting and Slen (1959), though they gave greater amounts of energy to larger ewes. The results agree more particularly with those of McClelland and Forbes (1970), in which they studied the response in liveweight of the Blackface ewe and the birthweight of its lamb, given different protein and energy levels. Levels of 0.15 lb D.C.P. per ewe per day are suggested as being adequate for a Blackface ewe of about 100 lb liveweight receiving energy between 1600 - 2000 kcals M.E. per ewe per day during the last 40 days of gestation. This suggests that the N.R.C. recommendations for protein during gestation are greater than necessary for the Blackface ewe and indeed for ewes of greater body weight, (Lowman, 1970; Robinson and Forbes, 1967).

It is clear that even though ewes may retain more nitrogen as D.C.P. intake increases, the maximum efficiency of nitrogen utilisation is likely to take place at a lower level of D.C.P. intake, (McClelland and Forbes 1970; Robinson and Forbes, 1967), though the latter will vary with energy intake. At the levels of energy intake likely to be used in practice the D.C.P. intake found by McClelland and Forbes, (1970), to equate with maximum efficiency of utilisation was 0.16 lb D.C.P. per day at 1600 kcals M.E. per day which is similar to the lower level of intake of D.C.P. in the group feeding experiments carried out in this investigation.

The different energy levels used during the four years feeding experiments have been discussed earlier in relation to the whole flock performance. In relation to the level of performance per ewe obtaining at present the levels used in 1965, 1967 and 1968 would appear adequate.

Russel et al. (1967), have estimated that at term the energy requirement of a 110 lb ewe with an averaged sized single foetus would be of the order of 900 g DOM or 3600 kcals M.E. which is approximately 180% of the value used in these investigations. The same workers suggest that the requirement for a similar ewe with twin foetuses may be of the order of 1250 g DOM or 5000 kcal M.E. which is 250% of the value used in these investigations. These calculations suggest that even allowing for the use of a proportion of body reserves the levels of energy currently being used would be inadequate for the flock if a greater output per ewe is likely to occur than exists at present.

Studies, reported later, on the change in body composition of ewes given levels of nutrition below those used here indicate that there is considerable utilisation of body tissue and that levels below 1200 kcals M.E. per day up to 100 days gestation and below 1600 kcals per day in the last 40 days gestation would be inadequate for the type of ewe used in these investigations. It is clear, however, that the ewes used by McClelland and Forbes, (1970), were able to perform satisfactorily on 1600 kcals M.E. per day during the last 40 days of gestation.

It has been suggested by Russel et al., (1967), on the basis of unpublished work by their colleague Eadie that the ewe on hill pasture obtains between 350-500 g DOM. (1400-2000 kcals M.E.), up to a month before parturition and then 700-800 g DOM, (2800-3600 kcals M.E.). These levels of intake appear high in relation to the levels used in these studies and particularly in regard to the liveweight increase of the Boghall ewes in the last 40 days gestation compared to the Howgate ewes. The ewes on Howgate are grazing on pasture not disimilar to those on which Eadie carried out his studies.

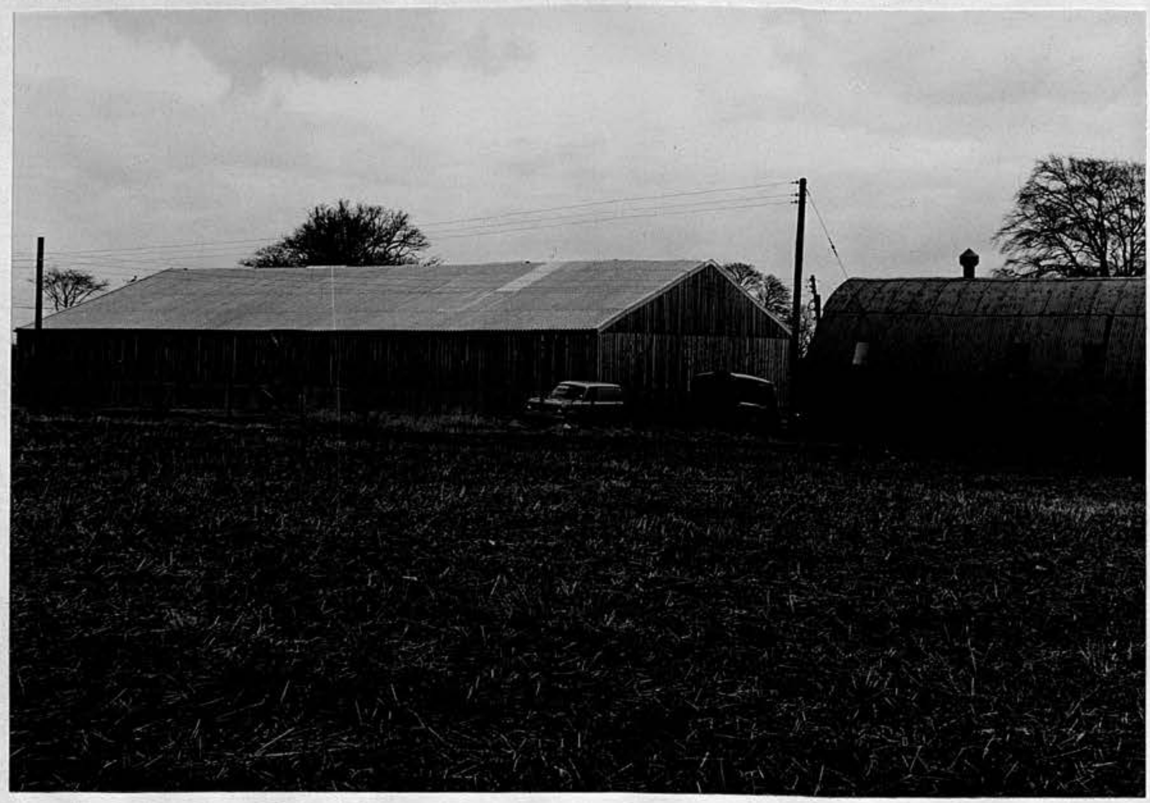
It is apparent that there are variations in the estimates made for the requirements of the pregnant ewe. Some of this variation may well be due to the differences in the efficiency of utilisation of energy used for foetal development. Graham, (1964) has calculated that the net efficiency of utilisation of a Merino foetus was 13% while Russel et al. (1967), have estimated this to be 7% for a Blackface foetus though using Graham's figure of daily energy storage in the foetus of 20 kcal per kg. Langland and Sutherland, (1968), estimate the foetal requirement to be 184 kcal per kg which is much lower than that of Russel et al., (1967), and of that suggested by Reid, (1963). The variation in efficiency of energy utilisation could be genetic or it may vary with the amount of energy being catabolised from the ewes own body reserves. It has been suggested by Graham, (1964), that the fat animal tends to be a less efficient utiliser of energy than the thin. This concept may also help to explain some of the variation in the estimates for energy during gestation. The extent to which any level of energy is likely to be adequate will depend on the amount of body reserves available and the ability of the ewe to utilise these efficiently.

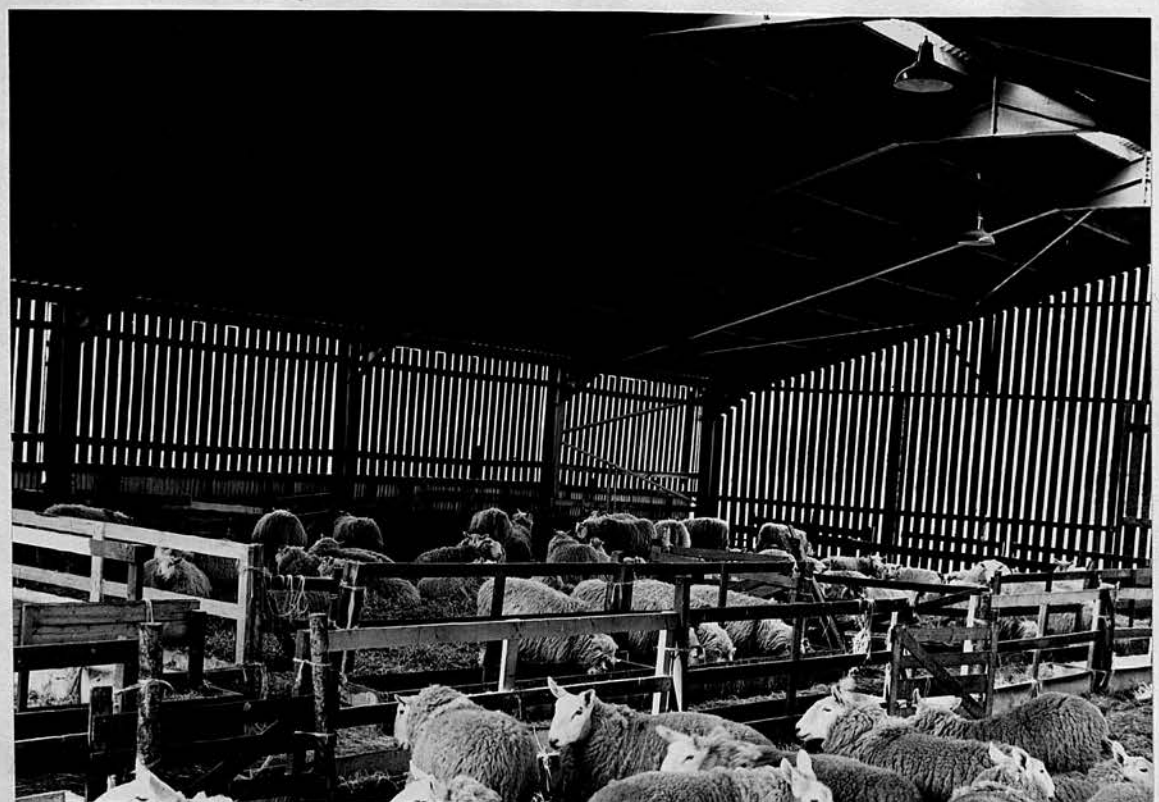
The pattern of foetal development (Cleote, 1939), suggests that increases in the level of nutrition of the pregnant ewe should be carried out incrementally over the last 40 days of gestation. By meeting the demand of the foetus more effectively in this way it is reasonable to expect that a more efficient use is made of the energy given, which may also have side implications relative to the utilisation of body reserves. The experiment carried out to test this on a group feeding basis indicated that there was a more efficient utilisation of feed during this period. This was indicated by a significantly greater increase in the liveweight of the ewes fed in this way during the last 40 days of gestation. This gain, however, was not reflected in a better performance in terms of either greater lamb birthweights or greater liveweight gains in the early life of the lamb.

Since undernutrition is inevitable at the levels of nutrition that are likely to be economically acceptable it is perhaps debateable whether any increase in efficiency of utilisation may be obtained by incremental feeding or indeed whether any improvement in performance can be realised from a ewe which appears to have adapted to a nutritional environment in which it can readily utilise body reserves. By feeding at a flat rate in the last part of gestation the worst that may happen is that there would be a delay in the utilisation of these reserves.

Out of this investigation various important aspects of animal management relative to the feeding and housing of ewes became evident.

It was quickly recognised that the Blackface ewe was readily adapted to a housed environment. The design of the house used, with its outside and inside areas for each pen, enabled the ewe to chose two different environments under certain climatic conditions. In general, all the ewes were sheltered from strong blasts of wind and in only exceptional cases did all the ewes attempt to get under cover; these were in heavy downpours, driving rain or snow; otherwise in light rain or snow ewes remained either outside or under cover.





It is, nevertheless, probably desirable to have a complete cover over the ewes, since once wet the slats became extremely slippery and could be dangerous, feed boxes were filled with water and hay in boxes could be spoiled. It would still be possible to ventilate the house sufficiently well to prevent pneumonia. An example of such a house is given in the photograph.

The number of ewes kept in any one pen should not exceed 50 and a lesser number is more desirable. The behaviour of housed ewes contrasts markedly with that of the ewe in a free and extensive grazing situation. Competition at feeding boxes encourages aggressiveness and a 'peck order' is quickly established. Clearly young ewes and thin ewes require to be housed seperately from the rest of the flock if they are to perform well. Undoubtedly the smaller the number of ewes kept in a pen will help to eliminate bullying especially if ewes noted for this characteristic are penned separately.

To be able to split ewes into groups, whether it be by age, condition or time of lambing is of considerable advantage in maximising the efficiency of total flock feed utilisation.

Shepherding conditions during the winter months are improved and the general care and husbandry of ewes can be maintained more effectively.

The lambing of some of the ewes inside proved on the whole to be satisfactory but the time and labour spent in moving ewes and lambs and 'mothering up' was excessive. Had the house been more closely adjacent to the hill area the use of the house for lambing would have been made practicable.

Stocking intensity in the house was generally too great for the purposes of lambing. Mismothering was apt to occur but this could be overcome if a continuous watch could be maintained on the ewes. In most practical situations this could not be done.

profit fell dramatically. In 1967/68 with a greater lamb crop and better prices and a further increase in Government Support income rose to its fourth highest level since 1945, at £1800 per farm (Government Support £2314).

Since 1957/58 there has been a further increase in labour costs of £0.19/ewe but there is some evidence that the number of man hours per ewe has become less. Other costs have risen by £0.42 per ewe since 1957/58.

From 1963 Government Support per farm has exceeded farm profit in every year except 1965.

A similar pattern of results from 1961/62 is evident from a larger sample selected from the whole of Scotland. The data in Table 1 shows the variation in net farm income from a varying sample of hill farms in Scotland. The sample remains the same for any two consecutive years. Table 2 shows the variation in total costs of the sample farms and Figure 2 shows the distribution of net incomes 1965-67. (Scottish Agric. Economics (1961-67)).

TABLE 1 : Net Farm Incomes From A Sample Of Scottish Hill Farms 1961-67 (£)

1961/62	1962/63	1963/64	1964/65	1965/66	1966/67	1967/68
1215	832					
	914	1546	1676			
			1578	1372		
				1259	776	
					966	1322

'The effect of Plane of Nutrition
and Stage of Gestation on the weight
of the major body components of
the Blackface ewe.'

The Effect of Plane of Nutrition and Stage of Gestation on the weight of the major body components of the Blackface ewe.

INTRODUCTION

Though it is generally accepted that the ewe utilises body reserves during gestation there is little information on the extent to which she does this. Russel, Gunn and Doney (1968) examined the effect of gestation on the carcass components of Blackface ewes which were selected from a flock of mixed ages grazing on hill pastures containing approximately 50% heather, the ewes were free grazing and no information on intake was available.

The study outlined below was an attempt to establish the effect of differences in plane of nutrition on the major body components of a group of Blackface ewes which were on a controlled feeding system of management during the last two-thirds of the gestation period.

EXPERIMENTAL

I. (1965)

A group of 40 ewes was mated and the day of mating noted. After 35 days the ram was withdrawn and the ewes weighed. The experimental group of ewes was selected according to date of mating, weight and condition. The group of ewes as a whole was expected to lamb within a period of seven days.

At that time, five of the twenty one ewes selected as being representative of the remaining ewes in weight and condition were slaughtered.

The remaining 16 ewes were distributed among four treatment groups, viz. P100 H, P100 L, P140 H and P140 L according to weight and condition, and fed individually on a ground barley straw pelleted diet during the last 100 days of gestation.

Groups P100 H and P140 H were allowed sufficient of the ground barley straw pellet to provide 1600 Kcals M.E./ewe/day and 64 g D.C.P./ewe/day. At 100 days after mating the ewes in group P100 H were slaughtered and the ewes in group P140 H were given an increased amount of ground barley straw pellet to provide 2000 Kcal M.E./ewe/day and 85 g D.C.P./ewe/day. These ewes were slaughtered at 140 days after mating.

Groups P100 L and P140 L were allowed sufficient of the ground barley straw pellet to provide 1120 Kcal M.E./ewe/day. At 100 days after mating the ewes in group P100 L were slaughtered and the ewes in group P140 L were given an increased amount of ground barley straw pellet to provide 1400 Kcals M.E./ewe/day. These ewes were slaughtered 140 days after mating.

The low plane of nutrition was 70% of the high plane of nutrition during the experimental period.

The ewes were penned individually in wooden pens 5' x 4', with sawdust bedding and water and feeding buckets. Water was on offer at all times and the ewes were fed once daily in the morning. They were housed in well ventilated accommodation and at temperatures which differed little from those outside. There was complete protection from wind and rain.

The composition of the diet used is given in Table 1 and digestible nutrients in Table 2.

TABLE 1 : Composition of Ground Barley Straw Diet

	%
Ground Barley Straw	69.0
Extracted Ground nut	13.5
Extracted Soya	2.0
Maize	0.8
Molasses	11.6
Tallow	0.3
Dicalcium Phosphate	0.4
Lime	1.2

TABLE 2 : Digestible Nutrients (%) of Ground Barley Straw Pellet

Organic Matter	44.7
Crude Protein	6.6
Other Extract	1.0
Crude Fibre	13.8
N.F.E.	23.3
T.D.N.	46.0
Kcals/g (D.M.)	1.50*

*(Calculated from the relationship 1 lb T.D.N. = 1616 kcals M.E.)

At slaughter each body component was removed and weighed as follows:-

Blood,

Pelt,

Feet,

Gravid Uterus and Gut with 'fill'

Pluck (liver, lungs, heart and trachea),

Warm carcass with head,

Head after removal.

The gut contents were removed by washing and the gut reweighed and the 'fill' calculated by difference.

The carcass was hung overnight, reweighed and split into two halves along the axis of the vertebrae.

One half of the carcass was dissected into, muscle, fat and bone, each being weighed separately.

Weighed, minced and homogenised samples of fat and muscle were dried to constant weight for approximately 36 hours at 105-110°C. Moisture contents were calculated. The remaining material was Soxhlet - extracted with petroleum ether. Fat free dry matter was calculated as the difference between the total dry matter weight of the sample, less the fat content.

One animal from group P140 H was discarded since it aborted four days before slaughter.

The effect of treatment on the various carcass components was ascertained after multiple regression on liveweight and foetal weight. Treatment means were then statistically tested for significant differences after adjustment for variation in liveweight and foetal weight.

II. (1966)

Twenty eight Blackface ewes were selected from a larger group of 40 ewes according to date of mating, weight and condition. Four ewes were slaughtered 35 days after mating and the remaining ewes were housed and fed individually on a pelleted grass diet during the last 100 days of gestation, at different rates of intake. Two levels of nutrition were allowed up to 100 days gestation and two levels from 100 to 140 days gestation in a comparative slaughter experiment of 2 x 2 factorial design.

This gave six groups of ewes as follows, with number of ewes in each group in brackets; P100 H (6), P100 L (6), P140 HH (3), P140 HL (3) and P140 LL (3), P140 LH (3). Due to loss of carcasses, (rejected as being excessively emaciated by slaughter house authorities and destroyed prior to collection from cold storage), deaths, and barren ewes groups P140 LH and P140 LL were abandoned.

Groups P100 H and P140 HH and P140 HL were allowed sufficient of the grass pellet to provide 1670 kcals M.E./ewe/day and 98 g D.C.P./ewe/day. At 100 days after mating the ewes of group P100 H were slaughtered. The amount of grass pellet allowed for ewes in group P140 HH was increased to provide 2490 kcals M.E./ewe/day and 146 g D.C.P./ewe/day. The grass pellet allowance was increased for ewes in group P140 HL to provide 1972 kcals M.E./ewe/day and 116 g D.C.P./ewe/day. Both these groups were slaughtered 140 days after mating.

Group P100 L was allowed sufficient of the pellet to provide 998 kcals M.E./ewe/day and g D.C.P./ewe/day. (See Table 3)

TABLE 3 : Experimental design 1966.

	P100 H	P100 L	P140 HH	P140 HL	P140 LL*	P140 LH*
No ewes	6	6	3	3	3	3
M.E./Day to 100 Days	1670	998	1670	1670	998	998
M.E./Day from 100-140 Days	-	-	2490	1972	1972	2490

* Abandoned

The procedure for slaughter and chemical analysis was carried out in exactly the same way as in 1965.

The composition of the grass pelleted diet is given in Table 3 and the digestible nutrients (%) which were obtained from a digestibility trial are presented in Table 4.

TABLE 4 : Composition of Grass Pelleted Diet (%)

Dried Grass	67.8
Maize Meal	18.5
Soya Bean Meal (Est)	10.0
Dicalcium Phosphate	0.8
Molasses	2.5
Vit. and Minerals	0.4

TABLE 5 : Digestible Nutrients of Grass Pelleted Diet (%)

Organic Matter	68.1
Crude Protein	14.9
Ether Extract	2.6
Crude Fibre	11.8
N.F.E.	38.8
T.D.N.	71.4
Kcals/g	2.54*

*(Calculated from the relationship 1 lb T.D.N. = 1616 kcals M.E.)

Statistical analysis was carried out in a similar way to that described for 1965 data.

For the purposes of statistical analysis the carcass components were designated as follows:-

Maternal Empty Body (M.E.B.) - the live body less, pelt, gut fill and gravid uterus.

Carcass (C) - total fresh weight of the muscle, fat, and omental tissues (the omental tissues constituting the pluck and gut).

Gravid Uterus (F)

Muscle (M) - total muscle expressed in the dry matter.

Fat (FA) - total fat expressed in the dry matter.

Omental Tissue (O) - expressed in the dry matter.

Bone (B) - as fresh.

Ether Extract (EE) - total ether extract of the muscle, fat and omental tissues.

Fat Free Dry Matter (FFDM) - total fat free dry matter of the muscle, fat and omental tissues.

Water (W) - the water contained in the muscle, fat and omental tissues.

Ether Extract of the Muscle Tissues (EEM).

Ether Extract of the Fat Tissues (EEFA).

Ether Extract of the Omental Tissues (EEO).

RESULTS

I. (1965)

The data obtained for each ewe and the mean of each treatment group is given in Table 6. The difference between the mean of the treatment groups and the mean of the initial group is given in Table 7 after adjustment for live-weight and foetal weight. The factors used for adjustment are also given in Table 3 where LM and FM the differences between the means of the treatment groups and the mean of all the ewes included in the initial and treatment groups.

TABLE 6 : Individual Body Component Weights and Unadjusted Group Means. (1965)

Ewe Identity	Classn.	LW	MEB	C	F	M	FA	O	B	EE	FFDM	W	EEM	EEFA	EEO
269	I	40.31	27.93	21.21	0000	2.80	3.45	2.35	3.03	5.38	3.22	12.61	0.71	3.13	1.54
254		39.30	29.89	23.24	0000	2.88	4.78	2.81	2.88	7.31	3.16	12.77	0.79	4.45	2.07
274		42.96	32.02	25.02	0000	3.13	5.87	2.79	3.04	8.44	3.35	13.23	0.90	5.49	2.05
261		44.62	32.38	24.96	0000	3.17	4.66	3.18	3.33	7.39	3.62	13.95	0.90	4.26	2.23
267		50.88	36.90	28.10	0000	3.44	5.38	3.71	3.72	8.65	3.88	15.57	0.96	4.94	2.75
		43.61	31.82	24.50		3.08	4.82	2.97	3.20	7.43	3.45	13.62	0.85	4.45	2.13
278	P100 H	41.90	28.34	20.28	03.53	2.85	3.37	2.66	3.14	5.67	3.21	11.40	0.70	3.03	1.94
277		42.63	28.16	20.12	03.94	2.61	3.10	2.83	3.22	5.73	2.81	11.58	0.72	2.82	2.19
243		43.11	30.25	21.29	04.70	3.07	3.69	2.76	3.68	6.57	2.95	11.77	0.89	3.46	2.22
241		50.59	32.43	22.91	06.18	2.98	3.91	2.85	4.26	6.57	3.17	13.17	0.95	3.55	2.07
		44.56	29.80	21.15	4.50	2.88	3.52	2.78	3.58	6.10	3.04	11.98	0.82	3.22	2.11
270	P100 L	43.40	28.31	19.96	04.00	3.03	2.77	1.97	3.52	4.70	3.07	12.19	0.93	2.45	1.32
265		41.90	27.64	19.93	03.52	2.71	3.67	2.15	3.14	5.54	2.99	11.40	0.66	3.32	1.56
245		42.77	30.52	22.19	02.91	3.10	4.34	2.61	3.62	6.81	3.24	12.14	0.95	3.93	1.93
244		49.13	34.25	25.02	04.74	3.12	4.67	2.36	4.12	6.34	3.84	14.56	0.82	4.03	1.47
		44.30	30.18	21.78	3.79	2.99	3.86	2.27	3.60	5.85	3.29	12.65	0.84	3.43	1.57
258	P100 H	54.22	28.52	19.03	13.31	2.36	2.39	2.29	3.67	3.73	3.31	11.89	0.38	1.99	1.36
260		43.69	25.56	17.04	07.92	2.53	1.48	1.89	3.34	2.98	2.92	11.14	0.67	1.26	1.05
255		51.84	30.86	22.74	09.24	2.48	2.00	2.31	3.12	3.79	3.00	15.95	0.59	1.73	1.47
		49.92	28.31	19.60	10.16	2.46	1.96	2.16	3.38	3.50	3.08	12.99	0.55	1.66	1.29
276	P100 L	47.05	27.83	19.27	09.89	2.29	2.34	2.56	3.34	4.17	3.02	12.08	0.52	1.97	1.68
264		44.57	23.28	15.34	07.14	1.82	1.66	2.00	3.34	3.09	2.39	9. 56	0.41	1.43	1.25
253		41.64	24.79	17.23	06.72	2.35	1.32	1.74	3.16	2.44	2.97	11.52	0.28	1.11	1.05
251		46.17	29.07	20.86	07.66	3.20	2.58	2.26	3.04	4.49	3.55	12.82	0.72	2.29	1.48
		44.86	26.24	18.18	7.85	2.42	1.98	2.14	3.22	3.55	2.98	11.65	0.48	1.70	1.37

TABLE 2 : Total Costs On A Sample Of Scottish Hill Farms 1961-67 (£)

1961/62	1962/63	1963/64	1964/65	1965/66	1966/67	1967/68
3781	4067					
	3994	4004				
		3895	3979			
			3645	3792		
				3795	3844	
					3922	4021

There is no comparable data available for the amount of Government Support on these farms.

While output per unit of input is higher than on most other types of farms (Table 3) this is largely the result of the extensive nature of hill sheep farms and a relatively low level of inputs. It also reflects the large subsidy element in the value of output.

Thus it is clear that the profitability of hill farming has been maintained by an increasing level of Government Support, particularly in recent years. Lamb prices have failed to increase relative to costs, thus, even with Government Support net farm incomes have not risen appreciably.

Substantial increases in the price obtained for store lambs is unlikely to take place with current levels of supply and demand. Economically, therefore, to make hill farming more secure, it would appear that it will need to develop in a direction similar to that seen elsewhere in farming, growing scale of business, with more intensive land use but using less labour. This is particularly so in the case of the smaller hill farm.

TABLE 7 : Fitted Value of the Mean Initial Group and Differences of the Treatment Groups After Adjustment for Differences in Liveweight and Foetal Weight from the Population Mean (LW_M and F_M) (1965)

	C	MEB	M	FA	O	B	W	EE	FFDM	EEM	EEFA	EEO
Initial	22.18	29.91	2.73	4.93	2.78	3.36	11.67	7.06	3.39	o.67	4.46	1.93
P100 H	-0.81	0.19	0.16	-1.35	0.02	0.25	0.42	-0.84	-0.32	0.15	-1.20	0.20
P100 L	-0.57	0.26	0.21	-0.99	-0.51	0.30	0.76	-1.20	-0.08	0.15	-0.98	-0.37
P140 H	-1.76	-1.66	-0.03	-3.40	-0.63	-0.37	2.39	-3.64	-0.42	0.03	-3.10	-0.57
P140 L	-1.76	-1.51	-0.03	-2.88	-0.43	-0.17	1.70	-3.06	-0.29	-0.04	-2.66	-0.36
LW_M	0.59	0.73	0.05	0.10	0.07	0.07	0.37	0.17	0.06	0.02	0.09	0.05
F_M	-0.68	-0.63	-0.09	-0.01	-0.06	0.01	-0.53	-0.13	-0.03	-0.05	-0.03	-0.06

TABLE 8 : Fitted Value of the Mean Initial Group and Differences of the Treatment Groups after Adjustment for Differences in Liveweight and Foetal Weight from the Population Mean (LW_M and F_M) (1966)

	C	MEB	M	FA	O	B	W	EE	FFDM	EEM	EEFA	EEO
Initial	20.01	30.09	2.97	2.59	2.34	4.54	12.11	4.63	3.28	0.86	2.19	1.57
P100 H	-0.51	-1.30	-0.20	-0.15	-0.37	-0.32	0.19	-0.60	-0.11	-0.06	-0.18	-0.37
P100 L	-1.68	-1.62	-0.52	-1.21	-0.90	-0.08	0.94	-2.17	-0.46	-0.20	-1.15	-0.82
P140 H	-1.99	-2.83	-0.28	-1.00	-0.32	-0.36	-0.37	-1.47	-0.15	-0.14	-0.91	-0.42
P140 L	-1.40	-2.84	-0.76	-1.20	-0.72	-0.63	1.28	-2.11	-0.57	-0.31	-1.06	-0.74
LW_M	0.48	0.67	0.02	-	-0.03	0.10	0.49	-0.08	0.06	-0.01	-0.02	-0.04
F_M	-0.53	-0.41	-0.03	-0.04	-0.01	0.06	-0.44	-0.04	-0.05	-	-0.04	-

TABLE 9 : Individual Body Component Weights and Unadjusted Group Means (1966)

Ewe Identity	Classn.	LW	MEB	C	F	M	FA	O	B	EE	FFDM	W	EEM	EEFA	EEO
414	I	44.19	32.92	22.09	0000	3.27	2.68	2.03	5.18	4.45	3.53	14.11	0.98	2.31	1.16
120		42.35	30.85	21.45	0000	3.02	2.23	2.36	4.11	4.11	3.50	13.54	0.80	1.78	1.53
249		39.95	30.10	21.74	0000	3.02	3.45	2.59	3.63	5.74	3.32	12.68	0.82	3.06	1.86
182		42.38	31.36	21.47	0000	3.03	2.57	2.59	4.34	4.81	3.38	13.28	0.83	2.16	1.82
		42.21	31.31	21.69		3.09	2.73	2.39	4.32	4.78	3.43	13.47	0.86	2.33	1.59
411	P100 H	39.45	26.63	18.90	03.13	2.87	2.26	1.98	3.57	4.01	3.10	11.79	0.86	1.98	1.17
553		41.78	28.08	19.08	02.88	2.76	2.27	1.81	3.97	3.52	3.32	12.24	0.76	1.73	1.03
125		47.36	31.98	20.78	05.66	3.20	2.70	2.00	5.04	4.20	3.70	12.88	0.84	2.11	1.25
250		42.12	28.73	19.62	02.06	2.71	2.97	2.20	4.17	4.92	2.96	11.74	0.80	2.59	1.53
412		44.07	30.17	20.53	03.00	2.60	1.52	1.63	4.17	2.54	3.21	14.78	0.66	1.11	0.77
413		44.13	29.43	19.38	04.87	2.58	2.88	2.07	4.92	4.59	2.94	11.85	0.88	2.40	1.31
		43.15	29.17	19.72	3.60	2.79	2.43	1.95	4.31	3.96	3.21	12.55	0.80	1.99	1.18
251	P100 L	39.82	26.86	16.98	02.61	2.53	1.39	1.40	4.57	2.67	2.65	11.66	0.82	1.14	0.71
316		40.50	27.79	17.54	02.49	2.34	0.85	1.33	4.32	1.63	2.89	13.02	0.53	0.56	0.54
106		37.87	26.18	16.64	02.27	2.23	0.92	1.31	4.34	1.90	2.56	12.18	0.56	0.67	0.67
263		37.79	25.11	16.20	03.33	2.23	2.17	1.83	3.51	3.98	2.25	9.97	0.83	1.85	1.30
273		38.82	27.45	17.90	02.07	2.62	2.17	1.97	3.97	4.02	2.74	11.14	0.93	1.81	1.28
225		43.93	28.35	19.12	03.56	2.55	1.05	1.31	4.25	1.92	2.99	14.21	0.54	0.77	0.61
		39.79	26.96	17.40	2.72	2.42	1.43	1.53	4.16	2.69	2.68	12.03	0.70	1.13	0.85
145	P100 H	45.28	27.48	17.72	07.02	2.21	1.07	1.49	4.44	1.91	2.86	12.95	0.48	0.78	0.65
207		46.72	29.97	20.63	03.79	2.69	2.16	2.20	4.17	3.77	3.28	13.58	0.72	1.72	1.33
150		42.05	26.32	15.69	05.41	3.11	1.23	2.08	4.97	3.05	3.37	9.27	0.91	0.94	1.20
		44.70	27.92	18.01	5.41	2.67	1.49	1.92	4.53	2.91	3.17	11.93	0.70	1.15	1.06
180	P100 L	43.47	26.89	17.38	05.89	2.18	0.45	1.21	4.67	1.08	2.76	13.54	0.37	0.31	0.40
301		45.04	26.73	17.45	08.02	2.00	1.06	1.69	4.10	2.19	2.56	12.70	0.54	0.78	0.87
178		44.87	28.14	18.63	06.11	2.26	2.21	1.64	4.17	3.42	2.69	12.52	0.67	1.79	0.96
		44.46	27.25	17.82	6.67	2.15	1.24	1.51	4.31	2.23	2.67	12.92	0.54	0.96	0.74

There was a loss in maternal empty body weight as gestation progressed.

Variations in M.E.B. weight were significantly related to variations in ewe liveweight ($p = 0.001$) and foetal weight ($p = 0.11$). There were no significant differences between nutritional treatments and while M.E.B. was greater in weight at 100 days after mating compared to 140 days the difference was not significant.

The multiple regression of M.E.B. on liveweight, foetal weight and treatment is given by:-

M.E.B. = 29.91 + 0.73 L.M. - 0.63 F.M. $\pm$ ($p = 0.0001$) where

is the fitted value due to the effects of treatment.

There was also a progressive loss in the weight of the carcass. Variations in carcass weight were significantly reflected by variation in liveweight ($p = 0.003$) and foetal weight ($p = 0.09$).

There were no significant differences between nutritional treatments or at the various stages of gestation.

The multiple regression for carcass weight on liveweight, foetal weight and treatment is given by

$$C = 22.18 + 0.59 L_M - 0.68 F_M - KC \ (p = 0.0001).$$

Differences in carcass components that were shown to be significant ($p < 0.10$) due to treatment effects, after adjustment, were evident for the omental (DM) tissue, and bone; other differences ($p < 0.20$) included fat (DM) tissue, total ether extract and ether extract of the muscle and omental tissues.

Variation in liveweight was significantly ($p < 0.10$) reflected in variation in weight of muscle (DM), fat (DM), omental tissue (DM) bone total EE, fat free dry matter, water, muscle EE, fat EE and omental EE. Variation in foetal weight significantly affected variations in the weight of water ($p = 0.056$) and ether extract of the muscle ($p = 0.20$).

Up to 100 days gestation the weight of omental tissue (DM) of the ewes on the high plane of nutrition (P100 H) was similar to that of ewes slaughtered at 30 days gestation. The ewes on a low level of nutrition (P100 L) over the same period lost 0.50 kg of omental tissue (DM). The difference between the two groups P100 H and P100 L was significant ($p < 0.05$).

The ewes on the high and low planes of nutrition up to 140 days (P140 H and P140 L) gestation lost respectively 0.63 kg and 0.43 kg omental tissue DM, due to treatment effects, the differences not being significant.

Variations in omental tissue were significantly related to differences in liveweight ($p = 0.005$). The significance of variations in foetal weight on omental tissue was low ($p = 0.35$).

The multiple regression of omental tissue on liveweight, foetal weight and treatment effect is given by

$$O = 2.78 + 0.074\ L_M - 0.06\ F_M \pm K \quad (p = 0.0006).$$

Bone weight was significantly affected ($p < 0.05$) by treatment. There was no significant change in weight of bone up to 100 days gestation but a loss in weight of bone thereafter. There were no significant differences between the high and low levels of nutrition.

The multiple regression of bone on liveweight and foetal weight and treatment effect is given by

$$B = 3.36 + 0.65\ L_M + 0.013\ F_M \pm K_B \quad (p = 0.0095).$$

Fat (DM) was affected by treatment ($p = 0.17$), there being a loss as gestation progressed. Differences in fat tissue weight between planes of nutrition was not significant but differences between fat (DM) at 100 days gestation compared to 140 days was significant ($p < 0.05$). This result suggests that there appears to be an increased utilisation of fat per unit of foetal weight in the last 40 days of gestation even though energy intakes were increased by 30%.

Variation in fat (DM) were significantly related to differences in liveweight, ($p = 0.06$), but not to foetal weight. The multiple regression of fatty tissue, on liveweight, foetal weight and treatment effect is given by $FA = 4.93 + 0.10\, L_M - 0.012\, F_M - K_{FA}$ ($p = 0.0001$).

The utilisation of total ether extract follows a similar pattern. There was a loss of EE as gestation progressed. The effect of treatment was significant ($p = 0.16$). The effect of stage of gestation alone was significant at $p = 0.05$. The mean loss of EE was 1.02 kg up to 100 days gestation and 3.34 kg up to 140 days gestation. This would again indicate that fat utilisation from all sources, during the last 40 days of gestation was greater per unit of foetal weight, and almost double that recorded in the first period of gestation (30–100 days) even though energy intakes increased by 30%.

Total EE was the sum of the EE of the muscle (DM), fat (DM) and omental (DM) tissues. The variations in these due to treatment was significant at $p = 0.21$, 0.24 and 0.04 respectively. Examined on the basis of the difference in the mean of treatments at 100 days compared to 140 days gestation this was significant at probabilities of 0.10, 0.05 and 0.30 respectively.

The effect of variation in ewe liveweight on these parameters was significant at probabilities of 0.10, 0.09 and 0.03 respectively. Variation due to foetal weight was significant at $p < 0.20$ for EE of muscle but for EE of fatty and omental tissues higher values of 'p' were obtained.

II (1966)

The ewes used in this year were less variable in liveweight at the start of the experiment and the fat (DM) content of the carcass was approximately 50% less than that in 1965.

As in the previous year there was a progressive loss in M.E.B. (Tables 8 & 9). Variation in M.E.B. was significantly related to variation in ewe liveweight ($p < 0.01$) and foetal weight ($p < 0.01$).

There were no significant differences in M.E.B. between nutritional treatments but there were highly significant differences due to stage of gestation, the loss in M.E.B. being 50% greater up to 140 days, compared to 100 days regardless of nutritional inputs during the period up to 100 days.

The multiple regression for M.E.B. on liveweight and foetal weight and treatment is given by

$$\text{M.E.B.} = 28.52 + 0.67\ L_M - 0.41\ F_M - \text{KM.E.B.}\ (p < 0.0001).$$

Similarly there was a loss in carcass weight as gestation progressed, and again variations in liveweight and foetal weight were significantly related to variations in carcass weight ($p < 0.01$ and $P < 0.01$ respectively).

There was a significant loss in carcass weight due to treatment ($p < 0.02$). In the period up to 100 days gestation the ewes on the low level of nutrition lost a significantly greater weight of carcass ($p < 0.05$). The loss in carcass of ewes on the high/low level of nutrition, was also greater than that on the high/high level of nutrition at 140 days gestation but the difference was not significant.

The loss in carcass weight was significantly ($p < 0.01$) greater from 30-140 days than from 30-100 days for ewes on similar nutritional levels up to 100 days.

The multiple regression for C on ewe liveweight and foetal weight and treatment is given by

$$C = 20.01 + 0.48\ L_M - 0.53\ F_M - K_C.$$

Variation in liveweight was significantly reflected by variation in the weight of bone, FFDM and water ($p < 0.10$). Variation in foetal weight was significantly related to variation in water ($p < 0.06$) and EE of the muscle ($p < 0.20$).

Up to 100 days gestation the ewes on the low level of nutrition lost more muscle tissue than those on the high level of nutrition, (0.52 kg compared to 0.19 kg, $p < 0.10$). Also during the period 30-140 days gestation ewes given a high level of nutrition up to 100 days and also a high level of nutrition between 100 and 140 days gestation lost significantly less muscle tissue ($p < 0.05$) than the ewes given the same level of nutrition up to 100 days, but at a reduced increase (25%) in energy in the last 40 days of gestation.

Fat (DM) utilisation was also significantly ($p < 0.05$) greater for ewes given a low level of nutrition up to 100 days gestation as compared to ewes given a high level of nutrition, but differences up to 140 days gestation were not significantly different, (ewes given a high level of nutrition up to 100 days gestation).

The loss of omental tissue during gestation followed a similar pattern to that of muscle (DM). Loss was significantly greater ($p < 0.05$) for ewes on the low level of gestation up to 100 days and greater ($p < 0.20$) for ewes on a high/low level of nutrition compared to a high/high level of nutrition from 30 : 100 : 140 days gestation.

Loss in total EE also follows a similar pattern to that of muscle (DM) and omental (DM) tissues. Loss of total EE was significantly ($p < 0.05$) greater for ewes on a low level of nutrition up to 100 days gestation and while the loss of EE was greater for ewes on the high/low, as compared to the high/high level of nutrition the difference was not significant. Though the mean loss of EE at a high level of nutrition up to 100 days was only 30% of the mean loss of both the high/high and high/low level for ewes up to 140 days the difference was not significant.

The pattern of change in total FFDM was similar to that of muscle (DM) tissue as might be expected. The loss in FFDM was almost five times greater for ewes given a low level of nutrition up to 100 days gestation compared to ewes given a high plane of nutrition. The difference was significant ($p < 0.05$). The ewes given a high/high plane of nutrition also lost significantly ($p < 0.05$) less FFDM than those given a high/low plane of nutrition.

Changes in the ether extract of the muscle followed a similar pattern to that of muscle (DM) and total FFDM but the differences were not significant. The loss of EEM up to 100 days, was significantly ($p < 0.05$) less than loss of EEM up to 140 days for ewes on the high level of nutrition up to 100 days and the last 40 days of gestation.

Ewes on the low level of nutrition up to 100 days lost significantly ($p < 0.05$) more EE in the fat tissue than ewes on the high level of nutrition and though the mean loss in EEFA for ewes on the high/low level of nutrition up to 140 days was more than five times greater than the mean loss of EEFA of ewes on the high/high level of nutrition up to 100 days the difference was not significant.

While the variation in EE of the omental tissue was due to treatment effects there was no significant difference between the means of the treatment groups.

DISCUSSION

Comparing the effect of treatment difference on the body components after adjustment to a mean liveweight and foetal weight appears to be highly artificial. This is particularly true in the case of adjustment to a mean foetal weight, since in these experiments the increase in the foetal weight is a function of the productive process under study. It is also true that foetal weight does not increase linearly with time (Cleote 1939) but since the study is confined to two specific times in gestation and with ewes reasonably close together in terms of time of parturition, this should not invalidate the adjustments made. Adjustments for foetal weight differences were thought to be necessary in order to eliminate within treatment variation due to twin births which might affect the utilisation of certain of the carcass components. This was clearly unjustified for the majority of the parameters studies.

The variation in liveweight during gestation will primarily be due to variation in body component utilisation and an increase in the weight of the foetus. It could be argued that adjustment would have been better made on the basis of initial weight of the ewe but since maintenance requirement of the ewe will vary according to liveweight during the various stages of gestation it seemed appropriate that liveweight adjustments should be based on the liveweight when slaughtered. Adjusting liveweight on this basis, of necessity, required that adjustment for foetal weight be made, since any affect due to variation in liveweight during gestation is likely to be modified by an increasing foetal weight.

In 1965 the variation in liveweight was significantly reflected by the variation in most of the other body components as gestation progressed. In 1966 this was not the case. Variation in liveweight influenced only the carcass, M.E.B. bone, FFDM and water. Clearly there was much less variation in liveweight differences in 1966, a fact which appeared to increase the sensitivity of the design of the experiment to pick up significant treatment effects. Multiple regression equations have only been presented where liveweight and/or foetal were responsible for a significant variation in the parameters measured.

The greatest limitation to the study as a whole is the number of ewes used. While the multiple regression equations for each parameter appear to account for most of the variation in that parameter the significance of the treatment affects tend to be low and differences between the adjusted means of treatments also tend to be low.

In 1965, the regression of MEB on liveweight, foetal weight and treatment indicated that there was a loss in weight of MEB as foetal weight increased. The rate of loss per unit of foetal weight formed, however, up to 100 days was not significantly different from that up to 140 days. In 1966 loss in MEB was also significantly related to increases in foetal weight but rate of loss was significantly different for the period up to 100 days compared to 140 days. It would appear that rate of loss per unit of foetus during the latter part of gestation was greater. On the basis of the unadjusted means there was a 6% reduction in MEB in 1965 and 10% in 1966 up to 100 days gestation and 14% reduction in MEB up to 140 days gestation in 1965 and 12% reduction in 1966. This reduction in MEB is 20 % less than that found by Russel et al (1967)

TABLE 3 : Gross Output Per £100 Input By Farming Type (Scotland)

	1965-66	1966-67	1967-68
Hill Sheep Farms	123	110	
		114	122
Upland Farms	113	105	
		102	110
Rearing with Arable Farms	106	101	
		102	112
Rearing and Intensive Livestock Farms	98	107	
		107	110
Arable Rearing and Feeding Farms	108	110	
		111	114
Cropping Farms	108	112	
		114	125
Dairy Farms	111	110	
		109	111

In recent years the competition for hill land by forestry interests has increased. Land once used for hill sheep farming has been planted with trees by the Forestry Commission and private woodland owners and foresters. The land most suited to tree planting is also land which has the potential for an increased output from hill sheep.

It has been estimated that the annual returns on capital invested in hill sheep farming and forestry are similar: (Report of the Land Use Study Group 1966) The only justification for the industries to compete for land but their initial group was slaughtered some six weeks earlier. In 1966 the general level of nutrition was below that in 1965 and it might have been expected that there would have been a greater percentage drop in MEB. The fact that the percentage fat in the MEB in 1965 was 15.1% compared to 8.7% in 1966 may account for some of this difference there being a greater amount of fat to mobilise in 1965. In 1966 it is also the case that there was a more significant loss in muscle (DM) and FFDM than fat (DM) and EE.

The pattern of changes in carcass weight during gestation was similar to that of MEB in 1965 and 1966. In 1966 there was a clear indication that nutritional treatment had an affect on carcass loss up to 100 days when the two nutritional levels were 1670 kcals and 998 kcals ME/ewe/day respectively the loss being over 300% greater for the low energy intake. The fact that the groups of ewes given the low level of nutrition up to 100 days and high and low levels from 100-140 days had to be abandoned due to losses through, deaths, abortion and rejection as excessively emaciated by slaughter house authorities is perhaps a clearer indication of the inadequacy of this level of energy than any statistical evidence that might have been presented.

In 1965, the loss of fat (DM) from the carcass during gestation was considerable it being reduced from 18.1% of the MEB to 15.6% at 100 days and 9.2% at 140 days. In 1966 the loss was not as great the percentage fat at 100 days being 9.2% of the MEB and 6.4% at 140 days compared to 12.1% initially. The rate of absolute fat loss (Table 9) up to 100 days compared to 140 days per unit of foetus was clearly greater for the ewes up to 140 days. This could be expected in view of the fact that the maintenance requirement of the lamb is increasing at a greater rate in the last 42 days of gestation assuming that the rate of increase in weight follows the pattern suggested by (Cleote 1939).

Increasing the level of energy during this last part of gestation would undoubtedly modify the rate of fat utilisation. The results suggest, however, that the level of nutrition given in the early part of gestation more nearly met the ewes requirement than in the last third, even though nutritional levels were raised in this latter period by 30%. There was no indication in 1965, however, that nutritional level affected the extent of fat loss significantly.

In 1966 there was a significant difference in fat utilisation between the two nutritional levels up to 100 days. Differences up to 140 days were not significantly different between treatments or for stage of gestation. This is somewhat surprising in view of the 1965 results. The fact that fat (DM) content in 1966 was initially low compared to 1965 might suggest that the degree of mobilisation was restricted and that this fact influenced the more significant utilisation of other tissues, for example muscle (DM) and omental tissue.

In 1965 the muscle tissue was virtually unaffected by nutritional treatment or by stage of gestation or indeed by liveweight. In 1966 however, muscle content was affected. Up to 100 days the ewes on the low level lost 70% more muscle than those on the high level of nutrition. The ewes in 1966 given a high/low level of nutrition from 30-40/100-140 days, also lost significantly more muscle than those on a high/high level of nutrition. This pattern of loss was also apparent for other body components, omental (DM) tissue, total EE and FFDM.

In 1965 there were significant reductions in weight of bone at 100 days gestation compared to 140 days gestation. There was no significant difference due to this effect in 1966. Russel et al (1967) showed a 28% loss in fat reserves in the bone in the last month of gestation. By virtue of the fact that the fat content of the carcass in 1966 was initially low it may well be that the contribution of bone to any nutritional difficiency could be expected to be low and unmeasurable.

In both years the moisture content of the carcass was significantly ($p < 0.10$) related to variations in foetal weight, the greater the weight of foetus the less moisture in the carcass. There was also a significant relationship between liveweight and moisture content, moisture content increasing with carcass weight. The effect of treatments in both years was erratic and non significant. Expressed as a percentage of the MEB the moisture content of the carcass components in 1965 were 42.8, 41.0 and 45.11% and for 1966, 43.0, 43.5 and 44.4% at the three slaughter dates. Russel et al (1967) showed that there was an appreciable loss of water from the maternal tissues during the earlier stages of gestation, but in late pregnancy the rate of water loss decreased. The two sets of results are not comparable due to the fact that their results contain the water from other tissues than those measured here; indeed the results presented here indicate that the composition of muscle, bone and omental tissues together varies very little during gestation.

There were clearly differences in the effect of level of nutrition during gestation in both years on the carcass components of the pregnant ewe. The tissue most affected in 1965 was fat (DM), muscle being virtually unaffected. In 1966, while fat (DM) was reduced, the most significant reduction was in terms of muscle (DM). It is suggested that the reason of the difference is to be found in the initial fat content of the ewes. Ewes with 18.1% of fat available early in gestation did not require to catabolise muscle, ewes with only 12.1% fat (1966) however, while showing a similar percentage loss in fat up to 100 days gestation, did catabolise muscle.

It is clear that under the circumstances described, the Blackface ewe has consierable ability to utilise body reserves. The extent to which muscle tissue is utilised is dependent upon the amount of fat tissue present at the start of gestation. In the case of ewes catabolising muscle tissue even when fat is still available it would appear that there is a threshold value of absolute fat below which fat catabolism does not readily take place.

The data suggests that the ewe is able to withstand a loss of at least 21% of initial muscle tissue and produce viable lambs. Russel et al (1967) indicated a loss of 20% of the FFDM of the Blackface ewe during gestation. The losses of FFDM in 1966 were equivalent to 8.5% of the initial FFDM present in these studies.

The low level of nutrition practised during the early period of 1966 undoubtedly was much too low in relation to the demands of maintenance and early foetal growth. From Eadie's estimates (Russel et al 1967) the energy intakes were probably below those obtaining on hill grazings, viz. 350-500 g DOM/day. The depletion of large amounts of body reserves during this early period of gestation could lead to a situation in which ewes are unable to meet the demands of the foetus particularly if the amount of fat available at the start of gestation is low.

It must be emphasised that these experiments were carried out with individually fed animals. While the general implications of fat utilisation and fat availability during gestation can be applied to situations in which animals are group fed, the fact that feed intakes are likely to vary must be borne in mind in assessing whether a particular level of feeding would be adequate. Thus for example, in 1965, when ewes individually fed were given 1120 kcal ME up to 100 days and 1400 kcals ME from 100 to 140 days they did not appear to be adversely affected during gestation, but ewes (1966 see p) which were group fed and given 1300 kcals ME up to 100 days and 1800 kcals ME thereafter undoubtedly were adversely affected.

It would appear, that depletion of body reserves under most practical feeding regimes will occur during gestation. The nutritional levels used in the group feeding system reported earlier in this thesis are within the range that would appear safe in relation to the degree of utilisation of the reserves present at the start of gestation. It is clear, however, that the position could exist in which initial body reserves are low and increased levels of nutrition may be required to maintain the ewe in a condition in which she can operate efficiently in a situation in which she is likely to utilise body reserves during early lactation by virtue of a more intensive grazing system.

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use would be that the demand for the product of one of the industries was greater than the other. It appears that the Government has chosen to back both industries by direct subsidy and have instructed the Forestry Commission to expand its acreage of trees to a fixed limit. Until that limit is reached the Commission will compete for hill land. Private owners will also compete for hill land for forestry until such time as the Government choose to alter the laws concerning the financing of afforestation with regard to tax concessions and arrangements by which the full burdens of death duties are avoided.

Though the utilisation of hill land gives poor economic returns it is thought to be desirable and prudent to maintain the social structure of these areas and maintain their general amenity. The argument that use must be made of this land because it is there may not be economically sound but it would seem to be in man's nature to do so.

It has also been argued that because there is a world shortage of food hill land should play its part in overcoming this. It must be accepted, however, that in world terms food could initially be more easily obtained by the exploitation of potentially better land.

Thus, the situation exists which demands that use must be made of hill land. Whether it be by sheep or trees will be decided by many factors important among which will be the possibilities that exist for improving the present management and technology of the two industries concerned and not only in their ability to adapt and integrate with each other but also with the increasing demands of urban dwellers for recreational facilities in these areas.

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The quest for improved management and technology in hill sheep farming is currently showing promise though thorough development of any new technique or system must be carried out. This thesis reports on the technical and economic implications of one such system.

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ACKNOWLEDGEMENTS

I wish to record my appreciation to Dr. J. M. M. Cunningham for his instruction, guidance, encouragement and interest during my years of study.

My thanks are also due to Mr. J. Harkins, Dr. T. H. Jackson and Dr. P. McDonald for advice and help.

I also wish to express my indebtedness for the assistance I received from Mr. Jack Fitzsimons, Mr. Allan Campbell and Miss A. R. Henderson and her staff.

For guidance and assistance with statistical analysis I must accord my thanks to Mr. A. F. Purser and Dr. St. C. S. Taylor of A.B.R.O.

My appreciation and thanks are due to Mrs. R. Keane who typed the final manuscript and to Messrs. G. Finney and D. Lowe who took the photographs and prepared all the figures.

SECTION I

INTRODUCTION

The Soil, Plant and Animal Complex

It is impossible to develop economically viable systems of hill sheep farming unless there is a rational understanding of the factors involved in the complex association of soil, plant and animal, and the extent to which climate can modify the potential of each of these factors.

The Soil

The quality of the soil is dependent upon the extent to which the parent material has been weathered and leached. Factors which affect the degree of weathering and leaching include temperature, moisture, time and topography. Conditions of rainfall and temperature in the hills of Britain are such that there is a tendency towards the accumulation of soil organic matter which is usually acid. Floate (1967) states that under these conditions the downgrading process of the soils tends to be self perpetuating under hill conditions, and is only counteracted by the slow release of bases from weathering, by the organic cycle, or by incremental additions of nutrients and bases in precipitation.

Frequently the climate of hill areas is such that the growth season is short and production from these areas is low. It could be concluded, therefore, that for very large areas of presently low production hill land, limitations are due more to soil fertility difficiencies than to severity of climate - though even these effects can be modified by other factors as shown by the work of King, Grant and Rogers (1967). They describe the effects of climatic variations associated with topography and altitude on plant growth.

The table shows relative dry matter yields in the growth of F rubra alone, at two fertiliser rates and in combination with S 184 white clover.

Relative Total Seasons Yield at different Altitude DM

Altitude	S184/F rubra	F rubra High N	F rubra Low N
750	80	85	86
1000 - 1250	100	100	100
1500	81	85	75
1750	67	84	71

The results show that the greatest overall production were obtained at intermediate levels of 1000-1250 feet. Four main factors were involved in these results. Temperature, rainfall and windspeed increased with altitude but evaporation decreased. The relative importance of these factors varied as the season advanced so that the optimum altitude for plant growth also varied seasonally. Yield depressions at low altitudes from July onwards were associated with moisture deficits while at high altitudes it was associated with high wind speeds and low temperatures.

Grant (1968) states that though the ultimate limit to growth is determined by the amount of light, energy and temperature, in practice fertility and moisture usually limit productivity. These are environmental factors which can be manipulated; improvement in summer production is possible by fertiliser application or drainage. In winter, the limits to productivity are definitely climatic. Where light is limiting growth variation in yield can be effected by method of harvest. Higher yields are obtained where swards are maintained near the optimum leaf area index thus making the best use of light available. Temperature cannot be manipulated and where temperature is limiting growth, improvement can only come about by varying the plant component, i.e. by choice of crop to be grown. It should be possible to isolate varieties of grasses with improved yields at temperature below the optimum. Such grasses could be used to improve selected areas of the hill with a view to providing early grass for the critical lambing and post lambing periods.

Alcock and Lovett (1968) also state that although variation in soil type is associated with wide variation in natural vegetation with characteristic production potentials, there is evidence that the influence of soil on productivity is less than the influence of variation in local climate.

It must be concluded that while in general the influence of soil, climate fertility and moisture on hill pasture productivity can be evaluated the relative importance of each in any given situation will be different and likely to be further modified by aspect and topography.

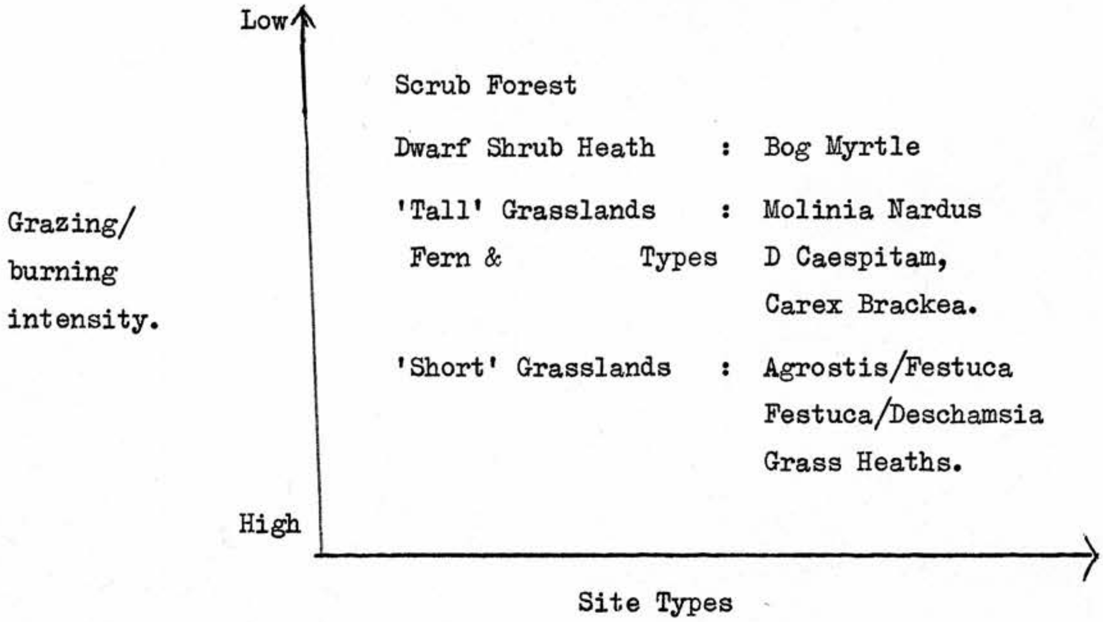
The upgrading of hill soils by fertiliser application frequently accompanied by cultivations and reseeding have received considerable attention (Stapledon 1932; Milton and Davis 1947; Ellison and Boyd 1952; Anderson and Batey 1957; Hunter 1962). Increases in herbage and animal productivity have been reported as a result of fertiliser application, cultivation and reseeding but the widespread application of such techniques is difficult due to topography, inaccessibility and high costs. Moreover where improvements have been carried out it is doubtful in some cases if the improvements in animal performance have been adequate to cover the cost of such improvement. The difficulties associated with integrating improved pastures into a system of traditional hill sheep management has frequently resulted in a poor utilisation and consequent deterioration of such land.

A less costly approach to problems of pasture improvement have been advocated by Heddle and Herriott (1968). These workers have shown that clover can be successfully introduced into hill pastures at a cost after grant of £10-£15 per acre. The long term nature of these improvements within the context of a free grazing environment are such that they may be unattractive to the hill farmer who is looking for a short term improvement. Incorporated into a controlled grazing policy the potential of such an improvement would probably be greater. The potential production from surface seeding has been outlined by Grant (1967) and undoubtedly the fact that these areas have been subject to controlled grazing has contributed greatly to their success as areas of better quality pasture.

Floate (1967) suggests that more widely applicable methods of production are likely to be found in indirect methods of increasing the efficiency of the organic cycle and promoting a more rapid circulation of nutrients around the soil-plant animal association. He indicates that grazing pressure may be of considerable importance in such a cycle.

The Plant

King, Grant and Rogers (1967) extend this concept and indicate within limits how grazing pressure can affect vegetation type (Diagram).



By suitable manipulation of the grazing pressure it is suggested that the vegetation can be changed to suit the nutritional demands of the grazing animal. Understocking or undergrazing can have undesirable effects and plant communities can become dominated by less useful species.

Equally the effects of frequent burning on some plant communities, particularly heather is likely to reduce the amount of available nitrogen. (Robertson and Davis, 1965). Such an observation has important implication in the management of hill farms where heather is the main animal nutrient source.

Grant and Hunter (1966) have studied the effects of defoliating heather by clipping and suggest that optimum grazing intensity would be one which removed about 60 per cent of the current season's growth. This would correspond to a fairly high grazing pressure and would tend to keep heather short, dense and physiologically young. Under these circumstances it may be that heather would require very little burning. They have shown that grazing increases the nutritive value of the current season's growth and may also lead to earlier spring growth but suggest that high grazing pressure after burning may delay re-establishment and could produce a change from heather to grassland.

The control of bracken by picloram and MCPA has been investigated and shown to be partially successful by Martin (1968). Experimental work carried out by I.C.I. and Shellstar has shown how the use of chemicals can help in the establishment of hill pasture improvement.

The use of selective herbicides in the control of hill pastures would appear to be of value, (King and Davies (1963)). For example Nardus and Molinia have been shown to be susceptible to low rates of application of Dalapon while the short grass species F. ovina and D. flexuosa are relatively resistant. Combining this technique with increased grazing pressure might eventually be adopted in the management of hill pastures for sheep.

The 'inexpensive' improvement of hill pastures by the manipulation of grazing intensity must be considered as a long term process in which the use of chemical sprays or burning will speed it up.

The effect of grazing intensity on different species and their seasonal growth needs more careful examination if improvements in hill pasture herbage populations are to be obtained. King, Grant and Rogers (1967) report that species differ in their sensitivity to defoliation, some giving greatly reduced yields in the following spring as a result of defoliation in October, others being less affected. When applied to mixtures of two species in swards this results in a tendency for the insensitive species to increase at the expense of the sensitive species. The effect of soil fertility also affects the differential effect of dominance between species.

The successful introduction of grass species to different hill pasture sites depends upon the characteristics of that site and the degree of modification of the site that can be obtained by fertiliser application, draining and cultivation. The choice of grass species for this method of improvement must ultimately be dependent upon the conditions that exist or can be obtained by modification.

The usefulness of any grass species in supplying an adequate level of nutrition at any given time is largely dependent upon its digestibility and in essence this in turn is dependent upon its stage of growth. Black (1967) catagorises stages of growth into three distinct periods, (1) in growth to maturity, (2) in re-growth after cutting, (3) in the period of senescence during winter. DM digestibility from first growth to maturity (date of 50 per cent ear emmergence) declines by some 10-20 per cent depending on grass species. The reduction in DM digestibility after cutting and re-growth at 15 weeks was not so great (10 per cent) but in practice these reductions can be modified by the effects of a summer depression related to climatic factors which can have an overall effect of reducing the total DM available.

The effect of climate during the winter months can affect digestibilities quite markedly. (Black 1967) gives the results of the effects of two extreme winters in terms of climate and the effects on digestibility of several grass species.

	1962-63		1965-66	
	Oct.	March	Oct.	March
D flexuosa	77	62	77	69
F rubra	73	48	72	63
L! perenne (S23)	74	43	77	62
M mallis	73	42	69	53
A tenuis	70	35	64	41

Such reductions in digestibility and the effect of reduced growth must appreciably lower the nutritional plane of the animal during this period.

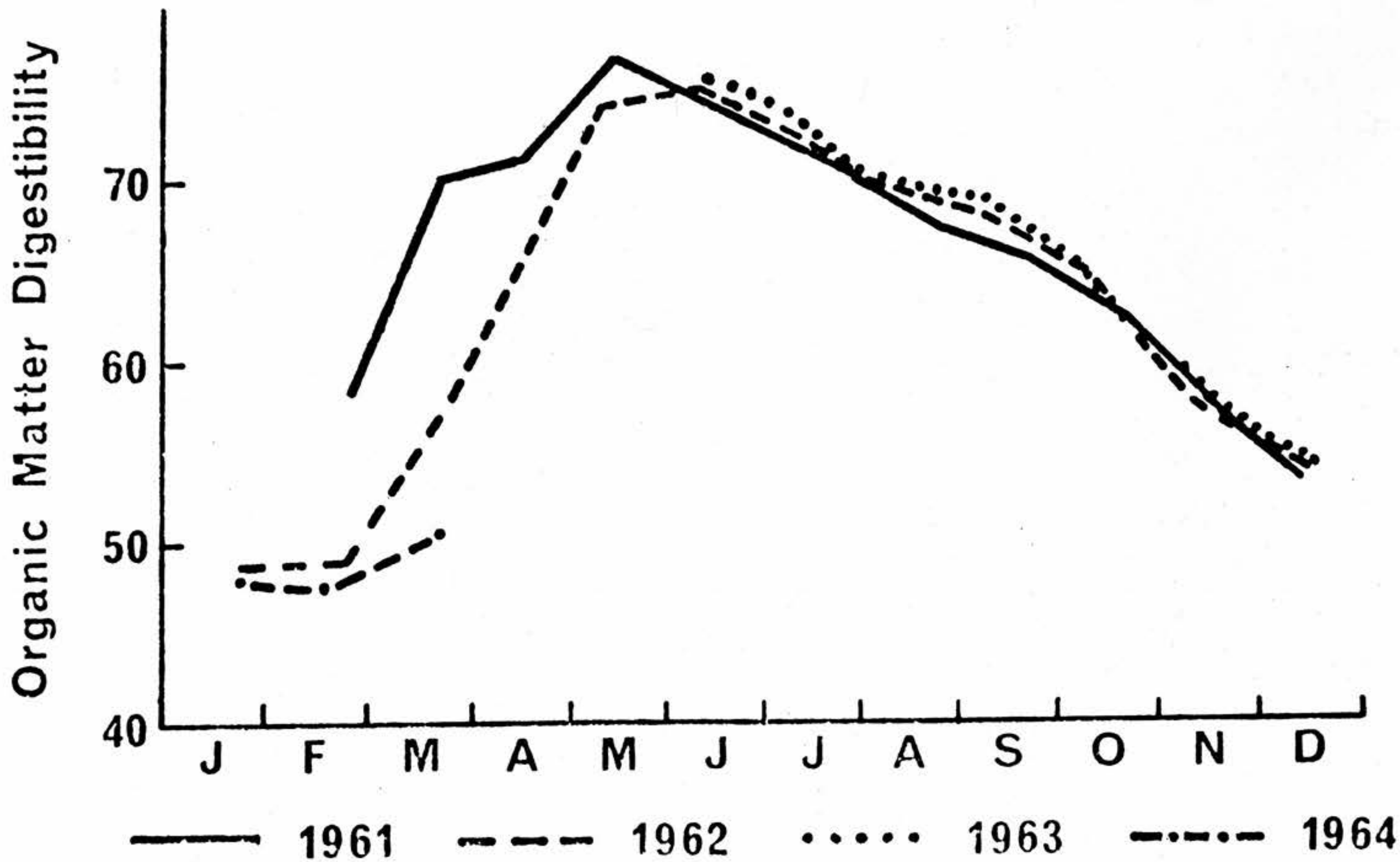
King et al (1967) has summarised three possible approaches to the improvement of hill pastures:

1. To produce or maintain dwarf shrub heath without site modification.
2. To produce indigenous short grass communities maintained by high grazing pressure, without modification of the site. If the site is modified by fertilization there is the further possibility of increasing the area of A-tennis/F rubra grassland at the expense of the F ovina rich communities.
3. To introduce lowland species, which may be tall or short in habit, accompanied by some modification of the site.

The Plant and the Animal

The relationships between pasture digestibility and availability, and the energy intake of the animal has been examined by Eadie (1967). Because pasture growth is seasonal and sheep are set stocked the amount of herbage consumed by the sheep during the period of active herbage growth is small in relation to what is produced. The dead material which is a large proportion of the total production, accumulates and dilutes the quality of the available feed not only in any current season but also in the next.

Even traditionally, stocking rates are maintained at levels which produce an acceptable performance per ewe. Actual stocking rates therefore are largely determined by the winter carrying capacity of the herbage and its ability to select a diet which is reasonably high in available nutrients



Seasonal changes in digestibility of pasture consumed by sheep set-stocked on a Cheviot hill

After Eadie (1967)

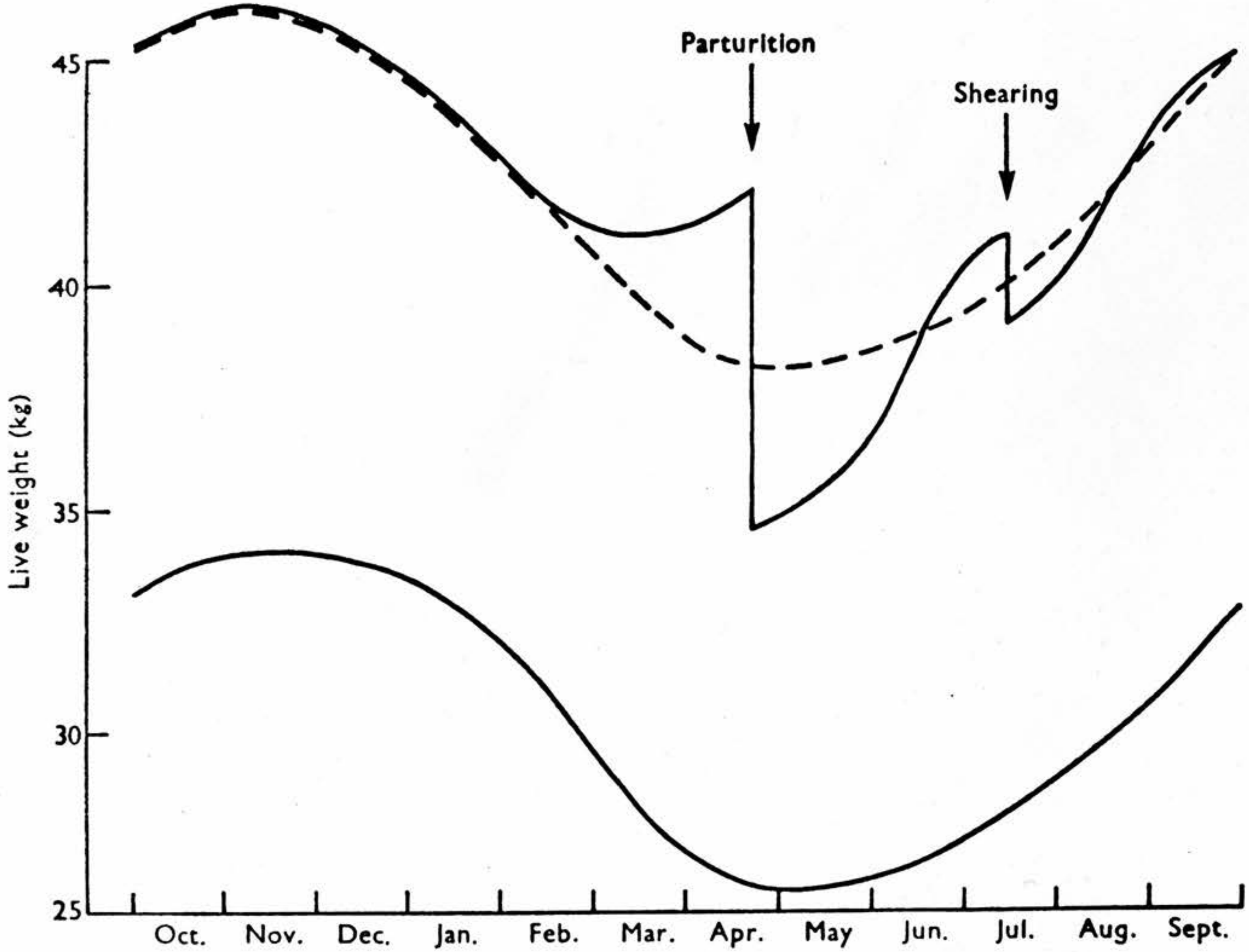
buffers the animal against a rapid fall in the digestibility of the herbage during the winter, and late summer. This selective process, however, combined with under-stocking in the summer creates an ever increasing amount of dead material which results in a general down-grading of the quality of the pasture and eventually of the soil environment which supports it. Eadie (1967) presents results which show the effect of accumulated dead herbage on the quality and quantity of DOM Intake.

Effect of Accumulated Dead Herbage on Quality and Quantity of DOM Intake

Dead herbage kg DM/acre	Stocking rate (per acre)	DOM utilised (kg/acre)	DOM intake (g/head/day)
	3	260	1135
900	5	370	930
	7.5	520	815
245	6	525	1155

Methods of removing dead herbage from hill pastures are being investigated but the grazing animal itself may provide a most useful tool in this respect. This would require a system of controlled grazing which would increase the utilisation of hill pastures and if grazed at the appropriate time in relation to the existing herbage species it could be used to favour the development of the better, as opposed to the poorer, herbage species for animal utilisation.

The possibilities of operating a two pasture concept are discussed by Eadie (1967). The basis of the early summer and early winter grazing would be based on Agrostis-Festuca pastures being rested during August, September and October. Eadie indicates that the bulk of the winter food supply will have to come from elsewhere. It is suggested that Nardus-and Molinia- dominant areas might provide this.



Curve of mean live weight (----), based on data in Figure 1, and stylized curves (——) illustrating changes in individual live weight (upper curve) and maternal empty body weight (lower curve) during the year.

After Russel et al. (1968)

The Animal

While one accepts the general improvements that might be made on hill pastures and the improved level of nutrition that follows, this in itself will not wholly solve the hill sheep farm problem though it will go a considerable way towards doing so.

A study of the effects of hill pasture nutrition on the ewe as reflected by body weight has been made by Russel, Gunn and Doney(1968) with particular reference to gestation. The graph shows how the maternal empty body weight of the ewe varies through an annual cycle and reflects to a very large extent the amount of body condition or fat tissue present at any given time.

It is apparent that there are times at which the nutritional status of the pastures seriously limit the productive potential of the animal. These are:

1. at mating
2. during the later stages of gestation
3. the early stages of lactation
4. the mid summer when grass is becoming an important part of the lambs diet but which coincides with a reduction in grass quality.

Eadie's (1967) graph shows that from May the DOM of hill pasture consumed by sheep set stocked on a Cheviot hill is falling and during November and December is likely to be of the order of 55%. Such limitations on the nutritional intake of the ewe has the effect of also limiting the multiple birth potential of hill sheep. Gunn (1967) has shown that considerable increases in the number of lambs born by lifting the nutritional restrictions at mating.

Russell et al (1967) states that free grazing hill ewes are generally undernourished during late pregnancy and that field investigations have shown that the severity of undernourishment of individual ewes is determined largely by foetal weight. Undoubtedly the level of mortality among ewes and lambs postpartum is often a consequence of poor pre-partum nutrition and small twin lambs are often poorly developed.

Peart (1968) shows that the growth potential of single hill lambs from birth to 6 weeks of age is almost double that normally found on hill pastures. It would, therefore, seem apparent that lambs produced from hill flocks have a growth potential which is rarely attained in normal practice.

The same author also shows that Blackface ewes have a high potential for milk production even when severely undernourished in late pregnancy. This potential is such that the growth rate of twins can equal that of single lambs, a fact hitherto unreported for suckling lambs as opposed to early weaning experimental data. Moreover, this equal growth potential of twin and single lambs is dependent on the twins being well developed at birth and it is in the production of well developed lambs at birth that adequate nutrition in pregnancy would seem vital.

The Development of Systems of Hill Sheep Production

Some broad aims in the long term development of a planned programme of improvement in the efficiency of production of hill sheep farming might be directed as follows:

1. A general improvement in the quality and utilisation of hill pastures (by the use of controlled grazing, increased stocking

rates, burning and modification by fertiliser treatment).

2. Increases in stocking rate.

3. Increases in output per ewe by increasing the number of multiple births.

While it is relatively easy to list the main opportunities for improving the efficiency of production of hill sheep farming the combining of them into a practical management plan is likely to be more difficult. The improvement of one part of the production cycle will clearly have effects on other parts so that no decision ought to be taken in isolation.

The chain of consequences that become apparent for example in the utilisation of an improved area of pasture, from which the quality and quantity of herbage available has increased, is conserable. Not only is the performance of the ewe improved in the spring and summer but her condition is likely to be improved in the autumn, conception rates are increased and nutritional demands on the flock as a whole is increased during the winter. Thus ghe question of supplementary feeding arises if the potential production from a system which incorporates improved pasture is to be fully realised.

On the other hand, supplementary feeding just before lambing, taken in isolation, will improve the ability of the lamb produced to survive and grow early in life, but if conception rates are poor the difficulty in recouping the cost of this feed can be very real.

Perhaps the pointer that should be used in determining how hill sheep management should be changed is an economic one, that the factor that most influences the economic viability of a hill sheep flock is the number of lambs sold per ewe.

The number of lambs produced will largely depend on the condition of the ewe at mating, the nutritional status of the ewe during the latter half of gestation, management at lambing and the provision of an adequate level of nutrition during lactation.

Unless considerable costs are to be incurred the means to meet this requirement must be in large measure from the hill pastures themselves. To do this efficiently, bearing in mind that the numbers of lambs sold/ewe needs to be increased, requires that some form of grazing control is practiced though in some hill environments it may also be necessary to establish better quality pasture by reseeding and renovation.

It has been postulated by Eadie (1968) that by fencing areas of particular herbage species and using them in relation to their seasonal productive capacity the hill pasture area as a whole will be used much more effectively. In experiments at Sourhope he has shown how this idea might be developed in relation to Agrostis-Festuca pastures.

The implication of a concept of grazing control can have an immediate effect on Autumn/early winter and spring pasture management in relation to increased output per ewe. By keeping stock off an area of quality pasture (e.g. Agrostis-Festuca) from mid August to mid October the accumulated herbage can be utilised by the ewe before mating to bring her into a condition that will improve her conception rate and provide her with an adequate level of nutrition into January at which time the area is rested, the animals are removed elsewhere and allowed to graze the whole hill area or some specific hill area where supplementary feeding can be readily given.

The area used in Autumn can then be utilised once again in the spring, initially for ewes with twins and subsequently as pasture availability allows.

By grazing this area in such a way that what is produced is also consumed ensures that dead material is not carried over into another grazing season and thereby reducing the quality of the fresh herbage ingested.

As such a system is developed the pastures will allow the animal a much improved annual nutritional cycle. Even in winter when by virtue of poorer pasture quality and availability the ewe will almost certainly be undernourished, the accumulated body reserves derived from a better summer and Autumn level of nutrition will lessen the strain on the physiological function of gestation at least until the third part of pregnancy.

Enclosing areas of hill pasture with high nutritional potential and utilising them at critical times of the ewes productive life is likely to lead to greater output per acre and per ewe.

By utilising the pasture fully and maintaining it in a condition in which there is no senescent material should allow an increase in the number of ewes kept.

What the ewe carrying capacity of hill pastures will be in such a controlled grazing system will vary with the amount of better quality pasture available and the means whereby adequate winter nutritional levels can be maintained.

Under such a system the production of more lambs per ewe is possible and desirable but care must be taken to produce lambs of reasonable quality. Thus the utilisation of spring and summer pasture must be done with this in mind and any consideration of increasing ewe numbers will need to be weighed against the possibility of producing a poorer quality lamb.

Hill pasture grazing control would appear to be the key to any future development in improvement in the efficiency of hill sheep production. The need for reseeding or pasture renovation will be apparent in situations where the amount of quality pasture is limited. In any situation in which improved pasture quality and utilisation has been introduced it is unlikely that the full potential benefits will be realised unless some form of winter supplementary feeding is made available in the last 40-50 days of gestation.

Economic Aspects

The incorporation of many of the concepts discussed into a cogent system of hill farm management with emphasis on improving the annual nutritional cycle of the ewe cannot be done regardless of cost since a factor which is almost as limiting as the nutritional status of the hill pastures themselves is the limitation of available capital to improve them.

All the improvements that have been discussed require some form of capital injection and it is therefore important to establish how this capital can be serviced efficiently at interest rates which compare favourably with other forms of investment. Harkins (1968) has developed an equation which permits an assessment of the return on marginal capital and the effects of varying any production parameters when additional capital injections are made on a hill farm.

The types of activity which might be associated with long term capital investment could be listed as follows:-

a) land improvement,
   large scale cultivations and reseeding
   large scale fertiliser application

b) fencing

c) housing

d) increased stocking rates

e) purchase of wethers that would be used to improve pasture quality by increasing grazing pressure.

Short term capital injection, which would be reflected in increased variable costs could be listed as follows:-

a) concentrate feeding

b) use of fertiliser nitrogen

c) veterinary charges

d) casual labour

e) dip

f) haulage

Labour costs are treated separately since they could vary with the modifications in management that could arise e.g. controlled grazing and in-wintering.

The equation is developed from a system of breakeven and parametric budgeting and is an extension of the gross margin technique.

In any situation where improvements to an existing gross margin (GM) are made by capital injection they will result in a new gross margin (GM_2) less an annuity charge (y) for the servicing of the capital invested in these improvements. The minimum acceptable value of GM_2 will occur when $GM_1 = GM_2$;

This can be extended to

$$E_1 \, (O_1 - b_1) \;=\; E_2 \, (O_2 - b_2) \pm L - y \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_} \quad (1)$$

Where E = is the number of ewes and hoggs

O = output

b = variable cost

L = labour change increase or decrease (change in labour cost)

For the hill sheep farm the calculation of the gross margin in full will be covered by the equation

$$E \left[a \, (x - d - e) + gd + c \right] \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_} \quad (2)$$

where a = price of lamb

x = lamb : ewe ratio at weaning

d = $(\text{number of lamb crops})^{-1}$

e = mortality of ewes

g = average cast ewe price

c = value of wool sold to ewe put to tup.

Equation (1) can therefore be extended to

$$E_1 \left[a_1 \, (x_1 - d_1 - e_1) + g_1 d_1 + c - b \right] =$$

$$E_2 \left[a_2 \, (x_2 - d_2 - e_2) + g_2 d_2 + c_2 - b - y \right] \quad \text{\_\_\_\_\_} \quad (3)$$

Although such an equation contains a considerable number of variables it is nevertheless of interest to consider the effects of major changes that might be expected due to capital investment (such as increased lambing percentages and increased stocking rates) and given these increases the annuity obtainable. The obtainable annuity would in turn determine the amount of capital invested at the various rates of interest that would be required.

Relationship between annuity obtained at varying prices per lamb and increases in lambing percentages.

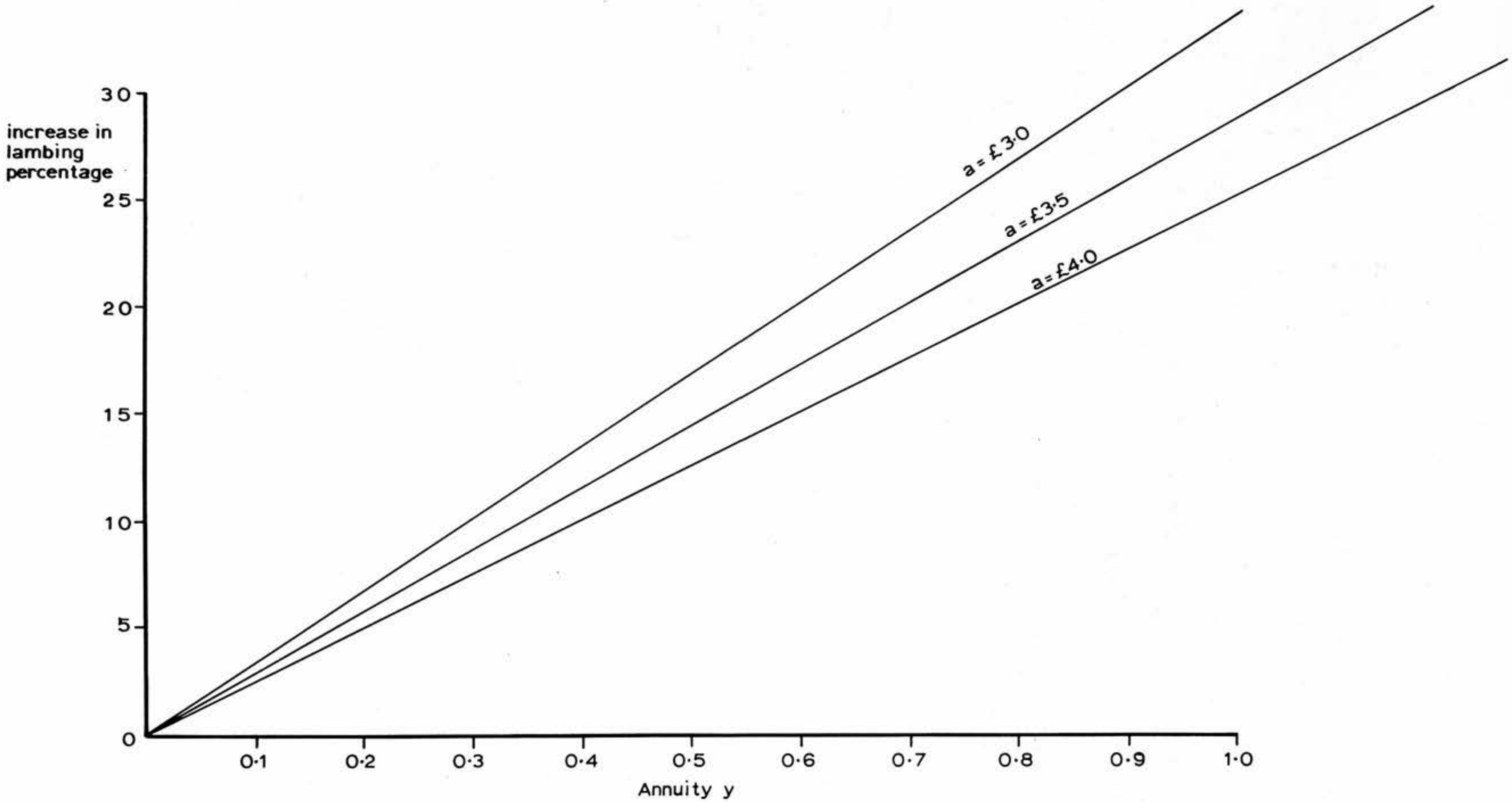


Figure 1.

In planning development work or even fundamental research, such an equation enables some measure or evaluation to be made of the consequences of any new technique that might be adopted, and highlights the problems of integrating this technique into commercial practice having particular regard to its economic implications. It is of interest, therefore, to consider some simple changes in the parameters contained in the equation and the effects of varying one or two of these. It has been advocated that lambing percentage could be improved. Consider first the effects of increasing lambing percentage without any change in other parameters.

Equation (3) can then be written

$$E_1 a_1 x_1 = E_1 a_1 x_2 - E_1 y.$$

and $$y = a_1 (x_2 - x_1) \qquad \text{———————— (4)}$$

The value of y in this case is therefore dependent on the price of the lamb (a_1) and the increase in lambing percentage ($x_2 - x_1$). A series of relationships from equation (4) can be obtained for different lamb prices.

Increase in Lambing %	10	20	30
a = £3.0 y	0.30	0.60	0.9
a = £3.5 y	0.35	0.70	1.05
a = £4.0 y	0.40	0.80	1.2

Graph. 1.

It can be seen that for any given increase in lambing percentage, by virtue of marginal increases in capital expenditure, the annuity obtainable would be greater as the lamb price increases. (Figure 1)

However, it is likely that any increase in lambing percentage even though produced initially or maintained by virtue of capital expenditure could nevertheless incur a marginal increase in variable costs if lamb price is to be maintained.

1. Relationship between annuity obtained at varying increases in variable cost at lamb price £3·5 with increases in lambing percentage.

2. Relationship between annuity obtained at varying decreases in lamb price at an initial cost of £3·5 with increases in lambing percentage.

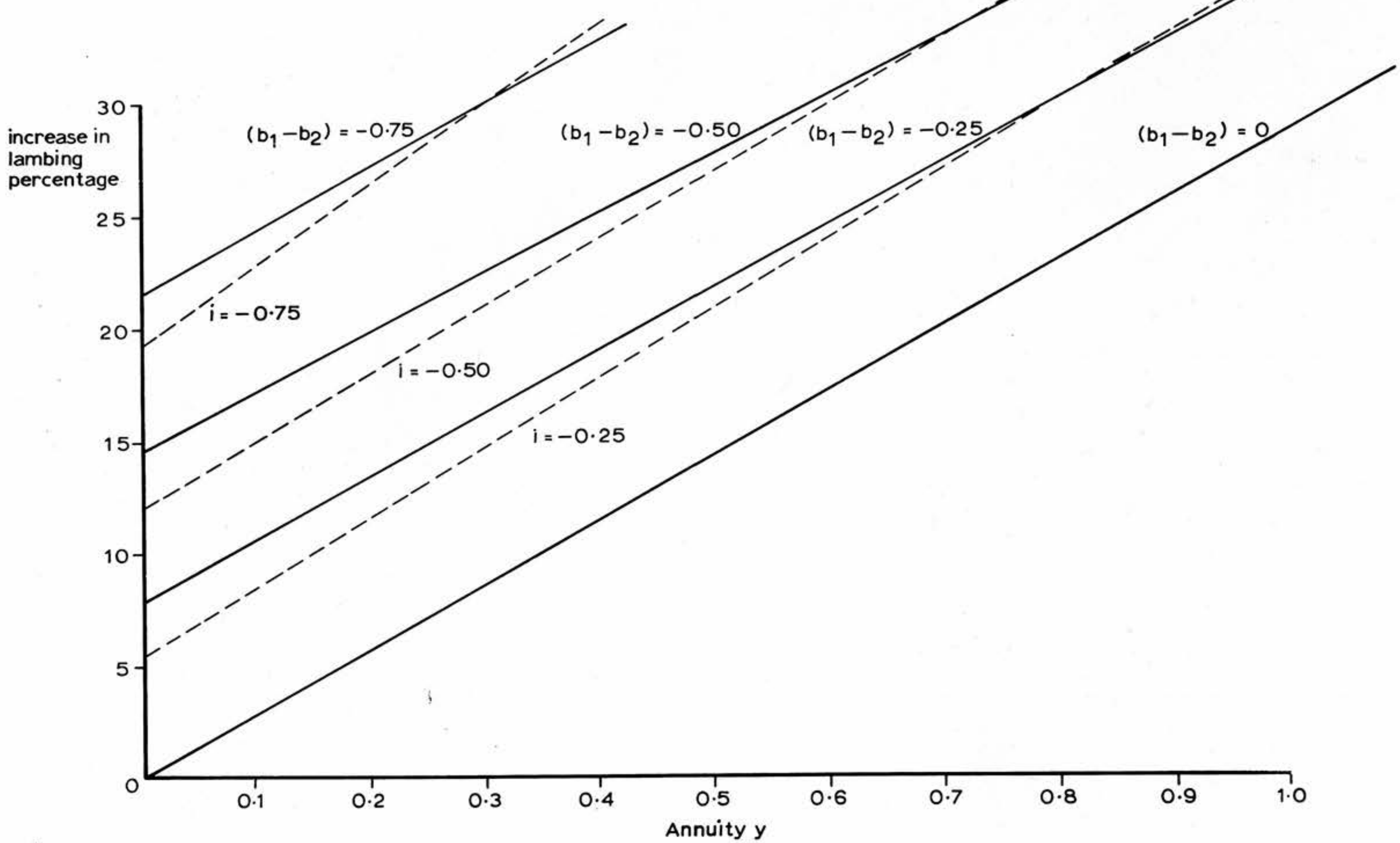


Figure 2.

Thus assuming that the lamb price is to be maintained at £3.5 the effects of an increase in variable costs can be examined by modifying equation (3) thus:-

$$a_1x_1 - b_1 = a_1x_2 - b_2 - y$$

$$\text{and } y = (b_1 - b_2) + a_1 (x_2 - x_1) \qquad \text{———————— (5)}$$

By varying $(b_1 - b_2)$ and $(x_2 - x_1)$ a series of relationships can be obtained for the effects of increasing lambing percentage at particular increases in variable cost. (Figure 2)

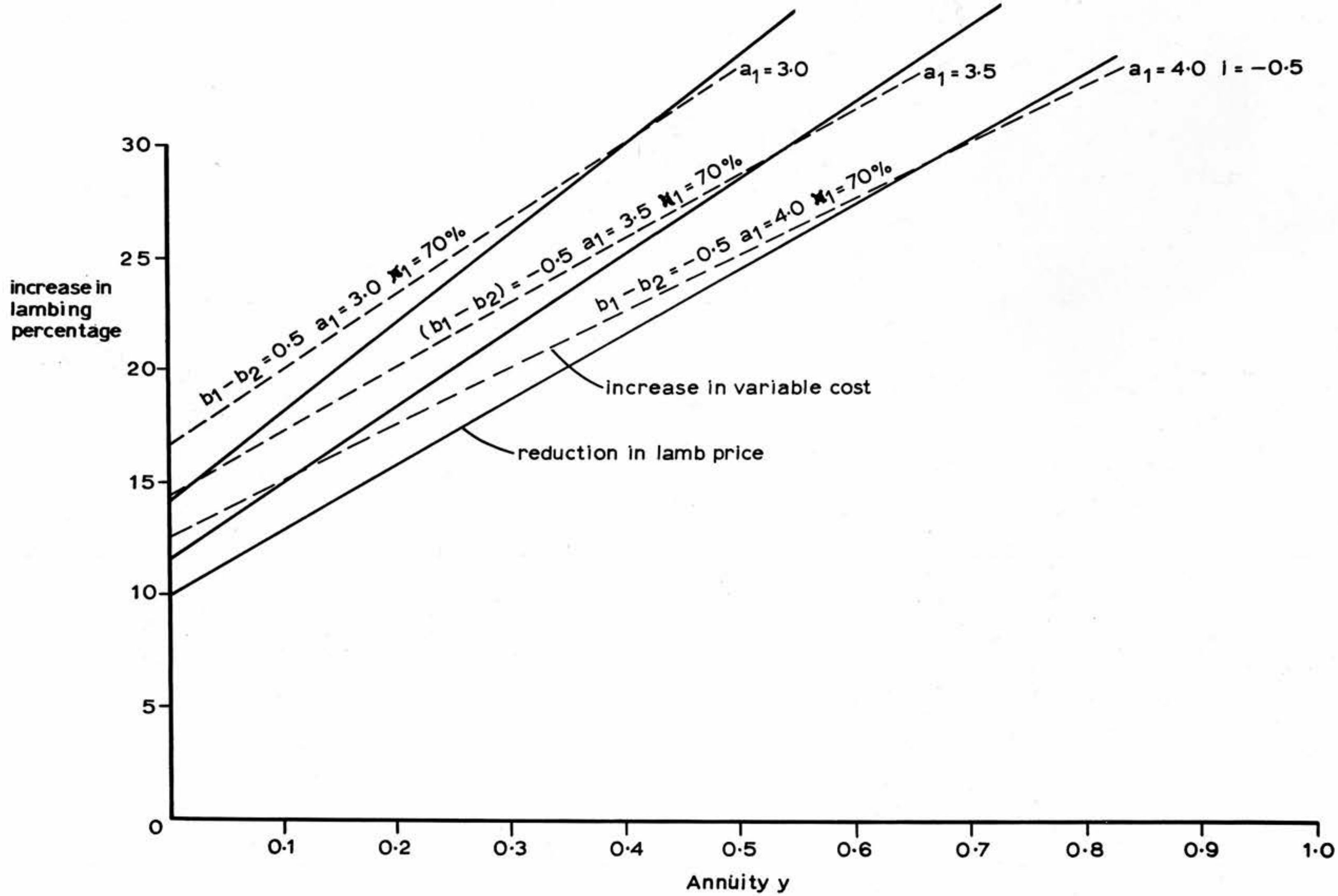
<u>Value of y at varying levels of $(b_1 - b_2)$ and lambing per cent</u>

$a_1 = £3.5$

Increase in lambing %			10	20	25	30
$(b_1 - b_2)$	=	0.25	0.10	0.45		0.80
		0.50		0.20		0.55
		0.75			0.125	0.30

The graph serves to indicate that for any given increase in lambing percentage the annuity obtainable becomes less as variable costs increase i.e. the amount of capital worthy of investment also becomes less as variable costs increase for a given increase in lambing %. Thus for example an increase in variable costs of £0.5 at a lamb price of £3.5 would require to give an increase in lambing percentage greater than 14.5% before it would be worth making any marginal capital investment for the purposes of increasing lambing per cent.

This illustration serves to indicate how the level of marginal investment is so intimately dependent on the existing level of variable costs.



increase in lambing percentage
30
25
20
15
10
5
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
Annuity y
a_1 = 3·0
a_1 = 3·5
a_1 = 4·0 I = −0·5
$b_1 - b_2$ = 0·5 a_1 = 3·0 α_1 = 70%
($b_1 - b_2$) = −0·5 a_1 = 3·5 α_1 = 70%
$b_1 - b_2$ = −0·5 a_1 = 4·0 α_1 = 70%
increase in variable cost
reduction in lamb price

Figure 3

The problems involved in maintaining lamb price (quality of lambs produced) as lambing percentage increases have been assumed to have been obtained by increasing variable costs but if it is now assumed that no increase in variable costs were made (i.e. no fertiliser nitrogen applied to inby pastures and no concentrate feeding immediately after lambing) equation (3) can be modified thus:

$$a_1x_1 - b_1 = a_2x_2 - b_2 - y$$

$$y = a_2x_2 - a_1x_1 + b_1 - b_2$$

Assume $(b_1 - b_2) = 0$

Then $y = a_2x_2 - a_1x_1$

but $a_2 = a_1 + i$ where i = any increase or decrease (-) in lamb price

Then $y = a_1x_2 + ix_2 - a_1x_1$

$$y = a_1(x_2 - x_1) + ix_2 \qquad (6)$$

Let a_1 = £3.5 x_1 = 70 and increase lambing percentage at three lamb price reductions viz. £0.25, £0.50 and £0.75

Increase in lambing %	10	20	30
i = -£0.25	0.15	0.48	0.80
= -£0.50	-	0.25	0.55
= -£0.75	-	0.025	0.30

Figure 3 shows that as for increases in variable cost, similar decreases in lamb price reduce the annuity available for any given increase in lambing percentage. It is of interest to note that for any given increase in lambing percentage the annuity available is greater when the effect of increased variable cost is compared with a similar reduction in lamb price

The effect of initial lambing per cent on the 'reversal' point between reductions in lamb price and increases in variable cost

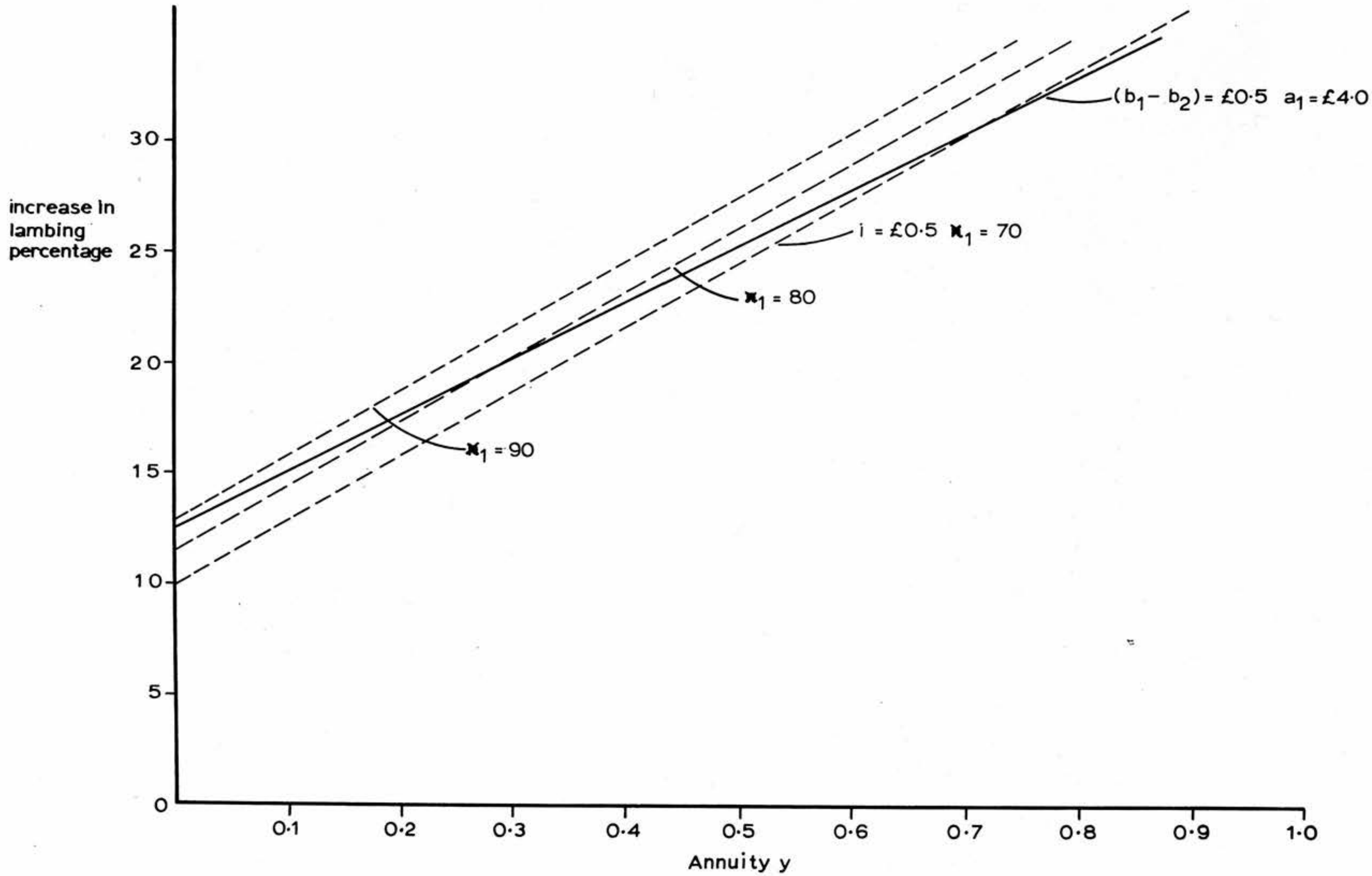


Figure 4

up to an increase in lambing per cent of 30 at which point the position is reversed. To establish how the point of this reversal is influenced by (i) initial lamb price (a_1) (ii) initial lambing percentage (x_1) a series of determinations were calculated.

In Figure 3 the influence of lamb price shows that the reversal point in terms of lambing percentage is the same for any given initial lambing percentage at a similar lamb price.

In Figure 4 it can be seen that as the value of the initial lambing percentage is increased the reversal point is progressively decreased until after having reached a value of 90 for x_1 it becomes clear that for any given increase in lambing per cent the annuity available will be less for a reduction in lamb price than that obtained for a similar increase in variable cost.

The effects of increased stocking rates on the available annuity for a given marginal increase in capital investment are important since much of the development and improvement of hill farm pasture will be based on increased intensification.

The simple effects of increasing stocking rate on the value of y without any change in production and cost parameters can be expressed from equation (3) as follows:-

$$E_1 = E_2 - E_2y$$

$$E_2y = E_2 - E_1$$

$$y = 1 - \frac{E_1}{E_2} \qquad (7)$$

If $E_1 = 100$ then increases in stock numbers by 25, 50, 100, 150, 200 and 250 per cent would give values of E_2, 125, 150, 200, 250, 300, 350 from which

The effect of increasing stocking rate (%) and the annuity obtainable without any change in the production and cost parameters.

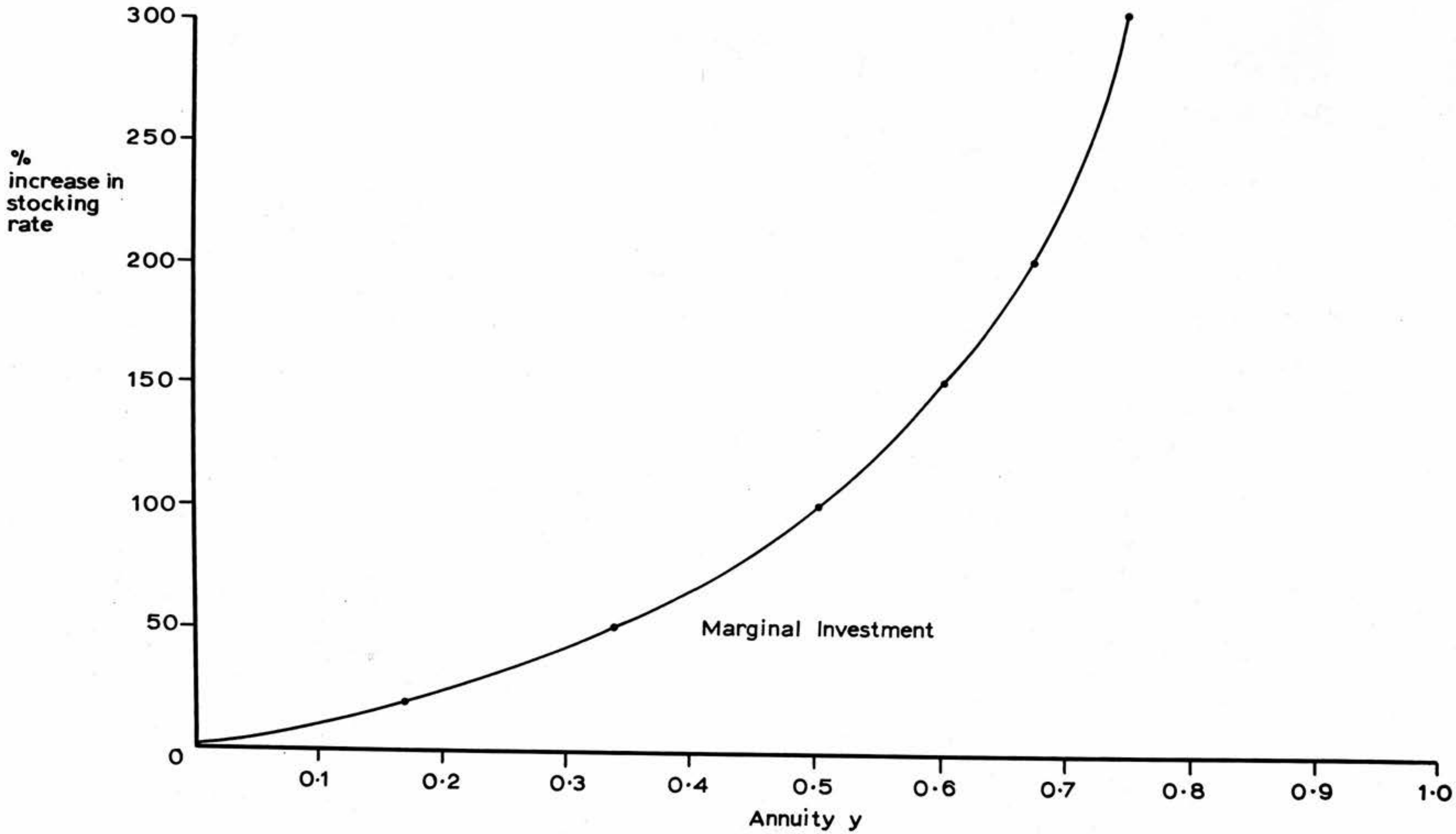


Figure 5

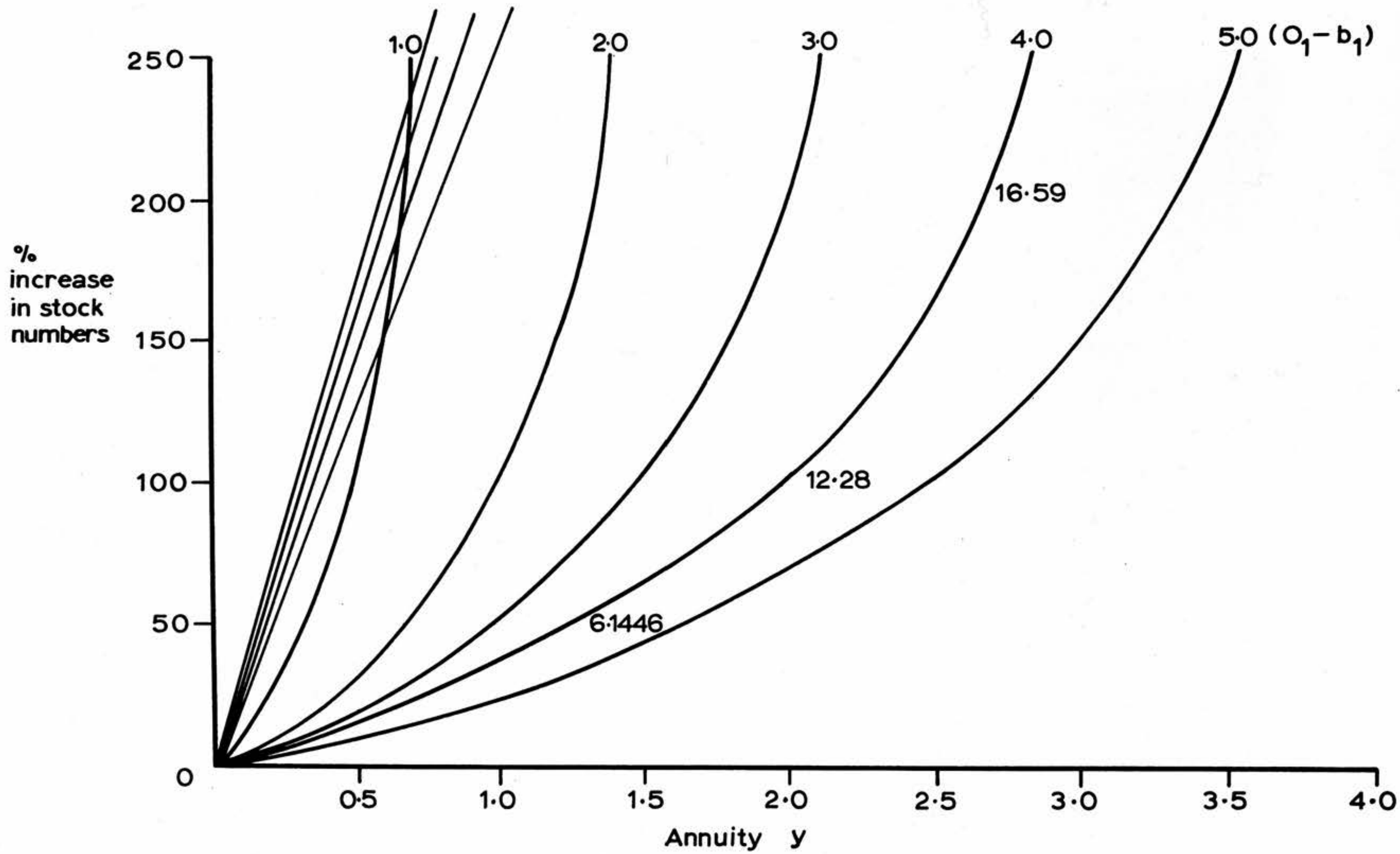
values of $\frac{E_1}{E_2}$ and y may then be calculated.

Stock increase %	25	50	100	150	200	250	300
$\frac{E_1}{E_2}$	0.80	0.67	0.50	0.40	0.33	0.29	0.25
y	0.20	0.33	0.50	0.60	0.67	0.71	0.75

The resultant curve is given in Figure 5, but as expressed from equation (7) is independent of the gross margin $(O_1 - b_1)$ which in practice would not occur. Figure 6 shows how the position of the curve is related to the gross margin of three given situations. These curves (Figure 6) are derived from situations in which the components of output and variable cost may vary but the difference of $(O_1 - b_1)$ is considered to be equal to $(O_2 - b_2)$. Hence if we think in terms of lamb price remaining static and attribute any change of $O_1 - b_1$ to increases or decreases in variable cost, it can be seen that for any given increase in stocking rate, the annuity available would decrease as variable cost increased; the extent by which it is decreasing becoming greater at higher levels of increased stocking.

The effects of increased stocking cannot easily be discussed against a theoretical background but it is of interest to understand the relative effects of increasing stocking rate and the variation that might take place among production and cost parameters because of this increase.

As has been pointed out, earlier, it is highly probable that because of increased stocking rates, increases in variable cost will also take place and it is obviously important to know the annuities that might be obtained to service capital invested in the extra stock, housing and fencing that under such circumstances would probably be carried out. Because initial



%
increase
in stock
numbers
250
200
150
100
50
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
4·0
Annuity y
1·0
2·0
3·0
4·0
5·0 ($O_1 - b_1$)
16·59
12·28
6·1446

Figure 6

productivity per ewe has a marked effect on the value of y it is proposed to examine two models having similar cost structures but having entirely different levels of ewe productivity. By doing this it is hoped to simulate the differences in the effects of capital investment on a 'poor' hill and a 'good' hill (environment, pasture, altitude, topography etc.).

A.	Lambing percentage	70	Cast ewe price	£3.0
	Lamb price	£3.0	No. Lamb crops	0.25
	Variable cost	£0.2	Wool	£1.0

B.	Lambing percentage	95	Cast ewe price	£3.5
	Lamb price	£3.75	Lamb crops	0.25
	Variable cost	£0.3	Wool	£1.0
	Ewe mortality	5%		

First look at the effects of increasing stocking rate at three different levels of increased variable cost, viz. £0.5, £1.0 and £1.5.

Values for situation A substituted in equation 3 produces the shortened version as follows:-

$$280 = E_2 (2.1) - E_2 y$$

$$y = 2.1 - \frac{280}{E_2}$$

Substituting various values of E_2 the following table can be computed.

E_2	125	150	200	250	300
% increase	25	50	100	150	200
$\frac{280}{E_2}$	2.24	1.87	1.40	1.12	0.93

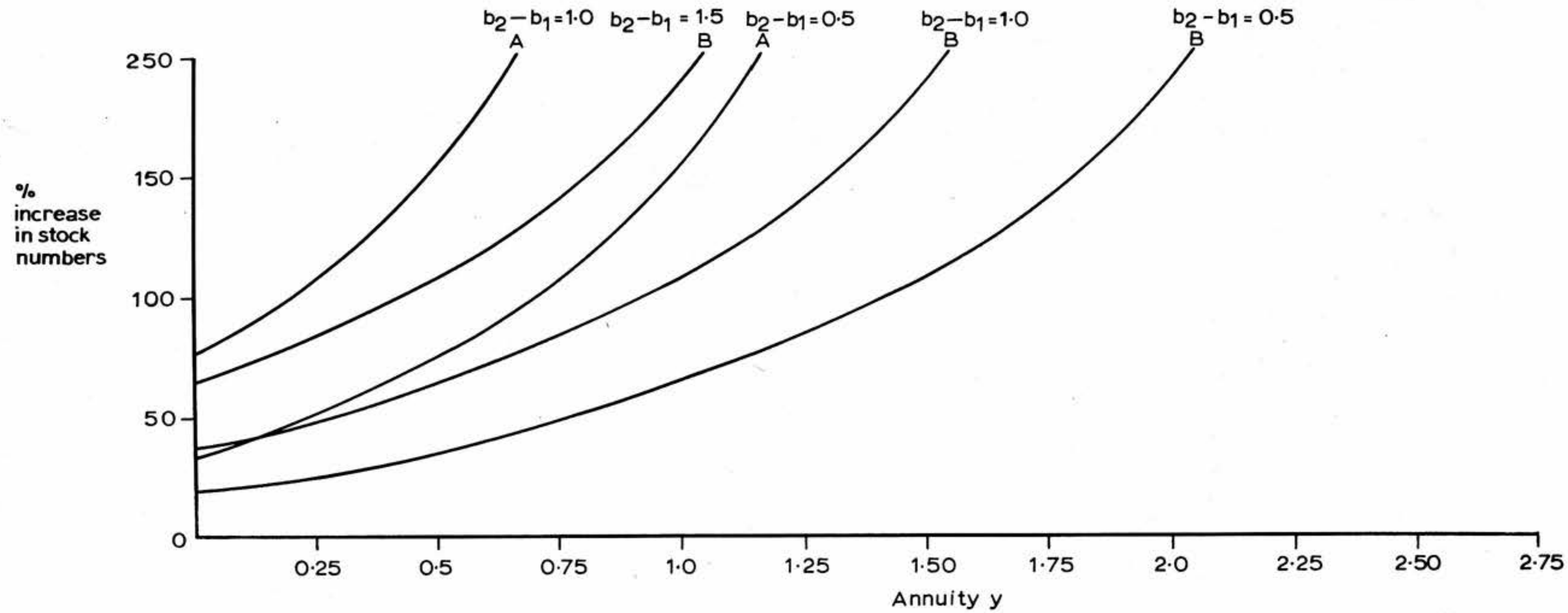

b2 − b1 = 1·0 A
b2 − b1 = 1·5 B
b2 − b1 = 0·5 A
b2 − b1 = 1·0 B
b2 − b1 = 0·5 B
250
150
100
50
0
% increase in stock numbers
0·25
0·5
0·75
1·0
1·25
1·50
1·75
2·0
2·25
2·50
2·75
Annuity y

Figure 7.

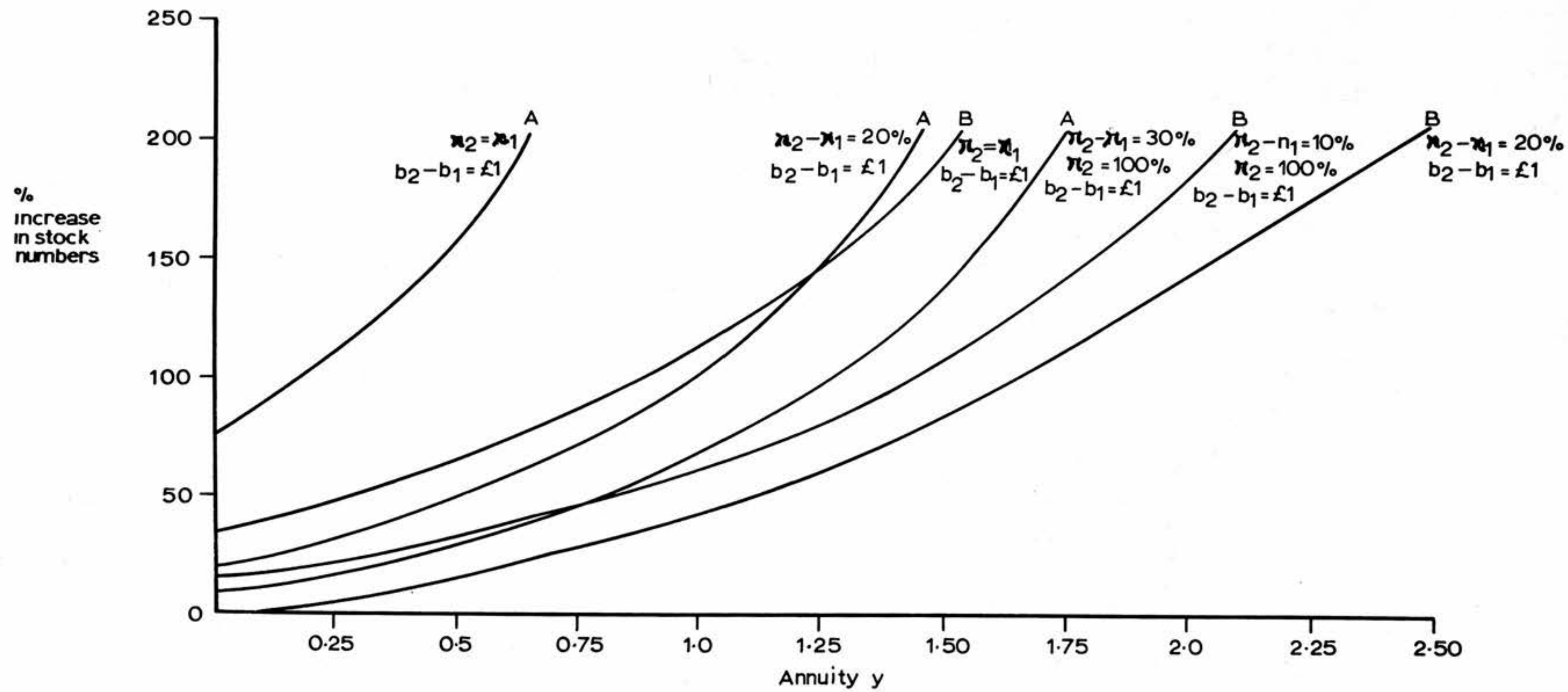

%
increase
in stock
numbers
250
200
150
100
50
0
0·25
0·5
0·75
1·0
1·25
1·50
1·75
2·0
2·25
2·50
Annuity y
A
n2 = n1
b2 − b1 = £1
A
n2 − n1 = 20%
b2 − b1 = £1
B
n2 = n1
b2 − b1 = £1
A
n2 − n1 = 30%
n2 = 100%
b2 − b1 = £1
B
n2 − n1 = 10%
n2 = 100%
b2 − b1 = £1
B
n2 − n1 = 20%
b2 − b1 = £1

Figure 8.

$y\ (b_2 = 0.7)$	-	0.23	0.70	0.98	1.17
$y\ (b_2 = 1.2)$	-	-	0.20	0.48	0.67
$y\ (b_2 = 1.7)$	-	-	-	0.40	Not Feasible

Values substituted for situation B in equation 3 gives the shortened version as follows:-

$$y = 3.34 - \frac{384}{E_2}$$

$\frac{384}{E_2}\ (b_1 = b_2)$	3.07	2.56	1.92	1.54	1.28
$y\ (b_2 = 0.8)$	0.27	0.78	1.42	1.80	2.06
$y\ (b_2 = 1.3)$	-	0.28	0.92	1.30	1.56
$y\ (b_2 = 1.7)$	-	-	0.42	0.80	1.06

From these calculations it becomes clear that on the basis of output per ewe remaining the same, the annuity available from situation A as opposed to B is much less for any given increase in variable cost. (Figure 7)

For 150% increase in stocking rate and an increase in variable cost of £1.0 the annuity available is £0.2 for A and £0.92 for B, which is equivalent to a marginal investment of £1.4 and £4.0 per ewe respectively, calculated on a discount rate of 10% on the marginal capital invested, (marginal capital required per extra ewe = £5).

However, if marginal investment has been spent on hill pasture improvement, as well as increasing stock numbers, and the level of the annual nutritional cycle of the ewe has been raised, improvement in ewe productivity is likely to occur. In taking the two examples A and B consider the effects of raising lambing percentage by 10, 20 and 30 per cent at an increased variable cost of £1.0 (Figure 8).

E_2	125	150	200	250	300	
% increase	25	50	100	150	200	
$y\ (x_2 = 0.9)$	0.16	0.53	1.00	1.28	1.47	For A.
$y\ (x_2 = 1.0)$	0.46	0.83	0.30	1.58	1.77	For A.
$y\ (x_2 = 1.0)$	0.32	0.83	1.47	1.85	2.11	For B.
$y\ (x_2 = 1.1)$	0.70	1.21	1.85	2.23	2.49	For B.

It immediately becomes clear that on the poor farm (A), an increase in lambing percentage has a dramatic effect on the annuity available even where lamb prices remain the same, at a quite low level. An increase in lambing percentage of 20 at increased stocking rate of 100% raises the annuity available by £0.8 which represents a possible increase in capital investment of £3.4 per ewe.

Similarly on the good farm the possibility of a substantial marginal investment per ewe is enhanced by an increase in lambing percentage. For example an increase of 10 in lambing percentage at an increase in stocking rate of 100% increases the obtainable annuity by (0.92 to 1.47) £0.55 which under the circumstances of investment considered allows a possible increase in marginal investment of £1.5 per ewe.

Increases in lambing percentages or output per ewe may be difficult to obtain especially in a situation where output is already high. Most hill situations are capable of supporting a lamb to ewe ratio of 1 : 1 during the summer grazing period but few are capable of supporting a ewe to lamb ratio much greater than this unless some quite substantial change is made in pasture quality. It is, therefore, reasonable to conclude that under these circumstances where there is greater scope for improving the output per ewe there may be also greater scope for marginal capital invested.

On examination (Figure 8) it is notable that the annuity available from the poor farm, with a stock increase of 100% and an increase in lambing percentage of 20 and in variable cost of £1.0, is greater than that obtainable from a good farm with a stock increase of 100%, lambing percentage remaining the same and an increase in variable cost of £1.0 by £0.8.

Obviously situations can differ greatly from those discussed but the possibilities of improvement in a given situation, as has been shown, can be assessed rationally in economic terms. In planning experimental or development work this economic relationship is of great importance since it can highlight the areas where technical improvements can have most effect.

It might be argued that because no account is taken of the existing capital investment situation the use of the equation is limited. It is evident, however, that the interest obtainable from traditional hill farming situations is low. Where an individual has chosen to invest money in hill farming or alternatively has inherited a hill farm he may wish to ensure that any further investment will produce an increased annual income if not immediately, certainly within a well defined period of time; this relationship provides him with a method of assessing whether he will do just that.

In relation to the commercial situation the effects of capital investment must be critically examined, and with more technical information becoming available relative to the responses in ewe productivity that might be obtained from given inputs, this method of assessment will become increasingly relevant.

Summary

It has been established that the environment existing on hill pastures relative to their utilisation by sheep is complex and that a clearer understanding of the plant/animal relationship is desired. It is possible in the light of present technical knowledge, however, to suggest a basis for the improvement in the efficiencies of production of some hill farming areas. The cost effectiveness of the improvements can be measured in economic terms and their relative importance, one with the other, (e.g. improvement in lambing percentage as opposed to increase in stocking rate), can be evaluated for a given situation.

'The effect of inwintering as a
means of increasing hill land
productivity.'

INTRODUCTION

To increase the efficiency of production from a hill farm by making increases in stocking rate to a level that utilises the available summer herbage efficiently, will without doubt necessitate the feeding of the ewe stock for a considerable period during the winter.

If the concept that the removal of the stock from the hill pastures in the first 3-4 months of the year, is accepted as being necessary to ensure the production of an earlier herbage availability, of better quality, two alternatives for the off wintering of stock offer themselves for consideration:

1. Housing
2. Accommodation in hill sacrifice paddocks at high stocking rates.

Little was known with certainty about either of the two methods and their effects on the animal in relation to nutritional requirement, health and subsequent productivity.

Location and climate are two important factors which will considerably influence the choice of an off wintering method.

In regions of heavy (winter) snowfall and rainfall the second method is likely to be highly undesirable. Feeding would be difficult and feed would be wasted, and the condition of a heavily stocked paddock could readily lead to problems of stock health.

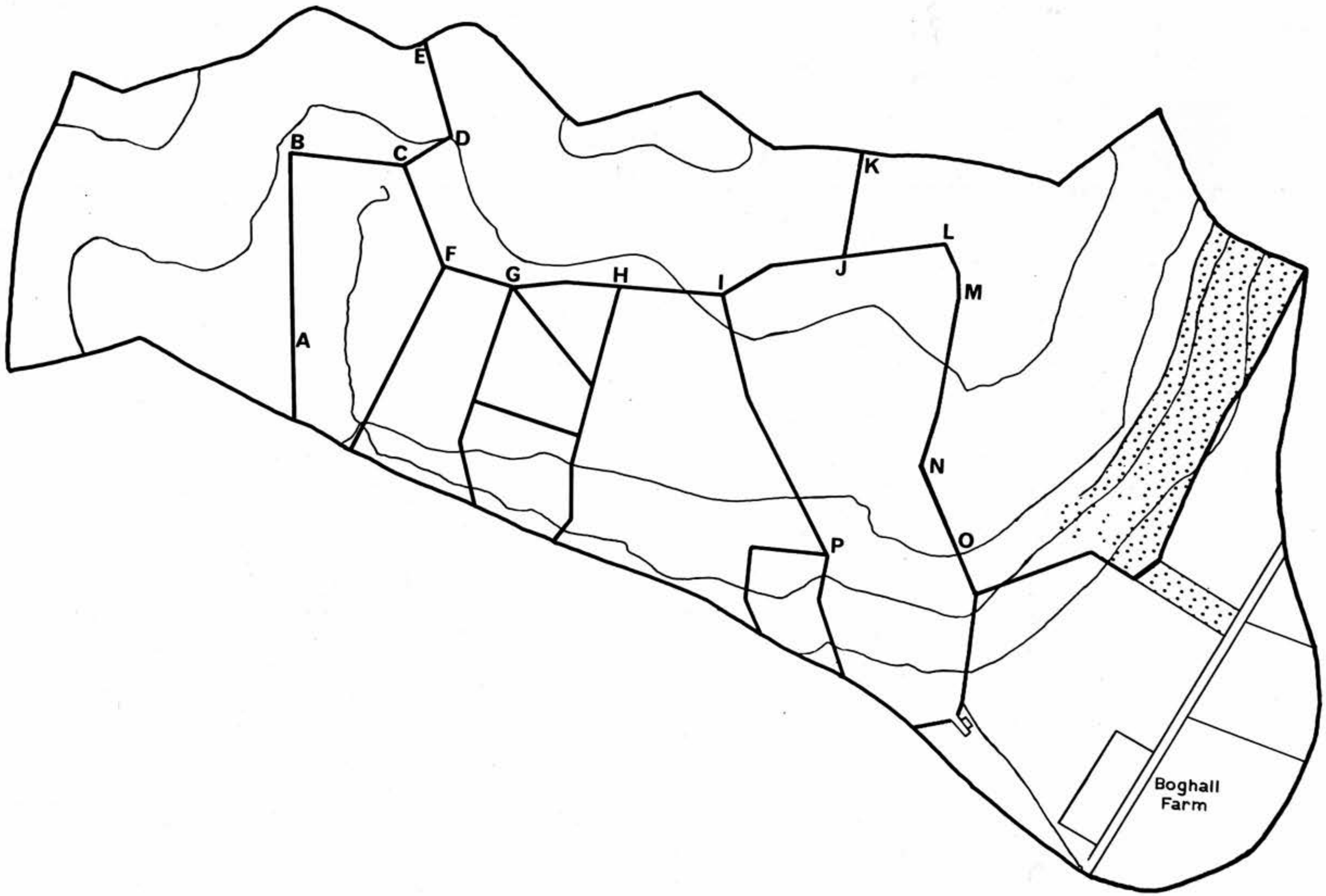
Where wintering is done outside in a limited area some form of natural shelter would be essential e.g. shelter belt and stone dykes. Where such features were absent the feeding area would almost certainly need to be of greater size so that sheep could run for natural shelter in snow storms and strong winds (e.g. lea of a hill) otherwise losses could be high.

Housed ewes would be largely unaffected by the weather in terms of precipitation and wind though temperature would be similar to that outside. Under housed conditions the control of the level of nutrition given to various age groups of ewes and thin ewes could be easily carried out while this might not be so where ewes were being fed in paddocks.

Labour requirement would be reduced during the wintering period under both circumstances but the ease with which winter shepherding could be carried out under housed conditions is likely to be much greater than in accommodation paddocks and it would be expected that the level of husbandry efficiency would be higher.

The effect of housing on the animal relative to heat loss and body maintenance requirement could be high. (Speight (1965)) in some preliminary work with an artificial sheep as devised by Blaxter and Joyce (1963) was able to show a difference of from 20-30% in heat loss between field conditions and a sheltered yard environment. Within this same group of experiments, however, there were no consistent differences between the birthweights of lambs from ewes in sheds, in sheltered yards and those in fields when fed at the same nutritional levels in the last six weeks of gestation (Cunningham & Speight 1968).

The maintenance requirements of ewes fed indoors are likely to be less than those fed out of doors (Lambourne 1961, Langlands et al 1963, Coop and Mill 1962) but other factors such as intensive indoor group feeding and other behavioural responses to the environment may offset any nutritional saving effects that might be derived from the protection of the animal from the elements. The nutritional maintenance requirement of the ewe in relation to climate will be discussed later (Part II).



Hill Area

Many aspects of management and husbandry in relation to housed sheep in the U.K. were not known when these investigations began in 1964 though some information from Iceland, the Scandinavian Countries and the Continent was available which indicated that as a system for overwintering sheep it was feasible.

Since it was considered that the advantages of housing sheep as opposed to accommodating them in paddocks might be greater in the hill situation it was chosen as the method of offwintering hill ewes.

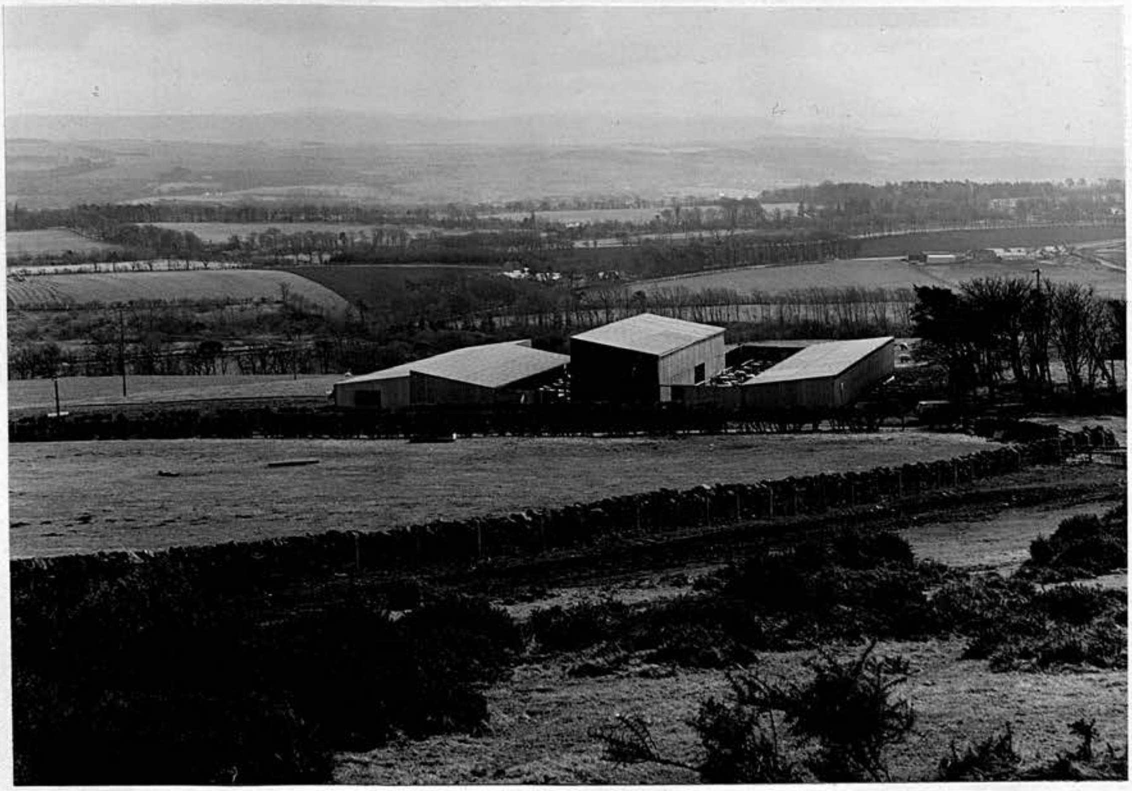
The investigation, therefore, was primarily concerned with increasing the overall efficiency of a hill sheep farm by making increases in its stocking rate, inwintering and feeding the ewes from January/February up to lambing and operating a system of controlled grazing with fertiliser application which it was hoped would improve the quality of the herbage available to the extent that it would also be able to support an increased output per ewe. Up to the present the investigation has been largely concerned with the practical problems in the management and feeding of the inwintered ewe and so far very little fencing for controlled grazing has been carried out.

EXPERIMENTAL

Location

Boghall hill farm (350 acres) on which the investigation has been carried out is situated at the northern tip of the Pentland hills on land rising from 800 to 1600 feet above sea level some 5 miles south of Edinburgh.

See map - Figure



Housing Accommodation

Pasture

The pasture is predominantly Nardus-Festuca with colonies of Calluna, bracken, Vaccinium myrtillus and Ulex europaeus on the upper slopes. At lower altitudes the pasture is dominated by Agrostis-Festuca and in the wetter parts is interspersed with Juncas Communis. Forty acres have been ploughed, reseeded and enclosed.

Stock

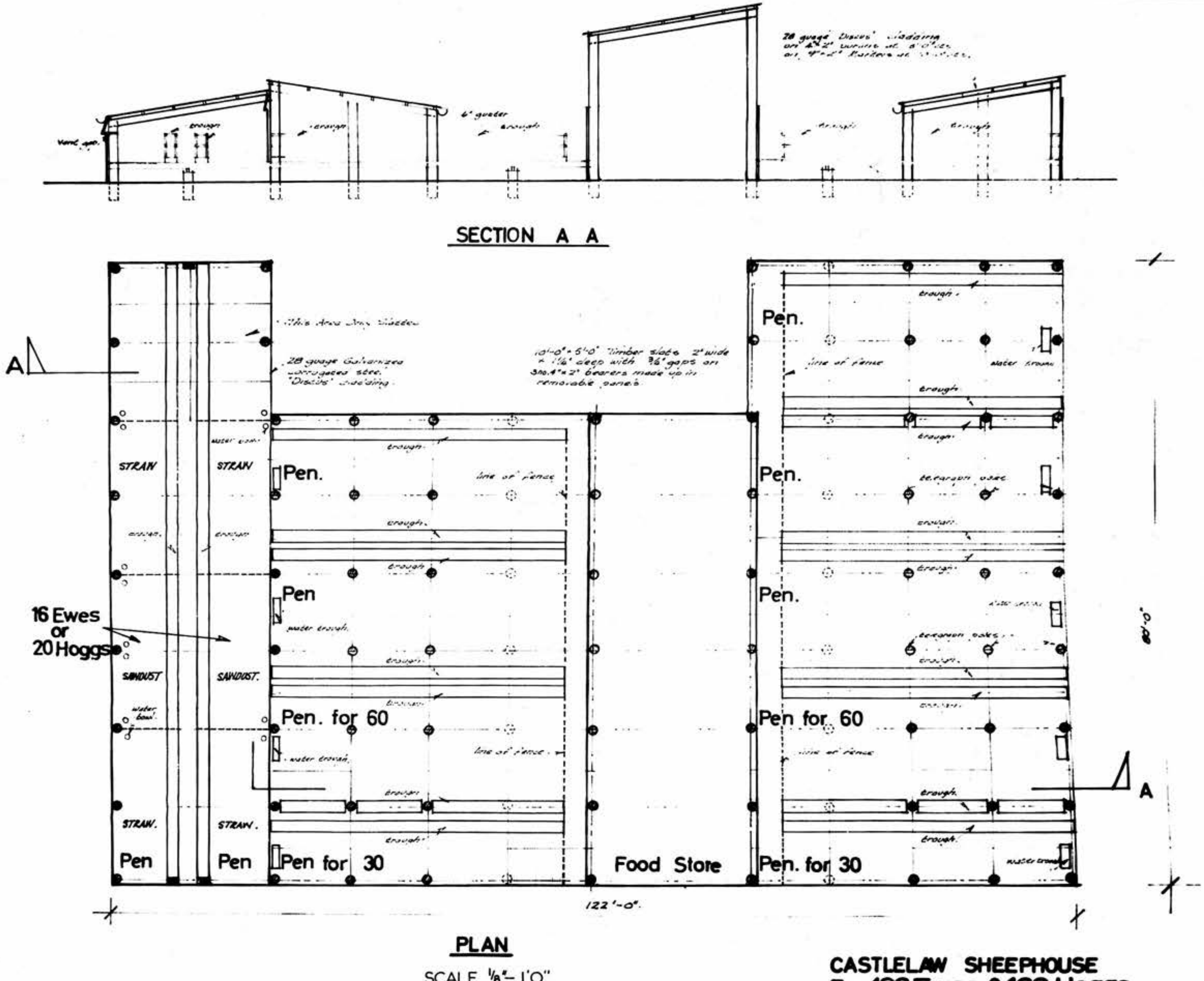
In the past the hill was stocked with 180-200 Blackface ewes of the Lanark type and 50 hoggs. In September of 1964 the ewe stock was increased to 286 by keeping back some ewes that would normally have been drafted and purchasing gimmers. 330 Blackface ewes were kept on the hill in 1967 and 1968.

Management

The ewes were mated on the hill in November. Since 1964 all the rams have been harnessed, the marking colours being changed at 16 day intervals. Currently, the practice has been to house the ewes at a time which was dependent upon the condition of the ewes and herbage availability though it has been recognised that the flock should be housed by the first week in February if the hill pasture is to be given sufficient time to recover for an early spring growth.

At housing the ewes were dosed for worms and liver fluke.

The ewes were taken out of their winter quarters before lambing according to expected lambing date, and lambed in the enclosures on the hill, though investigations on lambing groups of ewes inside have also been made.



CASTLELAW SHEEPHOUSE
For 480 Ewes & 160 Hoggs.

The enclosures were fertilised with 40 units of nitrogen some 6-8 weeks before lambing.

The ewes were clipped in mid July and the lambs weaned in the first week in September.

Ewes with twin lambs were kept in the enclosures and in 1968 one each of a number of twin pairs was early weaned (9-12 weeks), the single left with its dam being returned to the hill; they remained there as long as pasture is available.

Ewes were weighed at the end of November, at the beginning of January, February, March, and mid April and on the day they have been inwintered. They have also been weighed with their lambs at the end of May, mid July and when the lambs were weaned. The lambs were weighed within 24 hours of birth.

The wool clipped from each ewe was weighed and graded by a representative of the Wool Marketing Board.

Up to 1964 ewe hoggs were wintered away on lowground pasture. It has been a matter of policy since the ewes were housed to also house the ewe hoggs from mid December until after the first 14 days of lambing. This fulfils two purposes. One is that the incoming ewe stock is already acclimatised and adapted to a housing system and two, the ewes get the first bite of fresh pasture available in the spring. This latter point can be very important if spring growth is late.

Buildings

The housing accommodation is of simple construction using telegraph poles and heavy second hand timber. (See plan and photograph).

The sides of the building for sheep is lagged with corrugated metallic sheeting of fine gauge, as are all the roofs. The side of the food store

is clad with "Yorkshire" boarding 1" thick by 6" wide. An open yard was considered desirable to provide adequate ventilation. Slats were used and were thought necessary for the open yard since considerable quantities of straw would otherwise be required. Since straw could be an expensive item in some hill situations it was of interest to investigate the response of hill sheep to this type of 'bedding'.

Slats were made of two types of wood.

(a) a hard wood (b) and a soft wood, larch.

Slat width was not thought to be critical and since all the hard wood used was second hand timber it was not sawn into standard widths. These varied from $1\frac{1}{2}$" to $3\frac{1}{2}$". Spacing was initially $\frac{5}{8}$" but was found to be inadequate. Subsequently these were altered to $\frac{3}{4}$"-1" spacing and have proved to be entirely satisfactory for Blackface ewes and lambs 16-22 weeks old.

The feeding boxes were of Norwegian design, (see photograph).

Fencing

A diagram of the proposed fancing for Boghall hill is given in Figure . The fencing lines were decided by several factors.

1. The potential improvement of the enclosed land.
2. The feasibility of the fencing lines.
3. A supply of water.
4. The provision of a balanced seasonal grazing programme in relation to early and late maturing species of grass.

The potential improvement of the enclosed land has largely been dictated by the quality of the herbage types available e.g. area PIJLMNO is dominated by an Agrostis festuca type grassland while area ABCF is similarly dominated but also has in the past been treated with basic slag and lime, ploughed and reseeded.

By enclosing much of the hill and controlling the grazing pattern of the sheep according to the seasonal variation in pasture availability it is hoped to be able to increase the stocking rate even further than the levels now pertaining (1967-68).

Control Stock

The success of an improvement policy such as that envisaged, will only be relevant in economic terms, therefore it was important to establish the potential performance of a similar flock managed traditionally on a hill of similar botanical composition especially in regard to the effects of winter feeding on the ewe. A heft of 80 Blackface sheep in regular ages known as Howgate heft was chosen, the area of grazing extending to some 150-160 acres and stocked at 1 ewe to 2 acres. The ewes and lambs were weighed and recorded at approximately (within 1-5 days) the same time as similar weighings and recordings on Boghall hill.

Feeding

In Part II of this thesis the nutritional aspects will be dealt with more fully.

Initially the requirements for energy were based on the fasting metabolism of the Blackface ewe as derived by Langlands et al (1963) and maintenance calculated from the published A.R.C. (1965) relationships. In general the ewes have been fed on maintenance levels up to six weeks before lambing and thereafter at 125% of maintenance. The level of protein fed initially was based on the N.R.C. recommendations. Both levels of energy and protein have been varied during the four years investigation. (Table 1 & 2).

TABLE 1 : Energy feeding levels 1965-68
Kcals/ewe/day

Year	up to six weeks before lambing		Last six weeks		
			1st 2 wks.	2nd 2 wks.	3rd 2 wks.
1965	1600		2000	2000	2000
1966	1300		1600	1800	2000
1967	Treatments 1, 3, 4 & 5	1670	2000	2000	2000
	Treatment 2	1670	1800	2000	2200
1968		1800	2100	2100	2100

TABLE 2 : Protein feeding levels 1965-68
(gms/ewe/day)

Year	up to six weeks before lambing		Last six weeks		
			1st 2 wks.	2nd 2 wks.	3rd 2 wks.
1965	47.6		109	109	109
1966	47.6		82	109	127
1967	Treatment 1 & 3	45.4	118	118	118
	Treatment 2	45.4	95	118	150
	Treatment 4	45.4	109	109	109
	Treatment 5	45.4	136	136	136
1968	Treatment 1	59.0	110	110	110
	Treatment 2	59.0	68	68	68

Feeding has been based on roughage with varying levels of supplementary concentrates. Hay has been used extensively and the feasibility of using straw has been investigated.

The supplementary part of the diet has included proprietary protein nuts, with and without urea and also brewer's grains.

RESULTS

Statistical Analysis

The method used for the statistical treatment of the data is that outlined by Hazel (1946) in which he deals with the covariance of multiple classification with unequal subclass numbers and modified by Russell (1969).

As stated the feeding levels used were essentially the same in 1965, 1967 and 1968. In 1966 a lower level of nutritional inputs was allowed, Table 1. There was also within year variations in protein intakes in 1967 and 1968.

The data for all treatments within years has been combined and comparisons made on performance between years for Boghall and Howgate hefts.

The ewe liveweight and liveweight difference data has been corrected to a 4+ year old ewe bearing or suckling a single male lamb using correction factors derived over 4 years for Boghall and the February, April, Marking, Clipping and Weaning weights for Howgate and 3 years for the November, January, March weights for Howgate.

The lamb data has been corrected to a male single lamb from 4+ year old ewe using correction factors derived over four years for both Boghall and Howgate hefts.

Any weight record missing has been estimated from interpolation where the immediate pre- and post-weight records were available. Subsequently only ewes and lambs with full records were then analysed.

Ewe liveweights were subsequently examined after correction for twin effect but this, while altering the values of the weights, did not alter the order of the treatment effects.

Since seasonal differences have an effect on performance, a summary of the monthly climatic conditions is given in Table 3.

November weight

There is evidence (Table 4) that over the period 1965-67 there has been a gradual reduction in the liveweight of the ewes although it was only in 1967 that this reduction became significant ($p \leq 0.05$). With 4 years data available for the Boghall ewes and 3 years data for the Howgate ewes it is also clear that the 2 year and 3 year old Boghall ewes were significantly closer to the weight of their 4 year old flock mates than their Howgate counterparts.

There was no significant difference between the weight of the Boghall and Howgate ewes in 1965 and 1966 but the Howgate ewes were significantly heavier in 1967. No data was available for the Howgate flock in 1964.

The reduced weight of the Boghall ewes in 1967 meant that whereas in previous years the 2 year old ewes had been heavier than the Howgate 2 year olds, they were in this year the same weight (Table 6).

There would appear to be no reason to conclude that this low weight for the Boghall ewes in 1967 was due to the season and it will only become clear whether it is due to an increased stocking rate as more data is collected, though this will undoubtedly be modified by changes in pasture management.

TABLE 3 : Monthly Summary of Climatic Conditions November 1964 - September 1968.

Year	Dry Bulb (°F) 9 a.m.	Max. (°F)	Min. (°F)	Days of Snow Cover	Rain-fall (ins)	Sun-shine (hrs)	Year	Dry Bulb (°F) 9 a.m.	Max. (°F)	Min. (°F)	Days of Snow Cover	Rain-fall (ins)	Sun-shine (hrs)
November							December						
1964	42.3	47.8	36.4	-	2.09	64.6	1964	35.2	41.4	30.4	5	3.99	25.6
1965	35.8	41.1	32.1	15	3.44	56.4	1965	36.2	41.8	31.7	10	2.63	35.7
1966	39.2	43.8	33.7	-	3.24	38.2	1966	37.0	42.7	32.5	2	3.22	29.0
1967	40.1	46.7	35.6	-	2.03	59.7	1967	38.5	43.6	33.4	3	2.76	45.0
1968	40.3	45.2	35.4	-	3.09	36.1	1968	35.3	40.5	30.3	2	1.56	22.6
January							February						
1965	33.9	40.0	30.6	7	3.31	50.3	1965	35.2	41.5	31.1	4	0.86	44.7
1966	35.3	39.7	31.4	10	1.90	24.1	1966	35.6	40.4	31.2	15	3.25	28.9
1967	38.0	42.4	33.1	4	1.81	44.6	1967	38.6	44.6	34.6	3	4.24	74.7
1968	37.4	42.9	31.0	10	2.47	35.5	1968	31.5	38.0	25.6	16	2.51	67.6
1969	38.6	43.2	33.3	4	2.79	36.6	1969	30.8	36.5	25.9	24	2.72	65.2
March							April						
1965	37.2	44.1	31.3	13	3.73	100.6	1965	44.5	51.3	35.9	-	2.51	167.1
1966	41.8	48.4	36.8	-	1.46	126.6	1966	39.6	45.0	34.5	-	1.94	109.7
1967	41.5	46.5	36.4	-	2.82	131.0	1967	44.4	51.1	37.0	-	0.81	137.9
1968	40.9	46.9	33.8	6	3.02	99.6	1968	43.7	50.4	34.9	2	2.14	144.0
1969	34.6	39.2	29.9	7	0.83	69.3	1969	42.7	49.1	34.1	-	1.59	147.3

TABLE 3 contd.

Year	Dry Bulb (°F) 9 a.m.	Max. (°F)	Min. (°F)	Days of Snow Cover	Rain-fall (ins)	Sun-shine (hrs)	Year	Dry Bulb (°F) 9 a.m.	Max. (°F)	Min. (°F)	Days of Snow Cover	Rain-fall (ins)	Sun-shine (hrs)
May							June						
1965	49.6	55.7	41.9	1	2.83	131.4	1965	54.9	61.2	47.8	-	2.87	146.4
1966	50.5	57.9	40.4	-	1.88	204.5	1966	56.1	61.0	48.7	-	4.66	96.7
1967	47.2	52.2	39.8	-	5.89	124.3	1967	55.1	61.7	46.1	-	1.10	208.0
1968	45.5	51.3	38.0	-	3.86	117.3	1968	55.1	62.0	45.7	-	1.23	180.4
1969	55.9	62.5	46.0	-	2.08	198.2	1969	59.1	65.5	51.1	-	1.28	179.6
July							August						
1965	52.3	58.1	45.8	-	5.59	113.0	1965	55.9	61.7	47.2	-	3.02	163.8
1966	56.8	62.7	48.0	-	2.16	179.6	1966	54.4	60.5	46.7	-	7.79	95.3
1967	56.9	63.0	49.5	-	2.41	175.7	1967	57.5	62.9	49.4	-	2.43	141.6
1968	55.1	60.1	48.2	-	5.53	95.9	1968	56.1	62.1	49.1	-	2.44	166.4
1969	58.7	65.9	51.5	-	2.43	166.3	1969	54.0	59.7	47.0	-	2.52	109.6
September							October						
1965	51.5	56.9	46.0	-	5.60	60.3	1965	47.3	53.4	41.3	-	3.69	66.5
1966	54.1	60.1	48.8	-	2.38	110.8	1966	47.4	52.7	40.6	-	2.27	80.9
1967	53.2	59.2	45.3	-	2.79	103.1	1967	47.8	53.0	41.2	-	5.83	108.0
1968	53.5	58.8	45.6	-	4.78	84.0	1968	50.4	55.8	45.6	-	4.68	72.2
1969							1969	47.4	53.7	40.6	-	4.17	91.0

Table 5 shows that for the Boghall flock the ewes producing twins at birth were 4.4 lb heavier than those producing singles. This difference was significant ($p \leq 0.05$) and was also significantly greater ($p \leq 0.05$) than the difference between twin and single producing ewes on Howgate.

Though the ewes producing no lambs were 2.5 lb lighter than the single-bearing ewes on Boghall, this difference was not significant. The difference of 6.4 lb between the ewes producing no lambs and those producing singles on Howgate was greater than that on Boghall but not significantly so. The difference itself, however, on a within flock basis was significant ($p \leq 0.05$).

TABLE 4 : The corrected liveweight of the ewes on the Boghall and Howgate hefts, November 1964-67 (lb)

	Boghall	Howgate
1964	130.5 ± 1.1	*
1965	131.4 ± 0.9	131.4 ± 1.9
1966	129.0 ± 1.1	131.0 ± 2.0
1967	123.5 ± 1.1	129.3 ± 2.1

* Data available for Howgate for the years 1965-67 only.

TABLE 5 : The liveweight difference between the corrected weight and the weight of the two year old (A2), three year old (A3), twin-bearing (2LB) and barren ewes (OLB) on the Boghall and Howgate hefts, November 1964-67 (lb)

	Boghall	Howgate
A2	-16.6 ± 0.9	-22.4 ± 2.1
A3	$- 8.0 \pm 0.9$	-16.4 ± 2.1
2LB	$+ 4.4 \pm 0.8$	0.1 ± 1.9
OLB	$- 2.5 \pm 1.5$	$- 6.4 \pm 3.1$

TABLE 6 : The corrected liveweight of ewes by age on the Boghall (B) and Howgate (H) hefts, November 1965-67 (lb)

	2 yr. olds		3 yr. olds		4 yr. olds	
	B	H	B	H	B	H
1965	114.6	109.0	123.1	115.0	131.2	131.4
1966	112.5	108.6	121.1	114.7	129.0	131.0
1967	106.9	107.0	115.5	113.0	123.5	129.3

January Weight

There was no significant difference in the liveweight of the ewes on Boghall and Howgate in 1966 and 1967. The ewes on Boghall were significantly ($p \leq 0.05$) greater in weight in 1965 and significantly ($p \leq 0.05$) less in weight in 1968. (Table 7)

The Boghall ewes were significantly less in weight in 1968 ($p \leq 0.05$) than in any other year which is a continuation of the position reported for November. The period between November and January was relatively mild, thus this low weight may in part be due to an increased stocking density.

The loss in weight during this period was significantly greater than in 1965 and 1967 when the seasons were similar.

The substantial weight loss recorded for the Boghall ewes in 1965-66 was significantly ($p \leq 0.05$) greater than in other years and must in part be due to an inaccessibility of herbage during the late part of November, and December caused by a snow cover which lay for a minimum of 30% of the period. The loss recorded for the Howgate flock was not significantly greater than in any other year though it was the greatest loss that took place during the three years recorded.

Table 8 shows that the Boghall 2 and 3 year old ewes lost more weight than their 4 year old counterparts while the Howgate 2 and 3 year olds lost less weight. The difference between the two flocks in this respect was significant ($p \leq 0.05$).

TABLE 7 : The corrected liveweight and liveweight differences between the corrected weight and the weight of the 2 year old (A2), 3 year old (A3), and twin-bearing (2LB) ewes, on the Boghall and Howgate hefts. January 1965-68

	Boghall	Howgate	
1965	123.3 ± 0.9	111.9 ± 1.5	
1966	115.4 ± 1.2	118.1 ± 1.7	117.4 ± 1.9
1967	120.2 ± 1.2	119.8 ± 1.9	119.2 ± 1.8
1968	113.1 ± 1.2	116.9 ± 1.9	117.3 ± 1.8
A2	-17.7 ± 0.9	-20.8 ± 1.9	-20.9 ± 1.6
A3	- 9.1 ± 0.9	-13.6 ± 1.9	-12.3 ± 1.7
2LB	+ 5.7 ± 0.8	1.8 ± 1.8	+ 1.5 ± 1.5
OLB	- 2.9 ± 1.5		

TABLE 8 : The corrected liveweight gains or losses and differences in liveweight gain between the corrected value and that of the 2 year old (A2), 3 year old (A3), and twin-bearing (2LB) ewes, on the Boghall and Howgate hefts,

November 1964-67 to January 1965-68

	Boghall	Howgate
1965	-7.1 ± 0.6	
1966	-15.8 ± 0.5	-13.3 ± 1.1
1967	-8.8 ± 0.6	-11.2 ± 1.2
1968	-10.4 ± 0.6	-12.4 ± 1.2
A2	-1.1 ± 0.5	$+1.6 \pm 1.3$
A3	-1.0 ± 0.5	$+2.8 \pm 1.3$
2LB	$+1.3 \pm 0.4$	$+1.7 \pm 1.2$

February Weight

There was no significant differences between the liveweight of the Boghall and Howgate ewes in 1967. In 1966 the Boghall ewes were significantly heavier ($p \leq 0.01$), they having been housed at the beginning of January. In 1968 the Boghall ewes were significantly less ($p \leq 0.01$) than the Howgate ewes, and were also significantly less ($p \leq 0.01$) in weight than in any other year which is similar to the position reported for January. (Table 9).

There was a substantial gain in weight in only one year in four for the Boghall ewes which occurred in 1966 when the flock was housed from the beginning of January and given a diet which supplied 1300 Kcal M.E. per head. The gain was significantly greater than in any other year (Table 10).

The continued loss in weight which might have been expected in 1968 by the Boghall ewes on the basis of the losses occurring between November and January, in that year were modified by the fact that 100 thinner ewes were housed at the beginning of January while the remainder of the flock was housed at the beginning of February. This was also done in 1967.

It is worth noting, however, that the Howgate ewes lost weight in 1967 and gained weight in 1968 during a period when there was complete snow cover for a minimum of 10 days but during which time they had access to supplementary feeding (hay).

The twin-bearing ewes of both flocks were heavier than single bearing ewes but only significantly so from the Boghall flock. The twin-bearing ewes did not gain significantly more weight during the January/February period.

TABLE 9 : The corrected liveweight and liveweight differences between the corrected weight and the weight of the 2 year old (A2), 3 year old (A3), and twin-bearing (2LB) ewes, on the Boghall and Howgate hefts, February 1965-68

	Boghall	Howgate
1965	116.7 ± 1.1	
1966	120.4 ± 0.9	114.8 ± 1.8
1967	119.3 ± 1.1	116.0 ± 1.9
1968	114.0 ± 1.1	118.3 ± 2.0
A2	-19.3 ± 0.8	-22.0 ± 2.0
A3	- 8.6 ± 0.9	-13.4 ± 2.0
2LB	+ 5.5 ± 0.8	+ 2.2 ± 1.8

TABLE 10 : The corrected liveweight gains or losses and difference in liveweight gain between the corrected value and that of the 2 year old (A2), 3 year old (A3), and twin-bearing (2LB) ewes, on the Boghall and Howgate hefts,

January 1965-68 to February 1965-68

	Boghall	Howgate
1965	-6.6 ± 0.7	
1966	$+5.0 \pm 0.5$	-3.3 ± 1.9
1967	-1.0 ± 0.6	-3.8 ± 1.0
1968	$+0.9 \pm 0.6$	$+1.5 \pm 1.0$
A2	-1.6 ± 0.5	-1.2 ± 1.0
A3	$+0.4 \pm 0.5$	$+0.2 \pm 1.0$
2LB	-0.3 ± 0.5	$+0.4 \pm 0.9$

March Weight

There was no significant difference in the liveweight of the Boghall and Howgate ewes in 1966 and 1968. The Boghall ewes were significantly greater ($p \leq 0.01$) in weight than the Howgate ewes in 1967. This must, in large measure be due to the feeding and housing of the Boghall flock. The influence of supplementary hay feeding is shown by the significantly greater weight of the Howgate ewes in 1968 in a year when there was 16 days of snow cover between February and March compared to 1966 when with similar climatic conditions the ewes were some 3.5 lb less with no supplementary feeding. (Table 11).

The Boghall twin-bearing ewes were significantly ($p \leq 0.05$) greater in weight than their single-bearing flock mates. The Howgate twin-bearing ewes were greater in weight but not significantly so. The difference between the two flocks in this respect was significant ($p \leq 0.05$), the Boghall twin-bearing ewes being 7.5 lb greater, and the Howgate ewes being 3.1 lb greater than their respective single bearing counterparts.

The increase in weight recorded in all years for the Boghall flock as compared to the Howgate flock, except in 1966, is undoubtedly due to marked differences in nutritional intake. (Table 12).

The significant loss ($p \leq 0.01$) in weight recorded in 1966 compared to other years for the Boghall ewes is likely to be a reflection of the lower energy available from the diets given in that year (1300 Kcals M.E. and 0.11 lb D.C.P.). This loss must be contrasted by the gain obtained in the following years 1967 and 1968 when 1600 Kcals M.E. and 0.10 lb D.C.P. and 1800 Kcals and 0.13 lb D.C.P. were allowed respectively during the same period of gestation.

The significantly ($p \leq 0.01$) greater gain in weight of the 2 year old ewes of both flocks may well be due to their less initial weight in February (when over the four years was between 94.7 and 101.1 lb) and so far as the Boghall 2 year olds are concerned were given the same "maintenance" allowance as older ewes. Similarly, for a given availability of herbage the smaller 2 year old ewe on Howgate was less likely to lose weight than the heavier 4 year old during this period.

While the twin-bearing ewes of the Boghall flock over the four years gained significantly ($p \leq 0.01$) more weight than the single bearing ewes (+2.0 lb), the twin-bearing ewes of the Howgate flock lost weight, the loss being less than that recorded for the single bearing ewes though not significantly so.

TABLE 11 : The corrected liveweight and liveweight differences between the corrected weight and the weight of the 2 year old (A2), 3 year old (A3), and twin-bearing (2LB) ewes, on the Boghall and Howgate hefts.

March 1965-68

	Boghall	Howgate
1965	116.9 ± 1.2	
1966	115.3 ± 1.0	113.6 ± 1.7
1967	126.4 ± 1.2	112.0 ± 1.9
1968	120.3 ± 1.2	118.0 ± 1.9
A2	-16.9 ± 0.9	-19.4 ± 1.9
A3	- 7.7 ± 0.9	-13.0 ± 1.9
2LB	7.5 ± 0.9	3.1 ± 1.8

TABLE 12 : The corrected liveweight gains or losses and differences in liveweight gain between the corrected value and that of the 2 year old (A2), 3 year old (A3), and twin-bearing (2LB) ewes, on the Boghall and Howgate hefts.

February to March 1965-68

	Boghall	Howgate
1965	+ 0.2 ± 0.7	
1966	- 5.1 ± 0.6	- 1.2 ± 0.8
1967	+ 7.1 ± 0.7	- 3.9 ± 0.9
1968	+ 6.3 ± 0.7	- 0.3 ± 0.9
A2	+ 2.4 ± 0.5	+ 2.6 ± 0.9
A3	+ 0.9 ± 0.7	+ 0.4 ± 0.9
2LB	+ 2.0 ± 0.5	+ 0.9 ± 0.9

April Weight

The Boghall ewes were significantly greater ($p \leq 0.05$) in liveweight than the Howgate ewes in all years the difference ranging from 8 lb in 1966 to 20 lb in 1967.

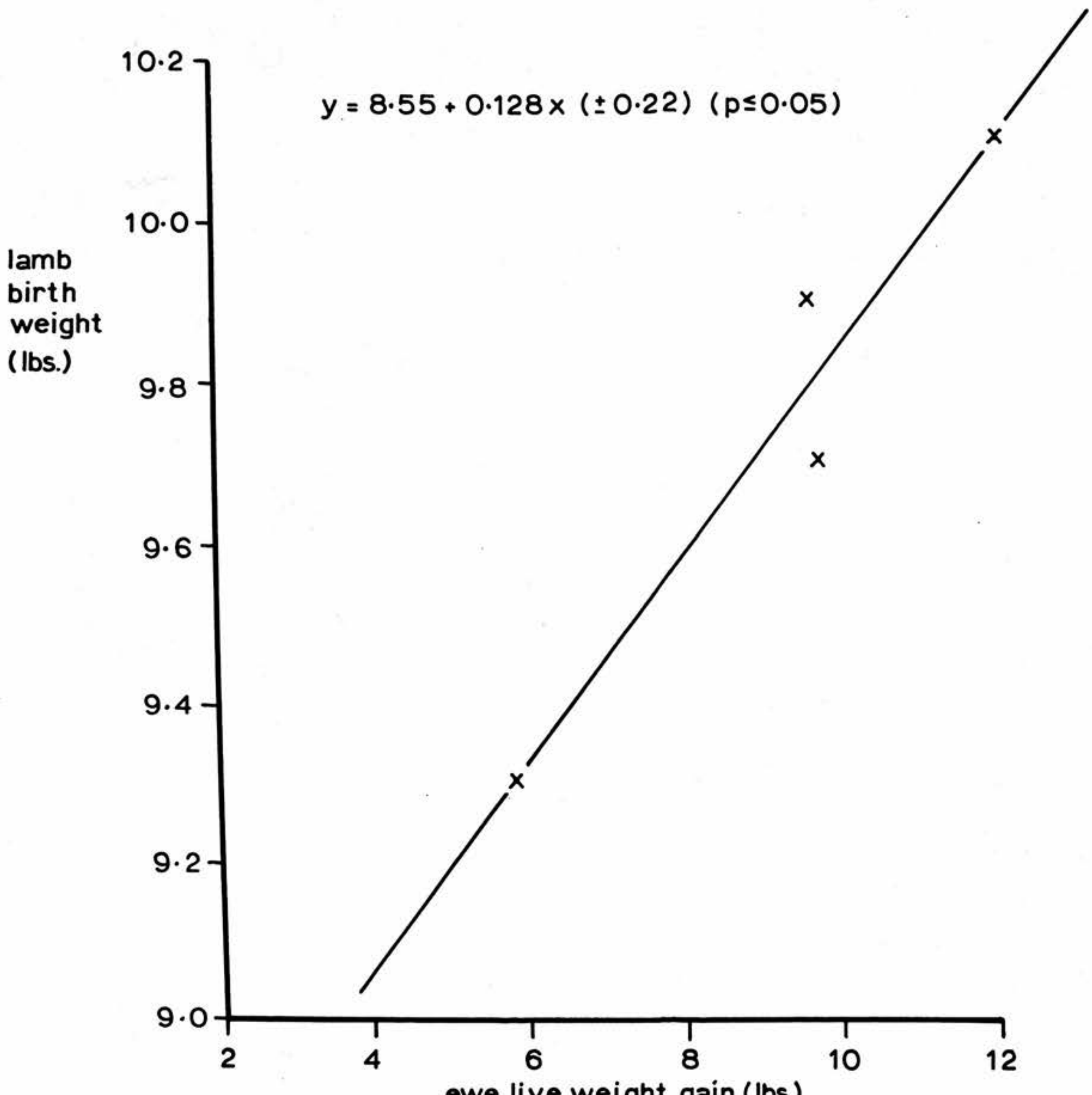
Over the four year period the twin-bearing ewes were on average 7.9 lb greater in weight than the single bearing ewes. This difference was significant ($p \leq 0.01$). (Table 13)

An increase in weight from March to April was recorded in all years for the Boghall flock. The increase in weight in 1966 was significantly less ($p \leq 0.01$) than in other years. In 1966 the energy allowance during the last 6 weeks was on average 1800 Kcals M.E. and 0.23 lb D.C.P./ewe/day while in 1965, 1967 and 1968, the energy allowance was 2000 Kcals M.E., 2000 Kcals M.E. and 2100 Kcals M.E./ewe/day respectively.

A gain in weight was recorded for the Howgate flock over the same period although it was significantly ($p \leq 0.01$) less than that recorded for the Boghall flock. The substantial gain recorded in 1967 was most likely due to the relatively mild March and April of that year and may in some way be compensatory for the significantly greater loss in weight recorded in March. (Table 14).

There was no significant difference in the weight gain of ewes of different ages in the Boghall flock, (value for 4 years) but the Howgate 2 year olds gained 2.0 lb more weight than other ages, this difference, however, was not significant. This perhaps might be expected where the availability of herbage is restricted, the nutritional limitations are likely to affect the older, heavier ewe more markedly than the younger, lighter ewe.

Regression of lamb birthweight (y) on ewe live weight increase in last six weeks housing (x)



The lambs produced by the two year old Boghall ewes were only 0.8 lb less over the four years than those from the 4 year olds while the lambs produced by the two year old Howgate ewes were 1.5 lb less than the 4 year olds. The difference of 0.7 lb between the two flocks was significant ($p \leq 0.05$). The difference may be due to better winter nutrition and to the fact that the two year old up to 1968 has been a generally bigger ewe than its Howgate counterpart.

The twin-bearing ewes of the Boghall flock gained only slightly more weight than the single bearing ewes. They gained significantly more weight than their Howgate counterparts, but this did not result in the Boghall twin lambs being any greater in weight (Table 15).

There appears to be a strong correlation between Boghall ewe liveweight (March to April gain) and birth-weight of lamb. The regression of ewe liveweight gain (x) and lamb birth-weight (y) is represented by the equation:-

$$y = 8.55 + 0.128x \quad (\pm 0.22) \quad (p \leq 0.05)$$

It has been suggested that the differences in liveweight gain during the March and April period are related to differences in energy intake and it must also be concluded that these differences are also responsible for differences in lamb birthweight. The year in which lamb birthweights were significantly lower than in any other year was the year when least energy was given during the last 6 weeks of gestation. Table 15.

It is apparent, nevertheless, that while the Boghall ewes gained weight during this period the Howgate flock lost weight and in only one year (1968) produced significantly ($p \leq 0.05$) lighter lambs. Though the loss in weight was not as great as in other years, it probably being modified by differences due to supplementary hay feeding, it did occur in a year when snow cover lasted for a minimum of 34 days from January to the end of April compared to 24, 25 and 3 days over the same period in 1965, 1966 and 1967. Table 17.

TABLE 13 : The corrected liveweight and liveweight differences between the corrected weight and the weight of the two year old (A2), three year old (A3) and twin-suckling (2LB) ewes, on the Boghall and Howgate hefts.

April 1965-68

	Boghall	Howgate	
1965	129.0 ± 1.4		116.8 ± 1.4
1966	121.2 ± 1.1	113.9 ± 1.8	113.2 ± 1.8
1967	136.2 ± 1.4	117.1 ± 1.9	116.7 ± 1.7
1968	130.0 ± 1.4	118.2 ± 1.9	118.2 ± 1.7
A2	-16.8 ± 1.1	-17.5 ± 2.0	-18.3 ± 1.5
A3	- 6.3 ± 1.1	-13.2 ± 2.0	-10.8 ± 1.6
2LB	+ 7.9 ± 1.0	+ 4.5 ± 1.8	+ 4.2 ± 1.5

TABLE 14 : The corrected liveweight gains or losses and differences in liveweight gain between the corrected value and that of the two year old (A2), three year old (A3), and twin suckling (2LB), on the Boghall and Howgate hefts.

April 1965-68

	Boghall	Howgate
1965	+12.1 ± 0.8	
1966	+ 5.9 ± 0.7	+ 0.3 ± 1.1
1967	+ 9.8 ± 0.8	+ 5.1 ± 1.2
1968	+ 9.7 ± 0.8	+ 0.2 ± 1.2
A2	+ 0.1 ± 0.6	+ 1.9 ± 1.2
A3	+ 1.4 ± 0.7	- 0.2 ± 1.2
2LB	+ 0.5 ± 0.6	+ 1.6 ± 1.1

TABLE 15 : The birthweight of the Boghall and Howgate lambs corrected to a male single equivalent (lb).

	Boghall	Howgate
1965	10.1 ± 0.13	10.0 ± 0.22
1966	9.3 ± 0.14	9.9 ± 0.22
1967	9.7 ± 0.12	9.8 ± 0.21
1968	9.9 ± 0.13	9.1 ± 0.22

TABLE 16 : The birthweight difference between the male single equivalent and a male twin (T) and female single (F), and a male single from a two year old (A2) and three year old (A3) ewe from the Boghall and Howgate flocks.

	Boghall	Howgate
A2	- 0.8 ± 0.12	- 1.5 ± 0.23
A3	- 0.2 ± 0.12	- 0.4 ± 0.21
T	- 2.4 ± 0.10	- 2.1 ± 0.17
F	- 0.4 ± 0.09	- 0.5 ± 0.15

TABLE 17 : Number of days of complete snow cover from November to April given monthly (1964-1968)

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total	Total Jan. - Apr.
1964-65	0	5	7	4	13	0	29	24
1965-66	15	10	10	15	0	0	50	25
1966-67	0	2	4	3	0	0	9	3
1967-68	0	3	10	16	6	2	37	34

June Weight

The Boghall ewes were significantly heavier ($p \leq 0.05$) than the Howgate ewes in 1965 and 1967. In 1966 and 1968 there was no significant differences in their weights (Table 18).

The lowest weight recorded for the Boghall flock was in 1966 at 107.3 lb which was significantly less than in any other year and in a year when the lowest energy intakes were allowed during pregnancy. The lowest weight recorded for the Howgate ewes was in 1965 at 105.5 lb which was significantly less than in any other year. The weight of the Boghall ewes in that year was also low (significantly, ($p \leq 0.05$) lower than in 1967, and 1968 at a higher stocking density). The months of April and May were similar in terms of temperature as to the same periods in 1967 and 1968 but with less rain and more sunshine. There was, however, no apparent affect on herbage growth due to these factors.

The Boghall ewes lost significantly ($p \leq 0.01$) more weight than the Howgate flock in every year over this period (Table 19). The loss of weight between the last preparturtion weight (mid April) and the June weight was around 14.0 lb for the Boghall flock in 1966, 1967 and 1968 which was significantly less ($p \leq 0.01$) than the loss of 18.5 lb in 1965. In the same year (1965) the Howgate ewes lost 11.3 lb which was also signiciantly ($p \leq 0.01$) greater than in any other year. While the heaviest birthweights were recorded for both flocks in this year, it is unlikely that this can entirely account for the between year difference which occurred. The growth rates of the Boghall lambs were significantly greater ($p \leq 0.01$) over this period (1965) than those on Howgate (Table 21), but the growth rates recorded for Howgate in 1965 were significantly lower than in any other year. The conclusion that ewe live-weight loss was due to a heavier lactation therefore cannot be made with any certainty.

The Boghall two year old ewes were significantly closer ($p \leq 0.10$) to the weight of their 4 and 5 year old flock mates than the Howgate 2 year olds to their 4 and 5 year old flock mates. A similar pattern existed for the 3 year olds.

The Boghall twin suckling ewe was significantly ($p \leq 0.05$) greater in weight than her single suckling flock mate as measured over the 4 year period. In the case of the Howgate twin suckling ewes the trend was the same but the difference was not significant. The difference between the two flocks in this respect was not significant (Table 18).

In both flocks the twin suckling ewe lost approximately 4.0 lb more weight from April to June than the single suckling ewe, this being significant ($p \leq 0.05$). The Boghall twin lambs, however, had growth rates which were significantly ($p \leq 0.01$) poorer than Howgate twin lambs in relation to their respective single lamb flock mates over the four year period (Table 20).

TABLE 18 : The corrected liveweight and liveweight differences between the corrected weight and the weight of the two year old (A2), three year old (A3), and twin suckling (2LB) ewes, on the Boghall and Howgate hefts. June 1965-68

	Boghall	Howgate
1965	110.5 ± 1.2	105.5 ± 1.8
1966	107.3 ± 1.0	108.2 ± 2.2
1967	121.5 ± 1.2	116.7 ± 2.1
1968	115.5 ± 1.2	114.2 ± 2.1
A2	-12.3 ± 1.0	-16.2 ± 1.9
A3	- 2.7 ± 1.0	- 6.9 ± 2.0
2LB	- 3.6 ± 0.9	- 2.3 ± 1.8

TABLE 19 : The corrected liveweight gains or losses and differences in liveweight gain between the corrected value and that of the two year old (A2), three year old (A3), and twin suckling (2LB), on the Boghall and Howgate hefts.

April 1965-68 to June 1965-68

	Boghall	Howgate
1965	-18.4 ± 1.2	-11.3 ± 1.5
1966	-13.9 ± 1.0	- 5.0 ± 2.0
1967	-14.7 ± 1.2	0.0 ± 1.8
1968	-14.5 ± 1.2	- 4.0 ± 1.8
A2	+ 4.6 ± 0.9	+ 2.1 ± 1.7
A3	+ 3.7 ± 0.9	+ 3.9 ± 1.7
2LB	- 4.3 ± 0.9	- 1.9 ± 1.6

TABLE 20 : The 35-day corrected male single equivalent lamb liveweight and differences in weight between a male twin (T), female single (F), and a male single from a two year old (A2) and three year old (A3) ewe from the Boghall and Howgate hefts 1965-68.

	Boghall	Howgate
1965	32.1 ± 0.4	29.0 ± 0.9
1966	30.0 ± 0.5	30.1 ± 0.9
1967	36.2 ± 0.4	34.8 ± 0.8
1968	33.6 ± 0.4	35.7 ± 0.8
T	- 7.17 ± 0.33	- 4.88 ± 0.66
F	- 1.00 ± 0.30	- 1.82 ± 0.60
A2	- 1.9 ± 0.41	- 2.8 ± 0.80
A3	- 0.3 ± 0.41	+ 0.1 ± 0.80

TABLE 21 : The 35-day corrected male single equivalent lamb liveweight gain and differences in weight gain between a male twin (T), female single (F), and a male single from a two year old (A2) and three year old (A3) ewe from the Boghall and Howgate hefts 1965-68.

	Boghall	Howgate
1965	22.0 ± 0.4	18.9 ± 0.8
1966	20.7 ± 0.4	20.2 ± 0.8
1967	26.5 ± 0.4	25.0 ± 0.8
1968	23.6 ± 0.4	26.7 ± 0.8
T	-4.8 ± 0.3	-2.7 ± 0.6
F	-0.6 ± 0.3	-1.3 ± 0.6
A2	-1.1 ± 0.40	-1.2 ± 0.8
A3	+2.8 ± 0.40	+0.5 ± 0.8

TABLE 22 : The corrected liveweight and liveweight differences between the corrected weight and the weight of the two year old (A2), three year old (A3) and twin suckling (2LB) ewes, on the Boghall and Howgate hefts.

July 1965-68

	Boghall	Howgate
1965	123.1 ± 1.2	124.4 ± 1.6
1966	114.9 ± 1.0	127.6 ± 2.0
1967	124.6 ± 1.2	123.7 ± 1.9
1968	123.5 ± 1.2	112.1 ± 1.9
A2	-10.9 ± 0.9	-16.0 ± 1.7
A3	- 2.0 ± 1.0	- 6.9 ± 1.8
2LB	+ 2.1 ± 1.0	- 1.1 ± 1.6

TABLE 23 : The corrected liveweight gains or losses and differences in liveweight gain between the corrected value and that of the two year old (A2), three year old (A3), and twin suckling (2LB) ewes on the Boghall and Howgate hefts.

July 1965-68

	Boghall	Howgate
1965	+12.5 ± 1.0	+19.0 ± 1.2
1966	+ 7.7 ± 0.9	+19.5 ± 1.5
1967	+ 3.1 ± 1.0	+ 7.0 ± 1.4
1968	+ 8.0 ± 1.0	- 2.1 ± 1.4
A2	+ 1.3 ± 0.8	+ 0.2 ± 1.2
A3	+ 0.7 ± 0.8	+ 0.0 ± 1.3
2LB	- 1.5 ± 0.8	- 3.4 ± 1.2

<u>July Weight</u>

There was no significant difference in the weights of the Boghall and Howgate flocks in 1965 and 1967. In 1966 the Boghall ewes were significantly lighter ($p \leq 0.01$) which is a continuation of the position reported for June of the same year. In 1968 the Howgate ewes were significantly lighter ($p \leq 0.01$), though for no apparent reason since the weight of the ewes of both flocks were similar in June, (Table 22).

The Boghall ewes gained significantly ($p \leq 0.01$) less weight than the Howgate ewes during this period in all years, except 1968 when the Howgate ewes actually lost weight, (Table 23).

The weight gains of the Boghall flock varied significantly ($p \leq 0.01$) over the four years the gains decreasing up to 1968 then increasing again. The Howgate flock gained appreciable weight in 1965 and 1966 during this period (19.0 lb), while the gain dropped significantly to 7.0 lb in 1967 and to a loss of -2.1 lb in 1968. Some of the variation may well be due to seasonal effects on grass growth and herbage availability. Insufficient evidence is available for any firm conclusions to be drawn.

September Weight

There was no significant difference in the weights of the Boghall and Howgate ewes in any of the four recorded years. The weights were greatest in 1967 (a year marked by 40 hours more sunshine during July and August than in other years) and significantly lower in 1968 for both flocks. Table 26)

As in July, the Boghall 2 year olds were significantly closer in weight to their 4 and 5 year old flock mates over the four year period than the Howgate 2 year olds. A similar pattern existed for the 3 year olds.

The weight gains of the ewes show no consistent pattern except that they are such as to bring the weight of the mean weight of the ewes for both flocks back to a similar value each year. Thus the greatest gain in weight for the Boghall flock was 10.3 lb in 1966; this was significantly ($p \leq 0.01$) greater than in any other year, and the greatest gain for the Howgate flock was 11.8 lb in 1968 which was also significantly ($p \leq 0.01$) greater than in any other year, (Table 27).

TABLE 24 : The 84 day corrected male single equivalentlamb liveweight and differences in weight between a male twin (T), female single (F), and a male single from a two year old (A2) and three year old (A3) ewe from the Boghall and Howgate hefts 1965-68.

	Boghall			Howgate		
1965	55.2	±	0.7	52.4	±	1.3
1966	51.0	±	0.7	58.3	±	1.3
1967	60.0	±	0.6	56.9	±	1.2
1968	59.6	±	0.7	50.7	±	1.3
T	- 9.60	±	0.52	- 8.98	±	1.01
F	- 1.98	±	0.47	- 2.45	±	0.90
A2	- 3.7	±	0.7	- 5.2	±	1.3
A3	- 0.3	±	0.7	- 0.1	±	1.3

TABLE 25 : The 84-day corrected male single equivalent lamb liveweight gain and differences in weight gain between a male twin (T), female single (F), and a male single from a two year old (A2) and three year old (A3) ewe from the Boghall and Howgate hefts 1965-68.

	Boghall			Howgate		
1965	23.2	±	0.5	23.5	±	0.8
1966	21.0	±	0.5	28.3	±	0.8
1967	23.8	±	0.5	22.0	±	0.8
1968	26.1	±	0.5	14.9	±	0.8
T	- 2.42	±	0.38	- 4.10	±	0.63
F	- 1.01	±	0.34	- 0.63	±	0.56
A2	- 1.8	±	0.5	- 0.5	±	0.8
A3	- 0.6	±	0.5	- 0.1	±	0.7

TABLE 26 : The corrected liveweight and liveweight differences between the corrected weight and the weight of the two year old (A2), three year old (A3), and twin suckling (2LB) ewes, on the Boghall and Howgate hefts.

September 1965-68

	Boghall			Howgate		
1965	124.7	±	1.3	124.5	±	1.7
1966	125.2	±	1.3	126.9	±	2.2
1967	126.2	±	1.3	129.5	±	2.1
1968	120.9	±	1.3	124.0	±	2.1
A2	- 9.4	±	1.0	-15.2	±	1.9
A3	- 1.3	±	1.0	- 6.3	±	2.0
2LB	+ 1.7	±	1.0	- 1.5	±	1.8

TABLE 27 : The corrected liveweight gains or losses and differences in liveweight gain between the corrected value and that of the two year old (A2), three year old (A3), and twin suckling (2LB) ewes on the Boghall and Howgate hefts.

September 1965-68

	Boghall			Howgate		
1965	1.6	±	0.9	0.1	±	1.0
1966	10.3	±	0.7	- 0.7	±	1.3
1967	1.6	±	0.9	5.8	±	1.2
1968	- 2.7	±	0.9	11.8	±	1.2
A2	+ 1.5	±	0.7	+ 0.8	±	1.1
A3	+ 0.7	±	0.7	+ 0.6	±	1.1
2LB	- 0.4	±	0.6	- 0.4	±	1.0

Lamb Performance

Lamb birthweights (Table 15) from the Boghall flock are largely a reflection of ewe nutrition and in 1965, 1967 and 1968 lamb survival was good. In 1966 when lamb birthweight was significantly ($p \lesssim 0.05$) less than in other years survival was poor and 60% of the lambs dying were less than 7 lb in weight.

Over the four years the equivalent male twin was 2.36 lb less than the male single in the Boghall flock, the equivalent figure for the Howgate flock being 2.14 lb less, the difference between the two flocks in this respect not being significant.

The female single lamb was on average 0.36 lb less than the male single in the Boghall flock while it was 0.51 lb less in the Howgate flock. The difference between the two flocks in this respect was not significant.

The low birthweight for the Howgate flock in 1968 has already been commented upon (see April Weight p. 49, para. 4).

The weight of the Boghall lambs compared to those at Howgate at 35 days was significantly greater ($p \lesssim 0.05$) in 1965 and significantly less ($p \lesssim 0.05$) in 1968 there being no difference in 1966 and 1967. The weight gains over the period were an exact reflection of the liveweights of the lambs. In 1967 the Howgate lambs gained significantly ($p \lesssim 0.05$) more weight than the Boghall lambs. The significantly ($p \lesssim 0.01$) greater gain in weight by the Howgate lambs in 1968 was surprising in view of the significantly poorer birthweight, but it is also notable that the year in which the Boghall lambs were significantly less in weight at birth, they also made up this difference in 35 days. While 1966 was climatically a poor year from January to May it is perhaps the fact that the Boghall ewes were going out to clean pasture that this difference was made up. This cannot explain the differences occurring in 1968 regarding the Howgate heft and the question as to whether the relatively poor gain obtained from the Boghall lambs in that year was due to over-stocking must be posed.

The significantly poorer ($p \leq 0.01$) performance of the twin lambs on Boghall over this period compared with the performance of the twin lambs on Howgate is obviously important in relation to the lamb that is finally produced at weaning.

Lambs from two year old ewes performed significantly ($p \leq 0.05$) poorer than those of 4+ year old ewes on Boghall and lambs from 3 year old ewes performed significantly ($p \leq 0.05$) better in terms of liveweight gain than 4+ year old ewes, over the four years.

The weights of the Boghall lambs at 84 days were significantly greater ($p \leq 0.05$) than those of Howgate in 1967 and 1968 and significantly less in 1966. The difference in 1965 just failed to be significant ($p \leq 0.05$). The liveweight gains show a similar pattern except for 1965 when there was no significant difference between the two flocks. (Table 24)

In 1966 when low levels of feeding were employed during gestation for the Boghall flock it is suggested that while the ewes were able to respond in early lactation to maintain growth rates to 35 days comparable with those of Howgate, the length of the lactation appears to have been shortened. The same might be said with regard to the poor performance of the Howgate flock in 1968 though the exceptional performance of the Boghall flock during the 35-84 day period in that year is surprising (the liveweight gain being significantly greater than in any other year) and confounds the notion implied with regard to the 35 day performance, that over-stocking might be occurring.

The twin lamb weights were significantly ($p \leq 0.05$) less in weight than the singles for the Boghall flock the difference having increased from -7.17 lb at 35 days to - 9.60 at 84 days, this being significant ($p \leq 0.05$). Similarly, the twin/single difference increased for the Howgate flock from - 4.88 at 35 days to - 8.98 at 84 days.

The weights of the lambs from the Boghall and Howgate hefts were not significantly different at 140 days in 1966, 1967 and 1968. Only in 1965 were the Boghall lambs significantly heavier, ($p \leq 0.01$). (Table 28)

The weight of the Boghall lambs at 140 days was significantly less ($p \leq 0.01$) in 1966 than in all other years and the gain during the period 84-140 days was significantly less compared to 1967 and 1968, though it was virtually the same as that in 1965. (Table 29) The lambs weaned in 1967 were significantly heavier ($p \leq 0.01$) than in any other year in both flocks.

It is suggested that the poor liveweight gains in 1967, and 1968 may well be due to increased stocking rates (increased ewes to 350 in 1967) and that the weight of the lambs at weaning has only been maintained by sustaining better growth rates earlier in the season which are likely to be due to better nutrition for the ewe during gestation and improved pasture quality or availability during the early summer.

The twin weights at 140 days were significantly ($p \leq 0.01$) less than the respective single weights for both flocks, they being -12.5 lb for Boghall and -11.1 lb for Howgate.

The effect of age of ewe on lamb weight was also similar for both flocks. The two year olds producing significantly ($p \leq 0.01$) lighter lambs than their 4+ year old flock mates (- 4.2 lb for Boghall and - 3.9 lb for Howgate).

TABLE 28 : The 140 day corrected male single equivalent lamb liveweight and differences in weight between a male twin (T), female single (F), and a male single from a two year old (A2) and three year old (A3) ewe from the Boghall and Howgate hefts 1965-68.

	Boghall	Howgate
1965	75.9 ± 0.9	70.7 ± 1.4
1966	71.9 ± 0.9	72.8 ± 1.2
1967	78.7 ± 0.8	77.8 ± 1.8
1968	74.1 ± 0.9	72.7 ± 1.7
T	-12.5 ± 0.7	-11.1 ± 1.4
F	- 2.0 ± 0.6	- 2.2 ± 1.2
A2	- 4.2 ± 0.8	- 3.9 ± 1.8
A3	- 0.8 ± 0.8	- 1.1 ± 1.7

TABLE 29 : The 140 day corrected male single equivalent lamb liveweight gain and differences in weight gain between a male twin (T), female single (F), and a male single from a two year old (A2) and three year old (A3) ewe from the Boghall and Howgate hefts 1965-68.

	Boghall	Howgate
1965	20.7 ± 0.6	18.2 ± 1.0
1966	20.9 ± 0.6	14.5 ± 1.0
1967	18.7 ± 0.6	21.0 ± 0.9
1968	14.4 ± 0.6	22.0 ± 0.9
T	- 2.9 ± 0.5	- 2.1 ± 0.7
F	- 0.6 ± 0.4	2.8 ± 0.7
A2	- 4.7 ± 0.6	- 0.7 ± 1.0
A3	- 4.0 ± 0.6	- 1.1 ± 1.0

Wool

The wool yield from the Boghall ewes has been significantly lower, in all years, than that of Howgate (Table 30). Some of the reasons for this are reported in relation to the dietary treatments given during the period of inwintering (Section II Experimental A).

TABLE 30 : Wool yield, unwashed, for the Boghall and Howgate flocks 1965-68, lb/ewe.

	Boghall	Howgate
1965	2.9 ± 0.13	4.9 ± 0.16
1966	3.2 ± 0.10	4.8 ± 0.20
1967	3.9 ± 0.13	4.6 ± 0.19
1968	3.7 ± 0.13	4.8 ± 0.19
A2	+ 0.23 ± 0.10	- 0.05 ± 0.17
A3	+ 0.09 ± 0.10	- 0.39 ± 0.18
2LB	- 0.13 ± 0.09	- 0.65 ± 0.17

While the Boghall two year old and three year old ewes yielded more wool than their four year old flock mates, the two and three year olds on Howgate yielded less than their four year old flock mates as calculated from four years data. The twin bearing ewes produced less wool than the single bearing ewes, significantly ($p \leq 0.05$) so in the case of the Howgate flock.

There was also differences in wool grading between the two flocks, (Table 31).

TABLE 31 : The percentage number of fleeces in each grade classification from the Boghall and Howgate flocks 1966–68.

		0	1	2	3	4	5	6
1966	Boghall	4.0	9.0	0.5	0.5	48.2	37.6	0
	Howgate	0	44.4	3.1	0	33.3	19.0	0
1967	Boghall	0	9.1	15.5	0.3	54.5	19.9	0.3
	Howgate	0	46.2	7.4	0	34.3	11.9	0
1968	Boghall	0	5.1	14.6	0.7	60.0	19.4	0
	Howgate	0	34.2	4.2	1.4	37.1	22.8	0

The grades 0–6 are equivalent to the Wool Marketing Board Grades as shown below.

Grade classification	Wool Board		Prices 1968
0	Broken fleece		Pence/lb
1	721	Blackface Deep Ewe & Wether	77
	722	" Medium " " Mattress	74½
	723	" " " "	66¼
	724	" " " " No. 2	61½
2	725	" Short Fine Hog, Ewe & Wt.	50½
	727	" Medium Ewe & Wether Rubby	58
3	728	" Deep Strong Hog	64
	729	" Hog No. 2	50¾
	730	" Hog	52¼
4	731	" " Rubby	44¼
	732	Hog, Ewe and Wether Light Cast	46

4	733	Blackface Hog, Ewe and Wether Heavy Cast	40
	734	" " " " " Cotts	55¼
5	790	" Dark Grey and Black Hog	37½
	792	Scotch Grey	40
	793	Blackface Light Grey Hog, Ewe and Wether Mattress	53½
	794	" " " Hog, Ewe and Wether	42½
6	797	" Hog Discoloured	45½
	798	" Ewe and Wether Discoloured	56¼
	799	" " " " Mattress Discoloured	66½

It is clear that in terms of wool quality the ewe clip from Howgate is of greater value than that from Boghall. The increasing proportion of fleeces graded 4 (731-734), Rubbies and Casts from the Boghall flock compares unfavourably with the high proportion of mattress grades (2, 721-724) occurring in the Howgate flock.

The number of grey's (4, 790-794) occurring on both flocks is higher than desirable and cannot be accounted for by an increasing proportion of older ewes in the flock, even though this may be the case for the Boghall flock.

Production Performance

The production data for the Boghall and Howgate flocks is given in Table 32. Lamb mortality for the Boghall flock was 7.8, 21.0, 7.6 and 5.8 per cent for 1965, 1966, 1967 and 1968 respectively. Lamb mortality on Howgate has been less than 2.0% in all years so far as could be ascertained.

It should be noted that stocking rates have increased on Boghall by some 75% since 1964 when the number of ewes at that time was 200.

Lambing percentage has remained high except in 1966 when it fell to the low level of 79.1%. It has remained high in relation to the Howgate flock though not as high as that achieved in 1968. The valuation on a per lamb basis was less for Howgate than that obtained for Boghall in all years except 1966. Table 33.

TABLE 32 : Production data for the Boghall (B) and Howgate (H) flocks.

Year	1965-65		1965-66		1966-67		1967-68	
Flock	B	C	B	C	B	C	B	C
Ewes mated	286	76	293	74	350	80	350	78
Lambs weaned	328	81	232	82	369	84	393	94
Ewe lambs retained	62	21	60	22	78	22	93	24
Lambs sold	266	60	172	60	291	62	300	70
Ewes died	6	-	23	-	16	2	15	1
Lambing %								
at weaning	114.6	106.5	79.1	110.8	105.4	105.0	112.2	120.5
Ewe mortality %	2.1	-	7.8	-	4.5	2.5	4.2	1.3
Wool lb/ewe								
including hoggs	4.1	5.8	3.4	5.8	4.8	5.5	4.1	5.6

TABLE 33 : Flock valuations 1965-68 £ per lamb
(Based on number available at time of valuation)

	1965		1966		1967		1968	
As stores:	B	H	B	H	B	H	B	H
Wethers	3.51 (175)	3.51 (41)	3.67 (97)	3.62 (45)	4.54 (132)	4.35 (40)	4.72 (125)	4.44 (45)
Ewes	2.72 (90)	2.25 (20)	2.25 (62)	2.50 (14)	4.39 (103)	3.83 (39)	4.11 (88)	3.99 (21)
Stock Ewe lambs	5.00 (63)	4.75 (20)	4.44 (73)	4.60 (23)	5.50 (78)	4.75 (22)	5.5 (66)	5.75 (24)
	1174.05 / 328	283.91 / 81	819.61 / 232	303.70 / 82	1480.45 / 313	420.21 / 99	1314.68 / 279	421.59 / 90
Total	3.58	3.51	3.53	3.70	4.73	4.24	4.71	4.68

The Cash income for the Boghall and Howgate flocks are given after Harkins (1968) in Tables 34 and 35 and the variable costs are given after Harkins (1968) in Tables 36 and 37.

These have been recalculated on a per cent basis in Table 38.

TABLE 34 : Cash Incomes for the Boghall flock 1965-68

	1965		1966		1967		1968	
	Nos.	£	Nos.	£	Nos.	£	Nos.	£
Lambs Sold	266	863.4	172	634.1	291	1305.1	300	1280.4
Wool	1216 lb	259.6	1040 lb	209.5	1679 lb	329.6	1439 lb	302.8
Cast Ewes	49	179.9	49	116.0	60	226.0	35	126.0
Subsidy		257.4		279.4		367.5		428.
Total		1560.3		1239.0		2228.2		2108.0

TABLE 35 : Cash Incomes for the Howgate flock 1965-68.

	1965		1966		1967		1968	
	Nos.	£	Nos.	£	Nos.	£	Nos.	£
Lambs Sold	60	187.0	60	202.4	62	257.2	70	314.8
Wool	442 lb	94.7	432 lb	87.1	444 lb	84.4	438 lb	93.5
Cast Ewes	17	79.9	15	45.2	22	105.6	24	92.0
Subsidy		68.4		70.3		84.0		81.9
Total		430.0		405.0		531.2		582.2

TABLE 36 : Variable Costs for the Boghall flock 1965-68

Foods	1964/65		1965/66		1966/67		1967/68	
Ewes	tons	£	tons	£	tons	£	tons	£
Concentrates	9.88	353.3	7.33	253.2	8.3	262.4	8.8	286
Hay	8.1	121.5	10.13	152.0	23.1	346.8	23.7	355.5
Straw	2.02	10.1	11.48	57.4	0.71	3.6		-
Hoggs								
Concentrates			0.53	15.9	0.8	24	1.4	42
Hay			2.08	31.2	2.79	41.9	7	105
Wintering		93		-		-		
Rams								
Concentrates		4.5		4.5		6		9
Hay		9		9		12		15
Total foods		591.4		523.2		696.7		812.5
Ram Replacement		71.5		73.3		87.5		87.5
Vet. and Medicines		28		82		72		75
Fertilisers						41.5		59.3
Haulage		34.0		24.6		48.1		35.3
Total Variable Costs		724.9		703.1		935.8		1069.6

TABLE 37 : Variable Costs for the Howgate flock 1965-68.

	1965	1966	1967	1968
Hogg Wintering	31.5	33.0	33.0	36.0
Ram Feed	5.5	5.5	5.5	5.5
Ram Replacement	19.0	18.5	20.0	19.5
Vet. & Medicines	7.6	11.4	12.0	11.5
Haulage	8.5	8.3	9.5	10.6
Total	72.1	76.7	80.0	83.1

TABLE 38 : Cash Incomes on a Per Ewe basis 1965-68 Boghall and Howgate and the means of 1967 and 1968 results (£).

	1965		1966		1967		1968		Mean 67/68	
	B	H	B	H	B	H	B	H	B	H
Lambs Sold	3.02	2.46	2.16	2.74	3.73	3.22	3.66	4.04	3.69	3.62
Wool	0.01	1.25	0.72	1.18	0.94	1.06	0.87	1.20	0.90	1.13
Cast Ewes	0.63	1.05	0.40	0.61	0.65	1.32	0.36	1.18	0.50	1.25
Subsidy	0.90	0.90	0.95	0.95	1.05	1.05	1.23	1.23	1.22	1.22
Gross Income	5.46	5.66	4.23	5.48	6.37	6.65	6.02	7.46	6.23	7.22
Variable Costs	2.53	0.95	2.40	1.04	2.67	1.00	3.06	1.07	2.86	1.03
GM/ewe	2.93	4.71	1.83	4.44	3.70	5.65	2.96	6.39	3.37	6.19

It is apparent that on a per ewe basis the Howgate flock is performing financially better than the Boghall flock due in the main to appreciably lower variable costs, but also due to a better return from wool and cast ewes.

To obtain a comparison on a flock basis and in order to establish the position that might have existed if no increase in stocking rate had been made on Boghall, the Gross Margin per ewe for Howgate could be multiplied by 200 and compared to the Boghall flock Gross Margin per ewe multiplied by 350. Taking the mean results for 1967 and 1968 this gives a Gross Margin of £1280 and £1238 for Boghall and Howgate respectively, i.e. any increase in total Gross Output for Boghall being offset by an increase in variable costs. This calculation takes no account of investments in buildings and extra stock. It is clear, however, from data presented by Harkins (1968) that there is a cash deficit of £1480 over the four year period with an increase in valuation of £993.

It is questionable whether this method of flock comparison is justified since the performance of a flock of some 80 animals is likely to be different to that of 200 and especially so under extensive systems of management, thus the flock of Howgate ewes may not legitimately represent the flock of 200 ewes that would have existed on Boghall if changes in management and stock numbers had not taken place.

There is also some difficulty in dealing with a situation in which an increased number of ewe lambs have been retained in order to build up stock numbers. Similarly ewes have been retained to older ages. Some of the increase however has been taken account of by an increase in valuation.

Clearly to break even on a flock comparison basis output per ewe must increase, and further increases in stocking rate made if possible. Increases in stocking rate might be made more possible by fencing. Fencing however, represents a further increase in capital investment which will demand repayment with interest.

DISCUSSION

In an investigation of this kind where increases in stocking rates are being made the only true measure of success or failure will be in the individual performance of the ewe as reflected by herself and her lamb. It is therefore of importance to establish within the period of this investigation whether any notable changes have taken place.

It is doubtful if any firm conclusions can be reached since the period of the investigation is short in relation to the degree of increased stocking rates adopted. Nevertheless indications of change do exist.

Changes in liveweight became most apparent during 1967-68, the last reported year of the investigation. The corrected weight of the Boghall ewes in November of that year was 123.5 lb, the lowest November weight recorded from 1964-67. This low weight could not be accounted for by seasonal effects since the control flock was significantly greater in weight and similar in weight as in 1966 and 1965.

A similar pattern existed in the weights recorded for the beginning of January 1968, the loss in weight from November being greater than in the two seasonally comparable years of 1966 and 1967 (Table 17).

The February weight in 1968 again was the lowest recorded and for the first time less than that of the control flock, though they had been supplementary fed. Even so 100 of the thinner Boghall ewes had been housed at the beginning of January and given hay and concentrates.

By March the weight of the ewes had increased to a level that was greater than that obtained in 1965 and 1966, though less than that obtained in 1967. By April, however, the effect of feeding had raised the weight of the ewes to 130.0 lb which was similar to that obtained in 1965 though still less than that in 1967. It was also achieved with greater energy inputs (2100 kcal M.E./ewe/day as opposed to 2000 kcal M.E./day).

The June weight of the ewes gave no indication that they were appreciably worse than in any other year and the 35 day lamb gains were comparable with other years.

The July weights also gave little indication of overstocking since the ewe weights were similar to those of other years (excepting 1966) and lamb growth from 35-84 days was better than in any other year.

For the first time however since the investigation began a loss in ewe weight was recorded between July and September in a year when the control ewes gained 11.8 lb (significantly more than in any other year). The live-weight gain of the lambs from July to September (84-140 days) was also poorer than in any other year, and in a year in which stocking rates had been reduced due to the early weaning of one lamb of a twin pair. There was even an indication that in 1967 the weight gain between July and September was poorer than in 1966 and 1965. It would appear that the September or weaning weight of the lambs in 1967 and 1968 on Boghall have only been maintained by virtue of improved growth rates earlier in the season. These are likely to have been obtained by providing the ewe with a level of nutrition during gestation which equates more closely with demand and providing a pasture which initially can sustain better growth rates earlier in the season.

The real effects of overstocking will only become apparent as the investigation proceeds but are nevertheless likely to be modified by changes in pasture management, with the erection of fencing and pasture grazing control.

As the number of lambs produced per ewe is increased the greater is the liklihood that the number of small lambs at weaning will increase. This being accepted the need to provide a substantially better plane of nutrition for the twin suckling ewe must be met by reserving better quality pasture for her and regulating stocking density according to pasture availability.

Nevertheless, stocking rates may be such that under no circumstances can the lamb maintain adequate growth rates during the latter part of the summer. Thus weaning may well have to be carried out earlier and renovated and reseeded pasture used for the lambs only, up to the beginning of September.

The effect of plane of nutrition practiced during gestation and the winter housing period on the performance of the flock is of importance. In 1966 the nutritional energy levels were considerably reduced (some 28%) compared to the levels used in 1965 and the consequences of this in terms of the liveweight of the ewe and performance of the lamb appear to be clear.

In January 1966 the Boghall ewes were significantly lighter than in 1965 or 1967 and the loss in weight from November was also greater than in any other year as a result of herbage inaccessibility due to snow cover for at least 30% of the period. By February, however, the weight of the ewes had increased to the extent that they were significantly heavier in that year than in any other as a result of housing at the beginning of January as opposed to later in other years.

Between February and March when given 1300 kcals M.E. and 0.14 lb of D.C.P. daily the ewes failed to maintain their weight and in fact lost weight (5.1 lb), the only year in which a loss in weight was recorded during this period.

At the beginning of March the energy allowance was increased to 1800 kcals M.E. and 92 g D.C.P. per ewe per day. The weight of the ewes just prior to lambing (mid April) and the gain between March and April was also significantly less than in any other year.

Both the birthweight and 35 day weight were poorest in 1966, and the growth rate between birth and 35 days was significantly less. The poor performance of the lambs was still evident at 84 days.

At weaning (140) days lamb weight was significantly less than in all other years though the gain between 84 and 140 days was comparable to that obtained in 1965 and significantly greater than that obtained in 1967 and 1968.

Ewe weights were significantly less than in all other years in June and July but were similar to the years 1965 and 1967 by September.

The mortality of ewes in this year was high (7.8%), and there were considerable losses amonglambs. (Table 14, p.148) Pneumonia among ewes and lambs occurred, it causing abortion in a number of ewes after which many made a full recovery. It is not clear whether pneumonia occurred incidentally or whether it was encouraged by the low levels of nutrition practised. Though incidence was more prevalent amongst animals given straw there is no evidence that it necessarily was responsible for the outbreak. The buildings have remained the same and since 1966 there has been little evidence of pneumonia.

Undoubtedly the incidence of pneumonia among lambs may have been aggravated in that year by poor conditions during the early part of lambing and by an attempt to lamb inside. Nevertheless many lambs showed little evidence of pneumonia until quite old (35-84 days) when at grass.

It is suggested that the poor performances of the flock as a whole in that year was basically due to poor nutrition during the period of gestation. While it would appear likely that pregnant ewes may well perform satisfactorily up to the beginning of February at the levels of nutrition used in 1966 (i.e. 1300 kcals M.E. per ewe per day and 50 g D.C.P.), the levels of nutrition required to maintain a high level of performance after this time are likely to be much greater.

Though it is apparent that the ewes on the control heft can produce lambs of equal birthweight without showing large increases in liveweight during the last six to eight weeks of gestation, the Boghall ewes on a group feeding regime of conserved roughage and concentrates, seemingly cannot.

In all years, apart from 1966, the Howgate ewes were assessed subjectively to have less body reserves than the Boghall ewes during the last period of gestation. Thus, though a difference in fat content, fat utilisation and nutritional intakes between the two flocks undoubtedly occurred during this period the birthweight of the lambs from the two flocks remained similar, while the difference in ewe liveweight gain was considerable.

Part of this difference might be attributable to the fact that the Howgate ewes were utilising body reserves at an almost similar rate as to the growth of the foetus while under a much more severe nutritional stress than the Boghall ewes, which were unlikely to require to utilise body reserves to the same extent.

Some of the differences in ewe liveweight gain, particularly between year differences, among Howgate ewes, may well be due to differences in 'gut fill', but so far as the Boghall ewes are concerned the between year differences are almost entirely accounted for by differences in lamb birthweight as indicated by the regression (p49).

The considerably greater loss in weight which has occurred in the Boghall flock during the period between the pre-parturition weight in April and the weight at marking in early June may be accounted for by:

(a) a period of dietary readjustment during a change from a conserved roughage/concentrate diet to a diet of fresh grass and other herbage species, and

(b) a period during which fat reserves (not used during pregnancy due to a higher level of nutrition) were being utilised to maintain a higher level of nutrition, stimulated by a greater availability of clean pasture, and

(c) a difference in the weights of the ancillary components of the uterus.

The relative importance of each of these factors is difficult to assess. It is highly probable that the consequences of dietary readjustment had the effect of increased fat utilisation in most years since the change of feeding was fairly abruptly carried out over one or two days. While there may be circumstantial evidence to suggest that there was a higher level of lactation in 1965, the growth rates of lambs on Boghall being significantly greater than those on Howgate, it would appear unlikely from the evidence collected in following years that the Boghall ewes were producing considerably more milk than the Howgate ewes. It is nevertheless of interest to note that in 1966, when early lamb growth rates were greater on Boghall than on Howgate, that dietary change was carried out over a much longer period.

It is not unreasonable to expect that early lamb growth rates might have been improved due to better levels of nutrition during gestation and clean rested hill pastures, but it has to be remembered that they have been maintained at a comparable level against a background of increased stocking rates and at a stocking rate approximately 50% greater than that existing on Howgate. Thus, it might be argued that early lamb growth rates were maintained only because the body reserves had not been extensively utilised during gestation, but were utilised during early lactation, so accounting for the loss in weight recorded. Under the circumstances it might also be conceivable that between postparturition and June the Howgate ewes might have actually gained weight, so exaggerating the loss in the weight of the Boghall ewes. Russel, Gunn and Doney (1968) recorded a gain in weight of traditionally managed hill ewes during the period of lactation.

Clearly there will be a strong interaction between level of winter feeding and potential summer stocking rate. The extent to which increases in stocking rate might be made by virtue of increases in winter feeding is a matter of hypothesis but the fact that such increases could be made on the basis of an increased level of feeding would appear to be less in doubt given that the level of ewe and lamb performance was maintained at least up to the middle of July. Thereafter, performance is likely to be determined more by pasture quality and availability than by any other factor.

The desirability of maintaining and where possible increasing output from the flock for economic reasons is very real. In the system adopted variable costs are high and if the system is to remain economically viable must be offset by high returns. The interaction of lambing percentage, variable cost and the extent to which marginal capital investment might be carried out was demonstrated in the introduction. The situation on Boghall is analagous to that outlined for farm B (p) in which output was already high before changes in management affecting capital investment and variable costs were introduced.

From the mean data calculated on a per ewe basis for 1967 and 1968 and using the equation

$$E_1 (0_1 - b_1) = E_2 (0_2 - b_2) - y$$

some assessment of how far performance falls short of requirement may be made. Taking the Howgate data for E_1, 0_1 and b_1, E_2 representing the Boghall ewe flock the equation becomes

$$200 (7.22 - 1.03) = 350 (0_2 - b_2) - y$$

y may be calculated on the basis of capital invested in stock and buildings.

The capital in extra stock is £1429. Allowing a ten year period for a return on capital, and allowing that a part of this capital is retrieved in cash, the annuity required per ewe per annum is £0.408 at a discount rate of 10%.

The capital in buildings, net of grant, is £1750. Assuming a ten year period for repayment with no scrap value the annuity required per ewe per annum is £0.814 at a discount rate of 10%.

The total annuity required for the total capital investment made is £1.22.

Substituting, equation becomes:-

$$200 (7.22 - 1.03) = 350 (0_2 - b_2) - 1.22$$

$$0_2 - b_2 = 4.76$$

i.e. the gross margin from the Boghall flock must be £4.76/ewe to break even on the results obtained from a flock equivalent of 200 ewes on a traditional system of management.

The actual Gross Margin per ewe for 1967/68 was £3.37, i.e. £1.39 less than that required for a break-even position.

If output from wool and cast ewes could **be** maintained at the same level for both flocks this difference would be reduced by £0.75.

Performance per ewe from Boghall would need to improve appreciably to offset this difference if wool output and cast ewe output remains the same.

In terms of lambing percentage an increase of 37% would be required at a lamb price of £3.69.

In terms of increased stock numbers, if extra stock is brought in at 2 year old costing £8, the total stock carried would be of the order of 600 ewes to break-even.

It is unlikely that these extremes need to be attained but rather that some combination of them with improvements in wool output and cast ewe output be made.

The actual parameters required to obtain a break-even position will vary according to whether tax is payed or not and the discounting rate chosen. (Harkins 1968).

The investigation has shown that inwintering can enable increases in summer stocking rate to be made and that in the environment studied there was some evidence to show that while output per ewe had been maintained the liveweight of the ewes on Boghall were less at the end of the four year period at a 75% stock increase.

To be economically viable, particularly in regard to marginal capital investment, the reduction in wool output must be rectified and the number of lambs per ewe must be increased with the possibility also of increasing ewe numbers. Clearly marginal capital investment can be more readily serviced in situations in which there is room for improvement in the number of lambs reared per ewe. An example of this type of situation is reported by McClelland (1968) in which the ewe stock on a 'poor quality hill grazing' was increased from 150 to 240 and the number oflambs increased from 100 to 240. Profit from the flock increased by more than £200 for a marginal capital investment of £900, (£450 in the house and £450 in extra sheep).

Thus the system of inwintering as a means to increasing output from a hill area is possible but the ease with which return on marginal capital investment is obtained will depend on the present level of output for a given situation.

SECTION II

'Some Nutritional Aspects in the Intensification of Hill Sheep.'

The Nutrition of the Hill Ewe

The ewe is kept to produce wool and meat (lamb) and in the latter capacity is therefore also required to produce milk. The biological mechanics of doing this requires that certain minimum nutritional inputs must be supplied to the ewe in amounts that will vary according to that part of the productive cycle in which she is functioning, i.e. pregnancy, lactation or the accumulation of body fat.

In animal production systems the basic nutritional requirements are for energy, protein, minerals and vitamins. It is in man's interest that he finds the most efficient way in the conversion of these into meat. There are, however, two conflicting principles at work since biological conversion efficiency does not always equate with economic efficiency. It is because of this that the level of nutrition of the farm animal does not always meet with the production demands of that animal. Hence while it may be possible for man to define in precise terms what the animal requires it may not always be in his economic interest to supply these requirements. In not doing so, however, will almost certainly involve biological inefficiencies which are only acceptable so long as they do not decrease economic efficiency.

The balance of what the animal actually requires for maintenance and production set against what its minimal requirements are to attain the same level of production without necessarily maintaining the animals own body composition and function, (a situation which is essentially confined to pregnancy and lactation), has intrigued agricultural nutritionists for some time. Indeed, until recently, it has not been possible to define accurately what the nutritional requirement of the ewe is during pregnancy so that any estimation of what nutritional allowances should be made to the ewe that uses a proportion of her own body reserves for production processes has been largely one of trial and error.

It may be argued that because at the present time it is difficult to establish precisely the body reserve of a hill animal there is little point in establishing the minimal nutritional allowance of an animal that is expected to utilise these reserves. On the other hand it can be argued that with an increasing standardisation of breeding policy and a more precise knowledge of body composition and liveweight relationships estimation of the body reserves of an animal from its liveweight will be possible in the future. With this information it should be possible, therefore, to establish what the minimal allowances would be for a ewe in a given body condition at any stage in its productive cycle.

Whether the accuracy with which this is done is likely to improve the efficiency of production systems is debateable since it might also be possible to obtain an improvement in efficiency without using such an elaborate technique. In general the poor performance of sheep flocks has been the result of inadequate nutrition during pregnancy and lactation. Increased levels of feeding would improve performance of these flocks quite quickly but because there are limiting economic pressures in sheep production systems it is essential that the quantity of feed inputs required should be more precisely defined since in intensive systems of production they can account for a high proportion of the costs.

Before the nutritional requirements of a ewe, which is using a proportion of her own body reserves in some stage of her productive cycle, can be stated it is first necessary to define accurately what the various requirements are for each of the metabolic and biological activities which are involved in the productive processes. In so far as the breeding animal is concerned, any productive process involves firstly the maintenance of the animals own basal metabolism and its body activity in feeding and digestion, and secondly, the metabolic processes directed towards the productive process itself (gestation, lactation, accummulation of body fat). Diagram:

Nutritional Requirements As Food	Efficiency of Digestive and Absorptive Process	Maintenance	Basal Metabolism	Maintenance Body Temp
			Feeding & Digestive Process	Maintenance of Cellular Activity
			Physical Activity	
		Gestation	Metabolic Processes Directed Towards Producing Progeny	
			In Utero Maintenance Requirements	
		Lactation	Metabolic Processes Directed Towards Milk Production	
		Accumulation of Body Reserves	Metabolic Processes Directed Towards Producing Mainly Fat But In Some Circumstances Also Muscle.	

Having defined the nutritional requirements, a factor which is essential in determining the amount of food required to supply these nutritional requirements, is the efficiency with which the animals digestive system can breakdown, release, convert (in the case of the ruminant) and absorbs the nutrients contained in that food. Hence it is first necessary to understand the principles that are involved in the processes of digestion which under normal circumstances tend to be characteristic of the food itself rather than as a result of any within species animal differences, though this statement must be qualified with the proviso that the physical form in which the food is presented to the animal is also defined.

The need to provide an optimim amount of food requires that the mechanics regulating voluntary intake and digestibility by ruminants are understood.

The regulation of intake by the simple stomached animal has received considerable attention and while many of the principles are directly applicable to the ruminant there are undoubtedly other factors involved which are specific to these species.

Bach and Campling (1962) have reviewed the literature concerning the various theories of regulation. That the central nervous system is involved in the co-ordination of many of the sensory and response mechanisms is not doubted (Brobeck 1955; Larsson 1954). More particularly it is known that two regions of the hypothalmus are concerned viz: the lateral hypothalmic nucleus and ventro-medial nucleus.

The thermostatic theory has been propounded by Brobeck (1960) and while it explains many of the phenomena of voluntary intake regulation there are some aspects which cannot be explained in these terms. Blaxter (1962) highlights the fact that the low voluntary intake of poor quality roughages is associated with a lower heat production than is obtained when high quality rations are given, cannot be explained in terms of the theory in which an animal eats in response to a fall in heat production.

The chemostatic theory (Mayer 1953) states in general terms that voluntary intake responds to differences between the concentration of the glucose in the venous and arterial blood. Kennedy (1961) has developed this further in a hypothesis that includes other metabolites and has specifically mentioned the metabolites resultant in the accumulation and depletion of body fat.

Whether these theories can be accepted in relation to the ruminant will be discussed later.

It is apparent from the studies carried out on non-ruminants that the regulation of food intake is unlikely to be controlled by any one factor. The results of oropharyngeal sensations, gastric contractions and distension, changes in heat production and changes in the levels of circulating metabolites co-ordinated by the central nervous system may severally be implicated. (Balch & Campling 1962).

While there are peculiarities of metabolism and range of diet specific to the ruminant it has nevertheless been shown that as in the simple stomached animal the central nervous system is implicated in the regulation of feed intake (Larsson 1954; Bell and Lawn, 1955 and 1957). The concept that appetite is regulated by the balance, or integration, of stimuli to the central nervous system, resulting in the manifestation or inhibition of appetite, was presented by McCly mont (1959).

The literature reviewed by Balch and Campling indicates that the effects of taste and smell in the regulation of food intake appear to be more specifically concerned in the initiation of eating than in the determination of the amount eaten.

Hesselbarth (1954) and Kruger et al (1955), have shown that there is a positive correlation between the speed of eating and voluntary food intake. Freer, Campling and Balch(1962) found that when the time of access to roughages was limited the rate of eating was increased. Blaxter and French (1944) and Burt (1957) with dairy cows and heifers reported significant differences between the rates at which different foods were eaten and also between the rates at which individual animals ate.

The fact that these relationships exist suggest that the consequences of social behaviour and more particularly, the competition for restricted amounts of food offered to groups of animals under intensive conditions, could have a substantial effect on the voluntary feed intake of animals under these conditions.

Blaxter (1958) suggests that a relationship between the bulk of food and the amount of it voluntarily eaten by ruminants would probably depend on the filling effect in the gut, especially the reticulo-rumen, and hence on such factors as the digestibility and rate of passage of the food. Blaxter et al (1961) examined the voluntary intake by sheep of roughages in which the digestibility of energy ranged from 38 to 70 per cent and found a close correlation between the apparent digestibility of energy and the voluntary intake. Campton, Domfer and Lloyd (1960) found a correlation of + 0.83 between the voluntary intake of a range of roughages and their in vitro digestibilities. Similarly Milford (1960) showed that intakes of subtropical pasture grasses of 28-32 per cent digestibility by sheep was 150-300 g of D.M. daily while herbage of digestibility of 56-57 per cent was eaten at the rate of 1300-1500 g D.M. daily. However, there is some evidence to suggest (Dodsworth and Campbell, 1952) that the voluntary intake of succulent foods such as silage and turnips could be associated with the D.M. content of these feeds rather than with their digestibility.

There are many experiments which show that the addition of urea to poor roughage increases intake. When these experiments included digestibility trials addition of urea usually, but not invariably, increased digestibility. (Balch and Campling 1962). The converse is also true; when digestibility was reduced by giving aureomycin or sulphanilamide, voluntary intake fell. (Bell, Whitelaw and Galiup 1951; Oyaent, Quinn and Clark 1951).

The addition of 150 - butyric, n-valeric and 150 - valeric acid with urea to a diet of hay was shown to increase the microbial protein concentration, digestibility and intake. (Hemsley and Main 1963).

Such results suggest that there is a close and probably causual relation between the extent and rate of cellulose or forage digestion and the voluntary intake of a roughage by ruminants.

There is good reason to believe that the gut size itself will affect the voluntary intake of food. Positive relations between the weight of the reticulo-rumen and voluntary intake have been found in lambs, (Wardrop and Coombe 1960, 1961). Paloheimo (1944) makes a pertinent point when he states that while it is possible to stretch the compartments of the stomach and intestines readily post mortem by slight increases in pressure, the volume occupied by the several compartments in life depends on the volume of the abdominal cavity as a whole.

Gordon and Tribe (1951) observed that voluntary intake of food by very fat ewes bearing twins might fall markedly in the last month of pregnancy. Forbes, Rees and Boaz (1967) in experiments concerning the feeding of silage to pregnant ewes show that the D.M. intake decreases as pregnancy advances and Forbes (1968) shows how this might be explained with reference to the abdominal anatomy of the pregnant ewe by serial section. Reid (1958) suggested that the space occupied by the foetuses may limit voluntary intake of food by twin-bearing ewes, because expansion of the reticulo-rumen within the abdominal cavity is restricted; this may partly be responsible for a marked fall in intake about the 110th day of pregnancy. Blaxter (1957) drew attention to the possible effect in limiting rumen volume during pregnancy of the large amounts of fat sometimes present in the abdominal cavity of very fat ewes and cows. Owen and Ingleton (1963) observe that when no limit was imposed by scarcity of grass, voluntary intake did not rise and even became depressed in spite of the increasing demands of the foetus, which suggests that, especially in ewes carrying twins, there is a physical limitation of food intake in late pregnancy. This is contrary to their experiences with the same ewes during lactation in which it was found that intake increased spectacularly. Hadjipieris and Holmes (1966) show that the feed intake of ewes fed dried ground grass as cakes were largely unaffected by pregnancy though there was some indication that ewes carrying twins and triplets were adversely affected. Ewes fed long hay showed a decrease in intake due to pregnancy though evidence for this was limited. Intakes of all their dietary treatments rose sharply during lactation. Similar results were obtained by Reid and Hinks (1962) in which the intake of ewes carrying twins was shown to be gradually reduced as pregnancy advanced though not so noticeably with ewes carrying singles while increases in intake as lactation commenced (30 days) was considerable. The diet throughout was a 1 : 1 roughage mixture of chaffed wheaten and lucerne hays.

Everett (1967) however, demonstrated a marked compensatory intake in previously ill fed ewes given pelleted lucerne and barley as pregnancy advanced, while the intake of well fed, fat ewes carrying single foetuses, declined slightly. The increase in voluntary feed intake of sheep during lactation is also confirmed by Cook, Mattox and Harris (1961); Wallace (1948); Coop and Drew (1963); Arnold and Dudzinski (1967).

In sheep (Ferguson 1956, 1958; Blaxter et al 1961; Owen and Ingleton 1963) fairly close relations have been reported between bodyweight and voluntary intake of D.M.; Blaxter et al (1961) suggested that in sheep voluntary intake varies with metabolic size ($W^{0.73}$). Owen and Ingleton showed that voluntary intake and metabolic weight ($W^{0.75}$) of pregnant and lactating ewes were highly significantly correlated.

It can be concluded that at least with diets consisting entirely or mainly of roughages physical distension of the reticulo-rumen is an important factor, though probably not the only one, regulating voluntary intake. There is no evidence on the nervous pathways involved in the process.

Since the voluntary intake of ruminants is dependent upon the passage of the contents of the reticulo-rumen to the lower regions of the gut the factors influencing this passage are important.

Balch and Campling (1962) point out the importance of digestion in the reticulo-rumen and suggest that with many diets more than 50% of the organic matter can pass undigested from the reticulo-rumen though normally it is much less than this (Blaxter 1962). The main factor responsible for reduction of food particules to a size sufficiently small to pass through the reticulo-rumen orifice is probably chewing during eating and rumination. However, the way in which the food is processed prior to eating will undoubtedly affect the mean time that undigested residues remain in the gut. Techniques involving the uses of dyed mint markers have been widely used to measure the mean retention time of residues in the gut. Blaxter et al (1956) using information from sheep fed on dried grass deduced on theoretical grounds the mean rate of flow of the digesta as a whole, expressed as the amount of faeces expected to be produced in a given period and subsequently calculated the amount of residues retained in the reticulo-rumen. Blaxter et al (1961) and Campling et al (1961, 1962) have shown that there is an inverse relation between retention time and voluntary intake of roughages by sheep and cattle.

Balch (1950), Castle (1956), and Blaxter et al (1956) have all shown that retention time of residues in the gut diminishes with increasing intake.

It has been observed that the rate of passage of stained long hay is slower than that of small amounts of stained ground hay given with long hay (Balch 1950; Castle 1956). Such an observation confirms that the reduction in particle size by chewing during eating and rumination is essential for the transferring of digesta from the reticulo-rumen to the lower regions of the gut. As a consequence of this phenomena the effect of reducing the particle size of roughages by grinding must be examined. In American experiments the degree of grinding necessary to pellet roughages was such that intake was not increased (Loosli 1959) though in earlier work a slight increase in intake and a reduction in digestibility especially of fibre was evident.

Balch and Campling (1962) have shown that with ground roughages the rate of flow of digesta from the reticulo-rumen may be greater, but the total time of retention in the gut may be lengthened by the presence of large amounts of digesta in the lower gut. This suggests that voluntary intake of finely ground hay or concentrates might be limited by the amount of contents in the abomasum or the same section of the lower gut.

With roughage diets changes in any of the processes responsible for reducing the rumen load may be expected to alter voluntary intake. The importance of growing highly digestible herbage is evident, but insufficient attention has been given to conditions causing differences in voluntary intake of individual animals. It is probable that the intake of diets rich in concentrates is governed by factors other than distension of the reticulo-rumen; it is therefore mainly with such diets that other regulatory mechanisms may be expected to operate. (Balch and Campling 1962).

In summarising the thermostatic and chemostatic effects on voluntary intake Balch and Campling (1962) conclude that the intake of roughages will be limited by a high concentration in the blood of a metabolite or metabolites of which the production in the rumen is positively correlated with the amounts of food ingested. The recent evidence of Simkins (1965) and Baile and Pfander (1966) would confirm this view.

From the evidence it is likely that the thermostatic effects could apply since it is well known that the heat increment of foods is very high (Balch and Campling 1962).

The opportunity for a thermostatic or chemostatic regulatory mechanisms to operate would appear to be much greater with diets containing substantial amounts of concentrates than with diets consisting of only roughages (Balch and Campling 1962).

In so far as chemostatic regulation is concerned this would appear to be controlled at least to some extent by volatile fatty acid concentration (Armstrong and Blaxter 1957; Rook and Line 1961; Simkins 1965; Baile and Pfander 1966).

There is no direct evidence that the lipostatic theory of Kennedy (1950, 1953), is applicable to ruminants. In cows and sheep, however, milk production is often so great that with normal systems of feeding, the animals lose weight during the first few months of lactation (Kruger et al 1955; Reid 1961; Russel, Gunn and Doney 1968). It has usually been considered that voluntary intake of ruminants increases with lactation and evidence of this has already been quoted. It is doubtful whether the reported increases of food intake by ruminants during lactation are long enough to provide evidence of lipostatic regulation.

From this short review it is clear that there are many mechanisms and factors which have an effect on the voluntary intake of the ruminant and that these are as yet, not fully understood. Much of the indirect evidence quoted nevertheless is such that the measurement of digestibilities of feeds and the effects on dry matter intake as a consequence of pregnancy and lactation provide sufficient information to enable a fairly precise estimate of the supply of nutrients to the animal from a given quantity of food to be made. The effects of modern compounding techniques are such that the introduction of pelleted ground roughages into production feeding systems is likely. It is important that the effect of this processing on intake and digestibility be more fully understood, especially diets where these roughages are pelleted along with concentrate supplements.

Dietary digestibility and digestive function in the ruminant is clearly of great importance in any assessment of nutritional requirements. Increasingly there has been an awareness of the part played by the micro-flora of the reticulo-rumen in the digestion of ruminant food.

While it is now recognised that the requirement for energy and protein in biochemical terms can be broadly referred to as requirements for steam volatile fatty acids and amino acids the efficiency with which the microflora of the gut produce these from the ingested food is of considerable importance.

Simple sugars are fermented in the rumen. Glucose, fructose and sucrose yield lactic, acetic, propionic and butyric acids. Maltose, lactose and galactose are usually fermented more slowly. Xylose is fermented to give acetic and propionic acids with small proportions of butyric acid. Fermentation of starch yields lactic, acetic and propionic acid.

The products of cellulose digestion have been generally agreed to be acetic and propionic acids (Blaxter 1962).

Triglycerides are hydrolysed in the rumen to give free fatty acids.

Food proteins are broken down in the rumen to peptides, amino acids and ammonia and a proportion of these may be resynthesised into microbial protein. The amino acids which result from the initial proteolysis are attacked by the rumen micro-organisms to yield ammonia, carbon dioxide and steam volatile fatty acids.

Much about the digestive process in ruminants can be deduced by considerations of the proportional losses of energy in the faeces and as methane when different foods are given. (Blaxter 1962). Factors which affect the digestibility of feedingstuffs and the subsequent release of their nutrients have already been referred to in the broader discussion relative to voluntary feed intake.

Even though ruminants vary considerably in size it was concluded by Watson et al (1949) that any differences in the ability of sheep and cattle to digest food were negligible. Within species differences have also been noted to be small (Blaxter 1962) and rarely exceed one unit of digestibility. Blaxter (1962) also concludes that neither pregnancy nor lactation affect the apparent digestibility of a constant ration of food.

It has already been discussed how the amount of food eaten can affect the apparent digestibility and how the rate of passage of food through the rumen is influenced by both the size of the particules of food and the rate at which new food is admitted. The curves derived by Blaxter (1962) in which long and, ground and pelleted grass was fed to sheep show that the more of the food given the steeper the curves, and the more finely ground the greater is its rate of passage. It would appear that in such instances microbial digestion of food particules does not always proceed to completion. In a further graph derived by Blaxter (1962) he shows the mean length of time dried grass spends in the digestive tract and its apparent digestibility. It would appear that maximal digestion occurs only if the passage of food is subject to a delay at those sites where microbial breakdown takes place. The importance of microbial fermentation and the time which the ingested food is subject to this process in obtaining the maximum amount of nutrients from it are obvious.

The effect of intake on protein digestibility could be variable. Watson (1947) in reviewing the work of himself and his colleagues concluded that the intake had only a small effect on protein digestibility. Raymond, Minson and Harris (1959) however, showed that a high level of intake had a reducing effect on N digestibility and associated this effect with a higher rate of passage of food through the digestive tract.

Digestibility differences occur between certain types of protein, notable among these being demonstrated by Head (1953) who showed a difference between fish meal and groundnut meal when fed to sheep and Forbes and Robinson (1967) who compared grass pellets and soya bean meal.

While the digestive process is directed towards liberating the nutrient products from ingested food the efficiency of utilisation of these products must be of interest.

The fermentation process itself gives rise to a considerable heat production, methane and CO_2 production, and while some of the heat loss may be directed towards maintenance of body heat the amounts of energy lost from the animal as heat can be considerable but varies to a great degree. Any measurement of heat loss is difficult and quantitative estimates impossible. Loss of energy as methane and CO_2 has been accurately defined (Blaxter 1962).

The production of volatile fatty acids by the microflora of the rumen completes a considerable part of the process of digestion in the ruminant. The pattern of VFA production and the subsequent absorption of these products is greatly dependent upon the diet offered. The rate of transfer of fatty acids from the gut across the rumen wall would appear to be dependent upon the concentration gradient. (Blaxter 1962; Annison 1968). The efficiency with which these acids are used for maintenance has been estimated to be between 80 per cent and 85 per cent irrespective of the type of diet given. (Martin and Blaxter 1961; Armstrong et al 1957). The metabolic pathways involved in the anabolic and catabolic activities of the blood liver and other tissues have been outlined and discussed by Blaxter (1962), Annison (1968), Annison and Lewis (1959), Armstrong (1965).

The digestion of protein by the ruminant has been outlined by McDonald, Greenhaulgh and Edwards (1967). The absorption of amino acids as a result of the digestion of microbical protein at the lower part of the gut makes the ruminant independent of dietory supplies of essential amino acids since these are supplied by the breakdown of the microbial proteins themselves. The production of ammonia from the diamination of the amino acids in the rumen is absorbed by the blood and converted to urea in the liver. Subsequently the urea is either returned to the rumen via the saliva or excreted in the urine. On returning to the rumen the urea may well be further utilised by the micro-organisms and rebuilt into amino acids.

The efficiency of utilisation of protein can be dependent upon the ratio of amino acids absorbed from the gut. For example Loosli and Harris (1948) and Klostermann et al (1951) showed that the addition of methionine to the diets of lambs and pregnant ewes respectively, improved N retention.

Since the amount of ammonia produced in the rumen is dependent upon the type of protein fermented and since it is known that ammonia production is associated with reduced N retention (Chalmers and Synge 1954) it is therefore likely that different protein types will effect N retention. Sherod and Tillman (1962); Tagaris, Ascarelli and Bondi (1962); and Whitelaw and Preston (1963) have also demonstrated that by using various heat processing techniques they have improved the utilisation of proteins by slowing down the release of ammonia to the rumen.

The interrelationships between voluntary feed intake, rate of passage, digestibility, microbial fermentation, nutrient absorption, and the metabolic and biochemical pathways of anabolism and catabolism are complex and though all of these factors have not been discussed the author has attempted to bring together information which seems relevant to the consideration of the nutrient requirement of the ewe with particular reference to the experimental work described.

Factors affecting the energy requirement for maintenance

Blaxter (1962) outlines the way in which a system of estimating energy requirements in terms of metabolisable energy has been devised and the advantages which it has over other systems. More recently Lofgreen and Garrett (1968) have outlined a similar system based on net energy. Common to both, however, are fundamental underlying principles.

A starting point from which the computation of energy requirement could be made was established in determining fasting metabolism i.e. the heat produced per unit time measured sufficiently long after the subjects last meal for the absorption of the energy yielding materials from its gut to be negligible.

In obtaining values for the fasting metabolism of sheep (ARC) those of Blaxter (1962) using wethers, Marston (1948) and the corrected values of Ritzman and Benedict (1930, 1931) have been used. Other values have also been obtained and are included in Table 1 (after ARC (1965)).

Because it has been established that the metabolism of different species varies with weight raised to a power close to 0.7 (Blaxter 1962) and that metabolism varies with age (Ritzman and Benedict 1930 and Blaxter 1962) the fasting metabolism of sheep have been expressed in this way (Table 2 after ARC 1965).

TABLE I : Estimates of the fasting metabolism of mature fasting sheep weighing 50 kg and aged 3-4 years.

Breed	Fasting Metabolism Kcal/day	Reference
Wethers of mixed breeding	1018	Blaxter 1962
Merino ewes	1030	Marston (1948)
Ewes (Hampshire)	1087	Brody (1945)
Merino Wethers	988	Lines & Purce (1931)
Scottish Blackfaces	1040	Langlands et al (1963)
Merino Wethers	945	Grahame (1964)

TABLE 2 : Preferred values for the fasting metabolism of sheep

Age of Animal (mths)	Fasting Metabolism Kcal/kg ~~100.73~~ $W^{0.73}$
2	116
6	65
12	63
24	59
48	55
48	52

Factors other than the use of energy for the maintenance of body function and cell metabolism, (basal metabolism) are involved in the maintenance of the animal in its 'natural' environment and are summarised below.

ENERGY FOR MAINTENANCE

Basal Metabolism — Cell Function; Organ Function

Body Movement — Walking, Standing, Lying; Harvesting of Food

Thermal Regulation*

*The maintenance of body temperature in varying environmental temperatures under conditions of varying energy intake.

The energy required for standing has not been clearly defined. From the work reviewed by ARC (1965) Hall and Brody 1933; Forbes et al 1927; Blaxter and Wainman 1962; McLean 1962) a value of 2.0 kcal/kg is suggested, all the estimates being obtained from indirect calorimetric methods. Using direct calorimetric methods Pullar (1962) found increases in metabolism of up to 70 per cent i.e. 8 to 10 times greater than the value obtained from indirect calorimetric methods. Webster and Vaulks (1966) have more recently estimated a requirement of 2.82 kcal/kg for standing as opposed to lying which agrees with the results of Hall and Brody (1933) and Forbes et al (1927).

Clapperton (1964) measured the energy cost of walking in sheep. On a horizontal plane he obtained a value of 0.59 cal/kg/m and in a vertical plane a value of 6.45 cal/kg/m. Coop and Hill (1962) have shown that the energy requirement for maintenance for the animal outside increases, and in their particular study, by some 40-80 per cent, and suggest that this increase in energy requirement is the cost due to the walking and harvesting of grass. This increase has also been confirmed by Lambourne and Reardon (1963) and Langlands et al (1963). While other factors such as differences in environmental temperature and competitive stress may also increase the energy requirements for maintenance of the animal outside, as opposed to the caged animal, Graham (1964) has shown that the energy cost of walking and harvesting can account for some 40 per cent of the total energy requirements for the maintenance of an animal which is grazing bare pasture (50 kg sheep), some 60 per cent of this increased energy requirement being needed for the actual process of eating.

A.R.C. (1965), however, have treated the act of grazing as two separate acts of walking, and of eating, or "shearing off the herbage". They regard the latter act as a "tax on food" rather than a specific animal requirement, in that for any one herbage it can be expected to vary with the amount eaten. A.R.C. (1965) concludes that the energy cost of grazing, Graham (1962), and the estimates of the energy cost of eating made by Blaxter and Joyce (1963) do not warrant the inclusion of any allowance for the work of grazing. From the later evidence of Graham (1964), there would seem to be some justification for making some addition to the maintenance requirement of animals grazing bare pasture, especially if the feeding value of that pasture is computed from data collected from animals fed in cages.

However, in a recent review on the "Nutrition of the grazing ruminant" McDonald (1968) suggests that the more recent measurements of energy expenditure in the act of grazing by Young et al (1967) and Corbett et al (1967) could not confirm an increased maintenance requirement when pasture availability was low (Lambourne and Rearden 1963; Coop and Drew 1963) and the metabolisable energy for maintenance was proportional to body weight. An improvement in the technique of measuring energy expenditure by using the entry rate of CO_2 into the body pool of CO_2 developed by Young et al (1967) will greatly facilitate measurements of energy expenditure at grazing (McDonald 1968).

One of the important energy costs for maintenance is that associated with the variable effects of climate in maintaining the animal at constant body temperature. This is of particular importance in relation to the inwintering aspects of the present study.

The ability with which a ewe forages and tolerates climatic stress is generally termed 'hardiness'. In general terms it might be argued that this characteristic is also associated with poor growth rates. Nevertheless in the hill and mountain situation in which sheep are outwintered, hardiness has become an essential feature of survival. Whether this characteristic is required in circumstances in which sheep are protected from nutritional stress by feeding conserved products, and from such climatic stress by housing, is open to question and will only be answered by long term investigation.

The "effective temperature range" (Graham et al 1959) for sheep is usually wide (e.g. 10°C to 30°C in Britain) and may be greater than that suggested by air temperature measurements alone, due to modifications caused by precipitation, wind, radiation and convection losses.

Because under some conditions of climatic environment heat production is increased Blaxter et al (1959) defined this characteristic in terms of critical temperature, which is the temperature below which heat production must be increased to maintain body temperature constant. Critical temperature is affected by the degree of body insulation (tissue layers, skin thickness and fleece length), the amount and quality of the diet fed (Graham et al 1959) and its temperature (i.e. food given that is below body temperature will require heat to bring it to this temperature).

Insulation of the sheep is characterised by:

(1) the air interface, the heat lost through it being directly proportional to the gradient of temperature between the skin surface and the air;

(2) the skin, the insulation properties of which can vary within breeds Blaxter (1967) and between breeds Slee et al (1967). Insulation by the skin is dependent on the degree of vasoconstriction and vasodilation (Blaxter et al 1959; Slee 1966) and therefore on the part of the body it is covering, since the blood supply to the skin surface areas tends to vary according to its location. The extremities of the animal, legs, feet and ears are more susceptible to a lowering of temperature though Webster and Blaxter (1966) have shown that cyclical changes of blood flow resulting in rapid heating and slow cooling have some control over this.

(3) the fleece, which varies with its length and depth (Armstrong et al 1960; Blaxter 1959) though the relationship is not linear. The relationship is complex due to heat loss mechanisms and regional temperature adjustments as well as physical ones of heat conduction, (Blaxter 1962).

Climatic variables will probably have a greater influence on heat loss.

In investigating the effect of wind speed on metabolism Joyce (1964) found that increases were due to variation in air temperature and depended on whether the reductions in insulation was sufficient to make the ambient temperature lower than the critical temperature. Thus, wind results in a greater convection heat loss and partially destroys the insulation properties of the fleece. Insulation was reduced by 50 per cent in sheep with a 50 mm fleece exposed to a 10 mph wind.

Rain also has the effect of reducing the insulation properties of the fleece. The water running off the coat removes heat by conduction and the heat required by the animal to dry out the coat results in an increased energy expenditure Blaxter (1962). Joyce (1964) estimated a 50 per cent reduction in the insulation of a 50 mm fleece in still air subject to rain falling at the rate of 0.4 inches per hour.

The effect on heat production can be quite considerable if rain and wind, are combined with reductions in air temperature.

Most of the information related to energy loss due to climatic factors has been obtained from animals under laboratory conditions and therefore the variation in these results due to the behavioural response of the animal to climate in its natural environment, are not known.

The fact that animals seek shelter in certain conditions of rain and wind will undoubtedly modify laboratory estimates. Nevertheless, changes in heat production are likely to be considerable in the climatic circumstances in which the hill ewe finds itself from time to time and which will be further aggrevated by under-nourishment and pregnancy in the winter months.

Efficiency of utilisation of energy

The utilisation of energy has already been touched upon but requires some further elaboration in connection with the different functions for which the energy is required. Using an absolute system of calculating feed requirements corrects the basic assumption of Kellners that feedingstuffs replace one another according to their fattening ability. Equally, however, the assumption by Forbes (1933) that the efficiency of utilisation of energy is constant at 58 per cent for fattening, 69 per cent for lactation and 75 per cent for maintenance while coming closer to the truth, is nevertheless inaccurate.

For maintenance A.R.C. (1965) concludes that the efficiency of utilisation of energy could be regarded with very little error at 74 per cent, which is very close to the value obtained by Forbes (1933). It is apparent, however, that the errors attached to the mean value for the efficiency of utilisation of metabolisable energy for maintenance (km) are standard deviations between foods, (Armstrong 1964, Blaxter and Wainman 1964), are associated with differences in dietory quality, more metabolisable energy being required for maintenance than for rations poor in quality. These differences, however, can be accounted for by using the regression equation,

Km = 54.6 + 0.30 Qm (A.R.C. 1965)

Qm being the percentage gross energy metabolised.

These small differences between diets for maintenance do not hold in considering the efficiency of utilisation of metabolisable energy for fattening (kf). The km values for the feeds used in Blaxter and Wainmans' (1964) and Armstrong's (1964) experiments ranged from 71-79 per cent, which is small, but the kf values for the same diets ranged from 29-69 per cent.

During pregnancy it is known that heat production increases (Graham 1964) but A.R.C. (1965) states that "whether it is legitimate to attribute part of the increase in the heat production of the fed animal to a low efficiency of the process concerned in the deposition of new material is doubtful. In dealing with pregnancy it appears to be more simple to assume that it is maternal maintenance cost which changes and that the energetic efficiency of the gains is the same as in normal growth." The evidence of Graham (1964) however, indicates that metabolisable energy was used for reproduction in sheep with a gross efficiency of 15-20 per cent and a net efficiency of 13 per cent, which is lower than that suggested by A.R.C. (1965). Russel et al (1967) in their experiments conclude that the energy cost of reproduction is considerably greater than that of other types of production and indicate a net efficiency of energy utilisation by the foetus of 7 per cent.

For maintenance, however, A.R.C. (1965) have calculated the km values for foods ranging in metabolisable energy values from 1.6 to 3.4 by assuming that the gross energy of a food is 4.4 kcal/g D.M. It would appear that for roughages diets of 'average' quality (ME 1.8 to 2.2) the km value will be between 67-70 per cent and for concentrate diets (ME between 2.8 and 3.2) the km value will be between 74 and 76.

The measurement of the efficiency of utilisation of energy for work done in walking, standing and 'shearing off herbage' is difficult. The way in which an assessment of the work done in these activities is carried out is similar to that described by Graham (1964). A.R.C. (1965) suggest that a calculation giving the reduction in energy retention of the exercising animal should be made; the metabolisable energy required to maintain the working animal is then the sum of the fasting energy expenditure, and the additional energy lost to the body by doing work, divided by the efficiency of utilisation of metabolisable energy for maintenance.

Graham (1966) in a paper, in which he outlines a system for predicting the maintenance requirements of sheep, has produced a table in which the energy requirements available at that time for the activities of walking (horizontal and vertical) standing, eating or grazing, ruminating are given, and is reproduced here.

Activity	Energy Cost per kg Body Wt.
Walking (horizontal component)	0.59 kcal/km
Walking (vertical component)	6.4 kcal/km
Standing	0.34 kcal/km
Eating or Grazing	0.54 kcal/km
Ruminating	0.24 kcal/km

Energy requirements for maintenance

Maintenance energy requirements for sheep have been calculated (A.R.C. 1965) by using the fasting metabolism figures obtained (Table 2) and adding 15 per cent to allow for the energy expenditure in exercise. Corrections are then made for the efficiency of utilisation of the diet using the equation

$$km = 54.6 + 0.30\ Qm$$

Energy requirements of the Pregnant Ewe

Many estimates of energy requirements during pregnancy have been made, most of these being the result of ad hoc feeding trials in which the liveweight gain of or loss of ewes and the birthweight of lambs have been taken.

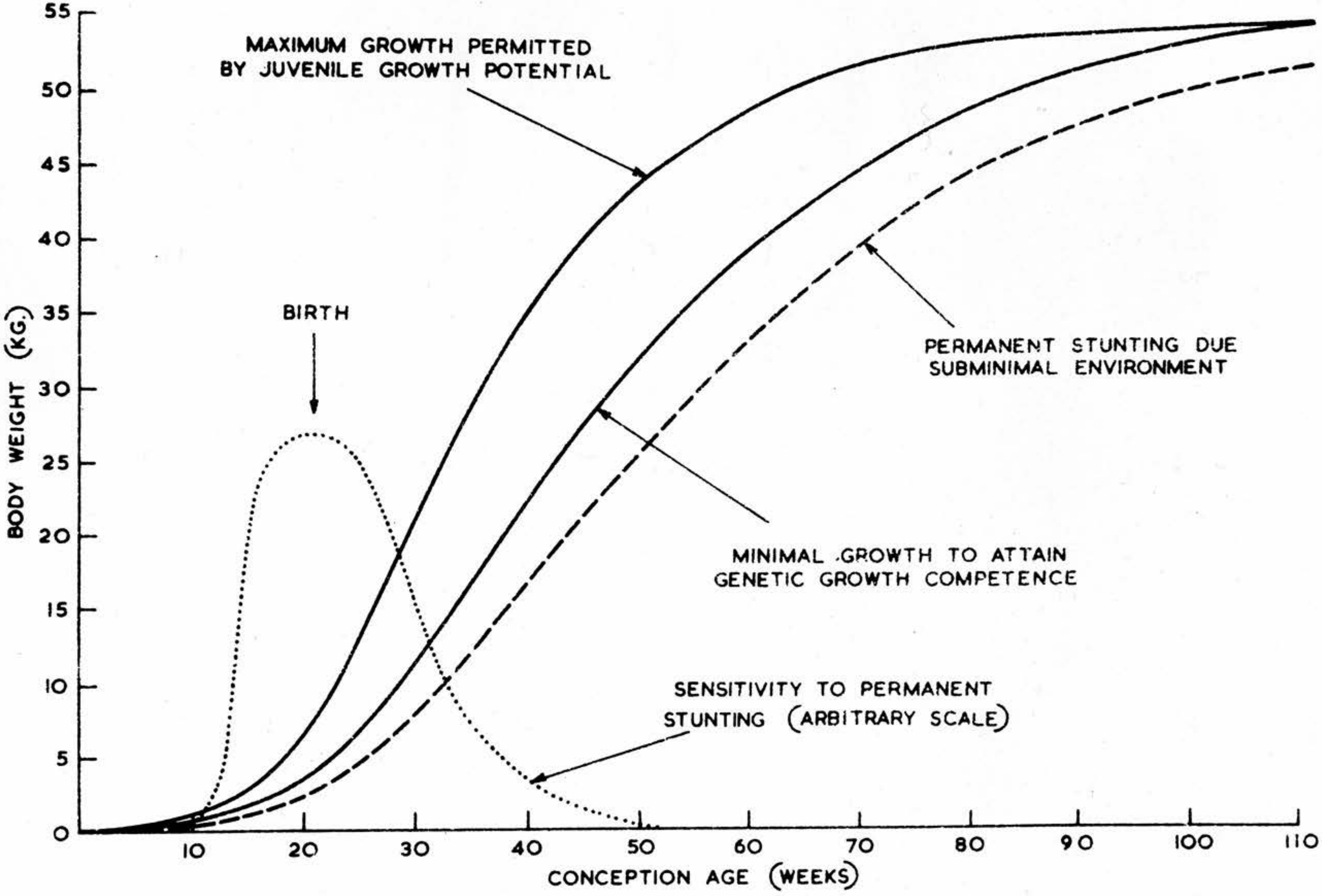
Very few experiments have been designed to obtain the absolute requirements of the sheep in gestation, mainly because of the difficulties in establishing the pattern in the partition of nutrients and, quantitatively the nutrient supply going direct from the body reserves of the dam to the foetus.

Birthweight itself is of little value. The importance of birthweight in relation to survival does, however, make it a parameter which is likely to give a criteria which can be used to judge whether survival is likely. Alexander, McCance and Watson (1955) and Alexander and Paterson (1961) have shown how birthweight is closely associated with lamb survival. More recently Alexander (1961, 1962) has reported on the influence of prenatal nutrition on energy metabolism of new born lambs and on their survival following starvation. Single lambs averaging 3.0 kg birthweight from ewes on low feed intakes during pregnancy survived for 43 hrs from birth, while single lambs averaging 4.0 kg from high intake ewes survived 68 hours. Alexander (1962b) examined summit metabolism of lambs in relation to body size, pre-natal nutrition, litter size and birth coat, and found that summit metabolism in lambs less than 3 days old was unrelated to any of these characteristics, it being 17 kcal/kg/hr. Summit metabolism per unit of body surface area increased with increasing birthweight but heat loss per unit body area was practically independent of weight hence many lambs were better able to maintain body temperature under adverse (cold and wet) climatic conditions than small lambs.

While thelamb is born with a capacity for high rates of heat production in early life, energy reserves are not great. Alexander (1962a) estimated the total energy reserves were about 1000 kcal and 400 kcal in lambs from well fed and poorly fed ewes respectively. Thus, food is required soon after birth. Since copious lactation is usually established within a few hours after parturition food becomes available to the lamb quite quickly.

The effect of the birthweight of the lamb on its eventual mature size has been discussed by Schinckel (1963). He states that "clearly, undernutrition of the ewe during late pregnancy, leading to the birth of small lambs, or undernutrition of the lamb during the period from birth to about 16 weeks, can result in a permanent restriction in the mature size of the animal." Schinckel describes an experiment in which he shows a difference of nearly 20 per cent in mature body weight as a result of differences in nutritional treatment prior to 4 months of age; both prenatal and post natal treatments resulted in about 10 per cent difference in mature weight; the effects of undernutrition in each period were additive. Gunn (1967) has shown that Cheviot ewes that were light in weight at 6 months of age continued to be so irrespective of subsequent treatment. This emphasises the need to maximise growth up to that point, which would also include prenatal growth. This phenomena in hill sheep is likely to be important though in this experiment it was not clear if the full genetic potential in weight of the ewe was realised in 6 months or not.

Other workers have shown that while body weight differences do exist between animals that have been subject to low levels of nutrition in early life, differences have been subsequently eliminated, (Crichton, Aitken and Boyne 1960; Coop and Clark 1955; Donald and Allden 1959; Jackson 1969). Compensatory growth appears to be a common phenomena, particularly following periods of suboptimal nutrition during the post weaning phases. It has also been noted in sheep following maintenance levels of nutrition during pre-weaning (Bassett 1960).

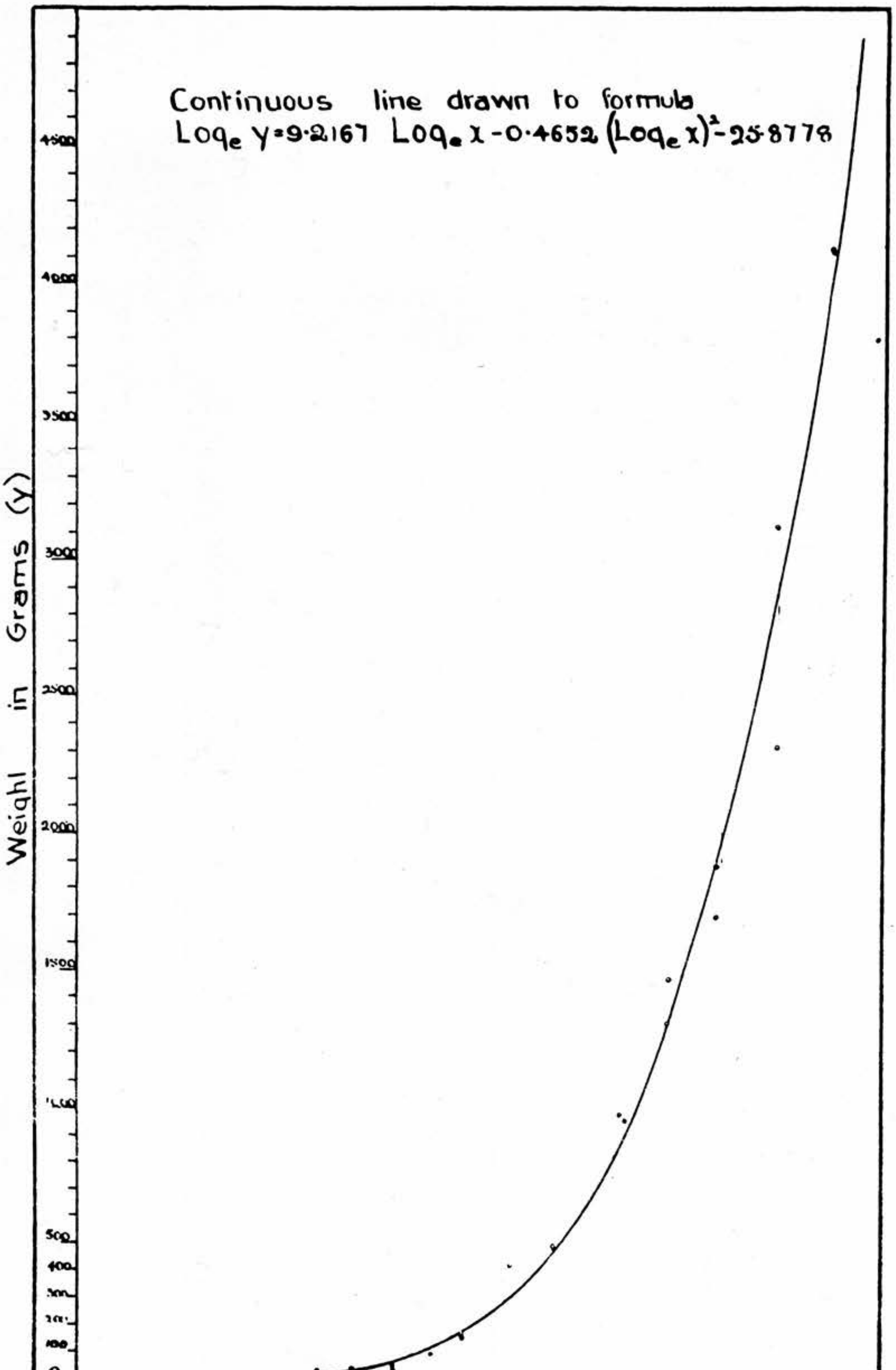


After Dickinson (1960)

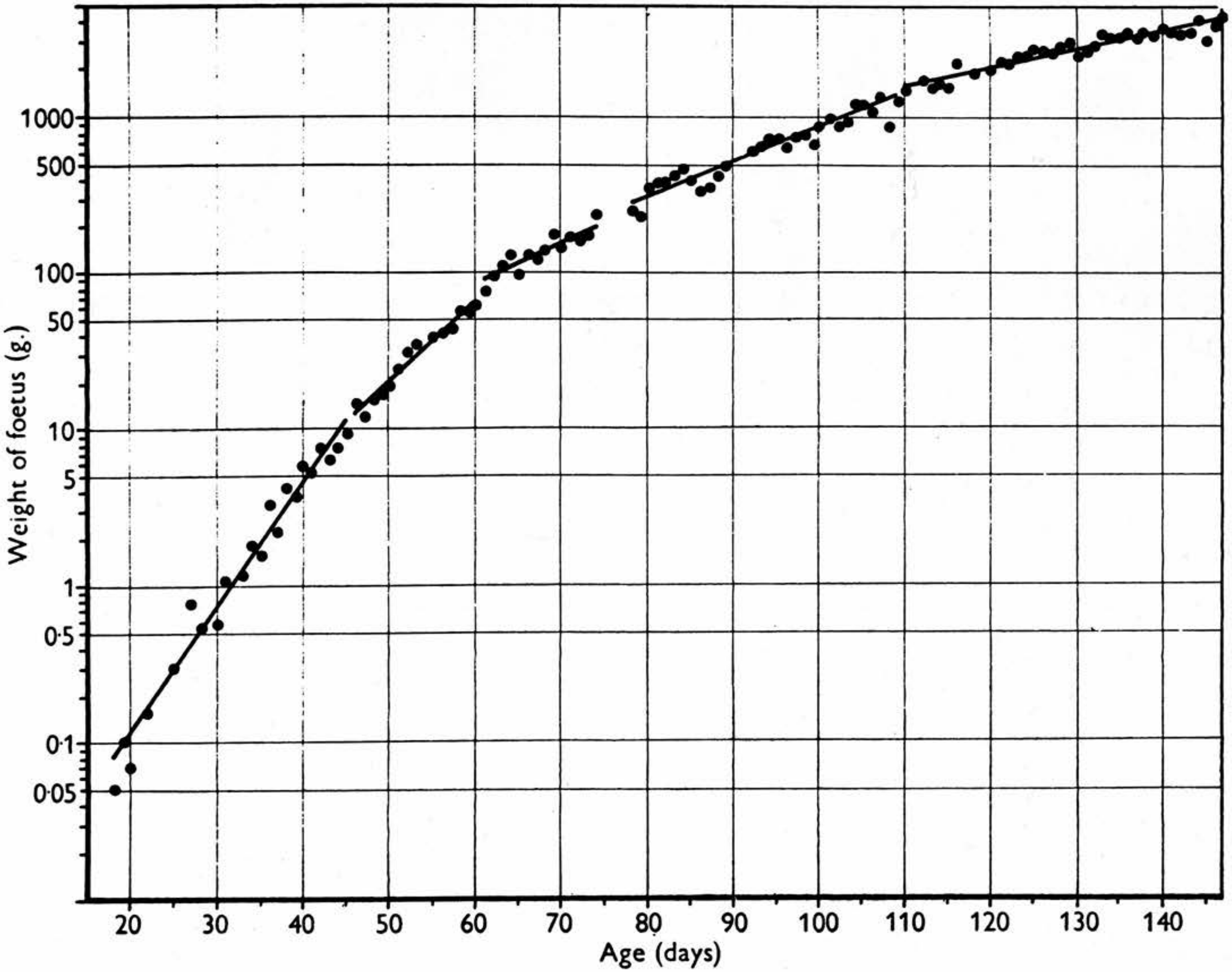
Schinckel (1963) concludes that there is no entirely satisfactory explanation of the variety of results obtained with respect to the effect of nutrition during growth or mature size, though Jackson (1967, 1968) has shown how levels of energy and protein can affect the muscle to bone relationship over a period of growth thus explaining the relative effects of nutritional limitations. Schinckel (1963) has summarised an interesting model of growth which Dickinson (1960) has proposed (Graph). The minimal curve represents "the boundary between growth which achieves a normal end point and sub-normal growth when the animals properties of physiological homeostasis have been overtaxed by an adverse environment at any time". The latter is the minimum growth path leading to normal mature size; deviation below this path due to sub-minimal environment leads to permanent limitation of size. The genetic growth competence of a character determines the minimum nutrient requirements for maintenance and growth and in periods of nutritional stress represents the competitive status of the character. It thus controls mature size. The "juvenile growth potential" represents the maximum growth curve which can be obtained when all controlling factors are optimal. In the present context it represents the ability of the young animal to make maximal gains as a result of abundant feeding. A period of sensitivity to "permanent stunting" has been superimposed on the graph as an approximation from results in the literature.

The fact that birthweight is a result of an orderly sequence of events prior to parturition involving cellulor proliferation, enlargement and differentiation, leads automatically to a discussion of the pattern of these events and how they are related to time. It is to be expected that the nutritional requirement in pregnancy will be related very closely to this

Growth in Weight.

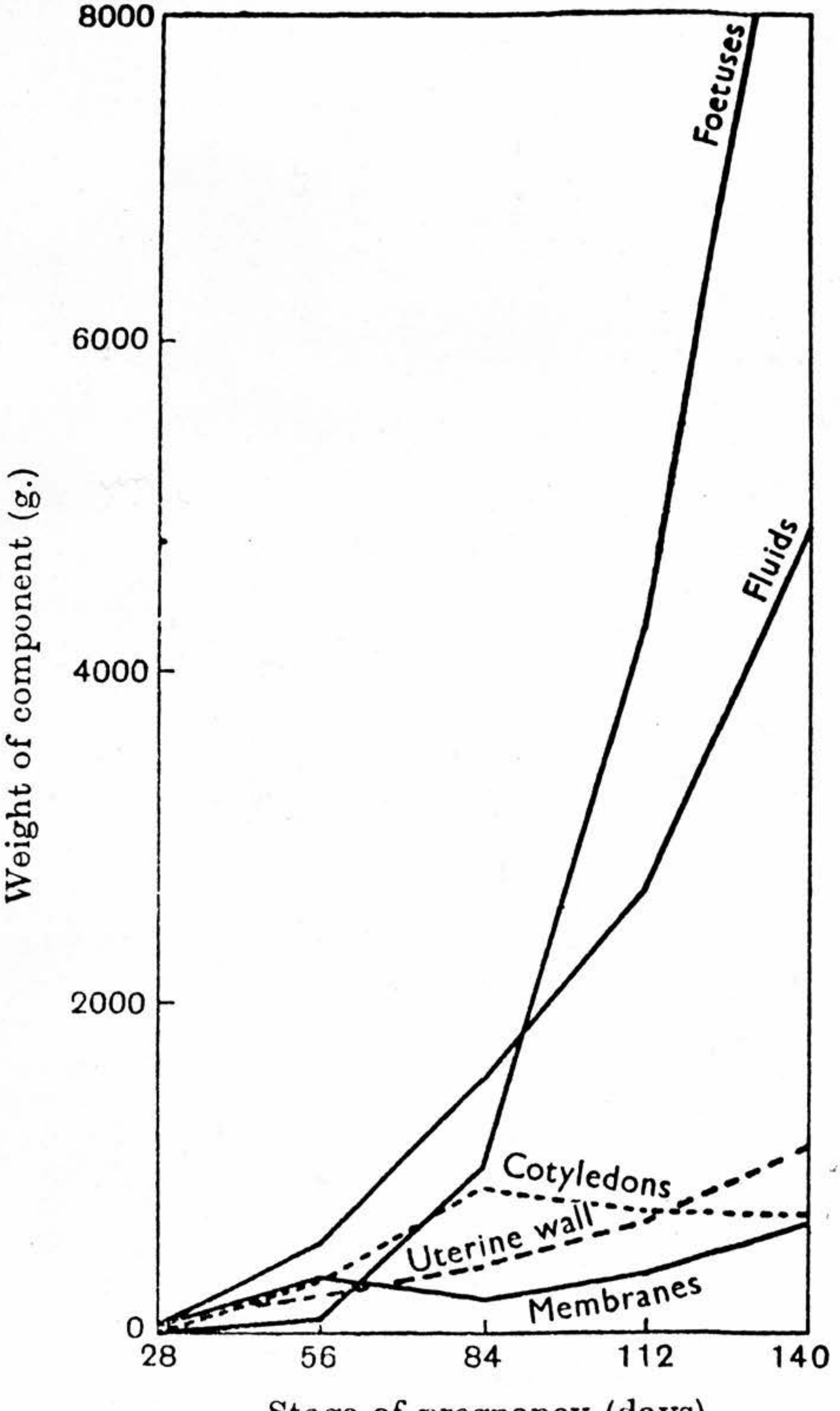


After Cleote (1939)



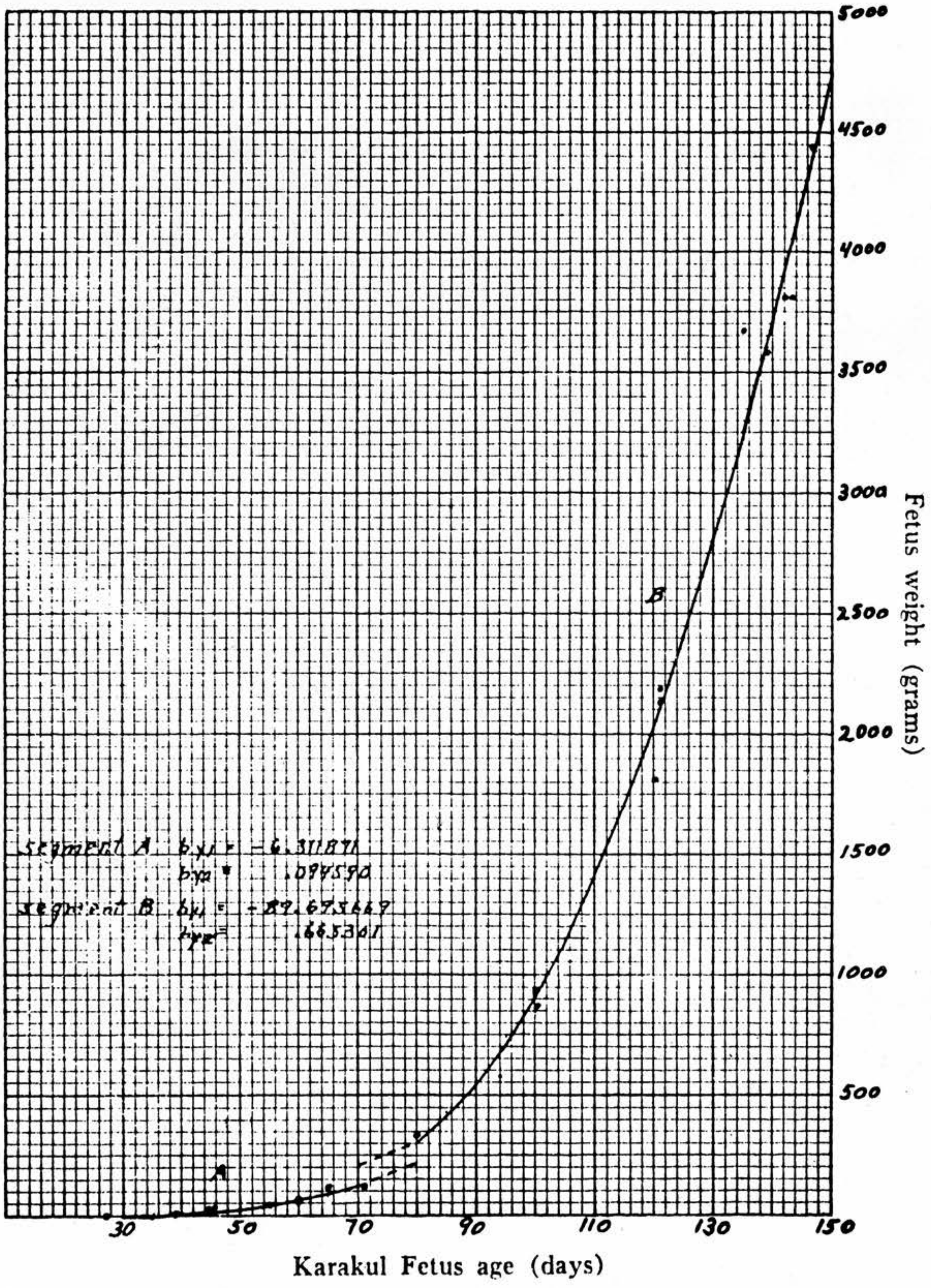
Relationship between age and weight.

After Wallace (1948)



Mean weight increase of major components of ditocous uteri.

After Eaton (1952)



After Joubert (1956)

pattern, and therefore it is of some significance to establish the rate of growth of the foetus relative to stage of pregnancy.

Figures I-IV show the derived relationships between the weight of foetus and age from experimental work carried out by Cloete (1939); Wallace (1948); Eaton (1952) and Joubert (1956) respectively.

Though it is not shown in the figure Cloete concludes that his data is best fitted by a curve of the second degree, expressed in the formula:-

$$\text{Log Wt.} = 9.2167 \text{ Log Age} - 0.4652 (\text{Log Age})^2 - 25.8778.$$

Thus a curve having two inflectious is produced, the first convex and the second concave to the axis, having a coefficient of variation of 20.0 per cent. In the figure the second inflection is indistinct but because of this inflection it becomes possible to join the curve of pre-natal growth and post natal growth, thereby depicting growth in weight as a continuous process without any abrupt change, which would seem logical.

The relationships of Wallace (1948) have been depicted as straight lines joining the points of mean weight of a group of lambs at a stated age. It is, therefore, not possible to establish a continuous curve, though the similarity in the pattern of pre-natal growth in weight established by each worker is clear.

The relationships derived by Eaton (1952) were derived from fewer animals than that of Cloete, which might explain the difficulty he encountered in forming a continuous curve.

The coefficient of variation of these relationships is much less than those of Cloete, however, it being 8.5 per cent. The similarity in the pattern of pre-natal growth is again clear though Eaton (1952) was unable to show the second inflection described by Cloete.

Joubert (1956) using many more animals than the previous workers has also established a similar pattern of pre-natal growth though he was unable to show this as a continuous curve. The coefficient of variation was 11.3 per cent.

From these relationships it is clear that the greatest nutritional demands will be in the second half, and more particularly the last third of pregnancy.

It is well established that birthweight is affected by the nutrition of the ewe during pregnancy, indeed it would be surprising if it were not so. The degree to which it is affected will depend not only on the feeding level of the ewe but also on the ewe's body reserves. Thus, while many workers have shown with few exceptions, that increased levels of nutrition are associated with increased birthweights the effect being usually more marked in twins, than singles, these results are of limited value in establishing an absolute requirement of nutrient intake since many of the experiments were done without any precise knowledge of the nutrient intake of the ewes in question. Even when the nutritional intake of ewes was controlled it is difficult to make comparisons since there are frequently breed differences occurring and differences in the number of lambs born.

The work summarised by Thomson and Aitken (1959); Schinckel (1963 and later by Russel (1968) uses change in maternal body weight as an index of level of nutrition in an attempt to find a common factor on which comparisons may be made between experiments.

Clearly changes in liveweight of the ewe would be expected to indicate whether the nutritional levels offered were adequate. The relative differences in birthweight of lambs from these experiments tended to show that where differences were small, the gain or loss of weight of the compared treatment groups of ewes was also small, suggesting that differences between levels of nutrient intake were slight (Coop 1950; Guyer and Dyer 1954) or what was assumed to be a low level of nutrition was in fact quite high (Papadopaulos and Robinson 1957).

There is no justification in assuming that where 'high' levels were shown to give significantly greater lamb birthweights, that the 'high' level of nutrition was the optimum level. Indeed in many of the experiments the birthweight of the lamb does not equate with the liveweight gain of the ewe which indicates that even where these ewes produced lambs significantly greater in weight than lambs from ewes with which they were compared, they were nevertheless undernourished.

Equally, as has already been indicated, weight gain comparatives may only be justified within breeds. Thomson and Aitken (1959) have calculated from Wallace's (1948) and Cloete's (1939) data respectively that the weight gain during the last four weeks of gestation need only be 0.32 lb to produce a 9 lb Merino lamb but 0.64 lb to produce a 13 lb Border Leicester/Cheviot x Suffolk lamb. Within the breed, however, this type of calculation offers some guide as to the liveweight gain one requires to produce lambs without severely undernourishing the ewe.

While Thomson and Aitken (1959) recognise that ideally the ewe should gain sufficient weight to allow optimum development of the genital tract and of the udder, without loss of weight in other tissues, they also recognise the need for economy in the use of feedingstuffs and for this reason (and in the case of especially fat ewes) some loss in weight may be safely allowed, and certainly nothing more than maintenance of weight need be considered in the first three months of pregnancy.

One aspect of these experiments and others which require some attention is the stage at which nutrition has had most effect. Thomson and Fraser (1939); Wallace (1948) and Gill and Thomson (1954) working with the Scottish half-bred and Hodge (1966) using Merino-crossbreds failed to show an effect on birthweight where levels of feed intake were restricted during the first 90 days of pregnancy though Hodge showed that it did affect wool growth. Bennet et al (1964); Taplin and Everitt (1964) and Everett (1966, 1967) however, have shown that ewes poorly fed during the first 90 days of gestation produce lambs of lower birthweights. Everitt (1964), showed that Merino ewes loosing 12 per cent of their body weight during the first 90 days of pregnancy produced lambs of significantly lighter weight than lambs produced from ewes gaining 12 per cent in body weight over the same period. On the other hand Hodge (1964) showed that a 17 per cent loss in liveweight to 108 days gestation of 3 year crossbred Merino ewes had no adverse effect on number or birthweights of lambs born. The significance of this comparison is in the fact that it highlights the necessity of knowing the status of the body reserves of the respective ewes before any relevant deductions from these results can be made.

Undoubtedly some of the differences noted in the undernourishment of ewes are the result of age differences between ewes. Bennet et al (1964) has shown that the birthweights of single lambs born to two year old Merino ewes were 20 per cent less than in older Merino ewes. It is also significant that the workers who were unable to show any effect of nutritional restriction during the first 90 days of gestation were using Scottish Halfbreds and Merino Crossbred ewes.

The effect of level of energy intake in the last 90-140 days of pregnancy has a greater affect on lamb birthweight. (Thomson and Aitken (1959), Schinckel (1963)). As already discussed from the relationships described by Winters and Feufel (1936); Cloete (1939); Eaton (1957) and Joubert (1956) this would be expected.

A number of experiments have been more recently carried out which have been designed to test the recommendations of N.R.C. (1957 and 1964); (Whiting and Sten, 1958; Smoliak and Sten, 1958; Wright, Pope and Philips, 1962; and Gardener and Hague, 1963). The level recommended by the N.R.C. for the last 6 weeks of gestation is 1.8 lb TDN per 100 lb liveweight which approximates to 64 kcal ME per kg liveweight (1 lb TDN being equivalent to 1616 kcal ME, Swift (1957)). All these workers indicate that this level is probably quite adequate for single births but limits the birthweight of twins. Gardener and Hague (1963) are the only workers that recommend an increase in the requirement for twin bearing ewes and suggest it be 2.25 lb TDN/100 lb L. W. or 81 kcal/kg.

The recommendations of the N.R.C. are based on ewe weight and while in their publication of 1964 they recognise that the requirement of the twin bearing ewe will be greater they nevertheless make no precise increase in the allowance.

The A.R.C. (1965) have made no recommendations for the energy requirements of the pregnant ewe having listed them as being "not available". During a long term study of the carbohydrate metabolism of sheep Reid (1958) and Reid and Hinks (1962 a, b) have used a different technique in estimating energy requirements during pregnancy. This technique is based on measuring various biochemical parameters which are closely correlated with body metabolism and function, the concentrations of which are directly related to the supply and demand of nutrients and the mobilisation of stored body fat. If an animal is undernourished it begins to utilise body fat giving rise to increases in the levels of free fatty acids (F.F.A.) as a result of fat catabolism. Though there is a diurnal variation in the concentrate level of F.F.A. (Annison 1960) this pattern can be established before any experimental limitations on the nutrition of the animal are made thus making it possible to measure the response in F.F.A. concentrations to these limitations. Though plasma glucose concentrations remain fairly static under normal feeding regimes in cases of severe undernutrition glucose concentration decreases to a degree which is variable but inversely related to F.F.A. concentrations (Reid and Hinks 1962) and plasma ketone concentrations also increase moderately.

In general terms, therefore, within limits, if an animal's nutritional demands are exceeded by its nutritional supply it will utilise body reserves, a fact which will be reflected by the F.F.A. concentration in the blood, the degree of fat mobilisation being reflected by the relative increases in F.F.A. blood concentration. Because F.F.A. concentration can be affected by other factors other than undernourishment (adrenaline secreted during excitement has the effect of raising F.F.A. concentration, also ruminants cannot maintain very high F.F.A. concentrations over prolonged periods) glucose plasma concentration and ketone levels are also used to confirm the changes in metabolic activity due to undernourishment.

One of the first studies of this type on pregnant ewes was carried out by Reid and Hinks (1962), in which the metabolism of glucose, F.F.A. and ketone bodies, and amino acids in late pregnancy and lactation were studied at three levels of feeding in an experiment designed to measure the increase in nutrient requirements of ewes with advancing pregnancy. The results showed that ewes fed at a constant intake (20g/kg of a 1 : 1 roughage mixture of chaffed wheaten and lucerne hays) and in a 'medium condition' mobilised fat reserves during pregnancy, the degree of mobilisation, as indicated by F.F.A. blood level, being directly correlated with foetal weight. These ewes, however, were unable to maintain blood glucose levels in the normal range in the late stages of pregnancy. Fat ewes fed ad libitum, on the other hand were better able to maintain blood F.F.A. and glucose levels. Blood ketone levels were therefore, also maintained in the normal range which as a consequence resulted in the conclusion that the usefulness of blood ketone level as a criterian of undernutrition during pregnancy was severely restricted. Nevertheless Reid (1963) has estimated the foetal requirements in the last 10 days of gestation on the basis of the diet he used as 150 g; Russel, Doney and Reid (1967) recalculated this on the basis of D.O.M. requirement as being 80 g/kg of foetus = 320 kcal ME/kg foetus. Reid (1961) has stated that the high energy requirement for the maintenance and growth of the foetus is largely dependent on glucose and suggests that if this is supplied largely from propionic acid the additional feed requirement of a twin bearing ewe in late pregnancy might be as great as the ewes own maintenance requirement. He also states that gluconeogenesis from protein cannot much affect the issue, because amino acids are required for foetal growth in correspondingly large amounts.

One other point which Reid and Hinks (1962) make and which is of some importance in this discussion is that the amount of additional feed required