MINISTRY OF AGRICULTURE, FISHERIES AND FOOD **CSG 15**

Research and Development

Final Project Report

(Not to be used for LINK projects)

Two hard copies of this form should be returned to:
Research Policy and International Division, Final Reports Unit
MAFF, Area 6/01
1A Page Street, London SW1P 4PQ
An electronic version should be e-mailed to c.csgfinrep@csg.maff.gsi.gov.uk

Project title	Organic Sheep and Beef Production in the Uplands
MAFF project code	**OFO147**
Contractor organisation and location	ADAS Redesdale Rochester, Otterburn Newcastle upon Tyne NE19 1SB
Total MAFF project costs	£ 648022
Project start date	04/01/98
Project end date	31/03/01

Executive summary (maximum 2 sides A4)

To study the potential of organic farming in the hills and uplands, a comparison of organic and conventional production systems at similar stocking rates was made at ADAS Redesdale. This was supported by additional assessments in two further organic flocks, managed at reduced stocking rates, and by data collection on 10 commercial organic farms. Data were provided on physical and financial performance, animal health and welfare, and changes in botanical composition. Specific studies were done to quantify the potential of novel crops for parasite control, the performance of treated and untreated animal manures, and the requirement for trace element supplementation in organic hill stock.

The direct comparison of organic and conventional systems at similar stocking rates (Dipper split heft) was maintained until mating in November 2000. Over the three-year period individual animal performance on the Organic Dipper continued a long-term decline relative to the conventionally managed flock. Organic ewes were significantly lighter ($p < 0.001$) at all stages of the production cycle. Poorer condition at mating was reflected in a lower lamb crop (108% *v.* 129%) for organic and conventional flocks respectively. Daily liveweight gain from birth to weaning (206 g/day *v.* 192g/day) was also significantly reduced ($p<0.001$) in organic lambs. This result confirmed the trend ($r = -0.39$) towards a progressive decline in the growth rate of organic lambs since 1992. Analysis of lifetime performance for each intake of homebred flock replacements, confirmed that across years organic breeding ewes were significantly lighter ($p< 0.001$) at each of first to fifth mating. Although differences in litter size were not statistically significant after first mating, organic ewes carried significantly ($p< 0.001$) fewer twins as determined by pregnancy scanning at second and third parity. Measured as numbers of lambs produced, ewes in the conventional flock tended to have a higher lifetime output ($p>0.10$). When organic stock were managed at reduced stocking rates (Cairn and Burnhead flocks), individual ewe and lamb performance were at higher levels. Lamb rearing percentage averaged 110% and 111% for Cairn and Burnhead flocks, with lamb daily liveweight gains of 210g and 204g respectively. Overall animal health and welfare was good. However, mortality rates tended to be higher in the Organic Dipper flock, reflecting increased nutritional stresses at similar stocking rates to the conventional. To date, there have been no adverse effects of removing clostridial and pasteurella vaccination from the Cairn flock. The majority of lambs were sold satisfactorily as stores for further finishing on an organic lowland farm. The price differential for organic lambs was 30%-40% above conventional prices. Flock gross margins averaged £30, £37, £40 and £39 for Conventional Dipper, Organic Dipper, Cairn and Burnhead flocks respectively.

Conception rates in the organic suckler herd were consistently 90%-95%. Calves grew at over 1 kg liveweight per day from birth to weaning, and 0.8 kg overall from birth to sale, normally at 16/17 months of age. Store cattle were sold at a premium of 25%-30% over conventional prices (110p and 130p/kg liveweight for heifers and steers respectively). Finished heifers sold autumn 2000, averaged 230p/kg and 261kg dead weight. Average suckler herd gross margin (including rearing and finishing) was £506 per cow.

The results from the Linked Farm Survey compared favourably with those achieved on the unit at Redesdale, and on Farm Business Survey (FBS) costed conventional farms. Mean stocking rate was calculated to be 0.9 Grazing Livestock Units (GLU) per adjusted ha, compared to 1.3 GLU for University College Wales and 0.7 GLU for Newcastle University FBS samples respectively. Lamb rearing percentage averaged 112%, compared to 115 % across three flocks at Redesdale. Sheep gross margins (before forage) averaged £52, £45 and £37 for Linked Farms, Redesdale and FBS farms respectively. Suckler herd gross margins (£/cow) averaged £301, £325 and £235. Fixed costs per adjusted ha varied greatly, reflecting differing enterprise requirements for capital investment, the individual nature of each business, and the willingness of the occupier to invest in farm infrastructure. While the majority of farms generated a profit, large capital expenditure on individual farms tended to skew the group average. Over the three years, Net Farm Income (NFI) per adjusted ha averaged £3, £91 and £58 for Linked Farms, Redesdale and FBS farms respectively. Data from the study were supplied to the Institute of Rural Studies (IRS) for incorporation into a wider economic appraisal of organic systems.

Overall, there were no statistically significant differences in botanical composition on native or improved hill land due to organic or conventional management. At similar stocking rates (Dipper split heft), heather cover on the native hill declined significantly under both management regimes. Where stocking rates had been reduced by 25% on the Cairn heft, heather did not show the same decline, but there was a trend towards an increase in *Molinia,* suggesting a lack of sufficient grazing pressure during the summer months. On the improved hill pastures, sown species content (ryegrass and white clover) declined on both organic and conventional areas, continuing the long-term regression of these swards, following land improvement 15-20 years previously. From aerial photography, percent rush cover was estimated at 18% to 49%, representing a loss in usable dry matter of 21% - 25%. On organically managed inbye fields clover cover was significantly higher, compared with conventional pasture receiving over 200 kg N ha^{-1} annually. In terms of herbage dry matter yield, organic swards consistently produced 75% of output on the conventionally managed fields. Botanical composition was strongly influenced by age of sward, and site conditions such as proximity to sources of weed invasion (e.g. persistent seedbank, seed-shed, invasion from adjacent land) and sensitivity to vectors such as ground disturbance. Immediately after reseeding, organic swards had a high level of annual weeds (notably chickweed) but these did not persist into the second year. On one field, docks increased to 30% cover before reseeding in spring 2001, illustrating the difficulty in controlling an established population of docks in organic semi-permanent grassland.

Autumn-sown birdsfoot trefoil failed to establish at Redesdale, and produced a crop only from early summer sowing. From IRS data, establishment rates of spring-sown crops of birdsfoot trefoil and chicory were approximately 70% and 85% respectively. Lambs fed birdsfoot trefoil had consistently lower faecal egg counts compared with those fed ryegrass/white clover. Conflicting results were obtained for chicory, which reduced faecal egg output in two years out of three. It is suggested that chicory may reduce parasite load by limiting the migration of larvae above 5cm on the plant, or by improving copper status in the lambs.

The third year of a replicated plot experiment was completed on an upland ryegrass/white clover pasture, comparing the agronomic effects of composting farmyard manure and aerating slurry, with zero nitrogen and conventional nitrogen control treatments. Compared to untreated controls, a yield advantage of 22% was obtained following the application of 240 kg N ha^{-1} ammonium nitrate. Slurry and farmyard manure applied at 120- 150 kg total N ha^{-1}, increased herbage yield by 11-14%. No benefits were apparent from aerating slurry.

In a pilot survey, seven out of nine linked farms considered they had an inherent trace element problem. Blood samples taken from lambs after weaning showed all farms to be above the reference range for copper, seven were deficient or marginal in selenium, and three marginal or deficient in cobalt. A combination of management and direct approaches (mainly conventional methods e.g. pasture treatments, stock supplementation, slow release boluses etc.) were used for supplementation. One producer changed from a spring calving herd, to a purchased store cattle enterprise, to overcome chronic selenium deficiency. On the unit at Redesdale, blood copper levels in lambs varied according to flock ($p < 0.001$), reflecting differences in botanical composition on the native hill. Copper levels were generally adequate, but significantly lower in the more highly stocked Dipper flocks. Selenium levels (GSH-Px) varied with season, but were sub-optimal in each of the three years. For individual animals, there was no consistent correlation between blood copper or selenium levels and improved growth rate. Use of a trace element bolus raised circulatory levels of all three trace elements. However, there were no significant effects on ewe liveweight, litter size or barren rate, compared to unsupplemented animals.

This research provides long-term comparative data on the performance of organic systems in the hills and uplands, thereby supporting government policy to promote the development of organic farming.

Scientific report (maximum 20 sides A4)

1.0 Introduction

It is Government policy in the UK to provide a framework in which organic farming can develop, promoting more sustainable and environmentally sound systems of livestock production. Scientific information is required on the development, performance and limitations of organic systems, to facilitate informed decision-making and to aid policy formulation (House of Commons Select Committee, 2000). Using the established organic unit at Redesdale, the overall objective of this project was to evaluate and demonstrate the long-term potential of organic livestock production in the hills and uplands.

2.0 Objectives

The overall objective of the project was to evaluate the physical and financial performance of upland organic beef and sheep production. Specific objectives were to:-

1. Manage the Unit to UKROFS standards, maintaining organic status on approximately 600 breeding ewes (in three flocks) and a herd of 30 suckler cows.

2. Compare the physical and financial performance of organic and conventional hill farming systems, identifying problems and constraints to sustained organic production, as well as longer-term effects on animal health and soil nutrient status.

3. Monitor 10 commercial hill/upland farms, organically managed or undergoing conversion. From the information collected from these linked farms, to provide each year a summary report and analysis of financial performance.

4. Using revised methodologies, to continue to assess the effect of organic management on botanical composition and vegetation change.

5. To complete the final year (1998/99) of a three-year plot experiment to assess the performance of various forms of animal waste when applied to a high clover organically managed sward.

6. To establish during 1998/99 a three-year collaborative experiment, to evaluate the potential of novel crops (e*.g. Lotus spp.*) for controlling parasitic gastro-enteritis in sheep.

7. From data collected at Redesdale and Pwllpeiran during 1998/99, to analyse the relationship between trace element levels in organic and conventionally managed soil, herbage and livestock, providing recommendations for further research, if appropriate.

8. Over the life of the project, to provide for adequate dissemination by a variety of media to organic and conventional sections of the industry

9. Maintain a Project Steering Committee, meeting twice a year to make recommendations on the overall direction, implementation and promotion of the research

3.0 Materials and Methods

The research was a collaborative study centred round the organic unit at ADAS Redesdale, and involving Institute of Rural Studies at University of Wales (Novel forages), Newcastle University (Vegetation monitoring), and commercial organic farms (Linked Farms Study). The management and implementation of the research was overseen by a Project Steering Committee, chaired by MAFF (now part of Defra), and made up of representatives from The Soil Association, Elm Farm Research Centre, organic farmers, Ecostopes Consultancy, and a farm veterinary surgeon.

3.1 Systems based studies (Objectives 1, 2, 8 and 9)

The experiment was sited on one discrete farm unit covering 518 ha. Approximately 400 ha had been put into conversion in 1991, so that the experimental period (1998-2001) represented years 5 to 8 years of full organic production.

Grassland

Grassland management was a modification of the 'Two Pasture' system of hill land management, making strategic use of three types of grazing (native hill, improved hill and inbye fields) to optimise sheep and beef production. The native hill is predominately peat, of varying depths, supporting typical hill vegetation of *Molinia* (Purple Moor Grass), *Calluna* (Heather) and *Carex spp*. (sedges). Improved pastures (reseeds) were established during the 1970's and 1980's by reseeding drier areas of the native hill. The improved swards still contained a proportion of sown species (ryegrass and white clover), but there was a high content of *Holcus* (Yorkshire Fog) and *Poa (*Meadowgrass) species. The inbye fields contained a range of mineral and peaty soils, and represented the best land on the unit. Sown species content on inbye fields was high (typically 60%-80%).

No inputs were made to organic or conventional areas of native hill. Conventionally managed hill reseed received 50 kg N ha $^{-1}$ in the spring. There were no inputs on organic managed reseeds, but some areas were taken for silage in August each year. All reseeds were cut or topped to control rushes. Conventionally managed inbye fields received an average of 230 kg N ha $^{-1}$. Given the small proportion of total land area, management on the inbye fields is relatively intensive, with these areas expected to produce early season grazing, conserved fodder, and autumn grazing for finishing stock or replacement ewe lambs. Inputs to the organically managed inbye fields were solely from slurry or FYM.

Comprehensive measurements were made of soil fertility, botanical composition and forage output. Soil cores were taken between November and February from all hill reseeds and inbye fields. Soil nutrient status was determined from samples take from the 0-7.5 cm horizon, and analysed using standard techniques for pH, extractable P, extractable K extractable Mg, total and available nitrogen. Botanical composition was assessed using a rapid grid technique (at similar quadrat points each year) which provided a measure of dominant and co-dominant species. Dominance scores were converted to percentage cover by dividing by 1.5. To measure forage output, measurements were made of herbage available at the beginning and end of the grazing season, herbage dry matter taken as forage, and number of grazing days by each category of stock. To provide a common basis for comparison, these data were converted to livestock unit grazing days (LUGD) following the method described by Pollot and Kilkenny (1976).

Livestock

The sheep on the unit were managed in four distinct flocks (Table 1). Following the splitting of one original heft in 1991, to form two areas of equal stock carrying capacity, two sub-flocks (Organic and Conventional Dipper flocks) provided a direct comparison of organic and conventional management. Stocking rates on the Cairn and Burnhead flocks were reduced from their original levels by 25% and 15% respectively in 1995.

Table 1. Mean sheep stocking rates on the unit (1998-2000)

	Con. Dipper	Org. Dipper	Cairn (Org)	Burnhead (Org)
Breeding ewe numbers	181	180	153	171
Ewe hogg replacements	58	58	52	55
Land area: Native hill	58 (71%)	77 (74%)	130 (79%)	86 (71%)
Improved hill	19 (23%)	21 (20%)	30 (18%)	30 (25%)
Inbye land	5 (6%)	6 (5%)	5 (3%)	5 (4%)
Total hectares	82 (100%)	104 (100%)	165 (100%)	121 (100%)

Scottish Blackface ewes were mated in November each year on improved areas of the hill. Over a four-year cycle, the same Scottish Blackface rams were used in each flock. The ewes were pregnancy scanned in February, and twin-bearing ewes segregated for better feeding. Twin-bearing ewes were housed in late March, and were retained on inbye fields for 5 weeks after lambing. Mean feed inputs are given in Table 2.

Table 2. Sheep flocks – mean annual feed inputs (kg/dry matter)

		Con. Dipper	Org. Dipper	Cairn (Org)	Burnhead (Org)
Ewes	Hay	39.0	41.6	27.7	44.5
	Silage	28.4	4.8	2.7	5.4
	Feed blocks	6.2	8.1	7.0	7.2
	Concentrates	35.8	28.6	27.9	27.6
Hoggs	Hay	5.7	2.2	3.2	2.9
	Silage	30.0	27.5	24.8	27.3
	Concentrates	32.2	45.8	48.1	48.8

Detailed flock records were maintained covering physical and financial performance. The incidence of disease, stock deaths and post-mortem results were maintained. Detailed parasitological data were taken including routine faecal and blood samples.

Suckler herd

The organic suckler herd of Angus X Friesian cows was managed to calve from mid-April each year. In July, the cows were mated to either a Charolais or Limousin bull on improved areas of the hill. The herd was housed in November, and the calves weaned in January at approximately 8 months of age. The cows were fed predominately on silage, which ensured that 99% of the winter ration (by dry matter) was organically produced. Mean dry matter intakes (per cow) over a 200-day winter were 2,128 kg silage, and 66 kg of concentrate (cereal, beans, minerals and seaweed supplement). Calves were fed silage, plus a concentrate ration of organic cereal/beans increasing to 2.0 kg/day fresh weight. Mean dry matter intakes for calves over the winter period were 967 kg forage and 307 kg of concentrate.

In 1998 and 1999, all calves were sold store in the spring at approximately 12 months of age through the Organic Livestock Marketing Co-operative (OLMC). In 2000, the male calves were sold store. However, the heifer calves were retained for a second summer, and finished successfully with some concentrate supplement (1kg/head/day) at 16-18 months of age.

3.2 Linked farms study (Objective 3)

To broaden the study, 10 hill and upland farms were recruited to provide information on physical and financial performance under commercial conditions. Geographically two clusters of farms were involved; Wales, and Northern England/Southern Scotland. Eight farms were fully converted to organic production, and are reported here. Although data were collected, information from two in-conversion farms has been excluded from the final collated results. The intention was to include these farms in the sample means once they had fully converted.

The sample was made up of a diversity of farm sizes and types. Farm area ranged from 55 ha to 733 ha with six farms extending to 100 ha or more. All farms had Less Favoured Area (LFA) status. Agricultural output was mainly based on sheep and cattle production. Pasture quality varied, from a very traditional hill farm with little improved land, to a farm with a high proportion of sown swards and some arable cropping.

Physical and financial data were collected, in addition to management information. Six farms were fully costed using ADAS business recording software (ABRS) to provide a management account, balance sheet and individual gross margin. The remaining two farms provided information to enterprise gross margin level only. Each farm business was costed using invoice-based recording of all financial transactions and physical transfers. Costs and returns were allocated to enterprises according to the farm records. Depending on the farm, financial year end ranged from December to May. All subsidies related to the same production year. Farm Business Survey data (Newcastle University, and University College Wales) for conventional hill and upland farms, as well as results from the organic unit at Redesdale, were used to assess commercial performance of the organic linked farms.

3.3 Vegetation monitoring (Objective 4)

Vegetation on native hill, improved hill and inbye fields was surveyed using a combination of 1) quadrat data collection, using a 1 m^2 rapid grid technique 2) ADAS Stand technique (Critchley and Poulton, 1998), and 3) low flight aerial photography (approx. 1:5500 scale). Aerial photos were scanned into digital format, and converted to a vegetation map using image processing software. The maps were imported into a GIS where assessments of cover were made based on the known area of the management unit. These data were used to investigate vegetation dynamics, by analysis of species data, and by using a community-based multivariate modelling technique based on National Vegetation Classification (Rodwell, 1991).

3.4 Sources of nitrogen trial (Objective 5)

Seven treatments were imposed in a randomised complete block design, to assess the agronomic performance of different forms of organic manure applied to upland grass/clover pasture. The treatments were; composted (Treatment A) and uncomposted (B) FYM; aerated (C) and unaerated (D) cattle slurry; ammonium nitrate (E); and zero nitrogen control (F). A further control treatment (G), to which slurry was applied in 1996 only, was added to provide a common control treatment over the first two years of the experiment. For the organic unit as a whole, it was calculated that 150 kg total N ha^{-1} would be available from livestock wastes. This rate of total N was applied to untreated slurry and FYM treatments. Following aeration, a similar volume of slurry was applied to treatment C as to unaerated slurry treatments. Ammonium nitrate was applied at a rate equivalent to 240 kg N ha^{-1}, consistent with conventional management at Redesdale. A mix of FYM from cattle and sheep enterprises was stockpiled and composted over a seven month period. This was applied at a rate calculated to supply 80% (120 kg ha^{-1}) of total N compared to untreated FYM treatment.

Simulating grazing and cutting management, herbage dry yield was assessed by mowing four times over the growing season. At each harvest date, botanical composition was assessed by pre-cutting a strip within the area to be mown, and hand sorting into grass, clover and weeds. A sample of dried herbage, bulked for each treatment, was sent for laboratory analysis. For each harvest date, data were obtained for crude protein (CP), digestibility (NCDG), total ash, total P, and total K content. At the end of each grazing season, five samples of soil were taken to a depth of 0-7.5 cm from all plots, and analysed for extractable P, extractable K, extractable Mg, pH, organic matter, total nitrogen, nitrate-N, ammonium-N.

3.5 Novel forages (Objective 6)

The potential for novel crops to control internal parasites in sheep was assessed through a combination of field studies and small plot experiments. Field trials were undertaken on two sites (Redesdale and at the Institute of Rural Studies, IRS Aberystwyth) to assess crop performance under differing climatic conditions. IRS undertook more detailed small plot studies to investigate potential mechanisms through which novel crops could affect parasite burden.

Redesdale site

Birdsfoot trefoil (*Lotus corniculatus* - variety Upstart) was sown in July 1998 as a pure stand at a seed rate of 18kg/ha. Originally, a 2 x 2 factorial design of sward type (*Lotus v.* ryegrass/white clover) and drenched *v.* undrenched lambs was planned. However, due to poor establishment of *Lotus,* the drenching treatment was abandoned. Following an August sowing in 1999, establishment was so poor that no lambs could be put onto the experimental plots. In 2000, the *Lotus* experimental plots were sown in May using the variety Leo (which from previous results at IGER was expected to be more reliable) as a replacement for Upstart. Assessments were made to determine seedling establishment, sward composition and herbage dry matter yield. Faecal egg output was measured in Scottish Blackface lambs weekly. Blood samples taken fortnightly, and analysed for blood pepsinogen levels.

Aberystwyth site

In each of three years, experimental plots were sown with either chicory (*Chicorium intybus*), birdsfoot trefoil, or ryegrass/white clover, to provide each treatment with two 0.5 ha replicates (10 –12 lambs per replicate). Chicory and birdsfoot trefoil were sown as monocultures at high seed rates of 18 kg ha $^{-1}$ and 20 kg ha $^{-1}$ respectively. Assessments were made of crop establishment rate, dry matter yield, botanical composition, nutritive value and trace element (Cu, Co and Se) levels. The effect of crop type on parasite burden was studied in weaned Lleyn lambs. Measurements were made of faecal egg count, plasma pepsinogen, peripheral eosinophil count, and trace element status. Total worm burden was recorded in lambs *post mortem* in years 2 and 3. The duration of the trial varied from 5 to 6 weeks, and was governed each year by herbage availability. The effects of crop type on hatching, development, survival and migration of free-living larval stages of the parasite were also studied in pot and small plot experiments, which included Greater birdsfoot trefoil (*Lotus pedunculatus*) as a further novel forage.

3.6 Trace element study (Objective 7)

As a pilot study, the relationship of herbage composition, trace element status in lambs, and the requirement for additional supplementation was analysed from data provided from ADAS Redesdale, ADAS Pwllpeiran, and the commercial organic farms linked to the study. Information on livestock and grassland management, and in particular any supplementation practices undertaken, were obtained by questionnaire from 9 of the 10 organic farms. For each farm, blood samples were taken 3-4 weeks after weaning, from 18 lambs per site (6 poorer, 6 average, and 6 better animals in each flock). Bloods were analysed for copper, cobalt and selenium by the local Veterinary Investigation Centre.

To measure whether or not there were any responses to trace element supplementation, a third of ewes in each of the four flocks studied at Redesdale were given (at random), either a trace element bolus (Cosecure™ - containing copper, cobalt and selenium) annually prior to mating, supplementary short acting selenium based on blood analysis, or no treatment. These treatments were repeated for the same individual ewes over the three-year period.

4.0 Results

4.1 Physical and financial performance

4.1.1 Grassland performance

Soil fertility

On organically managed fields soil pH ranged from 5.8 (on peaty soil) to 6.4 (mineral soil) - pH levels which should not have limited grass growth. Soil phosphate levels were Index 2 or above (12 – 27 mg/l) and soil potassium Index 1 (76 – 179 mg/l). The conventionally managed area, on a mineral soil, tended to be more acidic at pH 5.5 to 6.1, a likely consequence of higher silage yields and the addition of soluble ammonium nitrate. Soil phosphate was Index 1-2 (13 – 24 mg/l) and potassium Index 1 (73-122 mg/l) despite the addition of compound P and K fertiliser each year.

There were few differences in soil fertility between organic and conventionally managed areas of the improved hill. Soil pH for both systems ranged from 5.1 – 6.3, which is within the expected range for a peaty soil. Soil phosphate was at Index 2 (14 – 27 mg/l) and potassium Index 0/1 (63 – 184 mg/l). On the pastures which had been grazed only, soil fertility was very stable. The lowest levels of soil potassium were recorded on the hill reseeds which had been cut for silage, however potassium levels were quickly restored by the addition of composted FYM.

Forage output

Forage output on inbye fields (measured as Livestock Unit Grazing days per ha) are given in Table 3.

Table 3. Forage output on organic and conventionally managed inbye fields

	South Hayfield (conventional)	North Hayfield (organic)	West Hayfield (organic)	Bridge Haugh (organic)
1998	886	601	674	798
1999	693	516	446	692
2000	847	*244	456	874

* reseeded.

On comparable fields, (North and South Hayfields) forage output under organic management was typically 68% - 74% that of the conventional. This is in line with the results obtained from the replicated plot study (section 4.4)

4.1.2 Sheep flocks

The direct comparison of organic and conventional systems at similar stocking rates (Dipper split heft) was maintained until mating in November 2000 when, following consultation with the Project Steering Group, ewe numbers in the organic flock were reduced by 25%.

Ewe live weight and body condition score

Over the three-year period (1998-2000) individual animal performance on the Organic Dipper continued a long-term decline relative to the conventionally managed flock. Organic ewes were 3 kg – 7 kg lighter ($p< 0.001$) at all stages of the production cycle (Table 4).

Table 4. Ewe live weight (1998 –2000)

Flock		Con. Dipper	Org. Dipper	Cairn (Org.)	Burnhead (Org.)	Level of significance	
						All flocks	Con *v*. Org Dipper
Mating	1998	57.7	54.1	58.0	57.1	***	***
	1999	58.1	51.3	55.0	53.0	***	***
	2000	57.8	52.9	52.8	50.6	***	***
Scanning	1998	52.7	49.4	50.8	51.3	***	***
	1999	52.3	49.6	53.4	52.2	***	***
	2000	55.9	53.4	53.3	53.2	**	**
Marking	1998	57.2	52.5	57.7	56.9	***	***
	1999	56.2	52.6	57.8	55.6	***	***
	2000	51.4	48.1	53.0	49.1	***	***
Weaning	1998	57.5	54.9	60.0	58.8	***	***
	1999	59.3	53.6	59.2	55.8	***	***
	2000	58.0	54.2	57.0	55.2	***	***

Although recorded differences in ewe body condition score were less marked (Table 5), there was a consistent trend towards leaner ewes in the organically managed flocks. At lower stocking rates (Cairn and Burnhead flocks) ewe body condition score was more comparable to the conventional Dipper flock.

Table 5. Ewe body condition score (1998 –2000)

Flock		Con. Dipper	Org. Dipper	Cairn (Org.)	Burnhead (Org.)	Level of significance All flocks	Con *v.* Org Dipper
Mating	1998	2.70	2.38	2.56	2.53	***	***
	1999	2.51	2.32	2.42	2.34	***	***
	2000	2.73	2.68	2.22	2.28	***	N/S
Scanning	1998	2.42	2.25	2.41	2.40	***	***
	1999	2.35	2.35	2.46	2.33	***	N/S
	2000	2.54	2.54	2.70	2.59	**	N/S
Marking	1998	2.40	2.30	2.36	2.38	*	**
	1999	2.40	2.41	2.47	2.40	*	N/S
	2000	2.17	2.19	2.34	2.21	***	N/S
Weaning	1998	2.50	2.34	2.37	2.42	***	***
	1999	2.35	2.19	2.45	2.33	***	***
	2000	2.39	2.33	2.29	2.31	**	N/S

Reproductive performance

Poorer condition at mating of organically managed ewes was reflected in a lower lamb crop, averaging 108% *v.*129% for organic and conventional flocks respectively over the three-year period (Table 6).

Table 6. Ewe reproductive performance (from November mating 1998-2000)

Flock		Con. Dipper	Organic Dipper	Cairn (Org.)	Burnhead (Org.)
Barren rate (February)	1998	3.3	9.4	4.6	8.1
	1999	4.4	14.5	7.1	9.4
	2000	5.0	8.3	7.1	7.5
Scanning (February)	1998	135	111	115	118
	1999	145	94	108	112
	2000	144	115	115	115
Lambs born alive (April)	1998	131	126	133	120
	1999	128	104	107	115
	2000	136	91	103	111
Lambs reared (September)	1998	128	121	129	121
	1999	124	96	105	109
	2000	134	88	97	103

Further analysis of lifetime performance for each intake of homebred flock replacements, confirmed that organic breeding ewes were significantly lighter ($p < 0.001$) at each of first to fifth mating. Although differences in litter size were not statistically significant after first mating, organic ewes carried significantly ($p < 0.001$) fewer twins as determined by pregnancy scanning at second and third parity. Measured as total numbers of lambs produced, ewes in the conventional flock tended to have a higher lifetime output ($p > 0.10$).

Lamb performance

Statistically significant differences in lamb live weights were obtained between Conventional and Organic Dipper flocks (Table 7). This occurred despite the potentially dampening effect of increasing prolificacy i.e. the tendency for greater numbers of twin lambs to reduce mean lamb live weight at weaning.

Table 7. Lamb performance

Flock		Con. Dipper	Org. Dipper	Cairn (Org.)	Burnhead (Org.)	Level of significance All flocks	Con *v.* Org Dipper
Birth (kg)	1998	4.1	4.1	4.1	4.3	**	N/S
	1999	3.8	3.9	4.2	4.0	***	N/S
	2000	4.0	4.4	4.4	4.2	***	***
Marking (kg)	1998	15.3	13.9	14.4	14.9	***	***
	1999	15.1	14.9	13.9	13.6	***	N/S
	2000	15.1	16.7	16.1	16.0	***	***
Weaning (kg)	1998	32.8	30.0	31.6	32.5	***	***
	1999	33.1	30.9	32.7	30.1	***	***
	2000	33.7	32.9	33.6	33.3	N/S	N/S
DLWG (g)	1998	202	183	207	213	***	***
	1999	202	188	210	188	***	***
	2000	214	204	215	212	***	***

Daily liveweight gain from birth to weaning was significantly reduced ($p<0.001$) in organic lambs (206 g/day v. 192g/day). This confirmed the trend ($r = -0.39$) towards a progressive decline since 1992, in the growth rate of Organic Dipper lambs relative to the Conventional. Lamb performance levels comparable to the Conventional Dipper, were obtained in the less intensively managed organic Cairn and Burnhead flocks.

Wool yield

Wool growth can be a further indicator of nutritional status. It is not surprising therefore that out of the three organically managed flocks, the lightest fleeces tended to be recorded in the Organic Dipper (Table 8).

Table 8. Mean fleece weight (Kg/head - ewes and hoggs combined)

Flock	Con. Dipper	Organic Dipper	Cairn (Org.)	Burnhead (Org.)
1998	1.71	1.79	2.09	2.12
1999	1.95	1.79	1.90	1.88
2000	1.80	1.86	2.12	2.02

Health and welfare

The overall level of animal health and welfare was good. However, there were clear indications of the additional stresses placed on the Organic Dipper flock by maintaining similar stocking rates to the conventional flock. While mortality figures were well within acceptable limits and generally very low, there was a tendency towards higher ewe mortality in the organically managed flock (Table 9). Furthermore, where ewe lambs (hoggs) were under increased stress during autumn/winter, this resulted in a very high attrition rate (up to 36%) in replacement animals.

Table 9. Mortality rates and ewe lamb performance as indicators of flock health

Flock		Con. Dipper	Organic Dipper	Cairn (Org.)	Burnhead (Org.)
Ewe mortality (%)	1998	1.7	6.6	0.6	4.0
	1999	1.7	5.0	<1	1.7
	2000	3.3	2.8	6.5	5.9
Lamb mortality (%)	1998	7.7	6.6	8.4	7.8
	1999	10.4	12.6	7.6	10.8
	2000	7.7	3.7	6.7	6.3
Hogg mortality (%)	1998	1.7	3.3	2.0	3.6
	1999	1.8	0	2.0	1.9
	2000	0	2.2	2.0	0
Proportion of ewe	1998	100	77	98	89
lambs entering the	1999	97	97	86	64
as shearlings	2000	96	96	96	97

Parasite burdens, as measured by lamb faecal egg output at weaning were low, and anthelmintic input was limited to a few individual lambs. No adverse effects were recorded as a result of removing clostridial and pasteurella vaccination from the Cairn flock.

Marketing and disposals

The majority of lambs were sold satisfactorily as stores for further finishing on an organic lowland farm. The price differential for organic lambs was 30%-40% above conventional prices.

Table 10. Lamb disposals (as % of lambs weaned)

Flock		Con. Dipper	Organic Dipper	Cairn (Org.)	Burnhead (Org.)
Retained for breeding	1998	26	28	26	27
	1999	25	32	32	29
	2000	23	28	32	31
Sold for breeding	1998	7	1	5	3
	1999	12	1	0	1
	2000	13	1	3	1
Sold finished	1998	67	7	8	6
	1999	63	12	6	11
	2000	64	7	20	52
Sold store	1998	0	64	61	64
	1999	0	55	62	59
	2000	0	64	45	16

Carcass classification data from 1999-born lambs from the Conventional Dipper flock are compared in Table 11, with data obtained from cohort organic store lambs finished on an organic farm in Wiltshire. When sold in the January – March period, the organic hill lambs returned an acceptable carcass weight averaging 21 kg. As these lambs were sold direct, consumer feedback has also been very positive.

The 2000-born lamb crop provide a more direct comparison of carcass classification, as both types of lamb were sold through the same abattoir, and therefore were graded by the same abattoir staff. Both sets of data indicates that organic lambs can produce carcasses at least of similar quality to the conventional product.

Table 11. Carcass classification data

Carcass parameter		**1999 born lambs Con.**	**1999 born lambs Org*.**	**2000 born lambs Con.**	**2000 born lambs Org.****
Conformation (% distribution): best	*E*	0	2	0	0
	U	<1	33	1	9
	R	64	64	84	83
	O	36	1	15	8
: poorest	*P*	0	0	0	0
Fatness (% distribution): leanest	1	0	<1	0	0
	2	14	0	14	11
	3L	31	29	46	56
	3H	54	52	34	30
	4L	2	14	5	2
	4H	0	4	1	1
:fattest	*5*	0	<1	0	0
Mean carcass weight (kg)		15.1	21.0	16.6	16.7
Mean price per lamb (£)		22.08	37.10	31.97	42.15
Mean return (£/kg carcass)		1.52	1.20	1.92	2.54
Mean disposal date (ex. Redesdale)		28 Oct	16 Sept	17 Nov	8 Nov

* Sold as stores in September, and finished in Wiltshire.
** Sold finished, through the same abattoir as conventional lambs.

Sheep Gross Margins

Gross margin per ewe averaged £30.27, £36.60, £40.51 and £38.87 for Conventional Dipper, Organic Dipper, Cairn and Burnhead respectively. However, the differences in ewe gross margin between organic and conventional Dipper flocks converged over time , as the number and weight of lambs sold declined in the organically managed flock (Table 12).

Table 12. Ewe Gross Margin (£/head)

		Con. Dipper	**Org. Dipper**	**Cairn (org)**	**Burnhead (org)**
1997/98:	Gross output	52.78	59.90	65.97	60.87
	Variable costs (excl. forage)	18.23	17.02	17.59	17.03
	Forage costs	3.62	0.48	0.86	0.86
	Gross Margin	**30.93**	**42.40**	**47.42**	**42.98**
1998/99	Gross output	50.55	51.21	57.10	53.12
	Variable costs (excl. forage)	16.28	15.82	14.70	16.15
	Forage costs	2.74	0.79	0.58	1.07
	Gross Margin	**31.53**	**34.60**	**41.81**	**35.90**
1999/00	Gross output	51.87	48.48	46.95	53.81
	Variable costs (excl. forage)	20.68	15.24	14.52	15.84
	Forage costs	2.84	0.10	0.12	0.24
	Gross Margin	**28.35**	**32.79**	**32.30**	**37.73**

4.1.3 Suckler herd performance

Reproductive performance

Conception rates averaged 95 % over the three-year period (Table 13).

Table 13. Suckler herd reproductive performance

	1998	1999	2000
Calves born (April)	32	37	35
Calves died/dead at birth	1	0	2
Calves weaned (Dec)	31	37	33
Cows mated (July)	32	39	*34
Heifers mated (July)	7	11	6
Cows/heifers in calf (Dec)	38	47	38
Conception rate (%)	97	94	95

*13 cows were removed from organic herd, as their herd of origin could not be guaranteed BSE free.

Calf performance

Good rates of calf growth rates were achieved for a hill system of production. Daily liveweight gains of approximately 1.0 kg, 0.7 kg and 0.7 kg were obtained during the first grazing season, first winter and second grazing season respectively (Table 14).

Table 14. Suckled calf performance (Kg)

Year born	1997		1998		1999		2000	
	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers
First grazing season								
Calf birth weight (April)	-	-	39	41	44	43	35	40
Calf weaning weight (Nov/Dec)	-	-	261	275	257	279	248	255
DLWG (birth to weaning)	-	-	0.8	0.9	1.0	1.0	1.0	1.0
Winter growth rates								
DLWG (housing to turnout)	-	-	0.5	0.6	0.8	0.8	0.9	0.8
Second grazing season								
Turnout weight (May)	338	378	363	375	392	393	-	-
Sale weight	412	441	476	408	486	522	-	-
DLWG	0.7	0.6	0.8	N/A	0.6	0.8	-	-
DLWG (birth to sale)	0.7	0.8	0.9	0.9	0.8	0.9	-	-
							-	-
Sale price (p/kg)	105	130	133	135	135	127	-	-

Store cattle were sold at a premium of 25%-30% over conventional prices (110p and 130p/kg live weight for heifers and steers respectively). Finished heifers sold autumn 2000, averaged 230p/kg and 261kg dead weight.

Suckler herd Gross Margins

Gross margins per cow are given in Table 15.

Table 15. Suckler cow gross margin (£/head)

Production year	1997/98	1998/99	1999/2000
Suckler cow premium/HLCA	233.81	232.31	183.86
Beef Special Premium	64.11	63.22	47.12
Sales: Finished	-	-	201.75
: Store	511.31	518.67	213.93
: Cull cows	8.91	-	7.51
Herd replacement/valuation change	- 107.74	-124.94	-112.28
Gross output	**710.40**	**689.26**	**541.89**
Concentrate feed: cows	11.03	35.42	7.56
Concentrate feed: calves	79.10	85.74	53.90
Forage	18.93	18.69	14.57
Vet and Med	4.26	5.84	2.03
Commission/levies	12.78	12.97	12.10
Straw	14.29	13.37	14.28
Miscellaneous	2.86	2.86	1.63
Total variable costs	**143.25**	**174.89**	**106.07**
Gross margin	**567.15**	**514.37**	**435.82**

4.2 Linked farms study

Separate linked farm reports are available, giving detailed data for each financial year – 1997/98, 1998/99 and 1999/2000. Key findings from the study, over the three-year period, are given below.

Stocking rates ranged from 0.6 to 1.5 Grazing Livestock Units (GLU) per adjusted ha, with an average of 0.9. This figure is lower than that for conventional units from FBS survey data by IRS (1.3 GLU/ha), but exceeds that for Newcastle University (0.7 GLU/ha). Smaller units tended to be more intensively stocked.

Sheep represented 21%-80% of GLU's on the linked farms. Mean flock size was 520 breeding ewes. Overall levels of physical and financial performance were acceptable for a hill sheep production system. Lamb rearing percentage averaged 112% (up to 155% in individual flocks). The proportion of available lambs sold finished ranged from 0 to 100%. All farms retained lambs for breeding and most ran closed flocks, only buying in tups. Flock replacement rates varied from 19% to 35%. Terminal sires were chosen to meet market requirements, including Suffolk, Texel and Meatlink.

Lambs were sold through producer groups (e.g. OLMC, Organic Farmers Scotland, Border Livestock Exchange), as well as through local abattoirs e.g. Graig Farm Organic Meats in Powys. Two producers sold directly to Waitrose and Marks & Spencer. Organic prices had generally begun to be decoupled from the conventional, as conventional prices fell towards the end of the 1990's. Price premia for organic lamb in 1998 were generally 10%-15%. By 2000, this had increased to 40%-50% (260p – 280p/kg depending on carcass classification and time of sale). Furthermore, there was an increasing tendency for producers to seek alternative ways of direct selling (at up to 400p/kg), to reduce reliance on the formal marketing co-operatives. One producer had begun to develop a market for organic breeding stock.

Sheep Output and Gross Margins

Subsidies represented approximately 40% of Gross Output (given in Figure 1). Variable costs (excluding forage) averaged £15 per ewe. Most flocks used a proportion of non-organically produced feeds, but several did not make full use of the derogation available. Over the three years average Gross Margin per ewe (before forage) averaged £52, £45 and £37 for linked farms, Redesdale and IRS-FBS flocks respectively (Figure 2).

Figure 1. Comparison of Gross Output (£/ewe)

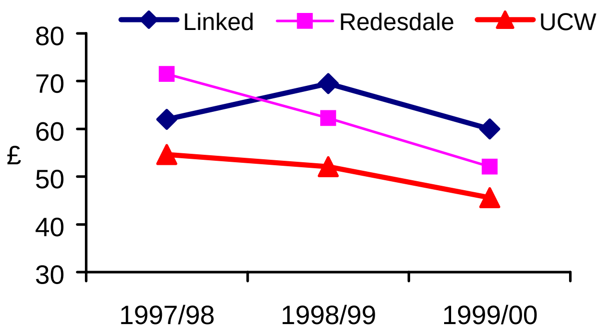
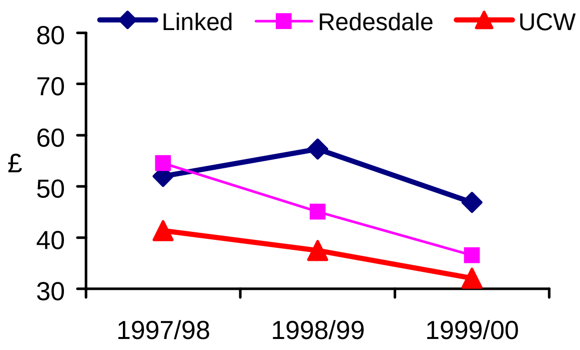


Figure 2. Comparison of Gross Margin (£/ewe)



Cattle Output and Gross Margins

Seven of the eight farms had suckler cows. Analysis of the cattle enterprise was split between the rearing phase for suckled calves (transferring calves out of the herd at 6 months of age), and a beef rearing/finishing enterprise. Herd size ranged from 10 to 96 suckler cows (mean = 40). Generally a high level of reproductive performance was achieved, averaging 91 calves reared per 100 cows mated. Mean annual herd replacement rates were 15%. Subsidies contributed 56% to total output (Figure 3). Mean variable costs (excl. forage) were £75, £124 and £113 per cow, for each of the three years respectively. On average, suckler herd Gross Margins on the linked farms (before forage, and to the production of a weaned calf) varied from £388 in 1998 to £235 in 2000 (Figure 4).

Figure 3. Comparison of Gross Output (£/cow)

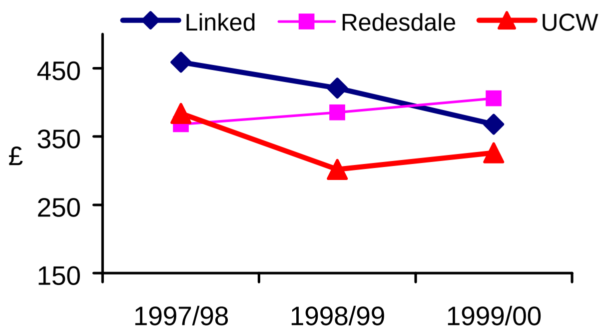
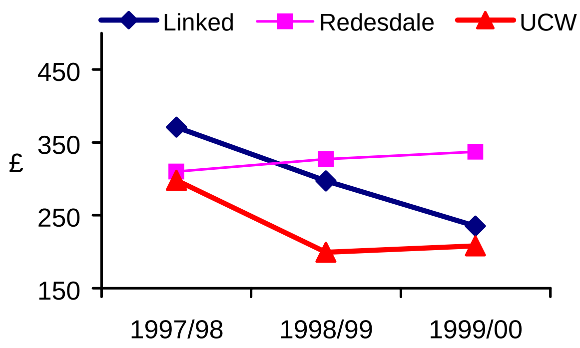


Figure 4. Comparison of Gross Margin (£/cow)



On most farms male cattle were kept until they were eligible for Beef Special Premium, and all claimed extensification premium. Gross margin per head for cattle finishing enterprises varied widely, across years and individual herds, from £404 to minus £214. Finished cattle prices varied from 220p-300p kg carcass weight.

Seven of the eight farms participated in conservation schemes, such as ESA, Habitat Scheme and Countryside Stewardship Scheme (CSS, CPS, Tir Gofal). While there were some constraints such as late cutting of forage (resulting in additional feed costs), farmers attitudes were generally very positive and used the schemes to benefit the environment through woodland planting, and wildlife features. Sources of income other than from livestock sales e.g. land management grants or cash crops, had a significant effect on farm output. Two of the collaborating farms had significant business interests outside of agriculture.

Whole farm Gross and Net Margin

Full farm costing was available for six farms, providing information on whole farm profitability. Average whole farm output (£ per adjusted ha) was £659, £625, and £607 for 1998 to 2000 respectively, producing Gross Margins of £529, £435 and £435. Corresponding levels of fixed costs were £515, £436 and £439 respectively. Mean Farm Net Margin varied from -£4 to £19 per adjusted ha (Figure 6).

Fixed costs reflected differing enterprise requirements for capital investment, the individual nature of each business, and

Figure 5. Whole Farm Gross margin (£/adj.ha)

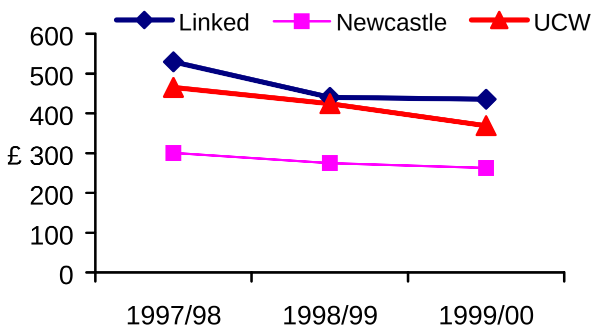
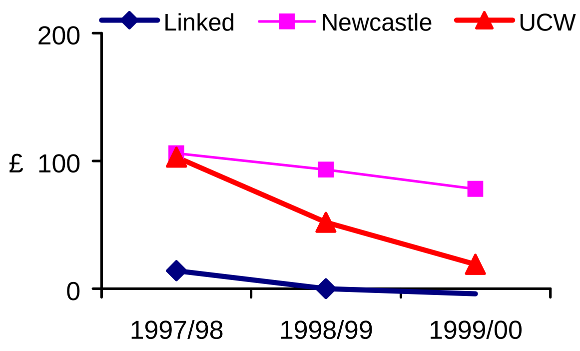


Figure 6. Net Farm Income (£/adj.ha)



the willingness of the occupier to invest in farm infrastructure. While the majority of farms generated a profit, large capital expenditure on one farm tended to skew the group average. If this farm is removed, and the analysis repeated, fixed cost components were at a very similar level (expressed as a % of farm gross margin) to UCW data. The most profitable linked farm combined high output and gross margin, with lower than average fixed costs, to give a net farm income ranging from £137 to £256 per adjusted ha. For all but this farm, Net farm Income (NFI) tended to be equal or lower than the value of manual labour provided by the farmer and spouse, giving a negative Management and Investment Income (MII). It is difficult to conclude that for this farm type, organic management necessarily requires a higher cost structure than conventional. Key components to profitability appear to be farm size (smaller units have concentrated fixed costs), value added (finishing stock is an important factor in realising market premia), and reliance on purchased inputs.

Data from the study were supplied to IRS for incorporation into a wider economic appraisal of organic farming systems.

4.3 Botanical composition

In terms of National Vegetation Classification (NVC), vegetation type was classified into sub-communities derived from MG6 (*Lolium perenne-Cynosurus cristatus*) and MG7 (*Lolium perenne*) for inbye land on the unit, while the native/unimproved hill tended towards U4 (*Festuca ovina - Agrostis tenuis - Galium saxatile*) communities.

Overall there were few statistically significant differences in botanical composition on native and improved hill land due to organic or conventional management. On the native hill and at similar stocking rates (Dipper split heft), the decline in heather cover under both management regimes reached statistical significance in 1999. Heather (*C. vulgaris)* cover tended to be lower (*P=0.057*) on the conventionally managed area. *Agrostis capillaris* and *Holcus lanatus* also appeared to be increasing on the conventional hill, but the trend over time was not statistically significant. Where sheep stocking rates had been reduced by 25% on the Cairn heft, heather cover did not show the same rate of decline, but there was a trend towards an increase in *Molinia,* suggesting a lack of sufficient grazing pressure during the summer months. Vegetation monitoring on the Burnhead hill in 2000, recorded 34 species, including 13 mosses.

On the improved hill pastures, sown species content (ryegrass and white clover) declined on both organic and conventional areas. This continues the long-term regression of these swards, following land improvement during the 1980's. Changes in botanical composition were similar under both management regimes, except for Yorkshire Fog (*Holcus lanatus)* in 2000, which had significantly higher cover (*P=0.013*) on the conventionally managed area. Cover of clover (*Trifolium repens*) declined significantly on the conventional area between 1997 and 2000, however, clover cover on both organic and conventionally managed areas was significantly lower than at the 1996 sampling date.

From aerial photography, percent rush (*Juncus effusus*) cover on the hill reseeds was estimated at 18% to 40%. On areas where silage was taken, this represented a loss in usable silage dry matter of 21% - 25% (0.63 – 0.94 t ha $^{-1}$).

On organically managed inbye fields clover cover was significantly higher, compared with conventional pasture receiving over 200 kg N ha $^{-1}$ annually. Botanical composition was strongly influenced by age of sward, and site conditions such as proximity to sources of weed invasion (e.g. persistent seedbank, seed-shed, invasion from adjacent land) and sensitivity to vectors such as ground disturbance. After reseeding, organic swards had a high level of annual weeds (e.g. chickweed – *Stellaria media*) but these did not persist into the second year. On one field, docks (*Rumex obtusifolius*) increased to 30% cover before reseeding in spring 2001, illustrating the difficulty in controlling an established population of docks in organic semi-permanent grassland.

Although some overall differences are beginning to emerge (e.g. *Agrostis* and *Holcus* cover on Organic and Conventional hefts), these changes have been very slow to materialise and, particularly in the case of *Calluna* cover, can be related more to stocking level than to management regime. Furthermore, although it is suitable for detecting changes in the larger and more vigorous plant species, the rapid grid technique is not so appropriate for monitoring changes in sensitive, less frequently occurring, species. Conversely, reversal of the decline in heather cover requires more drastic intervention than simple conversion to organic production.

4.4 Sources of nitrogen experiment

A detailed report covering three years of the experiment (1996-1998) is available separately. Over the three year period of the experiment, total nitrogen input from animal waste was 98%, 99%, 93%, 102%, and 98% of target for treatments A to D, and G respectively.

Effect of treatment on slurry and FYM

Composting FYM tended to increase manure dry matter, total nitrogen and nitrate-N content and reduce ammonium-N content, carbon:nitrogen ratio and organic carbon content. Aerating slurry reduced nitrate content, but differences in ammonium-N, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and total N content were not consistent.

Herbage yield and composition

Treatment differences in total annual dry matter yield were highly significant (P<0.001). Compared with the mean of both control treatments, ammonium nitrate/sulphate of ammonia increased herbage production by 22% (Table 16), consistent with previous results from this experiment, and also with previous research on the relative performance of grass clover systems. The yield response to slurry and FYM ranged from 108% to 114%, significantly below that achieved from 240 kg N ha $^{-1}$ applied as conventional fertiliser (P<0.05). There was no significant effect on herbage yield between the organic manure treatments. Aeration provided no additional yield benefit over untreated slurry.

Table 16. Effect of nitrogen treatment on herbage dry matter yield

Treatment		Yield (kg DM ha^{-1})	Mean clover %	Mean weed %	Yield response* (kg DM/kg total N applied)
A)	Composted FYM	12454	11.1	9.1	12.1
B)	Untreated FYM	12104	8.6	11.3	10.1
C)	Aerated cattle slurry	12732	7.5	12.1	13. 0
D)	Untreated cattle slurry	12812	8.4	9.2	12.5
E)	Conventional N	13408	4.7	4.6	10.2
F)	Zero control 1996/97/98;	10725	10.6	13.3	-
G)	Zero control 1997/98;	11190	8.9	16.2	-
	S.E.D.	419.5	2.59	4.71	
	Error CV% (18 df)	4.9	42.8	60.0	

* based on response above the mean of both control treatments.

Overall, there were no significant treatment differences in mean clover content, or in clover content at any harvest date. Although there was a tendency for ammonium nitrate to depress clover this was not statistically significant (p = 0.072). Despite a tendency for conventional fertiliser to reduce weed content, overall treatment differences were not statistically significant (p= 0.107).

Soil nutrient status

Treatment differences in soil pH were highly significant (p = 0.002). Soil pH ranged from 7.0 (ammonium nitrate) to 7.5 (untreated FYM). Large treatment differences (p<0.001) occurred in soil potassium, where the use of FYM and slurry produced consistently better levels (Soil Index 1 to 2) relative to conventional control and zero nitrogen treatments (Soil Index 0). Soil phosphorus levels were also significantly higher where organic manures had been applied (p=0.006). There was no benefit from composting FYM or aerating slurry on soil potassium and phosphorus. No significant treatment differences were obtained in soil total-N, nitrate-N, ammonium-N or organic matter content.

Herbage composition and nutrient uptake

As expected, high levels of conventional fertiliser produced the highest concentration of nitrogen in herbage resulting in the highest (P<0.001) nitrogen uptake. The lowest potassium concentration, was obtained from ammonium nitrate/sulphate of ammonia and zero nitrogen control treatments. Treatment differences in potassium uptake were highly significant (P<0.001). Despite reduced herbage yields, potassium uptake was higher where FYM or slurry had been used, compared with the conventional nitrogen treatment. Herbage phosphorus levels were generally uniform across treatments. Overall treatment differences in phosphorus uptake were highly significant (P<0.001), brought about by the lower herbage yield obtained from untreated control treatments.

Over the three years of the experiment (1995-98), inputs and outputs for nitrogen, potassium and phosphorus are given in Table 17.

Table 17. Total nutrient input Vs output (three year data)

Treatment	Nitrogen		Potassium		Phosphorous	
	Offtake (kg/ha)	Applied as % of offtake	Offtake (kg/ha)	Applied as % of offtake	Offtake (kg/ha)	Applied as % of offtake
Composted FYM	1108	32	915	87	131	70
Untreated FYM	918	49	1026	80	128	73
Aerated cattle slurry	873	48	1001	72	126	61
Untreated cattle slurry	1018	45	1040	71	133	59
Conventional N	1246	58	918	26	130	-
Zero control 1996/97/98;	933	-	758	-	117	-
Zero control 1997/98;	1052	14	925	40	129	22

Depending on treatment, the total quantity of nitrogen applied as a proportion of offtake, ranged from 0 to 58%.

The provision of additional potassium fertiliser, as Kali vinesse or muriate of potash, was not sufficient to maintain a positive nutrient balance. The largest deficit occurred on the conventional and zero nitrogen treatments, also reflected in long-term trends in soil potassium. The application of FYM or slurry achieved a balance of 84% and 71% respectively. However, this would have been reduced to approximately 66% and 52% respectively, without the additional input from Kali vinesse.

As a proportion of crop offtake, the return of phosphorus was approximately 70% for FYM and 60% for slurry, helping to maintain better levels of soil phosphorous compared to the conventional treatment.

4.5 Novel forages

Redesdale site

Agronomy

Pot tests prior to sowing in 1998, indicated a germination rate for *Lotus* of 67%. However, in the field *Lotus* was slow to establish. Its relatively poor competitiveness was evident in the high proportion of invading weeds (mainly chickweed) and grasses, which together made up 72% of sward total (1.75 t ha $^{-1}$) dry matter at the start of the experiment. In 1999, the crop failed completely.

In 2000, mean herbage dry matter yield for May-sown *Lotus* plots were 3.4 t ha $^{-1}$. However, this was made up of 24% grass, 33% *Lotus* and 43% weed. Mean dry matter yield from grass/clover was 3.4 t ha $^{-1}$, comprising 55% grass, 10% clover and 35% weed.

Grazing trials

In 1998, the *Lotus* sward sustained lambs for a four-week grazing period. Compared to a ryegrass/clover sward there were no statistically significant differences in ewe lamb live weight, until the end of the experiment when the *Lotus*-fed lambs were running short of grazing. Faecal egg counts at the start of the experiment were moderate at a mean of 620 e.p.g fresh faeces. There were no statistically significant treatment differences between crop type for the duration of the experiment.

Unfortunately in August 2000, the experiment was compromised by human error, which meant that animals were put into grazing plots (i.e. allocated to treatment) by experimental block rather than across blocks. This error was notified to MAFF within two weeks of the start, but a decision was made to continue the experiment in the hope that some useful data might still be provided. Despite using the initial blocking data as a co-variate in the analysis, no statistically significant treatment differences were obtained for lamb performance or parasite burden.

Aberysywyth site

Agronomy

In West Wales, better establishment rates for *Lotus* was obtained from spring sowing. Sown species content (% herbage dry matter) averaged 72% and 88% for *Lotus* and chicory respectively six weeks after sowing. Nevertheless, the grazing period each year was generally limited to 6 weeks by the total quantity of *Lotus* available. In 1998, significant hand weeding of the Lotus plots was required to remove charlock (*Sinapsis arvensis*). Compared with chicory, *Lotus* did not overwinter well, and both crops were resown each year.

Grazing trials

In each of the three years of grazing studies, lambs fed *Lotus* had lower faecal egg counts compared with those fed ryegrass/white clover. Log transformed data for faecal egg output is given in Table 18 .

Table 18. Log10 transformed total FEC data (DM adjusted) of lambs (with naturally-acquired parasite burdens) grazing chicory, Lotus or ryegrass/white clover, using faecal consistency as a covariate

Day of experiment	0	7	14	21	28	35
Chicory	3.727	3.656	3.773	3.781	3.861	3.532
Birdsfoot trefoil (*Lotus*)	3.690	3.313	3.537	3.819	3.750	3.790
Ryegrass and white clover	3.656	3.666	3.764	3.856	3.937	3.704
S.E.D.	0.0998	0.1253	0.0958	0.0788	0.0775	0.1157
Degrees of freedom	67	66	65	64	63	61
P-value	0.77	0.01	0.04	0.57	0.08	0.06

Lotus significantly reduced total worm, abomasal worm, and small intestinal worm burdens (Table 19).

Table 19. Rank transformed total adult helminths in lambs, with naturally-acquired parasite burdens, after grazing chicory, *Lotus* or ryegrass/white clover for 5 weeks

	Abomasum	Small intestine	Large intestine	Total
Chicory	11.2	14.5	10.6	13.4
Birdsfoot trefoil (*Lotus*)	6.8	8.0	13.5	7.6
Ryegrass and white clover	18.0	15.0	13.4	16.6
S.E.D	2.51	2.86	3.63	2.78
Degrees of freedom	19	20	20	20
P-value	0.001	0.05	0.67	0.01

Conflicting results were obtained for chicory, which reduced faecal egg output in two years out of three, and did not appear to affect total worm burden.

Underlying mechanisms

Total tannin content (µg/ml) of whole plants were 8.93 and 2.15 for *Lotus* and white clover respectively. Both *Lotus* and chicory had higher crude protein contents compared with ryegrass/white clover. As chicory does not contain tannins, the potential effect on faecal egg count requires an alternative explanation. The observed effect, for example, could be due to the morphology of the plant. Data from small plot experiments indicated fewer larvae were found above 5cm on the chicory plant, possibly due to a retarding effect on larval migration. Lambs grazing chicory also had significantly higher copper status by week six of the grazing period, but there were no consistent effect on cobalt or selenium status. Faecal culture indicated that in chicory-fed lambs, fewer eggs of four helminth parasite species hatched or developed to the infective stage compared to cultures from lambs fed on ryegrass/clover. However, feeding *Lotus* to lambs actually increased the percentage of helminth parasites that reached the infective stage in the faeces.

Results from the novel crop experiments show that crop type can affect parasite burden. However, there is a need to further validate the observations found in these experiments, and to explore more fully the range of underlying mechanisms (e.g. plant structure, larval development or trace element content) before considering commercial application. Chicory would appear to have much better agronomic performance compared to *Lotus spp.* Nevertheless, further work is required to improve the reliability of novel crops in the field, and to determine how best to use this approach in commercial practice e.g., strategic grazing in a monoculture, or as a component in a mixed continuously grazed sward.

4.6 Trace element study

Trace element status - Linked farms

Seven out of the nine linked farms surveyed considered they had an inherent trace element problem. This conclusion was reached on the basis of a combination of local knowledge, previous experience of the farms and laboratory analyses. Blood analyses taken from lambs after weaning showed all farms (Table 20) to be above the reference range (9 -19 µmol/l) for copper, seven were marginal or deficient (<50 u/ml GSH-Px) in selenium, and three were marginal or deficient (<221 pmol/l Vit B12) in cobalt. Copper availability was generally high, suggesting minimal inhibitory effects on absorption, for example through raised molybdenum or sulphur in the herbage, or from iron ingested through soil.

Table 20. Trace element survey - blood mineral level by farm

Farm	Total Cu µmol/l	Cu availability (%)	Available Cu µmol/l	Cobalt pmol/l Vit B12	Selenium u/ml GSH-Px
A	19.85	99.93	19.84	431	59.4
B	15.79	94.72	14.92	234	42.3
C	17.88	93.26	16.73	669	62.4
D	13.70	89.64	12.29	130	75.6
E	17.22	97.44	16.76	564	26.8
F	19.91	88.76	17.68	299	26.8
G	16.20	95.80	15.52	475	68.7
H	15.32	93.09	14.33	674	24.2
I	15.49	94.82	14.64	477	53.8
J	14.33	96.57	13.83	776	93.4
Mean	**16.57**	**94.40**	**15.65**	**473**	**53.3**
p-value	<0.001	<0.001	<0.001	<0.001	<0.001
SED	0.815	1.271	0.801	51.6	5.79
CV% (170df)	20.9	5.7	21.7	46.3	46.1

Depending on the farm, a combination of management and direct supplementation were used. Where trace element deficiency was perceived as a significant threat - conventional control methods predominated. Approaches included (number of farms in brackets); grazing management (3), fertilisers and soil conditioners (4), pasture sprays/dusts (2), forage herbs (2), mineral inclusion with winter rations (4), *ad lib* mineral (5), routine direct supplementation e.g. copper needles/boluses (3), specific periodic supplementation e.g. drenching or injection (5), other (1, referred to below). Naturally occurring rock sources of fertilisers were used on the basis of their wider mineral compared to more purified, water soluble forms of P and K fertiliser. Seaweed meal was commonly used as a supplement for livestock. One producer changed from a spring calving herd, to a purchased store cattle enterprise, to overcome chronic selenium deficiency.

Trace element status - Redesdale organic unit

Extensive analysis of herbage from the unit at Redesdale had previously confirmed low levels of trace elements (copper, selenium, iodine and zinc) in grazed and ensiled forage. Over the three year period, blood copper levels taken from lambs at marking and weaning, varied according to flock (p>0.001), most likely a reflection of differences in botanical composition on the native hill. Copper levels were generally adequate, but significantly lower in the more highly stocked, and less botanically diverse, Dipper flocks (p>0.001). Blood selenium levels (GSH-Px) varied with season, but were sub-optimal in each of the three years (Table 21).

Table 21. Blood copper (µmol/l) and selenium status (u/ml GSH-Px) at weaning

Flock		Con. Dipper	Org. Dipper	Cairn (Org.)	Burnhead (Org.)	Level of significance: All flocks	Level of significance: Con *v.* Org Dipper
Copper	1998	9.92	8.43	12.19	13.42	***	N/S
	1999	9.96	11.92	13.49	14.28	***	*
	2000	10.83	11.06	14.57	14.67	***	N/S
Selenium	1998	48.59	27.90	41.06	35.45	**	**
	1999	42.34	47.50	46.15	37.60	N/S	N/S
	2000	49.32	35.63	42.89	45.96	**	**

Response to trace element supplementation

Data from the four hill flocks at Redesdale were used to examine responses to trace element supplementation. Compared with untreated control ewes, use of a trace element bolus pre-mating raised blood copper (15.0 *v.* 12.1 µmol/l; $p<0.001$), GSH-px levels (149.4 *v.* 67.4 u/ml; $p<0.001$), and Vitamin B12 ($p<0.01$) at scanning. Over three years, no statistically significant treatment differences were obtained in the proportions of barren (6%-9%), single-bearing (65%-67%) or twin-bearing ewes (25%-28%). In addition, no treatment effects were seen in terms of ewe live weight or body condition score throughout of the production cycle.

Using data for a total of 430 lambs over three years, the relationship of individual lamb performance and trace element status was also statistically analysed. Overall, there was no consistent correlation between blood copper or selenium level, and individual rate of daily liveweight gain.

The results indicate the farm specific nature of trace element status, related to soil type and indigenous vegetation, the tendency to resort to conventional methods of supplementation where a significant shortfall is anticipated, and the difficulty in providing empirical data (notably to the Sector Body) to categorically prove the existence of a deficiency.

4.7 Technology transfer

A high level of technology transfer was undertaken, particularly to the farmer and grower sector. A list of output and activities is given in Annex 1.

5.0 Conclusions and relevance to policy

The results indicate that for many hill and upland units, converting to an organic system is not likely to be a matter of minimal changes to existing management. In particular, stocking rate and balance of sheep and cattle at the start of conversion will have a major impact on the management required to achieve acceptable levels of animal performance, financial performance, input reduction and environmental gain.

Data from the linked farm survey show that with the right cost base, commercial organic production can be profitable. The economic data at Redesdale suggest that financially, it has been possible to justify maintaining similar stocking rates on the organic split heft. However, on the basis of long-term vegetation change, and a steady decline in individual animal performance, it is clear that maintaining an existing level of stocking was unsustainable if wider environmental and ethical objectives are to be met. More importantly, this relative advantage has occurred at a time when conventional prices have been weak.

In the short-term, underdeveloped infrastructure and imbalanced development of the organic sector, will re-focus priority on good technical performance, rather than inflated price differentials or short-term conversion aid.

Without major differences in management or inputs between organic and conventional regimes, it is unlikely that significant differences in botanical composition on the native and improved hill land will accrue. If significant benefit, for example, in heather cover is expected from an organic farming regime, a much more proactive approach to hill management is necessary. The integration of organic farming with other agri-environmental schemes is important to financial returns, could be an important consideration for the wider uptake of organic production.

Nationally, hill and upland production has a significant role to play in assisting the year-round supply of organic beef and lamb, strategically balancing supplies during the period from Jan-April. However, the short-term imbalance in upland organic store lamb production relative to finishing capacity on lowland farms, suggests a glut of organic stores, with potential adverse effects on price and producer confidence. Finishing systems (particularly for lambs) and the supply chain need further and rapid development. Policies to increase the attractiveness of conversion on arable farms, would have a beneficial impact, both on the supply of organic feedstuffs and potential finishing capacity on lowland farms.

EU regulation 1804/1999 accentuates the drive towards more closed, lower external input systems, and restricts the use of non-allopathic treatments to organic stock. This could have significant financial, management, and animal welfare implications for hill and upland producers. Particular issues are the availability of suitable organically produced feeds, and the control of internal and external parasites.

6.0 Recommendations

Approximately 80% of the land put into conversion under the Organic Aid Scheme has been extensively managed grassland. In large part, this has been driven by the economic difficulties faced by the hill and upland sector, and the relative attractiveness of the Organic Aid Scheme payments. Yet, many farmers remain unconvinced about the long-term viability of the organic system, perceived risks to animal health and the maintenance of a robust market for organic produce. If this investment is to be sustained longer-term, and expanded, the successful evolution of sustainable organic systems in the hills and uplands need to be demonstrated. It is recommended that the systems study at Redesdale be continued, to maintain a long-term resource for research and demonstration.

Future research requirements could include:-

- developing and testing the integration of organic with other agri-environmental schemes;
- management and restoration of moorland for biodiversity and environmental benefit;
- control of perennial weeds (rushes, docks and bracken);
- requirements for trace element supplementation of organic stock;
- animal health and disease control;
- developing finishing systems for organic beef and sheep.

Annex 1 – technology transfer

Reports

Elliott, J., Smith, A. & Keatinge, R. (1999) Organic Sheep and Beef Production in the Hills and Uplands. Report of Linked Farms. 1997/98 Financial Year. January 1999. 53pp.

Elliott, J. & Keatinge, R. (2000) Organic Sheep and Beef Production in the Hills and Uplands. Report of Linked Farms. 1998/99 Financial Year. February 2000. 49pp.

Elliott, J. & Keatinge, R. (2001) Organic Sheep and Beef Production in the Hills and Uplands. Report of Linked Farms. 1999/2000 Financial Year. January 2001. 45pp.

Keatinge, R. (1998) Organic sheep and beef production in the uplands – efficient use of livestock waste within an upland organic system. Final experimental report. December 1998. 15 pp.

Marley, C., Lampkin, N., Barrett, J. and Cook, R. (2001) The potential of alternative forages in organic systems and their role in controlling helminth parasites in sheep. MAFF Project OF0147. Final report. March 2001. 47pp.

Oatway, D.E. & Sanderson, R.A. (1999) The effects of organic sheep and beef production on vegetation composition in the hills and uplands. MAFF Project OF0147. First interim report. April 1999.

Oatway, D.E. & Sanderson, R.A. (2000) The effects of organic sheep and beef production on vegetation composition in the hills and uplands. MAFF Project OF0147. Second interim report. April 2000.

Oatway, D.E. & Sanderson, R.A. (2001) The effects of organic sheep and beef production on vegetation composition in the hills and uplands. MAFF Project OF0147. Final report. April 2001.

Papers

Keatinge, R. (1998). The potential for organic farming in Less Favoured Areas. *FAUNUS*, Newsletter of the Research Network for Livestock Systems in Integrated Rural Development, Nov. 1998

Keatinge, R. (1999) Evaluating organic farming in hill and upland areas of the UK, Research Methodologies in Organic Farming, *REU Technical Series 58*, Food and Agriculture Organisation of the United Nations, Ed. Zanoli, R and Krell, R. 1999, pp148-150.

Keatinge, R. (2001) Organic sheepmeat production. In: Organic Livestock Farming. Eds. D Younie & J.M. Wilkinson, Chalcombe Publications 2001, pp145-158.

Marley, C.L., Barrett, J.B., Cook, R., Lampkin, N. H. & Keatinge, R. (2001) The potential for alternative forages to control helminth parasitism sheep. Res. Vet. Sci. 70 pp21.

Marley, CL & Howells, K. L. (2001) Research on alternative approaches to parasite control. Grass Farmer, 68, Spring 2001.

Events

- A specific Open Day featuring the organic research project was held on 5 August 1999.
- Conference paper, Organic Livestock Farming, Principles, Practicalities and Profits, Heriot-Watt University (9 Feb 2001) and Reading University (10 Feb 2001).
- A wide range of presentations/seminars/workshops were given e.g. to FRCA Field Officers, English Nature Field officers, Royal Show, Sheep 98, Nuffield Scholars, National Sheep Association , Alnwick Farming Conference, NFU, Broomfield College of Agriculture, Yorkshire Moors and Dales Project, Redesdale Discussion Group, Alnwick District Council, The National Trust, Soil Association Producers Services, Derbyshire Organic Producers, ADAS Meat Conference, Beef 99, agricultural students from Newcastle University and Kirkley Hall, Country Landowners Association.
- The Unit was visited in August 1998 by the then Minister for Agriculture, Rt. Hon. Jack Cunningham.

Annex 2 – References cited

House of Commons, Select Committee on Agriculture, Second Report , January 2001.

Pollot, G.E. and Kilkenny, J.B. (1976) A scheme for grassland recording based on the livestock unit concept. *Animal Production,* **22**, 147 (Abstract).

Rodwell, J.S. (1991). *British Plant Communities: Mires and Heaths*. Cambridge University Press, Cambridge.

Please press enter