DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **CSG 15**

Research and Development

Final Project Report

(Not to be used for LINK projects)

Project title	Optimising the production and utilisation of forage for organic livestock
DEFRA project code	**OFO328**
Contractor organisation and location	ADAS Consulting Ltd ADAS Redesdale, Rochester, Otterburn Newcastle upon Tyne NE19 1SB
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Executive summary (maximum 2 sides A4)

On most organic farms in the UK, forages are fundamental to the application of organic farming practices, particularly where dairy cattle, beef cattle and/or sheep are the major enterprises. Methods used for the production, conservation and utilisation of these forage resources have a major influence on the productivity, efficiency and overall sustainability of organic farms. Forage management and utilisation also have a pivotal role in the maintenance of animal health and in the minimisation of environmental impacts associated with livestock farming.

The objectives of this work were to review, extrapolate and further develop (through five different work packages) existing knowledge on forage management factors with regard to their importance in organic systems. As a result, an increased understanding of the underlying mechanisms involved in organic forage management should assist, both in policy formulation and in improved practical management on organic farms.

The first specific objective was to review the nutritional requirements of organic livestock and it was concluded that whilst some small differences may exist between the nutrient needs of organically managed and conventional livestock, there is insufficient evidence at present to justify making changes to the commonly accepted feeding standards used in the UK. However, where appropriate, existing nutrient allowances should be adjusted to take account of any extra demands placed on organic livestock as a result of additional energy expenditure associated with extra environmental or activity demands arising as a result of organic husbandry systems.

Objective 2 set out to assess the likelihood of meeting all or a minimum proportion of the nutrient requirements of organically managed animals from organic forages. Potential milk yield in dairy cows was calculated to range from 13 - 29 l/day, energy intake in ewes from 12.0 - 18.6 MJ/day and LWG in beef animals from 0.6 - 1.4 kg/day as the quality of organic forage varied between 8 and 12 MJ/kg DM and the concentrate DM input varied between 0 and 40% of the total ration. It was concluded that for dairy cows 100% organic forage diets will support low levels of milk production but that medium - high levels of milk output can be achieved by supplementing organic forages with up to 40% concentrates in the ration.

Examining the potential to adjust management and production systems to achieve a better balance of nutrient supply and demand within organic systems (Objective 3) highlighted the need to minimise forage conservation losses of both silage and hay crops. It also emphasised that the type of crop rotation and the balance between N-fixing crops (e.g. legumes) and N-demanding crops was an important variable in optimising the overall balance of nutrient supply and demand within organic systems. It also stressed the importance of achieving good yields, coupled with high quality of forages as the foundation of organic livestock systems.

The potential contribution from alternative forages and protein sources was considered in Objective 4. Alternative forages such as whole crop silage, maize silage or legumes such as lucerne could all play a significant role in the nutrition of organic ruminants depending on suitability, farm location and soil conditions. Grassland species other than ryegrasses and clovers, such as timothy and cocksfoot could also be important contributors to livestock nutrient supply in the cooler, wetter areas of the UK. Whether grown on the farm or bought in from another organic farm, protein-rich crops such as peas and beans were likely to be one of the major sources of supplementary protein in organic livestock rations.

Objective 5 examined the likely effects of organic rations on animal health and product quality. The issue of using herbs to improve the mineral nutrition of organic livestock was assessed and concluded that whilst these plants do have high mineral concentrations, their agronomic yield and persistency under UK climatic conditions is often unreliable. Future use of herbs within organic systems in the UK is likely to be directed towards their use in helping to control parasite burdens, particularly in sheep systems. The careful management of grazing and forage input to dairy cow diets was indicated as being a critical influence on milk quality in particular, and literature studies have indicated that for every 1% increase in dietary crude protein content, milk protein content could increase by 0.02%. Organic forage legumes were crucial in providing the optimum protein supply to highly productive organic livestock such as dairy cows, lactating ewes and rapidly growing cattle.

A spreadsheet-based simulation model was constructed of a total of 153 distinct organic dairy systems that represented the wide variety of potential organic dairy management situations across the UK. The main influences on the potential output (Objective 6) from an organic dairy system are the type of cropping rotation that is established, the source and quantity of concentrate feeds for the dairy herd and how efficiently forage is utilised both for grazing and conservation. When compared at similar levels of concentrate feeding per cow, the milk output per hectare from the systems based on home-grown forage and purchased concentrates was higher than those based on self-sufficiency and the growing of all feed sources on the farm.

Building on the models developed above, the environmental impacts of the three most common organic dairy systems likely to be practised within the UK were reviewed (Objective 7). The systems were based on either: an all-grass system with all purchased concentrates (S71), a grass and additional forage crops system with purchased concentrates (S76) and a grass and additional forage crops system with home-grown concentrates (S81).

Likely environmental impacts on land, to the atmosphere and on water were assessed. Little overall difference could be ascribed to any of the three systems studied but in general as the system became more intensive, with higher stocking densities, more purchased concentrates and higher outputs, then the greater the "leakiness" of the system beyond the farm boundary. When measured on a land area basis, S76 would have a 24% higher detrimental impact on the global environment compared with S81 and 9% higher impact compared with S71.

Overall, this body of work has indicated that a number of gaps in current knowledge exist such as: the particular suitability of diverse plants and animal genotypes for forage-based organic systems, methods for determining the nutritive value of organically produced forages, trace element nutrition of organic livestock and specific weed and pest control measures in organic crop production.

Further dissemination of the outputs from this study, drawn from the five separate work packages in which the work was conducted, will help underpin the sustainability of the organic sector.

Scientific report (maximum 20 sides A4)

1) Introduction and background

Organic farming seeks to develop sustainable systems of food production, which reduce reliance on external inputs, and emphasises high standards of animal welfare and care for the environment. Livestock play an important role in fertility building on mixed organic farms and provide a means of converting herbage to edible product within more extensive pastoral systems. The standards for organic production require that a minimum ratio of forage to concentrate is fed to ruminants. Organic pigs must have some roughage available to them, either at pasture or through supplementary feed. Organic poultry must also have access to pasture from which they will derive some nutritive value from vegetation and associated invertebrate populations.

Consequently, on most organic farms in the UK, either grazed or conserved forages are integral to the application of organic farming practices. Methods used for the production, storage and utilisation of forage have a major influence on the performance and efficiency of organic farms, animal health, and environmental impact. Impending changes in the standards for organic production (EU Directive 1804/99) will reduce flexibility in formulating livestock diets, place greater emphasis on home-grown organically produced feeds, and increase the importance of improving all aspects of forage production and utilisation. For many years, Defra have funded extensive studies on forage production and utilisation in conventional systems. While the performance of conventional and organic systems have been compared, relatively little work has been carried out to identify relevant management practices from conventional farming, and translate these to an organic farming context. The purpose of this study was to extrapolate, and further develop this information, to aid understanding of underlying mechanisms, assist in policy formulation, and improve practical management on organic farms.

2) Objectives of the project

The overall objective was to review existing information on forage production and utilisation in order to deliver more efficient, sustainable and environmentally friendly output from organically managed livestock. A database model has been developed using results from conventional studies to predict the net gains and losses from different organic systems and management strategies.

Specific objectives were:-

1) Extrapolating from published data, to review the requirements for energy and protein across the production cycle for organic milk, beef, lamb, pig and poultry production.

2) To predict the likelihood of meeting all or a minimum proportion of these requirements from a range of organically produced forages.

3) To examine the potential to adjust management or production system to achieve a better balance of nutrient supply and demand.

4) To consider the likely contribution from alternative forages and protein sources as home-grown feeds.

5) To assess likely effects on animal health and product quality.

6) To develop a database model to predict the potential output and benefits for organic farmers of implementing different options and strategies for forage production and utilisation.

7) To determine the environmental losses and gains at each stage of production and utilisation.

8) To provide specific guidelines for use by farmers, advisors and policymakers to maximise efficiency in the production and utilisation of forages within a range of organic livestock production systems.

3) Methodology and approaches taken

The work was a collaborative project between ADAS, Institute of Grassland and Environmental Research (Richard Weller) and Abacus Organic Associates (Dr Mike Tame), conducted as a series of five work packages, as outlined below:-

Work package	Title	Contributing to objective(s)
1	A review of the nutritional requirements of organic livestock	1,2
2	A review of energy and protein supply from forages in organic livestock production	1,2,3,4,5,8
3	Husbandry, management and cropping options to achieve a better balance of nutrient supply and demand.	3,4,5,8
4	Modelling the potential output from organic dairy systems.	6,7,8
5	A review of the environmental impacts of three organic dairy systems	7,8

Information derived from the work packages was used to address each of the specific objectives of the project.

4) Results and summary of outcomes for each project objective

Objective 1. Extrapolating from published data, to review the requirements for energy and protein across the production cycle for organic milk, beef, lamb, pig and poultry production.

Work Package 1 reviewed the applicability of the current nutritional recommendations for dairy cattle, beef cattle, sheep and pigs in the UK as standards for defining the nutrient requirements of organically managed livestock. Nutrients considered were energy, protein, major and minor minerals and vitamins. The water requirements of organic livestock were considered to be identical to conventional livestock so were not covered by the review under work package 1. The review began by summarising the existing nutrient requirement standards for conventional livestock and then considered any areas where there may be differences between conventional and organic systems of management and production.

The published nutrient requirement standards in the UK for dairy cows, beef cattle and sheep are summarised in Table 1, whilst the UK nutrient requirement standards for pigs are summarised in Table 2.

Table 1. Published standards commonly used in the UK for ruminant diets

Nutrient	Reference	Comments & application
Dairy Cows		
Energy (Metabolisable energy)	Offer *et al*, 2002	Revised ME System now in widespread use.
Protein (Metabolisable Protein)	Offer *et al*, 2002	Revised MP system now in widespread use
Minerals	Todd JR (1983)	Modification of ARC 1983
	Underwood and Suttle (1999)	Commonly seen as a minimum standard
Vitamins	Todd JR (1983)	Modification of ARC 1983
Beef and Sheep		
Energy (Metabolisable energy)	AFRC 1993	Basis of energy system
Protein (Metabolisable Protein)	AFRC 1994	Basis of protein system
Minerals	AFRC (1991)	Modification of ARC 1983
	Underwood and Suttle (1999)	Commonly seen as a minimum standard
Vitamins	Todd JR (1983)	Modification of ARC 1983

Table 2. Published standards commonly used in the UK for pig diets

Nutrient	Reference	Comments & application
Growing pigs		
Energy and Protein	Whittemore *et al* (2001)	Technical review of energy and protein requirements
Minerals and Vitamins	AFRC (1990)	The basic UK reference
	Stranks *et al* (1988)	Modification of ARC (1981). Rarely used as a standard in UK practice
	NRC (1988)	The standard reference
Sows and Boars		
	Close and Cole (2000)	Mineral and Vitamin recommendations included.

Standards for the pre-ruminant calf when managed conventionally are commonly based on the recommendations given by Roy (1980).

The review concluded that the fundamental nutritional physiology of a particular animal is no different whether reared conventionally or according to organic principles. Nevertheless, the principles of farming organically and the need in livestock systems to work within the regulations, does raise various issues in relation to meeting the nutrient needs of organically reared animals.

These issues include the fact that organic systems of production often use different breeds (often indigenous breeds) compared with conventional systems and that those animals may have different nutrient needs as a result of increased exposure to weather or increased energy expenditure on foraging activity. It could also be argued that organically managed animals may have a requirement for additional nutrients to promote a healthy immune system in order to counter disease challenges, that would be minimised under conventional management by the use of drugs.

The review concludes that there is evidence to indicate that some of these factors may have a marginal impact on the nutrient needs of organic livestock. However, there is insufficient evidence at present to justify making changes to the commonly accepted feeding standards used in the UK in ration formulation for animals reared to organic standards. Despite this, nutrient allowances must be adjusted to take into account the extra demands (due to environment and physical activity) of organic livestock under forage based feeding systems as well as allowing for any nutrient antagonisms and interactions that can take place when feeding a range of organically produced feedstuffs.

Organic poultry are reared under conditions where they have access to pasture. Birds obtain nutrients from pasture, from insects and other small invertebrates, and finally from small seeds, fruits and berries. Currently it is not known how important each of these sources of nutrition is likely to be. However, estimates of protein supply from pasture using the ADAS biological model of egg production (Charles, 1984, Hill *et al.*, 1988) indicate that only approximately 2.6% of protein supply is likely to come from grass. Work is currently underway to validate existing poultry models and determine their suitability when used for pasture-based, organic poultry systems rather than poultry housed and fed under conventional management (Defra Project OF0327). One issue that is already becoming apparent from this work is the need for increased nutrient intakes for organic poultry kept outdoors at ambient temperature, compared with conventionally housed poultry kept at temperatures above 15 ^{o}C.

However, most of the adjustments required would also apply to animals managed conventionally under similar systems and many of the current nutrient requirement standards for conventional animals already allow such adjustments to take place. Nevertheless, several areas have been highlighted where information is lacking (e.g. the accuracy of prediction equations to estimate the nutritive value of organically produced silages). It is also thought that certain breeds of pig (e.g. Duroc) may be more adapted to digesting forages than others, making them more suitable for outdoor organic systems than modern genotypes (e.g. Landrace-Large White). However, valid scientific justification for this belief remains to be confirmed (Pryce *et al.*, 2004).

Whatever system of production is chosen (organic or conventional), it is fundamental that the nutrient supply must be adequate to satisfy the animal's nutrient requirements in order to avoid poor production, metabolic disturbances, excessive loss of body condition and to maintain health and welfare. This can be particularly challenging for high-producing animals and at particular points in the production cycle. As the use of concentrated feeds are limited under organic farming systems, the production, management and utilisation of high quality forage is needed to meet the needs of livestock at the most productive parts of their production cycle (young rapidly growing animals, milk production and in the fattening phase of meat production).

Objective 2. To predict the likelihood of meeting all or a minimum proportion of these requirements from a range of organically produced forages.

Work Package 1 also estimated the nutrient supply and theoretical productivity levels from a range of mixed forage and concentrate diets for dairy cows. For 100% forage diets, potential milk yield ranged from 13 - 27 l/day as forage Metabolisable Energy (ME) values increased from 8 - 12 MJ/kg DM.

Similarly, for a 60:40 forage:concentrate diet (the maximum concentrate allowed in organic standards), potential milk yield ranged from 20 - 29 l/day as forage ME values increased over the same range (Table 3).

Table 3 The effect of forage ME and forage concentrate ratio on livestock production

Production system	Forage:conc ratio	Forage ME (MJ/Me/kg DM) 12	10	8
For dairy production:				
Theoretical milk yield (litres) at varying levels of forage energy level and using a concentrate of 13 MJ ME/kg DM	100:0	27	20	13
	80:20	28	22	17
	60:40	29	24	20
For sheep production:				
Calculated energy intake (MJ/day) of ewes in late pregnancy at varying levels of forage energy level and using a concentrate of 13 MJ ME/kg DM	100:0	18.0	15.0	12.0
	80:20	18.3	15.9	13.5
	60:40	18.6	16.6	15.0
For beef production:				
Calculated liveweight gains (kg/day) of growing beef cattle (350 kg) at varying levels of forage energy level and using a concentrate of 13 MJ ME/kg DM	100:0	1.0	0.7	0.4
	60:40	1.2	0.9	0.7
Calculated liveweight gains (kg/day) of growing beef cattle (500 kg) at varying levels of forage energy level and using a concentrate of 13 MJ ME/kg DM	100:0	1.2	0.9	0.6
	60:40	1.4	1.1	0.9

For pregnant ewes, 100% organic forage diets could supply 12 - 18 MJ/day of ME as forage ME value ranged from 8 - 12 MJ/kg DM. Alternatively, when 40% concentrates were added to the basal forage, ME intakes ranged from 15 - 18.6 MJ/day over the same range in forage ME value. For a 500 kg growing beef animal, potential liveweight gains (LWG) were between 0.6 and 1.2 kg/day when a 100% forage diet was offered as forage ME value ranged from 8 - 12 MJ/kg DM. Similarly, a 60:40 forage: concentrate diet supplied nutrients to support LWG's of 0.9 - 1.4 kg/day over the same range in forage ME value. From these derived data it can be concluded that diets based on 100% organic forage will only support relatively low levels of milk production in dairy cows and LWG in finishing animals. In contrast, including the maximum concentrate allowance of 40% means that moderate to high levels of milk production and LWG can be achieved depending on the quality of the basal forage.

Despite these calculations however, there are a number of ruminant production systems where reliance on diets approaching 100% forage are consistent with high levels of output. For example, spring calving suckler cows in both conventional and organic systems are traditionally fed only small amounts of concentrates, since the period of peak nutritional requirement (early lactation) coincides with the period of maximum spring grass growth (i.e. peak nutrient availability). The organically managed spring calving suckler herd at ADAS Redesdale receives < 5% (on a dry matter basis) of their annual feed inputs as concentrates, but still produces a commercially acceptable level performance, with calf growth rates to weaning in excess of 1.0 kg/day, and calving percentages of 95% (Project: OF0319).

Similar circumstances may apply with regard to sheep systems. The timing of spring lambing on both conventional and organic sheep farms is generally designed to coincide with the flush of spring grass growth to provide maximum nutrients for lactating ewes, yet minimise the need for expensive concentrate supplementation during this critical period of nutrient demand.

In these high forage systems, which are very reliant on grazed grass at critical times of the year, the nutritional value of grass becomes very important. Grazed forages based on either grass alone or on grass/clover mixtures (as in most organic systems) can range in energy value from approximately 7 MJ/kg DM for unimproved hill grassland during winter to approximately 12 MJ/kg DM for early spring herbage in improved swards. Low nutritional value of grazed swards need not be a problem if the nutrient needs of the animals grazing it are also correspondingly low. The critical factor in maximising the use of organic grazing and other forages in production systems is to match the nutrient needs of the animals and the supply available throughout the production cycle.

As forages are the main components of the diet in organic ruminant systems, the level of protein in the forage has a major influence on productivity. The most immediate requirement is to provide sufficient nitrogen for microbial synthesis. The need for protein supplementation with high quality sources of low rumen degradability to provide rumen by-pass protein is likely to be lower in organic systems, since production levels are generally lower. Where N supply in the rumen is low, through a low intake of rumen degradable protein, microbial growth can be limited, intake depressed and production affected. Recycled N in the form of urea is important in low N intake situations (NRC, 1985). The net effect is that the efficiency of dietary N utilisation is improved at lower N intakes. Protein synthesis within the rumen also requires an adequate supply of utilisable energy to support microbial growth, and this is taken into account in the revised MP system.

The production stages of organic ruminant systems where 100% forage diets are likely to be limiting are:- early lactation dairy cows, early lactating ewes lambing before the spring flush of grass, young, rapidly growing animals with a high demand for protein, and finishing animals during the final fattening phase where energy requirements may be high.

Conversely, the production stages of organic ruminant systems where 100% forage diets are unlikely to be limiting are:- non-lactating or late lactation breeding cattle and sheep, growing animals going through a "store" period or finishing animals where long production cycles are required (e.g. > 18 months for cattle). Where 100% forage diets are not considered adequate then concentrate supplementation at varying levels will be required (e.g. at up to the maximum organic allowance of 40% for dairy cows as described above).

For pigs it was concluded that forages can be utilised at high levels (potentially between 40 - 80 % of daily DM intake) to satisfy the nutrient needs of non-lactating, pregnant sows. However, even high quality forages will make relatively little contribution to the nutrient demands of lactating sows and growing pigs. As discussed above, it was concluded that access to pasture is likely to supply less than 5 % of the protein needs to organic poultry.

Objective 3. To examine the potential to adjust management or production systems to achieve a better balance of nutrient supply and demand.

Work Package 2 reviewed the energy and protein supply from forages in organic livestock production systems. The role of forages in organic livestock systems in the UK was assessed and the factors influencing forage yield, quality and utilisation, as well as measures of the efficiency of forage production and utilisation in practice, were examined.

The objective of Work Package 3 was to review the effects of forage conservation, concentrate supplementation, grazing systems, mixed forages and feeding strategy with regard to their potential impacts on nutrient supply and demand in organic livestock systems. Most of the available information in this area relates to conventional livestock management systems but the vast majority of the key principles are equally applicable to organic systems. The two main methods of forage conservation on organic farms will be either silage making or hay making. Both systems of conservation can incur highly variable losses of the herbage grown, as a result of field and storage losses (Table 4). The ensiling of organic forages may cause particular problems due to the highly buffered and brittle nature of the legume species (predominantly clovers) often used as the basis of organic forage production systems.

Table 4. Losses (%) in harvesting and storage of forages

Forage type	Field loss	Storage loss	Total
Direct cut grass silage	2-3	18-22	20-25
Haylage – 65% DM	11-13	8-12	19-25
Haylage – 50% DM	11-13	3-8	14-21
Lucerne hay	30-35	2-4	32-39
Grass-legume hay	18-23	2-4	20-27

The dry matter yields of organic swards based on ryegrass and forage legume mixtures might be expected to be slightly lower than conventional high-N grassland. For example work in Denmark has shown that forage production from conventional farms is 21-37% higher for cereal crops and 12-18% higher for fodder beet and grass/legume swards than the yields recorded on organic farms (Halberg & Kristensen, 1997).

Under organic standards, no acid preservatives can be used during the ensiling process, so strategies must be adopted which enhance the ensilability of organic forages, particularly if they contain considerable amounts of low DM, low sugar legumes. However, using mower conditioners to achieve a short rapid wilt of forage crops has been beneficial in reducing ensilage losses and stimulating voluntary feed intake (VFI) by 19.8% and improving animal performance by 2.8% in some circumstances (Yan *et al.*, 1996). During periods of adverse weather, when wetter grass/clover crops are being ensiled and wilting of the crop prior to ensiling is not feasible, there may be benefits from using an absorbent (e.g. straw) during ensiling, or for later cuts, ensiling the grass/clover crop with whole-crop cereals to reduce effluent losses and the risk of pollution.

The type of crop rotation and the balance between the total area of N-fixing (e.g. legumes) and N-demanding crops will also influence differences between organic and conventional systems in forage yields. However, the economic outputs per hectare can still be comparable due to the nutritive value and high intake characteristics of ryegrass:legume forage mixes used by organic farmers and organic price premiums achieved. However, due to the seasonal growth pattern of forage legumes in particular, matching the specific energy and protein needs of particular classes of organic livestock can be challenging, particularly on organic dairy farms.

In organic dairy cow systems, most herds adopt a spring calving pattern so that the peak nutrient demand (lactation) coincides with spring/summer grass growth. On dairy farms where shortage of protein is a problem (e.g. in the cooler north and west where growing peas and beans is restricted by climate or topography), it may be appropriate to delay the spring calving period until early summer.

This strategy would take advantage of the fact that late summer season grass/clover swards tend to be higher in protein than early season grass/clover swards. Alternatively, using some of the high protein, late season silage as a buffer feed in early spring may be an appropriate strategy on some organic dairy farms to alleviate low protein levels in early spring grazing.

The ideal buffer feed is one that is not eaten in preference to the grazed herbage but complements it nutritionally, and encourages optimum, total feed intake. Buffer feeding has been found to be more beneficial to ruminants with a high nutritional requirement and this has been attributed to the ingestion rate of the conserved forage being 2-3 times greater than that of the herbage (Phillips, 1989). However, to achieve this rate of eating the buffer forage needs to be high quality and readily digestible. The effect of buffer feeding on whole-farm land utilisation will depend on the type of forage fed and the relative efficiencies with which the swards are grazed and the forage conserved (Phillips, 1989). Conserving forages requires a greater input of support energy, mechanisation and labour compared to grazed herbage.

During winter feeding periods, it may also be appropriate to mix together different forages with complementary nutrient profiles to optimise the efficiency of organic dairy systems. Mixing high starch, low protein maize silage with low starch, high protein late season grass/clover silage (33:67 ratio on a DM basis) will stimulate VFI and improve milk output (Phipps *et al.*, 1995). On farms where growing maize silage is not possible, then blending early and late season organic grass/clover silages and whole crop cereals may be a more practical strategy to increase VFI and milk output. Given the limitation on concentrate input at 40% of total diet DM in organic systems, strategies to stimulate VFI are particularly important in organic dairy systems where nutrient demands are high.

Extended grazing can lead to both an earlier turnout and a longer grazing period in the autumn. However, this practice is not suitable for all farms and requires careful planning if poaching of the swards is to be avoided. Grazing may need to be restricted to a maximum of 2-6 hours per day (MDC, 2000; Frame, 2001). In organic systems there should be sufficient N-fixation during the late summer period to ensure adequate N is available for grass re-growth. Extended grazing until December has been successfully integrated into conventional grass/clover systems (MDC, 2000). An increasing white clover content in organic grass/clover swards during the summer will provide extra N for plant growth, with the targets suggested by Frame (2001) for grass systems based on fertiliser N, slightly higher than those that can be achieved in organic systems. However, accumulating excessive herbage prior to grazing has the risk of causing leaf senescence and the build up of excess dead material (Frame, 2001).

Extending the grazing season in the spring by grazing rye or an early ryegrass (Westerwolds or Italian) can reduce the quantity of silage required for the winter period, replace part of the concentrate input required and reduce feed costs (Leaver, 1990). However, forward planning is required to ensure there is sufficient herbage available once the rye has been grazed. On beef farms the practice of extended grazing for 2-3 hours per day may have limited benefits. Often, there will be neither the facilities or labour available to operate the system for a few hours a day, with most herds grazing for 24 hours per day prior to or after the housing period. Mixed grazing of cattle and sheep, may reduce the problems associated with poaching during wetter periods. An alternative option to grazing rye or Westerwold ryegrass in the early spring, is to zero graze the crops (depending on ground conditions and the availability of suitable machinery) and feed the cut crop to the animals indoors in addition to silage. Zero grazing may increase the utilisation of the crop, and reduce poaching and damage to the soil structure, but has associated increased fixed costs of labour and machinery.

For sheep and suckler cow systems, delaying the spring lambing and calving period may also be an appropriate strategy on organic farms where spring grass growth is slow to start. May lambing systems also offer the possibility of minimal or no concentrate inputs to the ewe flock.

In pigs, Rivera Ferre *et al.* (1999) studied grass utilisation by dry outdoor sows given restricted amounts of concentrates daily. Average herbage organic matter intake (OMI) ranged from 1.13 - 2.00 kg/day between spring and summer seasons with individual intakes varying from 0.5 - 4.6 kg/day across the different individual sows and seasons. Herbage OM digestibility ranged from 0.79 - 0.47 between spring and summer seasons. It was concluded that the large variation in herbage intake and digestibility would mean that the extent to which herbage could form part of the dry sow diet would also be highly variable in practice, even if sometimes substantial. In poultry systems, there is a need for more hard data to establish the extent to which pasture and the invertebrate populations it supports can help meet the nutrient needs of the birds.

Whilst ryegrass or other grass species and mixtures form the basis of most organic forage systems, other crops can also make a significant contribution to the nutrient needs of organic livestock. Popp *et al.* (2000) reviewed a number of trials in which different legumes were grazed by growing cattle or sheep. The results showed that in many trials significantly higher live-weight gains were recorded when legumes or legume-grass mixtures were grazed compared to grass-only swards. Red clover can also be particularly useful in swards destined for silage making. Similarly, white clover is the most important legume grown in organic systems and influences the quantity of forage that is produced for grazing and conservation, stocking density and output of marketable products (e.g. milk, meat) from the farm. Despite generally lower yields and limited geographic suitability, other legumes such as lucerne, sainfoin or vetches can also be useful components of organic forage systems.

Objective 4. To consider likely contribution from alternative forages and protein sources as home-grown feeds.

Both Work Packages 2 and 3 indicated that a range of alternative forage crops and concentrate protein sources were well suited for incorporation into organic farming systems. As well as the reliance on both white and red clover, alternative legumes such as lucerne, sainfoin or vetches could form part of organic cropping rotations. However, the potential of these alternative legume forages was generally limited to the southern, warmer and lowland areas of the UK. In the cooler, wetter northern areas, alternative grass species such as timothy or cocksfoot or whole crop cereal silage were more likely to be applicable.

Along with whole crop cereal silage, maize silage also has great potential as a complementary forage in organic systems for ruminants, particularly dairy cows, providing valuable energy in rations and stimulating voluntary feed intake. However, particular care does need to be taken with agronomic factors such as weed control if these alternative forages are to be successfully included in organic cropping rotations. Maize silage can form the sole forage in dairy cow and beef cattle rations (Phipps and Wilkinson, 1985) but such rations are very low in protein and would require significant amounts of protein to be supplied from the concentrate portion of the diet. Given the restriction on concentrate inputs within organic systems, it is unlikely that concentrate could practically supplement 100% maize silage diets in most cases. Consequently, where maize silage is used it is probably limited to supplying up to 50% of the forage intake of all but the lowest performing classes of stock.

Whole crop cereals are capable of achieving the same objectives of stimulating VFI in most cases and can also be grown across a much wider climatic range than maize. However, within organic systems they are ensiled as fermented rather than ammonia treated crops resulting in low protein levels compared with grass/clover silage crops. Consequently, it is also likely that for dairy cows at least, whole crop cereals should also be limited to approximately 50% of the forage component of the diet. Under certain circumstances however (e.g. non-lactating, spring calving suckler cows) it may be possible that whole crop cereals can be the major source of forage in the diet.

Peas and beans are likely to be a main source of organic protein in organic livestock rations generally, and can also be successfully incorporated into the cropping regime within arable and mixed organic farms. Peas and beans make an excellent protein source to complement maize silage-based diets, but their use in grass silage-based diets may be limited by their rapid rumen degradability in situations where rumen bypass protein is required (Wilkins and Jones, 2000). For finishing beef and lamb diets however, beans can be used as the sole protein source within the concentrate portion of the diet rather than the standard soyabean meal product used in conventional rations (e.g. Hyslop *et al*, 2003). Whilst their yield potential may limit the use of these crops within conventional cropping rotations, their role as a valuable source of dietary protein, means that these nitrogen-fixing crops can play a significant role within an overall organic rotation.

Catch crops such as kale, stubble turnips, swedes or forage rape can also be used within organic rotations to augment the supply of forage to organic livestock. All of these crops can be harvested and fed in the trough (e.g. Fraser *et al.*, 2001) but in most situations they are usually grazed *in situ* by finishing lambs, or by cattle and adult sheep during the autumn and winter months. They can be useful additions to the forage supply, often allowing an element of "double cropping" within the same year, since they can be sown after a crop of whole crop cereals or grass silage has been harvested and before the following spring sown crop is established.

The extra grazed forage from these crops can be very useful within organic systems when winter forage supplies are low due to poor spring growth of organic swards. Appropriate selection of suitable land for these crops is required since the high stocking rates needed to achieve economic utilisation rates of the forage can lead to soil damage due to poaching in water-logged soils. However, despite these problems it may be that these crops could be developed further as source of organic forage for out-wintered cattle (e.g. non-lactating spring calving suckler cows) in appropriate situations, especially where they may act to reduce nitrate leaching

Objective 5. To assess likely effects on animal health and product quality.

Maximising forage use in organic ruminant diets should encourage optimum rumen functioning. However, failing to meet the high nutrient demands of early lactation in milking cows, by restricting concentrate usage for example, may reduce the animals ability to combat diseases such as mastitis and lameness. Ketosis arising as a result of energy deficit, and other problems such as poor fertility leading to high culling rates, may also be the result of inappropriate nutrient supply in early lactation.

Work Packages 2 and 3 considered the effects of organic forages on aspects of animal health and product quality. Different plant species can contain significantly different concentrations of minerals. There is much speculation on the role of herbs to supply minerals to organic livestock, but scientific research into individual herbs species, their mineral concentrations and their availability is limited (Fisher *et al*, 1994). Chicory, sheep's sorrel, plantain, dandelion and *Lotus* species (trefoils) have all been investigated to some extent as sources of minerals in livestock diets. Whilst these herbs do have high mineral concentrations, their agronomic yield and persistency under UK climatic conditions is often unreliable.

Studies in the UK, under organic farming conditions (Marley et al, 2003) found that lambs with naturally acquired helminth infections grazing birdsfoot trefoil (*Lotus corniculatus*) had fewer helminth parasites than sheep grazing ryegrass/white clover (*Lolium perenne/Trifolium repens*). In the study, lambs grazed replicated plots of birdsfoot trefoil or ryegrass/white clover for 5 weeks. Live weight and faecal egg counts (FEC) were determined weekly and eight lambs per forage treatment were slaughtered at the end of the trial to determine total helminth intensities. Lambs grazing birdsfoot trefoil had a lower FEC on day 7 and fewer total adult helminths than those grazing the other forages on day 35. Future use of these herbs within organic systems in the UK is likely to concentrate on their association with parasite control.

Ensuring an adequate supply of herbage to lactating dairy cows whilst grazing has been shown to improve milk quality (Weller and Cooper, 2001). However, the low fibre levels in some organic swards containing a high proportion of low fibre legumes can lead to lower milk fat levels in dairy systems. Strategic use of buffer feeds to supplement grazed grass supply to dairy cows can improve milk quality in some circumstances. Forage legumes play a vital role in organic systems and it has been shown that for every 1% increase in dietary crude protein content, milk protein content increases by 0.02 % (Emery, 1978).

Diets for growing and finishing animals based on either fresh or ensiled grass or grass/clover swards can also improve the consumer acceptability of both beef and lamb products and improve the balance of fatty acids towards increased concentrations of poly-unsaturated fatty acids in human diets.

Objective 6) To develop a database model to predict the potential output and benefits for organic farmers of implementing different options and strategies for forage production and utilisation.

Work Package 4 modelled the potential output from organic dairy systems using the following variables:-

1) Farm or site classification (soil type, topography, location, etc)

2) Herd type and expected milk yield (ranged from 4,750 – 6,500 litres per annum)

3) Cropping systems (the balance between how much forage and concentrate is home-grown and how much is purchased onto the farm)

4) Crop yields and energy quality (including variation in grazed, conserved and combinable crops)

5) Variable estimates of herbage utilisation and conservation losses

Using published estimates of the variation in each of the above factors, a total of 153 distinct organic dairy systems were modelled using a Microsoft Excel spreadsheet. The review of the published data on the utilisation of both grazed and conserved forages (Work Package 2) showed large variations both between and within different studies. In the calculations for the individual systems modelled, the efficiencies of forage utilisation for the forage crops that have been used are either 85% and 20% (High), 75% and 30% (Medium) or 65% and 40% (Low) for grazed herbage utilisation and conservation losses, respectively.

Different cropping systems were modelled, with the management strategy based on either home-grown forage plus purchased concentrates, home-grown forage plus home-grown concentrates, or 100% home-grown forage and no concentrate supplementation. The annual concentrate inputs used were: 0, 0.5, 1.0 and 1.5 tonnes per cow per annum, with the feed supplied from cereal grain and field bean crops. A standard energy value of 12.5 MJ of metabolisable energy per kg DM was used for the purchased concentrate feeds.

The values used for calculating the dairy cow stocking densities were based on a 600 kg cow being equivalent to one livestock unit (LU). Predicted milk yields per cow used in the calculations ranged from 4,750 - 6,500 litres, calculated from the published energy level for both the concentrate feeds and types of forages grown within the systems. The calculation of the predicted feed intakes and milk output were based on the data published by Chamberlain & Wilkinson (1996), with standard milk quality values of 4.0% fat and 3.3% protein. The annual culling rates in organic herds range from 8-40% (Kristensen & Kristensen, 1998; Hovi *et al*., 2002) with the highest rates occurring in herds aiming for high milk yields per cow as many lower yielding animals are culled after the first lactation. An annual culling rate of 25% has been used in the current calculations. Changes in herd fertility and culling rates will influence both the output from the individual system and the number of replacements that need to be reared annually, and also affect the level of milk output that can be achieved, due to changes in the ratio of lactating to non-lactating animals.

The results indicate that a wide variation in the potential output from the different organic systems could be achieved under different combinations of management, farm location and feed self-sufficiency. The modelling exercise showed that the main influences on the potential output from an organic dairy system are the type of cropping rotation that is established, the source and quantity of concentrate feeds for the dairy herd, and how efficiently forage is utilised both for grazing and conservation.

When compared at similar levels of concentrate feeding per cow, the output from the systems based on home-grown forage and purchased concentrates was higher than those based on self-sufficiency and the growing of all feeds sources on the farm. The total milk production and income per hectare would be lower from self-sufficient systems feeding 1.0 tonnes of concentrate per cow. To be financially viable this type of system may require extra income from other sources, such as non-farming income or agri-environment schemes.

Nitrogen fixation by legumes is the primary source of N for crop production in organic systems, supported where appropriate by the return of animal waste as FYM or slurry. Both the quantity of legumes in the sward and the rate of fixation will vary annually and influence the level of crop production within the systems. For systems growing both high-energy forage crops and grain crops the availability of N may be below the optimal level, requiring a significantly higher proportion of legumes in the rotation to increase the total N input from fixation. These systems also require a longer rotation to be established.

The major dilemma identified is that of balancing the organic philosophy against the need to farm in an economically sustainable way. For a given farm size, simple grassland systems with bought-in concentrates and straw are likely to be more profitable. However, they may not be particularly robust or sustainable from an organic or self-sufficiency perspective. Self-sufficient organic systems with more complex cropping rotations using the same area of land (farm size) to produce both forage and all concentrate feed inputs, may be considered more organically sustainable and robust in the face of seasonal variation in crop output. However, they often place the farmer at a severe economic disadvantage since fewer cows can be kept and less milk produced from the same area of land.

It is worth noting that the output from the modelling options show that the potential output from organic systems is higher than figures reported in published data from organic dairy farms. These results suggest that the performance of farms could be improved, including maximising the yield, quality and utilisation of the forage crops grown on the farm.

Objective 7. To determine the environmental losses and gains at each stage of production and utilisation.

Work Package 5 reviewed the environmental impacts of three selected organic dairy systems with respect to the impact on land, impacts to the atmosphere, and the potential impact on water. Only the impact of the actual operations and products of the farms themselves were considered, such that indirect energy (e.g. that used to produce farm equipment) was not included, nor were the impacts of transported pollutants once they left the farm boundary (e.g. N_2O emissions downstream of run-off sites). The absolute values of pollutants produced were not calculated where these were considered equivalent in each system, only when there were differences between the systems.

Three organic dairy systems were selected from the total of 153 systems modelled in Work Package 4. The systems selected for environmental assessment under this work package were examined because they represent scenarios which incorporate typical organic dairy farm management regimes in the UK. The key features of the three selected systems were as follows:- (system IDs in parenthesis):

- an all-grass system where all feed concentrates are imported onto the farm (S71)
- a system where a large proportion of grass is supported by fodder crops supplemented by 1 tonne of imported concentrates (S76)
- a grass-based system supported by fodder crops and home-grown concentrates but with no imported concentrates (S81)

The percentage area of the farm under various crops was provided from Work Package 4, together with other information (such as stocking density). The livestock numbers (expressed as livestock units (LSU)) for the modelled lowland farm of 100 ha were given as 140, 152 and 120 for the three systems S71, S76 and S81 respectively, and it was also assumed that the cows were of medium size (i.e. 600 kg), and heifer replacements were introduced to the herd at a rate of 25 %. This amounted to 105, 114 & 90 adult milking cows housed on a slurry system, and 35, 38 & 30 calves/heifers housed on a straw-based manure system for the three systems respectively. It was also assumed that the cows were grazed outside for 50% of the time and housed for the remainder, which means that the three systems, S71, S76 and S81, would have annual slurry outputs of 1008, 1094 and 864 m^3 respectively. There would also be approximately 11, 12 & 10 t manure from the calves (housed 100% of time) and 205, 223 & 175 t manure from the heifers (assuming housed 50% of time), amounting to 216, 235 & 185 t farmyard manure (FYM) from the systems S71, S76 & S81 respectively.

Environmental impacts on land may include effects on soil organic matter (SOM), soil biological activity, and soil structure and erosion risk. The three systems all maintain at least 70% of the land under grass leys, so SOM concentration may be expected to be adequate, if not above average. If any difference exists between the systems, it is that cultivation on S76 and S81 may have lower SOM levels through oxidation. The overall slurry and manure returns in the three systems are broadly similar, although inputs for S81 are 15 - 20 % less than for the other two. Although no detrimental impact on soil organic matter levels is envisaged by any of the systems, they may rank in the order of S71 > S76 > S81 for SOM concentrations.

The factors that suggest there is little difference between S71, S76 & S81 in their impact on SOM, soil fauna and micro-biota, also suggests that there will be little difference in their maintenance of soil structure. Factors such as a high proportion and length of grass leys, as occur in the three systems studied, are precisely those that give a higher “soil protection index” (Hausheer *et al.,* 1998) for 80% of organic systems when compared to conventional. In addition, the spring timing of cultivation, although requiring careful soil management to avoid compaction problems, may be helpful with respect to protection from erosion. Hence no major problems in respect of soil structural degradation or erosion, are foreseen with any of the three forage cropping systems.

Atmospheric pollution can be considered in two categories, either the pollution of the local airspace by odours and gases that may have a deleterious effect on nearby communities or ecosystems, or the contribution to a net global effect. Of the operations likely to be carried out under the three productions systems considered, cultivation and harvesting operations will mainly have global impact, whereas those associated with the storing and spreading of slurry manure will have both global and local impacts.

Using the appropriate land area, slurry and manure application rates, the resulting ammonia and leached nitrogen flux rates were calculated by MANNER (Chambers *et al.,* 1999). In these scenarios, the slurry is assumed to be spread in mid-March and ploughed in within 1-2 days, whilst the farmyard manure is spread soon after and left on the surface. In both cases, clay loam soil was assumed, with about 30 mm of rain between spreading and the cessation of drainage at the end of March. Results indicate that there is little to choose in terms of ammonia volatilisation impact between the three regimes after land spreading, which is governed more by whether all spread slurry can be incorporated within two days (Chambers *et al.,* 1999), and whether the opportunity occurs for spreading in the narrow window of opportunity in March for spring cultivation.

The worst regime for total emissions, and hence the impact of ammonia in the atmosphere in creating acid rain problems, would be S76, and the least objectionable S81. However, in terms of local nuisance of odours, S71 is likely to be the most noticeable, as this has the highest emission rate during actual spreading, more than twice that of other regimes.

Table 5. The total estimated differential in annual greenhouse gas impact from 100 ha farms adopting the three forage production regimes of S71, S76 & S81. The equivalent impact of one mole of CH_4 and N_2O are taken to be 56 and 280, after Narbuurs *et al*. (1999), which equates 1 kg of the gases to 20 & 293 kg of CO_2 respectively.

	Forage regime		
	S71	**S76**	**S81**
CO_2 emissions due to cultivation (t CO_2)	28.7	29.8	29.2
CH_4 emission from livestock (t CH_4)	15.4	16.9	13.3
N_2O emission from manure (kg N_2O)	165	180	142
Total CO_2 equivalent impact (t CO_2)	**385**	**420**	**337**

The full impact of the three forage regimes on the global atmosphere can be estimated by adding together the differential impact of the major three greenhouse gases (i.e. carbon dioxide, methane and nitrous oxide, CO_2, CH_4 and N_2O respectively). Although in this analysis the S76 regime could be having 24 % more impact on global warming than S81, and 9 % more than S71 (Table 4), there is little to choose between them, because this difference must be set against the general consensus that organic farming systems emit only 34 – 52 % of the CO_2 emitted from conventional farming systems (Stolze *et al.,* 2000). This will be even lower for the total greenhouse gas impact, because they generally operate with lower nitrogen levels, and so are likely to emit less N_2O (Unwin *et al.,* 1995). In addition, these also tend to have lower stocking densities than conventional dairy systems and so would have lower CH_4 flux densities per unit area (Unwin *et al.*, 1995).

The three key indicators of environmental pollution to water resulting from agricultural practices relevant to this comparison of three production systems are, nitrate leaching, phosphate/sediment run-off and the incidence of pathogens in run-off and leached water (Shepherd *et al.*, 2003). Estimates were for only minor differences between the three systems modelled. A fourth common consideration, that of pesticide residue leaching and run-off, will not be important in this comparison of organic systems.

As with all assessments of the impact of farming practice on the environment, much depends on the specific detail of how each system operates. Much of this detail will depend on individual farmers, their preferences and their skills. This assessment, therefore, has to be general, being based on the scientific literature and calculations based on some assumptions about how the farming systems would operate. Nevertheless, it gives a good indication of the comparative impacts of the three systems, and is broadly in line with expectations. As the system becomes more intensive, with higher stocking densities and requiring the import of nutrients, the greater the ‘leakiness’ of the system beyond the farm boundary. However, we then need to consider if the comparison is made on a unit area, as in this comparison, or unit of product output basis.

On a wider perspective, the effects of high protein (nitrogen) grass and clover-based swards in organic systems may lead to N pollution if grazing, forage conservation and animal management strategies are not designed to utilise these crops effectively. Nitrate leaching or ammonia loss to the atmosphere may result if N fixed from the atmosphere by legumes is not harvested and consumed by organic dairy, beef or sheep animals effectively. Due to differences in rumen fermentation patterns, high forage diets (100%) tend to produce more methane and other Green House Gases than diets containing a substantial proportion of concentrates. Consequently, when viewed strictly on a kg of DM consumed basis, high forage diets such as those used in organic systems, may in fact be relatively more polluting than conventional diets where higher levels of concentrates are used.

Objective 8. To provide specific guidelines for use by farmers, advisors and policymakers to maximise efficiency in the production and utilisation of forages within a range of organic livestock production systems.

The main consideration for efficient organic forage utilisation is that of matching supply of organic forages with the nutritive needs of the animals at key stages of their production cycle. This can be achieved by optimising the output of grass/clover swards for both grazing and conservation purposes. Minimising ensiling and hay making losses through appropriate wilting strategies both maximises forage availability on the farm and minimises environmental losses. Appropriate use of alternative forages in addition to grass/clover varieties will both optimise feed intake potential, maximise product output and minimise the need for supplementary concentrates in organic livestock systems. Mixing different grass/clover silages with complementary nutrient profiles can also assist in optimising forage utilisation.

Another area where optimising forage use in organic livestock systems can be enhanced is to match the animal production cycles with the crop production cycles so that peak nutrient demand is matched with peak nutrient supply from organic forages. This may involve altering calving or lambing patterns and timing to coincide with particular stages of forage crop production (e.g. higher protein content in late summer grass/clover swards).

Although much more work needs to be done in the area of selecting the most appropriate animal genotype for any given environment, it is also apparent that selecting breeds that utilise forage well is a fundamental component of organic livestock systems. Care must be taken to ensure that the limitations imposed by organic feeding strategies (e.g. the 60:40 forage:concentrate rule) do not compromise the health and welfare of organic animals.

The results of this project suggest that the main problem on organic livestock farms is to ensure that sufficient forage of acceptable quality is conserved for the winter period without putting undue pressure on the grazing area. Recent research and observation has shown that the main problems that farmers have to overcome in organic forage management are as follows:-

- Growth is slow in early season
- Protein content is variable but generally low in early season
- Protein content rises rapidly from the end of May onwards and is very high from mid-June to mid-September
- Protein content is variable but drops rapidly from mid-September onwards
- The nutritional value of grass/clover swards appears to drop very rapidly from mid-October onwards.

All these points depend on both the season and the clover content of the sward. In seeking solutions to these problems farmers should be advised that:

- The efficiency of forage use, grazing utilisation and losses of conserved forage, has the largest effect on stocking rate, output per hectare and hence profitability. The effect is greater than either type of system or the soil/farm site class.
- Simple all-grass systems dependent on bought-in concentrates and straw can give good levels of production but are not very robust and are not truly sustainable.
- Systems with either more forages, including high energy forages such as maize and fodder beet, or cereals and beans but still using some bought-in concentrates and straw, gave slightly higher levels of production and were much more robust. They were still not truly sustainable and were much more complex and hence likely to be more costly.
- Self sufficient systems with no bought-in feed were more robust and much more sustainable, but resulted in much lower levels of production for a given land area, resulting in a severe economic disadvantage.

If at all possible, farmers should avoid depending on a single large cut of forage and adopt one or more of the procedures outlined below:

- Graze the sward before shutting up for silage. This will give a later cut but of higher quality. However, this is a risky strategy in areas with either low rainfall or light soils or both.
- Make an earlier but smaller first cut of high quality forage and a larger, higher protein second cut. Again this may be a risky strategy in areas with either a low rainfall or light soils or both.
- Introduce a second high protein forage for silage, such as whole crop cereals with vetches, peas, lucerne or lupins, to reduce reliance on bought-in proteins.

- Either layer different forages into a single silage clamp or put different forages into different clamps. A ‘Dorset wedge’ system with one forage in front of another should be avoided. The layered system means the composition of the forages fed out will be reasonably consistent throughout most of the season.
- A second forage in the system will make it more robust by introducing a crop rotation to break pest and disease cycles, that will also result in an increase in forage dry matter intake.
- Always analyse conserved forages so that a balanced winter ration can be made up to optimise production and minimise losses to the environment.

From a policy perspective, modelling the environmental impact of organic dairy systems clearly shows that as stocking densities and output increases and more purchased concentrates are used, then the greater the "leakiness" of the system and the greater the pollution potential. On a whole farm basis this raises the dilemma - organic philosophy versus economic pressures. Following the organic philosophy would suggest that each individual farm should seek to grow all its forage and concentrate requirements. This approach would ensure a self sufficient, robust and sustainable system of organic farming. However, due to the difficulties associated with, climate, topography and fixed cost structure on many farms, this approach may put farmers at a severe economic disadvantage. In many areas of the UK for example, it is very difficult to grow grain concentrate, or alternative forage crops on-farm (e.g. hill and upland areas). The change in organic feed regulations in 2005 requiring that all feed inputs to organic animals be organically grown is likely to make this problem worse as it will tend to pressurise farmers to grow more of their own feed rather than purchase concentrates. Policymakers might consider what wider environmental and economic benefits could accrue by encouraging the collaboration of individual farm units for more efficient and sustainable use of resources.

5) Knowledge transfer

a) Two scientific papers have been drafted as part of this project as listed below:-

Modelling the potential output from organic dairy systems
Weller, R. F. and Tame, M.
Submitted to the Journal "*Biological Agriculture and Horticulture*".

A modelled assessment of the environmental impacts of three organic dairy systems.
King, J., Shepherd, M and Keatinge, R.
Submitted to "*Biological Agriculture and Horticulture*".

b) A draft advisory note on forage production and utilisation was produced as part of the project and it has been agreed that this note will be printed and distributed by the Soil Association as part of its technical series to farmers and growers.

c) A poster presentation entitled "Organic dairy systems: their potential output" was made at the Dairy Event, September 2004.

d) The following Work Package reports have been produced:-

(i) A review of the nutritional requirements of organic livestock. December 2002, 23 pp.

(ii) A review of the energy and protein supply from forages in organic livestock production. December 2002, 86 pp.

(iii) A review of the husbandry, management and cropping options to achieve a better balance of nutrient supply and demand in organic systems, June 2003, 18 pp.

(iv) A computer-based simulation model of differing organic dairy systems, September 2003 (Excel based spreadsheet).

(v) A review of the environmental impacts of three organic dairy systems, April 2004, 20 pp.

6) Recommendations for future work

This broad body of work has indicated that a number of gaps in current knowledge exist which would benefit from future study. These include:-

(i) the particular suitability of diverse plant and animal genotypes for forage-based organic systems
(ii) determining the nutritive value of organically produced forages and their interaction with organic concentrates in specific animal rations where required productivity levels are high
(iii) trace element nutrition and the potential contribution made by herbs to the nutrient requirements of organic livestock
(iv) the development of mixed forage diets for ruminant livestock to stimulate VFI and output with specific reference to organic forages
(v) specific weed and pest control issues in organic crop production, particularly with regard to weed control in forage maize, forage brassicas and during establishment of legume based swards.

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