Grasses

AGRICULTURAL ADJUSTMENT UNIT · UNIVERSITY OF NEWCASTLE UPON TYNE

Grass Conservation and Dairy Farming

A Workshop Report

16

THE AGRICULTURAL ADJUSTMENT UNIT

THE UNIVERSITY OF NEWCASTLE UPON TYNE

In recent years the forces of change have been reshaping the whole economy and, in the process, the economic framework of our society has been subject to pressures from which the agricultural sector of the economy is not insulated. The rate of technical advance and innovation in agriculture has increased, generating inescapable economic forces. The organisation of production and marketing, as well as the social structure, come inevitably under stress.

In February 1966 the Agricultural Adjustment Unit was established within the Department of Agricultural Economics at the University of Newcastle upon Tyne. This was facilitated by a grant from the W. K. Kellogg Foundation at Battle Creek, Michigan, U.S.A. The purpose of the Unit is to collect and disseminate information concerning the changing role of agriculture in the British and Irish economies, in the belief that a better understanding of the problems and processes of change can lead to a smoother, less painful and more efficient adaptation to new conditions.

Publications

To achieve its major aim of disseminating information the Unit will be publishing a series of pamphlets, bulletins and books covering various aspects of agricultural adjustment. These publications will arise in a number of ways. They may report on special studies carried out by individuals; they may be the result of joint studies; they may be the reproduction of papers prepared in a particular context, but thought to be of more general interest.

The Unit would welcome comments on its publications and suggestions for future work. The Unit would also welcome approaches from other organisations and groups interested in the subject of agricultural adjustment. All such enquiries should be addressed to the Director of the Unit.

Unit Staff

Director:	Professor J. Ashton, M.A., B.Litt, M.S.
Head of Unit:	Professor S. J. Rogers, B.Sc.(*Econ*)
Administrative Officer:	B. H. Davey, B.Sc.(*Agric*), M.Econ

The Agricultural Adjustment Unit,
Department of Agricultural Economics,
The University,
Newcastle upon Tyne, NE1 7RU.

GRASS CONSERVATION AND DAIRY FARMING

A WORKSHOP REPORT

Bulletin No. 16

AGRICULTURAL ADJUSTMENT UNIT
UNIVERSITY OF NEWCASTLE UPON TYNE

1972

PREFACE

There has been rapid progress in the development and application of new techniques in agriculture in the post war period. But, the rate of improvement in the efficiency of grassland farming has in general been slow. This has been particularly the case with regard to conservation. In spite of the economic advantages of ensilage, less than 10 per cent of grass is conserved as silage. With all systems of conservation the average level of efficiency is well below what is technically possible and economically desirable, both in terms of the nutrient level of grass at cutting and the losses after cutting. Improvement must take account of such factors as: yield of grass, quality of fodder produced, degree of mechanisation, managerial skill and the place of conservation in the grass/livestock farming system. The interaction of such factors is complex, and members of this workshop have set out to provide a framework of an analysis to help farmers assess the application of different conservation systems to particular circumstances.

The workshop included specialists particularly concerned with grass and conservation, and this report is the joint product of members of the group. The fact that it is a team effort, however, does not imply that individual members of the workshop do not have any personal reservations about some of its contents. Furthermore, the views expressed in this bulletin do not necessarily reflect the views of the organisations from which members of the workshop are drawn.

The Agricultural Adjustment Unit would like to express its gratitude to the participants in the workshop.

JOHN ASHTON.

January 1972.

MEMBERSHIP OF THE WORKSHOP

Professor D. G. Armstrong, M.Sc., Ph.D., F.R.I.C., F.R.S.E.—Department of Agricultural Biochemistry, University of Newcastle upon Tyne.

T. H. Davies, B.Sc.—Agricultural Development Advisory Service.

P. D. Hebblethwaite, B.Sc., M.Sc., Dip.Agric., N.D.A.—Department of Agriculture and Horticulture, University of Nottingham.

J. N. Merridew, B.Sc.(Agric.), M.Sc.—Department of Agriculture, University of Newcastle upon Tyne.

K. B. Mosdell, M.A.—Agricultural Development Advisory Service.

Professor J. R. O'Callaghan, B.E., M.Sc., C.Eng., M.I.Mech.E., M.I.Agric.E.—Department of Agricultural Engineering, University of Newcastle upon Tyne.

J. H. D. Prescott, B.Sc.(Agric.), Ph.D.—Department of Agriculture, University of Newcastle upon Tyne.

Professor S. J. Rogers, B.Sc.(Econ.).—Agricultural Adjustment Unit, University of Newcastle upon Tyne.

G. Ross, M.A., B.Sc.(Econ.), Dip.Agric.—Agricultural Adjustment Unit, University of Newcastle upon Tyne.

GRASS CONSERVATION AND DAIRY FARMING

CONTENTS

CONTENTS—*continued*

INDEX TO TABLES

Table No. *Page*

INDEX TO TABLES—*continued*

INTEGRATING CONSERVATION AND DAIRYING SYSTEMS: COMPARATIVE ECONOMICS

INTRODUCTION

Temporary and permanent grassland in the United Kingdom amounts to about 18 million acres. Grassland provides about two-thirds of total feed requirements for ruminants in terms of starch, and even more in terms of protein. About six million acres, or one-third of the total area, is utilised for conservation. Most areas of the U.K. are suitable for grass production and it tends to be the cheapest and most suitable ruminant livestock feed. Despite the progress which has been made in grassland research, and in the application of this research by some farmers, the productivity of vast areas of grassland falls a long way short of the realistic potential.

Many of our pastures contain a high proportion of species other than those likely to produce the best yields. Average fertiliser levels applied to grassland are low, and for quite large areas no fertiliser at all is used. Production of grass is often low and utilisation may also be below optimum. Systems of grazing and conservation are often technically inefficient. It is, however, open to question whether maximum utilisation of grassland and achievement of high nutrient standards of conservation are economical. Depending on farm conditions and the attainable levels of grassland performance, the capital input and managerial expertise required for intensive systems of production and conservation may or may not be worthwhile. A consideration of these basic questions forms the central theme of this bulletin.

The problems of the effective utilisation of grassland were the subject of a Committee of Enquiry appointed in September 1957, known as the Caine Committee. The report was published in November 1958*. In the mid 1950's livestock numbers were expanding, imports of animal feeding stuffs were running at a high level and there was some evidence suggesting that the productivity of grassland was declining. As a matter of national interest, therefore, the Committee was asked: 'to consider methods of further stimulating the better production and use of grass in conjunction with other green fodder crops with a view to reducing the cost of production of livestock and livestock products and securing economies in imports of feeding stuffs'.

The Caine Committee concluded that there was no simple or single key to the better use of grass. While there may be some steps, particularly on the research education and advisory side, which might facilitate better grassland farming, the main requirement was thought to be higher standards of farm management generally. The situation since the 1950's has remained essentially the same, namely efficient utilisation of grass is complex, involving crop and husbandry aspects and requiring economically sensitive and technically well informed farm management. However, an additional dimension will be added by U.K. entry into E.E.C.,

* Report of the Committee on Grassland Utilisation. H.M.S.O. Cmnd. 547.

bringing a new set of price relativities and marketing conditions to U.K. agriculture. This Study Workshop attempts to provide a framework of analysis for these changing circumstances, but the critical importance of high management standards for the farm as a whole will remain.

The first part of the bulletin gives a review of the trends in grassland production and utilisation in recent years. The technical management of grassland for grazing and conservation and its use for livestock feed is then considered, with special emphasis on conservation systems for dairy farming. The complementary relationships between grazing, conservation and the animal, grazing systems and pasture management, and the implications of intensive grassland management on animal health are also included in the study. A discussion of the economic implications of intensifying grassland conservation for dairying leads into consideration of the application of crop husbandry, animal husbandry and farm management principles to provide a method of evaluating conservation systems. The report ends with some conclusions and recommendations.

I. GRASS IN BRITISH AGRICULTURE

Grass is the chief source of feed for ruminants in the United Kingdom. It provides two-thirds of their requirements for starch and an even bigger proportion of their protein requirements. Natural conditions in most parts of the country favour grass production, but it is difficult to quantify differences in potential productivity. Average dry matter yield per annum over a ten year period is probably the most satisfactory measure, but comparative information of this kind is not available for all regions. Temperature or soil moisture deficit could be used as indicators, but these are far from satisfactory, since growth depends on the combination of these and other variables, like solar radiation, species in the sward soil type and management. The potential productivity of grassland varies from leys on one extreme to hill-pastures on the other, although within the Lowlands this variation may not be as marked as is sometimes supposed.

The total area of temporary and permanent grass in the United Kingdom is about 18 million acres, 60 per cent of the total area of crops and grass and 30 per cent of the land area.[1] Approximately two-thirds of the grass area is permanent pasture and the remainder temporary leys. Table 1.1 shows the acreages of grass and crops from 1935 to 1968 and projected acreages of grass for 1972[2] and 1975.[3] Since 1935 the area of grass has declined gradually. From 1945 to 1962 there was a persistent upward trend in area of temporary leys, but since 1963 this trend has reversed.

Table 1.2 shows the regional distribution of grass and dairy cows, confirming the conventional generalisation that grass and dairying increase in importance as one moves westwards.

Permanent grassland can be classified into six grades based on the percentage of perennial ryegrass in the sward. Grade 1 contains 30 per cent more, grade 2, 15–30 per cent and grade 3, 5–15 per cent. The remainder of grass consists of Agrostis species, Yorkshire fog, crested dogstail, sweet vernal, rough and smooth stalked meadow grass, wild white clover and herbage plants. Grade 4 pastures have over 80 per cent Agrostis and less than 5 per cent ryegrass; grade 5 is Agrostis dominant with rushes and sedges and grade 6, Agrostis with fine fescues. Only 35 per cent of permanent pastures fall into the first three grades in Great Britain. 65 per cent or 8 million acres are low grade Agrostis pastures[4].

Rough hill grassland can be divided into five main types, (a) mountain or arctic vegetation, found at altitudes over 2,000 feet, and of little agricultural importance, (b) moorland and heathland improvable by burning, lime application and treading in grass seed, (c) rough pastures on acid land, (d) rough pastures on basic land, (e) low heaths, fens and seashore areas.[4] Although rough and hill grassland accounts for one-third of the land area, it contributes only 5 per cent of the gross agricultural output.

TABLE 1.1

ACREAGE OF CROPS AND GRASSLAND IN THE UNITED KINGDOM, 1935–1968
(000 acres)

	1935	*1945*	*1955*	*1965*	*1968*	*1969*	*1972*[1]	*1975*[2]
Total Crops and Grass	32,024	31,023	31,103	30,660	30,437	30,291	30,640	30,710
Arable Land	13,488	19,183	17,610	18,523	18,241	17,943	14,040[3]	12,860[3]
Permanent Grass	18,536	11,840	13,471	12,138	12,195	12,348		
Temporary Grass	4,373	5,334	6,022	6,518	5,873	5,738		
Total Grass	22,909	17,174	19,493	18,656	18,068	18,086	16,600	17,850
Total Grass as percentage of Total Crops and Grass	71·5	55·3	62·7	60·8	59·4	59·7	54·2	58·1
Rough Grazing (a)	16,336	17,260	16,875	17,830	17,537	17,568		
Total Cereals (b)	5,384	8,765	7,293	9,035	9,418	9,131	11,100	10,235

(a) Figures from 1959 onwards include the total area of deer forest land in Scotland.

(b) Wheat, barley, oats, rye for threshing.

1 Agriculture's Import Saving Role—Economic Development Committee for the Agricultural Industry.

2 Agricultural Projections for 1975 and 1985—O.E.C.D. Paris.

3 Total Tillage.

Source: Annual Abstracts of Statistics and U.K. Agricultural Returns.

TABLE 1.2

AREA OF GRASSLAND BY REGIONS IN THE UNITED KINGDOM

County or Region	*Grass acreage*			*Rough grazing* (a)	*Adjusted grass acreage in each region as a percentage of total adjusted U.K. grass acreage* (b)	*Adjusted grass acreage as a percentage total crops and grass + adjusted rough grazing in each region*	*Number of dairy cows*
	Total	*Temporary*	*Permanent*				
	000's	*000's*	*000's*	*000's*	*per cent*	*per cent*	*000's*
English Regions							
Eastern	752	221	531	91	3·6	20	135
South Eastern	1,490	498	992	178	7·1	50	300
East Midland	1,259	327	932	122	5·9	43	203
West Midland	1,815	474	1,341	115	8·5	64	429
South Western	3,028	934	2,094	564	14·6	72	739
Northern	1,670	455	1,215	149	7·9	69	256
Yorks and Lancs.	1,220	214	1,006	565	6·2	59	274
England	11,235	3,124	8,111	3,134	55·0	54	2,335
Wales	2,295	506	1,789	1,595	12·1	89	359
Scotland	2,761	1,709	1,052	12,172	24·1	77	329
N. Ireland	1,779	535	1,244	635	8·8	87	201
Total U.K.	18,064	5,874	12,196	17,536	100·0	—	3,224

(a) Including Common Rough Grazing.
(b) Temporary + Permanent Grass + Rough Grazing divided by 5.
Source: U.K. Agricultural Returns, 1968.

Of the main species sown on British farms ryegrasses account for 80 per cent of the seed used, timothy (8 per cent) and cocksfoot (8 per cent) are next in importance, with meadow fescue (4 per cent) fourth.[5]

Table 1.3 shows how grassland was mown or grazed from 1958 to 1968. Approximately a third was used for conservation, but the acreage used for conservation fell by about 1½ per cent a year while that for grazing by about 1 per cent. Table 1.4 shows the different ways of using grassland in different types of farming. In 1966 only about 5 per cent of temporary and 2 per cent of permanent grass was cut for silage in England and Wales. The high proportion of grass still used extensively, even on temporary pastures, is indicative of the potential for improving grassland management.

TABLE 1.3

MOWING AND GRAZING ACREAGE OF TEMPORARY AND PERMANENT GRASSLAND IN THE UNITED KINGDOM, 1958–1968

	1958	*1960*	*1962*	*1964*	*1966*	*1968*
Temporary Grassland	6,255	6,786	6,948	6,823	6,233	5,873
mowing (a)	3,128	3,171	3,359	3,440	2,941	2,824
grazing	3,127	3,616	3,589	3,383	3,292	2,049
Permanent Grassland	13,485	12,809	12,556	12,305	12,199	12,195
mowing (a)	3,415	3,372	3,170	3,232	3,018	2,872
grazing	10,070	9,437	9,387	9,072	9,181	9,323
Total Grassland	19,740	19,595	19,504	19,128	18,432	18,068
Total Mowing	6,543	6,543	6,529	6,672	5,959	5,696
Total Grazing	13,197	13,053	12,996	12,455	12,473	12,372
Total mowing as a percentage of grass acreage	33·1	33·4	33·5	34·9	32·3	31·5

(a) For hay, silage, drying or seed production.
Source: Annual Abstract of Statistics, 1968.

Table 1.5 shows the average yield and production of hay in the United Kingdom from 1958 to 1969.

The contribution of grass to the total supply of feeding-stuffs is difficult to measure accurately because of the problem of evaluating grazing. The method commonly used is to estimate the utilised starch equivalent of grass as a residual, after the full theoretical values of all other foods are subtracted from the theoretical total animal requirements. This method is subject to considerable error and since it

TABLE 1.4

PERCENTAGE OF GRASSLAND ACREAGE USED IN DIFFERENT WAYS, 1966
ENGLAND AND WALES

District type	*Grazed only*		*Mown (a)*	*Mown and Strip grazed*	*Cut for hay*	*Cut for silage*	*Mown once*	*Mown twice*
	Extensive	*Strip*						
Temporary grass—mainly cash crops	31	9	52	8 = 100	29	9	45	12
Cash crops, dairy cattle and sheep	36	9	49	6 = 100	39	9	50	3
Lowland grass districts, mainly dairy	31	17	30	22 = 100	33	16	48	2
Lowland grass districts, dairy and other livestock	39	4	53	4 = 100	47	5	51	4
Wales and English uplands	48	4	46	2 = 100	42	5	45	3
Permanent grass—mainly cash crops	55	7	38	0 = 100	32	1	32	1
Cash crops, dairy cattle and sheep	71	4	24	1 = 100	21	2	23	1
Lowland grass districts, mainly dairy	61	5	31	3 = 100	31	3	33	1
Lowland grass districts, dairy and other livestock	75	2	22	1 = 100	22	1	22	0
Wales and English uplands	76	2	21	1 = 100	20	2	21	1

(a) This includes grassland which was mown only, and also that which was mown and extensively grazed.
Source: Survey of Fertiliser Practice, 1966 (Preliminary Report) M.A.F.F.

TABLE 1.5

ESTIMATED YIELD PER ACRE AND ESTIMATED QUANTITY OF GRASS AND LUCERNE HARVESTED, 1958–1969
UNITED KINGDOM
Yield: cwt./ac. Production: tons 000's

	1958	*1960*	*1962*	*1964*	*1966*	*1968*	*1969*
Lucerne Hay							
Yield/ac.	38·5	41·8	41·8	42·7	41·7	45·7	—
Production	110	111	107	85	89	65	—
Hay							
Temp. Grassland— Yield	31·5	31·9	33·0	35·9	36·4	36·8	37·0
Production	4,208	4,401	4,799	5,364	4,676	4,608	4,573
Perm. Grassland— Yield	25·2	24·7	25·0	29·0	29·0	30·3	30·2
Production	3,250	3,249	3,546	4,219	3,880	3,787	3,959

Source: Annual Abstract of Statistics.

TABLE 1.6

UTILISATION OF FEEDINGSTUFFS AND LIVESTOCK REQUIREMENTS
June/May years million tons S.E.

	1938–39	*1950–51*	*1956–57*	*1962–63*	*1966–67*	*1967–68*
Total Livestock requirements	25·3	25·0	27·8	30·7	31·0	31·0
Concentrates	8·2	6·1	8·7	11·0	11·3	11·9
Residual	17·1	18·9	19·1	19·7	19·7	19·1
Grass—permanent and temporary	12·9	13·8	14·2	15·6	16·1	15·4
Other sources including rough grazing	4·2	5·1	4·9	4·1	3·7	3·7
Effective usage of grass (cwt. S.E. per acre)	11·2	15·0	14·5	15·9	17·4	17·0

Source: 1962–63, 1966–67 and 1967–68 Ministry of Agriculture, Fisheries and Food.
1938–39, 1950–51 and 1956–57 Report of the Committee on Grassland Utilisation. Cmnd. 547, 1958.

TABLE 1.7

DENSITY OF STOCKING IN THE UNITED KINGDOM, 1952–1969

Number of Grazing Livestock Units in U.K. 000's	*1952*	*1956*	*1960*	*1966*	*1968*	*1969*
Cows and Heifers in Milk—Dairy (a)	2,582	2,559	2,719	2,740	2,816	2,855
Cows and Heifers in Milk—Beef (a)	438	673	732	963	999	1,039
All other cattle	7,224	7,675	8,321	8,504	8,333	8,480
Sheep	12,543	13,121	15,353	16,100	15,217	14,582
Total grazing Livestock Units in U.K. (b) 000's	8,825	9,387	10,241	10,887	10,832	10,689
Total grazing Area adjusted acres 000's (c)	22,205	22,847	23,255	21,577	21,577	21,600
Total Livestock Units per 100 Adjusted Acres	39·7	41·0	44·0	49·5	50·2	49·0

(a) The U.K. Dairy/Beef ratio for the years before 1960 was estimated from the ratio in Great Britain.

(b) The following livestock unit conversion factors were used: cows and heifers in milk, dairy—100 (±0·01 for each 10 gallon difference in yield per cow from 700 gallons)*, beef—0·8; dry cows, in-calf heifers, bulls and other cattle over 2 years—0·75; other cattle 1–2 years—0·5; other cattle under 1 year—0·25; ewes for breeding** and rams—0·2; shearling ewes and other sheep over 1 year—0·1.

* The average yields per dairy cow in the U.K. for the years before 1962 were estimated from the yields in Great Britain.

** 'Ewes for breeding' includes lambs at foot up to 6 months. Since the number of lambs between 6 months and 1 year at June is likely to be very small, sheep under 1 year are neglected.

(c) To calculate the adjusted grazing area, the acreage of 'rough grazing' is given a weight of one-fifth as against the acreages of permanent and temporary grass.

assumes no wastage or over-feeding of other foods, it is bound to underestimate production from grazing. Calculations made by the Ministry of Agriculture, Fisheries and Food[6] on this basis are shown in Table 1.6. These approximations confirm that there has been a relatively low rate of increase in effective grass yields.

Table 1.7 shows the change in efficiency of utilisation of grazed pasture for dairy cows and other ruminant livestock from 1952 to 1969.

During the last 17 years the stocking density per 100 adjusted acres has risen by approximately 10 livestock units or by about 25 per cent although the figures since 1966 are relatively constant. The increase in stocking density cannot all be attributed to an increase in efficiency of grassland use, since the concentrated feedingstuffs feed per head of grazing livestock has also increased (Table 1.8).

TABLE 1.8

CONCENTRATE FEEDING RATES PER HEAD OF LIVESTOCK BY KIND IN THE UNITED KINGDOM, 1960–66

Class of Livestock	*1960–1*	*1961–2*	*1962–3*	*1963–4*	*1964–5*	*1965–6*
	Hundredweight per head					
Cows and Heifers in milk and in calf (milk types)	23·6	23·9	24·4	24·4	24·6	24·7
Cows and Heifers in milk and in calf (beef types)	7·8	8·0	8·3	8·4	8·5	8·7
Heifers in calf (first calf milk and beef)	5·0	5·0	5·1	5·1	5·2	5·3
Bulls for service, young bulls being reared	11·0	11·0	11·0	11·0	11·0	11·0
Other cattle over 2 years } Cattle 1 to 2 years }	5·7	6·1	6·5	7·1	7·3	7·8
Cattle under 1 year	5·0	5·2	5·4	5·6	5·9	6·3
Upland ewes, shearlings and rams	0·5	0·5	0·5	0·5	0·5	0·5
Lowland ewes, shearlings and rams	0·9	0·9	1·0	1·1	1·1	1·1

Source: Concentrated Feedingstuffs for Livestock in the United Kingdom. 1960–61—1965–66, P.W. H. Weightman, Cornell University, June 1967.

Yield and stocking density of grassland have therefore only increased moderately in the last ten years. The higher figures for dairy cows may reflect both the greater profitability of milk production and the increasing specialisation which has taken place. Except in upland areas with limited potential, beef and lamb production are more often subsidiary enterprises and may not attract the same level of management attention.

The increase in grassland productivity can be mainly ascribed to a modest increase in the use of fertiliser. Table 1.9 shows the percentages of temporary and permanent grass acreages receiving fertiliser in 1962 and 1966, while Table 1.10 shows the average dressings on those fields receiving fertiliser. In 1962 68 per cent of temporary grass in England and Wales received nitrogen compared to 75 per cent in 1966. Wales and upland areas received less than other areas. The percentage

TABLE 1.9

PERCENTAGES OF TEMPORARY AND PERMANENT GRASS ACREAGES RECEIVING NUTRIENTS IN 1962 AND IN 1966

District type	*N* 62	*N* 66	*P* 62	*P* 66	*K* 62	*K* 66	*Lime* 62	*Lime* 66	*FYM* 62	*FYM* 66
	Temporary Grass									
Arable	70	82	50	60	46	55	3	2	5	5
Mixed farming and dairying	74	78	60	72	54	65	6	4	17	20
Uplands and Wales	56	63	56	64	44	56	7	6	26	28
England and Wales	68	75	56	66	49	59	5	4	15	17
	Permanent Grass									
Arable	48	66	34	40	30	37	4	3	4	6
Mixed farming and dairying	40	44	34	43	28	35	6	4	14	20
Uplands and Wales	24	41	34	46	20	36	6	5	16	17
England and Wales	37	46	34	43	26	36	6	4	12	16

Source: Survey of Fertiliser Practice 1966 (Preliminary Report) M.A.F.F., 1966.

of permanent grass receiving nitrogen was only 37 per cent in 1962 but rose to just under 50 per cent by 1966. In 1966 about two-thirds of temporary grass had phosphate and potash dressings, in both cases higher than the 1962 level. Table 1.10 shows that there were large increases in average nitrogen dressings on both temporary and permanent grass for all district types between 1962 and 1966, but that the average phosphate and potash dressings were reduced. Nitrogen dressings were much smaller and phosphate dressings heavier in the uplands and Wales than elsewhere.

Table 1.11 shows fertiliser practice in 1966 in England and Wales on grassland according to utilisation. On the whole, the average manuring of leys was fairly similar while on permanent pasture, grass used for strip grazing received heaviest dressings.

Table 1.12 shows that the actual fertiliser dressings shown in Tables 1.10 and 1.11 are nowhere near the recommended levels.

The Economic Development Committee for Agriculture proposed an increase in the arable sector by 1972 of 1·7 million acres at the expense of grassland. They

TABLE 1.10

AVERAGE DRESSINGS GIVEN TO TEMPORARY AND PERMANENT GRASS IN 1962 AND 1966 (ON FIELDS RECEIVING NUTRIENTS)

District type	*cwt./acre × 100*					
	N		P_2O_5		K_2O	
	62	*66*	*62*	*66*	*62*	*66*
	Temporary Grass					
Arable	56	84	52	47	48	43
Mixed farming and dairying	57	68	57	55	46	38
Uplands and Wales	41	52	68	63	43	37
England and Wales	53	71	57	55	47	39
	Permanent Grass					
Arable	46	69	47	43	40	36
Mixed farming and dairying	45	53	59	54	43	36
Uplands and Wales	33	42	76	61	40	33
England and Wales	43	54	62	54	42	35

Source: Survey of Fertiliser Practice 1966 (Preliminary Report) M.A.F.F., 1966.

also proposed an increase in the dairy herd and expansion in beef and sheep production. The committee estimated that this expansion would require an increase in stocking rates of all grazing livestock of the order of 3¼ per cent per year over the five years. 'As all the additional stock would not then be fully grown, there would be need for a continuing improvement of the same order thereafter.'[2] The committee had no doubt that this was technically possible. 'Our conclusion is that, given the pressure of numbers on the reduced grassland acreage and the clear indications in recent years that farmers are becoming alive to the potentialities of their grassland an adequate improvement in stocking rate would be forthcoming.'[2]

While there is little doubt that grassland productivity can be improved, it is necessary to show that such developments increase the profitability of the individual farm, and that the methods involved do no demand an unreasonably high standard of management. The remainder of this bulletin attempts to show the conditions under which alternative systems of grassland management may be profitable.

TABLE 1.11

FERTILISER PRACTICE IN ENGLAND AND WALES ON LEYS AND PERMANENT GRASS ACCORDING TO 1966 GRASSLAND UTILISATION

	% acreage receiving					*Ave. dressing cwt./acre × 100*		
	N	*P*	*K*	*Lime*	*FYM*	*N*	P_2O_5	K_2O
2–7 year leys—								
Grazed extensively only	64	61	51	5	10	59	61	35
Strip grazed only	96	81	75	7	12	101	47	45
Strip grazed and mown	95	84	80	6	27	113	51	48
Cut for hay	77	67	63	3	24	58	49	38
Cut for silage	87	76	70	2	15	105	59	40
Permanent Grass—								
Grazed extensively only	41	40	33	4	10	49	55	36
Strip grazed only	83	56	54	4	16	80	45	37
Cut for hay	54	49	41	4	32	50	51	34

Source: Survey of Fertiliser Practice 1966 (Preliminary Report) M.A.F.F. 1966.

TABLE 1.12

ANNUAL RECOMMENDED DRESSING OF N, P AND K FOR CUTTING AND GRAZING (AVERAGE CONDITIONS)

	Units per acre		
	N	P_2O_5	K_2O
Cutting, Clover—Grass Swards for Hay or Silage followed by grazing	110	60	110
Continuous Cutting of Swards	300	60	210
Ordinary Grazing of Average Clover Grass Pastures	40	40	40
Moderate-intensity Grazing of Good Clover Grass Pastures	130	50	75
High-intensity Grazing of All Kinds of Swards	300	50	150

Source: Fertiliser and Profitable Farming, G.W. Cooke, 1964.

II. GRASSLAND UTILISATION

In many parts of the U.K. where high rainfall, infertile soils, high elevation and sloping fields occur, perennial grass is the only practicable crop. Even in more favourable areas, many fields are not ploughable. Where there are alternative arable crops grass may still be chosen as being the most profitable rotational crop.

The competitive position of grass depends on the type of husbandry applied to it. A realistic physical potential for grassland under practical farming conditions is 10,000 lb. (a) dry matter per acre in a year. This can be achieved almost anywhere in the United Kingdom provided:

1. A first-class sward of high yielding grass species is available or can be sown;
2. Generous fertiliser nitrogen is used—probably around 300 units per acre (or 300 kg. per hec.), depending on the season—in conjunction with adequate basic mineral nutrition;
3. Moisture is not a limiting factor, and the utilisation regime allows adequate rest between defoliations.

In practice, however, this potential is seldom achieved consistently over a large area of grassland. Most natural pastures contain a high proportion of species other than the most high yielding and to improve these pastures is a lengthy and uncertain business; to reseed them is expensive and involves a period when they are out of production. Liberal fertiliser nitrogen is not always used, mainly because there is slack to be taken up in animal husbandry, before it pays to use 300 units of nitrogen or more. Moisture is often inadequate—at least in some seasons—and irrigation is difficult to justify for grassland alone. A properly controlled utilisation regime is often impossible due to poor farm layout and water supply, awkward shaped fields, inadequate buildings and soils liable to poaching.

Choice of Grasses and Clovers

Now that there is better understanding of the production characteristics of the grasses and clovers, the number of different species considered useful in pastures has been drastically reduced. The useful species are represented by Italian and perennial ryegrass, timothy, cocksfoot, and meadow fescues grasses; white and red clover; and sainfoin and lucerne have a place in low rainfall areas where the soil is not acid. As the number of species has been reduced, the number of strains within each species has increased, and success in pasture utilisation now depends on the use of appropriate strains for particular purposes.

Broadly, strains of grasses differ in two major respects, earliness and persistency. Earliness is usually assessed on the basis of the date of ear emergence from the

(a) 10,000 lb. per acre=10,024 kg. per hectare.

sheath. Strains that have early ear emergence are usually capable of early growth in spring and rapid re-growth after cutting. In general, early strains are short lived and rapid growing. They give better performance for short-duration pastures, say for production over one or two years, especially under cutting regimes. For longer-duration and grazing pastures, a proportion of late strains should be included, to ensure persistence and to enhance the ability of the sward to withstand treading and defoliation under grazing.

Apart from agronomic characters the most important attributes of grasses for animal production are acceptability (feed intake) and digestibility. The more an animal eats, and the more that is digested, the higher will be the animal productivity per unit of feed. There are no completely reliable indications of acceptability of various strains and species of grasses. Direct assessments using the animal are necessary, and this has only been done on a limited basis. There is at present insufficient information available to provide a summary of differences in acceptability between strains of the various species.

By contrast, digestibility is measured routinely and figures are published[5] in the recommended list of grass strains compiled by the National Institute of Agricultural Botany. With some exceptions, a high level of digestibility is correlated with a high level of acceptability, and digestibility level is a reasonable index of nutritive value.

In grasses digestibility is closely related to stage of growth. Under frequent cutting or close grazing, where the grasses are utilised in the leafy stage before ear emergence, most species possess similar levels of digestibility. At later stages, after ear emergence, differences of digestibility between the various grasses should determine the stage at which they are utilised. As the grass plant matures yield of dry matter increases, but digestibility drops sharply. To obtain maximum animal output it is necessary to conserve herbage at a maximum yield of digestible dry matter.

The digestibility of grass can be fairly accurately assessed by inspecting the stage of ear development. Table 2.1 gives yields of the main categories of grass at a stage of high digestibility.

As grasses mature beyond 63 D-value their digestibility falls rapidly and their usefulness for high levels of production diminishes. The figures in Table 2.1 apply to the first growth in spring; re-growth during later periods of the growing season exhibits similar characteristics, but the decline in D-value is slower.

If early and late strains of grasses are used in separate production areas, conservation of the first spring growth can be spread from mid-May to mid-June. (Timing will vary with season, latitude and altitude.)

For general use, both under grazing and conservation regimes, perennial and Italian ryegrasses are the most useful species. They produce higher yields of dry

TABLE 2.1

Species	*Yield at 63 D-value cwt/acre*	*Stage of Growth at 63 D-value*	*Date at 63 D-value*
Early perennial ryegrass	65	14 days after EE*	Late May
Late perennial ryegrass	60	At EE	Mid June
Italian ryegrass	70	Up to 7 days after EE	Early June
Meadow fescue	60	Up to 7 days after EE	Late May
Early timothy	55	Up to 2 weeks before EE	Early June
Late timothy	45	3 to 4 weeks before EE	Early June
Cocksfoot	40	At EE	Mid May

*EE=50% ears emerged from sheath.

Source: N.I.A.B., Farmers Leaflet No. 16, 1969–70.

matter at any particular D value than other species. The rate of recovery of ryegrasses after defoliation is high. The early ryegrasses are the earliest of grasses to commence growth. Perennial ryegrass is a good companion in clover mixtures. In silage, ryegrass readily attains the concentration of soluble carbohydrate required for good fermentation, even at 70 per cent D value. For earliest growth and rapid re-growth, Italian strains are superior to perennial ryegrass, but they are not satisfactorily persistent beyond one growing season. Hybrid Italian and perennial ryegrass combine the qualities of both parent species, but in practice their agronomic behaviour is closer to early strains of perennial ryegrass than to Italian ryegrass. Ryegrasses have the disadvantage that unless they are harvested at 70 per cent D value their level of protein is low, compared with cocksfoot and timothy, which give 10 to 15 per cent crude protein at D values of 55 per cent and lower. Tetraploid strains of ryegrass are now available. These have larger seed and bolder leaves, but their growth characteristics and dry matter yield are in general not significantly different from comparable diploid strains. Digestibility of tetraploids is higher, but they are less persistent than the diploids, and because of their greater seed size, a higher seeding rate is necessary to achieve adequate establishment. Intake of the tetraploids has been shown to be lower than diploids, but the reasons for this are not clear.

Cocksfoot, more resistant to drought, has a role in pasture formation in drier regions. It gives good growth in autumn and early winter, but the digestibility is 3 or 4 units lower than perennial ryegrass, except at the young leafy stage when dry matter yield is low. Unless the season is very dry the yield and concentration of digestible organic matter of cocksfoot is lower than the ryegrasses, but it has fairly good protein and carotene content even at low D values. Cocksfoot is a useful companion in lucerne/grass pastures for artificial drying.

Timothy combines well with other grasses particularly meadow fescue, and also with clovers in mixtures. Although useful for grazing, timothy is best as a hay plant, because it does not experience a rapid fall in D value around heading time, hence allowing more time for cutting. However, its rate of recovery after cutting is slow. It grows well in cooler, wetter regions; in northerly areas, where winter hardiness is necessary, it tends to replace ryegrass in mixtures. Like cocksfoot it tends to be low in soluble carbohydrate, unless cut at low D values, and does not provide high quality silage unless additives such as molasses or formic acid are used. Work at Aberystwyth[8] has shown that a single cut from a sward of red clover and timothy can give a yield of 10,000 lb. dry matter per acre, suitable for conservation as silage, the clover augmenting the nutrient content of timothy.

Meadow fescue is a weak competitor with ryegrass and must be used with white clover or timothy. It is also a valuable companion grass for lucerne. Timothy-meadow fescue pastures, with or without white clover, give high yield of good quality which for early and mid-summer production, equals ryegrass. The persistence of meadow fescue is low, and establishment can frequently be disappointing.

The most important pasture legumes in the United Kingdom are red and white clover. Lucerne is used for artificial drying in the drier regions, but its use is confined to specialist producers of a high quality dried product. In addition to production of fodder, legumes contribute to the nitrogen status of soils, a good stand of clover contributing up to 200 units of nitrogen per acre a year.

Legume herbage is of higher quality than grass herbage in respect of feed intake, digestibility, mineral content and energy. Legumes also retain these values throughout the season better than grasses.

White clover is useful when the sharp drop in quality occurs in grasses after ear emergence, because of its uniformly high quality throughout the season. A proportion of clover in the livestock feed increases feed intake and live-weight gain.

Legumes have about twice the resistance to change in pH of grasses, because they contain higher amounts of non nitrogenous organic acid. A higher initial carbohydrate level is required for satisfactory conservation as silage, and the addition of sucrose is essential, when pure stands of clover or lucerne are ensiled. Because of a severe loss of leaf during natural drying, legumes are generally only useful for grazing or artificial drying.

The large-leaved strains of white clover are high yielding and rapid growing, but less persistent than the small-leaved types and are suitable for temporary pastures of up to 4 years duration. The smaller-leaved wild clover types, are persistent even under heavy grazing, and are the only legumes that can make a continued contribution to long-duration pastures. White clover is susceptible to competition from grass. When the grass is allowed to head, or if over 200 units of nitrogen per acre are applied, white clover will become dominated by grass.

Red clover can be obtained in single or double-cutting strains. The former flowers only once a season, while the latter produces a second flush. Double-cut types are earlier and rapid growing, but less winter hardy and persistent. Single-cut red clover may persist for up to 3 seasons in a pasture, but the double-cut types are productive for only 18 months. Although useful in short-duration grazing pasture, red clover is not as persistent as white clover, and its ability to recover from repeated defoliation is lower.

Lucerne suffers from competition with grass or weeds, (except under dry conditions), and is best grown alone. Alternatively lucerne can be sown with a companion to reduce competition from volunteer weeds, but the grass should be a non-aggressive species, such as meadow fescue. Lucerne requires a neutral or slightly alkaline soil, and will give 4 to 6 cuts a year of high quality fodder.

Clover and Nitrogen Fertilisers

Whether to rely on clovers or on artificial fertiliser for nitrogen depends almost entirely on the intensification required. In practice, the total size of the holding, existing farm buildings, and the availability of capital and labour, are as likely to be the limiting factors as the physical potential of the pastures.

Grass grown with clover without artificial nitrogen can only produce around 4,500 to 5,000 lb. per acre dry matter per annum. At this level of production about 2 acres of pasture are required per cow. At this stocking rate it would be uneconomic to apply artificial nitrogenous fertiliser to grow extra feed which could not be utilised. If, however, a stocking density of 1½ acres per cow is required, a grass clover sward alone cannot produce sufficient dry matter, and about 80 units of artificial nitrogen will have to be used. If intensification proceeds to 1 acre per cow, clover must be forgotten, and about 300 units nitrogen applied producing 10,000 lb. DM per acre. If stocking density is increased above this level, supplementary fodder must be bought in.

The way of using nitrogen differs for grazing and conservation. Where grazing is practised nitrogen is applied 'little-and-often' to obtain steady growth throughout the season. A reasonably large first dressing, say, 60 to 80 units per acre, is applied in spring to start vigorous growth as early as possible. Later dressings of 40 to 60 units per acre are applied, typically after each grazing, at 3 weekly or monthly intervals. When fields are cut for silage less frequent but larger dressings are required; around 100 units per acre for each cut of silage. With regard to hay, too heavy a dressing can result in crops that are too heavy and lush to cure, and 50 to

60 units per acre is usually adequate. The frequency of cutting for dried grass is nearer that of grazing so that rather small frequent dressings should be used.

On most soils grass cannot be grown for long periods using only nitrogen. The pH must not be allowed to become too low and a figure of around pH 6 is generally considered satisfactory. Soil type must be taken into account. Sandy soils need a higher pH than clays.

Phosphate off-take is not great, whether fields are grazed or mown, and a rate of only 25 to 50 units per acre per annum is usually sufficient, depending on the nutrient index of the soil. This may be applied as basic slag every few years, as superphosphate, or in compound fertilisers annually. On the other hand potash off-take differs for grazing and cutting. Grazing removes little potash, most of it being returned in dung and urine, and grazing pastures need no potash fertiliser. If the soils are naturally potash deficient, an annual 'insurance' dressing of some 20 to 30 units per acre should be applied. Under cutting potash removal is heavy, and it should be replaced at about 30 units of potash for every ton of dry matter removed. At this level sufficient potash is available for normal growth, but not enough quantities to encourage 'luxury' up-take.

Permanent grass is a variable resource, ranging from first-class perennial ryegrass dominant swards to poor Agrostis dominated pastures often associated with rushes or gorse. Temporary grass too can vary from one-year Italian ryegrass leys to long-term perennial ryegrass white clover pastures indistinguishable from good permanent grass. The best permanent grass fields are the equal of most leys. On the other hand the majority of permanent pastures are currently producing less than average quality leys. Permanent pastures carry no establishment charges and they are always in production. Most importantly, they form close turfy swards much more resistant to poaching than leys. Moreover, when given adequate fertiliser and grazed, they improve rapidly and approach the productivity of temporary grass. Management practices and intensity requirements, will dictate the choice between permanent pastures and leys, and the use of nitrogen fertilisers.

Grass and Animal Health

When highly fertilised grass is the basis of feeding there is some risk to animal health. In particular animals grazing pastures heavily fertilised with nitrogen and potash are prone to hypomagnesaemia. The cow has little reserve of available magnesium in its body, and the amount of the element in normal pastures, when allowance is made for its low availability, is not much above the animal's requirement. High levels of nitrogenous fertiliser, especially when applied in the form of the ammonium salt, lower the content of magnesium in the herbage, the effect being even more marked if potassic fertilisers are used simultaneously. In addition nitrogen applications reduce the clover content of the sward, and this will also contribute to lowered magnesium intake by the animal either grazing the sward or ingesting the conserved feed; legumes are richer sources of calcium and magnesium than grasses.

High fertiliser use does not necessarily result in increased risk of hypomagnesaemia. The partial replacement of nitrogen given as the ammonium ion by nitrate, and reduction in the amount of potash applied are useful ways of minimising the risk. Where herbage is consumed in situ (grazing) or farm effluent is returned as a slurry the requirement for potash will be much reduced. It is also relevant to note that 'luxury consumption' of potash can lead to the depression of the content of magnesium and sodium. Corrective measures include the application of dolomitic limestone. The feeding of calcined magnesite is also especially important when cows first go out to grass in the spring.

Faulty dietary calcium: phosphate ratios (Ca:P=3·6:1) have been associated with infertility, although the evidence is equivocal. Low manganese content, often due to heavy liming, has also been suggested as a cause of infertility.

The use of high-grade fertilisers in modern farming increases the rate of depletion of soil reserves of elements other than nitrogen, phosphate, potash and calcium. In part this is due to increase in yields; in part it is due to their high grade of purity compared with fertilisers used in the past. In most soils, reserves are adequate, but where they are low, it is advisable to make small autumn applications of crude materials like slag and kainit (and even F.Y.M.).

Grazing and Zero-Grazing

The task of maximising returns from grass is essentially one of balancing grazing and conservation. When grassland is lightly stocked, sophisticated grazing management is unnecessary. The modern trend, however, is to ever-increasing stock densities, which require controlled grazing to make the best use of the grass grown.

Controlled grazing must provide a sequence of leafy nutrious herbage throughout the grazing season. A compromise is required between eating out a pasture and over-maturity, taking account of conservation needs. At the same time grass needs time to recover from grazing so that it can make full use of solar energy and fertilisers. The system should be simple to operate.

These requirements are most easily met by paddock grazing. One acre of good grass will provide one day's grazing for 40 to 50 cows. If 200 units of nitrogen per acre are used over the season, half an acre of grass will generally provide sufficient grazing for one dairy cow for the period April to September. A 100 cow herd will therefore require 50 acres allocated for grazing. The total area is split into paddocks on the basis of the number of days allowed for the grass to recover, and the number of days the cows are in a paddock. There is some divergence of opinion regarding the best recovery period. To make optimum use of fertiliser nitrogen and solar energy, a 28 day recovery period seems desirable. But this means that the grass is quite long at each grazing, and there is a danger of rejection and loss through trampling. At the other extreme, some people prefer a 14 to 16 day recovery period, mainly on the grounds that the grass is always acceptable and of a high feeding value. In practice a recovery period of around 21 days seems to work very well. At the time of maximum growth in May and June the period can be temporarily reduced by removing several paddocks from the rotation and cutting the grass for conservation. Later in the season, when grass growth slows down, the rotation can be lengthened if necessary, by grazing aftermaths or using stand-by paddocks.

With a 21 day recovery period the grazing acreage is divided into either 22 equal parts for one-day paddocks, or 11 for two-day paddocks. One-day paddocks should be used wherever possible. They make for easier management, and are less likely to lead to milk yield fluctuations. With small herds, however, one-day paddocks often mean excessive fencing and small fields. Two-day paddocks are perfectly satisfactory in this case—they can even be temporarily sub-divided for each day's grazing. Once paddocks have been set up, grazing management becomes a matter of routine.

Many farms are not suited to a semi-permanent system such as paddock grazing. Different fields may be available each year and water supply or access may be difficult. However, strip-grazing using movable electric fences can be as efficient as paddock grazing. If the front fence is moved every day to give about an acre of good grass for every 50 cows, a back fence is brought up every few days or so and the cows complete a cycle every 21 days, the two systems are similar. In practice it hardly ever works out like this. An inadequate area of grass is offered and no back fence is used; cows browse back over the grass grazed the day or even the week before, so recovery is delayed; alternatively the grass ahead of the cows gets tall and stemmy and the system breaks down.

Since grass grows unevenly through the season, the movable fence could be used to adjust the area presented according to current growth rate and so make the system more efficient. In practice few people can judge grass growth rate well enough to vary the amount of grass presented accurately. One of the good features of the paddock grazing system is that it is relatively inflexible and at least ensures that cows are not presented with too little grass, although if standards are a little lax the cows may be offered too much. Topping of seed heads and surplus grass may be required from mid-May onwards with both paddock and strip-grazing.

Zero-grazing, where grass is cut and carted to cows, should theoretically be the most efficient means of utilising grass. It is thought by many to be reasonably simple to cut the right quantity of grass at just the correct stage of growth to feed cows kept on concrete. This, it is argued, saves all wastage caused by selective grazing, trampling and fouling, and results in a high output. However, it is just as difficult as any other system to obtain a sequence of grass at the correct stage of growth for cutting. Even judging the right quantity for feeding is not easy. Lack of selection in grazing, and mushing and heating of cut grass, often result in reduced intake and consequently lower animal output.

Watson and Runcie[9] found a direct advantage of zero-grazing over strip-grazing with cattle of 7·8 per cent: this advantage was in stock carrying capacity. Hood[10] found, comparing the overall advantages of zero-grazing over paddock grazing, a 5 per cent increase in beef production and an 8 per cent increase in stock carrying capacity. Against this modest level of advantage has to be set the disadvantages of the bother and cost of collecting grass every day, the provision of accommodation and the disposal of manure. For the most part the disadvantages outweigh the advantages. However, the trend is to larger herds, and the physical problem of management and movement of many cows, may well swing the balance in favour of zero-grazing. Other conditions which favour zero-grazing are—fragmented holdings or farms with difficult layouts; and poor fencing and water supply. A farmer with a limited acreage, but with available capital, may also be attracted to zero-grazing. But in all cases high standards of management are required.

Conservation

The value of conserved grass, and the production costs it merits, must be related to animal production systems which make the best use of all available feed resources. The most effective utilisation of conserved feeds may not be achieved by exclusive use of grass products alone; in many circumstances higher levels of animal production and more efficient feed conversion may attend the judicious use of limited quantities of supplementary feeds. Thus grass conservation systems cannot be evaluated in isolation.

When grass is treated as a crop, it can be harvested in a succession of cuts over the season, to produce a high yield of forage that is at least 70 per cent digestible on a dry matter basis which is equivalent to 64 D-value* (see Figure 4.1, Chapter 4).[11] Grass of this quality should be capable of supporting relatively high levels of animal production. Reference to Agricultural Research Council (A.R.C.)[12] feeding standards suggests that when it is fed *ad lib* as the sole feed to cows, it could support milk yields of 3–4 gallons per day. This is an appropriate target, since up to this level maintenance costs per unit of output fall rapidly, while the change is less marked as production rises higher. However this level of performance has rarely been attained on conserved grass alone, usually because feed intake has fallen below expectations. Even when it has been attained, there may have been a

* D value is defined as the percentage of digestible organic matter in the dry matter, determined by the *in vitro* method.

D-value $= 3{\cdot}3 + 0{\cdot}87$ DMD $\pm 1{\cdot}7$.

Source: Grass Res. Inst., Tech. Rept. No. 8.

case for supplementing grain with other feeds to increase production and feed conversion efficiency, for example when cows are at peak lactation. Early cutting of first growth of grass to obtain more digestible fodder, and reduce supplementary feeding, has been shown to lead to a disproportionate reduction in annual DM yield of pasture. Later cutting of first growth may increase the DM yield in that cut, but the digestibility of a major part of the crop is reduced below 64 D-value. The full consequences of differences in forage yield and digestibility can only be evaluated in the context of particular feeding systems, since the value of the forage is influenced by the type of diet in which it is fed, and the purpose for which it is used. This is considered later in Section IV of this report.

Feed Value of Grass

The value of conserved grass for animal production is a function of the amount consumed, the energy losses in digestion and the utilisation of digested energy for production. Since variation in intake, and efficiency of utilisation, are often correlated with variation in feed digestibility, digestibility provides an index of overall feed value. Determination of digestibility by the *in vitro* method (D-value or DOMD), or the use of a 'Modified Acid Detergent Crude Fibre' assessment (MADF), provide means of characterising forage in terms of energy value.

Digestibility of dry matter in forages varies from 40–85 per cent (38–77 D-value), and changes in digestibility greatly modify the energy value of the grass. An increase in dry matter digestibility from 50 per cent to 60 per cent is an improvement of 20 per cent, but because of the interrelationship between intake, digestibility and utilisation there may be as much as a five fold increase in energy intake above maintenance. Such cumulative effects of changes in digestibility are more marked in the lower ranges of dry matter digestibility up to 70 per cent (64 per cent D-value).

Grass and grass products are valuable sources of feed protein. It has sometimes been suggested that grass varieties should be selected for high energy characteristics rather than protein, using home-grown pulse crops or urea as supplementary protein sources. But present evidence suggests that urea is associated with reductions in the yields of cows producing more than three gallons of milk per day.[13]

Factors Affecting Feed Value

The feeding value of conserved forages is affected by intake, digestibility and utilisation of nutrient.

The more detailed factors involved are:

(i) the original chemical composition of the herbage;

(ii) the effects of the conservation process, associated with dehydration or ensilage;

(iii) physical processing of the forage prior to feeding;

(iv) variation in the overall level of feeding and in the nature of the other constituents of diet in which the forage is fed.

The decline in the digestibility of grass with advancing stage of growth, and the timing of cutting, is now well documented[14]. Varietal differences in digestibility at stages of growth were mentioned earlier. In haymaking reduced digestibility is associated with respiratory losses, with mechanical damage resulting in loss of leaf and with leaching. It is minimised by quick haymaking techniques and barn hay drying. Conservation by drying or ensilage need not appreciably reduce the digestibility of the forage. Methods of ensilage (without additives) do not necessarily lead to any change in digestibility. When substantial dry matter losses occur in silage making (15–50 per cent) these are largely due to aerobic respiration of material; feed energy losses may be as much as double DM losses and the digestibility of the silage is reduced. McDonald and Whittenbury have suggested that, by wilting to 30 per cent dry matter and sealing the surface to prevent air being drawn into the silage mass, anaerobic conditions can be maintained and losses associated with fermentation and respiration could be as low as 6 per cent.[15]

In many circumstances the voluntary intake of conserved grass by ruminants is a function of its 'filling effect' in the rumen, which can be measured in terms of the rate of disappearance of feed from the rumen. The more rapid the rate, the more feed the animal is able to consume. The rate of disappearance of feed from the rumen is a function of the speed with which plant material is broken down by rumination and fermentation into particles sufficiently small to pass out of the rumen. Since a major proportion of herbage is digested in the rumen, a close relationship may exist between the overall digestibility of feeds and their intake characteristics. This relationship is most evident with respect to dry herbage fed long or chopped. There is an almost linear increase in voluntary intake of feed as digestibility rises toward 65 per cent D-value then as digestibility rises higher there is no further increase in DM intake and indeed it is likely to be reduced. The intake of very highly digestible herbage or mixed diets is probably not limited by 'filling effects' but controlled by chemostatic regulatory processes.

Over the lower range of digestibility up to 65 per cent D-value intake of feed is influenced by physical factors affecting the passage of feed through the rumen. Within a particular species of forage, the higher the digestibility, the higher the intake. However, different forage species of similar digestibility have different intake characteristics and this is associated with the rate at which they are digested in the rumen. Thus the higher intake of lucerne than of S24 ryegrass of the same digestibility, is associated with more rapid breakdown and disappearance of lucerne in the rumen. This can be related to the higher proportion of soluble cell contents, relative to digestible crude fibre, in the dried lucerne compared with the dried grass.

Processing of forage by grinding and packaging into pellets or cobs reduces the particle size of the ingested feed, and facilitates more rapid passage through the rumen. In this situation, feed intake is increased but digestibility is depressed because the forage is exposed to fermentation for a shorter period. The character of the fermentation process is also modified, but the losses caused by undigested food passing into the dung is at least partially compensated by changes in the rumen, such that absorbed energy is utilised more efficiently for growth and fattening. The effects on intake vary with the particle size resulting from processing. Fine grinding increases intake, provided the pellets are not too hard, since excessive hardness will itself depress intake. The original digestibility of the forage also influences the effect of processing on forage intake. The most marked enhancement of intake is associated with forage of low digestibility, and the effect is progressively less with more digestible forage.

With forage in the higher range of digestibility (over 65 per cent D-value), the factors influencing intake and the regulatory effects are no longer rate of passage of feed particles, but are associated with the overall energy density of the diet. The animal tends to regulate feeding to maintain an intake of energy that is appropriate to its requirements.

The intake of DM from unwilted silage is up to 60 per cent less than that from well-made hay from the same sward, but the intake of heavily wilted silage may be as high as from barn-dried hay. The relationship between the dry matter content of ensiled grass and its intake characteristics is probably associated with the effect on silage fermentation of the original moisture content of the material. The main effects of wilting are a decreased quantity of free acids in the silage, and a reduction of protein degradation.

The effects of silage on rumen pH and on rumen nitrogen supply may be important. Well-made silage of low pH is consumed in smaller quantities than dried grass of the same digestibility. Silage of high pH on the other hand tends to have a higher content of ammonia-nitrogen and this is also associated with reduced intake. It is well recognised that forage crops with a low soluble carbohydrate content and high protein content, when ensiled without wilting, tend to give rise to an unstable fermentation associated with an increase in acetic and butyric acid, a high content of ammonia-N and a characteristically high pH.

Wilting enables a stable lactic acid-type fermentation to be produced by material with a lower level of soluble carbohydrates. The addition of molasses to unwilted silage to increase soluble carbohydrate is an alternative. Application of formic acid to unwilted forages has also been shown to maintain a controlled fermentation, preventing a rise in pH and the breakdown of protein to ammonia. Workers at Hurley have reported that with lucerne silages, the use of formic acid increased intake 12–23 per cent, but for ryegrass silages that were well preserved the increased intake was less than 5 per cent. However, intake levels of the ryegrass silages were all lower than those of less digestible lucerne silages.

Ryegrass swards cut in spring are likely to have a relatively high soluble carbohydrate content and even when direct-cut can make stable silages of low pH. Formic acid addition does little to improve intake of such silages, but may be useful as a means of regulating fermentation in circumstances in which the silo is filled relatively slowly.

The problem of silage intakes is so far only partially resolved but wilting still appears to be the most effective means of improving the intake characteristics of ryegrass silages. Wilting silage over the range from 15–30 per cent DM increases intake appreciably, and there have been further though less marked improvements when silage has been wilted to 50 per cent DM.

Discussion so far has been restricted to consideration of forages fed alone. In practice the deficiencies of conserved grass are made good by supplementary concentrate feeding. Concentrate feeding is necessary, when roughages provide basic feeds, if energy intake is to be sufficient to maintain highly productive stock. Supplementary concentrate feeding modifies both dry matter and digestible intake associated with *ad lib* feeding of conserved grass. Concentrate supplementation generally increases energy intake, and its effect on animal production is proportional to the extent to which it raises that intake above maintenance requirements. For this reason alone it is less effective when fed with highly digestible forages the intake of which is already high. Furthermore, the value of concentrates is influenced by the degree to which they substitute for forage rather than supplement it. At one extreme there may be complete substitution of concentrates for forage and thus little or no advantage; at the other there may be no substitution, and even an enhanced intake of forage.

Marked increases in the intake of low-protein roughages are produced by supplements that raise the crude protein content of the diet above 8 per cent. When the protein content of hay of low digestibility is above this level then low levels of concentrate feeding may have little effect on hay intake, but as concentrate levels rise to comprise one-third or more of total DM intake, hay DM intake is reduced 0·2–0·4 lb. per lb. of concentrate DM. This effect is more marked the greater the digestibility of the roughage.

Even high levels of concentrate feeding cause less depression of silage intake than of hay. Because of this, differences in intake between hay and silage, and between wilted and unwilted silage have been reduced when the forages have been supplemented with concentrates rather than fed alone. Intake of silage also appears to be influenced by the characteristics of the concentrates that are fed with it. Supplements containing groundnut cake result in a higher intake of feed and a higher milk production than that produced by the same level of barley supplement. This and other evidence suggests that the nitrogen in ensiled feeds may be used inefficiently, particularly when silage is fed as the sole feed. Even a moderate level of supplementary barley improves the utilisation of silage 'protein'.

Intake of feed is influenced not only by the diet but also by the potential of the livestock to which it is fed[16]. The productive potential of the cow influences both feed intake from a range of diets, and the relationship between diet digestibility and feed intake. For example, the dry pregnant cow has a lower feed intake than the milking cow. The dry cow adjusts her intake to suit her requirements when the overall digestibility of the diet rises above 55 per cent D-value, but for the cow yielding 5 gallons of milk the digestibility of the diet may limit intake up to a diet digestibility of approximately 65 per cent D-value. Thus when forage alone, or a combination of forage and concentrates, raises the digestibility and energy density of the diet above critical levels, the cow will tend to adjust her intake to meet her requirements. This points to the significance of providing a forage diet for the milking cow that is of appropriate digestibility. This will generally be one of 60-65 per cent D-value. Such a diet can be provided by well-managed grazing alone, but with conventional hay and silage concentrates will be needed.

Supplementary feeding may be used to compensate for variation in forage quality, or as corrective when inefficient conservation reduces nutritive value. The advantages of forage of at least 70 per cent digestibility are nonetheless considerable. High yielding digestible fodder will support high levels of animal production with little supplementary feeding. However, even with high quality forage it may be economic to use cereal supplements. When the cow is dry she will consume sufficient nutrients from forage alone. At peak lactation concentrate supplementation is justified, even to the extent that the potential contribuion from forage is reduced, so that the required high energy concentration can be attained in the diet as a whole. At this stage underfeeding will have consequences throughout lactation and there may well be a case, with autumn calving herds for supplementing silage and barley with high quality hay and succulent feeds, to boost total DM intake. In the later stages of lactation, concentrate feeding can be reduced and roughage increased gradually to its full extent.

Grass must be treated as a crop to realise its potential, and the management with regard to time of cutting and method of conservation must be designed to fit the animal production system. Dried grass will substitute for concentrates, but it is expensive and feeding must be controlled. Barn-dried hay and highly acceptable silage, supplemented with cereals, will provide winter diets for highly productive milking and growing stock. Heavy yields of conserved grass of low digestibility may find a place in maintenance diets for cows.

Assessing Grassland Potential

It is only recently that production of 1,000 gallons of milk plus maintenance of the cow have been obtained from grass and grass products alone. For some time previously research and technology had shown that this was possible. Indeed farmers could be forgiven if they had been persuaded that, provided nitrogen were increased, stocking densities were virtually unlimited. In general terms 10,000 lb. of DM from an acre of grass is a realistic upper limit, with the ecological optimum not much beyond this.

Pasture productivity, in terms of yield of grass or animal product, is difficult to measure and interpret. This has led to the measurement of grass feeding values as the residual, after assessing standard outputs of all other feeds, but such a system leaves much to be desired. Measurement problems also occur when attempting to assess production in terms of weight of harvested material. Livestock Units are used in the H.M.S.O. Bulletin, 'Why Grow Grass' No. 8, which gives feed costs in terms of shillings per unit of nutrient energy, and shows higher costs for all feeds than grass. Grazing is generally accepted to be the cheapest form of feed and this has given credence to two further assertions, namely:

(i) that this must be equally true of conserved grass products,

(ii) that grass must be conserved without physical waste.

As a consequence in recent years high cost systems of conservation have been widely and often indiscriminately adopted, quite often without any reduction in costs or increase in yields or quality.

The cost of nutrient energy must be related to specific grass utilisation systems, remembering that new techniques of barley growing and storage, of field root growing and harvesting, have reduced costs of alternatives considerably. Account must also be taken of variations in the prices of other sources of starch and protein. One disadvantage of grass is that, because of climatic variations, one cannot predict accurately the cost of producing conserved products before the material is harvested, processed and available for use. The old adage that the best hay is the cheapest made, still contains the germs of truth and, with the addition of modern wilting techniques, is equally valid for silage making.

There has been a tendency to think of profitability and intensity of production as synonymous, and this has led to the development of high cost systems. A dairy enterprise may be a high cost system because of high feeding inputs, high capital investment in fixed equipment and machinery, or under-utilisation of existing facilities.

The principal problems of such systems are firstly that they are demanding of management, and secondly, because they involve large cash inflows and outflows, small changes in prices (e.g. of milk or of interest rates) may materially alter profitability. The advantages of low cost systems are that they recognise managerial limitations, and with this in mind, aim for moderate yields, moderate stocking densities and cost minimisation. Moreover, low cost is not necessarily synonymous with low output. Such a system may be more resistant to unfavourable movements of input or output prices (e.g. feeding stuffs) since the ratio of variable costs to revenue is lower. Finally a low cost system, by having a low level of capital investment, may be more flexible.

It is clear that generalisations regarding cost and quality of grass and the economics of alternative policies, need qualification when applied to the particular farm. Nevertheless, it is possible to proceed further in a general vein, by considering in more detail a range of different systems of grass conservation.

III. SYSTEMS OF CONSERVATION AND THEIR COSTS

There are many systems of dairying with varying degrees of capital intensity and sophistication. Cows can be housed for six winter months, with covered accommodation ranging from simple kennels to substantial yards served by various manure disposal systems. Bulk feed can be either from a self feed clamp of silage or from a complex of haylage towers and ancillary equipment.

The main elements in dairying systems are given below; almost every item can be combined with other facilities in other columns to give a wide range of systems.

Five systems of grass conservation are in common use; (i) direct forage harvesting, (ii) wilted silage into clamps, (iii) wilted silage into sealed storage, (iv) haymaking, and (v) artificial drying systems.

Direct cutting by a flail type forage harvester, loading into trailers and transporting unwilted material into a clamp silo, is the lowest cost mechanisation system for field handling of material. Clamps are a cheap form of storage which lend themselves to self-feeding. However, because of the absence of wilting and poor control over the fermentation, it is difficult to ensure the quality of the fodder. This system is useful where the stored grass is only expected to provide maintenance for cattle during the winter months, but it is not suitable when the silage is expected to provide for milk production.

Housing	*Grass Conservation*	*Milking*	*Bulk Feeding*	*Effluent*
None Kennels Yard Yard and cubicles	Hay Tower silage Clamp silo Grass drying Barn hay drying	Bail Parlour Cowshed	Automatic Self-feeding Hand fed and carting Year round tower silage Zero graze	Straw yard—annual removal Straw bound tractor and fork daily Slurry tanks and vacuum system Intermittent slurry irrigation

The main aim in making wilted silage is to concentrate dry matter in the materials and to promote better fermentation, to facilitate a higher intake of feed so that the forage can sustain milk production as well as maintenance. Wilting is dependent on weather conditions and introduces additional field operations, both of which are disadvantages.

Fully chopped wilted material stored in tower silos is suitable for mechanised feeding. The capital requirements for silos and handling equipment favour the concentration of conservation in one place on the farm. A unit of less than 80 cows is likely to be too small for silos and ancillary equipment to be economic; even above this number each case needs careful evaluation.

Hay is the traditional method of conserving grass. It has the dual advantages of convenience of handling and a high dry matter content. But because of its high dependence on weather, the reliability of hay-making is low. Improvements in machinery have accelerated field drying, but in good drying conditions it still requires three days to reduce moisture content to a level suitable for baling.

Artificial drying systems are virtually independent of weather conditions, though the cost of drying increases as moisture content increases. There are two extremes of artificial drying processes. Firstly, there is the complete drying of freshly harvested material, which allows conservation to proceed in a predictable way, using equipment exhibiting economies of scale in operation. Where drying capacity is about $\frac{1}{2}$ ton per hour, a throughput of about 400 tons or so per year is required to spread the capital investment. Secondly, there is barn hay-drying, where most of the moisture is removed in the field, but drying is completed indoors, possibly using artificial heat. This system produces high quality material at relatively low cost, if the quantities handled are fairly small.

Any conservation system dependent on the weather has limitations with regard to both the quality of the feed and the predictability of work plans. Unwilted material can be harvested under a wide variety of conditions, but the final material is only suitable for maintenance rations. But these rations can be supplemented to produce a total ration which may be competitively priced. Artificial drying can produce high quality feed at competitive prices, but this requires a large annual throughput of the drier, and sensible feeding policies. The extent to which wafering and pelleting of the material are economic depends on the utilisation of feed and the scale of operation—intensive production and large-scale are required.

For small dairy units the choice is between conventional systems of hay or silage, with the risks they involve, and barn hay drying. Since the average herd size is around 30 dairy cows, these two systems are likely to dominate conservation methods for some time, although as the emphasis swings to larger herds of 100 cows or more, conservation systems will need to be related to this scale of enterprise.

Silage

The alternatives for silage are the conventional bunker (probably self fed) and the tower silo. The main argument in favour of towers is that lower losses are experienced, and therefore less land need be devoted to feeding the same number of cows. With the best clamp silage systems, however, losses can be fairly low (below 20 per cent) and changing to towers would not save much. In some bad seasons losses with

TABLE 3.1

a. TOWER SILOS

Herd Size (No. of Cows)	*Silo Size*	*Cost of Tower Concrete Base and Unloader*		*Field and Filling Machinery*		*Total Net Capital Cost*	*Net Capital Cost per Cow*	*Annual Charges*			
		Total	*Per Cow*	*Total*	*Per Cow*			*Buildings (10 yrs. @ 8%)*	*Machinery (Amortised over 5 yrs.)*	*Total*	*Per Cow*
		£	£	£	£	£	£	£	£	£	£
100(a)	1—55′ × 24′	(b) 5,232 Grant 1,260 3,972	39·7	3,782	37·8	7,754	77·5	592	945	1,537	15·4
150	2—55′ × 20′	(b) 9,128 Grant 2,220 6,908	46·1	4,082	27·2	10,990	73·3	1,029	1,020	2,049	13·7
200	2—65′ × 20′	(b) 11,128 Grant 2,820 8,308	41·5	4,082	20·4	12,390	62·0	1,238	1,020	2,258	11·3

(a) No substantial difference between 80 and 100 cow unit size.

(b) Grant payable on base and tower only.

TABLE 3.1

b. BUNKER SILOS

Herd Size	Silo Capacity Required tons 25% DM	Cost of Covered Bunker Silo		Field Equipment		Total Net Capital Cost	Net Capital Cost per Cow	Annual Charges			
		Total	Per Cow	Total	Per Cow			Buliding (20 yrs. @ 8%)	Machinery (Amortised over 5 yrs)	Total	Per Cow
		£	£	£	£	£	£	£	£	£	£
80	500	3,512 Less 1,053 2,459	30·7	1,435	17·9	3,894	48·7	251	359	610	7·6
100	640	4,300 Less 1,290 3,010	30·1	1,435	14·3	4,445	44·5	307	359	666	6·7
150	960	6,655 Less 1,996 4,659	31·1	2,085	13·9	6,744	45·0	475	521	996	6·6
200	1,280	8,300 Less 2,490 5,810	29·1	2,085	10·4	7,895	39·5	593	521	1,114	5·6

towers may be much the same as with clamps. However towers offer other advantages; less labour may be required for field work and filling and feeding can be mechanised.

The figures in Table 3.1 (a) and (b) give silage costs on the assumption that no silage accommodation is already available; they reflect the differing costs of providing towers or clamps and the different field and feeding equipment that would be necessary. The figures cannot be applied to a particular farm, without modification to take account of the assets of that farm and the consequence of alternative systems on the farm programme.

Grass Drying

After a fairly static period of dried grass production, there has recently been renewed interest in extending its usage to dairy cows. This interest is due to improvements in drying and packaging equipment, the development of improved grasses, and a better understanding of how to exploit new varieties to best advantage. The attraction of grass and legumes as break crops on farms with rotational problems is a further incentive.

Dried grass can be produced for consumption on the farm or for sale. At present, the market for dried grass remains unpredictable, and there is a risk that productive capacity may grow faster than consumption. Likely capital costs are assessed in Table 3.2.

TABLE 3.2

ESTIMATED CAPITAL COST OF GRASS DRYING

2.4 t.p.h. Drier (Before Grant)

	£
Drier and Installation	50,000
Miscellaneous Costs (including electrical work, fuel tank etc)	6,600
Waferer	7,000
Building, including bulk storage foundation	2,000
Structure, concrete floors and standings	29,000
Sundries	3,000
Harvesters 3 @ £8,500	25,500
Trailers 4 @ £1,250	5,000
Tractors 3	6,000
	£134,100

Table 3.3 shows the effects of scale on costs. The data assume efficient management but can be used to estimate the adverse effect of, for example, under-utilisation. Because capital costs of grass drying are high, it demands efficient organisation of cropping to keep the drier occupied for as long as possible. In estimating the potential output of a grass drier, allowance must be made for the practical difficulties of continuous operation.

TABLE 3.3

GRASS DRYING COSTS

	0.6 t.p.h Drier		*2.4 t.p.h. Drier*
	Single Shift Working	*Double Shift Working*	
Data			
Drier output t.p.h.	0·60	0·60	2·40
Drying hours daily	10·00	16·00	20·00
Drying days	90·00	110·00	120·00
Annual potential output dried grass tons	540	1,056	5,760
Yield dried grass acre (m. ton)	4·00	4·00	4·00
Average annual output (tons)	450	900	5,000
Costs			
1. Capital Costs—			
Cost of Drier	23,000 (Package Deal)	23,000	50,000
Wafer storage for part output	2,300	3,450	included below
	25,300	26,450	134,100
2. Costs per ton—			
Rent and Crop Production	7·25	7·25	7·25
Field Machinery repairs and renewals	0·70	0·70	0·70
Drier and ancillary repairs	0·70	0·70	0·90
Sundries	1·40	1·40	1·40
Fuel, oil and electricity	6·42	6·42	6·42
Labour	1·60	2·15	2·40
Amortisation 10 yrs @ 8%	8·37	4·38	3·99
Total	£26.44	£23·00	£23·06

'Standard' conditions for a grass drier are suggested as follows: incoming crop 80 per cent moisture content; dried product 10 per cent moisture content; water removed to produce 1 ton of dried product=3·5 tons.

Initial moisture content can be as high as 85 per cent, when it is necessary to remove 5·0 tons of water to produce 1 ton of dried product, and output falls to only 70 per cent of the 'standard' figure.

The feeding value of dried grass depends on its level of digestibility, and is influenced by its stage of maturity when cut, as Table 3.4 shows. It is likely that variable qualities will be produced, some of high digestibility and some only equivalent to good quality hay. Table 3.4 suggests that overall worth is likely to be in the region of £26 per ton and Table 3.5 works out the approximate net profit per acre

TABLE 3.4

DRIED GRASS FEEDING VALUE

DM Digestibility	*lb. Dried Grass to replace 4 lb. cake*	*Equivalent Value of Dried Grass*[1]
72%	5·0	30·1
66%	5·8	26·1
64%	6·2	24·4

[1] Compared with low density cake, 4 lb. per gallon, £38 per ton.

TABLE 3.5

DRIED GRASS ECONOMIC COMPARISONS

Net profit per acre

	0.6 t.p.h. Drier		*2.4 t.p.h. drier*
	Single Shift Working £	*Double Shift Working* £	£
Output per acre 4 tons @ £26	104·0	104·0	104·0
Cost per acre	105·76	92·00	92·24
Deficit/Surplus per acre	−1·76	+12·00	+11·76

on that basis. As can be seen, profitability is determined by scale of operation and utilisation of plant. Small variations in either can have a marked effect on profitability.

Within these general economic relationships dried grass can have differing roles on different farms. On a large-scale arable farm, dried grass (grown for sale) could be considered as one of the possible break crops, and compared with others, like field beans, for capital requirements. On the specialised grass dairy farm, dried grass may be considered solely as a substitute for bought-in concentrates, and evaluated as such. It is clear that dried grass may have a role to play, but it is a capital intensive enterprise and needs assessing for each individual farm business.

Barn Hay Drying

The advantages and disadvantages of barn hay drying can be listed as follows:

Advantages

1. Hay can be made early when grass is leafy and of high feeding value.
2. Hay making season can be extended by careful planning from mid-May–July.
3. Yield losses are lower than for field dried hay due to smaller tedding and weather losses and it is less prone to nutrient losses, due to shorter time lying in the field.
4. Labour for field work should be less; at least two more tedding operations are required for field hay.

Disadvantages

1. Additional capital is required.
2. It is difficult to conserve large quantities at any one time, because of limited drier and carting capacity.
3. Heavier work and more careful stacking at the barn is required, except where 'tumble' stacking is practised.

Farm hay drying is usually only considered where there is an existing barn, the sides of which can be sheeted and a false floor provided through which air is blown. Typical costs for this type of installation are shown in Table 3.6.

With the larger unit, if a second-hand tractor was purchased together with a fan, the cost would be similar; also in some cases the Moisture Extraction Unit (or the tractor and fan) can be used to dry both hay and grain, in which case the average capital cost is reduced.

TABLE 3.6

BARN DRYING, COSTS OF INSTALLATION

Size and Type	*34 Ton (2 Bay Dutch Barn)*	*102 Ton (6 Bay Dutch Barn)*
	£	£
Sheeting for sides	450	1,050
Floor	250	750
Electric Fan and Heater/Unit	280	—
	980	1,800
Less 30% Grant (if approved) on sides, floor and electrical work	270	540
	710	1,260
Moisture Extraction Unit	—	800
	710	2,060
Capital Cost per ton	£20·9	£20·2

TABLE 3.7

COST OF BARN HAY DRYING

	30–40 Tons (2 bays, electric fan)	*100–110 Tons (6 bays, multipurpose moisture extraction unit)*
	£	£
Fixed Costs per ton (Amortisation, 10 years @ 8% of building and equipment costs)	3·09	3·01
Running Costs per ton	0·90	0·90
Total Costs per ton	3·99	3·91

The figures in Table 3.8 which compare traditional hay and barn dried hay assume that the barn dried product is of high quality, cut early, largely unweathered, with a high energy and protein value. This should be the objective, rather than using the system as a hay conditioner and an insurance during inclement weather conditions. Properly used, the system can have far reaching effects, as it can allow the intensification of the whole grassland system.

TABLE 3.8

FEEDING VALUE AND RELATIVE COSTS OF BARN DRIED HAY

Feeding Value	*Traditional Hay*	*Barn Dried Hay*
Maintenance + 2 gallons		
Feed	18 lb. hay 9 lb. barley 8 lb. concentrates	18 lb. hay 8 lb. barley
Comparative costs:		
	£	£
Cost per cow per 160 days	30·66	24·26
Saving per cow over winter period		6·40

Capital and Taxation

The capitalisation in fixed equipment and ancillary equipment required by the various systems of dairying, can range from £30 to £400 per cow. The return on investment depends on the economic life of the capital equipment. In one calculation an assumed life of 10 years showed a half per cent return on a tower silo investment. In dairying consideration should be given to the possibility of a decline in the demand, and changes in institutional arrangements. A realistic and cautious approach suggests that a life of no more than 10 years should be used in any evaluations.

Taxation can be a major factor in determining whether high or low capitalisation is employed, depending on whether the marginal tax incidence is high or low. The effect of taxation of income, and allowances for capital expenditure, is to reduce the marginal cost of investment. With a progressive tax (i.e. one that impinges most on high incomes) the 'net-of-tax' cost of the investment to the wealthy man is effectively reduced. Consideration must be given to the total relief which is available both for farm improvements and the new higher rates of allowances for plant and machinery (80 per cent allowance in the first year followed by 25 per cent on the reducing balance in succeeding years.) The profits of the business must be large enough so that all these allowances can be set against income, and full advantage taken of the relief that is available. A farmer with a high income and high marginal rate of taxation has some incentive to choose the highly capitalised systems, provided he has access to capital. This is particularly true if the plant and ancillary equipment has an economic life in excess of its 'tax life'—the period allowed for depreciation by the tax laws. For example the time allowed for writing off buildings is 10 years, but many installations have a much longer life.

If capital is obtained by borrowing, the effective cost would be again reduced for the wealthy farmer paying higher levels of income tax, because the interest payments can be set against taxable income. It is true that any improved profits stemming from greater capitalisation will be subject to higher marginal tax rates as income increase. However at higher income levels post tax 'income' may be less important than the chance to accumulate fixed equipment cheaply, to enable expansion to take place, and to keep the farm provided with up-to-date equipment.

Flexibility of Equipment

A high degree of specialisation in dairy-farming may lead to a high level of sunk capital for dairy-specific items like effluent disposal, conservation and automatic feeding equipment, all of which may have little alternative use. To justify inflexible and high cost equipment there must be substantial technical advantages, and confidence that there will not be unduly rapid product or technical obsolescence, to ensure a sufficient period for capital recoupment. The remedy for high capital-demanding, but inflexible investment must be sought in two directions—either by building in flexibility (usually at a material cost), or by selecting low capital using specialised plant, e.g. cheap cubicles.

Natural Advantage

Although milk is produced throughout the U.K. some regions have a natural advantage over others, and this may well affect the investment pattern on the farm both for conservation equipment and for buildings. In the West, climatic conditions favour grass growth throughout a relatively long growing season, while arable areas of the eastern side of the country offer many arable by-products suitable for feeding to cows. Some areas and soil types confer an advantage, in that cows can be outwintered, thus obviating the need for capitalisation in buildings. On heavy land, say in the North-East, housing of some kind is necessary. If the market for milk is separated into two—for fresh milk and for processing—further locational factors are introduced, such as nearness of large urban populations.

Effects of joining E.E.C.

The Common Agricultural Policy (C.A.P.) of E.E.C. is still in a state of flux, and it is impossible to be dogmatic about the effects on U.K. dairy farmers of joining the Common Market. However, if the main aspects of C.A.P. are retained with respect to dairying, one would expect there to be incentives to move in two directions. Firstly the lack of variation in milk prices through the year should lead to a swing towards summer milk production, so that the total requirement for conserved fodder would change. Secondly the change in relative prices of milk and cereals could lead to a lower level of concentrate feeding, and a swing to grass-based systems with special emphasis on grass products of high feeding value. Nevertheless even these generalisations must be treated with caution, since milk—above all other products—is likely to be subject to major changes in prices and methods of support.

IV. INTEGRATING CONSERVATION AND DAIRYING SYSTEMS: COMPARATIVE ECONOMICS

The selection of a grass conservation system for a particular farm can be discussed under four headings, the yield and quality of the grass, the technical efficiency of the conservation operation, the forage utilisation policy with regard to different levels of milk yield per cow lactation, and the cost of the conserved product relative to the cost (and nutritive value) of alternative feeds, especially barley. Some general principles relating to these four factors are enunciated below.

Yield and Quality of Grass

As grass matures yields of dry matter per acre increase, but from ear emergence onwards the quality, in terms of nutritive value, deteriorates steadily. Successive regrowths after the first cut produce lower yields, but the loss of quality is at a slower rate. Except when taken very early in the season, first cuts account for the greater part of the toal production of dry matter. Thus if grass is cut first at 70 per cent digestibility (63 D-value) and then at six-weekly intervals, the first cut provides three-fifths of the annual yield (see Figure IV.1). In practical silage programmes, consisting of two or three cuts a year, the first cut will be an even larger proportion of the annual yield.

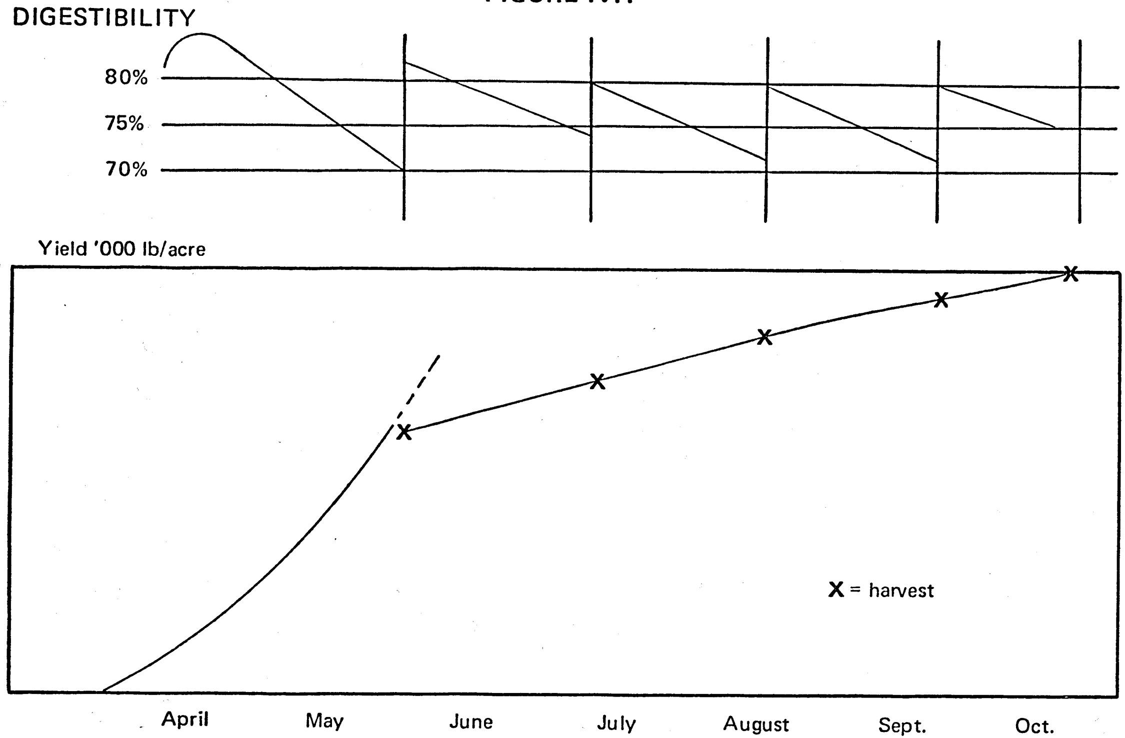
Typical data on grass are shown in Table 4.1, relating time of first cut to its yield and quality and total yield.

Assumptions on the relationship between time of cutting and the yield and nutritive value of the grass have been made after consideration of studies carried out at the Grassland Research Institute at Hurley, and at various National Institute of Agricultural Botany centres. They would be expected to correspond most appropriately to S.24 perennial ryegrass swards in South-East England, and while it is evident that different varieties and different locations may give different relationships, the difference between different cutting regimes seem likely to have a general relevance.

The assumptions with respect to yield of DM are: compared with early cutting of the first growth (corresponding with 70 per cent DMD or 64 D-value) 'medium' and 'late cutting' give increased DM yields of 18 and 29 per cent respectively ('medium' corresponding with maximum yield of digestible DM from the first growth); the annual yields following first cuts taken at the 'medium' and 'late' stage are 8 and 14 per cent higher than with an initial 'early' cut, but the annual yield of *digestible* DM is similar on both 'early' and 'late' cutting systems.

The principal assumptions with respect to time of cutting, upon which subsequent calculations are based, are the yield of DM and the nutritive value of the grass in terms of metabolisable energy and crude protein content. Further discussion of these factors is presented in the Appendix.

FIGURE IV.1



The yield of dry matter of S24 perennial ryegrass and the changes in the digestibility (in vitro) of the dry matter of the crop between harvests. Regrowth curves shown for first cut taken when digestibility was 70%.

Source : Woodford (1966)

TABLE 4.1

YIELD AND METABOLISABLE ENERGY OF THE STANDING GRASS CROP AT TIME OF FIRST CUTTING[1]

	Very[2] Early	*Early*	*Medium*	*Late*
(i) Yield of first cut (m. tons/acre)	2·41	3·18	3·75	4·09
(ii) Total Annual Yield[3]				
—3 cuts	3·32	4·09		
—2 cuts			4·43	4.77
(iii) Percentage, i/ii × 100	73	78	85	86
Quality of first cut, in vitro DMD_3	75	70	65	60
Metabolisable Energy (Megacalories per kg. Dry Matter)	2·70	2·50	2·35	2·10
Percentage of Crude Protein	19	16	13	9

[1] Further information on the basis for this assumption is presented in the Appendix.

[2] A full range of cutting dates is included in the Table for completeness, but in practice very early cutting is unlikely to be used in silage programmes, and early cutting is unlikely to be used in conventional systems of hay making.

[3] Nitrogen application: 1st cut 110 units per acre.
2nd cut 100 units per acre.
3rd cut 40 units per acre.

Technical Efficiency of the Conservation Operation

The conservation process inevitably gives rise to losses of quantity and quality of the standing crop of grass. In hay making losses arise mainly from respiration, leaching, mechanical damage, overheating and mouldiness. Silage losses arise from oxidation, unwilted material suffers effluent losses, while wilted material can suffer mechanical damage or leaching. The extent of these losses will vary with both the system of conservation and the competence of the operatives. The main variables concerned are dry matter and energy concentration, and reduction of protein content. Table 4.2 starts from the data in Table 4.1 and estimates the effects of three levels of efficiency on the yield and quality of silage, (hay is considered later in this section). The high level of efficiency (with 10 per cent losses of DM and 12½ per cent loss of nutrients) can probably only be achieved by skilled management of expensive equipment such as tower silos. Although there are differences in assumed losses between the medium category (with 20 per cent DM losses and 40 per cent loss of nutrients), the resultant differences in Metabolisable Energy and costs are relatively small. In consequence later calculations compare only high and low levels of efficiency.

As efficiency falls quality deteriorates and the cost of forage dry matter rises. The costings exclude depreciation of fixed equipment, which is likely to be an important factor in systems with the highest levels of efficiency, and direct comparison of high and low efficiency may be misleading. However, translating the information in Table 4.2 onto a per cow per winter basis (assuming a consumption by each cow of around 2.0 tons DM of silage), the difference in forage costs between high and low efficiency is of the order of £4.9 per cow.

The total feed requirements of a dairy cow, in terms of grazing, forage and concentrates, depends upon the time of calving, the length of the winter feeding period and the yield of the cow. In this evaluation of the influence of variation in efficiency of grass conservation on forage utilisation by the dairy cow, the principal analyses are based on a Friesian cow with a lactation yield of 900 gallons of milk, which receives winter feeding for 180 days from mid-October to mid-April. Two dates of calving have been examined—mid-March and mid-September—and the consequences of a shorter winter length are also considered.

Mean monthly milk yields for the autumn and spring calving lactations are shown in Table 4.3, and more details of the standard lactation curves are presented in the Appendix.

Over the 180 day winter period the September-calver requires on average feed for maintenance and the production of 3.7 gallons of milk, whereas the March-calver requires feeding for little more than maintenance plus one gallon for most of the period. It is intended to compare the influence of forage quality on winter feed costs for cows at these two contrasting levels of productivity, and also consider other features of seasonality in milk production.

Efficient use of different qualities of conserved grass involves matching them with appropriate amounts of concentrates, so that the feed requirements of the milking cow are satisfied. Deficiencies in the feeding value of forage, provided they are recognised, may be largely compensated by the replacement of conserved grass with cereals and protein concentrates. The feasibility of using straw-based diets is an extreme example of this.

In this study the substitution of concentrates for forage has been based on the principles of the A.R.C. (1965)[12] system of feeding standards. Rations based on varying proportions of forage and concentrates have been formulated with reference to the metabolisable energy content of the feeds, to provide diets of appropriate energy concentration that will meet the feed requirements of the cows at different stages of lactation.

The September-calving cow with a potential lactation yield of 900 gallons requires feeding for 'maintenance' and the production of 5 gallons of milk/day for the first month of the winter feeding period. These requirements should be satisfied by feeding 15.4 kg. (34 lb.) of feed DM per day, with the diet containing 2.6 Mcals. ME and 100 g. DCP/kg. DM. Such a diet can be formulated with forage

TABLE 4.2

TECHNICAL EFFICIENCY OF CONSERVATION AND ITS IMPACT ON THE QUANTITY, QUALITY AND COST OF SILAGE

	Time of cutting first growth of forage			
	Very Early	*Early*	*Medium*	*Late*
High Efficiency				
(10% DM losses: 12½% nutrient losses)				
Total Annual Crop				
Effective Yield (tons)	2·99	3·68	3·99	4·30
Cost (in £ per m. tons DM)[2]	10·1	9·1	8·4	8·1
M.E.[1]	2·63	2·43	2·28	2·04
C.P.[1]	18·4	15·5	12·7	8·8
Medium Efficiency				
(20% DM losses: 30% nutrient losses)				
Total Annual Crop				
Effective Yield	2·65	3·27	3·55	3·82
Cost[2]	11·4	10·2	9·4	9·1
M.E.	2·28	2·19	2·06	1·84
C.P.	16·6	14·0	11·4	7·9
Low Efficiency				
(30% DM losses: 40% nutrient losses)				
Total Annual Crop				
Effective Yield	2·32	2·86	3·10	3·34
Cost	13·0	11·7	10·8	10·4
M.E.	2·22	2·14	2·01	1·80
C.P.	16·3	13·7	11·1	7·7

[1] Metabolisable Energy derived by dividing calculated residual ME by calculated residual DM. Crude Protein percentage derived in similar way.

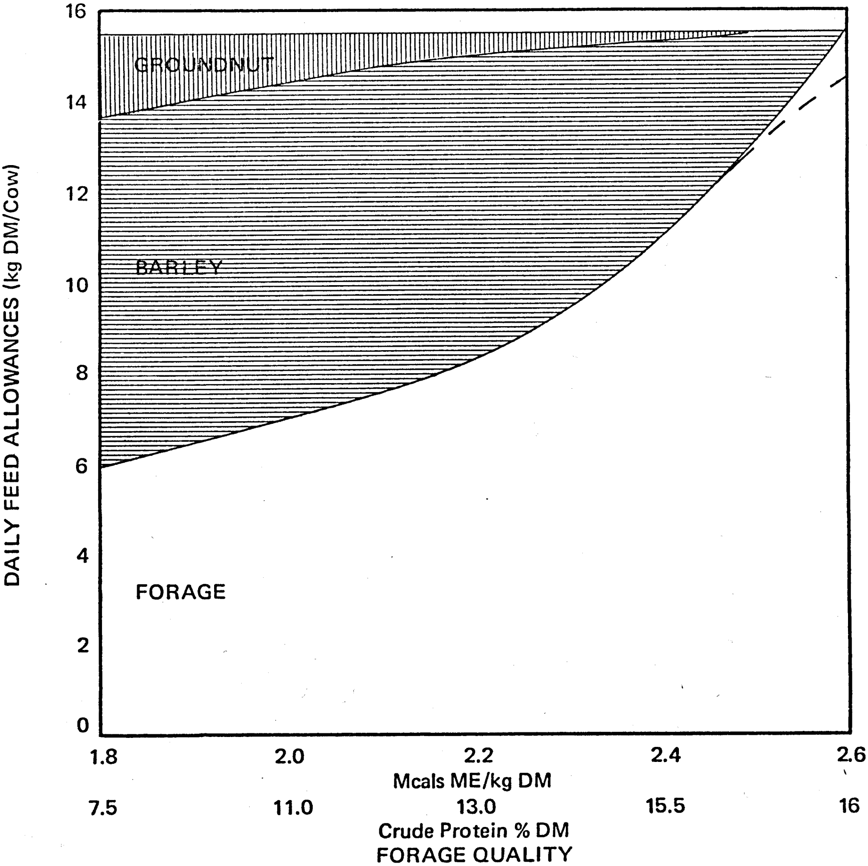
[2] Details of the costing assumptions are presented in the Appendix. Broadly the costs cover variable factors such as fertilisers and field work, but not fixed costs like depreciation of equipment and structures.

of varying quality using appropriate quantities of barley concentrate containing a varying proportion of groundnut cake. These principles are illustrated in Figure IV.2.

FIGURE IV.2

RELATIONSHIP BETWEEN CONSERVED FORAGE QUALITY AND FORAGE : CONCENTRATE RATIO IN THE DIET OF THE MILKING COW (1)

Friesian Cow Yielding 4.9 galls (22.4 kg) milk/day
Requiring 15.4 kg Feed DM/day(2)
Containing 2.6 Mcals ME and 100g DCP/kg DM
(after, A.R.C., 1965)



(1) This is the relationship that has been applied to the 900 gall, September-calving cow in the first month of the 180 day winter (see table 4.4 for details).

(2) This level of DM intake is equivalent to 2.6% Liveweight.

TABLE 4.3

DAILY YIELDS OF FRIESIAN COWS YIELDING 900 GALLONS/LACTATION AND CALVING IN SEPTEMBER AND MARCH (GALLS/COW/DAY)

Time of Calving	*Month of Year*											
	S	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*
Mid-September	4·4*	5·2	4·6	3·8	3·1	2·7	2·4	2·2	2·0	1·6	0·8*	Dry
Mid-March	2·2	1·6	1·4	1·1	0·8*	Dry	3·7*	4·6	4·6	4·0	3·4	2·7

Short Winter (120 days) (N–M)

Long Winter (180 days) (O–A)

1 gallon of milk = 4·55 kg.
* half month only.

The influence of forage quality on the total amount of conserved grass, barley and groundnut cake required in the winter diet of the milking cow has been calculated by formulating a series of such diets for cows at different stages of lactation. Those for the September-calving cow over a 180 day winter are presented in Table 4.4. These calculations are related to forage produced with different times of cutting and efficiency of conservation, by intrapolation from the graph relating total forage and concentrate requirements to forage quality (Figure IV.3).

This procedure has been used to estimate the winter feed requirements of dairy cows with different calving dates, winter lengths and milk yields, and is described in detail in the Appendix.

The practical features of the diets and allowances on which these calculations are based are indicated in Table 4.5.

With early-cut efficiently conserved silage, concentrate feeding is required in early lactation when the cow is producing almost five gallons of milk each day, but a daily allowance of just over 100 lb./day of silage alone will provide for maintenance and three gallons of milk in mid-lactation. The late-cut, inefficiently conserved grass requires considerable concentrate supplementation in early lactation when it will satisfy only 75 per cent of maintenance requirements, and it will only provide the full maintenance for the cow in late lactation.

Winter Feed Costs and Grass Acres required for Conservation

The quantity and quality of grass available for conservation therefore depends upon the nature of sward and climate, the level of fertiliser use, and the cutting regime adopted. The conservation process involves losses of dry matter and nutrient concentration, the extent of which depend both on the system of conservation and the technical efficiency with which it is operated. The utilisation of the conserved grass will also be influenced by the productive potential of the animal to which it is fed. Grassland management, conservation system and livestock production are interdependent. The economics of any one of these elements will influence the economics of the other two.

In the following sections an economic analysis is made of these variables. It must be appreciated that these calculations are not intended to relate to individual farm situations, each of which has its own special features. The systems analysed are derived from specific assumption, but raise features of general significance.

Silage

From Tables 4.1 and 4.2 the characteristics of silage made under different cutting regimes and levels of efficiency can be determined. For convenience, information on feed quality is repeated in the first section of Table 4.6. Similarly information for a 900 gallon September-calving Friesian can be obtained from Table 4.4,

FIGURE IV.3

The relationship between Forage quality and allowances of Forage, Barley and Groundnut in the diet of September-calving Friesian cow for a 180-day winter. (900 gall. lactation).

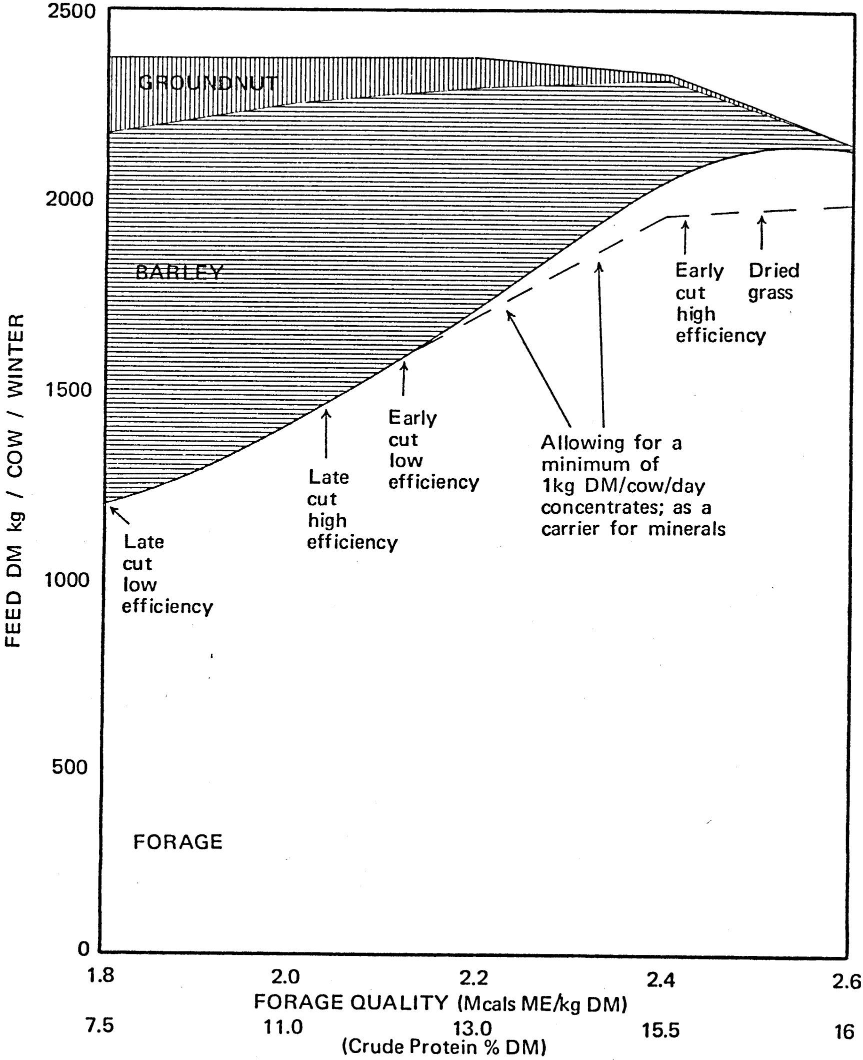


TABLE 4.4

FEED ALLOWANCES FOR A 900 GALLON, SEPTEMBER-CALVING FRIESIAN COW FOR A 180 DAY WINTER

	Quality of Forage (Mcals ME/kg. DM)				
	1·8	*2·0*	*2·2*	*2·4*	*2·6*
	Poor	*Moderate*	*Medium*	*Good*	*V. Good*
Early Lactation—30 days—Maintenance + 4·9 gall. (22·4 kg.) milk/day Required daily feed intake 15·4 kg. DM containing 2·6 Mcals. ME/kg. DM					
Daily feed: (kg. DM/cow) Forage	6·0	7·1	8·3	10·8	14·4
Concentrates	9·4	8·3	7·1	4·6	1·0[2]
[1]**Early Lactation**—30 days—Maintenance + 4·2 gall. (19·2 kg.) milk/day Required daily feed intake 13·8 kg. DM containing 2·6 Mcals ME/kg. DM					
Daily Feed: (kg. DM/cow) Forage	5·4	6·3	7·5	9·9	12·8
Concentrates	8·4	7·5	6·3	3·9	1·0[2]
Mid Lactation—90 days—Maintenance + 3·0 gall. (13·7 kg.) milk/day Required daily feed intake 12·5 kg. DM containing 2·4 Mcals ME/kg. DM					
(Daily Feed: kg. DM/cow) Forage	6·8	8·0	9·6	11·5	10·0
Concentrates	5·7	4·5	2·9	1·0[2]	1·0[2]
Mid Lactation—30 days—Maintenance + 2·3 gall. (10·6 kg.) milk/day Required daily feed intake 12·2 kg. DM containing 2·2 Mcals ME/kg. DM					
Daily Feed: (kg. DM/cow) Forage	8·5	10·0	11·2	9·8	8·6
Concentrates	3·7	2·2	1·0[2]	1·0[2]	1·0[2]
Total Feed for 180-day Winter (m. tons DM/cow)					
Forage	1·21	1·42	1·67	1·95	1·97
Concentrates	1·16	0·95	0·70	0·38	0·18

[1] Periods included in the short (120 day) winter (see page 107 for fuller discussion).

[2] Though forage alone could supply nutrient requirements these diets have been adjusted by an allowance of 1 kg. concentrate as a carrier for minerals substituting for 1 kg. forage.

TABLE 4.5

COW DIETS BASED ON E–H AND L–L SILAGE (LB. FEED/COW/DAY)

Silage System	*Feed*	*Month of Winter Period*			
		1st	*2nd*	*3rd 4th 5th*	*6th*
Early Cut	25% DM Silage	96	96	104	90
High Efficiency	88% DM Concentrate	12	7·5	2·5*	2·5*
	Groundnut % in Concentrate	2·5%	2·5%		
Late Cut	25% DM Silage	52	48	60	75
Low Efficiency	88% DM Concentrate	24	21	14	9
	Groundnut % in Concentrate	17%	17%	17%	17%

*this allowance of concentrates is required only as a carrier for minerals.

TABLE 4.6

COMPARISON OF THE COSTS OF WINTER FEEDING USING SILAGE OF DIFFERENT QUALITIES—180 DAY WINTER, SEPTEMBER-CALVING COW, 900-GALLON LACTATION

	Silage System			
	Early First Cut High Efficiency	*Early First Cut Low Efficiency*	*Late First Cut High Efficiency*	*Late First Cut Low Efficiency*
Silage Characteristics (from Table 4·2)				
Annual Yield (m. tons DM/acre)	3·68	2·86	4·30	3·34
ME Value (Mcals/kg. DM)	2·43	2·14	2·04	1·80
CP Percentage (in DM)	15·5	13·7	8·8	7·7
Feed Allowances (from Figure IV.3)				
Silage (m. tons DM/cow)	1·95	1·59	1·46	1·21
Concentrates (m. tons DM/cow)	0·35	0·78	0·91	1·16
Feed Prices (£/m. ton)				
Silage DM (from Table 4.2)	9·1	11·7	8·1	10·4
Concentrates[1]	35·08	38·27	39·06	40·86
Winter Feed Cost (£/cow)				
Silage	17·8	18·6	11·8	12·6
Concentrates	12·3	29·9	35·5	47·4
Total	30·1	48·5	47·3	60·0
Change in Winter Feed Cost (£/cow) with each £5 change in Barley cost.	1·9	4·0	4·5	5·5
Conserved Grass (acres/cow)[2]	0·53	0·56	0·34	0·36

[1] Cost per m. ton concentrate feed of 88 per cent DM, with Barley at £25/ton groundnut cake at £60/ton and £5/ton for rolling, mixing and minerals. The consequences of variation in barley price, in modules of £5/ton, are shown in Figure IV.4.

[2] Yield Silage DM/acre/annum ÷ Silage allowance/cow/winter.

showing the way in which the quality of forage influences the balance of forage and concentrate in the ration. Imparting prices to forage and concentrates enables feeding costs to be calculated. There are several significant conclusions. Most noticeable is the marked difference in feeding economy between high and low efficiency with early first cutting. The effect of efficiency on late first cutting is rather less pronounced. Taken together the early first cut, high efficiency silage system is the most economical silage for this type of dairy enterprise. A superficial paradox is that stocking density (cows per conserved forage acre) can be higher under the later-cut and less efficient silage regimes; it is, of course, no more than the consequence of being unable to depend on conserved grass for a large proportion of the feed, and buying in concentrates to replace conserved grass. This is analagous to buying in acres.

Finally, it is possible by making further assumptions to carry the arithmetic through to a gross margin per cow and a gross margin per acre basis as in Table 4.7.

In a similar fashion comparisons are made for higher yielding cows, for spring calving and for shorter winters, in the Appendix. One variable likely to be of concern to dairy farmers in the immediate future is the barley price. Figure IV.4 plots gross margins per cow and per acre with changing barley price.

As would be expected the highest gross margin per cow is obtained from early-cut high efficiency silage. On a gross margin per acre basis early cutting is less advantageous than late cutting when both are associated with highly efficient conservation and barley prices are £31/ton. Indeed late-cut high efficiency is the most profitable on a gross margin per acre basis below £37/ton for barley. At relatively low barley prices late-cut high efficiency silage leaves by far the highest gross margin per acre, and on this same per acre basis late-cut low efficiency silage improves its relative position considerably.

Hay

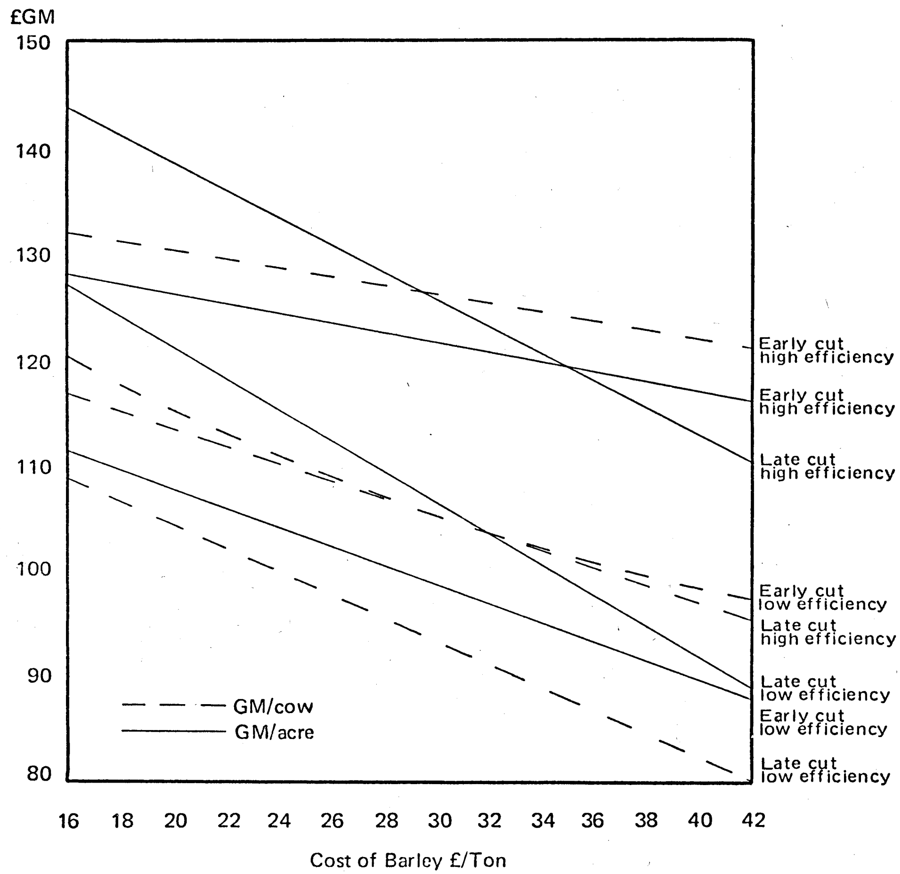
Following similar methods and adopting similar assumptions, comparable costs and gross margins have been calculated with respect to hay production under systems producing different yields and quantities; eight examples are presented in Table 4.8. An additional variable has been considered, namely that of using lower levels of nitrogenous fertiliser. With hay making it may not be possible, without either high managerial performance or investment in additional handling and drying equipment, to cope with the higher yields of grass produced by the higher nitrogen usage.

The results are consistent with the silage figures in Tables 4.6 and 4.7, which is to be expected with so many common assumptions. Late first cut, high efficiency, high nitrogen use, shows up with higher margins per acre. As might be predicted low nitrogen use produces similar gross margins per cow, but substantially lower gross margins per acre; the differences in margin between the two nitrogen levels can indicate how much this one element of crop yield justifies fixed equipment to move onto the higher plane of technical efficiency.

It should be noted that assumptions on yield reductions associated with the lower level of nitrogen were relatively extreme.[21] Alternative assumptions of a difference 75 per cent of that indicated here may be more appropriate i.e. £15 and £20/acre difference in gross margin in response to the higher level of nitrogen use.

FIGURE IV.4

Gross margins per acre and per cow, 900 gall. September calver, 180-day winter, with changing Barley price.



E

TABLE 4.7

GROSS MARGINS OF DAIRY COWS, FED ON DIFFERING SILAGE REGIMES

	Silage Method			
	Early First Cut High Efficiency	*Early First Cut Low Efficiency*	*Late First Cut High Efficiency*	*Late First Cut Low Efficiency*
Revenue per cow (£)[1] (net of replacement and sundry costs)	171	171	171	171
Winter Feed Costs per cow (£) (from Table 4.8)	30	49	47	60
Other Costs (£) (assumed)	13	13	13	13
Gross Margin per Cow	128	109	111	98
Land per cow for conservation (acres) (From Table 4.8)	0·53	0·56	0·34	0·36
Land per cow for summer grazing (assumed)	0·50	0·50	0·50	0·50
Gross Margin per acre (£) (=GM per cow ÷ acres per cow)	124	103	132	114

[1] From Nix.[22]

Milk Sales 900 gall. @ 19·35p	=	£174
Value of Calves less depreciation	=	£+5
Miscellaneous variable costs	=	£ − 8
Revenue	=	£171

Compared with silage, at the same level of fertiliser, hay production generates broadly similar margins. For the particular dairying system examined here (900 gallon, September-calving Friesians with 180 day winter), it would appear that there is a choice between hay and silage for the more efficient, which will depend largely on the predictability of making good quality hay over the years. For the less efficient, silage has more to offer in profitability, and is less subject to risk. But even here circumstances on the particular farm could invalidate these conclusions.

TABLE 4.8

A COMPARISON OF COSTS AND GROSS MARGINS USING HAY OF DIFFERENT QUALITIES

(900 gall. cow, September-calving, 180-day Winter)

	Hay System				*Hay System*			
	Early First Cut, High Nitrogen		*Early First Cut, Low Nitrogen*[1]		*Late First Cut, High Nitrogen*		*Late First Cut,*[1] *Low Nitrogen*	
	High Efficiency	*Low Efficiency*	*High Efficiency*	*Low Efficiency*	*High Efficiency*	*Low Efficiency*	*High Efficiency*	*Low Efficiency*
Total Winter Feed Costs (£/cow):								
Hay	18·9	19·9	19·9	20·8	12·7	13·6	13·7	14·6
Concentrates	12·3	29·9	12·3	29·9	35.5	47·4	35·5	47·4
	31·2	49·8	32·2	50·7	48·2	61·0	49·2	62·0
Summer Grazing Cost[2] (£/cow)	13	13	13	13	13	13	13	13
Gross Margin (£/cow)	127	108	126	107	110	97	109	96
Acres per cow:								
Winter forage	0·53	0·56	0·73	0·77	0·34	0·36	0·53	0·56
Summer grazing	0·50	0·50	0·50	0·50	0·50	0·50	0·50	0·50
Total acres/cow	1·03	1·06	1·23	1·27	0·84	0·86	1·03	1·06
Gross Margin per Acre (£)	123	102	102	84	131	113	106	91

[1] Low nitrogen use: 55 units of nitrogen per acre for the first cut (instead of 110 units) giving yields 36 and 41 per cent lower for early and late cut yields. See Appendix for further discussion.

[2] See Appendix for calculation of Summer Grazing Costs.

Dried Grass

It is difficult to compare dried grass directly with hay and silage for two reasons. In the first place dried grass has two potential roles in dairy feeding; it can be a substitute for concentrates; it is also possible to regard it as an alternative complete feed to forage plus concentrates, particularly for high yielding cows in the bigger herd. Secondly grass drying involves substantial capital expenditure on specialised equipment, whereas hay and silage making involves tractors, other machinery and buildings which have general uses on the farm.

Here dried grass is assessed as an alternative forage to silage for feeding the 900 gallon autumn calving Friesian with 180 day winter. The grass drying system envisaged is based on five cuts a year which, in response to 350 units of nitrogen per acre, yield 4·04 m.tons DM per acre, with conservation losses of only 5 per cent DM, an ME content of 2·5 M.cals/kg. DM and CP at 16 per cent. Table 4.9 compares dried grass to early first cut high efficiency silage. But the costing conventions differ in several respects, the most important being that dried grass costs include the capital and overhead costs associated with the drying equipment.

As can be seen the dried grass is assumed to produce forage of much the same quantity and quality as the good silage. In consequence the concentrate usage is low in both cases and the concentrate prices are similar. Equally the stocking rates are much the same. Under such assumptions it is not surprising that the cost per ton of dried grass (including as it does the fixed costs) leads to a substantially lower gross margin per cow or per acre. It is clear that to justify investment in a grass drier there must be not only continual use of the drier to reduce the unit costs of dried grass, but also some additional advantage in terms of yield or quality of feed so that there are off-setting greater stocking densities and or savings of concentrate feeding-stuffs.

In the absence of any such advantages for dried grass, if high quality silage at equivalent yield and nutritive value can be produced, these calculations suggest that as much as £22/cow could be available to service capital investment and increased costs of improved silage making, as an alternative to investment in grass drying, as illustrated in Table 4.9.

Alternative Assumptions

The comparisons which have been made so far have been on a single set of assumptions which, to a large extent, have conditioned the results. A wider range of assumptions are examined in detail in the Appendix, but here comment is confined to some generalisations.

Three features demand special qualification. They are the consequences of variation in the intake characteristics of the forage; variation in milk yield and feed costs; and the precision with which concentrates can be substituted for forage under practical conditions.

TABLE 4.9

COMPARISON OF COSTS AND MARGINS OF DRIED GRASS AND SILAGE AS FORAGES

	Dried Grass Very Early First Cut	*Silage Early First Cut High Efficiency*
Grass characteristics:		
Yield/acre (m. tons)	3·84	3·68
ME content (Mcals/kg. DM)	2·5	2·43
CP percentage	16	15·5
Feed requirements of 900 gallon September-calving Friesian, with 180-day winter:		
Conserved grass (m. tons/cow)	1·96	1·95
Concentrates (m. tons/cow)	0·28	0·35
Percentage groundnut in concentrates	0	2·5
Feed Prices:		
Grass (£ per m. ton DM)	23·0	9·1
Concentrates: £/m. ton	34·1	35·1
Winter Feeding costs per cow:		
Conserved grass	45·1[1]	17·8
Concentrates	9·5	17·3
Total (£/cow)	54·6	30·1
Summer costs per cow[2]	13	13
Gross Margin per Cow (£)[3]	103	128
Gross acres per cow:		
Winter feeding (acres/cow)	0·51	0·53
Summer grazing (acres/cow)	0·50	0·50
Total	1·01	1·03
Gross Margin per acre (£)	102	124

[1] Includes drying charges and fixed costs of equipment.

[2] See Appendix.

[3] Output net of replacement and miscellaneous variable costs £171.

Level of Feed Intake and Feed Quality

The feed intakes postulated are those expected to be well within the dry matter capacity of most Friesian cows on most hay and silage diets. In early lactation the assumed intake of dry matter (32 lb.) is equivalent to 2·5 per cent liveweight and in mid-lactation (26·5 lb.) is equivalent to 2·0 per cent liveweight.

Even though these intake levels are conservative it may be suggested, on the basis of available evidence, that some early-cut silage systems may result in less acceptable silage so that the contribution of the silage is restricted by low intake. If in these calculations a 15–20 per cent reduction in the intake of early-cut silage were compensated by increased concentrate allowances so that milk yield was maintained, then the gross margin/cow might be reduced (by up to £7), but because of reduced conserved grass requirements there would be little effect on gross margin/acre.

Variation in the intake characteristics of later cut silage of lower digestibility is likely to be of much less significance, as such forage will necessarily be fed together with an allowance of concentrates, which will tend to offset the effect of variation in silage intake.

By contrast, some forages may be more acceptable than these standards assumed. This could apply particularly to dried grass, early-cut barn dried hay and possibly early-cut, high dry matter silage. The consequences of improved forage acceptability might be the replacement of a greater proportion of the concentrate allowance by forage in diets sustaining similar milk yields, or the enhancement of total feed intake with effects on the level of milk yield.

If the intake characteristics of the more acceptable forage were such that in early and mid-lactation cows increased their feed intake by 2 kg. DM daily, this could support an extra 9 lb. milk/cow/day at peak lactation, and could increase lactation yield by almost 180 gallons. Additional feed costs and conservation requirements must be set against the extra return but an increase in output of this order would substantially improve GM/cow (by some £30) and GM/acre (by more than £26).

There is another feature of the feed intakes assumed in these calculations that requires some further comment. In mid-lactation the required intake of high quality forage is probably lower than the *ad lib* intake. If feeding level was not controlled then 'luxury' intake of feed would be likely in practice, and forage requirements would be increased with little effect on production. In extreme situations when only small quantities of high quality forage are required by the cow, additional fill may be required in the form of straw, and this would add somewhat to feed costs.

Level of Milk Yield

In the attainment of lactation yields well in excess of 900 gallons, feeding during early lactation can be of critical importance, since the yield established at this stage determines the potential for the whole lactation. High quality forages may have particular advantages during early lactation in that, with only moderate levels of concentrate feeding, they provide a diet of sufficient energy density to promote high energy intake, and also one that does not depress the mobilisation of body fat. Both feed intake and the mobilisation of body fat sustain high milk yield in the first weeks of lactation.

With cows in mid-lactation, the principal importance of forage quality will depend upon the extent to which it replaces more expensive concentrate feeds. High quality forages are likely to make their greatest contribution in this respect in sustaining yields of up to 4 to 5 gallons/cow/day. To sustain daily yields higher than this even high quality forages are likely to require appreciable concentrate supplementation. It may be argued that the advantages of high quality will be most fully exploited in diets for cows producing milk at this level over the whole winter, and this will in turn depend on both the time of calving and the lactation yield of the herd.

There is little difference in the concentrate sparing effect of higher quality forage in the diet of the 1,100 gallon cow compared with that for the 900 gallon cow on the basis of these calculations.

Precision of Replacement Concentrate Feeding

The assessment of the potential feed value of conserved grass upon which the foregoing calculations have been based assumes that the deficiencies of lower quality feeds will be precisely identified and compensated by concentrate feeding. In practice there is considerable risk that the feeding value of poor roughages will be overestimated and concentrate supplementation will be inadequate, so that milk yields (and profitability) are reduced.

On the other hand good quality silage or hay needs only moderate supplementation to provide a diet of high digestibility. With such diets, self-feeding and easy-feeding systems can be adopted in which cows will regulate their own intake of feed to meet their requirements. This allows for a simplification of feeding methods which is attractive both from the viewpoint of housing design and labour utilisation. It is a feature of increasing practical importance as building and labour costs rise.

These practical advantages of high quality forage are not taken into account in the preceeding calculations.

Seasonality of Calving and Shorter Winter Length

The effects of differing calving dates have also been calculated in a similar manner to that already described and full details of these calculations are shown in the Appendix. A summary of the results is shown in Table 4.10. It is noteworthy that, except in the case of early-cut high efficiency silage, March-calving cows may require as much forage per head as September-calving cows, and consequently require as much grass for conservation. This is especially evident with late-cut, low

TABLE 4.10

A COMPARISON OF THE FEEDING COSTS OF SPRING AND AUTUMN-CALVING HERDS

(900 gallon Friesian cow with 180-day winter)

	Silage			
	Early First Cut High Efficiency	*Early First Cut Low Efficiency*	*Late First Cut High Efficiency*	*Late First Cut Low Efficiency*
Winter Feed Requirements:				
September-calving[1]				
Silage (m. tons/cow)	1·95	1·59	1·46	1·21
Concentrates (m. tons cow)	0·35	0·78	0·91	1·16
Winter feed costs (£/cow)	30·1	48·5	47·3	60·0
Conserved grass acreage (acres/cow)	0·53	0·56	0·34	0·36
March-calving[2]				
Silage (m. tons/cow)	1·49	1·51	1·51	1·28
Concentrates (m. tons/cow)	0·13	0·28	0·34	0·59
Winter feed costs (£/cow)	18·2	28·4	25·5	37·4
Conserved grass acreage (acres/cow)	0·40	0·52	0·35	0·38

[1] See Table 4.8.

[2] See Appendix.

efficiency silage, but with cows at this low level of production there is scope for the replacement of low quality conserved grass with barley straw to save grass acres. The gross margin per cow has been calculated in Table 4.12 to take account of both seasonality in milk prices and grass acreage requirements, assuming full dependence on conserved grass.

The longer grass-growing season in the South and West of the United Kingdom leaves farmers with fewer 'hungry days' for which to provide forage, and winter length may be around 120 days instead of the 180 days in climatically less favoured areas. The effect of this on conservation requirements is shown in Table 4.11, and since summer grazing requirements are also affected an adjustment may also be required for this. Alternative estimates with or without such an adjustment are shown in Table A.11.

TABLE 4.11

A COMPARISON OF FEEDING REQUIREMENTS,
COSTS AND MARGINS OF 120-DAY AND 180-DAY WINTER LENGTHS
(900 gallon Friesian Cow, Autumn-calving)

	Silage			
	Early First Cut High Efficiency	*Early First Cut Low Efficiency*	*Late First Cut High Efficiency*	*Late First Cut Low Efficiency*
180-day winter[1]				
Total winter feed costs (£/cow)	30·1	48·5	47·3	60·0
Total acres per cow	1·03	1·06	0·84	0·86
120-day winter[2]				
Total winter feed costs (£/cow)	19·0	31·6	31·1	39·5
Acreage for conservation	0·36	0·36	0·22	0·23
Acreage for grazing[3]	0·67 (0·5)	0·67 (0·5)	0·67 (0·5)	0·67 (0·5)
Total acreage	1·03 (0·86)	1·03 (0·86)	0·89 (0·72)	0·90 (0·73)

1 See Table 4.8.
2 See Appendix.
3 Allowing for 60 days extra grazing—0·5 acres for 180 days
0·67 „ „ 240 days.
( ) assuming grazing acreage and grazing costs not increased by extension of grazing season due to favourable climatic conditions.

Dried Grass as a Concentrate

Mention was made earlier of the possibility of using dried grass as a substitute for concentrates rather than as a forage. Grinding and pelleting provides feed which is convenient to handle and readily consumed by cattle. Although the energy value of dried grass is approximated by the D-value, it is also influenced by variation in the content of soluble carbohydrate. Inadequacy in this respect may be corrected by the inclusion of about 15 per cent of cereal in the diet. A further problem is the possibility that ground and pelleted dried grass may lead to a lower butterfat content in the milk.

Diets containing ground and pelleted grass should include an adequate amount of coarse, fibrous roughage to prevent digestive upsets and the depression of milk fat content. The feeding of medium quality hay or silage for maintenance or the provision of 10–12 lb./head/day of barley straw will generally provide an adequate safeguard in this respect.

Within these dietary constraints, the use of ground and pelleted dried grass as a substitute for concentrates is most appropriately based on their relative metabolisable energy and digestible crude protein contents. The D-value of the forage provides an index of ME content and DCP can be calculated from CP with considerable precision*. Since in different samples of grass D-value and CP content vary widely relative to one another, it is necessary to take separate account of them in determining the feeding value of dried grass compared with concentrates. However, in terms of feed replacement value the contribution of the dried grass to dietary energy supply is markedly more important than its contribution to protein intake. In view of this, a useful approximation in practice is the assumption that dried grass of 64 D-value and at least 15 per cent CP content, when fed at 5 lb./gallon of milk, should substitute for the conventional dairy concentrate (3·0 Mcals ME/kg. DM, 18 per cent CP) fed at 4 lb./gallon. Alternatively, a 50/50 mixture of rolled barley and grass of 64 D-value and 20 per cent CP should provide for a gallon of milk if it is fed at 4½ lb./gallon, as a supplement to basic feeds already supplying a surplus of protein for maintenance needs.

Conclusions

The analysis in this section of the report has inevitably been complex, since the topic itself involves the interrelationships of many variables. Within the permanent caveat that particular farms will require individual evaluation, generalisations have been made on stated assumptions. Supporting argument and further details are contained in the Appendix. To conclude this section the main findings are tabulated in Table 4.12 and summarised below.

The economic value of improved efficiency of conservation is well represented by the model relating to the utilisation of silage by a September-calving cow with a lactation yield of 900 gallons fed through a 180 day winter. Improving efficiency of conservation from that associated with 30 per cent loss of DM to 10 per cent loss of DM reduced winter feeding costs and improved gross margin per cow by £19 (17 per cent) with early-cut silage and by £13 (13 per cent) with late-cut silage. In terms of gross margin per acre, with due allowance for the grass acreage required both for conservation and grazing, increased efficiency had an advantage of £21/acre (20 per cent) with early-cutting and £18/acre (16 per cent) with late-cutting. Clearly there may be justification for expenditure of up to £15/acre or more to improve efficiency of conservation.

In association with the highest level of conservation efficiency late-cutting was associated with an £8/acre (6·5 per cent) higher gross margin than early-cutting. Relative differences between systems based on different times of cutting and efficiency of conservation are much affected by variation in concentrate price, the

* ME Mcals/kg. DM $=0{\cdot}0363\times$ D-value.
DCP $=0{\cdot}960$ CP $-4{\cdot}3$.

TABLE 4.12 (A)

FEEDING COSTS, STOCKING DENSITIES AND MARGINS OF DAIRY COWS

	Silage (High Nitrogen)				*Hay (High Nitrogen)*				*Hay (Low Nitrogen)*			
	Early High Eff.	*Early Low Eff.*	*Late High Eff.*	*Late Low Eff.*	*Early High Eff.*	*Early Low Eff.*	*Late High Eff.*	*Late Low Eff.*	*Early High Eff.*	*Early Low Eff.*	*Late High Eff.*	*Late Low Eff.*
120-day winter 900 gallon Friesian[1]												
September-calving												
Winter feeding costs (£/cow)	19	32	31	40	20	32	32	40	20	33	32	41
Annual acreage (acres/cow)	1·03	1·03	0·89	0·90	1·03	1·03	0·89	0·90	1·16	1·17	1·01	1·03
Gross margin per cow (£)[3]	134	121	122	113	133	121	121	113	133	120	121	112
Gross margin per acre (£)	130	118	137	126	129	118	136	126	115	103	120	109
Change in gross margin with £5 ton change in barley price — per cow	1·1	2·6	3·0	3·6	1·1	2·6	3·0	3·6	1·1	2·6	3·0	3·6
— per acre	1·1	2·5	3·37	4·0	1·1	2·5	3·37	4·0	0·95	2·4	3·0	3·5
March-calving[2]												
Winter feeding costs (£/cow)	10	14	12	22	10	15	12	21	11	16	13	22
Annual acreage (acres/cow)	0·92	1·03	0·92	0·95	0·92	1·03	0·92	0·95	1·02	1·17	1·05	1·10
Gross margin per cow (£)[4]	138	134	136	126	138	133	136	127	137	132	135	126
Gross margin per acre (£)	150	130	148	133	150	129	148	134	134	113	129	115
Change in gross margin with £5 ton change in barley price — per cow	0·2	0·3	0·4	1·2	0·2	0·3	0·4	1·2	0·2	0·3	0·4	1·2
— per acre	0·2	0·3	0·4	1·3	0·2	0·3	0·4	1·3	0·2	0·3	0·4	1·1

1 Output per cow £171 See Appendix
2 Output per cow £164 See Appendix
3 Summer costs £18 grazing acreage 0·67 See Appendix
4 Summer costs £16 grazing acreage 0·67 See Appendix

TABLE 4.12 (B)

FEEDING COSTS, STOCKING DENSITIES AND MARGINS OF DAIRY COWS

	Silage (High Nitrogen)				*Hay (High Nitrogen)*				*Hay (Low Nitrogen)*			
	Early High Eff.	*Early Low Eff.*	*Late High Eff.*	*Late Low Eff.*	*Early High Eff.*	*Early Low Eff.*	*Late High Eff.*	*Late Low Eff.*	*Early High Eff.*	*Early Low Eff.*	*Late High Eff.*	*Late Low Eff.*
180-day winter 900 gallon Friesian[1] September-calving												
Winter feeding costs (£/cow)	30	49	47	60	31	50	48	61	32	51	49	62
Annual acreage (acres/cow)	1·03	1·06	0·84	0·86	1·03	1·06	0·84	0·86	1·23	1·27	1·03	1·06
Gross margin per cow (£)[3]	128	109	111	98	127	108	110	97	126	107	109	96
Gross margin per acre (£)	124	103	132	114	123	102	131	113	102	84	106	91
Change in gross margin with £5 ton change in barley price — per cow	1·9	4·0	4·5	5·5	1·9	4·0	4·5	5·5	1·9	4·0	4·5	5·5
— per acre	1·8	3·8	5·4	6·4	1·8	3·8	5·4	6·4	1·5	3·1	4·2	5·2
March-calving[2]												
Winter feeding costs (£/cow)	18	28	26	37	19	30	26	38	20	31	28	40
Annual acreage (acres/cow)	0·9	1·02	0·85	0·88	0·9	1·02	0·85	0·88	1·06	1·23	1·04	1·09
Gross margin per cow (£)[4]	134	124	127	115	133	122	126	114	132	121	124	112
Gross margin per acre (£)	149	121	149	130	148	120	148	130	125	98	119	103
Change in gross margin with £5 ton change in barley price — per cow	0·7	1·4	1·7	2·8	0·7	1·4	1·7	2·8	0·7	1·4	1·7	2·8
— per acre	0·8	1·4	2·0	3·2	0·8	1·4	2·0	3·2	0·7	1·1	1·6	2·6

[1] Output per cow £171 See Appendix
[2] Output per cow £164 See Appendix
[3] Summer cost £13 See Appendix
[4] Summer cost £12 See Appendix

effect of this variable being proportionately greater the lower the quality of the forage. The economic premium associated with improved efficiency of conservation increased by £1 to £2/acre for each £5 per ton rise in the price of barley. The difference in gross margin/acre between early and late-cutting, both with efficiency conservation, reduced by £3·6 for every £5/ton rise in barley price but early-cutting only shows to advantage in terms of gross margin per acre when the barley price rises above £37/ton.

The decision as to whether to cut early or late must clearly depend upon whether overall profitability of the dairy cow enterprise is more closely linked to gross margin per cow or gross margin per acre; if the former then early-cutting would be justified as it increases gross margin by £12/cow with barley at £25/ton; if the latter, then late-cutting is to be preferred until barley prices are over £35/ton.

With hay the effects of time of cutting and efficiency of conservation are similar to those described for silage, however, in addition account has also been taken of the effect of nitrogen fertiliser level. It is estimated that the restriction of conventional hay-making systems to a low level of fertiliser use, could in itself reduce gross margin per acre by £21–£25 (21–24 per cent) in association with otherwise efficient conservation.

From the comparison of dried grass and silage (early-cut, high efficiency) as alternative roughage bases of the cows' winter diet, it is suggested that because of the high fixed cost of grass drying as much as £22 per cow could be available to service greater efficiency in silage conservation as an alternative to grass drying.

Alternative assumptions in terms of level of forage intake and milk yield per cow have been considered. Only in circumstances in which change in forage intake is assumed to have affected milk output (as opposed to substituting for concentrates in diets sustaining a constant level of output) would it be likely to markedly affect gross margin per acre. Furthermore, comparison of September-calving cows yielding 900 or 1,100 gallons per lactation suggests that level of yield above 900 gallons is also unlikely to markedly affect the relative concentrate sparing effect of different qualities of forage.

With reference to time of calving, spring calving cows have been estimated to require similar *amounts* of conserved grass to autumn calvers except when very high quality forage is available (early-cut, high efficiency). Their winter feed costs are however much lower than those of autumn calvers producing similar amounts of milk because of their lower concentrate requirements. For this reason also, the premium on efficient conservation in terms of gross margin/acre is between 33 per cent and 50 per cent less with a spring calving herd than with an autumn calving herd.

On the basis of milk prices of 19·35 and 18·5p/gallon for September- and March-calving cows respectively, the use of late-cut, efficiently conserved silage is associated with gross margins per cow of £111 and £127 and gross margins per acre of

£132 and £149. Shorter winter lengths which enable grazing to be substituted for conservation are estimated to improve gross margin per cow but not gross margin per acre if the grazing acreage and cost is proportionately increased. It may however be more realistic to assume that climatic conditions favouring a longer grazing season will result in extra grass growth over the season, so that the grazing acreage required is not increased nor are grazing costs. Gross margins for September- and March-calvers respectively relating to a 120 day winter are £122 (£127) and £137 (£147) per cow and £136 (£140) and £148 (£189) per acre. These may be compared with those shown above relating to a 180 day winter.

V. SUMMARY AND CONCLUSIONS

Grassland occupies nearly 60 per cent of the area of crops and grass in the U.K. In addition there are extensive rough grazings in the hills and uplands. Recent projections in land use envisage some increase in arable crops at the expense of grass, but grassland will still be the major land-using crop. Production from grass-eating animals accounts for approximately 40 per cent of total agricultural receipts, although this somewhat overstates the contribution of grass itself, since there are substantial inputs of concentrated feedingstuffs. The future pattern of British farming is likely to show some increase in the production of both dairy cows and beef cattle if not of sheep, and consequently grass will continue to loom large in the economics of British farming.

There is wide variation in the levels of commercial efficiency of grassland utilisation, and on many farms performance falls far short of the economic optimum. It has been estimated that the average efficiency of grassland utilisation—on a utilised starch equivalent basis—may be up to 50 per cent below what is feasible. There have been some indications of relatively small improvements in performance in recent years, but at least part of the apparent improvements in stocking rates can be off-set by taking account of the increased use of concentrate feeds. The reasons for the short-fall from the economic optimum and the wide range of commercial performance are not hard to find. There are technical difficulties in harvesting the grass crop. It is not homogeneous, and there are considerable differences between years, and wide variations in both yield and quality with stage of growth at defoliation. The potential of grass-eating animals to produce meat and milk depends on a range of biological factors, which give rise to substantial variations both seasonally and during the life cycle. Thus, a complex set of relationships exists between animal and grass crop potential. There is also the possibility of buying in some part of food requirement in the form of concentrates. And there are yet more variables associated with the mechanisation of grass conservation systems. All these factors make the key to the economic utilisation of grass difficult to turn.

Grazing and grass conservation systems are closely linked by practical management considerations. It is therefore necessary, when evaluating alternative conservation methods, to examine the alternative whole grassland/livestock systems as the basis of comparison. In this bulletin systems of dairy farming are examined; results for beef and sheep farming can be obtained from analogous calculations, but this has not been attempted here.

The choice for conserved grass is between silage, hay, or dried grass. Within each of the three methods of conservation, considerable variation in the quality and yield of conserved product can be aimed at and achieved.

Accurate economic evaluation of conservation systems must take account of the individual farmer, and the peculiarities of the particular farm under discussion. However, it must be noted that the individual may be a poor judge of his own managerial ability, and often over-estimates the feeding value of his own forage, to the detriment of the cows' lactation and his own profit. The technical factors influencing the choice of conservation system are:—

The physical characteristics of pasture, including the quality and yield per acre of conserved material.

The capital and running costs of machinery, equipment and buildings employed to improve the efficiency of the conservation process.

The value which can be ascribed to fodder of different qualities, depending on the price of alternatives e.g. barley.

The yield potential of the dairy herd per lactation.

The time of herd calving.

The expected dependence on fodder, i.e. the length of the winter.

The quality of grass conserved depends upon the stage of growth at cutting time, and the efficiency of the conservation process. Achieving high quality forage by taking account of both these factors should give high gross margins per cow. However, gross margin per acre can be high when large yields of moderate quality are conserved. By harvesting more mature material of lower energy concentration, (even with lower conservation efficiency), a greater number of 'Winter forage allowances' per acre can be obtained. Moreover if high quality forage can be obtained only by substantial investment in specialised equipment, the overall economy may be relatively unattractive, except in unusual circumstances. However, it should be noted that *good* quality forage can be obtained without luxury investment by high management standards. So the main point for the individual becomes one of recognising his own performance level.

Whether autumn or spring calving is practiced the most important factor in conservation costs is still the length of the period of winter feeding. Areas with short winters have a pronounced cost advantage over areas with long winters, and this advantage applies both to autumn-calving and spring-calving herds. The traditional association of spring-calving with short winters tends to be an over-simplification. In practice dairying is clearly cheaper in the favoured areas of the West and South-West irrespective of seasonality of production. However, spring-calving herds require more pasture than autumn calvers, simply because less feed (i.e. land-equivalents) is bought in.

The effects of different prices for barley and milk are in the expected directions. In general the higher the price of barley, the more attractive production of high quality forage becomes. As far as milk price is concerned, the higher the price of milk the greater the cost of conservation that can be borne, but the relative profitability of the different conservation systems will remain the same.

As far as silage is concerned bunker self-fed silage generally offers the highest profitability. If attempts are made to improve the quality of silage by earlier cutting, lower yields of grass will be obtained. Capital expenditure can therefore only be justified generally in reducing wastage losses at the conservation stage itself. The capital costs of such equipment as tower silo must be offset by savings in concentrate feeding which would otherwise have been necessary to supplement the lower quality material in a bunker. In practice the improvement in quality is likely to be small, and will rarely justify high capital expenditure. Good grassland and conservation management makes high capital investments unnecessary.

Attempts to make hay from high yielding grass pose practical difficulties and low quality fodder is often obtained. This can be avoided by combining lower fertiliser application and reducing the total yield of grassland, so that although the number of forage allowances per acre falls, the quality of hay is improved. Most grass is still conserved as hay, usually from grass with low fertiliser intensity, for reasons of convenience in feeding and management. Attempting to step up the yields and quality of hay, by introducing expensive equipment including barn hay drying, usually generates technical and management problems, and if applied on a large scale the additional capital outlay may not be justified. However there is likely to remain a place for barn-drying of hay on the smaller farm, where careful management may provide an economical system.

Drying grass necessitates the continual operation of the equipment to spread the relatively high capital costs over a sufficient volume to keep fodder costs at a reasonable level. As a consequence dried grass systems must be based on high grass yield and high throughput. There are in any case economies of scale with the drying unit, so that small scale plants will be at a disadvantage. It is also likely that the dairy cows themselves should be high yielding animals to justify the input of high energy and high cost fodder or concentrate feed like dried grass. In view of increasing capital shortage, there is also the general question of the opportunity cost of capital investment. That is to say an investment in grass drying should be assessed not only in terms of its return on capital, but also by comparison with other investment opportunities, such as increasing stock numbers.

The availability of capital is a critical factor, affecting the rate of economic growth both of the individual farm and the national agriculture sector. In this situation rational investment decisions are likely to favour those propositions where the amount of capital involved is small. Furthermore, agricultural technology will continue to change very rapidly, so that flexibility in farming systems will continue to be an advantage. Tying up substantial funds in narrowly specific production methods, based on current technical opinion, which may offer only small advantages, will be less in the interests of the farmer than low-capital demanding more flexible systems, even though the latter may be slightly less efficient in the immediate future. This bulletin is in sympathy with the preceding sentiments, and in general the case has been made for low capital intensity conservation systems, linked by better management practices to high stocking rates, rather than spending large capital sums to improve the quality of conserved material. In mixed farming systems higher stocking rates with the same herd size would facilitate an expansion of arable crops on the farm. In areas where grass is the only profitable crop increased stocking rates would involve the acquisition of more livestock. In general, even in the latter case, capital invested in conservation equipment will show a lower return than additional capital tied up in livestock.

The present system of government support by means of capital grants and tax allowances for buildings and machinery encourages investment of capital, by reducing the real cost of such investment to the farmer. Although there is clearly a general case for encouraging capital investment to reduce costs and substitute for labour, with grass conservation equipment these incentives to capital investment may be leading to a misplaced assessment of the value of such equipment, and consequently to a waste of national resources. If government wishes to improve production from grassland, it might be more appropriate for it to look at other incentives and disincentives than those presently relating to capital investment. In this regard, entry into E.E.C., by limiting the ability of one member government to pursue goals in its own favour, may negate any such recommendation. The Northern Ireland silage subsidy, and the subsidies on bunker silos and fertilisers are all aimed more directly at improved grass utilisation than the grants and tax reliefs offered to those paying high marginal rates of tax. It can be noted that increasing or decreasing the price of milk, of itself, does not affect the relative profitability of different conservation systems. Other measures can be considered. It might be possible to find a direct way of encouraging high density stocking rates for dairy cows.

Joining the Common Market will not only change possible policy alternatives, but also the economics of conservation systems in several ways. The high price of barley will favour the use of conservation systems which produce high quality forage. On the other hand the even price for milk over the year will encourage more farmers to aim for spring-calving herds, so that the need for high quality of the conserved grass will be somewhat reduced. The balance between these two elements will depend on the actual or expected size of the price changes. In the longer term the Common Market is likely to have persistent problems with its agricultural policies, and some measures may have to be introduced to contain surpluses of production. Prominent among the comodities likely to be involved is milk, even though the immediate problems of 1969 and 1970 appear to have been solved. In the face of this uncertainty, entry into E.E.C. would further favour systems which were flexible and where capital investment could be quickly written off.

APPENDIX

A SYSTEMATIC ASSESSMENT OF THE INFLUENCE OF EFFICIENCY OF FORAGE CONSERVATION ON THE PROFITABILITY OF MILK PRODUCTION

J. H. D. Prescott and G. Ross

The efficiency of a grass conservation system varies with the yield of forage DM, the nutritive value of that DM and the costs associated with herbage production and the conservation process. The full value of the conserved grass can however only be assessed when its conversion into saleable animal products is taken into account. The conversion of conserved grass into milk will be influenced by the yield potential of the cow to which the grass is fed. In terms of different systems of milk production this will be affected by calving date in relation to winter feeding, the length of winter during which dependence is on conserved grass rather than grazing, and also the overall level of lactation yield attained by the herd.

In the subsequent sections the interactions of these separate factors on the overall profitability of milk production has been examined. The approach adopted has been to build up a series of models on the basis of stated assumptions. The *absolute* values derived in terms of winter feed costs, gross margin per cow and gross margin per grass acre, are not the principle features of interest as they are very much a product of these specific assumptions, but the *relative* values and the degree to which they are influenced by particular variables in both grass conservation and herd management are of more general interest.

VARIABLES IN THE SYSTEM OF GRASS CONSERVATION

The Yield of DM and Nutritive Value of Grass

Apart from the unpredictable effects of variation in the weather on the rate of growth of grass, there is now considerable evidence that the yield of DM and the nutritive value of grass is principally influenced by the level of nitrogen (N) fertiliser the sward receives, the stage of maturity at which the primary growth is cut, and the frequency of cutting of regrowths.

This study is based on certain assumptions with regard to the yield and nutritive value of grass harvested under different cutting regimes.

Assumptions on the relationship of cutting regime to yield and nutritive value have been derived after consideration of extensive published information from the Grassland Research Institute and the National Institute of Agricultural Botany[20] provincial centres. The principle assumptions are based on an extrapolation of information for S24 perennial ryegrass as presented by Woodford (1966).[11] Considerable information is available on the relationship between yield and nutritive value in terms of digestibility in the first growth but, this generally does not extend to as late a stage of growth at cutting as may be practiced in conventional hay making—extrapolation from the growth curves presented by Woodford[11] and Green, Corrall and Terry[19] have been made to account for this.

There are also some deficiencies in the published information on yield and digestibility relating to cutting regimes with only one or two cuts following the first. Since such systems are considered practically relevant it has also been necessary to intrapolate and extrapolate from published information to derive total crop yields.

Table A.1 shows the relationship that has been assumed between yield and nutritive value with both first growths and subsequent cuts.

On the basis of these assumptions as to DM yield, the first cut provides 73, 78, 85 and 86 per cent of the total DM yield from the annual conservation programme with very early, early, medium and late first cuts. Relative to the early-cut, medium- and late-cut systems are assumed to yield 18 and 28 per cent more DM in the first cut, but only 8 and 16 per cent more DM in the total annual yield. The annual yield of digestible DM is assumed to be no greater with medium and late cutting than with early cutting.

Since first cuts contribute so substantially to total yield, in the subsequent calculation the whole annual production on these different cutting regimes has been characterised with the digestibility and protein content specified in Table A.1 for the first growths. Such an assumption also corresponds with the assumption of longer periods for regrowth following medium and late first cutting, than for early first cutting.

TABLE A.1

ASSUMED RELATIONSHIP BETWEEN YIELD OF DM AND NUTRITIVE VALUE OF GRASS IN RELATION TO CUTTING REGIME[1]

	Very Early	*Early*	*Medium*	*Late*
First Cut				
Yield m. tons DM/acre	2·41	3·18	3·75	4·09
In vitro DMD %	75·00	70·00	65·00	60·00
Crude Protein % DM	19·00	16·00	13·00	9·00
Second Cut				
Yield m. tons DM/acre	0·45	0·45	0·68	0·68
Third Cut				
Yield m. tons DM/acre	0·45	0·45	—	—

[1] Assuming N fertiliser applications of:
110 units (56 kg.)/acre for the first cut.
100 units (51 kg.)/acre for the second cut.
40 units (20 kg.)/acre for the third cut.
Applications of P & K shown in Table A.3.

Very early-cutting is included in Table A.1 for completeness but is in practice unlikely to be used in silage or hay programmes. However the yield assumptions for grass drying which correspond most closely to the growth curve presented by Woodford (in his Figure 5 which is Figure IV.1 in the text), assume a very early first cut and four subsequent cuts at monthly intervals. The application of 350 units of N fertiliser/acre is assumed to be associated with the production 4,040 kg. DM/acre of 70 per cent DMD and 16 per cent CP content.

Alternative assumptions as to DM yield are also made with regard to hay systems. It is recognised that many farmers who make hay under conventional field drying conditions seek to maintain quality at the expense of yield, by limiting fertiliser use less than that assumed for Table A.1. They produce a lighter crop that is easier to handle. In this study the production of hay on a 'Low N' system has been adjusted for a reduction in both fertiliser application and DM production for the first cut only.

Yields of first cuts have been abated as follows:

Early Cut—allowing for a 35 day response period—40 kg. DM/kg. N fertiliser.

Medium Cut—allowing for a 40 day response period—50 kg. DM/kg. N fertiliser.

Late Cut—allowing for a 45 day response period—60 kg. DM/kg. N fertiliser.

These relationships between DM production and N fertiliser use were assumed after consideration of the information presented by Burg.[21]

The fertiliser responses used result in quite severe abatements of yield and are as extreme as the experimental data would justify, but it is considered that they are compatible with practical experience.

Compared with the 'High N' system involving 110 units of N fertiliser/acre, the 'Low N' system involved 55 units of N. This is a reduction of 27·9 kg. N/acre and yields for early and late first cuts have accordingly been reduced by 1,117 and 1,676 kg. DM respectively. The yield of DM in the first cuts at the early and late stage was thus reduced by 35 and 41 per cent and the total annual yield was reduced by 27 and 37 per cent respectively.

Derivation of Hay and Silage Costs

The cost of hay and silage production is restricted to what may be termed 'prime' costs, namely fertiliser and routine conservation operations. No consideration is given to the cost of specialised fixed equipment or allocation of general overheads. It is considered that the justification for such expenditure can be considered in relation to the final gross margins for the different systems.

(*a*) *Fertiliser Costs*

Unit costs of N, P and K are derived from Nix, Farm Management Pocket book[22] 1971 and are shown in Table A.2.

Fertiliser applications and costs per acre are shown in Table A.3. These are varied as follows; for 3 cut systems an extra 70 units of N are applied; for low N systems 55 units of N are withheld from the first cut, and K is reduced by 34 units, of which 20 units are assumed utilised by the first cut and 14 by subsequent cuts.

(*b*) *Yields of Dry Matter*

The different cutting regimes were assumed to be associated with variation in yield, digestibility of DM, and crude protein content of the DM. In order to assess the contribution of conserved grass to the energy required in dairy cow diets, it is necessary to relate variation in digestibility to variation in feed energy value.

The characterisation of the grass in terms of energy value has been on the basis of its metabolisable energy content, measured as Megacalories per unit weight of feed DM (i.e. Mcals./kg. DM).

The link between digestibility as indicated in Table A.1 and the ME value indicated in Table A.4 is the formula:

ME (Mcals./kg. DM) = *in vitro* DMD per cent × 4·4 m. cals. Gross Energy × 0·82
where *in vitro* DMD = dry matter digestibility,

and the factor 0·82 adjusting for an 18 per cent loss of digested energy in methane and urine (Source: A.R.C., 1965).[12]

TABLE A.2

COST OF FERTILISER PER UNIT OF N P & K

Nutrient	*Fertiliser*	*Cost per unit £*
N	Nitram 34·5% N	0·0420
P	Superphosphate 19% P	0·0434
K	Muriate of Potash 60% K	0·0213

TABLE A.3

HAY AND SILAGE FERTILISER COSTS £/AC.

System	*N*	*P*	*K*	*Cost £/ac.*
Low N 1st cut	55	30	60	4·88
2 cut 2nd cut	100	20	40	5·91
Total	155	50	100	10·79
3 cut 2nd and 3rd cuts	140	20	40	7·59
Total	195	50	100	12·47
High N 1st cut	110	30	80	7·622
2 cut 2nd cut	100	20	54	6·218
Total	210	50	134	13·84
3 cut 2nd and 3rd cuts	140	20	54	7·898
Total	250	50	134	15·520

Assumptions on the yield and nutritive value of the standing crop are extended to show the effect of different degrees of conservation efficiency on the dry matter yield, ME concentration and CP content of the conserved product in Table A.4.

Losses in both the quantity and quality of conserved grass depend on how efficient the farmer is in getting the standing crop to the point of feeding as either silage or hay.

Three levels of efficiency have been examined in this exercise:

I 10% loss of DM—12·5% loss of ME and CP.

II 20% loss of DM—30% loss of ME and CP.

III 30% loss of DM—40% loss of ME and CP.

TABLE A.4

TIME OF CUTTING AND EFFICIENCY OF CONSERVATION ON THE QUANTITY[1], QUALITY[2] OF CONSERVED GRASS

	Very Early	*Early*	*Medium*	*Late*
Standing Crop				
Yield (m. tons DM/acre)	3·32	4·09	4·43	4·77
ME (Mcals./kg. DM)	2·70	2·50	2·35	2·10
CP (% DM)	19	16	13	9
Efficiency I—High				
(involving 10% loss DM, 12·5% loss of ME & CP)				
Yield (m. tons DM/acre)	2·99	3·68	3·99	4·30
ME (Mcals./kg. DM)	2·63	2·43	2·28	2·04
CP (% DM)	18·4	15·5	12·7	8·8
Efficiency II—Medium				
(involving 20% loss DM, 30% loss of ME & CP)				
Yield (m. tons DM/acre)	2·65	3·27	3·55	3·82
ME (Mcals./kg. DM)	2·28	2·19	2·06	1·84
CP (% DM)	16·6	14·0	11·4	7·9
Efficiency III—Low				
(involving 30% loss DM, 40% loss of ME & CP)				
Yield (m. tons DM/acre)	2·32	2·86	3·10	3·34
ME (Mcals./kg. DM)	2·22	2·14	2·01	1·80
CP (% DM)	16·3	13·7	11·1	7·7

[1] Total annual yield from cutting systems described in Table A.1.

[2] ME and CP content of DM, derived by dividing calculated residual ME and CP by calculated residual DM.

Note: For dried grass a loss of only 5 per cent DM and 5 per cent of ME and CP is assumed with the result that from a standing crop yield of 4,040 kg./DM/acre containing 2·5 Mcals ME/kg. DM and 16 per cent CP, the effective yield of dried grass is assumed to be 3,838 kg. DM/acre of the same nutritive value as the standing crop.

Efficiency I was selected as a practicably attainable objective given most effective management of silage making. Specialist equipment, such as tower silos, is not considered to be essential for this, but may facilitate consistent attainment of such a highly efficient conservation.

The making of hay with this level of efficiency would require most unusually ideal weather conditions, if there was total dependence on field drying. Implementation of some system of 'barn hay drying' would most commonly be required to attain this objective.

TABLE A.5

COSTS OF LABOUR AND MACHINERY FOR SILAGE AND HAY

Hay Operations	*Basis of Calculation*	*Cost/kg. DM £*
Mowing	£1·3/acre for 32 cwt. Crop @ 85% DM	0·0009
Turning	£0·5/acre for 32 cwt. Crop @ 85% DM	0·0004
Tedding	£0·5/acre for 32 cwt. Crop @ 85% DM	0·0004
Baling	£1·4 per ton	0·0016
Carting	£1·72 per ton for 2 men and 1 tractor carting 6 ton in 8 hrs.	0·0020
Silage Operations		
Mowing	£1·3/acre for 6 ton/acre crop @ 25% DM.	0·0009
Load cart and clamp	£0·87 per ton for a 6 ton/acre crop. Labour and Machinery costs. 1·96/hr. including 1 man, forage harvester and extra tractor with backbrake, rate of work—3 acres in 8 hrs.	0·0035

Source: J. Nix Farm Management Pocketbook 4th Ed.[22]

Efficiency II and III are used to illustrate progressively poorer performance in conservation. Level III is considered to be representative of the low level of efficiency that is common with conventional hay making, and not uncommon with silage. In subsequent calculations only I and III are discussed and are termed High and Low efficiency.

In order to simplify subsequent calculations the association between ME and CP content has been assumed to be as follows:

ME Mcals./kg. DM.	1·8	2·0	2·2	2·4	2·6
CP % DM	7·7	11·0	13·0	15·5	16·0

This assumption corresponds reasonably well with the general relationship between ME and CP content that is developed in Table A.4.

(c) *Elements of Conservation Costs*

Having obtained fertiliser costs and dry matter yields on a per acre basis it is possible to obtain a fertiliser cost per kg. of DM for the various yields obtained with the different combinations of cutting and harvesting efficiency. These are displayed in Table A.6 and A.7.

TABLE A.6

CALCULATION OF HAY COST £/kg. DM

	High N				*Low N*			
	Early First Cut		*Late First Cut*		*Early Frist Cut*		*Late First Cut*	
	High Eff.	*Low Eff.*	*High Eff.*	*Low Eff.*	*High Eff.*	*Low Eff.*	*High Eff.*	*Low Eff.*
Yield m. ton DM per acre								
Standing Crop	4·09	4·09	4·77	4·77	2·97	2·97	3·09	3·09
Conserved	3·68	2·86	4·30	3·34	2·67	2·07	2·78	2·16
Fertiliser £/acre	15·52	15·52	13·84	13·84	12·47	12·47	10·79	10·79
Cost £/kg. DM	0·0042	0·0054	0·0032	0·0041	0·0047	0·0060	0·0039	0·0050
Harvesting								
Mowing	0·0010	0·0012	0·0010	0·0012	0·0010	0·0012	0·0010	0·0012
Tedding and Turning[1]	0·0009	0·0023	0·0009	0·0023	0·0009	0·0023	0·0009	0·0023
Baling	0·0016	0·0016	0·0016	0·0016	0·0016	0·0016	0·0016	0·0016
Carting	0·0020	0·0020	0·0020	0·0020	0·0020	0·0020	0·0020	0·0020
Total Harvesting	0·0055	0·0071	0·0055	0·0071	0·0055	0·0071	0·0055	0·0071
Total	0·0097	0·0125	0·0017	0·0112	0·0102	0·0131	0·0094	0·0121

[1] Two operations for high efficiency, four for low.

TABLE A.7

COST OF SILAGE £/kg. DM

	Time of Cutting							
	Very Early		*Early*		*Medium*		*Late*	
	1st Cut	*Total Crop*	*1st Cut*	*Total Crop*	*1st Cut*	*Total Crop*	*1st Cut*	*Total Crop*
Fertiliser/acre	7·622	15·520	7·622	15·520	7·622	13·840	7·622	13·640
Harvesting cost (£/kg. DM)	0·0044	0·0044	0·0044	0·0044	0·0044	0·0044	0·0044	0·0044
Efficiency I 10% loss DM								
Dry Matter m. ton/acre	2·17	2·99	2·86	3·68	3·38	3·99	3·68	4·30
Fert. £/kg. DM	0·0035	0·0052	0·0027	0·0042	0·0023	0·0035	0·0021	0·0032
Harvesting factor $\frac{10}{9}$	0·0049	0·0049	0·0049	0·0049	0·0049	0·0049	0·0049	0·0049
Total £/kg. DM	0·0084	0·0101	0·0076	0·0091	0·0072	0·0084	0·0070	0·0081
Efficiency II								
Dry Matter m. ton/acre	1·93	2·65	2·55	3·27	3·00	3·55	3·27	3·82
Fert. £/kg. DM	0·0039	0·0059	0·003	0·0047	0·0025	0·0039	0·0023	0·0036
Harvesting factor $\frac{10}{8}$	0·0055	0·0055	0·0055	0·0055	0·0055	0·0055	0·0055	0·0055
Total £/kg. DM	0·0094	0·0114	0·0085	0·0102	0·0080	0·0094	0·0078	0·0091
Efficiency III								
Dry Matter m. ton/acre	1·69	2·32	2·23	2·86	2·62	3·10	2·86	3·34
Fert. £/kg. DM	0·0045	0·0067	0·0034	0·0054	0·0029	0·0045	0·0027	0·0041
Harvesting factor $\frac{10}{7}$	0·0003	0·0003	0·0003	0·0003	0·0003	0·0003	0·0003	0·0003
Total £/kg. DM	0·0107	0·0130	0·0097	0·0117	0·0092	0·0108	0·0090	0·0104

Labour and machinery costs for silage and hay production are also shown in these tables and are based on the following assumptions.

In the case of hay the mowing, turning and tedding costs are applied to a standing crop yield, and carting and baling costs to the reduced DM resulting from applying the particular efficiency losses. This means that for this purpose all DM losses are taken to occur in the field. In silage making on the other hand it is assumed that all losses of DM occur in the clamp and all harvesting costs are applied to standing crop yields. This means that when costs are applied to standing crop yields, in order to get a cost for residual yields after applying efficiency losses, the costs must be raised by factors of $\frac{10}{9}$ and $\frac{10}{7}$ for high (90 per cent) and low (70 per cent) efficiency.

The cost elements are based on figures for standard costs related to a 32 cwt. crop of hay of 85 per cent DM, and a 6 ton crop of silage of 25 per cent DM. These are shown in Table A.5.

FORMULATION OF DAIRY COW DIETS INVOLVING CONSERVED GRASS

The utilisation of conserved grass has been examined in the context of milk production systems involving certain specified assumptions.

(i) The standard cow for this purpose has been assumed to be a Friesian, of 590 kg. liveweight.

(ii) The standard lactation yield has been taken to be 900 gallons. This level of production was selected as corresponding

(*a*) with good commercial practice

(*b*) with a reasonable spread of cow maintenance feed requirements relative to production

(*c*) with a level of milk production that can be sustained on high quality conserved grass without substantial dependence on concentrates.

The influence of a higher level of milk production on forage : concentrate ratio and winter feed costs, has been assessed in supplementary calculations based on a lactation yield of 1,100 gallons of milk.

(iii) The use of the forage by either autumn- or spring-calving herds has been considered. In practice in most dairy herds calvings are spread over a period of several months. However, in general the two extreme systems of production are to aim for maximum milk output in winter or in summer. For this reason mid-September and mid-March are taken as representative calving dates for comparing winter and summer milk production. Standard lactation curves for these calving dates and 900 gallon yield are shown in Table A.8.

(iv) The length of winter, for which provision of conserved forage has to be made, varies between different regions. The South-West has shorter winters than the North-East, consequently it is necessary to take account of the effect of this in feed requirements for the yield and calving dates of (*a*) and (*b*) above. It was considered that a reasonable distribution of winter length would be between the extremes of 120 and 180 days. These two periods are therefore taken as being representative. The 180 day winter being assumed to run from mid-September to mid-March, and the 120 from mid-November to mid-March.

The assumptions above lead to four specifications:

(1) Mid-September calving, long winter.
(2) Mid-September calving, short winter.
(3) Mid-March calving, long winter.
(4) Mid-March calving, short winter.

TABLE A.8

LACTATION CURVES FOR FRIESIAN COWS YIELDING 900 GALLONS[1]

Autumn Calving	*Gallons[1] per day*	*Spring Calving*	*Gallons per day*
September ($\frac{1}{2}$ month)	4·36	March ($\frac{1}{2}$ month)	3·72
October	5·22	April	4·55
November	4·63	May	4·61
December	3·81	June	4·02
January	3·05	July	3·35
February	2·69	August	2·74
March	2·44	September	2·20
April	2·22	October	1·62
May	2·00	November	1·38
June	1·64	December	1·07
July ($\frac{1}{2}$ month)	0·81	January ($\frac{1}{2}$ month)	0·84

1 gallon of milk = 4·55 kg.
Source: A.D.A.S. (1961).[1]

[1] The lactation curve for cows yielding 1,100 gallons was derived by adjusting mean monthly milk production upwards by +22 per cent.

The specifications of calving and winter length influence feed requirements and this will be further affected by the quality of conserved forage making up the ration.

In this assessment of the relative merits of different conservation systems in the production of feed for the dairy herd, conserved grass and barley concentrates have been considered to be alternative feeds that may be combined in varying proportions, to provide diets of appropriate energy and protein content that will be consumed in sufficient quantity by the dairy cow.

In this study the substitution of barley/groundnut concentrates for conserved grass has been based on the principles of the A.R.C. (1965) system of feeding standards.

The estimated daily feed DM requirements of Friesian cows producing different daily yields of milk and receiving *diets* of different ME concentration have been defined by A.R.C. (1965) and are presented in Table A.9.

Diets of a particular ME concentration can be formulated by matching conserved grass with varying proportions of barley concentrate as is shown in Table A.10. The protein content of the diet can be formulated in a similar manner; adjusting for variation in the crude protein content of the forage by including varying proportions of groundnut cake in the concentrate (see footnote to Table A.10).

TABLE A.9

DRY MATTER FEED REQUIREMENTS OF LACTATING FRIESIAN COWS ON DIETS OF DIFFERENT ENERGY CONCENTRATION[1]

Production Required	*Metabolisable Energy Concentration of the Diet (Mcals./ME)*						
	1·8	2·0	2·2	2·4	2·6	2·8	3·0
Maintenance only	7·8	6·9	6·1	5·5	5·0	4·5	4·2
Maintenance+late pregnancy gain	13·6	11·6	9·8	8·8	7·9	7·0	6·3
Maintenance plus:							
5 kg.[2] milk/day	11·5	10·1	8·8	7·9	7·1	6·5	6·0
10 kg. milk/day	16·0	13·7	11·8	10·5	9·3	8·5	7·9
15 kg. milk/day			15·0	13·2	11·7	10·6	9·8
20 kg. milk/day					14·2	12·9	11·8
25 kg. milk/day					16·8	15·3	13·8
30 kg. milk/day					19·9	17·9	15·9

[1] Cow 590 kg. liveweight. Activity allowance two miles walking and five hours standing daily. Milk of 3·6 per cent butterfat.

[2] 1 kg. of milk=0·22 gallons.

These adjustments to the protein content of the diet have been calculated on the assumption that the CP in the forage is 70 per cent digestible $\left(\text{i.e. DCP} = \frac{70 \times \text{CP}}{100}\right)$ and that the DCP content of barley and groundnut cake is respectively 7 per cent and 42 per cent of the DM.

It must be accepted that these feeding standards require some qualification as to their precision at the extremes of, on the one hand, all forage and at the other, high concentrate diets. For cows in early and mid-lactation, diets that could theoretically be based on forage alone have been formulated to substitute 1 kg. concentrate DM for an equivalent quantity of forage. The qualification with regard to the extreme high concentrate diets seems most pertinent to the case of the cow that has been assumed to be capable of producing more than 5 gallons of milk/day from a diet based on poor quality forage and containing 75 per cent of concentrates (see Table A.19).

It is also recognised that this approach to the assessment of the nutritive value of forage of varying quality takes account only of its nutrient content and not of its intake characteristics. In practice variation in the voluntary intake of different types of conserved grass is *per se* of considerable practical significance. In this study

TABLE A.10

PERCENTAGE OF FORAGE OF DIFFERENT QUALITIES IN FORAGE: CONCENTRATE DIETS FORMULATED TO A RANGE OF DIFFERENT ENERGY CONCENTRATIONS[1]

Required Dietary Metabolisable Energy Concentration Mcals./kg. DM	*Quality of Roughage in terms of ME Concentration (Mcals./kg. DM)*						
	1·8	2·0	2·2	2·4	2·6	2·8	3·0
1·8	100						
2·0	85	100					
2·2	70	82	100		Excess quality of roughage		
2·4	54	64	77	100			
2·6	39	46	54	72	100		
2·8	24	28	32	44	60	100	
3·0	8	10	10	16	20	38	100

[1] Remainder of the ration is assumed to be barley, with the following characteristics.
Using ARC (1965) standards and a safety margin it has been estimated that with forage having an ME content of 2·5 Mcals/kg. DM and 16 per cent CP or more, the protein content of the diet is adequate using only straight barley as the concentrate feed. When ME is lower than 2·5 Mcals/kg. DM, and associated with this CP content is lower, there is a need for supplementation of barley with groundnut as follows:

	Quality of Roughage in terms of ME concentration (Mcals./kg. DM)				
	1·8	2·0	2·2	2·4	2·5
Assumed Crude Protein % of Forage	7·5	11·0	13·0	15·5	16·0
Groundnut % in concentrate feed	17·0	12·2	7·4	2·6	—

the assumptions of intake have been set at a level at which variation in the acceptability of the forage seems unlikely to be limiting. Conclusions with regard to concentrate : forage substitution are subject to some further discussion and qualification later.

The influence of forage quality on the total amount of conserved grass, barley and groundnut cake required in the winter diet of the milking cow has been calculated by formulating a series of such diets for cows at different stages of the winter period, corresponding approximately with different stages of lactation.

A series of such calculations for cows yielding 900 gallons per lactation calving in September or March, and for September-calving cows yielding 1,100 gallons per lactation are presented in the subsequent tables A.11, A.12, A.13. Cow feed requirements have been related to forage qualities associated with different cutting regimes and efficiencies of conservation, by intrapolation from graphs relating total forage and concentrate requirements to forage quality over a range from 1·8 to 2·6 Mcals. ME/kg. DM. (Figures A.1, 2, 3, 4 and 5.)

Qualifications of Diet Formulations

The dry matter intake of the milking cow varies with stage of lactation, and generally rises to a maximum in the third month after calving, whereas energy output in the milk rises to a peak in the first month and then declines. In formulating diets allowance has been made for this variation in feed intake relative to nutrient requirements, in that the specified energy concentration in the diet for the September-calving cow has varied from 2·8 Mcals. ME/kg. DM in early lactation, to 2·6 and then 2·4 Mcals./kg. DM in later lactation.

With the March-calving cow in very late lactation, and the dry period, it has been assumed that a diet containing as little as 2·2 Mcals. ME/kg. DM will be consumed in sufficient quantity to meet the requirements of the cow. Assumptions as to feed requirements for the spring calver in the early winter are considered to be relatively generous. The practical justification is that at this stage of lactation cows will readily consume an excess of nutrients relative to their minimal requirements. Indeed some 'luxury' consumption of forage would be most likely under liberal feeding regimes, and provides for the replenishment of body reserves in preparation for the demands of a subsequent lactation.

On the basis of these assumptions it is evident that the early-cut, efficiently conserved grass is capable of providing for maintenance of the cow and the production of 3 gallons of milk/day, but if conserved with only a low level of efficiency will only provide for maintenance and 2 gallons of milk/day. The late-cut grass, conserved with low efficiency will at best provide only for maintenance.

The feed intakes that are postulated are expected to be well within the dry matter capacity of most Friesian cows on most hay and silage diets. In early lactation the assumed intake of dry matter (32 lb.) is equivalent to 2·5 per cent liveweight and in mid-lactation 26·5 lb. is equivalent to only 2·0 per cent liveweight.

Even though these intake levels are conservative it may be suggested that on the basis of available evidence some early-cut silage may be less acceptable than has been asumed, and that the contribution of such silage would be restricted by low intake. The consequences of a 20 per cent reduction in the intake of early-cut, efficiently conserved silage compensated by increased concentrate allowances regulated to maintain milk yield are indicated as follows.

In Table A.11 silage containing 2·4 Mcals. ME/kg. DM is required at the level of 1·95 m. tons DM/cow/winter to support the specified level of yield. If silage intake were restricted to 20 per cent below this level 0·39 m. tons of silage DM would require replacement with 0·30 m. tons of concentrate containing 3·1 Mcals. ME/kg. DM.

Variation in the intake of later cut and less efficiently conserved silage is likely to be of much less significance, as such forage will necessarily be fed together with an allowance of concentrates. Supplementary concentrate feeding offsets the effect of variation in silage intake.

In contrast to the foregoing, some forages may be more acceptable than has been assumed in these calculations. A higher intake potential could be a particular feature of dried grass, early-cut barn dried hay and possibly early-cut, high DM silage. The consequence of greater forage acceptability could be the replacement of a greater proportion of the concentrate allowance in diets sustaining similar milk yields or the enhancement of total feed intake resulting in an increase in milk yield.

If the intake characteristics of more acceptable forage were such that in early and mid-lactation cows increased their feed intake by 2 kg. DM daily, this could support an extra 4·1 kg. (9 lb.) milk/cow/day at peak lactation and could increase lactation yield by approximately 180 gallons. The additional feed requirements may be estimated as 0·31 m. tons forage DM and 0·05 m. tons of concentrate DM.

Another feature of the feed intakes assumed in those calculations is the relatively small quantities of high quality forage that are actually *required* by cows in late lactation and when first dried off. The intakes specified in these calculations (e.g. 7·9 kg. DM containing 2·4 Mcals. ME/kg. DM for a cow producing 1 gallon of milk/day; equivalent to only 1·3 per cent of liveweight) are most probably lower than the likely *ad lib* intake of these cows. If the feeding level was not controlled then 'luxury' intake of feed would be likely in practice, and forage requirements would increase with little effect on production. Alternatively in such situations additional 'fill' might be provided in the form of barley straw.

The general milk yield potential of cows will influence the relative value of forages of different qualities, principally through effects established in early lactation.

In the attainment of lactation yields well in excess of 900 gallons, feeding during early lactation can be of critical importance since the yield established at this stage determines the potential for the whole lactation. High quality forages may have particular advantages during early lactation in that, with only moderate levels of concentrate feeding, they provide a diet of sufficient energy density to promote high energy intake, and also one that does not depress the mobilisation of body fat. Both feed intake and the mobilisation of body fat sustain high milk yield in the first weeks of lactation.

TABLE A.11

FEED ALLOWANCES FOR A 900 GALLON, SEPTEMBER-CALVING FRIESIAN COW FOR A 180 DAY WINTER

	Quality of Forage (Mcals. ME/kg. DM)				
	1·8	2·0	2·2	2·4	2·6
	Poor	*Moderate*	*Medium*	*Good*	*V. Good*
Early Lactation—30 days—maintenance+4·9 gall. (22·4 kg.) milk/day. Required daily feed intake 15·4 kg. DM containing 2·6 Mcals. ME/kg. DM.					
Daily Feed: (kg. DM/cow) Forage	6·0	7·1	8·3	10·8	14·4
Concentrates	9·4	8·3	7·1	4·6	1·0[2]
Early Lactation[1]—30 days—maintenance+4·2 gall. (19·2 kg.) milk/day. Required daily feed intake 13·8 kg. DM containing 2·6 Mcals. ME/kg. DM.					
Daily Feed: (kg. DM/cow) Forage	5·4	6·3	7·5	9·9	12·8
Concentrates	8·4	7·5	6·3	3·9	1·0[2]
Mid Lactation[1, 2]—90 days—maintenance+3.0 gall. (13·7 kg.) milk/day. Required daily feed intake 12·5 kg. DM containing 2·4 Mcals. ME/kg. DM.					
Daily Feed: (kg. DM/cow) Forage	6·8	8·0	9·6	11·5	10·0
Concentrates	5·7	4·5	2·9	1·0[2]	1·0[2]
Mid Lactation—30 days—maintenance+2·3 gall. (10·6 kg.) milk/day. Required daily feed intake 12·2 kg. DM containing 2·2 Mcals. ME/kg. DM.					
Daily Feed: (kg. DM/cow) Forage	8·5	10·0	11·2	9·8	8·6
Concentrates	3·7	2·2	1·0[2]	1·0[2]	1·0[2]
Total Feed for 180 day winter (m. ton DM/cow).					
Forage	1·21	1·42	1·67	1·95	1·97
Concentrates	1·16	0·95	0·70	0·38	0·18

[1] Periods included in the short (120 day) winter (see page 106 for further discussion).

[2] Though forage alone could supply nutrient requirements, these diets have been adjusted by an allowance of 1 kg. concentrate as a carrier for minerals substituting for 1 kg. forage.

With cows in mid-lactation, the principal importance of forage quality will depend upon to the extent to which it replaces more expensive concentrate feeds. High quality forages are likely to make their greatest contribution in this respect in sustaining yields of up to 4 or 5 gallons/cow/day; to sustain daily yields higher than this even high quality forages are likely to require appreciable concentrate supplementation. It may be argued that the advantages of high quality will be most fully exploited in diets for cows producing milk at this level over the whole winter, and this will in turn depend on both the time of calving and the lactation yield of the herd.

It is notable that there is little difference in the concentrate sparing effect of higher quality forage in the diet of the 1,100 gallon cow compared with that for the 900 gallon cow, the basis of the calculations in Tables A.11 and A.13.

The costs of winter feed for cows in various specified circumstances have been calculated by relating appropriate forage costs (from Table A.7) to estimated forage requirements (from Figures A.1, A.2, A.3, A.4 and A.5). The total requirement for concentrates has been related to appropriate concentrate costs derived as is shown in Table A.14. The summaries of a series of these calculations are presented in Tables A.15, A.16, A.17, A.18 and A.19.

Calculation of Gross Margins for different silage qualities for the 900 gallon cow

Tables A.15, A.16, A.17, A.18 and A.19 include gross margin calculations. They also contain several essential elements in a Gross Margin calculation, but further assumptions are necessary before the GM can be arrived at. The output per cow is taken to vary with time of calving because of the change in milk price. The mid-September calver is credited with 19·35p per gallon and the mid-March with 18·5p. The net effect of calf sales and cow depreciation is an additional £5, and miscellaneous variable costs are £8. Thus the margin per cow over replacements and miscellaneous variable costs is £171 and £164 respectively.

Continued on page 114

TABLE A.12

FEED ALLOWANCES FOR A 900 GALLON, MARCH-CALVING FRIESIAN COW FOR A 180 DAY WINTER

		Quality of Forage (Mcals. ME/kg. DM)				
		1·8	2·0	2·2	2·4	2·6
		Poor	*Moderate*	*Medium*	*Good*	*V. Good*
Mid Lactation—30 days—maintenance+1·5 gall. (7 kg.) milk/day. Required daily feed intake 10 kg. DM containing 2·2 Mcals. ME/kg. DM.						
Daily Feed: (kg. DM/cow)	Forage	7·0	8·2	10·0	9·0	8·0
	Concentrates	3·0	1·8	—	—	—
Late Lactation[1]—90 days—maintenance+1·1 gall. (5 kg.) milk/day. Required daily feed intake 10·1 kg. DM containing 2·0 Mcals. ME/kg. DM.						
Daily Feed: (kg. DM/cow	Forage	8·6	10·1	8·8	7·9	7·1
	Concentrates	1·5	—	—	—	—
Dry-Precalving[1]—30 days—maintenance+late pregnancy. Required daily feed intake 8·8 kg. DM containing 2·4 Mcals./kg. DM.						
Daily Feed: (kg. DM/cow)	Forage	4·8	5·6	6·8	7·8	6·9
	Concentrates	4·0	3·2	2·0	1·0	1·0
Early Lactation—30 days—maintenance+4·0 gall. (18 kg.) milk/day. Required daily feed intake 13·8 kg. DM containing 2·6 Mcals./kg. DM.						
Daily Feed: (kg. DM/cow)	Forage	5·2	6·1	7·1	9·5	12·2
	Concentrates	8·0	7·1	6·1	3·7	1·0
Total Feed for 180 day winter (m. tons DM/cow)						
Forage		1·284	1·506	1·509	1·50	1·45
Concentrates		0·585	0·363	0·243	0·14	0·06

[1] Periods covered in the short (120 day) winter (see page 110 for further discussion).

TABLE A.13

FEED ALLOWANCES FOR A 1,100 GALLON, SEPTEMBER-CALVING FRIESIAN COW FOR A 180 DAY WINTER

	Quality of Forage (Mcals. ME/kg. DM)				
	1·8	2·0	2·2	2·4	2·6
	Poor	*Moderate*	*Medium*	*Good*	*V. Good*
Early Lactation—30 days—maintenance+6·0 gall. (27·3 kg.) milk/cow/day. Required daily feed intake 16·5 kg. DM containing 2·8 Mcals. ME/kg. DM.					
Daily Feed: (kg. DM/cow) Forage	4·0	4·6	5·3	7·3	9·9
Concentrates	12·5	11·9	11·2	9·2	6·6
Early Lactation—30 days—maintenance+5·1 gall. (28·4 kg.) milk/cow/day. Required daily feed intake 14·5 kg. DM containing 2·8 Mcals. ME/kg. DM.					
Daily Feed: (kg. DM/cow) Forage	3·5	4·1	4·6	6·4	8·7
Concentrates	11·0	10·4	9·9	8·1	5·8
Mid Lactation—90 days—maintenance+3·7 gall. (16·7 kg.) milk/cow/day. Required daily feed intake 12·6 kg. DM containing 2·6 Mcals./kg. DM.					
Daily Feed: (kg. DM/cow) Forage	4·9	5·8	6·8	9·1	11·6
Concentrates	7·7	6·8	5·8	3·5	1·0
Mid Lactation—30 days—maintenance+2·8 gall. (12·9 kg.) milk/cow/day. Required daily feed intake 12·1 kg. DM containing 2·4 Mcals./kg. DM.					
Daily Feed: (kg. DM/cow) Forage	6·5	7·7	9·3	11·1	9·6
Concentrates	5·6	4·4	2·8	1·0	1·0
Total Feed—for 180 day Winter (m. tons DM/cow).					
Forage	0·86	1·02	1·19	1·56	1·89
Concentrates	1·57	1·41	1·24	0·86	0·49

TABLE A.14

CALCULATION OF COSTS OF CONCENTRATES CONTAINING VARYING PROPORTIONS OF GROUNDNUT CAKE FORMULATED TO BALANCE WITH VARYING QUALITIES OF CONSERVED GRASS
(with Barley £20/m. ton, Groundnut £60/m. ton air-dry feed)

	Forage				
	Dried Grass	*Early First Cut High Efficiency*	*Early First Cut Low Efficiency*	*Late First Cut High Efficiency*	*Late First Cut Low Efficiency*
Groundnut cake % Barley-Gn. mix	0	2·5	10·5	12·5	17
Cost/m. ton mix (£)	20·0	21·0	24·2	25·0	26·8
Cost of preparation and minerals	←		£5/ton		→
Cost/ton air-dry concentrate (88% DM)	25·0	26·0	29·2	30·0	31·8
Cost/ton DM	28·4	29·54	33·18	34·09	36·14
Change in Concentrate Price with each £5/ton change in the price of barley (£/ton DM)	5·68	5·54	5·09	4·97	4·72
Cost with Barley at £25/m. ton air-dry feed	34·08	35·08	38·27	39·06	40·86

TABLE A.15

COMPARISON OF THE COSTS OF WINTER FEEDING USING SILAGE OF DIFFERENT QUALITIES—180 DAY WINTER SEPTEMBER CALVING COW, 900 GALLON LACTATION

	Silage System			
	Early First Cut		*Late First Cut*	
	High Efficiency	*Low Efficiency*	*High Efficiency*	*Low Efficiency*
Silage Characteristics (from Table 4.2)				
Annual Yield (m. tons/DM/ac.)	3·68	2·86	4·30	3·34
ME Value (Mcals/kg. DM)	2·43	2·14	2·04	1·80
CP Percentage (in DM)	15·5	13·7	8·8	7·7
Feed Allowance (from Fig. A.1)				
Silage (m. ton DM/cow)	1·95	1·59	1·46	1·21
Concentrates (m. ton DM/cow)	0·35	0·78	0·91	1·16
Feed Prices (£ m. ton)				
Silage DM (from Table 4.2)	9·1	11·7	8·1	10·4
Concentrates[1]	35·08	38·27	39·06	40·86
Winter Feed Cost (£/cow)				
Silage	17·8	18·6	11·8	12·6
Concentrates	12·3	29·9	35·5	47·4
Total	30·1	48·5	47·3	60·0
Conserved Grass (acres/cow)[2]	0·53	0·56	0·34	0·36
Total Grass (acres/cow)	1·03	1·06	0·84	0·86
Summer Costs (£/cow)	13	13	13	13
Gross Margin (£/cow)[3]	128	110	111	98
Gross Margin (£/acre)	124	103	132	114
Change in winter feed cost with £5/ton change in Barley Price	1·9	4·0	4·5	5·5
Change in GM/acre with £5/ton change in Barley Price	2·5	4·6	6·4	7·4

[1] Cost per m. ton concentrate feed of 88 per cent DM, with barley at £25/ton, Groundnut cake at £60/ton and £5/ton for rolling, mixing and minerals. The consequences of variation in barley price are shown in Fig. 4.4 and Fig. 4.6.

[2] Yield of Silage DM/ac/annum ÷ Silage allowance/cow/winter.

[3] Output net of replacement and miscellaneous variable costs £171/cow.

FIGURE A.1 (From Table A.15)

The relationship between Forage quality and allowances of Forage, Barley and Groundnut in the diet of September-calving Friesian cow for a 180-day winter. (900 gall. lactation).

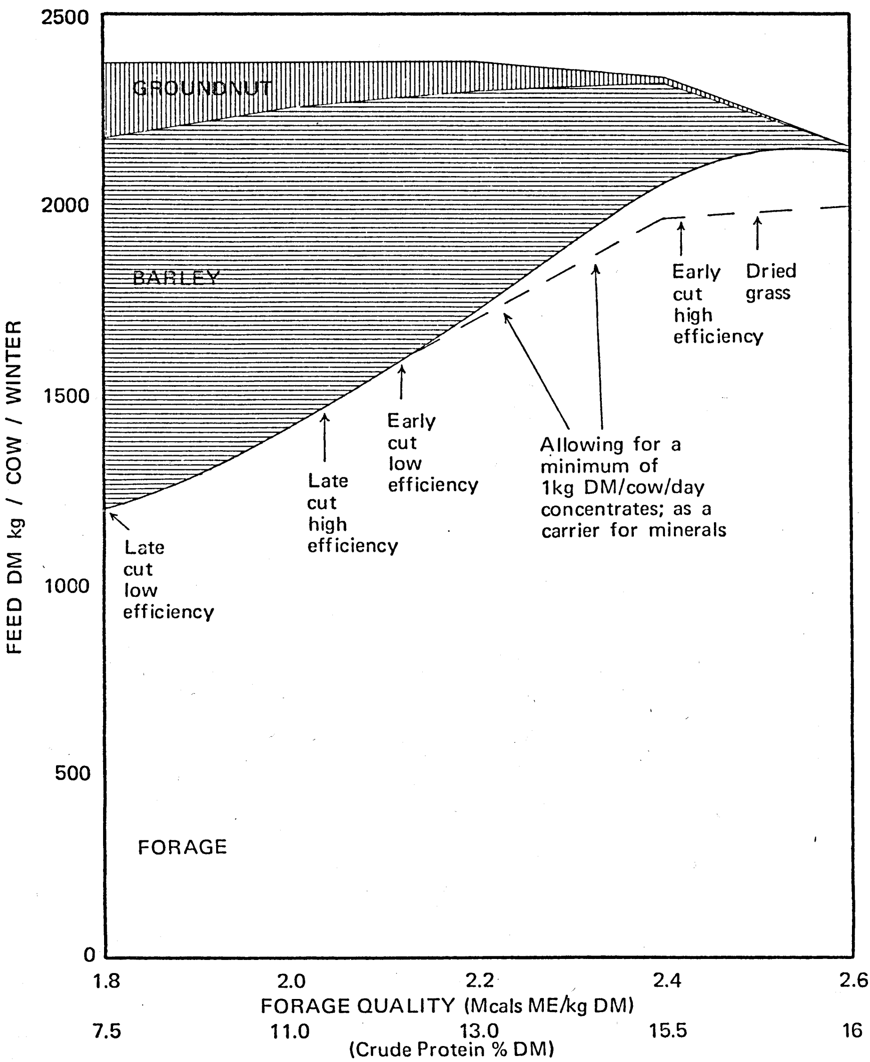


TABLE A.16

COMPARISON OF COSTS OF WINTER FEEDING USING SILAGE OF DIFFERENT QUALITIES—120 DAY WINTER SEPTEMBER CALVING, 900 GALLON LACTATION

	Silage System			
	Early First Cut		*Late First Cut*	
	High Efficiency	*Low Efficiency*	*High Efficiency*	*Low Efficiency*
Feed Allowances (from Fig. A.2)				
Silage (m. ton DM/cow)	1·32	1·03	0·94	0·77
Concentrates (m. ton DM/cow)	0·20	0·51	0·60	0·77
Winter Feed Costs (£/cow)[1]				
Silage	12·0	12·1	7·6	8·0
Concentrates	7·0	19·5	23·5	31·5
Total	19·0	31·6	31·1	39·5
Conserved Grass (acres/cow)[2]	0·36	0·36	0·22	0·23
Total Grass (acres/cow)	1·03	1·03	0·89	0·90
Summer Costs (£/cow)	18	18	18	18
Gross Margin (£/cow)[3]	134	121	122	114
Gross Margin (£/acre)	130	118	137	126
Change in winter feed cost per £5 change in Barley Price	1·1	2·6	3·0	3·6
Change in GM/acre per £5 change in Barley Price	2·2	3·7	4·7	5·3

[1] Feed prices as per Table 4.6.

[2] Silage characteristics as per Table 4.2.

[3] Output net of replacement and miscellaneous variable costs £171/cow.

FIGURE A.2 (From Table A.16)

Relationship between Forage quality and allowances of Forage, Barley and Groundnut in the diet of 900 gallon, September-calving Friesian cow for 120-day winter.

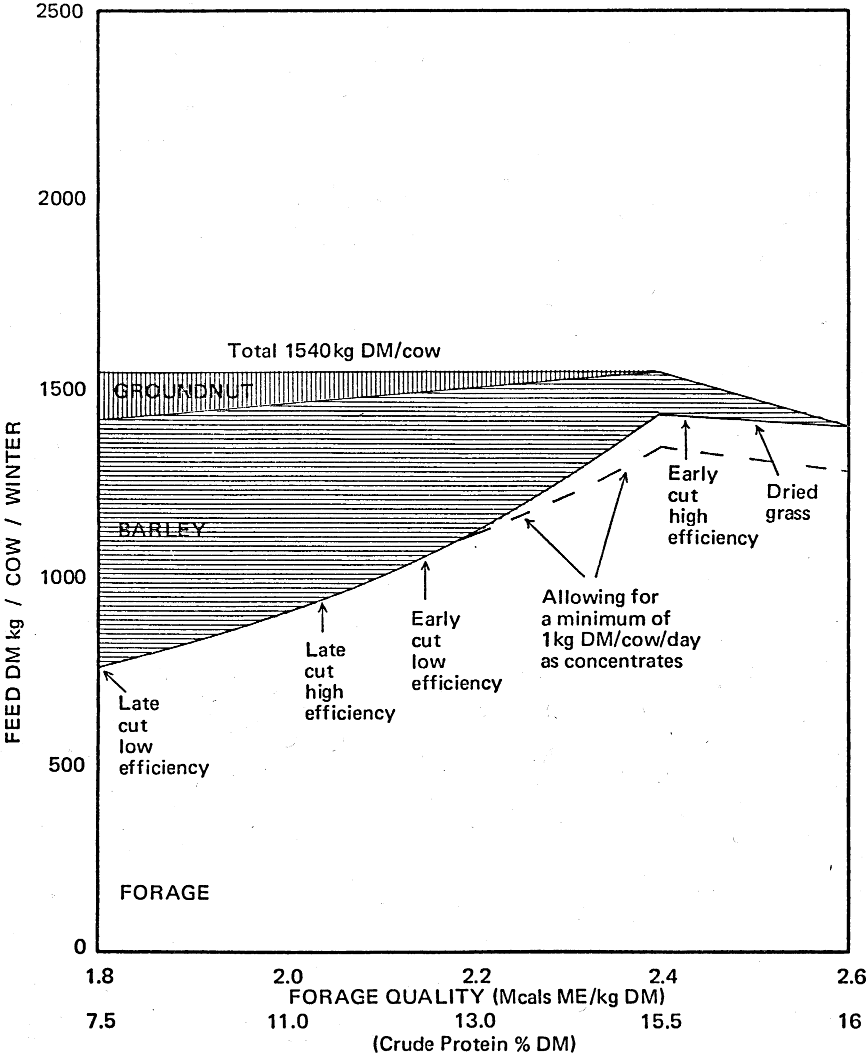


TABLE A.17

COMPARISON OF COSTS OF WINTER FEEDING USING SILAGE OF DIFFERENT QUALITIES—180 DAY WINTER MARCH CALVING COW, 900 GALLON LACTATION

	Silage System			
	Early First Cut		*Late First Cut*	
	High Efficiency	*Low Efficiency*	*High Efficiency*	*Low Efficiency*
Feed Allowances (from Fig. A.3)				
Silage (m. ton DM/cow)	1·49	1·51	1·51	1·28
Concentrates (m. ton DM/cow)	0·13	0·28	0·34	0·59
Winter Feed Cost (£/cow)				
Silage	13·6	17·7	12·2	13·3
Concentrates	4·6	10·7	13·3	24·1
Total	18·2	28·4	25·5	37·4
Conserved Grass (acre/cow)	0·40	0·52	0·35	0·38
Total Grass (acre/cow)	0·90	1·02	0·85	0·88
Summer Costs (£/cow)	12	12	12	12
Gross Margin (£/cow)[1]	134	124	127	115
Gross Margin (£/acre)	149	121	149	130
Change in winter feed costs per £5/ton change in Barley Price	0·7	1·4	1·7	2·8
Change in GM/acre per £5/ton change in Barley Price	1·6	2·1	2·8	4·0

[1] Output per cow net of replacement and miscellaneous variable costs £164/cow.

[2] Other footnotes as Table 4.6.

FIGURE A.3 (From Table A.17)

The relationship between Forage quality and allowances of Forage, Barley and Groundnut in the diet of a March-calving Friesian cow for a 180-day winter (900 gall. lactation).

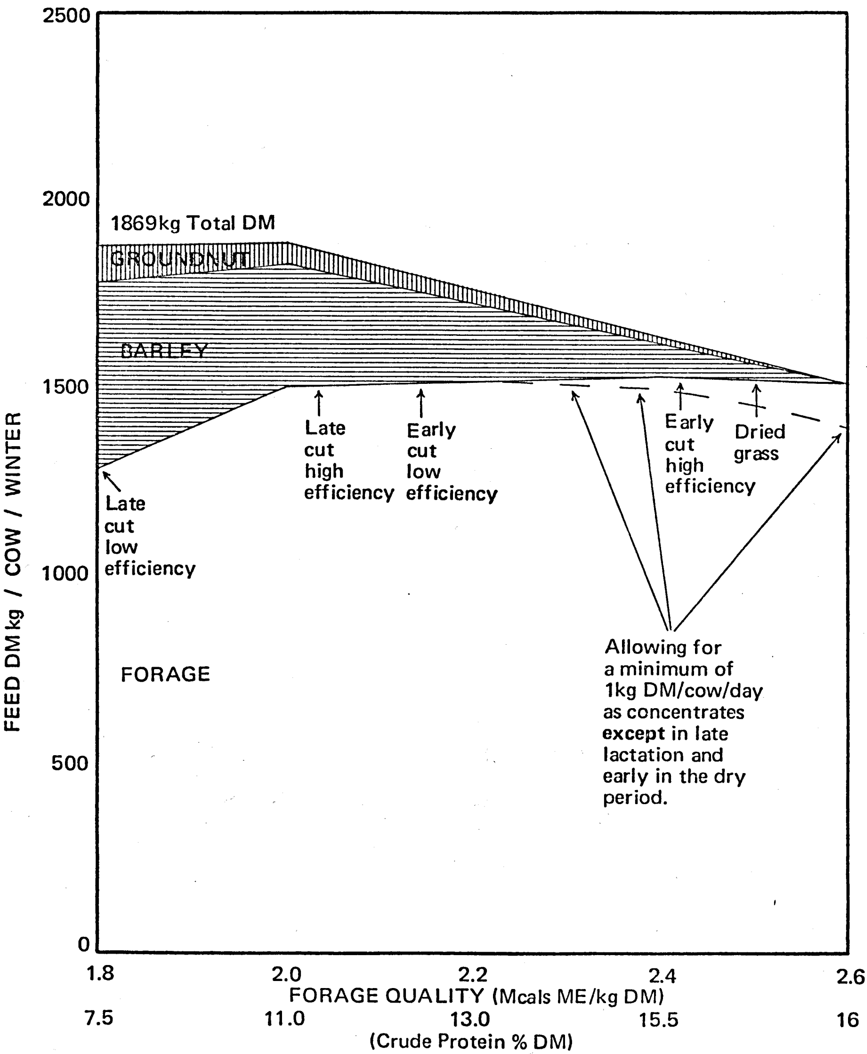


TABLE A.18

COMPARISON OF COSTS OF WINTER FEEDING USING SILAGE OF DIFFERENT QUALITIES—120 DAY WINTER MARCH CALVING, 900 GALLON LACTATION

	Silage System[1]			
	Early First Cut		*Late First Cut*	
	High Efficiency	*Low Efficiency*	*High Efficiency*	*Low Efficiency*
Feed Allowances (from Fig. A.4)				
Silage (m. ton DM/cow)	0·93	1·03	1·06	0·92
Concentrates (m. ton DM/cow)	0·03	0·06	0·08	0·26
Winter Feed Costs (£/cow)[2]				
Silage	8·5	12·1	8·6	11·3
Concentrates	1·1	2·3	3·1	10·6
Total	9·6	14·4	11·7	21·9
Conserved Grass (acre/cow)	0·25	0·36	0·25	0·28
Total Grass (acre/cow)	0·92	1·03	0·92	0·95
Summer Costs (£/cow)	16	16	16	16
Gross Margin (£/cow)[3]	138	134	136	126
Gross Margin (£/acre)	150	130	148	133
Change in winter feed costs per £5/ton change in Barley Price	0·2	0·3	0·4	1·2
Change in GM/acre per £5/ton change in Barley Price	1·2	1·2	1·4	2·2

[1] Silage as per Table 4.2.

[2] Feed Prices as per Table 4.6.

[3] Output per cow as per Table A.17.

FIGURE A.4 (From Table A.18)

Relationship between Forage quality and allowances of Forage, Barley and Groundnut in diet of 900 gallon, March-calving Friesian cow for 120-day winter.

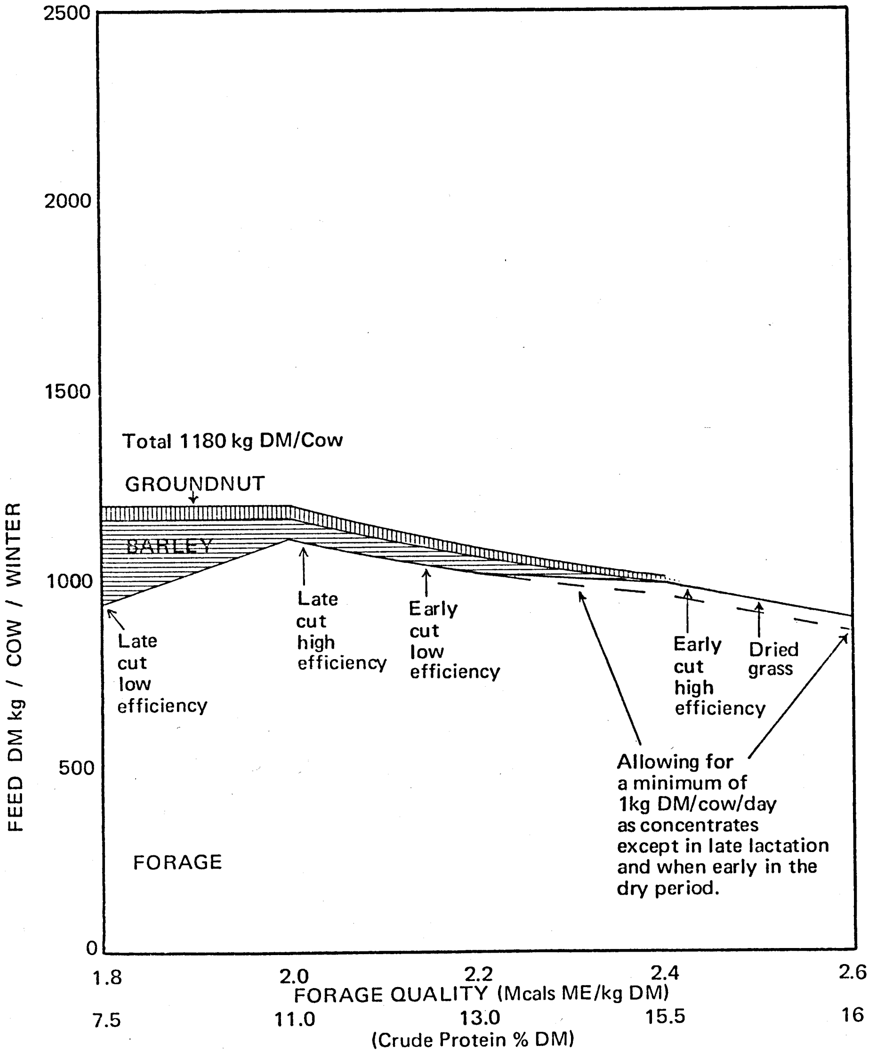


TABLE A.19

COMPARISON OF COSTS OF WINTER FEEDING USING SILAGE OF DIFFERENT QUALITIES—180 DAY WINTER SEPTEMBER CALVING, 1,100 GALLON LACTATION

	Silage System[1]			
	Early First Cut		*Late First Cut*	
	High Efficiency	*Low Efficiency*	*High Efficiency*	*Low Efficiency*
Feed Allowances (From Fig. A.5)				
Silage (m. ton DM/cow)	1·61	1·14	1·06	0·86
Concentrates (m. ton DM/cow)	0·81	1·29	1·37	1·57
Winter Feed Costs (£/cow)[2]				
Silage	14·7	13·3	8·6	8·9
Concentrates	28·4	49·4	53·6	64·2
Total	43·1	62·7	62·2	73·1
Conserved Grass (acre/cow)[1]	0·44	0·40	0·25	0·26
Total Acres/cow	0·94	0·90	0·75	0·76
Summer Cost (£/cow)	13	13	13	13
Gross Margin (£/cow)[3]	154	134	135	124
Gross Margin (£/acre)	164	149	180	163
Change in feed cost per £5 change in Barley Price	4·5	6·6	6·8	7·4

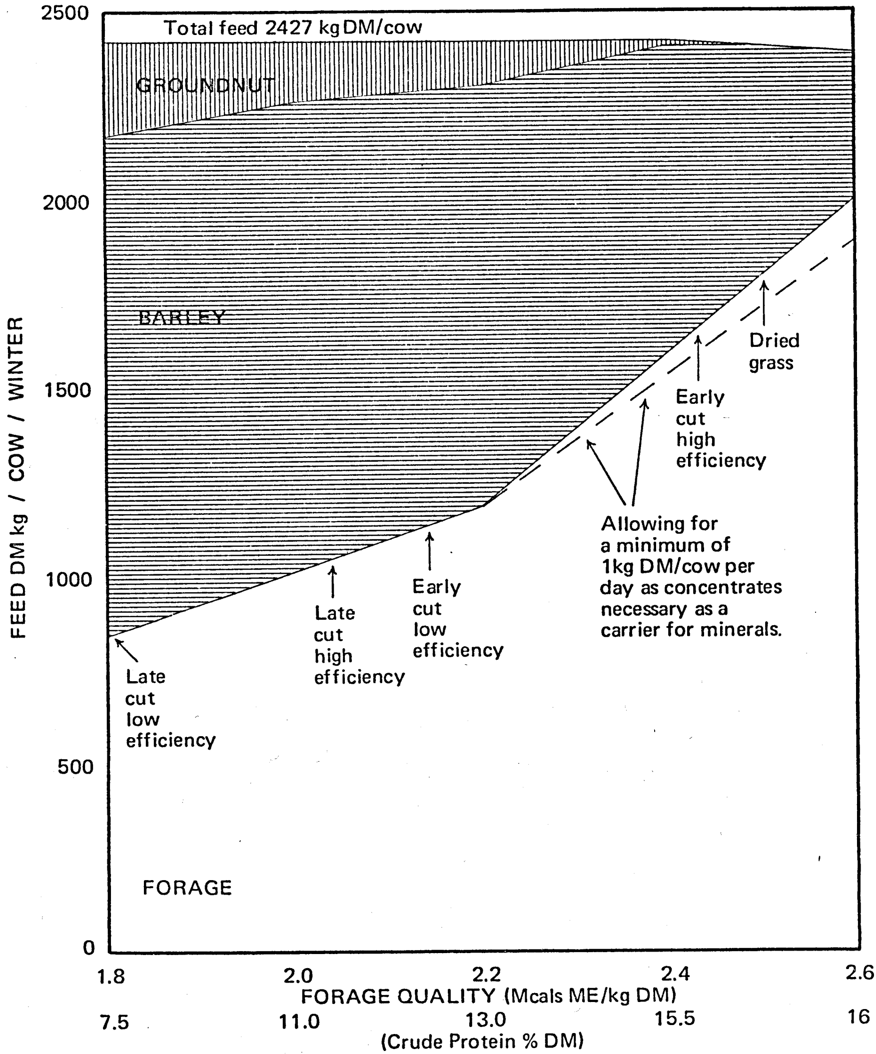
[1] Silage as per Table 4.2.

[2] Feed Prices as per Table 4.6.

[3] Output net of replacement and miscellaneous variable costs £210/cow.

FIGURE A.5 (From Table A.19)

Relationship between Forage quality and allowances of Forage, Barley and Groundnut in the diet of a 1100 gallon, September-calving Friesian cow for 180-day winter.



The only food costs calculated so far relate to winter feeding, the summer costs are calculated as follows:

September calving cow:

Fertiliser cost/grazing acre

250 units N = 10·5
50 units P = 2·2

12·7

Cost per cow at 0·5 acres £6·35.

Concentrate Cost

30 days in Autumn early lactation yielding 4·5 gallon milk/day
12·5 lb. of concentrates/day = 375 lb. (170 kg.)
= 150 kg. DM
= £5·8 at £0·039/kg.

30 days in Spring late lactation yielding 2 gallons milk/day
2·5 lb. of concentrates/day = 75 lb. (34 kg.)
= 30 kg. DM at £0·034/kg.
= £1·0

Total costs for 180 days of summer grazing:

Fertiliser	£6·35
Concentrates	£6·80
	£13·15/cow at 0·5 acre per cow.

For 240 days of summer, costs and acreage requirements are proportionately increased, thus a September-calving cow with a 120 day winter has summer costs of £17·5 and requires 0·67 acres. Alternatively it might be assumed that with climatic conditions favouring a longer growing season neither grazing acreage nor costs would necessarily be greater than in less favoured areas restricted to a shorter grazing season and longer winter.

March calving cow:

30 days in Autumn: late lactation 2 gallons milk/day
12·5 lb. concentrates/day = 375 lb. (170 kg.) containing 12·5% GN
= 150 kg. DM
= £5·8 at £0·39/kg.

Total costs for 180 days of summer grazing:

Fertiliser	£6·35
Concentrates	£5·8
	£12·15/cow at 0·5 acre per cow.

For 240 day summer, costs are increased proportionately £16·2/cow and require 0·67 acre. Alternative assumptions involving no increase in either feed costs or grazing acres may be appropriate, as is indicated above.

Precision of Replacement Concentrate Feeding

The assessment of the potential feed value of conserved grass upon which the foregoing calculations have been based assumes that the deficiencies of lower quality feeds will be precisely identified and compensated by concentrate feeding. In practice there is considerable risk that the feeding value of poor roughages will be overestimated and concentrate supplementation will be inadequate so that milk yields (and profitability) are reduced.

Furthermore good quality silage or hay needs only moderate supplementation to provide a diet of high digestibility. With such diets self-feeding and easy-feeding systems can be adopted in which cows will regulate their own intake of feed to meet their potential requirements. This allows for a simplification of feeding methods which is attractive both from the viewpoint of housing design and labour utilisation. It is a feature of increasing practical importance as building and labour costs rise.

Both these factors add appreciably to the practical advantage of producing as high a quality of conserved grass as possible, and this is not taken into account in the preceeding calculations.

REFERENCES

1. Report of the Land Use Study Group. Forestry, Agriculture and the Multiple Use of Rural Land. H.M.S.O. 1966.
2. Agriculture's Import Saving Role—Economic Development Committee for the Agricultural Industry. H.M.S.O. 1968.
3. Agricultural Projections for 1975 and 1985—O.E.C.D., Paris.
4. Harkness, R. D. (1969). Types of British Grassland. Scottish Agriculture, Vol. 48, No. 2.
5. N.I.A.B. Farmers Leaflet No. 16. Recommended Varieties of Grasses. 1969/70.
6. Report of the Committee on Grassland Utilisation. Cmnd. 547. 1958.
7. Dairy Facts and Figures. 1968. M.M.B.
8. Cherry, M. (Ed) (1968). Grass Conservation Handbook, Farmers and Stockbreeder and Iliffe Books, London.
9. Watson and Runice (1960). Outlook on Agriculture. Vol. II. No. 6.
10. Hood, *J. Brit. Grassld. Soc. Vol. 17.*
11. Woodford, E. K. (1967). *J. Brit. Grassld. Soc.* **21,** 100–116.
12. Agricultural Research Council (1965). 'Nutrient Requirements of Farm Livestock'. No. 2. Ruminants. *Rech. Reviews* p. 260.
13. Armstrong, D. G. and Trinder, N. (1966). *J. Univ. Newcastle upon Tyne Agric. Soc.* **20,** 3–15.
14. Green, J. D., Corrall, A. J. and Terry, R. A. (1971). Grassld. Res. Inst. Tech. Report No. 8.
15. McDonald, P. and Whittenbury, R. (1968). 'Fodder Conservation'. *Symposium Proc. Brit. Grassld. Soc.* pp. 76–84.
16. Holmes, W. (1968). *J. Farmers' Club.* March.
17. Minson, D. J., Raymond, W. F. and Harris, C. E. (1960). 'Studies in the digestibility of herbage.' VIII. 'The digestibility of 537 cocksfoot S.23 ryegrass and S.24 ryegrass. *J. Brit. Grassld. Soc.* **15,** 174–180.
18. Minson, D. J., Harris, C. E., Raymond, W. F. and Milford, R. (1964). 'The digestibility and voluntary intake of (various grasses)'. *J. Brit. Grassld. Soc.* **19,** 298–305.
19. Green, J. P., Corrall, A. J. and Terry, R. A. (1971). Grass species and varieties. Relationships between stage of growth, yield and forage quality. Tech. Report No. 8. Grassld. Res. Inst., Hurley, Maidenhead, Berks.
20. Aldrith, D. T. A. and Dent, J. W. (1967). The relationship between yield and digestibility in the primary growth of nine grass varieties. *J. Nat. Inst. Agric. Botany.* II. 104–113.
21. Burg, P. F. J. van (1961). 'Nitrogen Fertilisation and the Seasonal Production of Grassland Herbage'. *Proc. 8th Int. Grassld. Congr.*, Reading. pp. 142–152.
22. Nix, J. Farm Management Pocketbook. 4th edition. Wye College. (1971).

LIST OF PUBLICATIONS

Bulletins	Price	Postage & Packing
1. Farmers and the Common Market .. .. .. B. H. Davey and S. J. Rogers	25p	3p
2. Efficiency in Agriculture and the Share of the Domestic Market.. .. .. J. Ashton	25p	3p
3. Trends in Agriculture: A Review of Current and Future Developments .. .. B. H. Davey	25p	3p
4. Elements of Agricultural Adjustment .. .. .. S. J. Rogers	25p	3p
5. Farming Systems and the Common Market .. .. C. S. Barnard, H. Casey and B. H. Davey	50p	5p
6. Farm Size Adjustment .. .. A Workshop Report	25p	3p
7. Capital Adjustment in Agriculture .. .. .. A Workshop Report	25p	3p
8. A Discussion of Current Policies and the Future Structure of Agriculture .. .. A Symposium	50p	5p
9. Stability and the Beef Market .. .. A Unit Study	50p	5p
10. The Changing Agricultural Labour Force .. .. Implications for Training C. E. Heath and M. C. Whitby	50p	5p
11. A Comparison of Structural Policies in Agriculture .. S. H. Lane	50p	5p
12. Economic Aspects of the Dairy Manufacturing Industry A Workshop Report	50p	5p
13. Hill Sheep Farming Today and Tomorrow .. .. A Workshop Report	50p	5p
14. Structural Change in Northern Farming .. .. .. Studies in Structural Change	50p	5p
15. F.E.O.G.A.: The Agricultural Guidance and Guarantee Fund of the E.E.C.	50p	5p
16. Grass Conservation and Dairy Farming .. .. .. A Workshop Report	50p	5p
Monograph		
1. Models of Population and Income: Economic Planning in Rural Areas	50p	5p

Books	*Price*	*Postage & Packing*
Economic Change and Agriculture .. .. .. Edited by J. Ashton and S. J. Rogers (Oliver and Boyd 1967)	£2·10	22½p
Research, Education and Extensions in Agriculture .. Edited by J. Ashton and R. F. Lord (Oliver and Boyd 1968)	£1·50	15p
The Economic Prospects for Horticulture .. .. Edited by E. D. Sargent and S. J. Rogers (Oliver and Boyd 1970)	£1·50	15p

Technical Papers		
TP1A. Organisational Possibilities in Farming and Types of Business Organisation .. .. by M. A. Gregory and I. S. Stephenson	15p	3p
TP2. Life Assurance in the Farming Business .. .. by Leo Ménage	15p	3p
TP3. Management Techniques for Reducing Costs or Increasing Revenues .. .. by R. W. Helme	15p	3p
TP4A. Current Taxation and Some Future Possibilities .. by R. L. Herdman and I. Weir	15p	3p
TP5. Insurance in Agriculture .. .. by C. T. Jameson and J. Rawlings	15p	3p
TP6. Budgeting and Budgetary Control .. .. by J. C. Cole	15p	3p
TP7A. Estate Duty and Capital Gains Tax in Agriculture .. by C. Townsend	15p	3p
TP8. Modern Management .. .. by J. R. Gemmell	15p	3p
TP9. Agricultural Co-operative Activities and Case Histories of Co-operatives .. .. by D. G. Bailey and E. T. Gibbons	15p	3p
TP10. Human Factors in Agriculture .. .. .. by Dr. J. D. G. Troup	15p	3p
TP11. The Role of Ergonomics in the Efficient Utilisation of Agricultural Labour .. .. by J. Matthews	15p	3p
TP12. Efficient Labour Organisation .. .. .. by N. W. Dilke	15p	3p
TP13. Labour Relations in Farming .. .. .. by D. Hodsdon and J. N. Merridew	15p	3p

Details of the publication programme and a subscription scheme can be obtained from the Administrative Officer of the Unit.

January 1972

Printed by Hindson Print Group Newcastle upon Tyne X7163