THE ROLE OF A FERTILISER TRIAL IN RECONCILING AGRICULTURAL EXPECTATIONS AND LANDSCAPE ECOLOGY REQUIREMENTS ON AN OPENCAST COAL SITE IN SOUTH WALES, UNITED KINGDOM [1]

by

C E L Humphries [2], R N Humphries [3] and H Wesemann [3]

Abstract. Since the 1940s the restoration of opencast coal sites in the UK has been predominantly to productive agriculture and forestry. With new UK government policies on sustainability and biodiversity such land uses may be no longer be acceptable or appropriate in the upland areas of South Wales. A scheme was prepared for the upland Nant Helen site with the objective of restoring the landscape ecology of the site; it included acid grassland to provide the landscape setting and for grazing. The scheme met with the approval of the planning authority. An initial forty hectares (about 13% of the site) was restored between 1993 and 1996. While the approved low intensity grazing and low fertiliser regime met the requirements of the planning authority and the statutory agencies, it was not meeting the expectations of the graziers who had grazing rights to the land. To help reconcile the apparent conflict a fertiliser trial was set up. The trial demonstrated that additional fertiliser and intensive grazing was required to meet the nutritional needs of sheep. It also showed typical upland stocking densities of sheep could be achieved with the acid grassland without the need for reseeding with lowland types. However this was not acceptable to the authority and agencies as such fertiliser and grazing regimes would be detrimental to the landscape and ecological objectives of the restoration scheme. A compromise was agreed whereby grazing intensity and additional fertiliser have been zoned. This has been implemented and is working to the satisfaction of all parties. Without the fertiliser trial it is unlikely that the different interests could have been reconciled.

Additional Key Words: biodiversity, acid grassland, landscape ecology, fertiliser application, sheep rearing.

Introduction

Since the 1940s the restoration of opencast coal sites in the UK has been predominantly to agriculture and forestry. This was in line with government policy at the time. The result has been regional and local changes in landscape character and the reduction of wildlife habitats, particularly in the uplands where there has been much less agricultural improvement. Opencast mining provided the means whereby improvement could be achieved, both physically (eg change in gradients) and economically. It was also the principal means whereby dereliction left by previous mining (surface and underground) could be cleared without additional cost to the UK tax-payer. The agricultural and forestry uses after coal extraction were accepted as standard practices by the planning authorities. In the early 1990s there was a major change in thinking by the planning authorities. This was driven by new government policies of sustainability and biodiversity (UK Government, 1990 and 1994). As a result, the restoration of sites to agriculture or forestry were no longer considered to be acceptable by default, particularly in areas of unimproved landscape and wildlife character as occurs in much of the upland landscape of the exposed coalfields in South Wales.

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[2]Undergraduate Student, School of Agriculture Food and the Environment, Cranfield University, Silsoe MK45 4DT, UK.

[3]Consultants, Humphries Rowell Associates, Loughborough, LE11 3NP, UK.

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Celtic Energy's 360 ha Nant Helen site in South Wales is an opencast operation mining anthracite and began in 1986 and was due to be restored by 2001. The site before mining had been largely open moorland, comprising a range of upland grassland and mire vegetation which was typical of the surrounding undisturbed land. Adjacent land and along the outcrop of coal which had been previously mined was restored to productive pasture and forestry. In contrast, the undisturbed land was also used for sheep and cattle grazing, but in a less intensive traditional manner without the need for reseeding and fertiliser.

One of the conditions of the planning permission was that a restoration scheme had to be submitted to the planning authority for approval within 6 years of operations starting. The planning authority indicated that the restoration to productive agriculture was not acceptable and that it expected a scheme which was compatible with the local and the premining landscape ecology.

The restoration scheme submitted in 1993 proposed to restore a varied landform and upland habitats (acid grassland, heathland, peat mire, and upland oligotrophic ponds) (Humphries, 1992). These were typical of the surrounding land and ones subsequently listed in the UK's Biological Action Plan (UK Government, 1995). The acid grassland was to be the dominant vegetation type and was to provide the landscape setting and hill grazing. There was also a small amount of enclosed pasture typical of the local valley sides.

Approval of the proposed restoration scheme was given in 1993 and some 35 ha has since been restored to acid grassland, with about 4 ha to peat mire and heathland, between 1993 and 1996. The remaining land will be restored later as mining progresses into an extension granted permission in 1998.

Although the mining company owned the land there are grazing rights as common land, and hence the acid grassland had also to provide for the needs of the graziers. Whereas the planning authority expected the return to low intensity hill farming, the graziers expected productive land for the raising of sheep and of a type similar to that previously restored in the area. The grassland in the early years met the landscape and ecological objectives, and the approval of the planning authority. However, the graziers were not satisfied and requested higher levels of fertiliser to be applied, something which the government agency charged with landscape and wildlife responsibilities did not want for fear of conversion of the grassland into improved pasture. The application of fertiliser, cultivation, liming and seeding have been the main cause of loss of upland acid grassland (UK Government, 1995).

As a means of reconciling the apparent conflict a trial was established in 1997 to investigate whether or not the acid grassland could meet the requirements of the graziers, and whether higher levels of fertiliser were needed. This paper describes the trial and the solution subsequently agreed.

The Trial

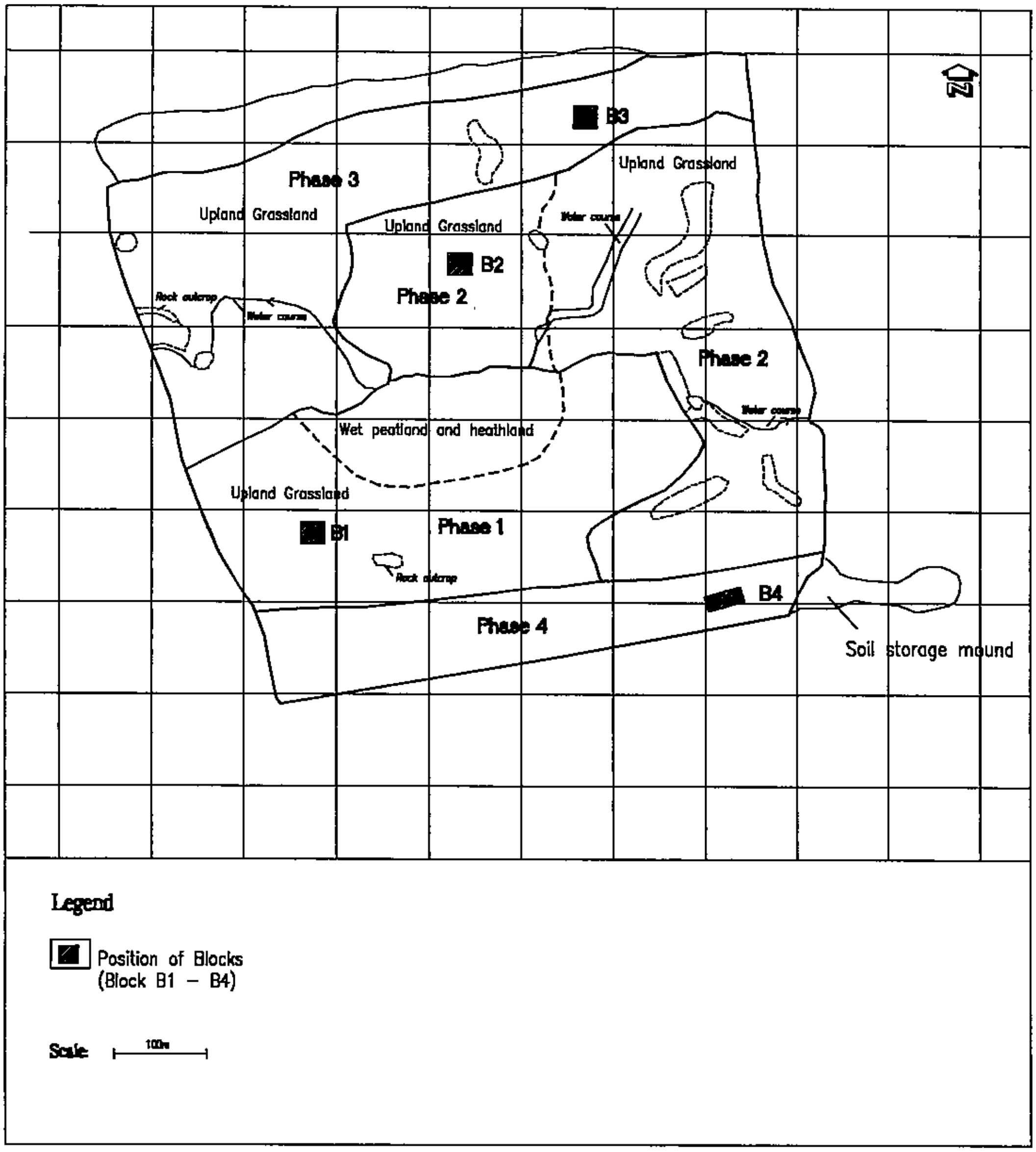
The site is at about 275m above sea level and has an annual rainfall of about 1900mm. About 40ha of the site was restored in four annual phases between 1993 and 1996. Part of the site had been worked in the 1960s resulting in the loss of soils and little soil was recoverable from the remainder. To overcome the shortage of soils a sandy shale deposit in the overburden layer was used as a soil substitute ('soil forming material'). In the areas restored to grassland this was placed at about 0.5m thickness. Texturally the soil material was typically a very stony (often 50% or more) silty clay/clay loam, moderately acidic (pH 5), and low available phosphate but very high levels of magnesium.

The acid grassland seed mixture comprised mainly highland bent (*Agrostis castellana*), sheeps fescue (*Festuca ovina*), red fescue (*Festuca rubra*), flattened meadow grass (*Poa compressa*), and ryegrass (*Lolium perenne*) with a small amount of wavy hair grass (*Deschampsia flexuosa*). Flattened meadow grass and ryegrass were included as early ground cover species for erosion control, as the other species are very slow to establish.

To aid establishment about 30kg N, 100 kg P_2O_5, and 50 kg K_2O were applied per hectare as a slow release inorganic fertiliser at sowing. Subsequently, slow release organic fertiliser applications of 56 kg N, 28 kg P_2O_5, 50 kg K_2O in the spring and 8 kg N, 38 P_2O_5, 28 kg K_2O in the autumn were applied to each phase.

The objective of the trial was to determine if the acid grassland, under the above low fertiliser regime, could meet the forage requirements for

Figure 1. Nant Helen: Location of Phases and Blocks with Fertiliser Treatments



supporting ewes with a single lamb (typical of upland flocks). If not, could this be achieved through higher fertiliser addition without the need to reseed with a lowland mixture and change in husbandry. The approach adopted was to compare production and nutritional value of the grassland under a range of fertiliser treatments. The trial incorporated combinations and rates of nitrogen and phosphorus applications as these were considered to be the prime limiting nutrients. Limestone addition, with and without additional nutrients, was also included. Both the additional fertiliser and limestone rates used were within those typically recommended for sheep enterprises.

Methods

The trial was a fully randomised block design, with a block located in each of the four years of progressive restoration (Figure 1). Each plot within the block represented a fertiliser treatment; each plot was 5m x 3m in size with a 2m guard row between them.

Twelve fertiliser treatments were applied in 1997 and 1998. They comprised background NPK with additional nitrogen and or phosphate at two levels, with limestone applied to certain combinations (Table 1). Limestone was applied to the surface of some plots. The background fertiliser was the same formulation and rates that had been applied in the spring (April) and autumn (September) following establishment (see above). All fertiliser was applied after the grass cuts were taken.

Cuts to a standard 50mm height were taken from each plot monthly from April to July with a further cut in September. The cuts were weighed (fresh weight).

Bulked tissue samples were taken during 1997 from three selected fertiliser treatments within Blocks 3 and 4 (having little ryegrass and ryegrass as a co-dominant respectively) for determination of herbage quality (water content, digestibility, metabolisable energy, and crude protein) and mineral content (phosphorus, potassium, calcium and magnesium). Tissue analyses had to be restricted and bulked samples were taken in preference to replicates. The samples represented no additional fertiliser (Plot 1) and high additional nitrogen and phosphate (Plot 7). Samples were taken in May, June, July and September before the fertiliser applications.

Soil samples were taken from the same selected treatments, but from all four Blocks, in April and September 1998 before fertiliser application for determination of extractable phosphate, potassium and magnesium, and pH.

Both tissue and soil samples were sent to a certified laboratory for analysis by standard methods (Ministry of Agriculture Fisheries and Food, 1986).

Analysis of Data

The fresh weight data were subjected to an analysis of variance (ANOVA) to separate year, treatment and block effects from background variation; this also provided an error mean square whereby a multiple range test could be undertaken. However, simple inspection of the data for evident effects was considered to be sufficient for the purpose of the trial (ie to determine trends in fertiliser effects), especially in view of the preliminary nature of the design (Ridgman, 1975). It was anticipated that these results could be used subsequently to design a more refined experiment should further work be required.

The published ranges in Speedy and Bazely (1987) for ryegrass (Table 2) were used to assess the nutritional value of the grass tissue samples, and an intake of 2.5 kg dry matter per day (MacDonald, Edwards, Greenhalgh and Morgan, 1995) the nutritional value of the grassland.

Results

Production

The total fresh weight of grass produced was higher in 1997 than 1998. However, the ANOVA only detected significant year and treatment effects, but no interaction (Table 3). Hence the fertiliser effects were similar in both years. This allowed the pooling of data for 1997 and 1998. There was also a significant year – block interaction effect, but no year - treatment interaction.

The increase in growth response to additional fertiliser indicated that nutrient availability was limiting grass production, and that additional nitrogen, rather than phosphate, was limiting production (Table 4).

Table 1. Additional Fertiliser Treatments in 1997 & 1998 *

Plot	Timing & Rate of Application (kg/ha)					Total Additional (kg/ha)			
	April	May	June	July	September	N	P_2O_5	K_2O	Limestone (t/ha)
1	-	-	-	-	-	0	0	0	
2	-	40N	20N	-	-	60	0	0	
3	-	80N	40N	-	-	120	0	0	
4	-	$26P_2O_5$	$14P_2O_5$	-	-	0	40	0	
5	-	$52P_2O_5$	$28P_2O_5$	-	-	0	80	0	
6	-	$40N+26P_2O_5$	$20N+14P_2O_5$	-	-	60	40	0	
7	-	$80N+52P_2O_5$	$40N+28P_2O_5$	-	-	120	80	0	
8	33N	50N	$50N+25P_2O_5+25K_2O$	33N	-	166	25	25	
9	1.75t/ha limestone	-	-	-	1.75t/ha limestone	0	0	0	3.5
10	1.75t/ha limestone	-	-	-	3.5t/ha limestone	0	0	0	7
11	1.75t/ha limestone	$40N+20P_2O_5$	$20N+14P_2O_5$	-	1.75t/ha limestone	60	40	0	3.5
12	1.75t/ha limestone	$80N+52P_2O_5$	$40N+28P_2O_5$	-	3.5t/ha limestone	120	80	0	7

* All plots (except Plot 8) received 53kgN/ha + 23kgP_2O_5/ha + 30kgK_2O/ha in April and 7.5kgN/ha + 37.5kgP_2O_5/ha + 37.5kgK_2O/ha in September

Table 2. Tissue Nutritional Values for Ryegrass

	Range *
Digestibility	66- 77% w/w
Metabolisable energy	9.6 - 11.6 MJ/ kg
Crude protein	120 - 220 g/ kg
Phosphorus	3.1 - 4.3 g P/ kg
Potassium	24 - 35 g K/ kg
Calcium	5.3 - 9.9 g Ca/ kg
Magnesium	1.7 - 3.6 g Mg/ kg

* Source: Speedy and Bazely (1987)

Table 3. Analysis of Variance Table

		Sum of Squares	**Degrees of Freedom**	**Mean Square**	**F-stat**	**Significance Level (%)**
Main Effects	**Year**	722.649	1	722.649	28.700	<0.1
	Block	5204.058	3	1734.686	68.893	<0.1
	Treatment	3660.297	11	332.754	13.215	<0.1
Interactions	**Year & Block**	3205.868	3	1068.623	42.440	<0.1
	Year & Treatment	142.336	11	12.940	0.514	NS
Error		1661.835	66	25.179		
Total		14597.043	95	153.653		

NS = not significant

Table 4. The Effect of Additional Fertiliser Application on Grass Production

Plot	Additional Fertiliser (kg/ ha)		Mean Total Fresh Weight per Plot on Average Over 1997 & 1998 (kg/plot)
	N	P_2O_5	
1	0	0	5.7
2	60	0	14.8
3	120	0	18.6
4	0	40	6.4
5	0	80	6.5
6	60	40	14.9
7	120	80	26.1
8	166	25	19.2

Phosphate became limiting above about 120 kg of additional nitrogen/ha, and for a response to higher nitrogen applications, phosphate would be required. There was no increase in growth with the addition of limestone (Table 5).

Table 5. The Effect of Limestone Application on Grass Production

Plot	Additional Fertiliser (kg/ ha)		Limestone (t/ha)	Mean Total Fresh Weight per Plot on Average Over 1997 & 1998 (kg/plot)	pH
	N	P_2O_5			
1	0	0	0	5.7	5.3
6	60	40	0	14.9	-
7	120	80	0	26.1	5.2
9	0	0	3.5	9.4	5.5
10	0	0	7.0	6.1	5.0
11	60	40	3.5	11.8	-
12	120	80	7.0	20.2	-

The year - block interaction was due to the almost total decline in ryegrass in 1998 in Block 4 (the phase established in 1996). The same had already occurred in the other blocks after two years from establishment. The decline was attributed to the acidity of the soils, rather than soil nutrient deficiencies, as the ryegrass did not persist even when the highest levels of fertiliser were applied.

Forage Value

Digestibility of the grass cuts from the ryegrass – bent – fescue co-dominant Block 4 was within the range given in Table 2 in all cuts and fertiliser treatments (Table 6); except for the autumn September cut in the absence of additional fertiliser. Similar digestibility was only achieved in the bent – fescue dominated Block 3 (without ryegrass) in the early summer samples, in the late summer and autumn digestibility was lower; fertiliser addition had no effect on digestibility of this grassland.

Generally, metabolisable energy values for both types of grassland were greater than (early summer) and within (late summer and autumn) the range given in Table 2. Fertiliser addition had no effect on metabolisable energy levels.

Crude protein values were above or within the range given in Table 2 in all samples from both grassland types when additional fertiliser was applied, but only in the early summer samples in the absence of additional fertiliser.

Tissue phosphorus levels were similar in the two types of grassland with no seasonal trend or effect of additional fertiliser (Table 7). However, levels were below the range in Table 2.

Trends in tissue potassium were more variable than phosphorus, and lower in the absence of additional fertiliser in both types of grassland where the level fell well below the threshold given in Table 2.

Tissue calcium levels were similar for the two grassland types and were not affected by additional fertiliser addition. There appeared to be a seasonal effect with higher levels in late summer and autumn. Tissue calcium levels did not reach the range given in Table 2.

Magnesium levels were similar in both types of grassland and unaffected by fertiliser addition, and were in the range given in Table 2.

Table 6. Forage Value of Harvested Grass Tissue

Dry Matter (%w/w)

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1	32.6	32.5	38.7	39.6	22.7	27.0	25.2	18.8
7	32.2	27.1	29.7	29.7	21.0	23.2	23.1	14.2

Digestibility (neutral detergent cellulase digestion (%w/w))

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1	77.6	77.0	67.2	59.7	79.4	80.4	61.5	61.6
7	79.6	78.5	55.9	60.8	83.4	80.0	68.1	67.3

Metabolisable Energy (MJ/kg)

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1	11.9	12.0	10.7	10.0	12.1	12.3	10.1	10.1
7	12.1	12.1	9.4	10.0	12.5	12.3	10.8	10.9

Crude Protein (g/kg)

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1	184	150	90	100	167	150	103	116
7	184	259	130	116	199	227	173	217

* Plot 1 no additional fertiliser
Plot 7 additional high nitrogen and phosphate

Table 7. Mineral Nutrient Content of Harvested Grass Tissue

Phosphorus (g/ kg)

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1*(1)	2.4	2.1	1.6	2.3	2.1	1.9	2.0	2.1
7*(2)	2.2	2.0	1.9	2.7	2.0	2.2	2.2	2.3

Potassium (g/ kg)

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1	21.90	28.70	14.50	17.20	25.00	21.50	19.40	12.50
7	22.30	27.10	20.20	26.90	24.80	26.30	27.90	18.20

Magnesium (g/ kg)

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1	1.7	2.2	1.5	1.7	1.7	1.4	2.0	1.1
7	1.8	2.1	·1.9	2.6	1.7	1.8	2.4	1.4

Calcium (g/kg)

Plot *	Block 3				Block 4			
	May	June	July	Sept	May	June	July	Sept
1	1.4	1.9	2.6	2.3	1.3	1.7	2.6	2.2
7	1.2	1.7	2.3	3.3	1.7	1.4	2.5	2.4

* Plot 1 no additional fertiliser
Plot 7 additional high nitrogen and phosphate

Soil Nutrients

The spring soil analyses confirmed the moderate acidity, low phosphate and potassium, but high magnesium status of the materials. Soil phosphate level appears to be increasing with time, although additional phosphate appeared to have little effect on soil status (Table 8). The surface application of limestone also appears to have had little effect on pH (Table 5).

Table 8. Spring Soil Nutrient Levels

Phosphorus (mgP/l of <2mm fraction)

Plot *	Block 3		Block 4	
	1997	1998	1997	1998
1 *(1)	7.6	15.8	6.2	11.4
7 *(2)	6.6	14.8	5.8	13.0

Potassium (mgK/l of <2mm fraction)

Plot *	Block 3		Block 4	
	1997	1998	1997	1998
1	78	172	88	146
7	81	143	48	120

Magnesium (mgMg/l of <2mm fraction)

Plot *	Block 3		Block 4	
	1997	1998	1997	1998
1	116	231	323	400
7	169	166	249	270

pH (<2mm fraction in water)

Plot *	Block 3		Block 4	
	1997	1998	1997	1998
1	5.0	5.2	5.2	5.3
7	5.2	5.4	5.0	5.2

* Plot 1 no additional fertiliser
Plot 7 additional high nitrogen and phosphate

Discussion

Production

The trial demonstrated that the quantity of grass production is largely determined by three factors, weather, grassland composition, and soil nitrogen level.

The higher spring and summer temperatures in 1997 probably explains the higher production in 1997. Rainfall, which was markedly higher in 1998, appears to be of less importance.

Whilst potentially a greater amount of grass is likely to result from grassland with ryegrass, the trial also demonstrated that ryegrass is unlikely to persist for more than two years in the acidic soils, even when additional fertiliser is applied. The soils are inherently acidic and favour the bent - fescue grassland even when limestone is applied.

The amount of grass produced is determined primarily by the level and timing of nitrogen. Without fertiliser application grass production is limited to the May – June period (Table 9). Fertiliser nitrogen applied in the early spring and late summer is needed to extend the grazing period.

Assuming a dry matter requirement of 2.5 kg/day (McDonald et al, 1995), it is possible to estimate the stocking density of ewes (with lamb) the grassland might support during the grazing season (April – September) from the fresh weight harvests and tissue data in Table 6.

Stocking density = (fresh weight per ha x % dry weight / number of days between harvest) / 2.5

This exercise was carried out for Blocks 3 and 4 for which there were data.

The stocking density was markedly lower in the acid type of grassland (Block 3) compared with the more lowland ryegrass type (Block 4). The application of additional fertiliser raised the carrying capacity in the early, late summer and autumn in both grassland types (Table 10), but not in the spring in the bent – fescue acid grassland where growth is later in starting than when ryegrass is present. The stocking density of the ryegrass grassland type was higher in the spring and was raised in the spring by the additional fertiliser. Although the carrying

Table 9. Patterns in Grassland Production (Average for bent-fescue swards, Blocks 1, 2 & 3)

	Fresh Weight kg/ plot								
Plots *	**April - May 97**	**May - June 97**	**June - July 97**	**July - Sept 97**	**Sept 97 - April 98**	**April - May 98**	**May - June 98**	**June - July 98**	**July - Sept 98**
Treatment 1	0.75	0.85	0.96	0.34	0.46	0.99	1.06	1.13	0.37
Treatment 7	0.75	1.79	10.29	2.90	1.22	1.21	2.13	12.53	1.50

* Plot 1 no additional fertiliser
Plot 7 additional high nitrogen and phosphate

Table 10. Estimated Stocking Density of Grassland in 1997

		Number of Ewes per Hectare				
	Plot *	**April - May**	**May - June**	**June - July**	**July - Sept**	**Average over Grazing Season**
Block 3	1	3.0	6.3	3.0	1.1	3.3
	7	2.4	10.4	23.9	4.9	10.4
Block 4	1	11.5	13.0	7.0	2.2	8.4
	7	15.0	22.2	38.2	13.7	22.3

* Plot 1 no additional fertiliser
Plot 7 additional high nitrogen and phosphate

capacity was lower in the acid grassland it did, with additional fertiliser provide for 6 – 10 ewes/ha during the summer, an acceptable target for hill livestock enterprises. However, the bent -- fescue acid grassland type was unlikely to support early spring grazing, but this is typical of upland hill grazing where there is reliance on low lying improved pastures.

Forage Value

The difference in digestibility of the two types of grassland is genetically based and is a reflection of the higher fibre content in bents and fescue grasses (Spedding and Diekmahns, 1972; Gill and Vear, 1980). However, the digestibility of the acid grassland can be maximised by keeping the grass in the pre-stem elongation growth stage by continued intensive grazing. The low phosphorus and calcium status of the grass tissue is also partly genetically controlled with the bent and fescue species having lower levels than ryegrass (Spedding and Diekmahns, 1972). The low soil levels are also a contributing factor to tissue levels, and this could be corrected by fertiliser and lime addition.

Assuming a dry matter intake of 2.5 kg/day, both types of grassland are likely to meet the energy needs of lactating ewes with a lamb (McDonald et al, 1995), and should result in live weight gains. For satisfactory crude protein levels additional nitrogen fertiliser would be necessary in the summer. However, the late season utilisation of the bent – fescue grassland may be lower than with ryegrass owing to the decrease in digestibility, but this may be of less importance as the lambs will be fully weaned by this time.

At a daily intake of 2.5kg dm/day the phosphorus tissue concentrations should meet the requirements of 4.6 – 5.4 g P/kg cited by McDonald et al (1995), and daily requirements of magnesium are also likely to be met. In contrast, it is unlikely that calcium and potassium requirements will be met without fertiliser and lime additions.

An Agreed Solution

In terms of grassland production for sheep, the trial supported the case by the graziers that additional fertiliser was required, with fertiliser nitrogen required across the growing season. The trial also supported the planning authority view that the restored land need not be reseeded and could provide for agricultural use.

In terms of landscape ecology, the trial supported the planning authority and wildlife agency view that the character of the grassland would change if the grazier's agricultural requirements were to be implemented (ie higher fertiliser application and intensive grazing). However, the low fertiliser - low grazing intensity regime was not acceptable to the graziers.

A compromise solution was proposed by Celtic Energy whereby the acid grassland was to be retained and fertiliser application was to be 'zoned'. The 'lower' slopes were to receive additional fertiliser and were to be grazed throughout the growing season (March – November). The 'upper' slopes were to receive no additional fertiliser and were to be grazed April to mid-summer. The intermediate areas were to receive lower additional fertiliser and a restricted grazing period. The scheme was agreed to by all parties and was implemented. Currently the scheme appears to be meeting the requirements of all parties.

It was agreed that the trial had served its purpose and that no further experimentation was required for the time being. Without the fertiliser trial it is unlikely that the different interests could have been reconciled.

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