ADAS Science Review 2003 – 2004






ADAS

Stephen Collier
Chief Executive

ADAS Science Policy

Our commitment to Research and Development

ADAS carries out internationally renowned, fully independent research in the terrestrial and aquatic environments, agriculture and the rural economy. We specialise in translating the results of our applied research into practical tools, techniques and advice. It is this strong scientific ethos which drives and underpins our consultancy work and differentiates ADAS from other organisations.

The ADAS Science Policy has been developed for our Government and corporate clients, who look to us for advice and guidance in the development of policy and supporting decisions. The aim is to evolve and adapt the policy, through our science strategy, to meet their present and future needs.

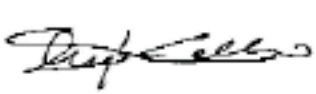
The ADAS Directors have made the following commitment to developing and promoting the quality and independence of our science. ADAS will:

- Strive to remain at the forefront of high quality, impartial research and development
- Provide independent, objective, scientific advice
- Provide an authoritative voice and leadership at national and, where appropriate, international level
- Develop scientific excellence through:
  - The appointment of high quality graduate and post-doctoral research staff
  - Staff membership of professional bodies and learned societies
  - Membership of scientific committees
  - A proactive staff development programme with succession planning and mentoring
  - Collaboration with research organisations, universities and other academic institutions
  - Leading the debate on issues such as diffuse pollution, waste management, sustainability and rural issues
- Encourage the dissemination of research through:
  - The publication of scientific papers on peer-reviewed journals
  - Conference presentations and proceedings
  - Reviews and position statements
- Maintain our quality accreditations, including ISO9001, the Joint Code of Practice, Good Laboratory Practice and other standards that apply to research and development
- Set objectives and targets to improve our scientific performance and to provide information to stakeholders as to how we are progressing with our policy implementation
- Support the ADAS Science and Policy Expert Group to develop systems to implement our Science Policy

Responsibilities

The Board of Directors is fully committed to the implementation of the ADAS Science Policy and I have primary responsibility for this. The ADAS Executive is responsible for reviewing the policy statement and progress in implementing the policy.

We will work with all our employees in order to achieve the aims and objectives set out above and provide the necessary training and resource to ensure that our commitments are met. We will also require ADAS subcontractors to share the same research ethics.



FOREWORD

Mike Griffin
Research and Science Director
(retired in 2004)

The ADAS research programme focuses increasingly on aspects of integrated land management and sustainable farming. This reflects government priorities, the requirements and demands of new legislation, and development at the regional level of Sustainable Strategies for Food and Farming. Interactions between farming systems and unwanted emissions to air and water, and between farming and wildlife, are complex. Provision of sustainable solutions for land management requires an holistic approach to research. Such studies tend to be large and multidisciplinary, with funding from several sources and the close involvement of key stakeholders.

This 2003 Science Review has a dedicated section for **Multidisciplinary Studies**. The Whittle Dene project examines the interactions between land use and water quality in a sub-catchment in north-east England. The LINK project on Sustainable Arable Farming For an Improved Environment (SAFFIE) seeks to achieve a balance between profitable farming and conservation, with particular focus on skylarks. The Sustainable Grazing project is developing environmentally and economically viable grazing systems for restoring and maintaining heather moorland. The final article reports on nitrogen losses to air and water following application of animal manures to land, with the emphasis on 'nitrogen pollution swapping'.

The 13 articles on **Environmental Science** are arranged under four sub-headings: catchment management; environmental risk assessment; sustainable land management; and waste management. Topics reported include bioremediation systems to limit pesticide pollution from farmyards, development of exposure modelling for veterinary medicines in the European Union, a survey of vegetation change and management practices in upland hay meadows, and management of farm manures.

The **Sustainable Crop Management** section has nine articles, three of which focus on biorenewables, mainly miscanthus. Other articles cover management of weed control to achieve a balance between biodiversity and crop yield, genetic improvement of wheat for specific end uses, and integrated control of botrytis in glasshouse ornamentals.

The nine articles in the **Livestock Science** section report research studies on beef cattle, sheep, pigs and poultry. These include the effect of nutrition on parasites in organically-managed ewes, finishing systems for different genotypes of suckled calf, effect of floor type for growing pigs on ammonia emissions, and production of eggs in furnished cages.

The **Rural Economy** section has five articles which include a project on food chain management in Gloucestershire and a mid-term evaluation, for Defra, of the England Rural Development Programme (ERDP).

Contents

Contents

Multidisciplinary Studies

James Clarke

Head of Science and Business Development - Sustainable Crop Management

Responsible for crop science and a specialist in farming systems, weed management and herbicide resistance.

Contact:
james.clarke@adas.co.uk

Brian Merrell

Head of Science and Business Development - Animal Health and Welfare

Responsible for livestock science and a specialist in hill and upland livestock systems and the impact of livestock farming on the upland environment.

Contact:
brian.merrell@adas.co.uk

Professor Brian J Chambers

Soil scientist and organic manure specialist

Specialist in research on the beneficial recycling of organic manures to land, and development of sustainable farming systems that minimise the impacts of agriculture on the environment. Special Professor at Cranfield University.

Contact:
brian.chambers@adas.co.uk

Brian Angell

Head of Rural Policy and Economics - Management Consultancy

A specialist in rural policy, rural development and agricultural extension.

Contact:
brian.angell@adas.co.uk

Multidisciplinary research in ADAS

Andrée Carter
ADAS Gleadthorpe

The rural landscape is complex and varied, but research programmes have traditionally investigated separate functions and processes. The challenge has been to integrate the different aspects of this research, identify how processes interact and recognise the synergies or conflicts that can occur. Ultimately, land managers require integrated, multidisciplinary solutions for the management of their land, which are both economically and socially sustainable.

Historically, ADAS has been a key provider of this subject-focussed research and, through its advisory function, has worked to translate the different results into practical and effective measures which farmers and land managers can implement. ADAS has achieved this because it has a very broad scientific skill base covering environment and agriculture, and works with colleagues in the socio-economic disciplines to achieve sustainable solutions (Fig.1).

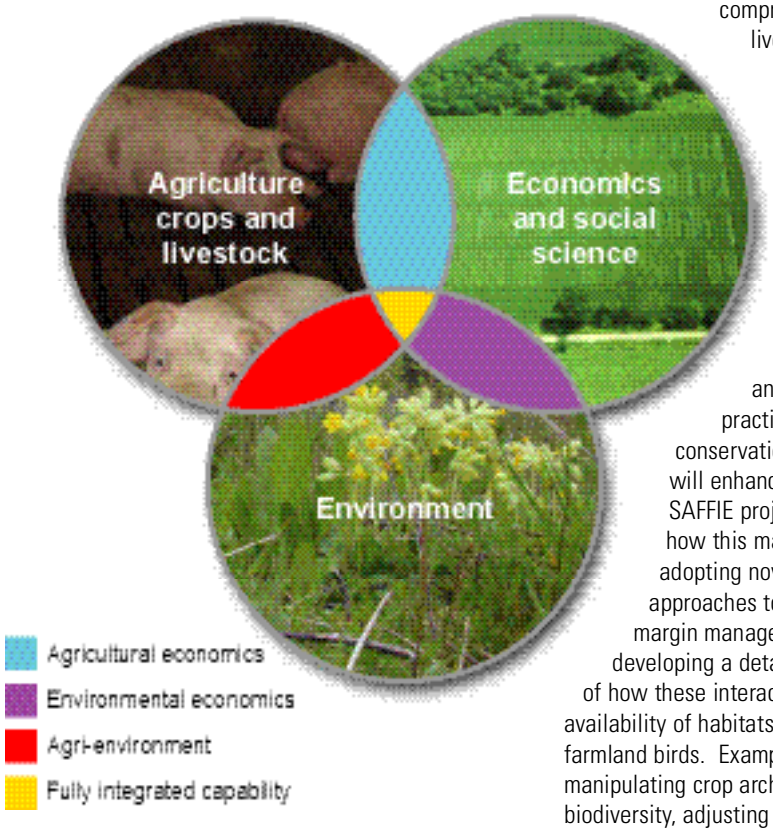


Figure 1. ADAS integration

More recently, we have recognised that our research projects themselves need to be fully integrated. They take account of all these different interests and drivers, particularly those introduced by new legislation, such as the Water and Waste Framework Directives, and the development of the regional Sustainable Strategies for Food and Farming.

Integrated catchment management

Water quality can be vulnerable to the impacts of agriculture and other rural activities, which need to be identified and prioritised if protection is to be achieved. Baseline monitoring in the Whittle Dene Catchment in Northumberland has highlighted that pesticides and microbial pathogens in water are of concern to a number of stakeholders. The study has shown that some conflicts between management solutions do exist, but ongoing research will develop a balance whereby improvements to the key priority concerns are achieved without compromising rural livelihoods.

Sustainable Arable Farming For an Improved Environment (SAFFIE)

The agricultural industry needs to trade-off efficient and profitable farming practices with conservation measures that will enhance biodiversity. The SAFFIE project aims to show how this may be achieved by adopting novel, integrated approaches to crop and field margin management, and by developing a detailed understanding of how these interact and impact on the availability of habitats and food for farmland birds. Examples include manipulating crop architecture to increase biodiversity, adjusting crop protection inputs to increase the abundance of beneficial plant and insect species, and managing crop margins to produce a range of habitats and food sources.

Sustainable grazing of moorland

ADAS is leading a multidisciplinary project to develop environmentally sustainable and economically viable grazing systems for restoring and maintaining heather moorland. UK moorlands, including dry heather-dominated grouse moor, wet heaths and blanket bog, are important internationally for their biodiversity and as a grazing resource. A combination of plot and modelling studies is being used to assess heather restoration techniques and the grazing preferences of different sheep and cattle breeds. System studies assess the impact of grazing by sheep and cattle, on moorland vegetation recovery, livestock production, birds and invertebrates.

Pollution swapping

Approximately 90 million tonnes of animal manure, containing approximately 450,000 tonnes of nitrogen (N), are recycled to land in the UK each year. The efficient utilisation of manure nutrients is important for sustainable crop production, and ADAS has worked with farmers to develop recognition of the economic value of manures. However, applications to land need to be managed carefully to minimise diffuse pollution of the air and water environments. Strategies are needed which minimise one form of N loss without exacerbating losses via another route (so called 'N pollution swapping'). Experimentation integrates ADAS expertise in measuring ammonia and nitrous oxide emissions to air, nitrate leaching to ground water and the agronomic benefits of manure applications to land. Future work will assess the effects of manure management strategies to minimise N losses on phosphorus and microbial pathogen losses to the water environment, as part of the continued development of integrated diffuse pollution mitigation measures.

Challenges and solutions for managing the farmed landscape

James Clarke
ADAS Boxworth

Andrée Carter
ADAS Gleadthorpe

Brian Merrell
ADAS Redesdale

Looking back over 50 years, the reliability of food production in the UK, and the quality of the food produced, have been greatly improved. Agriculture should be proud of this success, which has also shaped the countryside we know and the rural communities it supports. However, consumers have a broadening range of expectations from the use of land and the products from land-based industries. Farming and land-based research must adapt to meet fully these expectations and both will be more challenging in the future.

Although current demands on farming and land management are often conflicting, profitable production of quality food, energy and other plant- and animal-derived products remains essential. Profitability is still dependent on high productivity of quality products, but revenue is increasing from payments for environmental and recreational benefits. The requirement for an enhanced environment means that we now need profitable production which also supports greater diversity of flora and fauna, together with reduced impacts of many of the management measures whose introduction led to the previous 50 years' achievements. There is a need to meet these broadening expectations for land use and to deal with issues that will improve the quality of life for the wider community through more sustainable use of land.

Within an unsupported market, the reaction is generally to make shorter-term decisions. However, delivery of biodiversity and other environmental objectives needs longer-term planning, stability and management. The term 'sustainable agriculture' is often used to recognise the need for an economic return from land-based activities, together with the delivery of other environmental goods and services. This concept has been at the heart of ADAS' activities for many years, is a core aspect of much of our current multidisciplinary science, and is clearly demonstrated in this "ADAS Science Review 2003".

There are many definitions of 'sustainable agriculture', but most define a sustainable agricultural business as being one that is dynamic, and adapts in response to new findings. It is considered as being sustainable if all components (economic, ecological and social) are taken into account equally, even though their respective objectives might only be achieved to varying degrees. This means that a number of indicators for different objectives or components of an agricultural system are required to assess sustainability. These might include:

- robustness of the business (economic, ecological and social) and its ability to cope with change;
- knowledge of resources available to the business (including staff, habitats, soil);
- awareness and compliance with current regulation, and planning for future regulation (e.g. Nitrate Vulnerable Zones, Ground Water Directive);
- awareness and pro-active approach to future drivers for change (Common Agricultural Policy (CAP), consumer concerns, pesticide resistance);
- appropriate use of best decision-making tools, information, technology, and advice;
- training for self and staff to improve standards.

A major factor going forward is the economic driver. We will increasingly see larger business units that employ fewer people and operate with greater efficiency. Much of our research is aimed at addressing environmental, consumer and rural issues in the context of the economic needs and implications. At a practical level, options exist for maintaining economic returns with reduced inputs and offtake by increasing product quality or by changing the management of crops and livestock.

Agriculture faces several key issues to meet the demands that will be placed on it in future. In particular:

- enhancing biodiversity;
- responding to climate change;
- meeting the needs of consumers;
- protecting water quality;
- protecting and enhancing landscapes;
- improving animal welfare;
- implementing cross compliance.

Below, for each of these challenges, we indicate the key issues, the state of current progress in achieving these, and identify the needs to ensure a sustainable future.

Enhancing biodiversity

Issue
UK has international agreements to meet biodiversity targets. Achievement of many of these is dependent on appropriate management of agricultural land.

Work on the interactions between crop management and margin management shows the importance of the farming system for biodiversity.

James Clarke
ADAS Boxworth

Current progress
Increasing biodiversity requires improved management techniques for crops, livestock and the non-cropped areas. Recent results have demonstrated the interactions of livestock management on abundance and diversity of plant and insect species. It is only relatively recently that significant work has started on the management of crops and the interaction with margin management. All these show the importance of the farming system for delivering biodiversity.

Future needs
There is a need to transfer the existing knowledge on management of crops, livestock and the adjacent land. Much is already known in many areas. However, it is essential to recognise that it will not be possible to achieve everything everywhere. To make significant progress in future, it is important that there are clearer, more specific targets for enhancing biodiversity – what can be achieved, where and how. It will be vital to understand both what improvements can be achieved for target habitats and species by managing the non-productive land, and what is dependent on good management of productive land.

Responding to climate change

Issue
The government is committed, by the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC), to reducing greenhouse gas emissions and adapting to climate change impacts.

Current progress
Bioenergy crops are a developing sector for renewable energy and may help to mitigate climate change by reducing emissions from combustion of fossil fuels. However, the response within the industry towards adaptation is slow, as there is greater concern about other more immediate drivers of agricultural change than about climate change. Moreover, there is little guidance on what practical measures the industry can adopt and on what timescales.

Future needs
Research is underway on the impact of climate change for biodiversity, flooding and water resources, but the findings of this work need to be linked to strategies for agricultural adaptation to indicate how the rural landscape as a whole needs to adjust to climate change. Links also need to be made between the effects of mitigation policy on, for example, the uptake of biorenewables and the impacts of climate change on their production. There also needs to be a better understanding of how to encourage the agricultural industry to incorporate climate change responses into their business strategies, and how climate change may interact with other drivers of change such as cross compliance and sustainable development policies.

Meeting the needs of consumers

Issue
Consumers demand increasingly high standards of food quality – food that is safe, free from serious blemishes, available almost continuously and containing the minimum necessary levels of artificial chemicals.

Current progress
A particular challenge is balancing the level of pesticide residues in produce and retaining food quality and supply throughout the year. Pesticides typically enable producers to supply the market over a longer period of the year and maintain the appearance and quality of produce.

The rural landscape will need to adjust to climate change.

Consumers are now demanding that this be achieved with even fewer residues than the currently low levels.

Future needs
Pesticide resistance typically results in an increase in pesticide use, and pests need to be managed to avoid problems. Minimising pesticide resistance and achieving satisfactory quality and supply are important challenges to be addressed. There is also an increased demand for availability of 'biopesticides' that many people presume to be safer for consumers, for users and for the environment. The safety and role of such products needs careful evaluation. Pesticide use could be

Pestiside use could be reduced through improved understanding of weed, pest and desease biology.

Andrée Carter
ADAS Gleadthorpe

In many catchments, agriculture will play a dominant role in improving chemical and ecological aspects of water quality.

reduced through improved understanding of weed, pest and disease biology to allow pesticide applications to be better targeted in relation to need and natural predation. Minimising pesticide residue risks through improved crop storage and management, reducing pesticide use, integrated crop management, improved field application technology, improved exploitation of varietal resistance, and increasing the opportunity for natural predation, are all areas which need further research.

Protecting water quality

Issue
The Government's vision for water policy identifies diffuse pollution from agriculture as a priority issue. The Water Framework Directive will drive actions to improve chemical and ecological aspects of water quality. As 75% of England is farmland, agriculture plays a dominant role in many catchments.

Current progress
Research and pilot studies have demonstrated that practical solutions are available, at least at the plot scale. Examples of farm management solutions include better fertiliser management, better manure management, and better cultivation management. Examples of soft engineering solutions include farm ponds, wetlands, and biobeds. All have a role to play. Integrated catchment management can, therefore, supply low cost, high impact, multiple benefit solutions.

Future needs
Questions about pollution mitigation measures still have to be answered, including long-term efficacy, effects at the catchment scale, and the timescale of their effectiveness. Reducing inputs, in many circumstances, might be the only strategy for achieving pollution targets. However, do we really know the scale of land use changes that might be needed to deliver benefits to water quality? Control of diffuse pollution often requires a higher level of on-farm management, and there is sometimes a cost. Solutions have potential links with environmental schemes, regulation and CAP reform. Only after an assessment of cost benefit can decisions be made on how best to implement measures to control diffuse pollution.

Protecting and enhancing landscapes

Issue
Landscape change and degradation of historic features are conspicuous concerns of the public and governments alike. They are increasingly being targeted by European Directives and legislation.

Current progress
Existing legislation protects a number of features that might be considered to be characteristic of traditional landscapes. This includes protection for important trees and hedgerows, semi-natural grassland, Sites of Special Scientific Interest, archaeological monuments, and valuable woodlands. This is likely to be further strengthened by the requirements under the Single Payment (SP) scheme requiring stone walls to be retained and affording greater protection for hedgerows. Existing schemes (such as Environmentally Sensitive Areas and the Countryside Stewardship Scheme) provide additional funding for preserving or enhancing particular landscape features (e.g. restoration of traditional field barns, rebuilding stone walls and reversion of arable land to grassland).

Future needs
The challenge for the future will be to integrate the management of farm businesses with the preservation of these landscapes and landscape features, in a cost-effective manner, ensuring that farming continues to be profitable, including in marginal areas, and that any additional costs associated with preserving landscapes are either minimised or receive targeted funding. The provision of good advice and interpretation of existing knowledge for new applications will go some way in ensuring success. However, changes in practices that may follow the changes in the support system, such as the abandonment of certain areas of land

A medieval bastle at ADAS Redesdale: existing legislation provides protection for characteristic features of traditional landscapes.

Brian Merrell
ADAS Redesdale

(albeit temporary), could have a profound effect on the appearance of the countryside. Joined-up thinking on the relationships between farming profitability, enhanced biodiversity and preservation of traditional landscapes will be required.

Improving animal welfare

Issue
Increasingly, consumers expect, and legislation demands, that the husbandry systems used to rear animals promote good standards of animal welfare. For obvious reasons, most effort is focused currently on improving intensive livestock rearing systems.

Current progress
Recent research has shown that reducing stocking density and the modification of poultry cages to provide birds with more space and areas for perching, stretching and pecking improved animal performance and enhanced health and welfare. By contrast, free-range systems of poultry production, perceived as being a welfare friendly system, have not always shown improvements in animal welfare and have sometimes been shown to compromise it.

For pigs, environmental enrichment has been shown to improve welfare without compromising animal performance. However, not all forms of enrichment work equally well and it is important that any enrichment meets the animals' behavioural needs.

Future needs
While research has been done to look at ways of adapting intensive husbandry systems to promote high standards of animal welfare, further research is needed. A better understanding of the often conflicting requirements of animal performance, practical application and animal welfare is required so that husbandry systems can be developed which are competitive and financially viable in a free market environment. There is a plethora of impending animal welfare legislation and it is important that the livestock industry is provided with clear guidance and scientifically generated practical recommendations.

Environmental enrichment for pigs can reduce harmful, social behaviours.

Implementing cross compliance

Issue
The reform of the Common Agricultural Policy allows de-coupling of subsidies from production and will allow farmers to realign to their markets and consumers. These structural changes are likely to lead to overall improvements in environmental protection since the new subsidy, called the Single Payment (SP), will be linked to compliance with environmental standards. All farmers claiming the SP and other direct payments will need to meet the two key cross compliance components.

Current progress
Farmers, land managers and agricultural contractors will need to meet Statutory Management Requirements – 19 EU Directives and Regulations which cover aspects of environment, public, animal and plant health, and animal welfare. Farmers will also need to maintain their land in Good Agricultural and Environmental Condition (GAEC). The GAEC measures that each Member State adopts will vary but will focus on protection of soils (soil erosion, soil organic matter and soil structure), habitats and landscape features.

Good Agricultural and Environmental Condition (GAEC) measures will focus on protection of soils, habitats and landscape features.

Future needs
There is a need to translate existing research knowledge into simple cost-effective messages that will assist farmers to change their practices and meet the policy requirements of cross compliance. There is, however, a lack of understanding by advisers and farmers on the requirements of the legislation, what remedial measures exist and how they can be implemented at the farm or catchment scale. ADAS, on behalf of the Department for Environment, Food and Rural Affairs (Defra), will be leading key advice programmes that will assist the process of knowledge transfer in the key requirement areas.

Farming catchments to comply with future constraints

Dr Jonathan Hillman
ADAS Gleadthorpe

The Whittle Dene Project examines the interactions between land use and water quality in a small sub-catchment in north-east England. The project is unique in that it takes an holistic approach to:

- identification of multiple point and diffuse water pollutants, pollution sources and transport mechanisms;
- farm and land management;
- stakeholder engagement and involvement.

Over the past 12 months, the project has attracted significant support from the water industry, farmers and landowners, environmentalists and the general public. This wide support is reflected in the additional funding sources and steering group members, including the Environment Agency, Crop Protection Association, UK Water Industry Research, Northumbrian Water, the National Farmers' Union, and the University of Newcastle. The main funder is the Department for Environment, Food and Rural Affairs (Defra).

Phase I of the project is now in progress, and is designed to collect the necessary baseline information to allow informed, science-based decisions to improve the water quality in a small agricultural catchment. The implementation of these decisions, and the assessment of impact on water quality, farm management and profitability, will be addressed in Phase II, together with the collection of ancillary information on wider issues such as biodiversity and regional, rural development.

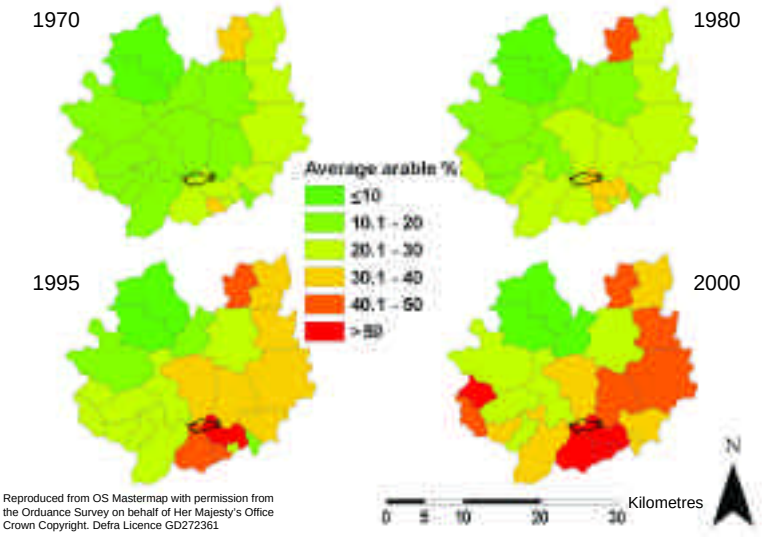


Figure 2. Percentage arable land in the Whittle Dene area 1970 – 2000.

Detailed information on water quality is being collected using automatic, flow-proportional sampling and telemetry at six carefully selected sites across the catchment. Samples are collected during rainfall and storm events and during dry conditions. Water samples are regularly analysed for pesticides, nitrate, phosphorus, faecal indicators and sediment. A survey of aquatic vegetation and ecology has also been conducted.

Concurrently, the project team is working proactively with local farmers. Detailed information has been collected on farm infrastructure, such as pesticide handling and washdown areas, and manure storage. Data have also been collected on the cropping and management of individual fields within the catchment, including pesticide and fertiliser application rates and timings, and cultivation strategies. For the majority of fields, soils have been analysed for P, K, Mg and pH, while mineral N was determined to 90 cm depth, in the autumns of 2002 and 2003. A survey of soil structure and drainage was also conducted. Pesticide and nutrient loss models have been run for the western sub-catchment, and a 30 km^2 area of its environs (Fig. 1). The land use, soil type and hydrology have also been mapped in the wider area (Fig. 2).

A catchment management plan for implementation in Phase II (2005 to 2008) is currently being devised in conjunction with local farmers and other stakeholders. There are many voluntary and statutory schemes which will have an impact on farm profitability and water quality in the coming years, and it is important to implement these in the most effective way for farm profitability and the water environment, while reducing the administrative burden. The Whittle Dene Project will work closely with the Voluntary Initiative on Pesticides, and liaise with farmers, consultants, agronomists and other stakeholders to ensure that the Single Farm Payment, Cross Compliance, Entry Level and Higher Level Schemes, have the maximum positive effect.

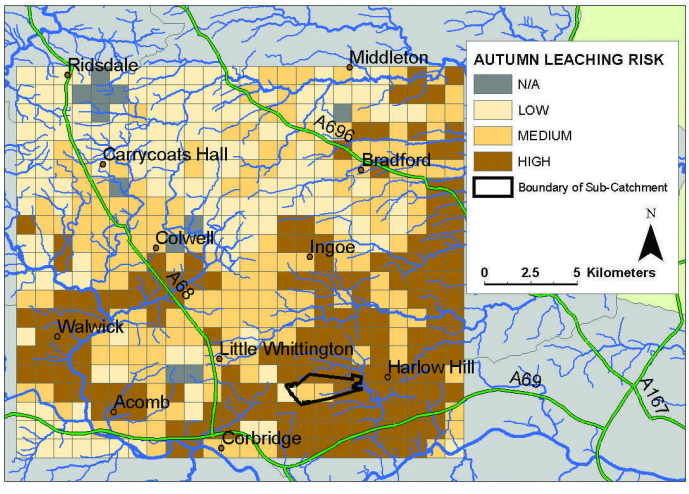


Figure 1. Risk of the herbicide, isoproturon (IPU), leaching from autumn applications.

Sustainable Arable Farming For an Improved Environment (SAFFIE)

Sue Ogilvy
ADAS High Mowthorpe

The UK Government is committed to several Biodiversity Action Plan (BAP) targets and has included wild bird populations as one of 15 quality of life indicators. Specifically, the Department for Environment, Food and Rural Affairs (Defra) has a Public Service Agreement to reverse the decline in a suite of farmland bird species by 2020, and a BAP target to increase the area of cereal field margin under conservation management. Alongside this, UK farmers are under strong economic pressure to improve the efficiency of their farming practices. The industry needs to balance efficient and profitable farming practices with conservation measures that will enhance biodiversity. The SAFFIE project (**www.saffie.info**) aims to show how this may be achieved by adopting novel, integrated approaches to crop and margin management, and by developing a detailed understanding of how these interact and impact on the availability of habitats and food for farmland birds.

ADAS has a major role in managing and co-ordinating this five-year, multidisciplinary project, which began in autumn 2001. The number of partners involved indicates the complex interactions that exist between modern crop management and wildlife. Defra, the Scottish Executive Environment and Rural Affairs Department (SEERAD) and English Nature sponsor this Sustainable Arable LINK project. Project partners include ADAS, British Potato Council, British Trust for Ornithology, Central Science Laboratory, Centre for Agri-Environment Research - University of Reading, Centre for Ecology and Hydrology, Crop Protection Association, Game Conservancy Trust, Home-Grown Cereals Authority, Jonathan Tipples, Linking Environment And Farming (LEAF), National Trust, Royal Society for the Protection of Birds (RSPB), Safeway Stores plc, Sainsbury's Supermarkets Ltd, Scottish Agricultural College (SAC) and Syngenta Ltd.

There are several interconnecting strands of work within this project, which include manipulating crop architecture to increase biodiversity, adjusting crop protection inputs to increase the abundance of beneficial plant and insect species, and managing crop margins to produce a range of habitats and food sources. The work is being done on three ADAS research centres, Boxworth, Gleadthorpe and High Mowthorpe, and 32 commercial farms.

For two years, on 10 experimental sites, the crop structure of winter wheat was managed to benefit wildlife, including the skylark (*Alauda arvensis*), a BAP target species. Conventionally-sown winter wheat was compared with wheat crops containing undrilled patches (two 16 m^2 patches per hectare) and crops with wide row (24 cm) spacing (double normal width, with the same seed rate as conventional). Provisional findings indicate benefits from both of these novel management practices, with minimal impact on crop profitability. The greatest and most consistent biodiversity benefits related to the undrilled patches and, for the skylark, these were:

- a prolonged breeding season;
- fewer nest failures;
- larger clutch sizes;
- more skylark nestlings per breeding attempt.

More plant species, flies and beetles in the undrilled patches, resulted in a greater abundance of food for the birds, while in sparser vegetation they may have been able to find food more efficiently, so that they supported their broods for longer into the cropping season (Fig. 1).

Crop yield was not significantly different between the conventional and novel treatments. The cost of undrilled patches ranged from £2 to £8 per hectare, depending on the price of grain. The undrilled patch technique was offered to farmers in the Pilot Entry Level Scheme in England, expected to be fully rolled-out in 2005. Results from SAFFIE indicate that this technique could play a major role in halting the decline in skylark populations, if it is widely adopted by farmers.

Work is ongoing to evaluate the effects of margin seed mix and management treatment on biodiversity, and the interactions between crop and margin on biodiversity, food sources and habitats are being examined. These detailed, interlinking studies will provide the underpinning science on which to base future decisions on crop and margin management for the benefit of wildlife.

A skylark (*Alauda arvensis*) chick.

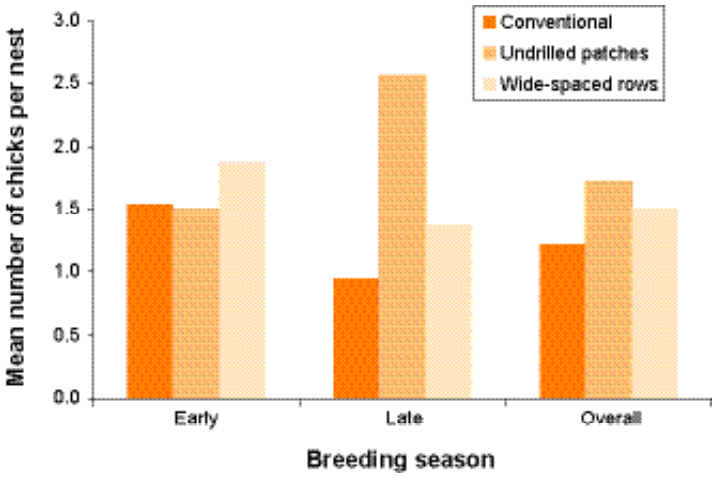


Figure 1. Skylark productivity per nesting attempt, 2002 – 2003 (source - RSPB).

Sustainable grazing of moorland

Dr Nigel Critchley
ADAS Redesdale

UK moorlands, including dry heather-dominated grouse moor, wet heaths and blanket bog, are important internationally for their biodiversity and as a grazing resource. Overgrazing by sheep has degraded many of these areas, but simply reducing sheep numbers on degraded moorland does not guarantee successful restoration, because increased biomass of competitive grasses (e.g. purple moor-grass, *Molinia caerulea*) can inhibit regeneration of dwarf shrubs and other desirable species.

To address these issues, ADAS is leading a multidisciplinary project funded by the Department for Environment, Food and Rural Affairs (Defra), English Nature and the Countryside Council for Wales, to develop environmentally sustainable and economically viable grazing systems for restoring and maintaining heather moorland. Project partners are the Centre for Ecology and Hydrology, Institute of Grassland and Environmental Research, Newcastle University, Royal Society for the Protection of Birds (RSPB), and Scottish Agricultural College (SAC).

New grazing management guidelines for moorland managers and their advisers will be devised from the five interlinked elements of the project (Fig. 1). Following a scoping study, current practice at a selection of sites is being evaluated with respect to its impact on biodiversity and economic viability. Simulation and analytical models are also being developed to provide insights on the processes driving change and to assess the potential outcomes of different management scenarios. Central to this is a vegetation model developed by ADAS, which is used to assess changes in plant species composition following grazing by sheep and/or cattle, combined with management techniques. This model is linked to models devised by other partners in the project, which will allow the wider implications for moorland invertebrate and bird numbers, and livestock production, to be assessed and evaluated against system-scale studies. Experiments are also underway to assess heather restoration techniques and the grazing preferences of different sheep and cattle breeds.

Stocking rate per ha	Purple moor-grass dominated		Purple moor-grass with heather	
	Baseline	2003	Baseline	2003
0.66 ewes	60	75	42	56
0.66 ewes + 0.75 cattle (summer)	59	31	46	24
1.5 ewes	62	55	34	40
1.5 ewes + 0.75 cattle (summer)	72	27	36	17

Table 1. Effects of different grazing treatments on the percentage cover of purple moor-grass in two vegetation types after the first year of the system-scale study at ADAS Redesdale. Differences between the baseline and 2003 were statistically significant at all stocking rates except 1.5 ewes per ha.

System-scale studies are being carried out at ADAS Pwllpeiran and ADAS Redesdale to assess the impact of sheep and cattle grazing on moorland vegetation recovery, livestock production, birds and invertebrates. At ADAS Pwllpeiran, four grazing treatments with Welsh Mountain sheep and/or summer grazing by Welsh Black cattle are being compared on mat-grass dominated moorland. In the first year, only minor effects were noted.

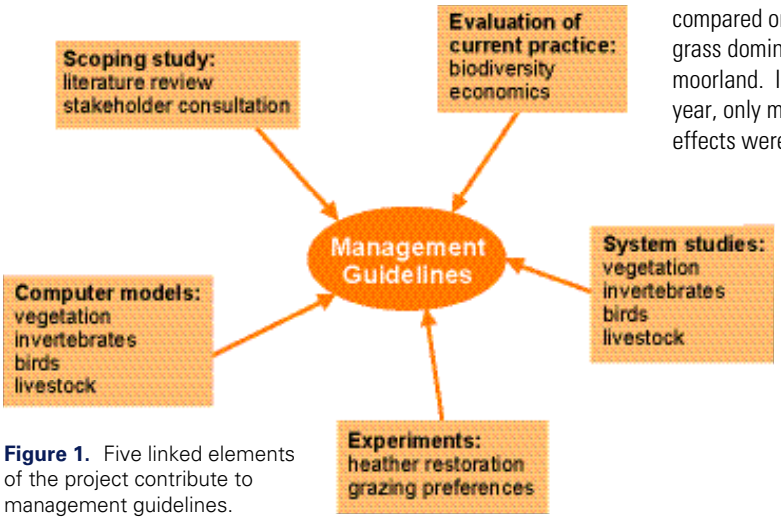


Figure 1. Five linked elements of the project contribute to management guidelines.

At Redesdale, Scottish Blackface sheep at 0.66 or 1.5 ewes per ha are being grazed on mixed wet heath alone, or with Continental cross cattle at 0.75 cattle per ha, for nine weeks in summer. Results following the first year of grazing studies at Redesdale were encouraging and showed that cattle selectively-grazed the purple moor-grass-dominated areas of former heather moor. Cover of purple moor-grass declined in paddocks with cattle, but when sheep alone were grazed, cover continued to increase at the lower stocking level and remained the same at the higher stocking level (Table 1). Cattle gained 42 – 67 kg liveweight and body condition scores increased. The presence of cattle had no impact on sheep performance or lamb growth rate up to weaning.

Flowering heather with purple moor-grass in mixed, wet heath.

The project will finish in 2007, and will help government to deliver the UK Biodiversity Action Plan for the recovery of this important natural resource.

Nitrogen losses to air and water following the application of animal manures to land

John R. Williams
ADAS Boxworth

In the UK, approximately 90 million tonnes of animal manure, containing approximately 450,000 tonnes of nitrogen (N) are recycled to land each year. The efficient utilisation of manure nutrients is important for sustainable crop production, but manure applications need to be carefully managed to minimise diffuse pollution of the air and water environments.

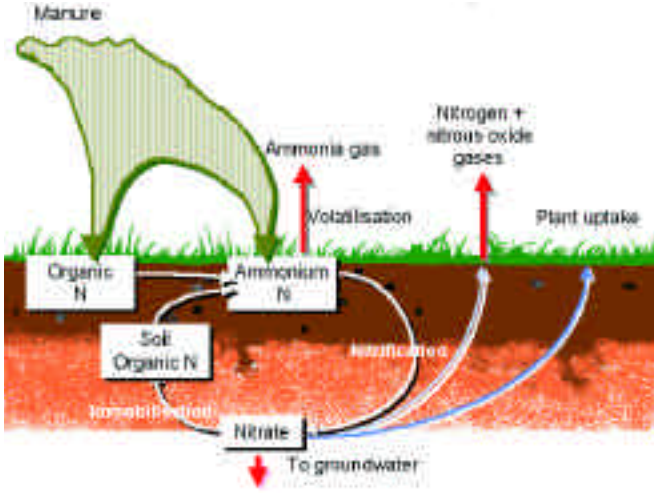


Figure 1. Fate of manure N following application to land.

Over 70% of nitrate entering UK water systems is estimated to originate from agricultural land, with nitrate leaching losses, following autumn/winter manure applications, estimated at 58,000 tonnes of N per annum. Ammonia (NH_3) and nitrous oxide (N_2O) emissions are other potential N loss pathways (Fig. 1). Total UK ammonia emissions have been estimated at 320,000 tonnes per annum, with emissions from agriculture estimated at 265,000 tonnes, 83% of the total. The UK is committed to reduce national ammonia emissions to less than 297,000 tonnes by 2010 to meet the conditions set by the Gothenburg Protocol and the European Commission's National Emission Ceilings Directive (Directive 2001/81/EC). An estimated 87,000 tonnes of nitrous oxide N is produced from UK agriculture each year. Nitrous oxide is a powerful greenhouse gas, with a global warming potential over 300 times greater than for carbon dioxide. The UK is obliged to reduce emissions of greenhouse gases to 12.5% below 1990 levels by 2012 as part of the commitment to the Kyoto Protocol.

Work to date has focussed on understanding the factors and processes controlling nitrate leaching losses following manure applications to land. The results from these studies have contributed to the science underpinning the Nitrate Vulnerable Zone (NVZ) Action Programme, which controls manure application rates and timings.

There is a clear need to ensure that strategies to minimise one form of N loss do not exacerbate losses via another route, so called 'N pollution swapping'. For example, the soil incorporation of manure, or band spreading slurry, are both effective management strategies for reducing ammonia losses compared with surface broadcast spreading. However, reducing ammonia losses will increase the soil mineral nitrogen pool, which will increase the potential for nitrous oxide emissions, nitrate leaching and the amount of manure N available for crop uptake (Fig. 2).

ADAS and the Institute of Grassland and Environmental Research (IGER) North Wyke are currently working on experiments, funded by the Department for Environment, Food and Rural Affairs (Defra), to investigate the effects of strategies to reduce ammonia losses on nitrous oxide emissions and nitrate leaching. The factors being tested include slurry application rate, timing and technique (band spreading or shallow injection

Trailing shoe band spread slurry application.

compared with surface broadcasting), and contrasting soil incorporation practices for solid manures.

These experiments integrate ADAS expertise in measuring ammonia and nitrous oxide emissions to air, nitrate leaching to ground water and the agronomic benefits of manure applications to land. Overall, the studies aim to identify manure management strategies that minimise N losses, and situations where reducing losses by one route will exacerbate losses by another (N pollution swapping). The focus of future work should be to assess the effects of manure management strategies to minimise N losses, on phosphorus and microbial pathogen losses to the water environment, as part of the continued development of integrated diffuse pollution mitigation measures.

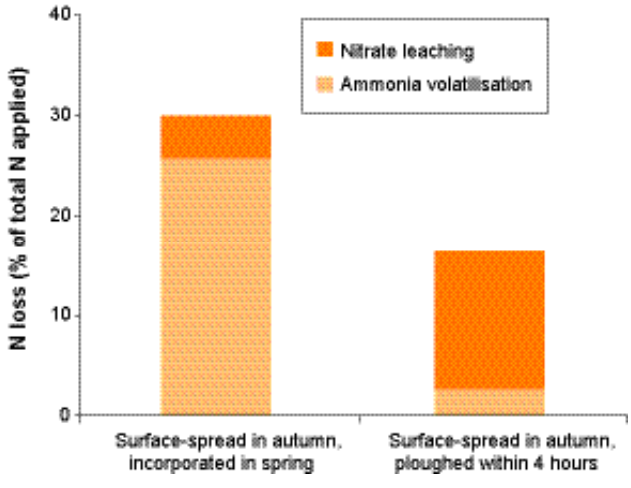


Figure 2. Nitrate leaching and ammonia volatilisation losses from sandy soil following autumn application of broiler litter.

Environmental Science

Dr Mark Shepherd

Head of Science and Business Development - Catchment Management

Coordinates research and consultancy on water quality and water management.

Contact:
mark.shepherd@adas.co.uk

Chris Britt

Vegetation, ecology & wildlife specialist

Responsible for research in ecology, forestry, arboriculture, vegetation management and climate change.

Contact:
chris.britt@adas.co.uk

Professor Brian J Chambers

Soil scientist and organic manure specialist

Specialist in research on the beneficial recycling of organic manures to land and development of sustainable farming systems that minimise the impacts of agriculture on the environment. Special Professor at Cranfield University.

Contact:
brian.chambers@adas.co.uk

Dave Arnold

Head of Cambridge Environmental Assessments

Specialist in the fate and ecotoxicology of chemicals in the environment, and associated risks.

Contact:
dave.arnold@adas.co.uk

On-farm bioremediation systems limit point source pesticide pollution

Dr Mark Shepherd
ADAS Gleadthorpe

Pesticide losses to water are of great concern. It might be thought that loss from the field after or during application is the main cause of pollution. However, research in the UK and Europe has shown that 20 – 70% of the total pesticide load leaving a surface water catchment can originate from handling operations in the farmyard. In particular, ADAS research in the Cherwell catchment, near Banbury, found that 40% of the loss of the cereal herbicide isoproturon originated from the farmyard. In response to this finding, we have been developing a simple approach to reducing losses from these 'multiple point sources' within a catchment.

The objective of this work, underway since the late 1990s, funded by the Department for Environment, Food and Rural Affairs (Defra), has been to investigate the use of a range of bioremediation systems to limit pesticide pollution originating from the farmyard. In particular, this includes all activities associated with the handling and mixing of pesticides, filling of spray equipment, disposal of any waste pesticides and the washing down of the spray equipment after usage.

The bioremediation systems work by providing enhanced conditions for fungal and bacterial populations, which can then break down the pesticide residues. The challenge is, therefore, the development of systems that favour the creation and maintenance of an active biomass and which keep the biomass in contact with the pesticide residues they encounter. We have evaluated the effectiveness of several bioremediation systems to retain and/or degrade pesticides from these pollution sources prior to discharge to the environment. These systems have been generally based around biobeds, which are a mixture of straw, topsoil and peat-free compost.

Three full-scale bioremediation systems were designed and established by ADAS in 2001 on a large arable farming enterprise in Lincolnshire. Pesticides with a range of physico-chemical properties were applied artificially to each system to simulate a severe contamination event. The suite of pesticides investigated was isoproturon (herbicide), pendimethalin (herbicide), chlorothalonil (fungicide), epoxiconazole (fungicide), dimethoate (insecticide) and chlorpyrifos (insecticide). The performance of each system has been monitored since then by taking sub-samples of input run-off and/or output leachate from the systems and analysing for pesticide residues.

The three systems constructed were:

- bunded concrete spray equipment pad draining to a lined biobed;
- drive-over lined biobed;
- bunded concrete spray equipment pad draining to a lined loamy soil area.

The concentration of pesticides in the liquid discharged from these treatment systems typically indicated a 10,000- to 100,000-fold improvement over the input concentration (Table 1). Careful control of the water management within these systems using small temporary storage tanks and simple pumps, together with the elimination of unnecessary clean water entry from other farmyard surfaces, is considered critical to their effectiveness. Covering the biobed or soil area with a turf cover also assisted in encouraging evapotranspiration and hence less leachate loss from the systems.

Further work is still needed to investigate the lifespan of these on-farm bioremediation systems in the UK environment under normal commercial use, and to consider the disposal options available, within current regulations, for the spent biomix when it loses its effectiveness to retain and/or degrade pesticides and would, therefore, need to be replaced.

Drive-over biobed.

Pesticide	Concrete intercept to biobed		Drive-over biobed	Concrete intercept to biobed	
	Run-off	Leachate	Leachate	Run-off	Leachate
Dimethoate	44,277	0.9	15.5	24,800	<0.5
Chlorothalonil	96,807	0.3	<0.1	94,600	<0.1
Isoproturon	140,850	<0.5	1.2	55,900	<0.5
Chlorpyrifos	77,646	0.7	0.4	56,300	0.8
Pendimethalin	205,550	2.3	0.5	107,900	0.8
Epoxiconazole	9,108	0.8	0.7	9,450	0.8

Table 1. Maximum pesticide concentrations (µg/litre) in run-off or leachate (Sept. – Nov. 2002).

The UK-ADAPT project

Rebecca Humphrey
ADAS Gleadthorpe

There are a number of policy drivers for improving water quality, including the Water Framework Directive which requires management of freshwater at the river basin scale. The Agricultural Diffuse Aquatic Pollution Toolkit (UK-ADAPT) project aims to support implementation of diffuse pollution policy by providing a reference point for relevant research projects. UK-ADAPT is funded by the United Kingdom Water Industry Research, Water UK, the Environment Agency, and the Department for Environment, Food and Rural Affairs (Defra). It has the support of the Scottish Executive. The initiative was conceived to coordinate the considerable current research activity addressing Diffuse Water Pollution from Agriculture (DWPA).

The objectives are to produce a DWPA research resource for funders, policy makers, researchers and practitioners, to improve networking and knowledge sharing between stakeholders, to identify gaps in research and to provide recommendations for further work.

The UK-ADAPT web site (**www.uk-adapt.org.uk**), launched in February 2003, includes an interactive project search facility. All projects registered on the database were reviewed in August 2003.

Overall, projects in the database provided good information about all aspects of diffuse pollution control, and many included an element of modelling. However, most did not cover all pollutants, but focused on one or two. Few projects operated at larger catchment scale and few projects included the full interactive involvement of stakeholders. Social and economic aspects of diffuse pollution were largely omitted from studies. More detail is needed of the water quality monitoring methodologies employed.

Research needs identified were that:

- the full range of pollutants should be studied in each catchment and ecological monitoring should be increased;
- models need to be better validated and demonstrated, more practical and user-friendly, focused on a wider range of pollutants, and tailored to policy requirements;
- long-term effects of mitigation methods must continue to be monitored, new methods must be scaled-up and applied at catchment level, and multi-pollutant mitigation techniques need to be developed;
- proven methods of stakeholder engagement need to be made available to all researchers, and more projects need to examine socio-economic issues.

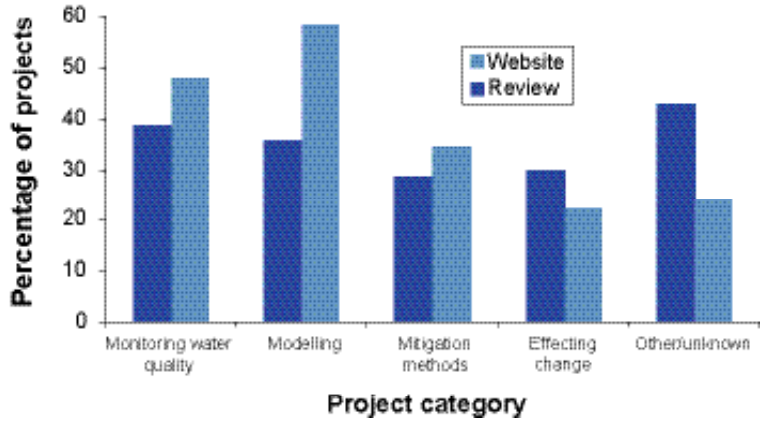


Figure 1. Distribution of projects by category, as registered by the project leader (Website), and as assessed when reviewed (Review).

The resource is increasingly recognised as a valuable research tool by a wide range of stakeholders involved in catchment management. By March 2004, there were over 130 projects registered in the website database.

Figure 2. The UK-ADAPT website homepage.

Phosphorus and Sediment Yield CHaracterisation In Catchments - (PSYCHIC)

Eunice Lord
ADAS Wolverhampton

Phosphorus (P) and sediment are major contributors to the biological degradation of many UK surface waters. Improvement of water quality requires identification of the critical locations and activities that contribute to degradation, and the development of targeted mitigation strategies. ADAS is leading the development of a catchment-based decision support system to guide the cost-effective implementation of control measures for sediment and P loss from agricultural land, taking, as case studies, two priority catchments suffering the effects of diffuse pollution. The project is designed to provide end-users with a means of identifying where control measures need to be adopted within a catchment, and to develop practical solutions.

The project is funded by the Department for Environment, Food and Rural Affairs (Defra), the Environment Agency and English Nature. The ADAS-led project consortium includes the National Soils Research Institute, the Centre for Ecology and Hydrology and the Universities of Exeter, Sheffield and Reading.

A process-based model of sediment and phosphorus movement to waters (PSYCHIC) is being developed in two modes, a strategic version for use at catchment scale, and a field-scale version for more detailed assessment of mitigation strategies. In developing a catchment management plan, the first step is to identify the 'hot spots', i.e. the locations and land uses that are the main contributors of sediment and phosphorus to waters. This is achieved by the strategic PSYCHIC model linked to spatial data on agricultural and environmental factors, held within a geographical information system (GIS). The resulting maps of pollutant loading, and of contributory factors (e.g. livestock number, field slope and soil type), can guide the preparation of targeted mitigation plans. Implementation of mitigation options at farm scale will draw on field guides to prioritise fields and select the most cost-effective mitigation approaches within the farm. Impacts of such changes will be assessed using the field-scale version of the PSYCHIC model.

The PSYCHIC model is designed to take account of landscape and land management factors, and their interactions. The modelling approach integrates knowledge of key transport processes and pathways that affect phosphorus loss, with a focus on identifying control points associated with farm practices that can be practically changed. Key control factors that have been identified include time and method of application of manures and fertilisers, soil damage including poaching, tramlines and the presence and effectiveness of land drains. The scientific basis for the model was derived from results of recent research projects (e.g. Defra studies PE0106 and PE0111); and, in the process, a number of areas where additional field research is needed have been identified.

The approach is being tested in two catchments (the Rivers Wye and Hampshire Avon). Results for the Wye catchment (Figure 1) illustrate the greater losses associated with the intensive arable and grass systems in the low-lying east of the catchment, compared to the more extensive grazing in the wet uplands of the west. Localised 'hot spots' are often associated with pig or poultry farming. The modelling case study is supported by an analysis of Environment Agency archive river water quality data, intensive monitoring of selected streams, fingerprinting studies to determine the origins of sediment reaching streams, bed sediment phosphorus release measurements and field scale investigations.

Related Project

Title: DESPRAL (DEtermining Soil and Phosphorus Run-off from Agricultural Land).

Funders: European Commission, Defra, the Environment Agency.

Contract Manager: Paul Withers, ADAS Rosemaund.

Comments: To develop a laboratory method for predicting soil dispersion potential. Six European partners are involved; ends autumn 2004 (**www.despral.org.uk**).

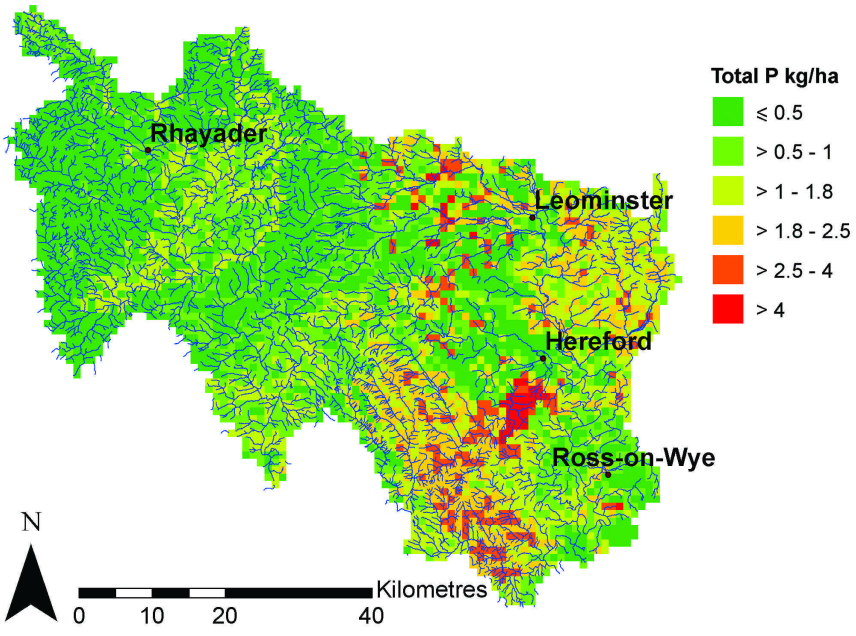


Figure 1. Modelled estimates, using the PSYCHIC catchment-scale model, of P transfer from land to the River Wye catchment.

A diffuse pollution screening tool for Scotland and Northern Ireland

Dr Steven Anthony
ADAS Wolverhampton

The Water Framework Directive 2000/60/EC (WFD) establishes a comprehensive basis for the management of water resources in the EU with the intention of achieving good ecological status of all water bodies, encompassing both chemical and biological criteria. To establish a baseline, the WFD requires, by December 2004, characterisation of diffuse pollution pressures on all water bodies. Where possible, this is to be based on measured water quality and should identify whether the primary pressures are point or diffuse sources. However, in Scotland and Northern Ireland, existing monitoring schemes are focussed on lowland areas of intensive agricultural and industrial activity, and do not adequately represent sensitive upland environments. Neither do they consider the full range of pollutant pressures that may impact on the status of waters. In response to this, the Scottish and Northern Ireland Forum For Environmental Research (SNIFFER), and the Scottish Executive, have sponsored the development of a screening tool to support the respective national bodies, the Scottish Environment Protection Agency, and the Environment and Heritage Service for Northern Ireland, in undertaking this characterisation. The screening tool takes a model-based approach to characterising pollution pressures in the absence of measured data, with the intention of quantifying pollutant loadings from all diffuse sources, including agriculture, forestry, and run-off from road networks and urban areas.

ADAS is leading a project consortium, including the Macaulay Institute, HR Wallingford Ltd and the Scottish Agricultural College, that brings together specialist expertise for key pollutants, and sources of environmental data. The screening tool has been developed in three distinct stages: the use of Geographic Information Systems (GIS) to construct a comprehensive agricultural and environmental database, including data on soils, climate, land use and infrastructure; the identification and development of simulation models appropriate for use at the catchment and national scale; and model calibration and risk assessment using available data. The environmental database was a major undertaking and describes the catchments of more than 14,500 individual lochs and rivers within Scotland alone.

The screening tool uses a suite of modelling techniques to provide indicators of pollutant load or concentration in drainage entering watercourses or leaching to groundwater. It includes pressures associated with sediment (from soil erosion), Biological Oxygen Demand (BOD), nitrate, phosphate, pesticides and the priority substances: pathogens, heavy metals and acidifying pollutants. ADAS has been responsible for constructing the models for soil erosion, phosphorus, BOD and pesticides. For this, we have developed models from the scientific literature, and implemented new models developed with funding from the Department for Environment, Food and Rural Affairs (Defra), most notably PSYCHIC (Phosphorus and Sediment Yield CHaracterisation In Catchments) (Fig. 1).

The screening tool allows visualisation of pollutant losses, and source apportionment by sector, across Scotland and Northern Ireland at a high spatial resolution. Calibrated model outputs have been used to predict water quality status with respect to legislated criteria, together with uncertainty bounds. This information provides decision support for characterisation, and targeting of future monitoring, research work and remediation planning. The full report of the outputs from the screening tool will be available for public view via the SNIFFER web site (**www.sniffer.org.uk**) in 2004.

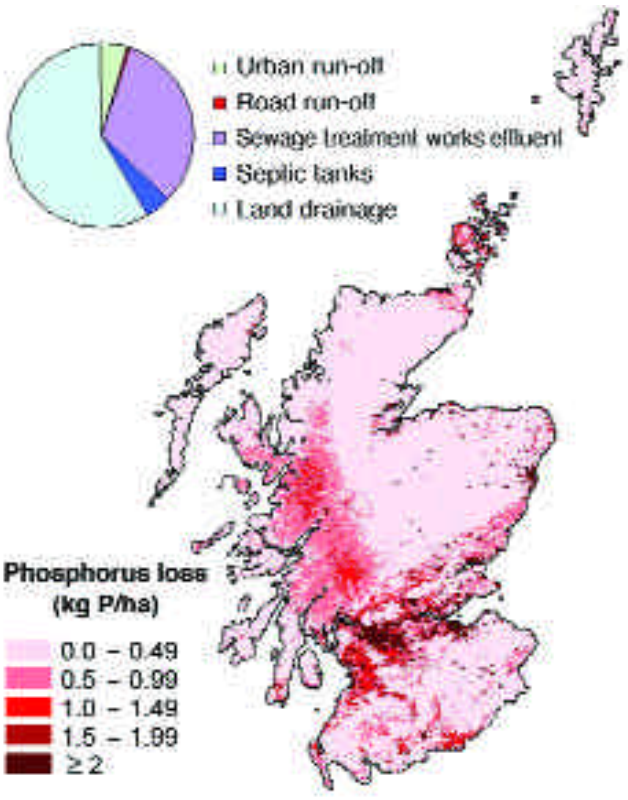


Figure 1. Spatial distribution of modelled annual losses of phosphorus to rivers and lochs, and proportional contribution by source, for Scotland.

Related Project

Title: Modelling AGricultural Pollution and Interactions with the Environment (MAGPIE).

Funder: Defra.

Contract Manager: Eunice Lord, ADAS Wolverhampton.

Comments: A decision support system integrates nitrate leaching models with a spatially-referenced national environment database to support national pollution modelling of nitrates. The database includes information on soils, weather, land cover, land use, and river hydrology for England and Wales.

Development of exposure modelling approaches for veterinary medicines in the European Union

Dr Neil Mackay
ADAS Boxworth

As a requirement of EU Directive 92/18/EEC, there is a need to conduct Environmental Impact Assessments (EIAs) in order to evaluate the risks posed to the environment from veterinary medicines. Within the regulatory procedures for veterinary medicines, applicants may seek registration either via a centralised (harmonised pan-European application in which a competent authority is appointed by the European Medicines Evaluation Agency (EMEA)) or decentralised route (where registration is sought for an individual Member State via the relevant competent authority). As a consequence, the Veterinary Medicines Directorate (VMD), the competent authority in the United Kingdom, has a requirement to evaluate the environmental impact of these products not only within its own national jurisdiction but, more broadly, throughout Europe as a rapporteur on behalf of the EMEA. Traditionally, environmental assessments conducted by applicants to meet the EIA requirements have been very simplistic and necessarily conservative, often failing to address the diversity of usage practices and environments throughout Europe.

A two-year project, which started in 2002, funded by the Department for Environment, Food and Rural Affairs (Defra), is developing a software modelling tool ("VetCalc") that will assist both applicants and VMD to estimate exposure in the three environments considered at greatest risk: soil, surface water and groundwater (Fig. 1). The model will address a wide variety of agricultural and environmental situations across Europe by including:

- characteristics of major food-producing animals;
- associated manure characteristics;
- local agricultural practices;
- characteristics of the local environment.

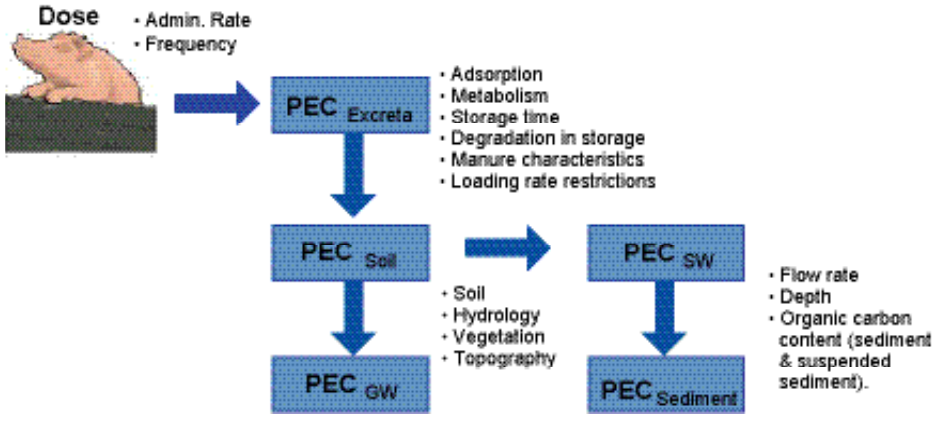


Figure 2. Conceptual framework for the environmental impact assessment of veterinary medicines (PEC = predicted environmental concentration, SW = surface water, GW = ground water).

Much of this exploits research on nutrient management undertaken by ADAS for Defra. The software will provide key regulatory exposure endpoints in the form of Predicted Environmental Concentration (PEC) in excreta, soil, groundwater, surface waters and sediments based upon 'base-set' physical chemistry and environmental fate data required within regulatory submissions (Fig. 2). Flexibility has been built into the model to include, where data are available, exposure mitigation considerations such as the potential for degradation in slurry or manure during storage.

A set of 11 scenarios (four of which are based in the United Kingdom) is being compiled to represent a broad diversity of production and environmental situations throughout Europe. Where possible, these scenarios are being based upon existing research sites supporting modelling projects for veterinary medicines or pesticides in order to ensure a high quality basis for decision making. Ultimately, it is envisaged that the model will provide a common benchmark for evaluation of veterinary medicines in the UK by both regulators and registrants. It is also hoped that, more broadly, this tool could assist in the design and evaluation of more complex field-based research projects for veterinary medicines.

Figure 1. VetCalc Software.

The environmental fate and behaviour of sheep-dip chemicals disposed to land

Dave Arnold
ADAS Boxworth

Ectoparasite infestations of sheep are commonly treated by dipping sheep in a bath of water containing insecticide. Disposal of used sheep-dip to land may be done only with prior authorisation from the Environment Agency (EA). Control is governed by the UK Groundwater Regulations 1998, which are currently under review. However, concerns remain as to the environmental consequences of the disposal of used sheep-dip to land in terms of the potential for contamination of ground or surface waters. The most common active substances in sheep-dip are the organophosphate insecticide, diazinon, and the synthetic pyrethroid, cypermethrin. Whilst these chemicals have long been used in agriculture, and their consequent fate and behaviour characteristics studied, little is known about their behaviour when formulated as sheep-dip chemicals.

Question	% of respondents saying yes
Organophosphate dip used	74
Synthetic pyrethroid dip used	26
Deactivation treatment used	10
Dip disposed of undiluted without additional water or slurry	30

Table 1. Results from a survey of sheep-dipping practice (October/November 2002).

Funded by the EA, and in collaboration with the Centre for Ecology and Hydrology, ADAS has completed the first part of a two-phase investigation into the fate and behaviour characteristics of diazinon and cis-cypermethrin. This has included:

- a telephone survey of 100 farmers/contractors in the main sheep dipping areas of England & Wales to investigate dipping practices;
- sampling and measuring chemical residues in used sheep-dip, and deactivated (by the addition of an alkali) used sheep-dip, at nine locations;
- determination of sorption characteristics of the active substances in selected soil types;
- laboratory-scale degradation studies of the active substances, in soils, with and without cattle slurry amendment (used dip is often disposed of mixed with slurry);
- identification of prospective field sites for phase two, including construction of conceptual models of the site hydrology.

The telephone survey sought information on current dipping and disposal practice, and products used. It enabled the identification of farms from which samples of used dip could be taken for analysis of residual active substance, and for further use in laboratory studies. Some findings from the survey are given in Table 1.

Analysis of samples of used dip showed variability in concentration of both diazinon and cypermethrin compared with the recommended doses. This was probably due to a number of factors including the number of sheep treated, variable amounts of mud, fleece and faecal material in the dip bath, and different time periods between mixing and sampling of the used dip. Deactivation treatments were effective in substantially hydrolysing (>90%) the active substances in the used dip

Soil adsorption coefficient (K_d), a measure of the capacity of soil to bind to the chemical, was determined for diazinon in four soil types from potential phase-two field study sites (Table 2). The very high K_d value, i.e. high degree of binding, for the soil from ADAS Redesdale was probably due to its relatively high organic matter content and low pH. Sorption studies were repeated with the addition of the aqueous phase taken from a filtered mixture of cattle slurry and water, instead of water alone. In three out of four soils, there was a marked decrease in K_d (by up to 50%), indicating a possible increase in leaching potential of the active substance in soil. In the soil degradation studies, slurry amendments did not affect the rate of degradation of diazinon. Degradation half-lives for diazinon in unamended soils from ADAS Gleadthorpe and Pwllpeiran were 14 and 8 days respectively, and in slurry-amended soils from Gleadthorpe and Pwllpeiran, 17 and 8 days respectively. No decay curves could be determined for cypermethrin in the same soil types, possibly due to adsorption to soil organic matter.

Dipping sheep.

These preliminary investigations have aided the design of outdoor field, and semi-field-scale studies that will, in phase two, aim for a better understanding of the fate and transport of sheep-dip chemicals to ground and surface waters.

Location	Soil texture	K_d (litres/kg) unamended	K_d (litres/kg) amended
ADAS Rosemaund	Silty clay loam	4	2
ADAS Gleadthorpe	Sandy loam	12	6
ADAS Pwllpeiran	Clay loam	26	13
ADAS Redesdale	Peat over silty clay loam	111	98

Table 2. Diazinon sorption coefficient (K_d) for four soils (unamended and amended with aqueous extract of slurry).

Vegetation change and management practices in upland hay meadows

Dr Nigel Critchley
ADAS Redesdale

Unimproved upland hay meadows are of high biodiversity value, and are identified as a priority for conservation in the UK Biodiversity Action Plan. Upland hay meadows in the valleys of northern England are characterised by high numbers of plant species per unit area, often with a distinctive assemblage of herb species including wood crane's-bill (*Geranium sylvaticum*), pignut (*Conopodium majus*), and lady's-mantle (*Alchemilla* spp.). In the latter half of the 20th century, many meadows were lost due to intensive agricultural practices, and most of those remaining declined in quality. Agri-environment schemes such as the Pennine Dales Environmentally Sensitive Area (ESA), introduced in 1987, are intended to reverse this trend by encouraging farmers to adopt more traditional farming practices.

Botanical surveys of hay meadows in the Pennine Dales have been carried out at intervals since 1987. In 2002, following widespread concerns about a continuing decline in quality, the Department for Environment, Food and Rural Affairs (Defra) commissioned ADAS to re-survey 164 meadows in the Pennine Dales. Surveys were based on fixed 1m^2 quadrats previously established in fields to monitor plant species composition. Comprehensive data on management practices were also collected for each field. Statistical models were built to establish which combinations of management practices might be linked to changing quality of the hay meadows. Quality was measured by indicators derived from the species data.

The majority of meadows in the sample had been subjected to only low levels of agricultural improvement prior to the introduction of the ESA. Overall, their quality was maintained between 1987 and 2002. The most improved meadows were slightly enhanced, the total number of species per m^2 having increased from 17.8 to 19.5. However, the top 12% of the sample, that represented the best unimproved hay meadows, had deteriorated. For example, the number of herb species per m^2 declined from 13.8 to 9.6.

The statistical models showed that there were clear relationships between changes in quality at individual sites, and the management practices previously applied. The main findings were:

- number of herb species per m^2 was more likely to increase at sites cut after 22 July, and to decline if cutting was before 15 July (Fig. 1);
- spring grazing, especially if continued after 15 May, was associated with reduced vegetation quality (Fig. 2);
- vegetation quality tended to decline at sites receiving inorganic N applications;
- reduced grazing levels at some sites in 2001, due to foot and mouth disease restrictions, had a detrimental effect;
- cattle grazing was sometimes detrimental, but often in interaction with other practices (e.g. late closing date);
- rolling or harrowing could be beneficial, but not if combined with intensive practices.

The results of the project will help Defra to improve the effectiveness of agri-environment schemes in conserving upland hay meadows. Management practices often acted together, so that enhancement is most likely to be achieved by combining beneficial practices. The higher level tiers of agri-environment schemes already include some of these. However, revised restrictions on cutting and closing dates, and duration of spring grazing, could provide further benefits for species-rich hay meadows.

Upland hay meadows in the Pennine Dales.

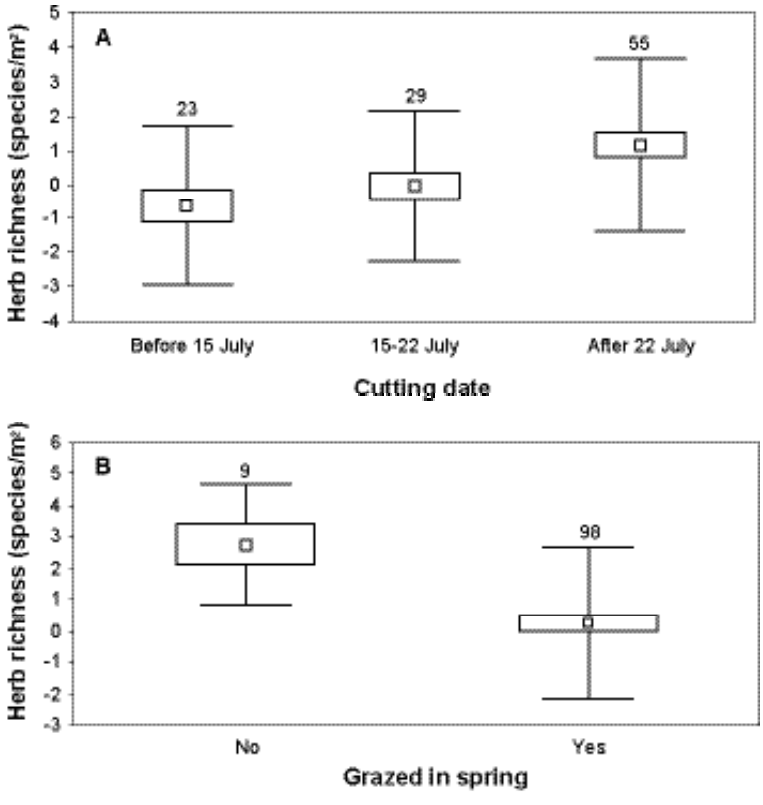


Figure 1. Change in number of herb species per m^2 in upland hay meadows between 1987 and 2002 in relation to cutting date. Data are group means, standard errors (boxes) and standard deviations (bars); numbers are sample sizes.

Stocking levels for enhanced biodiversity in semi-natural lowland grassland

Dr Francis Kirkham
ADAS Preston

Appropriate grazing management is essential to help maintain the wildlife conservation and biodiversity value of most semi-natural grasslands. In planning stocking requirements, in addition to the specific sward requirements of the site, managers must also consider factors such as climate, location, topography and soil wetness. A study, funded by the Countryside Council for Wales, English Nature, Scottish Natural Heritage and the Environment and Heritage Service for Northern Ireland, aimed to provide conservation site managers and agri-environment project officers with updated guidance on stocking levels. Current grazing prescriptions from all UK agri-environment schemes were also reviewed.

Stocking information and other site and management data were acquired by questionnaire from a wide range of nature conservation sites in the UK (66 sites, providing a total of 108 discrete grazing units). Five lowland grassland Biodiversity Action Plan (BAP) priority habitats were targeted: coastal and floodplain grazing marsh (CFGM), lowland calcareous grassland (LCG), lowland dry acid grassland (LDAG), lowland meadow (grazed only) (LM) and purple moor-grass and rush pastures (PMGRP). Information was also gained from a sample of six fairly species-rich semi-improved grasslands (SRSIG). Predictive modelling was used to identify the influence of climatic and other site-based variables on the stocking levels that should be applied within each habitat to achieve desired biodiversity targets. Where data were in the form of single independent units, multiple linear regression models were used. In other cases, models were developed using Restricted Estimated Maximum Likelihood (REML), allowing variation due to site, grazing unit and year to be taken into account as random factors, with the variables of interest entered into a fixed model. Stocking levels were measured as livestock units (LU) per hectare. For example, an adult dairy cow is equivalent to 0.7 to 1.1 LU depending on breed size, and an adult ewe ranges from 0.08 to 0.15 LU.

Grazing marsh on a Somerset peat moor. (Floodplain grazing-marsh stocking records averaged 140 LU days/ha/year).

Habitats differed both in annual total stocking levels, and in the seasonal pattern of grazing (Fig. 1). CFGM, PMGRP and LM sites were grazed largely by cattle. Horses and ponies were more often used in LM sites than in other habitats. Half of the LCG sites were grazed predominantly by cattle, the remainder by sheep, or by both sheep and cattle. Most LDAG sites, and four of the six SRSIG sites, were grazed predominantly by sheep, with the remainder grazed mainly by cattle in each case.

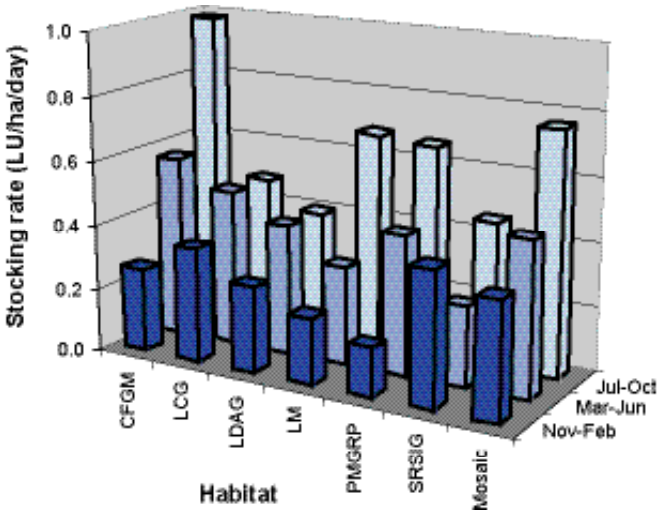


Figure 1. Mean stocking rates applied during three time periods within seven habitat types ('Mosaic' = sites where no one habitat type predominates, see text for details of the other habitat types).

Guidelines were produced for each habitat except SRSIG and LDAG (for which too little stocking information was obtained). Management records for CFGM habitats, for example, showed that daily levels of < c. 20 LU/ha were needed for coastal sites in summer where no grazing was allowed during the preceding winter and spring, < 5.0 when grazed only from April to October, and <2.0 LU/ha when grazed all year round. Annual totals ranged from 140 LU days/ha on floodplain to 230 LU days/ha on coastal sites. Management records also showed that year-to-year variation in annual stocking rate was relatively low for CFGM habitats (e.g. ±5% of the site mean averaged over all years, exceptionally up to ±20%). By contrast, requirements for LCG habitats are much lower. Daily levels range between <1 and about 4 LU/ha, depending upon specific site requirements. Modelling showed that, on dry sites and where winter grazing by sheep predominates, annual stocking levels may be about 47 LU days/ha, but can be 215 – 220 LU days/ha at more productive sites grazed by cattle. Year-to-year variation in annual stocking requirements, as indicated by management records, may be ±20 – 25%, exceptionally up to ±40%.

Related Project

Title: Grazing marsh for birds and livestock.

Funder: Department for Environment, Food and Rural Affairs (Defra).

Contract manager: Francis Kirkham, ADAS Preston.

Comments: A study, in collaboration with the Central Science Laboratory, on coastal and floodplain grazing marsh, produced predictive models relating ground-nesting bird occupancy to sward structure and landscape features, and sward structure to grazing management.

Young farm woodlands enhance biodiversity in arable landscapes

Chris Britt
ADAS at Defra, Drayton

Semi-natural woodland provides an important habitat for many native plants and animals, including several rare or declining species. In a nation with a low proportion of woodland cover, the considerable potential for woodland creation on ex-agricultural land should be exploited. The Farm Woodland Premium Scheme (FWPS) of the Department for Environment, Food and Rural Affairs (Defra) provides incentives for farm woodland planting, with the aims of providing new habitats for wildlife, and enhancing biodiversity. To evaluate the contribution to farmland biodiversity of over 40,000 ha of new FWPS woodland established since 1992, ADAS undertook a three-year (2000 – 2002) ecological monitoring project for Defra in, and around, a young woodland at ADAS Boxworth. This was established in 1989 – 90, as a replicated experiment comparing nine tree species. Comparisons were made with adjacent arable land.

Young farm woodland can have a diverse ground flora.

Results confirmed the importance of hedgerows to farmland biodiversity, but also clearly demonstrated that the young, predominantly broad-leaved woodland provided useful habitat for numerous species, including many that are infrequently recorded in arable fields. Plant and animal communities within the woodland had characteristics that distinguished them from those of other habitats. The ground flora of woodland plots was much more diverse than the arable field, although 50 – 60% of the total ground cover comprised only three species; bristly oxtongue (*Picris echioides*), rough meadow-grass (*Poa trivialis*) and false oat-grass (*Arrhenatherum elatius*). No ancient woodland indicators were recorded, but there were several shade-tolerant species, characteristic of woodland edges e.g. wood avens (*Geum urbanum*).

Greater numbers of ground beetles were captured in the arable field (32.7/trap/week), but there were no significant differences in numbers of species in different habitats. Total ground beetle numbers in ash (12.9/trap/week) and poplar (13.0/trap/week) were relatively high. Higher numbers of rove beetles were trapped in the hedgerow (9.0/trap/week) and woodland (7.5/trap/week) than in the arable field (3.6/trap/week). Butterflies were scarce in the arable field, but relatively frequent in the woodland. Butterflies were abundant on woodland edges, where 19 species were recorded, and quite frequent within some woodland plots. For example, the total number of butterflies recorded per 100 m in the arable field (from 34 transect walks) was only 3, compared with 589 per 100 m along the edges of woodland plots. Several species (e.g. meadow brown (*Maniola jurtina*) and ringlet (*Aphantopus hyperantus*)) preferred the relatively open beech plots (Fig. 1). The total number of moths captured in the arable field was 344, compared to a mean of 471 in the three woodland blocks.

A total of 17 mammal species was recorded in the woodland. Wood mice (*Apodemus sylvaticus*) were trapped mainly in the arable field in summer, but more evenly in all habitats in autumn. Bird surveys recorded 40 species on field boundaries, where densities were highest, 36 in the

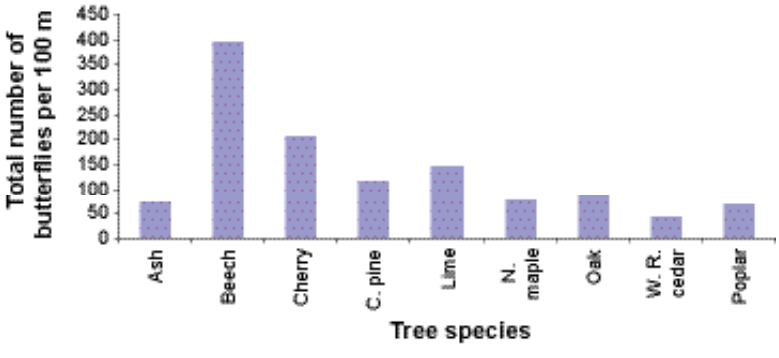


Figure 1. Total numbers of butterflies per 100 m transect within woodland plots (C. pine = Corsican pine, N. maple = Norway maple, W. R. cedar = Western red cedar).

Young beech woodland.

woodland and 9 in the arable field. These included several species of conservation concern (e.g. starling (*Sturnus vulgaris*), yellowhammer (*Emberiza citrinella*), song thrush (*Turdus philomelos*) and bullfinch, (*Pyrrhula pyrrhula*)). Several species held breeding territories within woodland plots (e.g. chaffinch (*Fringilla coelebs*), blackbird (*Turdus merula*) robin (*Erithacus rubecula*) and yellowhammer), which were also important for pheasants (*Phasianus colchicus*), wrens (*Troglodytes troglodytes*), goldfinches (*Carduelis carduelis*), blackbirds and yellowhammers in winter.

The study has shown the value of even very young woodland to farmland biodiversity. As well as providing new habitats, plantations can provide a refuge for arable fauna. Woodland planting beside species-rich hedgerows can also benefit this Biodiversity Action Plan habitat, as well as providing a source of appropriate plants and animals to colonise the new woodlands. The continued promotion of farm woodland planting on arable land should help Defra to meet biodiversity targets.

Organic carbon inputs and soil quality

Dr Anne Bhogal
ADAS Gleadthorpe

The depletion of soil organic carbon reserves through oxidation following the cultivation of land has led to concerns that soil organic matter may be reaching critically low levels, and that arable crop production may not be sustainable in the long-term on some soil types. Organic carbon (OC) additions in the form of farm manures, crop residues and other organic amendments (e.g. biosolids and composts) provide a valuable means of replenishing soil organic matter reserves and maintaining the inherent fertility of arable land.

Farm manure applications recycle *c.* 5 Mt of OC to land each year, biosolids *c.* 0.15 Mt of OC and the return of crop residues (straw, stubble and chaff) *c.* 15 Mt, which could confer benefits to soil quality and fertility. However, in the medium-term following application, many of the claimed benefits from organic manure additions are based largely on anecdotal evidence. Research by ADAS, in collaboration with Harper Adams University College and The Arable Group, funded by the Department for Environment, Food and Rural Affairs (Defra), quantified the effects of repeated farm manure additions (OC input range 5 – 65 t/ha) over a period of seven to nine years, on soil chemical, physical and biological properties. There were four sites with contrasting soils; ADAS Gleadthorpe (6% clay), Harper Adams (12% clay), Bridgets (Hampshire) (23% clay) and ADAS Terrington (28% clay). Similarly, measurements were made at three sites, Gleadthorpe (5% clay), Morley Research Centre (Norfolk) (13% clay) and Ropsley (Lincolnshire) (27% clay), which had received differential fertiliser nitrogen (N) rates (range 0 to *c.* 250 kg N/ha/yr) for 17 – 23 years (OC input range up to 32 t/ha from crop residues).

Over all the seven study sites, there was a positive relationship between OC inputs (from both the manures and crop residues)

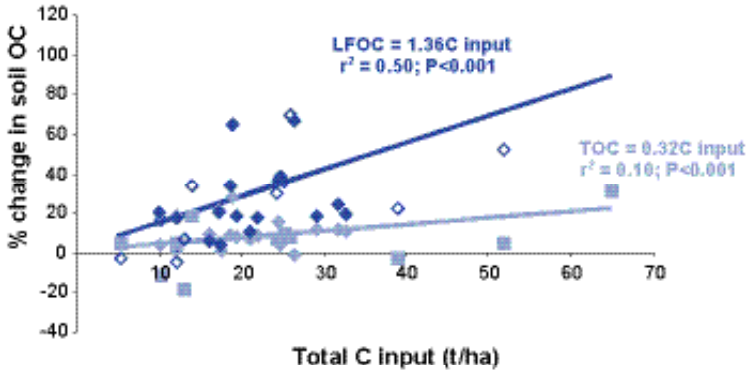


Figure 1. Relationship between total organic carbon (OC) input and topsoil OC content. (■ Total OC (TOC), ◆ Light Fraction OC (LFOC), Closed symbols: Crop residue C, Open symbols: Manure C).

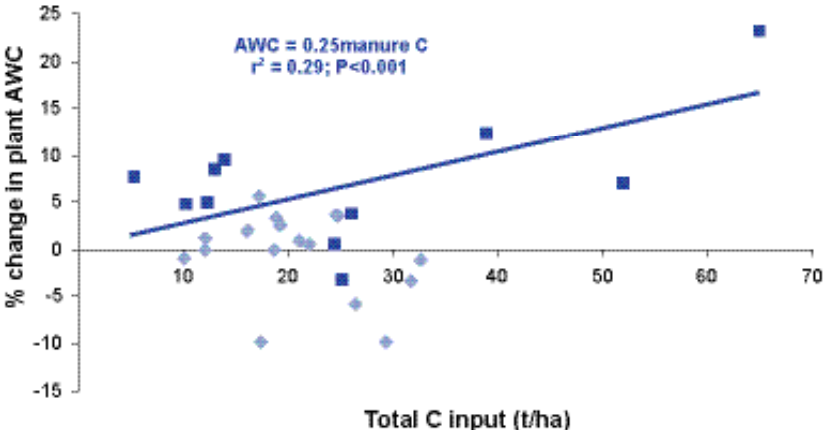


Figure 2. Relationship between total organic carbon (OC) input and plant available water capacity (AWC). (◆Crop residue C, ■ Manure C).

Farm manure applications recycle approximately 5 Mt of organic carbon (OC) to land each year.

and changes in total soil (0 – 15 cm) OC and light fraction OC; with the light fraction OC providing a more sensitive indicator of changes in soil organic matter status (Fig. 1). The OC inputs were also related to measurable ($P < 0.05$) decreases in soil shear strength. The manure OC inputs (but not crop residue OC inputs) increased topsoil porosity, decreased bulk density and increased the plant available water capacity (AWC) (Fig. 2). The 10% increase in plant AWC calculated for a 40 t/ha OC input from the regression line was estimated to increase the yield of unirrigated potatoes by *c.* 1.25 t/ha (worth *c.* £100/ha). In similar studies following biosolids addition (OC inputs up to *c.* 5 t/ha) at ADAS Gleadthorpe, AWC increases of *c.* 5% were measured. This was estimated to be worth *c.* £60/ha in additional potato yield.

The OC inputs from both the manures and crop residues increased the size (measured as biomass C) and activity (respiration rate) of the soil microbial community. Similarly, the manure and crop residue N inputs increased soil microbial biomass N and the potentially mineralisable N capacity of the topsoil, which has implications for long-term effects on nitrate leaching losses.

Overall, repeated and relatively large OC inputs were needed to produce measurable changes in soil properties, particularly physical properties. However, the OC inputs changed a large number of soil properties, which in combination, produced measurable improvements in soil quality and fertility. Future work needs to understand the processes and linkages through which OC additions influence soil quality and fertility and sustainable crop production.

Ammonia emissions - prediction and abatement

Jim Webb
ADAS Wolverhampton

Critical levels of acidification and nutrient-N are still exceeded in many parts of Europe. Reductions in sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) emissions have been achieved. In consequence, by 2010, ammonia (NH_3) is likely to be the largest contributor to acidifying and gaseous nitrogen (N) emissions. Measures to reduce NH_3 emissions are required under the 1999 protocol to the UN Convention on Long-Range Transboundary Air Pollution to abate acidification, eutrophication and ground-level ozone (O_3).

Prompt incorporation of manure by soil cultivations reduces NH_3 emissions.

The greatest emissions of NH_3 from livestock farming in the UK take place following the spreading of manures and slurries to land (38% of the total from livestock farming), and from buildings housing livestock (36%). Emissions during grazing, from farm hard standing and from manure stores are much smaller at 11.8, 8.1 and 5.7% respectively. Hence the priorities for reducing NH_3 emissions are from spreading to land, and from housed animals.

Total ammoniacal-N (TAN) in livestock excreta is the source of NH_3. At each stage of manure management, TAN may be lost, mainly as NH_3, and the remainder passed to the next stage. Hence, measures to reduce NH_3 emissions at the various stages of manure management are interdependent, and combinations of measures are not simply additive when assessing emission reduction. Ammonia conserved in buildings may be lost from stores, or after spreading, if no further measures are introduced. The TAN-flow concept is the basis of the UK National Ammonia Reduction Strategy Evaluation System (NARSES). NARSES enables rapid and easy estimation of the consequences of NH_3 abatement at one stage of manure management on NH_3 emissions at later stages, and gives unbiased assessment of the most cost-effective measures. Cost-curves produced by NARSES prioritise NH_3 abatement at the end of the manure management cycle, together with measures to immobilise or otherwise stabilise TAN (Fig.1).

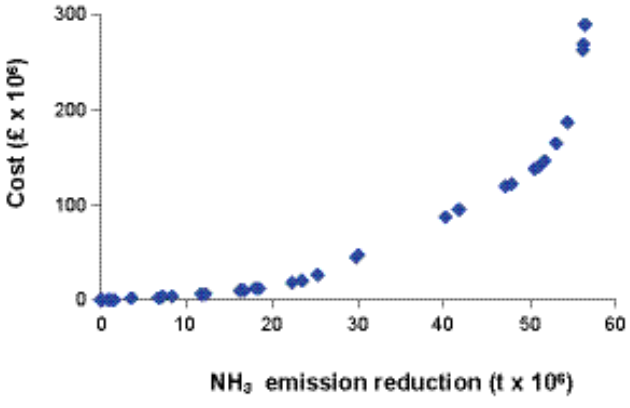


Figure 1. Example of a cost-curve output for the UK from the NARSES model.

Ammonia emissions following manure spreading are a surface phenomenon. Ammonia emissions arise before applied N enters the pool of plant-available N, and hence a different strategy is required to that needed to reduce losses of nitrate (NO_3) and nitrous oxide (N_2O). Unlike emissions of those two pollutants, reducing excess N inputs to crops will have a limited effect on reducing emissions of NH_3; specific measures are needed.

ADAS has carried out a number of projects, funded by the Department for Environment, Food and Rural Affairs (Defra), to quantify the most effective means of reducing NH_3 emissions following spreading of cattle and pig farmyard manure (FYM) and poultry manure to land. Incorporation of FYM within 4 h (75% reduction in emissions compared with no incorporation) was more effective than incorporation within 24 h (50% reduction). Incorporation of FYM by inversion ploughing was more effective (80% and 60% reduction for 4 h and 24 h incorporation times) than by disc cultivator (55% and 30% reduction for 4 h and 24 h incorporation times). The effect of time to incorporation was slightly less for poultry manure (90% and 75% reduction for 4 h and 24 h incorporation times). However, while ploughing may be the most effective method, on a plot scale, in these experiments, would the faster workrate of other implements, such as discs, be more effective at the field scale? The Manure Ammonia Volatilisation and Incorporation System (MAVIS) was developed to answer this question. Model output indicated it was always better to incorporate by inversion ploughing regardless of field size, incorporation strategy or distance to store. However, there were only limited data for incorporation by implements other than the plough, and for machinery workrates to confirm model output. Hence, a project is currently underway, also funded by Defra (ES0116), to validate MAVIS output for cattle and pig FYM, and layer and broiler manure. These field studies will also measure emissions of N_2O and estimate leaching losses in order to quantify the impacts of abatement on other polluting losses of N.

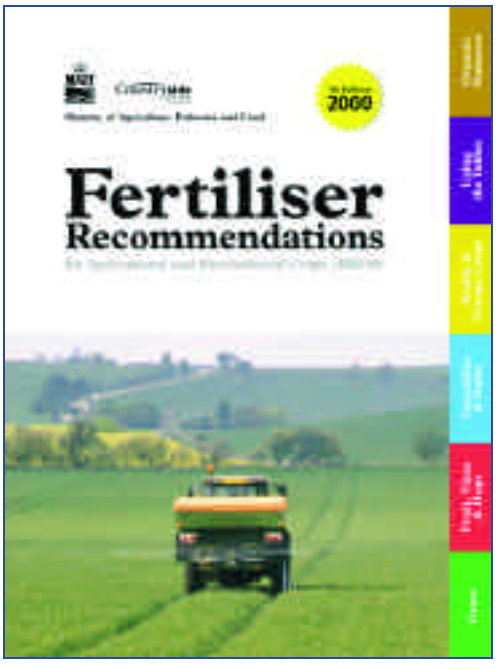
Fertiliser recommendation systems

Peter Dampney
ADAS Boxworth

The correct management of fertiliser and organic manure nutrient applications is of vital importance both to the profitability of farm businesses, and for reducing the risks of diffuse pollution of the water, soil and air environments. Action Programme rules within Nitrate Vulnerable Zones require farmers to apply no more nitrogen than the crop requires, and to record details of all organic manure and nitrogen fertiliser applications. Moreover, the development of a farm nutrient management plan will contribute to qualification for payment, from 2005, under the Entry-Level Stewardship agri-environment scheme.

User-friendly, but science-based, recommendations for the use of all nutrients under a wide range of cropping and environmental (mainly soil and weather) conditions have always been needed in order to encourage and guide good agricultural practice for individual crops. In England, Wales and Northern Ireland, there is a unified system of fertiliser recommendations embodied in the 'Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209)' book. Ever since the first edition of RB209 (1973), development and revision of the RB209 recommendations has been led by ADAS on behalf of the Ministry of Agriculture, Fisheries and Food, and more recently, the Department for Environment, Food and Rural Affairs (Defra). The recommendations are based on the synthesis of a huge amount of mainly field-based research over many years, and wide consultation within the UK research and advisory sectors. Thus, RB209 represents an agreed industry standard and commands a high degree of credibility amongst farmers and the rest of the agricultural industry.

The RB209 book (currently 7th edition, published 2000, available from The Stationery Office, **www.tso.gov.uk**,) is a 178-page detailed reference manual giving recommendations for nitrogen (N), phosphate, potash, magnesium, sulphur and sodium for all major crops. Based on a large body of recent research information, the main changes included in the 7th edition were a revision of soil N indices, and improved assessment of the nutrient value of organic manures and biosolids. Soil nitrogen supply indices can be determined from either the history of cropping and N fertiliser and manure use, or from analyses of soil samples for mineral-N (nitrate-N and ammonium-N). The revised values for crop available nitrogen are based on manure type, soil type, timing of soil incorporation and drainage volume following application.



Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209).

It has long been recognised that calculation of the fertiliser replacement value of organic manure applications, and decisions on the optimum rate and timing of nutrient additions, is a complex process. To help farmers and advisers with this task, and to help ensure that the RB209 recommendations are used correctly, two computerised systems have been developed by ADAS.

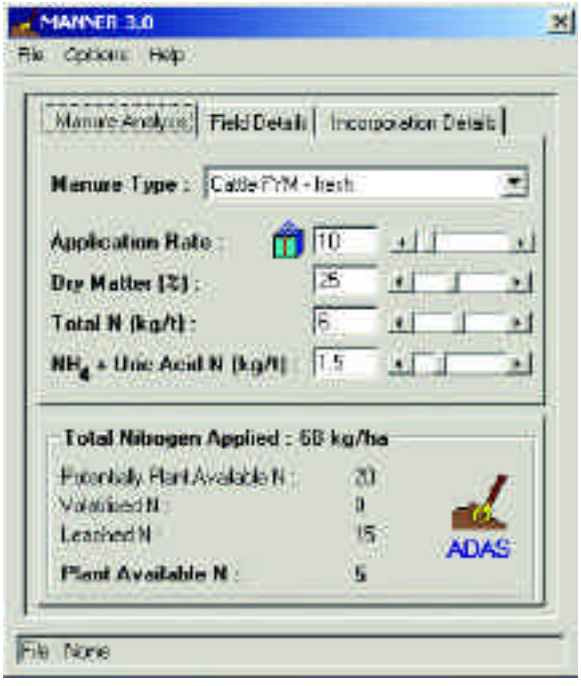


Figure 1. MANNER manure nutrient availability calculation software.

MANNER (MANure Nitrogen Evaluation Routine) calculates the crop available N value of an individual manure application taking account of manure type, rate and date of application, soil incorporation method, soil type and rainfall after application (Fig. 1). Developed by ADAS (funded by Defra), and launched in 1997, over 8,500 copies of MANNER have been distributed.

PLANET (Planning Land Application of Nutrients for Efficiency and the environmenT) has been developed by ADAS (funded by Defra, the Environment Agency and the Department of Agriculture and Rural Development for Northern Ireland (DARDNI)), and was launched in summer 2004. PLANET provides a complete fertiliser planning system for routine use at the field level. The output mimics the RB209 recommendations. Records of the actual use of manures and fertilisers are used to generate next year's recommendations. The PLANET software has been made available to agricultural software companies for possible inclusion in future updates of their products.

Farm manure management

Ken Smith
ADAS Wolverhampton

Organic manures represent a major nutrient resource but require careful management within sustainable farming systems. However, over the past 30 years, manures have remained poorly understood, sometimes poorly managed and generally underutilised. Research during this period has contributed to a greatly improved understanding of the fate of manure nutrients following application to land, and has highlighted reasons for the poor perception, by farmers, of the value of manures. The ready availability and low cost of mineral fertilisers has undoubtedly contributed to this perception. However, a lack of good technical information and advice has also been a problem, and despite the progress provided by research, understanding amongst farmers and consultants still needs to improve. There is a general failure to take into account the nutrients supplied from organic manures within farm fertiliser policies. Clear evidence of this is seen in annual statistics which indicate that the average fertiliser use on fields receiving a manure application prior to the crop is almost the same as on those fields not receiving a manure application (Fig. 1).

Farmers have long been advised against the application of organic manures with a high proportion of readily available nitrogen (N), such as cattle and pig slurries, and poultry manure, in the autumn and winter months, to reduce the risk of N leaching. However, high proportions of slurry (>50%) and poultry manure (>60%) are still applied during this high-risk period. This is because of better access to land for spreading in autumn/early winter, and the high costs of manure storage, particularly for slurries. Research on the impact of slurry application timing on freely draining soils has confirmed the N leaching risk associated with autumn applications. However, some slurry N is still recovered by the next crop grown (Fig. 2), and should be taken into account in farm fertiliser policies, to the benefit of both the farmer and the environment.

The Nitrate Vulnerable Zone Action Programme precludes the application of slurries and poultry manures to arable land from 1 August to 1 November, and to grassland from 1 September to 1 November. Research has also confirmed the lower leaching risk associated with farmyard manure (FYM), which has a low readily available N content. Timing restrictions are not required for the application of these low leaching risk manure types.

Research undertaken over the last 10 – 15 years has contributed to the development of a decision support system capable of predicting both environmental emissions, and the crop availability of manure N following application to land. The MANure Nitrogen Evaluation Routine (MANNER), funded by the Department for Environment, Food and Rural Affairs (Defra), takes account of manure analysis, ammonia volatilisation, nitrate leaching and mineralisation of manure organic N in order to predict the manure N available to the crop. MANNER has been shown to provide a reliable estimate of the fertiliser N value of farm manures under a range of conditions. Farmers and advisers find the software simple to use and, under Defra funding, over 8,500 copies of the software have been distributed since it was launched in 1997. It is clear that MANNER, and the enhanced version presently under development (MANNER-NPK), funded by Defra, can play a key role in promoting the better management of farm manures with reduced environmental emissions – a potential 'win-win' situation for farmers and the environment.

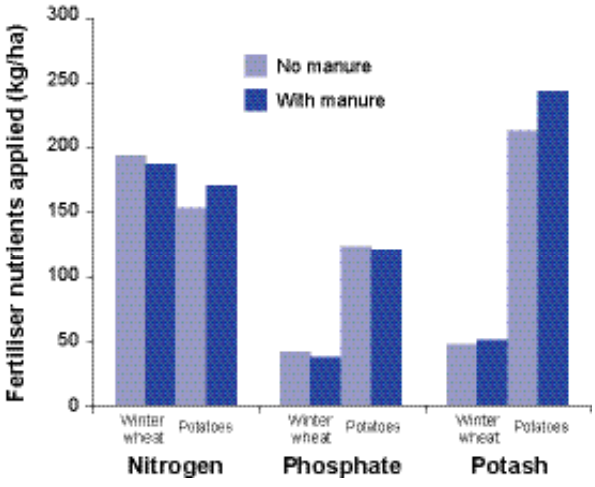


Figure 1. Average 'artificial' fertiliser use, on fields cropped with potatoes or winter wheat, with or without an organic manure application (source: British Survey of Fertiliser Practice, 2002).

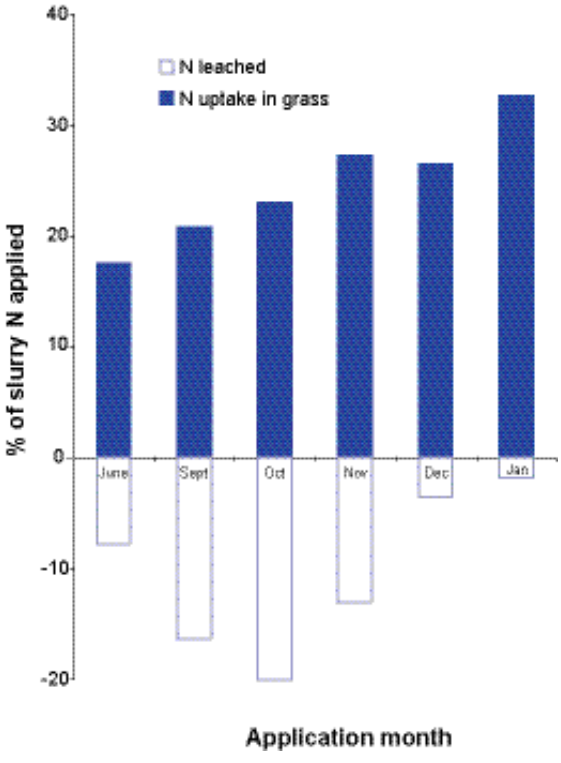


Figure 2. Effect of slurry application timing on nitrate-N leaching losses and N uptake in grass cut for silage (1990/91 – 1993/94; 15 site-years of data).

Sustainable Crop Management

James Clarke

Head of Science and Business Development - Sustainable Crop Management

Responsible for crop science and a specialist in farming systems, weed management and herbicide resistance.

Contact:
james.clarke@adas.co.uk

John Spink

Head of crop physiology and agronomy

Responsible for research and strategic consultancy in effects of environment and genetics on crop performance and quality for specific end uses including food, pharmaceutical, industrial and energy markets.

Contact:
john.spink@adas.co.uk

Dr Neil Paveley

Plant Pathologist

Specialist in cereal pathology research and crop-environment interactions with pathogenic fungi.

Contact:
neil.paveley@adas.co.uk

Professor Roger Sylvester-Bradley

Crop physiologist

Leading crop physiologist in ADAS and Special Professor at the University of Nottingham. Specialises in yield formation, crop design and crop nutrition.

Contact:
roger.sylvester-bradley@adas.co.uk

Integrating production with biodiversity

Lynn Collings
ADAS Boxworth

Government-funded research has highlighted the importance of weeds for biodiversity in agricultural ecosystems. The decline in weed seedbanks, through the use of herbicides over the last 40 years, is thought to be a critical component in the decline of many farmland bird species such as skylark (*Alauda arvensis*) and grey partridge (*Perdix perdix*). Farmers generally consider weeds to be undesirable, as they can have a large effect on crop yield and profitability. Increasingly, weeds have also developed resistance to herbicides, making control strategies more difficult. However, some weed species compete with the crop less aggressively than others, and can be desirable, below certain threshold population densities, as a source of food and shelter for birds and small mammals within arable fields. Some weed species are now so rare that their survival needs to be encouraged, so it is important to get the correct weed control balance by careful crop management and forward planning.

ADAS is involved in several projects which aim to manage weed control to benefit biodiversity without affecting crop yield. One of these is the Weed Management Support System (WMSS) project, a Sustainable Arable LINK (SAL) project sponsored by the Department for Environment, Food and Rural Affairs (Defra) and led by ADAS (**www.wmss.net**). Project collaborators include Rothamsted Research, Silsoe Research Institute, Scottish Agricultural College (SAC), the Home-Grown Cereals Authority (HGCA), BASF, Bayer CropScience, Dow AgroSciences, DuPont and Syngenta. WMSS is a 'user friendly' strategic management tool for use in winter wheat, providing information on the best methods for controlling weed species from an economic and environmental perspective (Fig. 1). It also considers herbicide-resistance implications, both within a season and over a rotation. WMSS includes a concise herbicide encyclopaedia containing detailed information on the majority of herbicides used in winter wheat. There is also a weed encyclopaedia providing information on the biology and ecology of weed species, and identifying rare and beneficial weeds.

As part of WMSS, herbicide tolerance trials were undertaken in glasshouses at ADAS Boxworth and SAC Edinburgh, screening 30 rarer weed species against 20 herbicides at two dose rates. These are new data and have helped characterise the effect of herbicides on these weeds.

Figure 1. An example of an encyclopaedia page from WMSS.

ADAS is also working on a Defra-funded collaborative project with Rothamsted Research to improve decision making in long-term weed management, in relation to biodiversity and crop yield. Data from field trials at ADAS Boxworth, ADAS High Mowthorpe and ADAS Terrington are being used to develop and test models of competition between weeds and crops, and will also be used in the WMSS biological models where data gaps have been identified.

The trials contrast the fate of the same weed populations in spring- and winter-sown crops (wheat, oilseed rape and beans). Plots are monitored over an 18-month period, to study the longer-term implications of different weed management practices. The data generated provide more precise model parameter estimates, including data on seed production per plant (Fig. 2), allowing model outputs to be refined. Six key weed species have been targeted as beneficial for in-field biodiversity, providing an important source of food for birds or invertebrates:

- *Stellaria media* (chickweed);
- *Senecio vulgaris* (groundsel);
- *Tripleurospermum inodorum* (scentless mayweed);
- *Chenopodium album* (fat hen);
- *Poa annua* (annual meadowgrass);
- *Polygonum aviculare* (knotgrass).

Results from these two projects are feeding into another SAL project, Sustainable Arable Farming For an Improved Environment (SAFFIE), to produce the right combinations of herbicide treatments to control aggressive weeds and leave behind beneficial weeds for wildlife. These results will also be used to inform policy-makers, farmers and non-government organisations on the best management practices for both crop production and biodiversity.

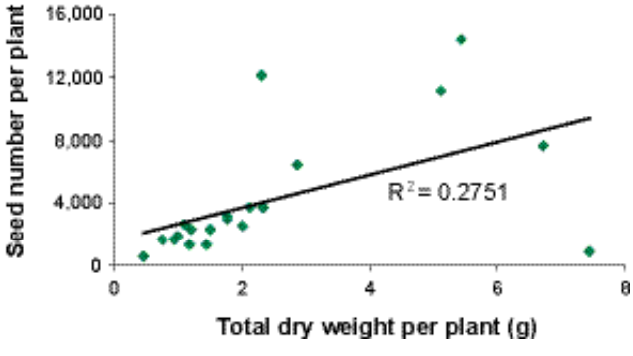


Figure 2. The effect of dry weight per plant (g) on seed number per plant, for untreated *Senecio vulgaris* in a winter wheat crop.

Genetic improvement of crops for specific end uses

John Spink
ADAS Rosemaund

The need for more sustainable farming will increase in the next few decades. Sustainability can be thought of in a number of ways: financial, environmental and in relation to the use of resources. These pressures are likely to drive down the use of external inputs in crop production systems. Given the high cost structure of UK farming, this must be achieved with minimal loss in output, or preferably, an increase. This would be best achieved by developing crop varieties which require lower levels of external inputs, whilst maintaining or increasing output.

Since the early 1990s, ADAS has been disentangling how certain varietal traits influence the response to environment and crop management inputs. This information can be collated to design crop ideotypes with improved performance. Ultimately, such ideotypes must be converted into commercial varieties to deliver the sustainability benefit. The recently-awarded, LINK-funded project, 'Genetic Reduction of Energy use and Emissions of Nitrogen in cereal production' (GREEN Grain), is sponsored by the Department for Environment, Food and Rural Affairs (Defra), and is an example of how crop design, and progress towards commercialisation, is being addressed. Project partners are ADAS, Foss Ltd, Grampian Country Foods Ltd, Home-Grown Cereals Authority (HGCA), Syngenta, Scottish Crop Research Institute, Scotch Whisky Research Institute and Wessex Grain.

In terms of financial sustainability, it is expected that, in the 21st century, there will be an expanded market in north-west Europe for grain that delivers an energy-dense feedstock for bioenergy, non-ruminant livestock, food and bio-materials. It is estimated that, if EU member states are to meet the recommendations of the Biofuels Directive from home supplies, grain production must increase by 20 million tonnes (about 15%) by 2010. Wheat is the most suitable cereal for this use, and is already the dominant cereal used for grain whisky and potable white spirit production. However, wheat has not been bred for these markets, and there are significant production and grain quality deficiencies. Some of the information needed to overcome these deficiencies is lacking.

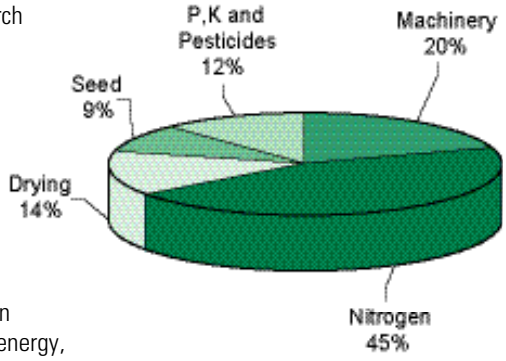


Figure 1. Energy costs of growing wheat.

Wheat production in north-west Europe is intensive, and is being challenged by impending EU legislation concerning CO_2 and N emissions. Wheat varieties in the UK have always been bred and tested with ample levels of fertiliser N; there has been no attempt, hitherto, to reduce fertiliser requirements of wheat by breeding. Indeed, N requirements have tended to increase through breeding.

The main breeding focus for wheat quality has been bread-making. Gliadins are storage proteins held in the endosperm which, together with glutenins, form the gluten needed for making bread. However, gliadins are less useful for animal feed, as they are very low in lysine and other amino acids essential for non-ruminant nutrition. Therefore, they constitute waste protein when fed to pigs and poultry, and must contribute to excreted N. Probably, gliadins are also detrimental in distilling because of reduced processing efficiency, reduced lysine content of distillers' grains, and increased volume and N content of downstream wastes.

Energy content, ethanol yield, feed quality and fertiliser requirements are all poorly understood traits, and known to be controlled by many genes. For performance in distilling, it is clear that grain texture and starch content are of most importance, but other factors probably contribute. Surveys of variety trials in Scotland demonstrate that there is no relationship between alcohol yield and grain hardness, specific weight or size; the clearest relationship (inverse) is with grain N content.

With respect to non-ruminant feeding, although wheat constitutes the major component of pig and poultry rations, formulation focuses on minimising cost for a standard composition. Commercial formulations commonly treat all wheat as having a fixed composition, so there can often be a significant oversupply in some constituents (e.g. protein), and hidden costs. The industry has detected problems with some varieties, but by focussing on least cost, it is not set up to exploit developments in energy content.

With respect to N requirements and N use efficiency of crops grown for energy yield, the main considerations are recovery of

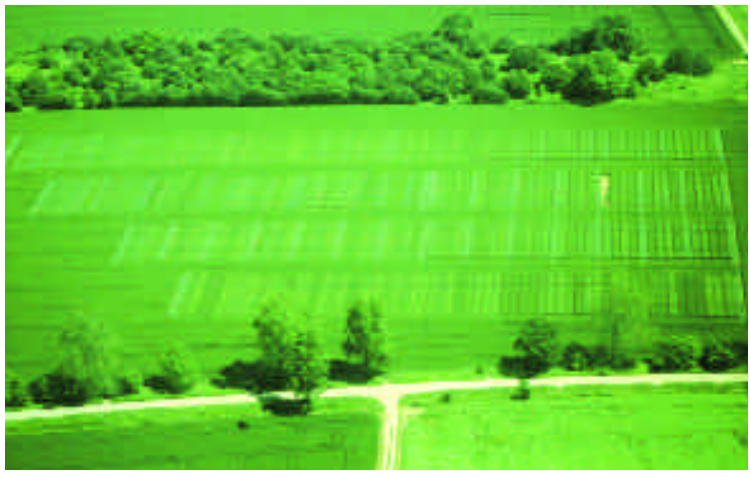
A bioethanol plant, a poultry house and whisky: end uses for wheat include energy, animal feed, and production of spirits.

Wheat has good potential as a biofuel crop.

soil-derived and fertiliser N, effectiveness of canopy N in photosynthesis, and harvest index. Use of N is particularly important because of the high proportion of energy costs that are associated with fertiliser N applications (Fig. 1). Recovery rates for soil-derived N and fertiliser N are very variable and unpredictable. Soil-N recovery may be related to subsoil rooting. Work on drought tolerance provides evidence that subsoil-N recovery has not improved through recent breeding. On the other hand, recovery of fertiliser N, which remains in the topsoil during growth, apparently has improved. Fertiliser N recovery relates inversely to soil immobilisation of N, and hence to carbon deposition by roots in the topsoil. Thus, there appear to be prospects for an improvement in N recovery through more uniform distribution of wheat roots through the soil profile.

Turning to photosynthetic N use efficiency, leaves need 1 – 2 g N per m^2 green area, depending on light intensity. Analysis of UK wheat canopies showed that leaf laminae tend to match these levels, but also found substantial additional N in the true stem and leaf sheaths. There has been very little research on the form and purpose of this stem N, but it appears that it is surplus to photosynthetic requirements, and represents a 'store' that may be unnecessary in managed environments.

In conclusion, wheat has not been bred specifically for the biofuel, distilling and feeding markets, so there is considerable potential for improvement. Development of new wheat varieties tailored to these markets is hampered by incomplete understanding of biochemical processes and their underlying genes, lack of rapid screening techniques and poor parental characterisation. Although the necessary research could not be justified within commercial plant breeding programmes, there is scope to substantially improve the effectiveness of the UK wheat industry, from breeder through to consumer.



Experiments have shown that recovery rates for soil-derived N and fertiliser N are very variable.

Related Project

Title: Identifying genetic markers for lodging resistance in wheat.

Funders: Defra, Advanta Seeds UK Ltd, HGCA.

Contract Manager: Pete Berry, ADAS High Mowthorpe.

Comments: Similar approaches to those applied in the GREEN Grain project are used to identify genetic control of stem and anchorage strength in wheat.

Related Project

Title: Fellowship in crop environment interactions with pathogenic fungi.

Funders: Defra.

Contract Manager: Neil Paveley, ADAS High Mowthorpe.

Comments: This project is identifying and prioritising the genetic control of traits related to *Septoria tritici* escape and tolerance.

Related Project

Title: Understanding *Sclerotinia* infection in oilseed rape to improve risk assessment and disease escape.

Funders: Defra, CPB Twyford Ltd., HGCA.

Contract Manager: Caroline Young, ADAS at Defra Drayton.

Comments: Apetalous oilseed rape is being used to help understand more fully the development of *Sclerotinia* and the role that the apetalous trait may have in avoiding severe infection.

Producing crops that meet the needs of consumers

Dr Richard Weightman
ADAS Boxworth

Sustainable crops must meet the requirements of the market, satisfying both the quality and safety requirements of end users (processors and consumers). Research by the ADAS PhytoInnovations team, based at ADAS Boxworth, focuses on these aspects for traditional UK crops, and looks to develop new arable and horticultural crops for high value and specialist markets.

Physiological traits influencing hardness and vitreosity in wheat grain are being studied in a project funded by the Department for Environment, Food and Rural Affairs (Defra), and collaborative with Campden and Chorleywood Food Research Association, The John Innes Centre and the University of Nottingham. This project, which started in September 2001, builds on previous ADAS research on the physiology of winter wheat, and aims to provide strategic guidance to the plant breeding industry by identifying desirable combinations of drought resistance and quality traits that will provide stable yield and quality.

In 2003, ADAS invested in new analytical facilities to provide specialist analysis of phytochemicals in natural crop products such as herbal medicines and pharmaceuticals. As well as state-of-the-art analytical equipment such as High Performance Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GCMS), we have facilities for extraction of essential oils, and quantification of chemicals associated with flavour and aroma in fresh produce and flowers.

Many medicinal herbs can be grown in the UK, but producers are slow to enter the market, which now has a value of £350 million per annum in the UK. Barriers to expansion include the lack of reliable production systems tailored to the UK market, and our farm cost structure. The quality of processed material is becoming more important to the industry, with increasing interest in traceability and crop assurance protocols. A four-year, Defra-funded study, aims to examine the risks of contamination of herbal products with pesticide residues, mycotoxins and heavy metals. Three model crops were grown at ADAS research sites. The effect of pesticides on the yield and quality of German chamomile flowers (*Matricaria recutita*; used dry as a tea), and borage seed oil (*Borago officinalis*; grown for its nutritional oil) are being studied. The uptake of heavy metals into the roots of valerian (*Valeriana officinalis*, a herbal drug used to induce sleep) is also being studied. The concentrations of six heavy metals have been measured in the dried roots of valerian, grown on either normal soil, or soil amended with sewage sludge (to represent a worst case scenario for heavy metal contamination). The risk of heavy metal contamination in the harvested roots is clearly demonstrated (Table 1), as is the beneficial effect of washing roots after harvest.

The risks associated with poor drying and the incidence of micro-organisms are being studied using chamomile flowers and valerian roots. In the final stage of the project, the knowledge gained from these studies is being incorporated into a Hazzard Analysis Critical Control Point (HACCP) analysis, which can be used as a basis for a crop assurance protocol, and which will help the UK industry compete with lower quality imports.

Meeting market requirements necessitates working closely with industry, so much of our research is collaborative and

Related Project

Title: Sampling for nitrate in lettuce and spinach.

Funder: United Kingdom Food Standards Agency.

Contract Manager: Richard Weightman, ADAS Boxworth.

Comments: The aim of this project is to improve the sampling protocols used in the collection of samples for surveillance of nitrate levels in lettuce and spinach.

Surveillance of nitrate in fresh spinach requires improved sampling protocols.

Treatment of roots	Heavy metal concentration in roots (mg/kg)					
	Cd	Cr	Cu	Pb	Ni	Zn
Washed						
Uncontaminated soil	0.11	2.2	5.5	1.3	4.0	27.6
Contaminated soil	0.64	29.2	17.3	20.3	4.8	50.5
Unwashed						
Uncontaminated soil	0.23	13.4	10.6	6.2	11.5	39.8
Contaminated soil	2.10	169.0	53.8	84.6	15.4	134.7

Table 1. Concentrations of heavy metals in dried roots of valerian, grown either on uncontaminated soil, or on soil treated with sewage sludge.

Valerian (a medicinal herb) growing at ADAS Arthur Rickwood, and following harvesting and washing of the roots.

multidisciplinary. ADAS is leading a major LINK project, called PHYTODERM, funded under the Competitive Industrial Materials from Non-Food Crops LINK programme, sponsored by Defra and BBSRC and with five other partners. We are examining the production of skin-protecting chemicals by developing the use of two plant species for ingredients to protect against skin damage and ameliorate ageing. Novel production techniques are being developed to enhance the yield of the phytochemicals of interest, and to improve the consistency of supply of raw materials throughout the year.

ADAS is also developing new crops with overseas customers. Uganda was recently selected by the United Nations Conference on Trade And Development (UNCTAD) for the BIOTRADE Initiative alongside four Latin American countries. The mission of the BIOTRADE Initiative is to stimulate trade and investment in biological resources to further sustainable development in line with three objectives: the conservation of biological diversity; sustainable use of its components; and fair and equitable sharing of the benefits arising from the utilisation of genetic resources. Nile Botanical Resources Ltd. is one of the five commercial organisations in Uganda selected for UNCTAD funding. Their remit is to develop new products for export (raw plant materials and extracts) and to establish new markets for these commodities. Nile Botanical Resources Ltd. is building on the knowledge and capability developed in the pyrethrum extraction business to establish a portfolio of plant materials and extracted products. ADAS is currently assisting Nile Botanical Resources Ltd. with the recruitment of European buyers.

Sun-drying guava leaves in Uganda.

In this context, the challenge is to use biodiversity as a basis for sustainable development. For example, the sustainable use of biodiversity could support both development and nature conservation, as it would generate tangible economic benefits, so the users and owners of these resources would therefore have an incentive to protect and preserve them.

The potential end-products of materials from Nile Botanical Resources Ltd. are many and varied, and include novel foods, cosmetics, pharmaceuticals, dyes and even pot pourri. Our strategy, therefore, has been to review the information available on specific Ugandan plants, drawing up a list of those species with the most valuable, confirmed or reputed, useful properties.

Future work will include assisting with the development of Nile Botanical Resources Ltd. products, to meet the exacting specifications of European customers. This is likely to involve consultancy on, for example, production techniques, sustainable growing and sourcing, and quality assurance and trademarking. The ADAS PhytoInnovations team will help with the chemical characterisation of extracts destined for particular end-users, such as the pharmaceutical industry.

New century, new challenges for crop protection?

Dr Bill Parker
ADAS Wolverhampton

Protecting crops from the ravages of pests, diseases and weeds is an age-old challenge. In the 21st century, however, the challenges facing crop protection researchers and practitioners are interwoven with the politics of farm support, retailer demands, environmental and consumer concerns, and a host of issues associated with the globalisation of food supply. At the same time, the pests, diseases and weeds themselves continue to throw up new challenges, while a largely urbanised population views some scientific and technical advances in crop protection (e.g. GM technology) with suspicion.

Fundamentally, the challenge facing UK farmers and growers is to strike the balance between proven, economic, crop protection methods, and the introduction of newer, more 'environmentally-friendly', but potentially complex and uncertain techniques now emerging from the research pipeline. Since the late 1990s, the driving force shaping crop protection practice in the UK has been the introduction of produce certification schemes that promote best practice under the banner of Integrated Crop Management (ICM). This system is now well-established and has had profound impacts on the crop protection industry and farm practice, but crop protection techniques (outside organic farming and some protected crops) have remained largely pesticide-based. However, this approach is becoming increasingly untenable. Regulatory pressures are reducing (and in some cases eliminating) available pesticides, particularly for minor crops. Pesticide resistance also limits the useful life of some key product groups. Resistance to recently-introduced strobilurin fungicides in *Septoria tritici* on wheat is a case in point.

The current research drive is for the development of novel, sustainable crop protection methods, including the development of bio-pesticides, novel semiochemicals, new monitoring techniques (Fig.1), farm habitat modification, and the implementation of conservation and/or augmentative biological control systems in outdoor field crops. Such approaches require a detailed understanding of the complex physiological and ecological interactions between host plants and their associated pests and diseases. These are essential lines of research, but the challenges associated with turning these approaches into practical, economic techniques that farmers can use are enormous, even assuming that the research effort is successful. Changes in the regulatory framework are required to enable the cheaper, faster registration of novel 'biological' actives, and to demonstrate to farmers and growers that such techniques can be used economically. Appropriate access to technical information and advice is vital, whether through direct professional contact or the development of sophisticated decision support systems.

Understanding how crop protection practices impact on the wider farm environment will be a key issue for the next few years.

Ultimately, the direction of agriculture in the UK will be shaped by the implications of changes in the support payment system. With the Common Agricultural Policy mid-term review resulting in the de-coupling of support from production, the nature of arable farming in particular may fundamentally change over the next 10 years, particularly if there is a need to meet agri-environmental conditions to qualify for payments. This may lead to new, unforeseen challenges for crop protection. Overcoming these challenges will require sound, practically-orientated, field-based research to be continued. This is an ADAS strength, and our crop protection researchers are well placed to meet the challenge.

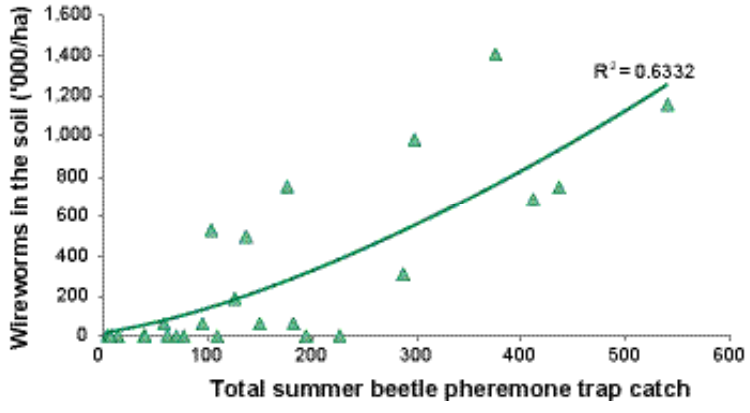


Figure 1. Pheromone trap catches of adult click beetles can be used to predict the population level of wireworms remaining in the soil and hence the risk of damage to potato crops (funded by the British Potato Council).

Related Project

Title: Tri-trophic interactions determining aphid phenology on potato.

Funder: Department for Environment, Food and Rural Affairs (Defra).

Contract Manager: Dr Bill Parker, ADAS Wolverhampton.

Comments: This four-year project is collaborative with the University of York (Professor Angela Douglas) and Dynamix Software Ltd (Dr Neil Kidd), and tests the hypothesis that the mid-season aphid population crash is mediated by the interaction between plant nutritional factors and other determinants such as natural enemies and weather. This is being done by a combination of fieldwork, laboratory studies on aphid nutrition, and aphid population modelling.

Integrated control of botrytis in glasshouse ornamentals

Dr Tim O'Neill
ADAS Arthur Rickwood

The British Bedding Plant Association identified botrytis, or grey mould (*Botrytis cinerea*), as its number one disease problem, with annual losses estimated at £6.8 million. Major losses occur in cyclamen, primula and nursery stock plants propagated by cuttings. The key industry requirement is a more sustainable approach to botrytis management. Following discussions with industry representatives and researchers, a Horticulture LINK project (HL025) was sponsored by the Department for Environment, Food and Rural Affairs (Defra) and led by ADAS.

Work focused on four objectives, with ADAS leading objectives 3 and 4. These were:

1. defining the effect of microclimate on infection of cyclamen;
2. measuring leaf wetness and within-crop humidity;
3. determining the efficacy of novel fungicides and crop management practices;
4. devising and evaluating integrated chemical and greenhouse environment management strategies.

There were two important findings on the fundamental biology of botrytis. Firstly, infection of cyclamen leaves by *B. cinerea* conidia was influenced primarily by high humidity (>95% at 10 – 20°C), not free moisture. Secondly, germination was reversible by exposure to a lower humidity (<80%) for 2 h, within the first 3 h of a high humidity period. This latter feature formed the cornerstone of a control strategy for cyclamen crops in winter.

Experiments with fungicide products and application timings demonstrated that 4 – 6 sprays of novel products (e.g. azoxystrobin, mepanipyrim and pyrimethanil), applied at appropriate growth stages, could greatly reduce disease severity in a range of crops, compared with 6 – 7 sprays of older fungicides (e.g. iprodione). Omission of sprays until botrytis was visible, generally gave poor control, but extended spray intervals were possible if two early protectant sprays were applied. These novel fungicides are now used widely on crops of protected ornamentals. Non-chemical methods found to reduce botrytis were removal of dead leaves and increased air movement via a perforated polythene tube.

In glasshouse experiments on commercial nurseries and at HRI Efford, a night-time heat boost and vent to reduce humidity within cyclamen crops was implemented during the high-risk, October to December period. In the absence of fungicide application, this treatment reduced botrytis by 30 – 50%, was economic to apply, and had no detrimental effect on plant quality. When combined with fungicides, and other non-chemical control measures devised in the project, the integrated programme gave excellent control of botrytis (Fig. 1). Priva UK Ltd were involved in the latter stages of the project and are seeking to include a botrytis management action, as an option for growers, within the software of the Priva Integro climate control computer.

Members of the consortium were ADAS, Campbell Scientific Ltd, the Horticultural Development Council, Horticultural Research International, the Scottish Agricultural College, Silsoe Research Institute, S. Coutts, and the University of Reading.

Botrytis (*Botyris cinerea*) is a common and damaging disease of cyclamen.

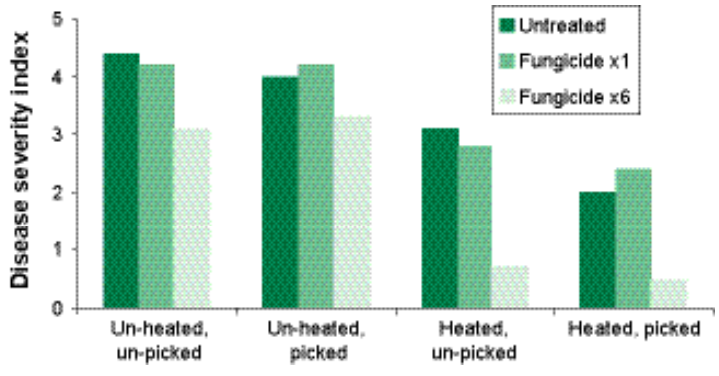


Figure 1. The effect of fungicide programmes (1 or 6 sprays), a 2 h, night-time humidity reduction (heat-boost with vent), and picking-off of dead leaves, on the severity (0 – 5 index) of botrytis on cyclamen at marketing.

Related Project

Title: Reducing latent botrytis in cut flowers and pot plants for reduction of supply chain wastage.

Funders: Defra, Marks & Spencer plc, FlowerPlus Ltd., Carlton Lodge Nursery Ltd., DA Needham Ltd., DoubleH Nurseries Ltd. and WJ Findon and Son Ltd.

Contract Manager: Dr Tim O'Neill, ADAS Arthur Rickwood.

Comments: This is an ADAS-led Horticulture LINK project, collaborative with Central Science Laboratory and the University of Reading, and was prompted by the discovery of symptomless, systemic infection of primula by *B. cinerea* during work on the integrated control of botrytis in glasshouse ornamentals.

Integrated management of celery leaf spot (*Septoria apiicola*)

Dr Kim Green
ADAS Arthur Rickwood

Celery leaf spot, or septoria (*Septoria apiicola*), is the most destructive disease of field-grown celery. Following severe outbreaks in East Anglia in 1999, estimated to have caused crop loss to a value of £100k, two projects were commissioned by the Horticultural Development Council (FV237 and FV237a). The aim was to improve disease management by:

1. identifying alternatives to the fungicide thiram for elimination of septoria from celery seed;
2. ensuring cost-effective and sustainable use of fungicides by evaluation of product effectiveness and optimisation of spray timing;
3. identifying cultural practices to minimise the risk of disease spread.

The effects of a range of treatments (fungicides, hot water, disinfectants, plant extracts, microwaves and ultra-violet light) on seed-borne *S. apiicola* were tested. Promising results were obtained with hot water treatment and with 5% peroxyacetic acid (Jet 5) as a soak and a vapour treatment. For example, treatment in hot water at 48°C for 30 minutes reduced the percentage of celery seeds with viable septoria infection to 1%, compared with 18% in the untreated control.

An inoculated field experiment, at ADAS Arthur Rickwood in 2001, showed that effective control of septoria was achievable in the growing season, even under high inoculum pressure, using timely fungicide sprays, e.g. alternating Amistar (azoxystrobin), Plover (difenoconazole) and Bravo 500 (chlorothalonil) at 14-day intervals. To complement fungicide use, a 'Grower Factsheet' was produced summarising cultural measures, from propagation through to crop harvest, which can minimise septoria risk.

Temperature (°C)	Leaf area diseased (%) at leaf wetness durations (h) of:					
	1	6	24	48	72	96
5	0.7	3.5	2.9	2.2	1.5	19.0
10	0.0	0.0	0.2	3.8	32.8	50.1
15	0.1	0.2	0.3	10.5	24.2	25.8
20	0.1	1.7	4.4	27.9	43.7	38.3
25	0.3	0.5	20.9	43.2	55.7	50.9
30	0.0	0.1	0.4	10.7	31.1	26.5

Table 1. Effect of incubation, at different leaf wetness durations and temperatures, on celery leaf spot (% leaf area diseased), 28 days after inoculation.

Controlled environment studies showed that there was a trend for diseased leaf area to increase with both temperature (5 – 25°C) and leaf wetness duration (1– 96 h), providing a rational basis for disease risk prediction (Table 1). Under optimum conditions (e.g. 20°C, >24 h leaf wetness), septoria lesions developed 10 days after inoculation. As septoria development is highly dependent on leaf wetness duration and temperature, spray applications can be decreased by spraying only when conditions are conducive for disease development.

In an inoculated field experiment in 2002, fungicides were applied either prophylactically, or according to criteria based on leaf wetness duration or mean night temperature. The best disease control and least number of sprays were achieved where fungicides were applied only following leaf wetness durations exceeding 12 h (Table 2). Results suggested that leaf wetness duration is a more accurate indicator of septoria risk than temperature. Also, disease control is dependent not only on correct spray timing in relation to infection events and environmental conditions, but also appropriate product choice.

In a third inoculated field experiment in 2003, we evaluated spray programmes with application times according to leaf wetness periods, and product choice according to recent and forecasted rainfall. In a dry season with low disease pressure, good disease control (<2% leaf area diseased) was achieved using only one fungicide application (timing based on a leaf wetness period of >24 h). Complete control was achieved using five sprays (timings based on leaf wetness periods >12 h) compared with six in the prophylactic spray regime.

Results provide the basis for development of a decision tool to aid fungicide application timing and product choice for effective septoria control, whilst minimising the number of fungicide sprays.

Fungicide timing	No. of sprays applied	Mean leaf area diseased (%)
Prophylactic, 14-day interval	6	10.1
Using leaf wetness criterion	5	1.8
Using temperature criterion	6	8.1
Untreated control	0	27.8

Table 2. Fungicide spray regimes for septoria control in 2002, each using a sequence of Amistar, Plover and Bravo 500. The leaf wetness criterion was wet leaves for >12 h, and the temperature criterion was a mean night temperature >10°C.

Under favourable conditions, celery leaf spot (*Septoria apiicola*) develops rapidly.

Modelling miscanthus yields across England and Wales

Dr Laura Fawcett
ADAS Wolverhampton

Miscanthus (*Miscanthus x giganteus*) is a perennial rhizomatous grass that is grown for biomass energy production. Both financial and environmental (CO_2 life-cycle analysis) sustainabilities of this crop rely on high annual biomass yields and long-term crop productivity over at least 15 years. Therefore, it was important to predict the annual biomass yield at different locations and to monitor crop productivity over time.

Projects funded by the Department for Environment, Food and Rural Affairs (Defra) have involved the establishment of miscanthus trials at seven ADAS sites in England, representing different geographical locations and soil types. The yield potential, calorific value and appropriate plant spacing of the crop were determined. After an initial three to five-year establishment period, yields at the seven sites have averaged 16 oven dry tonnes per ha per year, over a four-year period.

Further work, again funded by Defra, involved modelling mature crop yields of miscanthus across England and Wales under current and future climate scenarios. A simple model of above-ground dry matter yield, based on the Monteith resource capture equation, was used. The equation was parameterised for miscanthus by using meteorological and crop growth measurements from the seven trial sites. Seasonal differences in yield were observed at most sites, and in many instances water availability was a limiting factor that restricted yield. Therefore, a drought factor was included in the model, which was a function of the available water in the soil profile. Water availability is, in turn, a function of soil type, effective rainfall and evapotranspiration. The equation was applied to the seven trial sites on a daily basis for the duration of each growing season. The modelled estimates provided realistic estimates of measured yields, including reduced biomass yields when drought was experienced (Fig. 1).

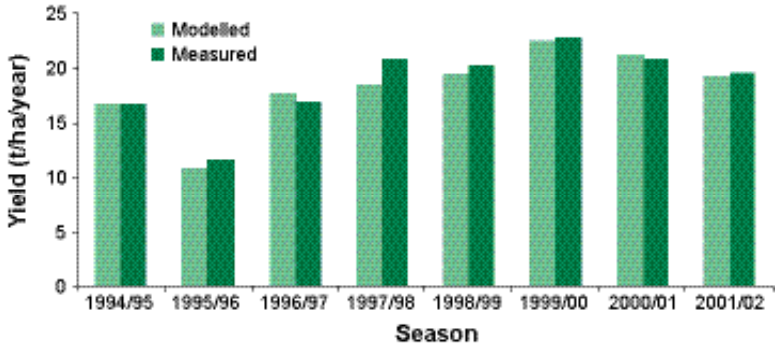


Figure 1. Modelled and measured yields (oven dry tonnes/ha/year) of miscanthus, for field trials (1994 – 2001) at ADAS Arthur Rickwood.

The temporal and spatial variability, across England and Wales, of the potential miscanthus yield was explored. The simple model was applied in a GIS framework using geographic databases (climate, soils, land use), on a 5 x 5 km grid, to derive a map of predicted yields for England and Wales under current climate and predicted climate conditions centred on the year 2050 (Fig. 2). The model indicated that, on average over a 30-year period, consistently good yields above an estimated profitability threshold of 12 oven dry tonnes per ha per year, may be currently expected in many areas of England and Wales, but with poorer yields on higher ground and shallow soils. Under the future climate scenario for 2050, modelled average yields were improved, despite drier summers, for many areas of England and Wales with deep, moisture-retentive soils. However, yields on shallow, light soils were predicted to become increasingly variable due to water limitation.

The project highlighted the importance of suitable site selection, particularly in relation to water availability, to ensure consistently good yields. This information is of value to all concerned with miscanthus productivity, both now and in the future, such as farmers, planners and biomass project developers.

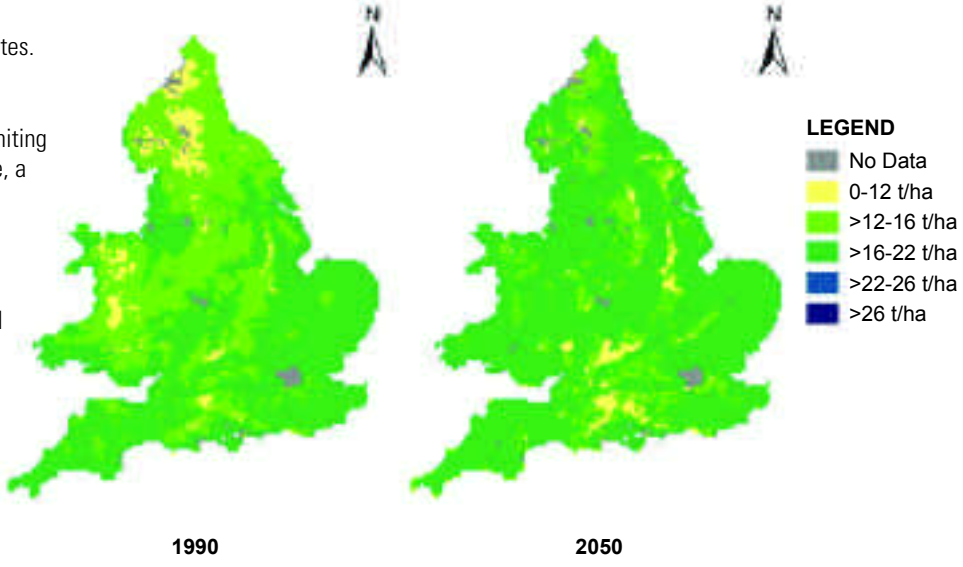


Figure 2. Average, water-limited yield (oven dry tonnes/ha/year) for miscanthus on a 5 x 5 km grid of England and Wales, predicted for 1990 and 2050.

The miscanthus breeding programme

Peter Nixon
ADAS Arthur Rickwood

Miscanthus x giganteus (miscanthus) has become established as a biomass crop suitable for lowland England and Wales. The miscanthus crop grown for biomass in Europe consists almost exclusively of *M. x giganteus* clones. While *M. x giganteus* is native to south-east Asia, it grows well on suitable sites in temperate zones, providing an average yield of 18 oven dry tonnes per ha per annum. Although *M. x giganteus* is an introduced species, it is non-invasive and does not produce seed.

ADAS has been involved with miscanthus research since 1991. We have led investigations into miscanthus physiology and economics and have also been involved in taxonomy studies and collecting and maintaining a miscanthus genebank. The ADAS Bio-Renewables group initiated a miscanthus breeding programme in 2002. The development of miscanthus varieties will improve annual yields for growers, improve quality parameters for end-users, and change the current monoculture status of all UK planting.

To breed new miscanthus varieties, we are working with two species, namely *Miscanthus sinensis* and *Miscanthus sacchariflorus*. *M. x giganteus* is a self-sterile triploid resulting from a natural cross between these two progenitor species. Living specimens of these species are maintained in the miscanthus genebank at ADAS Arthur Rickwood, including wild accessions collected from south-east Asia. In any natural population, natural selection directs gene frequencies and phenotypes, to ensure adaptation to local environments and maximum reproductive fitness. Therefore, genotypes collected from the wild are well suited to their particular environments and may display characteristics of interest, such as low temperature photosynthesis in a population from an elevated site. The breeding programme aims to identify these environmental adaptations and introduce them into high biomass-yielding lines.

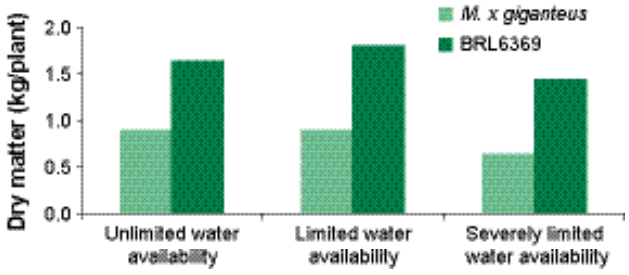


Figure 1. Breeding line BRL6369 has improved drought resistance, compared with *M. x giganteus*, producing more biomass in conditions of either unlimited or limited water supply.

The choice of characteristics to be modified includes those that will increase the geographic range of the crop, like cold tolerance. Particular concerns for combustion are being addressed, including moisture content of the delivered crop, and the concentration of minerals such as chloride, potassium, sulphur and nitrogen. Other characteristics, such as heavy metal and salt tolerance, are aimed at producing multi-purpose crops for phytoremediation and energy.

One area that we have focused on is improved drought resistance. The effect of drought is to reduce plant survival rates if experienced during crop establishment, and to reduce annual yields if experienced during subsequent growing seasons. Fig. 1 shows the ability of one of our breeding lines (BRL6369) to perform well in water-limited conditions. As with every characteristic investigated, *M. x giganteus* was used as a standard for comparison. It is of particular interest that the ability of line BRL6369 to withstand drought (Fig. 1) is not associated with any negative effects when water supply is not limiting. This breeding line produces greater biomass than *M. x giganteus* when water supply is limiting, or is not limiting.

The breeding programme will ensure that the increased demand for biomass crops can be met by varieties of miscanthus bred for a range of cropping areas, and improved utility in power systems. The overall goal of the miscanthus breeding programme is to achieve crop improvement without increasing production costs, without exhausting natural resources and with the level of inputs reduced or static.

- We acknowledge the contribution made to this work by Dr. Ellen O'Connor, who has since left ADAS.

Individual specimens in the miscanthus genebank at ADAS Arthur Rickwood. The plants shown are all the same age and indicate the variation present.

Greenhouse gas and energy balances of wood-fuelled and miscanthus-fuelled heating systems

Dr Rebecca Heaton
ADAS Arthur Rickwood

In February 2003, the UK Government released challenging targets for renewable energy production and carbon dioxide (CO_2) abatement, including aspirations for 10% renewable energy by 2010 and 20% by 2020, and a 60% cut in CO_2 emissions by 2050.

Bioenergy projects burning wood or energy crops are often described as 'carbon-neutral', because CO_2 taken in by the crop during growth is released on burning. However, this does not allow for the CO_2 and other greenhouse gas outputs required to manage, harvest, transport and prepare the fuel for burning.

The study was funded by IEA Bioenergy Task 38, and is one of a group of greenhouse gas studies being undertaken in several countries. The objective was to study two small-scale heat systems, and compare the greenhouse gas balances and energy budgets. The first system was a 70 kW heat system, to heat an office block, fuelled by 5 ha of miscanthus planted in 2002. The second system was a 150 kW heat system, heating a large house and cottage, using wood chips from the surrounding woodland and local sawmill residue.

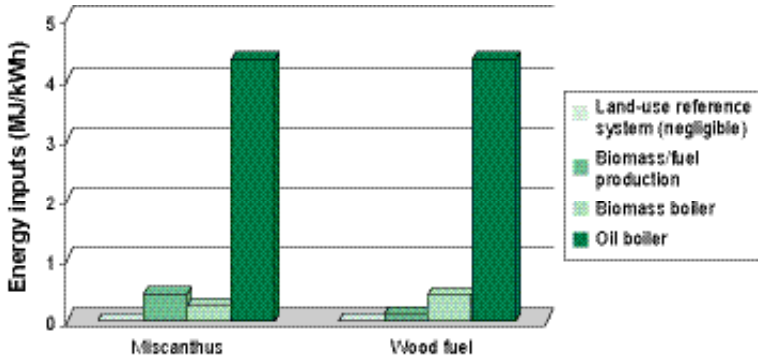


Figure 1. Energy inputs (MJ/kWh) for fuel production and reference land-use systems.

All major greenhouse gases produced by these heating systems were studied: CO_2, methane and nitrous oxide. Baseline reference systems were chosen to compare what would happen if the heating system was not installed (Table 1).

For the wood fuel system, the harvesting and transport of the wood was taken into account. For the miscanthus system, production, storage and transport of rhizomes, ground preparation, planting, harvest and storage options were included. Boiler installation and pipework were taken into account for both systems.

Fuel	Reference system		Life cycle analysis	
	Energy	Land use	Energy	Land use
Miscanthus	Oil heating	Set-aside	70 kW boiler	Miscanthus
Wood	Oil heating	Un-thinned woodland	150 kW boiler	Low-level thinning

Table 1. Energy sources and land use for the reference systems and the life cycle

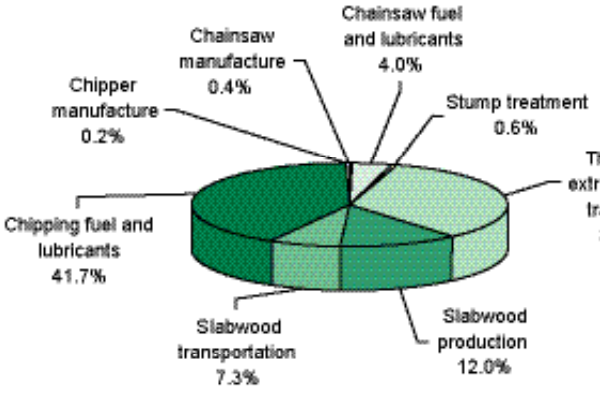


Figure 2. Greenhouse gas outputs (% of total) for wood fuel production from slabwood and thinnings.

For both case studies, biomass fuel production was responsible for more energy inputs and greenhouse gas outputs than the land-use reference system. However, overall, the biomass heating systems had lower energy inputs and greenhouse gas outputs due to avoidance of the oil burning in the reference systems (Fig. 1).

Fuel	Reference system	Biomass system
Miscanthus	49.7	6.4
Wood	44.3	4.9

Table 2. Greenhouse gas emissions (tonnes of CO_2 equivalent) per annum.

The wood fuel system had lower energy inputs and greenhouse gas outputs than the miscanthus system. However, when compared with reference systems, the wood fuel system had a smaller decrease in greenhouse gas emissions than the miscanthus system, because the miscanthus reference system had greater energy inputs and greenhouse gas emissions associated with set-aside (Table 2). For both systems, transport fuel and diesel to run machinery was responsible for the majority of energy inputs and gas outputs, as shown for the wood system in Fig. 2.

Annual greenhouse gas emissions avoided by each of these two systems were 43 tonnes (miscanthus) and 39 tonnes (wood fuel) of CO_2 equivalent (i.e. contributing an equivalent amount to global warming as would this quantity of CO_2). In the wider UK context, this represents a small quantity of avoided emissions, but the replicability of these two systems is important. Biomass heating has an important role to play to achieve targets for decreased greenhouse gas emissions in the UK. Readily available technology, combined with low capital costs, make small-scale biomass systems easier to implement than larger electricity generating schemes.

Livestock Science

Andrew Walker

Head of Animal Health and Welfare

Responsible for animal health and welfare work, with a particular interest in poultry welfare and systems research.

Contact:
andrew.walker@adas.co.uk

Brian Merrell

Head of Business Development - Animal Health and Welfare

Responsible for livestock science and a specialist in hill and upland livestock systems and the impact of livestock farming on the upland environment.

Contact:
brian.merrell@adas.co.uk

Mervyn Davies

Head of Beef and Sheep

Specialist in animal breeding, nutrition, and the impacts of meat quality and safety on livestock management systems.

Contact:
mervyn.davies@adas.co.uk

Professor Ian Givens

Head of Nutritional Sciences

Research expertise in all aspects of feed evaluation. Special experience in the understanding of micro-nutrient disorders of ruminants, their diagnosis and correction.

Now in the Chair of Animal Science in the School of Agriculture, Policy and Development at the University of Reading

The effect of nutrition on parasite burden in organically-managed ewes

Ray Keatinge
ADAS Redesdale

The UK standards for organic production prohibit the prophylactic use of anthelmintics for controlling internal parasites. In organically-managed ewes, the peri-parturient rise in nematode (roundworm) egg count in faeces (FEC) is a significant factor in the epidemiology of Parasitic Gastro-Enteritis (PGE). This arises as a consequence of a nutritionally related relaxation in host immunity during the period of high metabolic demand in late pregnancy and early lactation. Previous research has indicated a positive role for additional dietary protein in maintaining immune responses during the peri-parturient period. However, this information has been derived from studies using housed, conventionally-managed animals, following artificial infection with a known level of challenge, usually of a single parasite species. As part of a Department for Environment, Food and Rural Affairs. (Defra) funded project (OF0185 – Controlling internal parasites in organic livestock without the use of pharmaceutical anthelmintics), this nutritional hypothesis was tested in a replicated experiment at ADAS Redesdale using organically-managed ewes, carrying a mixed naturally-acquired infection.

To provide challenging experimental conditions, twin-bearing Scottish Blackface ewes were lambed at a body condition score of 2-2¼, and grazed at a sward height of 4.5 cm for the first eight weeks of lactation. Animals in the test group were supplemented with 0.6 kg freshweight per day per ewe of expelled non-GM soyabean meal. Ewes in the control group received no energy or protein feed supplement. Herbage intakes were estimated during weeks four to five of lactation using an N-Alkane marker technique. Supplementation increased intake of energy (24 vs 32 MJ/day) and metabolisable protein (222 vs 399 g/day), resulting in significantly ($P < 0.05$) improved ewe liveweight and muscle depth. Based on repeated measures statistical analysis, there was no overall effect of supplementation on FEC, taking the experimental period as a whole (Fig. 1). However, control ewes had a statistically significantly greater FEC during weeks four to six following lambing, which coincided with peak lactation.

Figure 1. Effect of feed supplementation on ewe peri-parturient nematode egg output in

The proportion of parasite eggs by genera was determined by the culture of a bulked sub-sample of faeces (Table 1). *Teladorsagia* (*Ostertagia*) spp. eggs predominated during the first month of lactation. However, *Trichostrongylus* spp. and *Chabertia* spp. became more prominent as the experiment progressed. The proportion of eggs recovered from genera found in the large bowel, such as *Chabertia* spp., is noteworthy. In conventional production, these genera are not normally recorded, even when anthelmintic use is infrequent. Resident in organically-managed sheep, they may contribute to observed total egg output in faeces, but are less pathogenic than other genera found in the stomach and small intestine. In organic systems, this is likely to affect the interpretation of total egg output in faeces, used for diagnostic and management purposes.

The magnitude of observed effects on FEC was less marked than in earlier controlled studies in housed sheep. This suggests that the level of nutrition provided to the control ewes, although challenging, may not have been sufficiently low to result in a substantial breakdown in host immunity. Alternatively, the presence of a naturally acquired, mixed-species infection, could provide an explanation, as the effect of nutrition is thought to be more pronounced in roundworms found in the stomach, relative to those that normally live in the small intestine.

The results underline the importance of meeting nutrient requirements in early lactation, as well as prioritising inputs towards more vulnerable classes of animal, e.g. young sheep lambing for the first time, and ewes rearing twin lambs. The experiment supports the theory that nutritional manipulation can improve immunity to gastro-intestinal parasites, and provides a basis for preventive nutritional approaches advocated for disease control in organic livestock production.

Time relative to lambing (weeks)	*Teladorsagia* spp.	*Trichostrongylus* spp	*Chabertia* spp.
0	78	6	16
+2	75	5	20
+4	87	4	9
+6	49	16	35
+8	7	47	46

Table 1. The proportion of parasite nematode eggs, by genus, in ewe faecal samples (mean of test and control groups) in the eight weeks following lambing.

Crossbred sheep in the hills

Dr Barbara McLean
ADAS Pwllpeiran

The move in farm support from headage payments to area payments, coupled with changes to the Hill Livestock Compensatory Allowance Scheme, has presented hill sheep farmers with the opportunity to reassess their lamb production systems. In order to maximise the weight of lamb produced from each ewe, hill farmers have a number of options. These include switching to a larger breed of ewe, improving the genetics of the current flock or using a different breed of sire. Changing to a larger breed of ewe can bring about rapid change, but a period of adaptation would be needed, together with significant changes to the management system. Improving the genetic basis of an existing flock can happen only over several years unless a farmer is part of a group-breeding scheme with detailed recording systems. Switching to a different breed of crossing sire, with more desirable conformation traits, could also result in lambs finished in a shorter time and nearer market requirements. However, using crossing sires of a different breed could have implications for flock replacements.

At ADAS Pwllpeiran, in a study funded by Welsh Sheep Strategy, Welsh Mountain ewes were crossed with one of four sires (Cheviot, Dorset, Lleyn and Texel) to produce crossbred lambs in each of three consecutive years. Carcass traits from the resulting male progeny are given in Figure 1. Lleyn cross lambs produced heavier carcass weights (16.7 kg) than the other crosses (16.2 to 16.5 kg); however, 86% of Texel cross lambs graded R or above compared with 61 to 76% for the other crosses. Fifty female lambs from each cross were retained each year and compared with fifty pure-bred Welsh Mountain ewe lambs in lifetime performance studies. After away-wintering as ewe lambs, the sheep returned to Pwllpeiran where they were allocated to either a heather-dominated mountain or a semi-improved hill. At the first shearing, liveweight, body condition score, fleece weight and grade were recorded. Thereafter, liveweight and body condition scores will be recorded at tupping, at pregnancy scanning, eight weeks post-lambing and at weaning. All crossbred ewes, along with the pure-breed Welsh Mountain ewes, will be put to a Suffolk tup and performance of the progeny recorded from birth to finishing.

Variate	Cheviot Cross		Dorset Cross		Lleyn Cross		Texel Cross		Welsh Mountain
	M	H	M	H	M	H	M	H	H
Weight at tupping (kg)	41.2	41.1	43.1	44.6	37.1	39.0	36.7	45.2	39.0
Body condition score at tupping	3.4	3.3	3.5	3.6	3.1	3.2	3.1	3.8	3.6
% barren ewes	15	11	15	9	5	5	7	0	12
% single lambs	65	83	54	59	65	37	90	86	73
% twin lambs	20	6	31	32	30	58	3	14	15
Lamb birth weight (kg)	3.6	4.2	3.9	3.8	3.2	3.2	4.5	4.6	3.6
Lamb weight at eight weeks (kg)	18.6	18.5	19.5	19.6	16.2	18.2	20.9	22.0	15.7

Table 1. Performance of crossbred ewes grazing heather-dominated mountain (M) or semi-improved hill (H) in summer 2002.

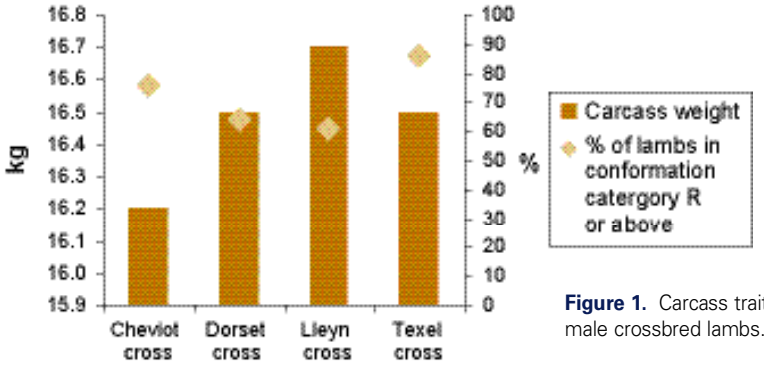


Figure 1. Carcass traits of male crossbred lambs.

On tupping weight and subsequent reproductive performance (Table 1). This effect was most noticeable for Texel cross ewes, where those grazed on the heather-dominated mountain were, on average, 8.5 kg lighter at tupping than those grazed on the semi-improved hill. However, for all ewes, tupping condition scores were above the target of 3.0. A higher proportion of crossbred ewes grazed on the heather-dominated mountain were barren (10.5%) compared to their counterparts on the semi-improved hill (6.25%). Overall, 11.8% of pure-bred Welsh Mountain ewes were barren.

Preliminary results show that careful selection of both crossing sire and the resulting female progeny could improve farmers' income. However, the implications of heavier, more productive ewes on ewe longevity and on mountain and hill vegetation need further evaluation.

Crossbred ewes with lambs grazing semi-improved hill at ADAS Pwllpeiran.

Finishing systems for different genotypes of suckled calf

Dennis Chapple
ADAS Rosemaund

Suckled calf production is the only financially viable cattle system on many farms in the hills and uplands. Grazing cattle are also beneficial in the management of ecologically sensitive semi-natural hill grassland. Recent research funded by the Department for Environment, Food and Rural Affairs (Defra), the Meat and Livestock Commission, Dovecote Park Ltd and Waitrose Limited focussed on improving the sustainability of suckler cows in the hills and uplands and on identifying the optimum finishing system for different types of weaned, suckled calves produced by contrasting suckler cow types. The development of efficient and sustainable finishing systems that provide consumers with high quality beef was the objective.

Suckled calves were sired by two contrasting breeds, Aberdeen Angus (AA) or Charolais (CH), from two types of crossbred suckler cow, either Belgian Blue x Holstein (BB) or Simmental x Holstein (SIM). Calves were reared to weaning at ADAS Redesdale. After weaning, suckled calves were finished using one of three finishing systems. Heifer calves were finished either intensively at ADAS Redesdale on a concentrate-based diet, or on either an 18-month or a 24-month system at ADAS Rosemaund using grazed grass and grass-silage based diets. Bull calves were either left entire and finished on concentrates, or finished as steers on a grass and silage-based system at 18 months.

Weaned, suckled heifers grazing a perennial ryegrass/white clover sward.

Liveweight gain was highest on the concentrate-based diets, at over 2 kg/d for bulls and 1.1 kg/d for heifers (Fig. 1). This compared with daily liveweight gains of 0.5 to 0.7 kg in the forage-based finishing systems, for both steers and heifers. Target carcass grading at slaughter was R4L across all the systems. The heaviest carcass weights were from bulls finished intensively, confirming the potential of this system to produce heavy carcasses without the animals becoming overfat (Fig. 2). However, heifer growth rates had to be restricted in the other systems to ensure that they did not become overfat at low carcass weights.

CH sired bulls grew faster (P <0.001), produced heavier carcass weights (P <0.001), had better carcass conformation (P <0.001) and lower carcass fat scores than AA sired bulls. However, meat quality and consumer taste panel comparisons at Bristol University indicated that AA sired steers and heifers produced beef that was less tough (P <0.05) and had greater overall consumer acceptability (P <0.05) compared with CH sired steers or heifers. Consequently, with the exception of finished bulls, AA sired cattle achieved a price premium of approximately 15%.

This project has clearly demonstrated the value of selecting an appropriate suckler cow breeding strategy to coincide with an appropriate weaned calf finishing system and then targeting the beef produced at the optimum consumer market. Where feed efficiency and rapid growth within intensive finishing programmes were desired (e.g. bull-beef), then CH sired cattle proved more suitable. Alternatively, where lower growth rates within forage-based finishing systems were appropriate (e.g. extensive steer or heifer finishing), and the cattle were targeted towards the premium end of the beef market, then AA sired cattle were preferable.

- We acknowledged the contribution made to this work by Dr Jimmy Hyslop, who has since left ADAS.

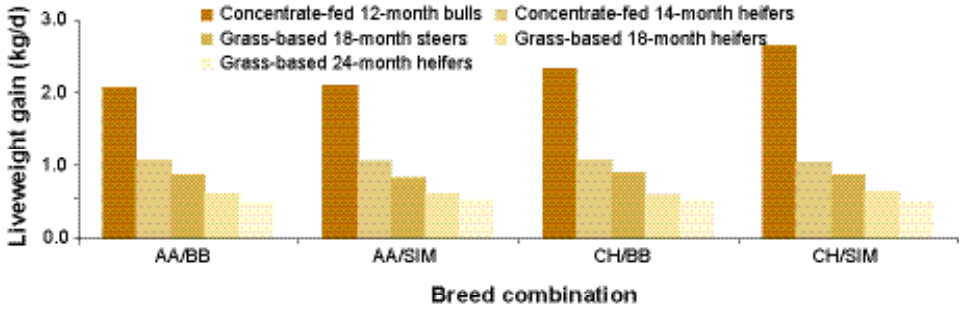


Figure 1. Typical liveweight gain for four contrasting crosses, in five suckled calf finishing experiments (Bulls: AA = Aberdeen Angus, CH = Charolais. Cows: BB = Belgian Blue x Holstein, SIM = Simmental x Holstein).

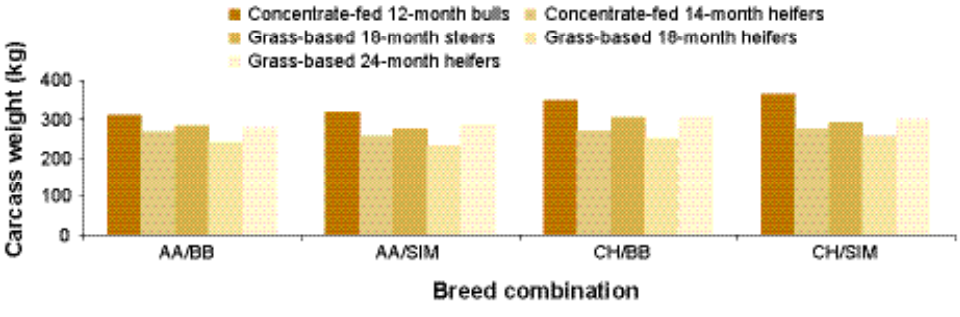


Figure 2. Typical carcass weights from four contrasting crosses, in five suckled calf finishing experiments.

Achieving clean beef cattle and sheep at slaughter

Mervyn Davies
ADAS Rosemaund

Food-borne illness is of considerable importance to the human population; during 2000, the Food Standards Agency (FSA) reported 65,209 cases of food poisoning. Many outbreaks are linked to the consumption of red meat, with beef as the most frequent offender, followed by pig meat and then lamb. Both cattle and sheep carry harmful bacteria, such as *Escherichia coli* O157, *Campylobacter* and *Salmonella*, in their digestive tracts without showing clinical signs of disease. It is impossible to eliminate these bacteria because they are ubiquitous in animals, and are widespread in the natural environment.

Research is continuing to investigate practices with the potential to reduce the presence of pathogens on cattle and sheep at abattoirs. ADAS, through a number of surveys and research studies funded by the FSA since 1999, in collaboration with the University of Bristol, the Scottish Agricultural College, Silsoe Research Institute and the British Leather Confederation, has been investigating the source and spread of bacterial contamination of beef cattle and sheep. Various potential intervention measures on-farm, in market and in lairage environments were evaluated to reduce the risks of bacterial contamination of carcasses.

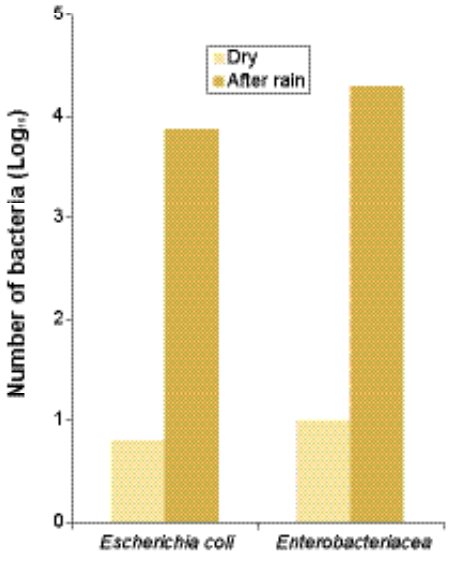


Figure 1. Numbers of *Escherichia coli* and *Enterobacteriacae* on swabs taken from cattle hide before and after a period of rainfall (30 minutes at 2 mm per hour).

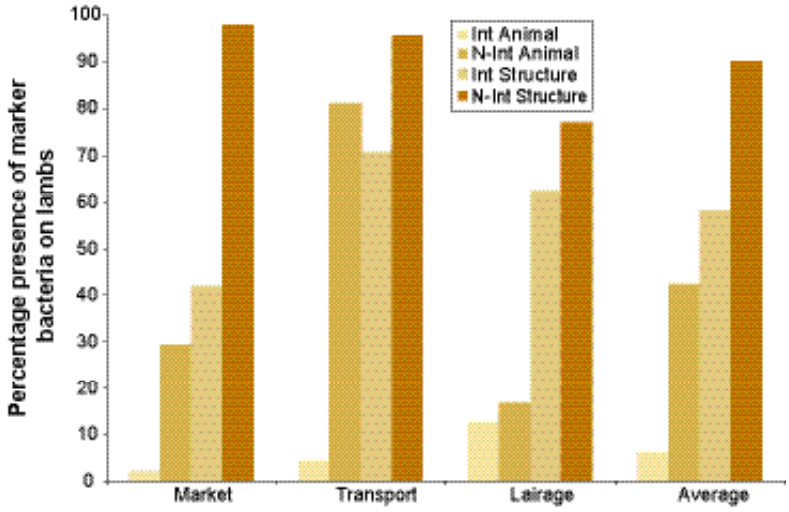


Figure 2. Percentage presence of marker bacteria from animal and environmental origin on lambs (Int = intervention, N-Int = no intervention, Animal = marker applied to the fleece of a lamb, Structure = marker applied to structural surfaces).

All investigations have used harmless marker bacteria to simulate the path of food-borne pathogens. In beef cattle, mixing clean animals with cattle whose hides were contaminated with faeces during transport resulted in significantly ($P < 0.05$) dirtier animals. Relatively light rainfall (2 mm/hr) at unloading resulted in an increase in *Enterobacteriacea* and *E. coli* on the hides of cattle (Fig. 1). In a livestock market, the prevalence of marker bacteria introduced at three distinct points (in the pre-sale pen, the sale ring, and post-sale pen) increased from an initial 9% of animals affected, to 39%, 15% and 54% respectively by the end of the market process. At an abattoir, an initial 11% of animals carrying marker bacteria at unloading increased to 100% of animals with bacteria on the hide, and 89% with bacteria on the skinned-carcass after slaughter. Marker bacteria placed onto surfaces in lairage pens, races and the stunning box, were detected on 83% of hides and 89% of carcasses.

Intervention studies with sheep during the market, transport and lairage phases of their journey from farm to slaughter showed that large reductions in marker bacteria spread can be achieved. On average, contamination of animal origin to the fleece and carcass of sheep reduced from 42% to 6%, and of structural origin reduced from 90% to 58% (Fig. 2). The reductions were greatest ($P < 0.001$) during the transport and market phases, and smaller, but still significant, ($P < 0.05$) for the lairage phase.

The most effective interventions were keeping sheep dry, short transport, marketing and lairage times, the availability of clean bedding and regular disinfection of the conveyor and roll-out at the abattoir.

The studies clearly demonstrated that transport, livestock market, lairage and abattoir all present opportunities for extensive spread of microbial contamination between animals, by both direct hide and fleece contact, and also, very importantly, via surfaces of structures. A combination of interventions throughout the production chain is required to reduce the level of bacterial contamination on animals, and particularly, its presence on the final carcass. Once these aspects have been more fully researched and understood, the results should form the basis of a Hazard and Critical Control Point (HACCP) approach to producing clean carcasses, and hence reduce cases of food poisoning.

- We acknowledged the contribution made to this work by Dr Virginia Collis, who has since left ADAS.

Related Project

Title: Clean sheep knowledge transfer.

Funder: Food Standards Agency.

Contract Manager: Dr Virginia Collis, ADAS Rosemaund.

Comments: This project translates existing research information into 'Best Practice' messages which are being disseminated to the sheep industry during 2004 at key shows and producer group events.

Dietary enzyme studies for pigs and poultry

Dr Fiona Short
ADAS Gleadthorpe

During the last five years, a substantial amount (over 40 individual studies) of work has been done at ADAS Terrington and ADAS Gleadthorpe assessing the efficacy of feed enzymes. The majority of this has been done for EU product licence approval.

The use of feed enzymes in non-ruminant feed began around 1990, when initially they were used in broiler diets containing a proportion of barley. Now, the vast majority of non-ruminant feeds, in particular for poultry, contain at least one enzyme. The majority of enzymes are produced through microbial fermentation e.g. phytase is commonly produced by *Aspergillus niger*.

Feed enzymes increase the availability of nutrients in the diet by breaking down antinutrient factors such as non-starch polysaccharides, or by assisting in the release of a nutrient, for example, phosphorous from phytate in plant material. Other improvements as a result of feed enzyme inclusion are increased digestibility of nutrients including protein, carbohydrates and phosphorous. Positive side-effects of enzymes have been found to include increased leg strength in broilers, and lower phosphorous concentrations in the manure from laying hens and pigs.

Diets can also be reformulated with nutrients such as phosphorous added at a lower inclusion rate as they are used more efficiently in the presence of enzymes, with the result that nutrient concentrations in excreta are lower. A further benefit of using feed enzymes is that they can enable feed ingredients of a slightly lower quality to be used, thereby saving costs.

Turkeys on study at ADAS Gleadthorpe.

To be registered in the EU, an enzyme has to be shown to be safe, and to work in the target species over a specific time period. Studies must prove that an enzyme increases digestibility or improves production over 16 weeks in the case of turkeys, and 5 weeks for broilers. The effect must be shown in three separate studies, on at least two different sites, under normal commercial conditions.

Typical studies involve a comparison with a competitor enzyme at varying inclusion rates, with animal performance assessed. These may also be assessed against a control diet with no enzyme supplementation. In some cases, a negative control diet is used which is slightly limiting in one or more nutrients. This is to assess whether the enzyme can improve the specification of the diet so that it is no longer limiting. Other checks, such as the palatability of the enzyme, and effects on the well-being of the animal are also made.

Studies by ADAS have predominately investigated animal growth, feed intake, feed conversion and mortality. Further work has involved the feeding of an inert marker, e.g. titanium dioxide, in the diet, with faecal samples taken for digestibility analysis. These studies have been performed in all species of poultry at ADAS Gleadthorpe, and in pigs of different growth stages at ADAS Terrington. Detailed reports are written, often to regulatory standard, to be submitted to the authorities by the clients.

Enzymes are routinely used in broiler diets.

Growth responses of broiler chickens to increasing dietary concentrations of whole rapeseed and rapeseed meal

Sue Gordon
ADAS Gleadthorpe

The UK broiler industry depends mainly on imported soya as a dietary protein source. Other vegetable protein sources, including rapeseed, are used with caution because of the risk of poor performance, poor litter quality, or meat taint. Any of these problems are costly to the producer, some are unacceptable to consumers, and there might be welfare implications. Thus, constraints are applied to alternative protein sources such as rapeseed, and this often means that it is excluded from commercial diets. By improving our understanding of the young chicken's growth responses to rapeseed, there might be scope to relax these constraints.

The objective of this work, underway since 2001, funded by the Department for Environment, Food and Rural Affair (Defra), the Home-Grown Cereals Authority and Grampian Country Food Group, was to investigate the growth response of broilers to increasing dietary concentrations of blends of UK-grown rapeseed meal, or whole rapeseed. The diets were iso-caloric, iso-nitrogenous and balanced for their amino acid content.

Nine concentrations of rapeseed meal, from 0 to 160 g/kg in equal increments of 20 g/kg, were fed between day-old and 21 days of age. From 22 to 42 days of age, birds previously fed 0, 20, 40 or 60 g/kg rapeseed meal remained on the same concentration, but birds previously fed greater than 80 g/kg were fed none. The relatively low metabolisable energy (ME) content of rapeseed meal limits its inclusion rate in higher-energy finisher diets. At concentrations of more than 60 g/kg rapeseed meal, the calculated ME value of the diet was too low, and so these treatments were necessarily discontinued. This was not a problem with whole rapeseed, as the oil content boosts the ME value. Six concentrations of whole rapeseed, 0 to 100 g/kg in equal increments of 20 g/kg, were fed between day-old and 42 days of age.

	Broiler liveweight (kg/bird) at dietary rapeseed meal concentrations (g/kg) of:								
0 to 21days	0	20	40	60	80	100	120	140	160
22 to 42 days	0	20	40	60	0	0	0	0	0
Male	2.96	2.84	2.97	2.83	2.77	2.86	2.86	2.82	2.95
Female	2.44	2.33	2.45	2.49	2.49	2.44	2.54	2.41	2.45
Mean	2.70	2.59	2.71	2.66	2.63	2.65	2.70	2.62	2.70
Diet	sed ±0.0450		NS						
Sex	sed ±0.0212		P <0.001						
Interaction	sed ±0.0636		NS						

NS: Not significant.

Table 1. Effect of dietary rapeseed meal concentration on broiler liveweight at 42 days of age (kg/bird).

Liveweight of males or females at 42 days of age was not affected by dietary rapeseed meal concentration (Table 1), and feed conversion efficiency (FCE) was similar across all treatments (mean FCE was 0.558). Liveweight of males at 42 days was significantly (P <0.001) greater than for females.

Increasing dietary concentration of whole rapeseed linearly reduced liveweight at 42 days of age (shown for the males in Fig. 1). This was due to reduced feed intake (P <0.05 for males and P <0.001 for females), as FCE was not affected.

Mortality was not affected by feeding rapeseed. Litter quality was good throughout the study and the birds were free from hock burn damage.

The findings suggest that rapeseed meal may be fed at concentrations of up to 60 g/kg, without affecting liveweight gain or FCE, and whole rapeseed may be fed at concentrations of up to 100 g/kg without affecting FCE, although liveweight gain is likely to be lower.

In continuing to examine the data from these studies, the growth responses to glucosinolate (anti-nutritional) intake will be determined. This will improve our understanding of the effects of rapeseed meal and whole rapeseed on broiler performance, and it will assist in the application of findings by commercial feed formulators.

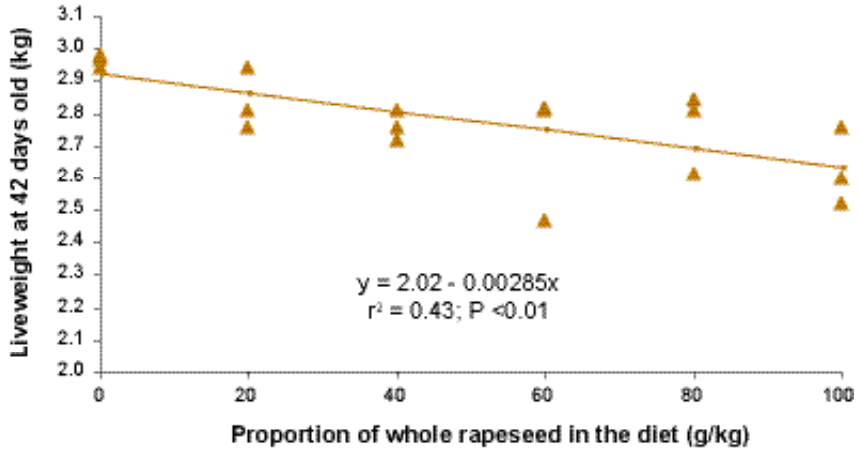


Figure 1. Effect of dietary whole rapeseed concentration on male liveweight at 42 days of age (kg/bird).

Environmental enrichment for pigs: improving welfare in intensive farming systems

Dr Heleen van de Weerd
ADAS Gleadthorpe

Since January 2003, the provision of appropriate environmental enrichment for pigs of all ages has been a legal requirement (Directive 2001/93/EC and the Welfare of Farmed Animals (England) Regulations (2003)). Enrichment can prevent high levels of harmful social behaviour such as ear and tail biting in growing pigs, which are major welfare issues for the pig industry.

A study was done at ADAS Terrington, in collaboration with the University of Newcastle, and was funded by the Department for Environment, Food and Rural Affairs (Defra), BOCM PAULS, GE Baker UK Ltd (Quality Equipment), Pig Improvement Company UK Limited, Quality Meat Scotland and Tesco. The objective was to determine the immediate and developmental consequences of different types of environmental enrichment on pig welfare and production, and to develop lifetime strategies for enrichment within commercial production systems.

The first part of the project identified the characteristics of substrates that allowed pigs to express exploratory behaviour. More than 1000 pigs were presented with different types of objects and substrates, and object-directed behaviour was measured in order to identify the properties that the favoured objects had in common. The important characteristics were olfactory stimulation, ingestibility, deformability and destructibility, suggesting a link with foraging behaviour.

This information was used to design different methods of enrichment, and to compare these with a commercially-used enrichment device consisting of a plastic cone with four protruding plastic spikes (Bite Rite, Ikadan System, Denmark), to assess their effectiveness in preventing undesirable behaviour. A pen with a full bed of straw was included as a positive control. The designed objects tested were all used to a lesser extent than straw (Table 1), but they did reduce levels of tail biting in terms of the number of pens of pigs affected (Table 2). The benefit of the commercial object as enrichment was questionable, as it did not prevent tail biting, despite its use by the pigs.

Different methods of enrichment, such as a rooting box or a chewable liquid-dispenser, were also evaluated to determine to what extent early-life enrichment modified the use of enrichment objects later in life, or affected the development of harmful social behaviour. The enrichment or control treatments, either strawed or barren pens, were provided to litters of pigs either during a 4-week period immediately post-partum, or a 4-week period post-weaning.

At 10 weeks of age, the ability of the pigs to cope with stress was assessed in behavioural tests. After this, the animals were regrouped and housed in either straw-enriched or minimally-enriched finishing pens (with only the commercially-used enrichment object) and their behaviour and performance monitored until slaughter.

Type of enrichment	Use (%)
Straw	31.5
Commercial object	6.2
Straw rack	14.5
Feed dispenser	4.8

Table 1. Use of environmental enrichment objects by growing pigs as a percentage of observations in which pigs

Type of enrichment	Pens (%)
Straw	17
Commercial object	83
Straw rack	50
Feed dispenser	33

Table 2. Number of pens affected by tail biting incidents (i.e. an occasion where some level of (fresh) damage to the tail of at least one pig in a pen was diagnosed).

Few consistent effects of early-life environmental enrichment were found in the behavioural tests, or in the level of pig-directed behaviour later in life. However, the environment in the finishing pen had a much bigger influence on behaviour. Levels of straw manipulation in straw-bedded pens were three times greater than use of the minimal enrichment object, and a greater level of undesirable pig-directed behaviour was seen in the minimally enriched pens. This suggests that the finishing pen environment exerts a greater influence on pig-directed behaviour than the environment early in life (to 10 weeks of age).

The results of this project will help producers and policy makers reduce the risk of tail biting in pigs by using enrichment strategies designed according to species-relevant requirements.

Straw is regarded as one of the best forms of enrichment for pigs.

The effect of floor type on ammonia emission, and on performance and behaviour of growing pigs

Dr Kate Breuer
ADAS Terrington

Following EU Directive 96/61/EC on integrated pollution prevention and control, the reduction of ammonia emissions from pig housing systems has become a priority for the UK pig industry. Systems with fully-slatted floors, used by a large proportion of the UK pig industry, have been found to be associated with 30% greater ammonia emissions than part-slatted systems. The Council of Europe has proposed that part-slatted flooring be adopted in preference to fully-slatted flooring but whether this policy is in conflict with the policy of improving pig health and welfare has not been investigated previously. The Department for Environment, Food and Rural Affairs (Defra) has funded research at ADAS Terrington investigating the effect of floor type on the emission of ammonia, and the behaviour, welfare and physical performance of growing pigs.

The study, from 2001 to 2003, compared five floor types: 1) fully-slatted, 2) fully-slatted with rubber matting over 50% of the slats, 3) fully-slatted with 'structural' modifications which involved 'paving' over 50% of the slats and partitioning-off the slurry channel beneath the solid floor, 4) part-slatted, and 5) a novel Dutch part-slatted floor (domed floor with sloping slurry channels) with UK pig stocking density. Groups of 10 pigs, each weighing approximately 40 kg at the start, were on test for 10 weeks. The emission of ammonia was measured continuously, and behaviour of pigs was recorded by videotape. General activity levels, aggressive interactions and pig-directed activity were recorded. The number of bruises, scratches, and wounds on each of three body regions (head/shoulders, flank, tail/vulva) were counted immediately after mixing and subsequently every two weeks. Lung and snout scores were recorded to assess respiratory health. Each of the five lobes of one lung was scored for lesions, and the scores were totalled (0 for a perfect lung, to 55 with severe lesions in every lobe). Snouts were scored for deformities to the turbinette bones. Liveweights and feed intake were measured to calculate feed conversion efficiency. All pigs were screened, by faecal sampling, for *Brachyspira pilosicoli* and *Salmonella* spp. as indicators of the level of enteric disease.

Ammonia emissions were not significantly different, but tended to be lowest (P = 0.06) in the Dutch system (Table 1). There was no significant effect of floor type on behaviour, or on the level of skin damage observed immediately after introduction to the pens. In the longer term, skin damage from the fully-slatted and fully-slatted with rubber matting systems was greater than with the other floor types (Table 2) but, as there were no differences in behaviour, it is possible that this greater skin damage was due to physical wear and tear from the pen environment. Treatment had no effect on snout score, and lung scores were low in all treatments (median score = 0). Pigs on the novel Dutch system had greater lung scores (Quartile 1 = 0, Quartile 3 = 2.3) than pigs on the paved systems (Quartile 1 = 0, Quartile 3 = 0). Floor type did not affect liveweight. Incidence of *Salmonella* spp. was too low to analyse, but tended to be greater in the part-slatted and fully-slatted systems.

Floor type	Ammonia emission (g NH_3–N/lu/d)
Fully-slatted	47.5
Fully-slatted + rubber mat	50.7
Fully-slatted + paving	45.8
Part-slatted	38.7
Novel Dutch system	23.8
	sed = 7.9, P = 0.06

Table 1. The effect of floor type on ammonia emission from finishing pigs.

Growing pigs in a fully-slatted pen.

These results demonstrate that, within the floor types investigated, there was very little difference in pig welfare. However, further work is needed to develop slurry-based systems that enable compliance with the Welfare of Farmed Animals Regulations 2003, and to investigate the effect of other materials, such as straw, on ammonia emission.

Related Project

Title: Demonstrating opportunities for reducing ammonia emissions from pig housing.

Funders: Defra, Meat and Livestock Commission, Environment Agency, and pig industry companies.

Contract Manager: Roger Kay, ADAS Terrington.

Comments: Results confirmed that the Dutch part-slatted system offers the best opportunity to reduce ammonia emission from pig buildings. However, recent improvements in the design of part-slatted systems in the UK, with domed floors and automatically controlled natural ventilation offer a less expensive alternative.

Time since introduction to pen (weeks)	Floor type					sed	P
	Fully-slatted	Fully-slatted +mat	Fully-slatted +paving	Part-slatted	Novel Dutch system		
2	6.75	5.42	4.78	6.00	4.73	1.409	0.594
4	7.43	8.63	5.53	5.80	5.72	2.113	0.544
6	6.05	6.58	5.82	5.07	5.62	1.378	0.852
8	6.43	8.32	4.72	4.47	5.07	1.085	0.037
10	9.63	7.33	6.65	5.50	9.53	1.780	0.249

Table 2. The effect of floor type on skin damage on finishing pigs (total number of bruises, scratches and wounds on each of three body regions (head/shoulders, flank, tail/vulva)).

Production of eggs in furnished cages

Rebecca Croxall
ADAS Gleadthorpe

The Department for Environment, Food and Rural Affairs (Defra) funded a study at ADAS Gleadthorpe to determine the effect of stocking density on the health and production of laying hens in furnished cages. The purpose of the study was to determine whether a stocking density of 750 cm^2/hen, as specified in Directive 99/74/EC, is justified.

The area of the furnished cages was 960 x 508 mm. The furnished cages in this study differed from conventional cages by including perches at 15 cm/hen and a nest box of 240 x 508 mm. The nest-box floor was covered with an Astroturf pad.

Three flocks of hens were studied. The first flock comprised ISA Brown and Babcock B380 hens, housed at 16 weeks of age (w.o.). The treatments included colonies/stocking densities of 10 (609 cm^2/hen), 9 (677 cm^2/hen), 8 (762 cm^2/hen), 7 (870 cm^2/hen) and 7 hens (609 cm^2/hen). The colony/stocking density of 7 hens (609 cm^2/hen) was produced by inserting a partition into one end of the cages and therefore narrowing them. All feeders were 120 cm long with the exception of the narrowed cages that had feeders 84 cm long.

Hens with more space consumed more feed ($P < 0.001$) (Fig. 1) and had a greater egg production ($P < 0.05$) than those kept at a higher stocking density. ISA Brown hens laid heavier eggs than the Babcock B380 hens ($P < 0.05$).

The second flock comprised Babcock B380 hens; half were beak-trimmed and half had intact beaks. Hens were housed at 16 w.o. in colonies of 6, 8 and 10, providing stocking densities of 1,010, 750 and 625 cm^2/hen. Although management procedures and dietary specifications were maintained as per flock 1, cannibalism developed in the hens with intact beaks. At 35 w.o., a decision was made to depopulate the flock early as mortality in the hens with intact beaks had reached 10.4%, compared to only 1.4% in the beak-trimmed hens. The hens with intact beaks also had poorer feather cover ($P < 0.001$). Hens with more space consumed more feed ($P < 0.05$), had a higher egg production ($P < 0.01$), laid heavier eggs ($P < 0.05$) and had better foot condition ($P < 0.05$).

The third flock comprised Shaver and Hy-Line hens with intact beaks, housed at 14 w.o. in colonies of 6, 8 and 10, providing stocking densities of 1,010, 762 and 609 cm^2/hen. Hens with more space consumed more feed ($P < 0.001$), had a higher egg production ($P < 0.001$), laid heavier eggs ($P < 0.05$) and had a higher egg mass output ($P < 0.05$) (Fig. 2) than those kept at a higher stocking density.

Laying hens in a furnished cage.

These results show that there are advantages to the health and production of laying hens in providing them with a stocking density of 1,010 cm^2/hen compared to 609 cm^2/hen. Therefore, a stocking density of 750 cm^2/hen as specified in Directive 99/74/EC is justified, as it is a more generous stocking density than in conventional cages. However, in this study, the stocking density effects may have been confounded by those of feed trough length per hen; this requires further investigation.

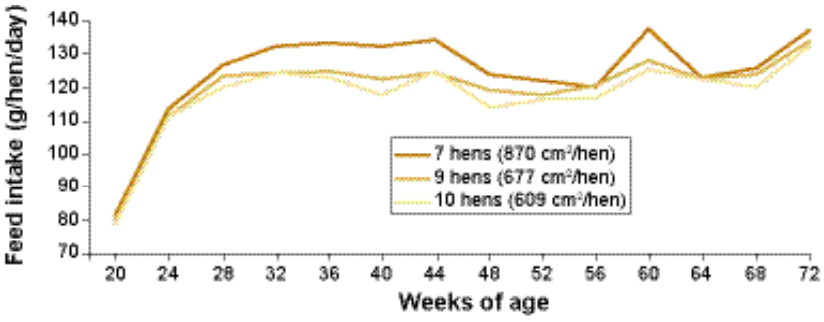


Figure 1. Effect of stocking density of ISA Brown and Babcock B380 hens in furnished cages on feed intake.

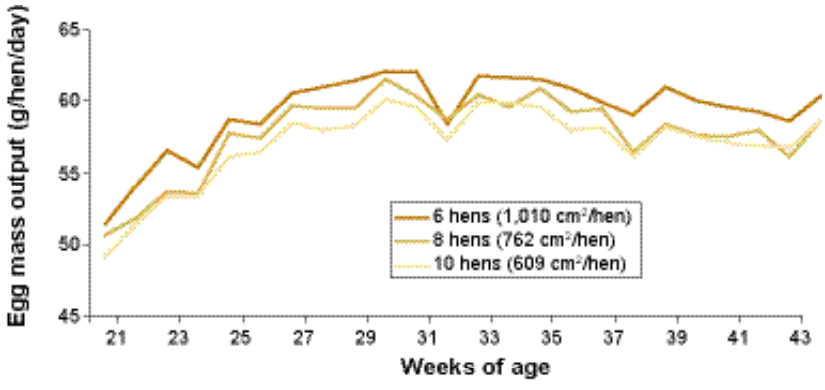


Figure 2. Effect of stocking density of Shaver and Hy-Line hens with intact beaks in furnished cages on egg mass output.

Rural Economy

David Lancaster

Head of Business Development - Management Consultancy

Responsible for developing business in rural policy and economics, market and policy research, business management, people development and food chain management technology.

Contact:
david.lancaster@adas.co.uk

Brian Angell

Head of Rural Policy and Economics - Management Consultancy

A specialist in rural policy, rural development and agricultural extension.

Contact:
brian.angell@adas.co.uk

Martin Wilkinson

Head of Business Management

A specialist in business management and agricultural policy, and leads work on business development, diversification and rural development.

Contact:
martin.wilkinson@adas.co.uk

Martin Jones

Head of ADAS International

Responsible for rural development and knowledge transfer projects across central and eastern European countries, with particular expertise in project management, rural development and agricultural extension.

Contact:
martin.jones@adas.co.uk

Food chain management and technology contribute to a sustainable future for local communities

Lynne de Motte
ADAS Wolverhampton

Management of the food chain from farm to fork is a topical issue that affects us all through the food we eat. A key priority for all stakeholders in the chain is management of the safety, quality and traceability of the products they eat. Increasingly, management of these aspects needs to be set within the context of wider socio-economic issues such as environmental impact, ethical trading, economic regeneration and public perception.

In 2001, the World Health Organisation (WHO) convened a strategy meeting on food safety to produce recommendations to reduce the incidence of food-borne disease. The WHO strategy also recognised the need for sustainable agricultural production systems in all regions of the world and identified risk analysis as the key tool for the management of food safety. Key points from the strategy included: promotion of a holistic approach for the elaboration, production and safe use of foods; a desire to promote inter-disciplinary collaboration in food safety management; and the formulation and communication of risk-based approaches for food safety regulation.

The Gloucesterhire Food Vision is an exciting concept to develop an integrated food policy for the long-term benefit of the people of Gloucestershire. Led by consultant Adrian Jevans, five elements were considered in the development of the food policy:

1. access;
2. education;
3. procurement;
4. industry;
5. food safety.

ADAS used a coordinated, inter-disciplinary approach, drawing on consultants with expertise in each of these five elements.

The key project outputs were:

- identified areas of good practice;
- strategies for improvement;

Fresh coriander - food chain management starts at primary production.

- identification and development of 'Key Result Areas' for Gloucestershire;
- detailed action plans for the short, medium and long-term for each of the five elements;
- long-term goals based on the concept of creating a 'Food Action Zone' (action zones have previously been created for dealing with health and rural issues elsewhere in the country).

The stakeholders, businesses and residents of Gloucestershire are currently reviewing these project outputs, which will be, where appropriate, incorporated into the finalised policy framework used in Gloucestershire to secure the delivery of healthy, safe and affordable food in the long-term.

This is an example of how we are harnessing our consultant skills, in a coordinated approach, in line with the WHO strategy. The ADAS Food Chain Management and Technology team provides practical consultancy solutions that are underpinned by up-to-date technical knowledge of principles, market drivers and legislative requirements.

Using this approach elsewhere, a project was delivered to retain and increase market share, and to develop a new product development programme for a fresh herb and salad producer in Norfolk. Initially, a business review was conducted and a business plan was put together. A relevant government fund was identified, and training and consultancy was delivered. This work has enabled the company to enhance staff skills, and develop and implement food safety and quality management systems that meet the needs of new customers. Consequently, new contracts have been won, securing the future of the company and adding to the economy of the region.

Related Project

Title: Food and drink sector business cluster development.

Funder: Yorkshire Forward.

Contract Manager: John Elliott, ADAS Wolverhampton.

Comments: This project provided research and consultancy to advise Yorkshire Forward on the potential and strategy for developing a business cluster programme for the food and drink sector. The aim of this cluster programme was to create a policy framework to develop existing clusters, or establish new clusters, of companies and organisations in related industries that have economic links.

The consequences of changing agricultural policy for sustainability of farming businesses

Martin Wilkinson
ADAS Wolverhampton

The Government's rural white paper set out plans and aspirations for the rural economy and included the 'New Direction for Agriculture'. The white paper made reference to the importance of a vibrant farming industry in the rural economy. This was amply demonstrated in 2001, when Foot and Mouth Disease affected the whole rural economy instantly and dramatically. The Policy Commission on the Future of Farming and Food was set up in August 2001 with a remit to advise the Government on how to encourage a sustainable, competitive and diverse farming and food sector that contributes to a thriving and sustainable rural economy. In response to the policy commision report, the government produced the Strategy for Sustainable Farming and Food. The support of food production is one strand of agricultural policy and is inextricably linked to the broad thrust of the Common Agricultural Policy (CAP) in delivering a sustainable rural economy.

The focus on sustainable food production is about to change dramatically. The Mid Term Review of the CAP will remove all forms of production-based subsidies, replacing them with a Single Farm Payment, paid irrespective of farming activity. The primary objective is to provide flexibility for farmers to respond to market signals, whilst meeting basic conditions set out in the detail of 'cross compliance'. These payments will be modulated to fund schemes that deliver public goods, and environmentally responsible stewardship of natural resources. Increasingly, the market place will drive the formation of robust and efficient supply chains, creating opportunities for branding and direct selling.

The impact of decoupled support will be determined as farmers assess opportunity, and change farming systems. ADAS reviewed the impact of decoupling on the beef and sheep sectors for the Department for Environment, Food and Rural Affairs (Defra), and concluded that farming profitability depends on the current efficiency and competitiveness of the business. The top performers operating in niche markets, or producing to a specification for premiums, will continue to compete well, but farming income for commodity producers will fall. ADAS also developed a whole-farm model to assess the impact of the reforms for all farming sectors. This reiterated the importance of business competitiveness on future business viability. Fig. 1 shows the impact on dairy farming businesses.

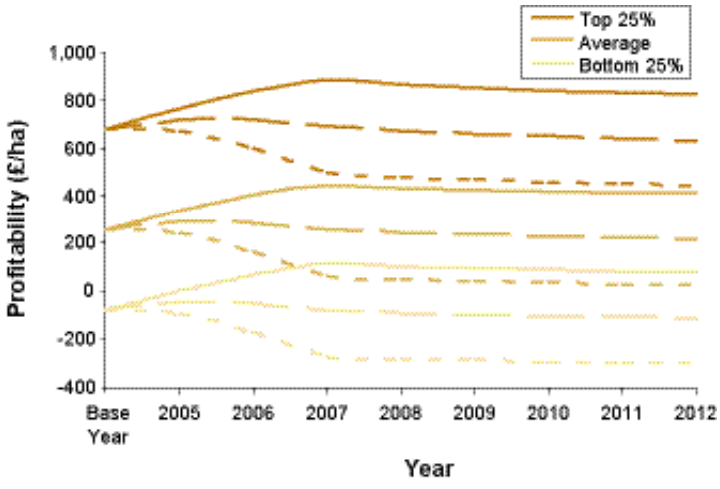


Figure 1. Predicted dairy farm profitability under decoupled support. Solid lines assume no change in milk price while the other lines show the impact of two (– –) and four (- - - -) pence per litre milk price cuts.

It is inevitable that the poorer performers will need to plan exit strategies from milk production. The impact of enterprise changes will be modified by the uptake of environmental programmes, and by how farming assets are used for other activities, often supported through the 'second pillar' of the CAP, the Rural Development Regulation.

ADAS has worked with public sector and individual Small and Medium sized Enterprises (SMEs) to deliver real change in rural communities. We have worked with over 100 businesses throughout the nine regions of England to assess development opportunities and, where worthwhile, to make investments supported by England Rural Development Programme (ERDP) funding, to achieve diversified business growth. At the same time, we have helped farmers gain improved reward from implementing organic conversion and Countryside Stewardship Schemes. As well as the work for individual farmers, ADAS also works with Local Authorities and Regional Development Agencies developing the strategic and infrastructure frameworks in which business development takes place.

Related Project

Title: Regional Development Plan for the Commodity Food and Alternative Crop Sector.

Funder: One North East.

Contract Manager: Steve Ford, ADAS Wolverhampton.

Comment: ADAS worked with One North East, and their partners, to develop a series of actions to help deliver the Strategy for Sustainable Farming and Food goals for all the main commodities produced in the region. A similar role was provided in the West Midlands.

Related Project

Title: Agronomic potential for energy crops in Staffordshire.

Funder: Advantage West Midlands.

Contract Manager: Martin Wilkinson, ADAS Wolverhampton.

Comment: ADAS identified the agronomic potential for energy crops in Staffordshire to supply raw material for a power generation facility in the county.

Rural policy research and evaluation

John Francis
ADAS Wolverhampton

A key feature of the European Commission's rural development policy is the evaluation cycle. As a condition of receiving funds, national or regional authorities are required to undertake an evaluation programme that is carried in three stages (Fig. 1).

This process is key to shaping both the policy and its implementation. ADAS is in a strong position to assist national and regional bodies in undertaking this evaluation process, and has been involved in 10 evaluations of rural policy programmes over the last four years.

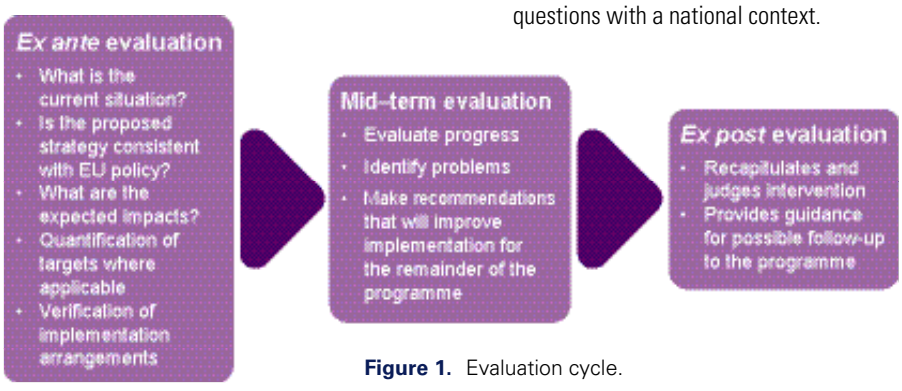


Figure 1. Evaluation cycle.

During 2003, ADAS undertook the mid-term evaluation of the England Rural Development Programme (ERDP) which is at the core of the Government's Strategy for Sustainable Farming and Food. It encompasses 10 separate schemes, which target rural initiatives for economic, social and environmental issues. A total of £1.6 billion of EU and UK government money is being made available under these schemes in England during the seven years (2000 – 2006) of the Programme, and the evaluation contributes to the accountability for, and transparency of, this expenditure.

The specification for the evaluation was complex and involved answering over 500 evaluation questions which sought information on economic, social and environmental indicators. The evaluation team was asked, by the Department for Environment, Food and Rural Affairs (Defra), to address a further set of evaluation questions with a national context.

Additionally, three regional case studies were undertaken, which assessed the rationale and effectiveness of the ERDP, and compared the pattern of take-up between the regions. Finally, eight sub-regional area case studies were undertaken, chosen to represent a range of environmental and socio-economic type profiles. These addressed the cross-cutting issues and looked for evidence of additional outputs and outcomes with low displacement (e.g. ensuring that increased gains made by ERDP are not offset by losses elsewhere) and high multiplier effects (e.g. economic benefits are passed on from the direct beneficiary to their suppliers, employees or other local businesses).

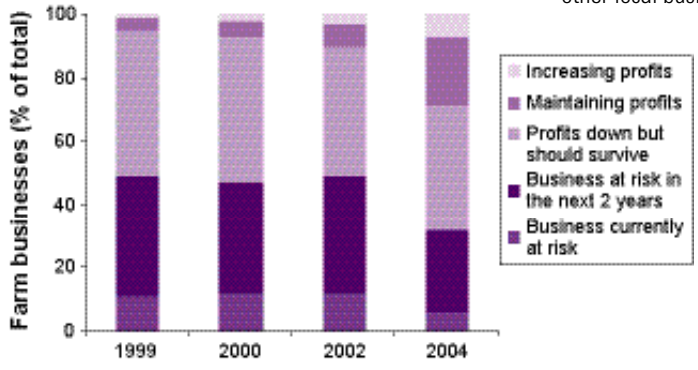


Figure 2. Profitability trends, ADAS Farmers' Voice survey, 1999, 2000, 2002 and

ADAS undertook this evaluation in collaboration with SQW Limited. The ADAS project team consisted of economists, agri-environment policy experts, ERDP scheme specialists, environmental scientists, foresters, geographic information system (GIS) specialists and survey specialists.

The project team answered the majority of the EC questions, drawing upon combinations of survey and monitoring data, published scientific research, socio-demographic data, economic data and GIS modelling. Separate economic evaluations were undertaken for each of the programmes within the ERDP and the regional and sub-regional case studies relied upon extensive consultation with stakeholders in each study area.

Some of our evaluation and policy research projects are underpinned by unique data from the ADAS Farmers' Voice Survey, funded by Defra and Regional Development Agencies. The surveys, annual since 1999, gauge the health and wealth of farm businesses in England and Wales. National and regional policy makers have used the results to obtain a better understanding of the issues facing the industry. Since ADAS first undertook the Farmers' Voice Survey in 1999, we have been able to monitor some key trends over a period of change in agriculture. For example, Fig. 2 shows profitability trends for the four years that the Farmers' Voice survey has been undertaken.

Related Projects

Title: South West Livestock Markets' Study.

Funder: South West Regional Development Agency.

Contract Manager: Christopher Bowden, ADAS Wolverhampton.

Title: Development of the East of England Food and Drink Strategy.

Funder: East of England Development Agency.

Contract Manager: Jackie Evans, ADAS Wolverhampton.

Comments: These research projects draw on the same skills and methods used in the evaluations. They focused on the development of strategy for: the future co-ordinated regional development of livestock markets in the South West of England, and the development of the food and drink industries in the east of England.

Sustainable rural livelihoods - the key to rural regeneration

Brian Angell
ADAS Wolverhampton

There is increasing interest in the sustainability of rural areas, with the long-term, environmental, and economic sustainability of agricultural and rural economic systems, under worldwide scrutiny.

Rural development has frequently focused on farming and agricultural systems. Concern about the sustainability of natural resources has been a more recent development, and there is now the realisation that rural sustainability embraces the social, economic and environmental aspects of the whole community. The Sustainable Rural Livelihoods concept has evolved in developing economies and increasingly is being adopted in the UK, through integration of agricultural and non-agricultural economic activity with the cultural and social dimensions of rural life.

Simon Turner and Martin Jones (ADAS Wolverhampton) have been instrumental in applying this process in the eastern European states, working with the Department for International Development. In the Lodeinyole Pole Raion, in the Leningrad Oblast of Russia (a raion approximately equates to a parish, and an oblast to a county), an ADAS-led programme contributed to alleviating the poor economic situation from 1999 to 2001 (Table 1).

The project focused on the following activities:

- revitalising and restructuring bankrupt former collective farms;
- regulating land ownership, including encouraging the expansion or rental of private household plots;
- business start-up advice and training;
- encouraging plot owners to start or expand profitable enterprises;
- aiding the establishment of wholesalers and input supply companies;
- developing off-farm businesses, including tourism and local arts and crafts;
- creating revolving credit schemes that offer small loans;
- establishing Third Party Arbitration Courts for conflict-free resolution of land and property disputes;
- creating the Rural Consultancy Centre for impartial advice on agricultural production.

The project's success depended on working closely with in-country partners, an approach also used to great effect in the UK.

Although on a different scale, the economy of the town of Melton Mowbray and its livestock market suffered in the aftermath of the 2001 Foot and Mouth Disease epidemic. As well as being a vital link in the meat supply chain, the market was a major tourist attraction and vital engine of the rural economy. Working with the District Council and the private-sector market partners, ADAS applied for £200,000 from the East Midlands Development Agency (EMDA) to help reinvigorate the market.

Senior Consultant Julia Hawley presenting to Sir Donald Curry, Graham Norbury, Rural Director Government Office East Midlands, and members of the Policy Commission on the Future of Farming and Food.

The flagship project was a £400,000 refurbishment of the market café and farmers' market hall, which was reopened, at the end of 2002, as the social centre of the market and a showcase for local food. This development was supported by ADAS research into farmers' market best practice and customer needs. An analysis of strengths, weaknesses, opportunities and threats for the market, and analysis of training needs for stallholders, facilitated access to capital grants and supported training for individual businesses. Julia Hawley of ADAS presented to a best practice tour by Sir Donald Curry (see picture), during which it was noted that the market had now regained its former status.

Indicator	1999	2000	2001
Leningrad Oblast officially-defined subsistence income per person per month*	£25	£25 (+0%)	£25 (+0%)
Percentage of population living below this subsistence level	92%	74% (-18%)	51% (-23%)
Average income per rural resident (including in-kind)*	£14	£20 (43%)	£25 (25%)
Level of employment among the rural population, including self employment	54%	59% (+5%)	63% (+4%)
Food security status (percentage of basic 'food basket' a rural resident is able to afford)	123%	160% (+37%)	174% (+14%)

*Converted at 2001 exchange rates

Table 1. Change in income and employment in Lodeinyole Pole Raion, Lenningrad Oblast, 1999 to 2001. Percentages in brackets indicate change from the previous year.

Related Project

Title: Bedfordshire Rights of Way Market Research.

Funder: Bedfordshire County Council, Countryside Agency.

Contract Manager: Dianne Simpson, ADAS Wolverhampton.

Comments: The Countryside and Rights of Way Act 2000 requires every local authority to prepare a Rights of Way Improvement Plan. ADAS researched the issues surrounding the use of rights of way and identified the key priorities, using a combination of qualitative and quantitative techniques. The need for communication was a key finding: the routes needed to be packaged and promoted more effectively to meet the differing needs of specific user groups.

Knowledge transfer and skill development

Anne Martins
ADAS Wolverhampton

Small and medium-sized businesses are crucial to the sustainability of rural areas. Over 96% of businesses have less than 50 employees (Table 1), and enabling these businesses to grow and flourish is a vital component of rural sustainability. Businesses that have an ambition to become larger, and/or improve efficiency and value, face many challenges. Key among these challenges are: the recruitment and retention of motivated staff who support each other and the achievement of the company's objectives; and ensuring that staff have the skills to excel and adapt in an increasingly competitive, technologically advanced and changing environment.

The Directors of Barcham Trees Plc recognise these challenges. Their company is a specialist business producing container-grown trees for the amenity market. It has grown significantly over the last 10 years, with the number of employees increasing from 6 to 40, and the company earning its position as the market leader for container-grown trees within Europe.

Anne Martins and Sue Whitmore, of ADAS, worked with Barcham Trees to help determine what needed to happen to ensure that the medium and long-term objectives of the company could be achieved. The work started with a review of the company, its strengths and successes, and current and future challenges. The review encompassed all aspects of the company, including its business plan, its products and key markets, and how these related to the staff and their skills. A staff survey was conducted to ensure that their thoughts and concerns were understood.

From this work, we designed a three-year programme for development of knowledge, skills and attitudes of all the staff, and systems to support them in their work. The programme aimed to address the key challenges of skills development, providing the right environment for attracting new staff, retaining and motivating existing staff and achieving business objectives. The programme, which was delivered by a group of companies, including ADAS, covered:

- a performance development system to ensure ongoing skills development and the achievement of individual and company objectives;
- a manpower and succession plan;
- organisational training to develop skills and perspectives across the company;
- training for individuals and groups including finance and accounting, account management, marketing, negotiation, project management and recruitment;
- a successful Vocational Training Scheme application to secure funding for the programme.

This concerted effort has yielded many benefits, and among these are the improved motivation and leadership skills of staff, better communication among staff, a greater appreciation by managers of the challenges faced within different parts of the company, and better integration of staff into the team. These benefits have led to improved product quality, customer care and productivity, as highlighted by Production Director Warren Holmes-Chatfield in an article in The Furrow (Summer 2004 issue): "Employees now receive far more information than they did in the past. They often offer valuable insights and suggestions as to how their part of the business can be improved. The quality of work and output has definitely gone up."

This programme is now at its close and is viewed as highly successful by the directors and their staff. Having established a sound working environment with effective management capability, a fully adopted performance development system, and cooperation within and between teams, the company has employed Anne Martins to work with them in the development and implementation of a second programme. Training is an ongoing process, which helps ensure business objectives are met and enhances the job security and loyalty of the staff.

The business specialises in producing container-grown trees for the amenity market.

Number of employees	Rural	Urban
1 – 10	85.4	82.7
11 – 49	11.7	13.2
50 – 299	2.6	3.7
300 +	0.2	0.4

Source: 'The state of the countryside 2003 report' The Countryside Agency, May 2003.

Table 1. Percentages of rural and urban businesses categorised by numbers of employees, April 2001.

Related Project

Title: Local Learning and Skills Councils (LLSCs) Rural Delivery Review.

Funder: Department for Environment, Food and Rural Affairs (Defra).

Contract Manager: Anne Martins, ADAS Wolverhampton.

Comments: As a part of its work in 'rural proofing' government policies, Defra commissioned this research to determine how the LLSCs were identifying and addressing specific training needs in rural areas, and to assist the development of the LLSC strategies, for 2005/06. The work found wide variation in the way these issues were addressed.

Staff Publications

Abang, M.M., **Green, K.R**., Wanyera, N.W. & Iloba, C. (2001). Characterisation of *Colletotrichum gloeosporioides* Penz from yam (*Dioscorea* spp.) in Nigeria. In: Akoroda, A.O. & Ngeve, J.M. [eds] *Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root Crops – Africa Branch*. Benin, pp. 613-615.

Abang, M.M., Winter, S., Mignouna, H.D., **Green, K.R**. & Asiedu, R. (2003). Molecular, taxonomic, epidemiological and population genetic approaches to understanding yam anthracnose disease. *African Journal of Biotechnology* **2**: 486-496.

Afdal, M., **Givens, D.I., Rymer, C**., Owen, E. & Mould, F.L. (2003). The relationship between diet and the chemical composition of faeces. In: *Proceedings of the British Society of Animal Science 2003*, p. 150.

Appleby, M.C., **Walker, A.W**., Nicol, C.J., Lindberg, A.C., Freire, A.C., Hughes, B.O. & **Elson, H.A**. (2002). Development of furnished cages for laying hens. *British Poultry Science* **43**: 489-500.

Augustsson, H., **Van de Weerd, H.A**., Kruitwagen, C.L.J.J. & Baumans, V. (2003). Effect of enrichment on variation and results in the Light/Dark test. *Laboratory Animals* **37** (4): 328-340.

Balsdon, S.L., Chadwick, D.R., **Webb, J. & Day, J.E.L**. (2002). Evaluation of increased straw use as a means of reducing ammonia emission from housed cattle and pigs. In: Venglovsky, J. & Greserova, G. [eds] *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 291-292.

Baumans, V., Bouwknecht, J.A., Boere, H., Kramer, K., Van Lith, H.A., **Van de Weerd, H.A**. & Van Herck, H. (2001). Intra-abdominal transmitter implantation in mice: effects on behaviour and body weight. *Animal Welfare* **10**: 291-302.

Beattie, V.E., **Breuer, K**., Dunne, L.M., Slade, E.C., O'Connell, N.E., Mercer, J.T., Rance, K.A., Sneddon, I.A., Sutcliffe M.E.M. & Edwards, S.A. (2001). The effect of salt deficiency on the behaviour of finishing pigs in a tail chew test. In: *Proceeding of the International Society of Applied Ethology (UK and Eire) Annual Conference*, April 2001, York, paper PC2.

Beckwith, C.P., Lewis, P.J., **Chalmers, A.G., Froment, M.A. & Smith, K.A** . (2002). Successive annual applications of organic manures for cut grass. Short term observations on utilisation of manure nitrogen. *Grass and Forage Science* **57**: 191-202.

Berry, P.M., Parker, S.R, van den Bosch, F. & **Paveley, N.D**. (2002). A rational basis for the design of wheat canopy ideotypes. In: *Proceedings of an Association of Applied Biologists conference – Genotype-Phenotype: narrowing the gaps*, 16-18 December 2002, Royal Agricultural College, Cirencester, pp. 73-74.

Berry, P.M., Spink, J.H., Foulkes, M. J. & **Wade, A**. (2002). Quantifying the contributions and losses of dry matter from non-surviving shoots in four cultivars of winter wheat. *Field Crops Research* **80**: 111-121.

Berry, P.M., Sylvester-Bradley, R., Philipps, L., Hatch, D.J., Cuttle, S.P., Raynes, F. & Gosling, P. (2002). Is the productivity of organic farms restricted by the supply of available nitrogen? *Soil Use and Management* **18**: 1-8.

Berry, P.M., Spink, J.H., Sterling, M. & Pickett, A. (2003). Methods for rapidly measuring the lodging resistance of wheat cultivars. *Journal of Agronomy and Crop Science* **189**: 390-401.

Berry, P.M., Sterling, M., Baker, C. J., **Spink, J.H**. & Sparkes, D.L. (2003). A calibrated model of wheat lodging compared with field measurements. *Agricultural and Forest Meteorology* **119**: 167-180.

Berry, P.M., Sylvester-Bradley, R., Philipps, L., **Smith, K.A., Lord, E.I**., Watson, C.A. & Fortune, S. (2003). N, P and K budgets for crop rotations on nine organic farms in the UK. *Soil Use and Management* **19**: 12-18.

Bhogal, A., Chambers, B. & Nicholson, F. (2003). Effects of farm manure and crop organic carbon returns on soil quality. In: *Proceedings of the Royal Geographical Society, and Institute of British Geographers Annual Conference*, 3-5 September 2003, London, CD-Rom [abstract].

Bhogal, A., Nicholson, F.A., Chambers, B.J. & Shepherd, M.A. (2003). Effects of past sewage sludge additions on heavy metal availability in light textured soils: implications for crop yields and metal uptakes. *Environmental Pollution* **121** (3): 413-423.

Blake, J.J., Spink, J.H. & Dyer, C. (2003). *Factors affecting cereal establishment and its prediction*. Research Review No. 51, Home-Grown Cereals Authority, London, 53 pp.

Blümmel, M., Griggs, E.E., **Moss, A.R. & Givens, D.I.** (2003). A mechanistic approach to the estimation of intake by ruminants by methane excretion and in vitro fermentation characteristics. In: *Fort Keogh Livestock and Range Research Laboratory 2003 Research Update*, USDA-ARS, pp. 86-87.

Bowes, M.J., House, W.A. & **Hodgkinson, R.A.** (2003). Phosphorus dynamics along a river continuum. *Science of the Total Environment* **313**: 199-212.

Bowles, L., Buckingham, N. & Simms, M. (2003). *Review of livestock market provision in south west England*. Report for the South West Regional Development Authority (http://download.southwestrda.org.uk/file.asp?File=/regeneration/general/livestock-report.pdf).

Bradshaw, N.J. (2002). *The awareness, use and promotion of integrated crop & pest management amongst farmers & growers*. A survey for Defra, London, and the Crop Protection Association, 132 pp. (www.voluntaryinitiative.org.uk/_Attachments/ICM%20FINAL%20REPORT%202002V2%20pdf.pdf).

Bradshaw, N.J. (2003). Subgroup fungicides; review ratings given at the Edinburgh workshop & rate efficacy of fungicides for late blight and Alternaria. In: Westerdijk, C.E. & Schepers, H.T.A.M. [eds] *Proceedings of the Workshop on the European Network for the Development of an Integrated Control Strategy for Potato Blight*. 2-6 October 2002, Poznan, Poland, PAV Special Report No. 9, pp. 23-26.

Breuer, K., Beattie, V.E, Dunne, L.M., Slade, E.C., Davies, Z., Mercer, J.T., Rance, K.A., Sneddon, I.A., Sutcliffe, M.E.M. & Edwards, S.A. (2001). Validation and development of a behavioural test to predict the predisposition of growing pigs to perform harmful social behaviour such as tail biting. In: *Proceedings of the British Society of Animal Science 2001*, p. 50.

Breuer, K., Hemsworth P.H. & Coleman, G.J. (2001). The effect of positive and negative handling on the behaviour and stress response of Holstein-Friesian heifers. In: *Proceedings of the British Society of Animal Science 2001*, p. 18.

Breuer, K., Sutcliffe, M.E.M., Mercer, J.T., Rance, K.A., Beattie, V.E., O'Connell N.E., Sneddon, I.A. & Edwards, S.A. (2002). Interrelationships between exploratory and harmful social behaviours in the weaner pig. In: Koene, P., Spruijt, B., Ekkel, D., Odberg, F., Spoolder, H., Blokhuis, H., van Reenen, K., van den Bos, R. & Schouten, W. [eds] *Proceedings of the 36th International Congress of the International Society for Applied Ethology*. 6-10 August 2002, Wageningen, Netherlands, p. 109.

Breuer, K., Sutcliffe, M.E.M., Mercer, J.T., Rance, K.A., Beattie, V.E., Sneddon, I.A. & Edwards, S.A. (2002). The effect of breed on the expression of adverse social behaviour in pigs. In: *Proceedings of the British Society of Animal Science 2002*, p. 33.

Breuer, K., Hemsworth, P.H. & Coleman, G.J. (2003). The effect of handling on the behaviour and stress physiology of non-lactating heifers. *Applied Animal Behaviour Science* **84**: 3-22.

Breuer, K., **Kay, R.M.**, Demmers T.G.M. & **Day, J.E.L.** (2003). The effect of floor type on ammonia emission, welfare, health and behaviour of growing pigs. In: *Proceedings of The Appliance of Pig Science*, 9-10 September 2003, Nottingham University, Sutton Bonington, pp. 157-163.

Breuer, K., Sutcliffe, M.E.M., Mercer, J.T., Rance, K.A., Beattie, V.E., Sneddon, I.A. & Edwards, S.A. (2003). The effect of breed on the expression of adverse social behaviour in pigs. *Applied Animal Behaviour Science* **84**: 59-74.

Breuer, K., Sutcliffe, M.E.M., Mercer, J.T., Rance, K.A., O'Connell, I.A., Sneddon, I.A. & Edwards, S.A. (2003). An estimate of heritability of clinical tail biting on a commercial pig breeding farm. In: *Proceedings of the British Society of Animal Science 2003*, p. 138.

Britt, C. & Garstang, J. (2002). *Bioenergy crops and bioremediation – a review*. Report for Defra, London, 120 pp.

Britt, C. (2003). *Methodologies for ecological monitoring in bioenergy crops. A review and recommendations*. Report for Defra, London, 59 pp.

Britt, C., Mole, A., Kirkham, F. & Terry, A. (2003). *Guidance on the use of herbicides on nature conservation sites*. In: Burn, A., Wills, M., Bacon, J., Jefferson, R. & Roworth, P. [eds] *The Herbicide Handbook*, English Nature, Peterborough, 189 pp.

Staff Publications

Bullard, M., Garstang, J., Elliott, J., Martin, D. & van den Broek, R. (2003). *Feasibility study for the production of bio-ethanol from agricultural, forestry and other organic wastes*. Report for the East of England Development Agency (http://www.eastofenglandobservatory.org.uk/observatory/reports/environment/BioethanolFinalReportJune2003.pdf).

Caligari, P.D.S., Lobley, K., **Weightman, R.M., Sylvester-Bradley, R. & Temple, M.** (2002). *The role of future public investment in the genetic improvement of UK grown crops*. Report for Defra, London, 222 pp.

Chadwick, D.R., Matthews, S., **Nicholson, R.J., Chambers, B.J. & Boyles, L.O.** (2002). Management practices to reduce ammonia emissions from pig and cattle manure stores. In: Venglovsky, J. & Greserova, G. [eds] *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 219-222.

Chambers, B.J. & Smith, K. (2002). *Making the most of organic manures for optimum results and cost savings*. British Potato Council, Oxford, 8 pp.

Chambers, B.J., Williams, J. & Phillips, R. (2002). Ammonia emissions from pig farming. In: *Ammonia in the UK*, Defra Publications, London, PB6865, pp. 48-55.

Chambers, B.J. (2003). Composting for removing human pathogens. In: *Proceedings of a Soil Association / WRAP Conference: Soil and Compost - The Foundations for Health*, May 2003, Holme Lacy College, Hereford, Technical Session D [abstract].

Chambers, B.J. (2003). Ways forward: organic manures to land. In: *Proceedings of a Water Framework Directive and Diffuse Source Pollution Conference*, May 2003, Cranfield University, Paper 11.

Chambers, B.J. & Dampney, P. (2003). Technical support and advice for farmers. *Adapting to Farming within an NVZ: Science into Practice*. Society of Chemical Industry symposium, London, March 2003 [abstract].

Chambers, B.J. & Hickman, G. (2003). Nutrient measurement and sustainable management. *Measurements for Biosolids Compliance; Cranfield University and EPSRC Conference*, May 2003, Paper 4.

Chambers, B.J., Nicholson, F.A., Aitken, M., Cartmell, E. & Rowlands, C. (2003). Benefits of biosolids to soil quality and fertility. *Water and Environmental Management Journal* **17**: 162-167.

Chambers, B.J., Williams, J.R., Cooke, S.D., Kay, R.M., Chadwick, D.R. & Balsdon, S.L. (2003). Ammonia losses from contrasting cattle and pig manure management systems. In: McTaggart, I. & Gairns, L. [eds] *Agriculture, Waste and the Environment*, the Scottish Agricultural College, pp. 19-25.

Chapman, A.S., Foster, I.D.L., Lees, J.A., **Hodgkinson, R.A.** & Jackson, R.M. (2003). Sediment and phosphorus delivery from field to river via land drains in England and Wales. A risk assessment using field and national databases. *Soil Use and Management* **19**: 347-355.

Chapple, D.G. & Hyslop, J.J. (2002). Extensive finishing of Aberdeen Angus and Charolais x heifers at 22-24 months of age. In: Lowman, B.G. [ed.] *Proceedings of the international suckler cow workers meeting*, September 2002, St. Boswells, Scotland, pp. 8-10.

Chapple, D.G. (2003). Aspirations: a weighty problem. *Deer Farming*, No.73, Summer 2003: 16-18.

Chapple, D.G. (2003). Environmental impact of farming deer. *Proceedings of British Deer Farmers' Association*, November 2003, p. 26.

Chapple, D.G. (2003). The wealth of clover. *Deer Farming*, No.74, Autumn 2003: 31-33.

Chapple, D.G. (2003). White clover for red deer. *Grass Farmer*, No.74, Spring 2003: 15.

Chapple, D.G., Cottrill, B., Harrison, R. & Davies, M.H. (2003). *Study to review carbon and nitrogen efficiencies in venison production*. Report for Defra, London, 59 pp.

Chapple, D.G., Deakin, D.W. & Davies, M.H. (2003). Winter feeding regimes for 16-22 months old red deer stags and hinds. In: *Proceedings of the British Society of Animal Science 2003*, p. 124.

Chapple, D.G., Grundy, H.F., Hardy, R., Keatinge, R. & Wilson, D.W. (2003). A comparison of Simmental x Holstein-Friesian and Piemontese x Holstein-Friesian cows in a hill suckler herd. 2. Performance of the progeny during finishing. *Irish Journal of Agriculture and Food Research* **42**: 79-87.

Chapple, D.G., Wheeler, K.P.A. & Hyslop, J.J. (2003). Extensive finishing of weaned suckled heifers sired by Aberdeen Angus or Charolais bulls from autumn calving continental cross cows. In: *Proceedings of the British Society of Animal Science 2003*, p. 99.

Chapple, D.G., Wheeler, K.P.A., Witt, M.W. & Blackburn, W.E. (2003). Evaluation of an ensiled mix of moist sugar beet feed plus maize distillers as a supplement for twin-bearing March-lambing ewes fed straw-based diets. In: *Proceedings of the British Society of Animal Science 2003*, p. 98.

Charles, D.R. & Walker, A.W. (2002). *Poultry environment problems - a guide to solutions*. Nottingham University Press, 88 pp.

Clarkson, J.P., Staveley, J., Phelps, K., **Young, C.S.** & Whipps, J.M. (2003). Ascospore release and survival in *Sclerotinia sclerotiorum*. *Mycological Research* **107**: 213-222.

Collier, R.H., Mead, A., **Parker, W.E. & Ellis, S.A.** (2003). A risk management system for controlling the foliar pests of Brassica crops. In: *Proceedings of the BCPC International Congress - Crop Science & Technology*, 10–12 November 2003, Glasgow, pp. 335-340.

Collings, L.V., Ginsburg, D., Clarke, J.H., Milne, A.E., Parsons, D.J., Wilkinson, D.J., Benjamin, L.R., Mayes, A., Lutman, P.J. & Davies, D.H.K. (2003). WMSS: Improving the precision and prediction of weed management strategies in winter dominant rotations. In: *Proceedings of the BCPC International Congress - Crop Science and Technology*, 10-12 November 2003, Glasgow, pp. 329-334.

Collings, L.V., Blair, A.M., Gay, A.P., Dyer, C. & Mackay, N. (2003). The effect of weather factors on the performance of herbicides to control *Alopecurus myosuroides* in winter wheat. *Weed Research* **43**: 146-153.

Collis, V.J. (2002). Clean livestock production vital to reduce transfer of pathogens. *Mid West Farmer*, October 2002, pp. 22-23.

Collis, V.J. (2002). *Clean livestock production*. Educational poster and leaflet produced for the Food Standards Agency, London.

Cormack, W.F., Shepherd, M. & Wilson, D.W. (2003). Legume species and management for stockless organic farming. *Biological Agriculture and Horticulture* **21**: 383-398.

Cormack, W.F., Welsh, J. & **Elliott, J.** (2003). *Review of obstacles to meeting the Defra action plan targets for organic cereals*. Report for Defra, London, 23 pp.

Cottrill, B.R. & Givens, D.I. (2003). Enhancing the selenium content of milk. *Proceedings of the British Society of Animal Science 2003*, p. 215.

Critchley, C.N.R. (2001). Arable plants on the edge. *British Wildlife* **13** (1): 42-43.

Critchley, C.N.R., Stevens, D.P. & **Burke, M.J.W.** (2002). Agri-environment review: lowland grasslands. *British Wildlife* **13** (4): 301-302.

Critchley, C.N.R., Burke, M.J.W. & Stevens, D.P. (2003). Conservation of lowland semi-natural grasslands in the UK: A review of botanical monitoring results from agri-environment schemes. *Biological Conservation* **115**: 263-278.

Croxall, R.A. (2003). *Technology transfer to the poultry sector, December 2002 – June 2003. Summary of research findings and implications for the poultry industry.* Report for Defra, London, 10 pp.

Dampney, P.M.R., Silgram M. & Slater J.A. (2001). Farm crop and agri-environment end-user requirements for remote sensing. In: Milsom, T.P, Sherwood, A.J., Rose, S.C., Town, S. J. & Runham, S.R. [eds] 3rd *SAR symposium 'Dynamics and management of plant communities in ditches bordering arable fenland in eastern England'*, Sheffield University.

Dampney, P., Hillman, J., Goodlass, G. & Mason, P. (2002). Methods and measures to minimise the diffuse pollution of water: a critical appraisal. In: *Proceedings of Science for Water Policy Euroconference*, 2-4 September 2002, Norwich, p. 653.

Dampney, P.M.R., King, J.A., Lark, M., Wheeler, H.C., Bradley, R.I. & Mayr, T.R. (2003). Automated methods for mapping patterns of soil physical properties as a basis for variable management of crops within fields. In: *Proceedings of the Fourth European Conference on Precision Agriculture*, 15-19 June 2003, Berlin, Germany, pp. 135-140.

Demmers, T.G.M., **Kay, R.** & Teer, N. (2003). Opportunities of reducing ammonia emissions from pig housing in the UK. In: *Proceedings of an International Symposium: Gaseous and odour emissions from animal production facilities*, 1- 4 June 2003, Horsen, Denmark, pp. 249-256.

Demmers, T.G.M., **Kay, R.** & Teer, N. (2003). Opportunities of reducing ammonia emissions from pig housing in the UK. In: *Proceedings of 12th Nitrogen Workshop*, 21- 24 September 2003, Exeter University.

Docking, C.M., Kay, R.M., Day, J.E.L. & Chamberlain, H.L. (2001). The effect of stocking density, group size and boar presence on the behaviour, aggression and skin damage of sows mixed in a specialised mixing pen at weaning. In: *Proceedings of the British Society of Animal Science 2001*, p. 46.

Docking, C., Van de Weerd, H.A., Day, J.E.L. & Edwards, S.A. (2003). Do pigs of different ages synchronise their behaviour in enriched pens? In: *Proceedings of the 37th International Congress of the ISAE*, June 2003, Abano Therme, Italy, p. 112.

Dragosits, U., Theobald, M.R., Place, C.J., **Lord, E.I., Webb, J.**, Hill, J., ApSimon, H. & Sutton, M.A. (2002). Ammonia emission, deposition and impact assessment at the field scale: a case study of sub-grid spatial variability. *Environmental Pollution* **117**: 147-158.

Drakes, D., O`Neill, T.M. & Bennison, J. (2001). *Alternatives to methyl bromide – a guide for protected crops*. Report for MAFF (now Defra), London, 15 pp.

Drakes, D. & O`Neill, T.M. (2003). *Protected lettuce disease control - avoiding pesticide residue problems*. Report for Defra Pesticides Safety Directorate, York, 13 pp.

Drakley, C., Elson, H.A. & Walker, A.W. (2002). Production efficiency of laying hens at four stocking densities in furnished cages of two heights. In: *Proceedings of the 11th European Poultry Conference*, 6-10 September 2002, Bremen, Germany, p. 37.

Elliott, J., Bullard, M., Garrod, G. & Willis, K.G. (2002). *Renewable energy and its impact on rural development and sustainability in the UK*. Report for Future Energy Solutions, Harwell, Didcot, Oxfordshire, 70 pp. (http://www.dti.gov.uk/energy/renewables/publications/pdfs/kbd00291.pdf).

Elliott, J., Doel, C. & Pringle S. (2002). *Food and drink cluster development*. Report for Yorkshire Forward, 9 pp. (http://www.yorkshire-forward.com/images/1875.pdf).

Elliott, J., Temple, M.L., Clinton, S., Tiffin, A.L., Rees, E.& Standen, J. (2003). *Evidence assessment to inform the review of the Organic Farming Scheme.* Report for Defra, London, 69 pp. (http://statistics.defra.gov.uk/esg/evaluation/ofs/default.asp).

Elliott, J., Temple, M.L., Francis, J., Tiffin, A.L. & **Chalmers, A.** (2003). *Economic evaluation of the processing and marketing grant scheme*. Report for Defra, London, 71 pp.

Ellis, S.A., Hockland, S. & **Blood-Smyth, J.** (2002). An evaluation of the efficacy of aldicarb and alternative nematicides against plant parasitic nematodes in carrots. In: *Proceedings of the British Crop Protection Conference – Pests and Diseases 2002*, pp. 255-260.

Fawcett, C.P., Gibbons, M.M., Brown, F.A., Dampney, P.M.R., Richardson, S.J. & Chambers, B.J. (2003). Your farm and NVZs: A decision support system for farmers and consultants. In: Piccarolo, P. [ed.] *XXX CIOSTA - CIGR V Congress Proceedings – Management and Technology Applications to Empower Agriculture and Agro-Food Systems*, DEIAFA Universita Degli Study di Torino, Italy, Volume 1, pp. 484 - 489.

Fearne, A., Garcia, M., Bourlakis, M., Brennan, M., **Temple, M. L. & de Motte, L.** (2003). *Mapping future food safety economics research requirement*. Report for the Food Standards Agency, London, 26 pp.

Firbank, L.G., Smart, S.M., **Crabb, J., Critchley, C.N.R., Fowbert, J.W.**, Fuller, R.J., **Gladders, P., Green, D.B.** & Henderson, I. (2003). Agronomic and ecological costs and benefits of set-aside in England. *Agriculture, Ecosystems and Environment* **95**: 73-85.

Forbes, M. & **Gordon, S.** (2003). A better range. *Organic Farming*, Issue No.78, pp. 14-15.

Forster Brown, C. & **Rose, S.** (2002). *Scoping studies for enhancement and diversification of grassland at Cors y Llyn NNR*. Report No. 529 for the Countryside Council for Wales.

Foster, I.D.L., Chapman, A.S., **Hodgkinson, R.A.**, Jones, A.R., Lees, J.A., Turner, S.E. & Scott, M. (2003). Changing suspended sediment and particulate loads and pathways in underdrained lowland agricultural catchments, Herefordshire and Worcestershire, UK. *Hydrobiologia* **494**: 119-126.

Frost, D. (2003). *A review of the environmental and socio-economic effects of organic farming*. Report for the Welsh Assembly Government, 66 pp.

Frost, D. (2003). A role for organic farming in protecting genetic diversity? *Cambrian News*, 10 July 2003, p. 11.

Frost, D. (2003). *Improving knowledge of pest and weed control in organic crop production in Wales*. Report for Organic Centre Wales, 34 pp. (http://www.organic.aber.ac.uk/library/pest%20and%20weed%20control.pdf).

Frost, D. (2003). It's the fight against the blight. *Cambrian News*, 2 October 2003, p. 14.

Frost, D. (2003). New techniques can stimulate growing. *Cambrian News*, 17 April 2003, p. 16.

Frost, D. (2003). Preaching Conversion: The Organic Conversion Information Scheme in Wales. In: *Proceedings of the European Society for Rural Sociology 20th Annual Conference: Work, Leisure and Development in Rural Europe Today*, 18-22 August 2003, Sligo, Ireland.

Frost, D. (2003). Report paints a picture of a billion-pound market. *Cambrian News*, 18 December 2003, p. 14.

Frost, D. (2003). The risks and rewards of organic farming. *Cambrian News*, 12 June 2003, p. 15.

Frost, D. (2003). What CAP reform will mean. *Cambrian News*, 15 May 2003, p. 16.

Frost, D. (2003). Workshops whet growers' appetites for new knowledge. *Gwlad*, Issue No. 21, October 2003, p. 13 (http://www.gwlad.wales.gov.uk/).

Frost, D. & McLean, B.M.L. (2003). Controlling ectoparasites on organic sheep farms. *Gwlad*, Issue No. 23, December 2003, p. 11 (http://www.gwlad.wales.gov.uk/).

Frost, D., McLean, B.M.L. & Clarke, A. (2003). Evaluating seed mixtures for weed control in an organic upland grass-clover ley reseed. In: *Proceedings of the 7th British Grassland Society Research Conference*, 1- 3 September 2003, pp. 83-84.

Frost, D. & Wacher, C. (2003). A new incarnation – the role of the OGA in changing the production and marketing of organic produce. In: *Proceedings of the European Society for Rural Sociology 20th Annual Conference: Work, Leisure and Development in Rural Europe Today,* 18-22 August 2003, Sligo, Ireland.

Gardner, S.M. (2002). Managing upland vegetation for sheep and conservation. *British Grassland Society, Occasional Symposium* No. 36: 115-118.

Garforth, G., **Angell, B.**, Archer, J. & Green, K. (2002). *Improving access to advice for land managers: A literature review of recent developments in extension and advisory services*. Report for Defra, London, 73 pp.

Garforth, G., **Angell, B.**, Archer, J. & Green, K. (2003). Fragmentation or creative diversity? Options in the provision of land management advisory services. *Land Use Policy* **20**: 323-333.

Garforth, G., Angell, B., Archer, J. & Green, K. (2003). Improving farmers' access to advice on land management: Lessons from case studies in developed countries. Agricultural Research and Extension Network (AgREN) Paper No. 125, 18 pp.

Georgieva, S.S., McGrath, S.P., Hooper, D.J. & **Chambers, B.J.** (2002). Nematode communities under stress – the long-term effects of heavy metals in soil treated with sewage sludge. *Applied Soil Ecology Journal* **20**: 27-42.

Gibbons, M.M., Anthony, S.G., Brown, F.A. & Smith, K.A. (2003). SPREADS - controlling the costs and efficiency of manure & slurry spreading on farms. In: *Proceedings of the XXX CIGR conference CIOSTA. Management and technology to empower agriculture and agro-food systems*, 22-24 September 2003, University of Turin, Italy, pp. 514-521.

Gibbs, P.A., Parkinson, R., Burchett, S. & Misselbrook, T. (2002). Environmental impacts of cattle manure composting. In: Insam, H., Riddech, N. & Klammer, S. [eds] *Microbiology of Composting*, Springer-Verlag, Berlin, pp. 445-456.

Staff Publications

Gibbs, P.A., Chambers, B.J., Carlton-Smith, C., Godley, A.R., Chaudri, A. & McGrath, S.P. (2003). Soil heavy metal pollution: effects on soil microbial activity and crop productivity. *British Society of Soil Science and Society of Environmental Toxicology and Chemistry Conference*, 8-10 September 2003, University of Aberdeen [abstract].

Givens, D.I., Allison, R. & Blake, J.S. (2003). Enhancement of oleic acid and vitamin E concentrations of bovine milk using dietary supplements of whole rapeseed and vitamin E. *Animal Research* **52**: 531-542.

Givens, D.I., Davies, T.W. & Laverick, R.M. (2003). Effect of variety, nitrogen fertiliser and various agronomic factors on the nutritive value of husked and naked oats grain. *Animal Feed Science and Technology* **113**: 169-181.

Givens, D.I., Rymer, C., Moss, A.R. & Allison, R. (2003). The effect of duration of feeding oilseeds to dairy cows on the persistency of response in milk fatty acid composition. In: *Proceedings of the British Society of Animal Science 2003*, p. 22.

Givens, D.I. & Shingfield, K.J. (2003). Improving the nutritional quality of milk. In: Smit, G. [ed.] *Dairy Processing, Improving Quality*, Woodhead Publishing Ltd., Cambridge, pp. 515-531.

Gladders, P. & Green, K.R. (2003). *Phloeospora leaf spot of parsnips*. Horticulture Development Council, Factsheet 08/03, 2 pp.

Glen, D.M., **Green, D.B., Oakley, J.N.**, Wiltshire, C.W., Bohan, D.A. & Port, G.R. (2003). Progress in improving the prediction and integrated control of slug damage in arable crops. In: *Proceedings of the BCPC Conference – Slugs and Snails: Agricultural, Veterinary & Environmental Perspectives*, Symposium Proceedings No. 80, 8-9 September 2003, Canterbury, pp. 35-42.

Goodlass, G. (2003). Soil fertility building crops in organic farming. *Organic Farming*, Winter 2003, pp. 22-23.

Goodlass, G., Halberg, N. & Verschuur, G. (2003). Input output accounting systems in the European community - an appraisal of their usefulness in raising awareness of environmental problems. *European Journal of Agronomy* **20**: 17-24.

Goodlass, G., Wilshin, S. & Allin, R. (2003). *British survey of fertiliser practice: fertiliser use on farm crops for crop year 2002*. The BSFP Authority, London, 105 pp.

Gordon, S.H. & Elson, H.A. (2002). Organic poultry production in the UK. In: *Proceedings of the 11th European Poultry Conference*, 6-19 September 2002, Bremen, Germany, p. 33.

Gordon, S.H. & Hovi, M. (2003). *Technical difficulties associated with organic breeding and hatching*. Report for Defra, London, 98 pp.

Gough, K.C. & Whitelam, G.C. (2003). Production of antibodies using transgenic plants. In: Singh, R.P. & Jaiwal, P.K. [eds] *Plant Genetic Engineering Vol. 1: Applications and Limitations*. Sci Tech Publishing, USA, pp. 261-277.

Green, D.B., Gladders, P., Perkins, S., Johnson, C. & Bailey, S.W. (2002). *Review of pests, diseases and weeds – 2001/2002 cropping year*. Report for Defra Pesticides Safety Directorate, York, 173 pp. (www.pesticides.gov.uk/farmers/pest disease weeds report psdreport2002.pdf).

Green, D.B., Gladders, P., Perkins, S., Bennett, S. & Hossell, J. (2003). *Review of pests, diseases and weeds – 2002/2003 cropping year*. Report for Defra Pesticides Safety Directorate, York, 175 pp.

Green, K.R., O'Neill, T.M. & Wilson, D. (2002). Effect of leaf wetness duration and temperature on the development of leaf spot (*Septoria apiicola*) on celery. In: *Proceedings of the British Crop Protection Conference 2002 – Pests and Diseases*, Volume 1, pp. 225-230.

Green, K.R. (2003). Chicory root rot. *HDC News*, December 2003, p. 13.

Green, K.R. (2003). Phytophthora rot – an emerging problem on UK asparagus. In: *Proceedings of the Asparagus Growers Association Conference 2003*, Peterborough, p. 3.

Green, K.R. & Dyer, W. (2003). *Phytophthora rot: An emerging problem on UK asparagus*. Horticulture Development Council, Factsheet 17/03, 4 pp.

Green, K.R., O'Neill, T.M. & Pettitt, T. (2003). Potential antagonists for tomato stem botrytis. *HDC News*, May 2003, pp. 24-25.

Green, L.E., **Hedges, V.J.**, Schukken, Y.H., Blowey, R.W. & Packington A.J. (2002). The impact of clinical lameness on the milk yield of dairy cows. *Journal of Dairy Science* **85**: 2250-2256.

Hartley, S.E., **Gardner, S.M.** & Mitchell, R.J. (2003). Indirect effects of grazing and nutrient addition on the hemipteran community of heather moorlands: the role of soil type, vegetation structure and plant species richness. *Journal of Applied Ecology* **40**: 793-803.

Hedges, V.J., Deakin, D., Hutchison, M. & **Davies, M.H.** (2002). Factors affecting the meat hygiene scores of sheep arriving at abattoir and the subsequent bacterial carcass contamination. In: *Proceedings of the 48th International Congress of Meat Science and Technology*, August 2002, Rome, Italy, pp. 926-927.

Hetherington, S.L., Mclean, B.M.L., Gardner, S.M., Wildig, J. & Griffiths, J.B. (2002). The impact of Environmentally Sensitive Areas policy in relation to conservation and farming objectives. *British Grassland Society, Occasional Symposium* No. 36: 85-88.

Hillman, J. (2003). Catchment management; multidisciplinary studies and stakeholder involvement. *Water UK Agriculture and Water Conference*, 27 November 2003, London [abstract].

Hickman, G. & Chambers, B.J. (2003). Impacts of legislation, market forces and competition from other materials on the agricultural landbank. *IQPC 11th Annual Forum on Sewage Sludge Treatment and Use*, 26-27 June 2003,Kensington Close Hotel, London, 11 pp.

Hillman, J.P., Hill, J., Morgan, J.E. & Wilkinson, J.M. (2003). Recycling of sewage sludge to grassland: a review of the legislation to control the localisation and accumulation of potentially toxic metals in grazing systems. *Grass and Forage Science* **58** (2): 101-111.

Hobbs, P.J., **Webb, J., King, J.** & Grant, B. (2002). Contributions of non-methane volatile organic compounds to the atmosphere from UK agriculture. In: *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 223-226.

Hodgkinson, R.A., Chambers, B.J., Withers, P.J.A. & Cross, R. (2002). Phosphorus losses to surface waters following organic manure applications to a drained clay soil. *Agricultural Water Management* **57**: 155-173.

Hossell, J.E., Ellis, N., Harley, M. & Hepburn, I.R. (2003). Climate change and nature conservation: Implications for policy and practice in Britain and Ireland. *Journal for Nature Conservation* **11**: 67-73.

Hossell, J.E., Riding, A.E. & Brown, I. (2003). The creation and characterisation of a bioclimatic classification for Britain and Ireland. *Journal for Nature Conservation* **11**: 5-13.

Huijsmans, J., Verwijs, B., Rodhe, L. & **Smith, K.A.** (2003). Costs of emission-reducing manure application. *Bioresource Technology* **93**: 11-19.

Hutchinson, M.L., Ashmore, A.K., Crookes, K.M., Wilson, D.W., Groves, S.J., Chambers, B.J., Keevil, C.W. & **Moore, A.** (2002). Enumeration of pathogens in livestock wastes and factors affecting their survival. In: *Proceedings of the joint CIWEM and Aqua Enviro Technology Transfer 7th European Biosolids and Organic Residuals Conference*, Session 3, Paper 15, 6 pp.

Hutchison, M.L., Gittins, J., **Walker, A.**, **Moore, A.**, Burton, C. & Sparks, N. (2003). Washing table eggs: a review of the scientific and engineering issues. *World's Poultry Science Journal* **59**: 233-248.

Hyslop, J.J., Keatinge, R. & Chapple, D.G. (2002). Physical and financial performance of weaned Aberdeen Angus and Charolais cross bulls from an autumn calving suckler herd finished on a cereal based ration. In: Lowman, B.G. [ed.] *Proceedings of the international suckler cow workers meeting*, St. Boswells, Scotland.

Hyslop, J.J., Keatinge, R. & Chapple, D.G. (2002). Suckler herd conception rate, weaned calf output and replacement rate from two contrasting genotypes of autumn calving continental x dairy cows managed on an upland farm in the UK. In: *Proceedings of Farm Animal Genetic Resources*, British Society of Animal Science, Occasional Publication No. 29, p. 34.

Hyslop, J.J. (2003). In vivo methodology to measure the degradation profile and effects of processed feeds in different segments of the equine digestive tract. In: *Proceedings of the 54th Annual Meeting of the European Association for Animal Production*, Rome, Italy, p. 414.

Hyslop, J.J. (2003). Partitioning degradation of feeds between different segments of the equine digestive tract. In: *Emerging Equine Science*, British Society of Animal Science, Occasional Publication No. 30, pp. 18-19.

Hyslop, J.J. (2003). Relationship between crude protein intake and water intake in forage based equine diets. In: *Emerging Equine Science*, British Society of Animal Science, Occasional Publication No. 30, pp. 46-47.

Hyslop, J.J. (2003). Suckler beef trials. *Beef Farmer*, Spring 2003, p. 24.

Hyslop, J.J. (2003). Suckler cow comparisons. *Beef Farmer*, Winter 2003, pp. 16-17.

Hyslop, J.J. (2003). Voluntary feed intake, apparent digestibilities and nutritive values in ponies given ad libitum access to complete pelleted diets made from wheat straw and unmolassed sugar beet pulp. In: *Proceedings of the British Society of Animal Science 2003*, p. 161.

Hyslop, J.J., Keatinge, R. & Chapple, D.G. (2003). Intake, growth and feed conversion in weaned suckled bulls finished on a cereal-based ration. In: *Proceedings of the British Society of Animal Science 2003*, p. 11.

Hyslop, J.J., Keatinge, R. & Chapple, D.G. (2003). Liveweight and pre-weaning growth in suckled calves sired by either Aberdeen Angus or Charolais bulls from contrasting autumn-calving continental x dairy cows over three years. In: *Proceedings of the British Society of Animal Science 2003*, p. 97.

Hyslop, J.J., Kennedy, F.A., Adamson, H.F. & Keatinge, R. (2003). Voluntary herbage intake and diet selection in Scottish Blackface ewes suckling twin lambs and grazing perennial ryegrass white clover swards with or without protein supplementation. In: *Proceedings of the British Society for Animal Production 2003*, p. 192.

Hyslop, J.J., McLean, B.M.L. & Moore-Colyer, M.J.S. (2003). Relationship between water holding capacity and fibre concentration in equine feeds. In: *Emerging Equine Science*, British Society of Animal Science, Occasional Publication No. 30, pp. 48-49.

Hyslop, J.J., Murray, W.A. & Keatinge, R. (2003). Intake, liveweight gain and feed conversion in organic Scottish Blackface lambs finished on contrasting clover based silages and concentrates with different ratios of wheat and beans. In: *Proceedings of the British Society of Animal Science 2003*, p. 96.

Karley A.J., Pitchford, J.W., Douglas, A.E., **Parker, W.E. & Howard, J. J.** (2003). The causes and processes of the mid-summer population crash of potato aphids. *Bulletin of Entomological Research* **93**: 425–437.

Keatinge, R. (2003). Organic livestock production in the hills and uplands. In: *Proceedings of the British Society of Animal Science 2003*, p. 237.

Keatinge, R., Chapple, D.G., Hardy, R. & Wilson, D.W. (2003). A comparison of Simmental x Holstein-Friesian and Piemontese x Holstein-Friesian cows in a hill suckler herd: 1. Reproduction and calf performance to weaning. *Irish Journal of Agricultural and Food Research* **42**: 71-77.

Kilpatrick, J.B. & Twining, S. (2003). On-farm monitoring and auditing of field scale genetically modified crops in the UK – a co-existence case study. In: *Proceedings of the 1st European Conference on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops GMCC-03*. 13-14 November 2003, Denmark.

King, J., Gay, A., Sylvester-Bradley, R., Bingham, I., Foulkes, J., Gregory, P. & Robinson, D. (2003). Modelling cereal root systems for water and nitrogen capture: towards an economic optimum. *Annals of Botany* **91**: 383-390.

Kirkham, F.W., Mole, A., Gardner, S.M. & Wilson, D.W. (2003). *Review of stocking levels recommended for semi-natural lowland grasslands*. Report No. 596 for the Countryside Council for Wales, 121 pp.

Koike, S.T., Subbaro, K.V., Verkley, G.J.M., **O'Neill, T.M.** & Fogle, D. (2003). Phoma basal rot of lettuce caused by *P. exigua* in California. *Phytopathology* **93**: S47.

Laws, J.A., Pain, B.F., **Webb, J. & Forrester, A.** (2002). Practical aspects of abating ammonia emissions on UK farms. In: Venglovsky, J. & Greserova, G. [eds] *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 227-230.

Laws, J.A., **Smith, K.A., Jackson, D.R.** & Pain, B.F. (2002). Effects of slurry application method and timing on grass silage quality. *Journal of Agricultural Science* **139**: 371-384.

Lee, P.A. & Kay, R.M. (2003). The effect of commercially formulated, reduced crude protein diets, formulated to 11 apparent ideal digestible essential amino acids, on nitrogen retention by growing and finishing boars. *Livestock Production Science* **81**: 89-98.

Li, Y., Collins, M.S., Whitelam, G.C. & Alexander, D.J. (2002). Rapid pathotyping of Newcastle disease virus using a single-chain Fv displayed on phage against the C-terminal end of the F2 polypeptide. *Archives of Virology* **147**: 2025-2037.

Loveland, P.J. & **Webb, J.** (2003). Is there a critical level for soil organic matter? A review. Soil and Tillage Research 70: 1-18.

Lovell, D.J., **Parker, S.R., Jewell, K. & Paveley, N.D.** (2003). Quantifying phenotypic expression of dwarfing genes in wheat, affecting escape from *Septoria tritici*. In: *Proceedings of the 8th International Congress of Plant Pathology*, Christchurch, New Zealand, Volume 2, p. 294.

Lovell, D.J., **Parker, S.R., Paveley, N.D.** & Worland, A.J. (2003). Understanding field resistance mechanisms for improved control of *Septoria tritici*. *Plant Protection Science* **38** (Special Issue 1): 165-169.

Lyne, A., Temple, M.L., Scott, P.E., Alison, A. & Standen, J. (2002). *Proposal to consolidate and simplify EU food hygiene legislation: Work to inform the preparation of a regulatory impact assessment*. Report for the Food Standards Agency, London, 49 pp.

Marley, C.L., Cook, R., Barrett, J., **Keatinge, R.**, Lampkin, N.H. & McBride, S.D. (2003). The effect of dietary forage on the development and survival of helminth parasites in ovine faeces. *Veterinary Parisitology* **118**, 93-107.

Marley, C.L., Cook, R., **Keatinge, R.**, Barrett, J. & Lampkin, N.H. (2003). The effect of birdsfoot trefoil (*Lotus corniculatus*) and chicory (*Cichorium intybus*) on parasite intensities and performance of lambs naturally infected with helminth parasites. *Veterinary Parisitology* **112**: 147-155.

Maslen, S., **Chambers, B.J., Hadden, S.W. & Royle, S.M.** (2003). Making soil from waste materials. In: Moore, H.M., Fox, H.R. & Elliott, S. [eds] *Proceedings of the 7th International Conference of the International Affiliation of Land Reclamationists*. 13-16 May 2003, Runcorn, pp. 207-210.

McIntyre, J., Beattie, V.E., **Breuer, K.** & Edwards, S.A. (2001). The chewing behaviour of growing pigs presented with tail models soaked in different fractions of blood, as a test for tail biting predisposition. In: *Proceedings of the International Society of Applied Ethology (UK and Eire) Annual Conference* , April 2001, York, paper OC3.

McGrath, S.P., Chaundri, A.M., Zhao, F., **Nicholson, F.A. & Chambers, B.J.** (2002). Prediction of Cd concentrations in wheat grain using simple soil and crop data. *Society of Environmental Toxicology and Chemistry (SETAC) 23rd Annual Meeting*, November 2002, Utah, USA, Abstract No. 162, p. 38.

McQuilken, M.P. & **O'Neill, T.M.** (2002). *Control of grey mould (Botrytis cinerea) in container-grown ornamentals: unheated greenhouse crops*. Horticulture Development Council, Factsheet 23/02, 8 pp.

Milne, A., **Paveley, N.D.**, Audsley, E. & Livermore P. (2003). A wheat canopy model for use in disease management decision support systems. *Annals of Applied Biology* **143**: 265-274.

Milne, J.A., Pakeman, R.J., **Kirkham, F.W.**, Jones, I.P. & **Hossell, J.E.** (2003). Biomass production of upland vegetation types in England and Wales. *Grass and Forage Science* **57**: 373-388.

Misselbrook, T.H., **Nicholson, F.A. & Chambers, B.J.** (2002). Predicting ammonia loss following the application of livestock manure to land. In: Venglovsky, J. & Greserova, G. [eds] *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 209-213.

Moffett, B.F., **Nicholson, F.A.**, Uwakwe, N., **Chambers, B.J.**, Harris, J. & Hill, T.C.J. (2003). Zinc contamination decreases the bacterial diversity of agricultural soil. *FEMS Microbiology Ecology* **43**: 13-19.

Moore-Colyer, M.J.S., **Hyslop, J.J.**, Longland, A.C. & Cuddeford, D. (2002). The mobile bag technique as a method for determining the degradation of four botanically diverse fibrous feedstuffs in the small intestine and total tract of ponies. *British Journal of Nutrition* **88**: 729-740.

Staff Publications

Nason, J.L.M., Farrar, J.F., Sylvester-Bradley, R. & Paveley, N.D. (2003). Nitrogen affects resistance of wheat (Triticum aestivum cv. Brigadier) to *Stagonospora nodorum*. In: *Proceedings of the 8th International Congress of Plant Pathology*, Christchurch, New Zealand, Volume 2, p. 133.

Neumann, S., **Paveley, N.D. & Sylvester-Bradley, R.** (2003). Nitrogen affects host capacity to carry epidemics of yellow rust (*Puccinia striiformis* f. sp. *tritici*). In: *Proceedings of the 8th International Congress of Plant Pathology*, Christchurch, New Zealand, Volume 2, p. 130.

Nicholson, F.A., Groves, S.J., Hutchinson, M., Nicholson, N. & Chambers, B.J. (2002). Pathogens in animal manures: their survival during storage and following land application. In: Venglovsky, J. & Greserova, G. [eds] *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 41-44.

Nicholson, F.A., Chambers, B.J. & Dampney, P.M.R. (2003). Nitrogen value of poultry litter applications to root crops and following cereal crops. *Journal of Agricultural Science* **140**: 53-64.

Nicholson, F.A., Smith, S.R., Alloway, B.J., Carlton-Smith, C. & **Chambers, B.J.** (2003). An inventory of heavy metal inputs to agricultural soils in England and Wales. *The Science of the Total Environment* **311**: 205-219.

Nicholson, R.J., Webb, J. & Moore, A. (2002). A review of the environmental effects of, and a suggested method of assigning environmental ratings to, different livestock manure storage systems. *Biosystems Engineering* **81** (4): 363-378.

O'Connell, N.E., Beattie, V.E., Sneddon, I.A., **Breuer, K.**, Mercer, J.T., Rance, K.A., Sutcliffe, M.E.M. & Edwards, S.A. (2003). An investigation into consistent individual variation in behavioural strategies of pigs. In: *Universities Federation for Animal Welfare, Symposium 2003*, April 2003, Edinburgh.

O'Neill, T. M. (2002). Clear the way - Soil sterilisation options for field-grown ornamentals. *Horticulture Week*, 3 October 2002, pp. 16-18.

O'Neill, T. M. (2002). First report of *Verticillium albo-atrum* causing wilt in Ve-resistant tomato in the United Kingdom. *Plant Pathology* **51**: 810.

O'Neill, T.M., Pettitt, T.R., McQuilken, M.P. & Hamer, P.J.C. (2002). Integrated approaches to control of grey mould (*Botrytis cinerea*) in greenhouse crops of container-grown ornamentals. In: *Proceedings of the British Crop Protection Conference 2002 - Pests and Diseases*, Volume 1, pp. 213-218.

O'Neill, T.M. & Pye, D. (2002). Evaluation of fungicide treatments for control of rose downy mildew (*Peronospora sparsa*). In: Dehne, H.W., Gisi, U., Kuck, K.H., Russell, P.E. & Lyr, H. [eds] *Modern Fungicides and Antifungal Compounds III*, AgroConcept, Bonn, Germany, pp. 263-271.

O'Neill, T. M., Pye, D. & Locke, T. (2002). The effect of fungicides, irrigation and plant density on the development of *Peronospora sparsa*, the cause of downy mildew in rose and blackberry. *Annals of Applied Biology* **140**: 207-214.

O'Neill, T. M. (2003). Grey mould on greenhouse ornamentals – an integrated energy-efficient solution. *Agriculture LINK Newsletter*, Number 12, p. 5.

O'Neill, T.M.& Fletcher, J.T. (2003). Aspects of the biology and control of tomato Verticillium wilt (*V. albo-atrum*) on Ve-resistant varieties in the UK. In: *Proceedings of the 8th International Congress of Plant Pathology*, Christchurch, New Zealand, p. 119.

O'Neill, T.M., Green, K. & Pettitt, T. (2003). *Control of lisianthus downy mildew*. Horticulture Development Council, Factsheet 12/03, 4 pp.

O'Neill, T.M. & Hanks, G.R. (2003). Evaluation of fungicide treatments for control of narcissus smoulder (*Botrytis narcissicola*). In: *Proceedings of the 8th International Congress of Plant Pathology*, Botrytis workshop, 1-2 February 2003, Christchurch, New Zealand, p. 26.

O'Neill, T.M., Hanks, G.R. & Kennedy, R. (2003). *Control of narcissus smoulder and white mould*. Horticulture Development Council, Factsheet 14/03, 8 pp.

O'Neill, T.M., Pettitt, T. & Hamer, T. (2003). *Control of grey mould (Botrytis cinerea) in protected container-grown ornamentals: heated greenhouse crops*. Horticulture Development Council, Factsheet 24/02, 8 pp.

O'Neill, T. M., Smith N. C. & Elphinstone, J. G. (2003). Disinfestation of water contaminated with *Ralstonia solanacearum*. In: *Proceedings of the 8th International Congress of Plant Pathology*, Christchurch, New Zealand, p. 73.

O'Neill, T.M., Spence, N., Mumford, R. & Skelton, A. (2003). *Pepino mosaic virus of tomato: new results on virus persistence and disinfection*. Horticulture Development Council, Factsheet 20/03, 4 pp.

O'Neill, T. M. & Stokes, D. (2003). *Control of powdery mildew diseases on cut flowers*. Horticulture Development Council, Factsheet 11/03, 8 pp.

Olsson, I.A.S., Nevison, C.M., Patterson-Kane, E.G., Sherwin, C.M., **Van de Weerd, H.A.** & Würbel, H. (2003). Understanding behaviour: the relevance of ethological approaches in laboratory animal science. *Applied Animal Behaviour Science* **81**: 245-264.

Parker, S.R., Paveley, N.D., Foulkes, M.J., Lovell, D.J., Welham, S.J. & Worland, A.J. (2002). Improving and exploiting self-defence against wheat diseases. In: *Proceedings of the BCPC Crop Protection Conference - Pests and Diseases 2002*, Volume 2, pp. 919-924.

Parker, S.R., Berry, P.M., Paveley, N.D., Van Den Bosch, F. & Lovell, D.J. (2003). A rational basis for the design of wheat canopy ideotypes. In: *Proceedings of the BCPC International Congress – Crop Science & Technology*, November 2003, Glasgow, pp. 1101-1106.

Parker, S.R., Berry, P.M., Paveley, N.D., Van Den Bosch, F. & **Sylvester-Bradley, R.** (2003). *A rational basis for the design of wheat canopy ideotypes*. Report for Defra, London, 32 pp.

Paveley, N.D., Foulkes, J., **Parker, S. & Sylvester-Bradley, R.** (2003). Designing wheat to reduce fungicide dependence. In: *Proceedings of the 8th International Congress of Plant Pathology*, Christchurch, New Zealand, Volume 2, p. 297.

Paveley, N.D., Thomas, J.M., Vaughan, T.B., Havis, N.D. & **Jones, D.R.** (2003). Predicting effective doses for the joint action of two fungicide applications. *Plant Pathology* **52**: 638-647.

Phillips, R. & **Chambers, B.J.** (2002). Ammonia emissions from poultry farming. In: *Ammonia in the UK*. PB6865, Defra Publications, London, pp. 56-61.

Phipps, R.H., **Deaville, E.R. & Maddison, B.** (2003). Detection of transgenic DNA and protein, in rumen fluid, duodenal digesta, milk, blood and faeces of lactating dairy cows. *Journal of Dairy Science* **86**: 4070-4078.

Pollak, R. & **Collings, L.V.** (2003). Kerb (propyzamide), its role in reducing *Alopecurus myosuroides* seed banks in arable crops. In: Bekker, R.M., Forcella, F., Grundy, A.C., Jones, N.E., Marshall, E.J. P. & Murdoch, A.J. [eds] *Proceedings of an AAB Conference: Seedbanks - Determination, Dynamics & Management*, 17-18 September 2003, Reading, pp. 63-67.

Pötzsch, C.J., **Hedges, V.J.**, Blowey, R.W., Packington, A.J. & Green, L.E. (2003). The effect of biotin supplementation on white line disease in dairy cattle. *Journal of Dairy Science* **86**: 2575-2582.

Priestley, C.M., Williamson, E.M., Wafford, K.A. & Sattelle, D.B. (2003). Thymol, a constituent of thyme essential oil, is a positive allosteric modulator of human GABA(A) receptors and a homo-oligomeric GABA receptor from Drosophila melanogaster. *British Journal of Pharmacology* **140** (8): 1363-72.

Roden, J.A., **Merrell, B.G., Murray, W.A.** & Haresign, W. (2003). Genetic analysis of live weight and ultrasonic fat and muscle traits in a hill sheep flock undergoing breed improvement utilising an embryo transfer programme. *Animal Science* **76**: 367-373.

Rose, S.C. & Carter, A.D. (2003). Agrochemical leaching and water contamination. In: Garcia-Torres, L., Benites, J., Martinez-Vilela, A. & Holgado-Cabrera, A. [eds] *Conservation agriculture: environment, farmers' experiences, innovations, socio-economy, policy*. Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 417-424.

Rose, S.C., Basford, W.D, Carter, A.D. & Mason, P.J. (2003). Practical on-farm bioremediation systems to limit point source pesticide pollution. In: *Proceedings of the BCPC International Congress - Crop Science and Technology*, 10-12 November 2003, Glasgow, UK, pp. 597-602.

Rose, S.C., Basford, W.D. & Carter, A.D. (2003). On-farm bioremediation systems to limit point source pesticide pollution. In: Del Re, A.A.M., Capri, E., Padovani, L. & Trevisan, M. [eds] *Proceedings of XII International Symposium on Pesticide Chemistry*, 4-6 June 2003, Piacenza, Italy, pp. 559-566.

Ross, S., Adamson, H. & Moon, A. (2003). Evaluating management techniques for controlling *Molinia caerulea* and enhancing *Calluna vulgaris* on upland wet heathland in Northern England. *Agriculture, Ecosystems and Environment* **97**: 39-49.

Staff Publications

Ryder, S. J., **Heasman, L.**, Warner, R. & Dexter, G. (2003). Oral challenge of lambs with scrapie results in dramatically shortened incubation period: a new model for study of scrapie in sheep. In: *Prion Diseases: From Basic Research to Intervention Concepts*, 8-10 October 2003, Munich, Germany, p. 178.

Rymer, C., Givens, D.I. & Wahle, K.W.J. (2003). Dietary strategies for increasing docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) concentrations in bovine milk: a review. *Nutrition Abstracts and Reviews*, Series B, **73**: 9R-25R.

Shepherd, M.A., Harrison, R. & Webb, J. (2002). Managing soil organic matter – implications for soil structure on organic farms. *Soil Use and Management* **18**: 284-292.

Shepherd, M.A. (2003). Clear water farming. *Water and Environment Manager*, April 2003, pp. 8-9.

Shepherd, M.A. (2003). Making the case. *Organic Farming*, Summer 2003 (Issue 78), pp. 26-27.

Shepherd, M.A. (2003). Managing manures in organic systems. In: *Proceedings of the British Society of Animal Science 2003*, p. 240.

Shepherd, M.A., Pearce, B., **Cormack, W.F.**, Philipps, L., Cuttle, S., **Bhogal, A.**, Costigan, P. & Unwin, R.J. (2003). *An assessment of the environmental impacts of organic farming*. Report for Defra, London, 80 pp. (www.defra.gov.uk/science/project_data/DocumentLibrary/OF0405/OF0405_909_TRP.doc).

Short, C. & **Temple, M.L.** (2001). *Economic evaluation of the arable stewardship pilot scheme*. Report for Defra, London, 84 pp. (http://www.Defra.gov.uk/esg/economics/econeval/asps/index.htm).

Short, C. **Angell, B., Francis, J. Powell, J. & Hart, K.** (2003). *Economic evaluation of the upland experiment (Bodmin Moor Project and Bowland initiative*). Report for Defra, London, 58 pp. (http://statistics.defra.gov.uk/esg/evaluation/agri.asp).

Silgram, M. & Chambers, B.J. (2002). Effects of long-term straw management and fertiliser nitrogen additions on soil nitrogen supply and crop yields at two sites in Eastern England. *Journal of Agricultural Science* **139**: 1-13.

Simms, L.C., Wilson, M.J., Glen, D.M. & **Green, D.B.** (2002). Protecting oilseed rape from slug damage using metaldehyde, methiocarb and imidacloprid seed dressings. In: *Proceedings of the BCPC Conference – Pests and Diseases 2002*, 18-21 November 2002, pp. 679-684.

Smith, K.A., Beckwith, C.P., **Chalmers, A.G. & Jackson, D.R.** (2002). Nitrate leaching following autumn and winter application of animal manures to grassland. *Soil Use and Management* **18**: 428-434.

Smith, K.A. (2003). *Improving the utilisation of farm livestock manures applied to agricultural land, with special reference to environmental impacts*. Ph.D. thesis, University of Rakuno Gakuen, Ebetsu, Hokkaido, Japan, 200 pp.

Smith, K.A., Anthony, S.G., Henderson, D. & Jackson, D.R. (2003). Critical drainage and nitrate leaching losses from manures applied to freely draining soils in Great Britain. *Soil Use and Management* **19**: 312-320.

Smith, K. & Chambers, B. (2003). Improved precision in the application and use of livestock manures. In: *Precision Livestock Husbandry*, Society of Chemical Industry symposium, London, February 2003 [abstract].

Sterling, M., Baker, C.J., **Berry, P.M., Spink J., Wade, A., Sylvester-Bradley, R.** & Sparkes, D.L. (2002). Dynamic loading of cereal crops. In: Freathy, P. [ed.] *5th UK Conference on Wind Engineering*, August 2002, Nottingham, pp. 36-41.

Sterling, M., Baker, C.J. & **Berry, P.M.** (2003). An experimental analysis of the wind induced failure of wheat crops. In: Ruck, B., Kottmeier, C., Mattheck, C., Qunie, C. & Wilhelm, G. [eds] *Wind Effects on Trees*, 16-18 September 2003, University of Karlsruhe, Germany, pp. 47-54.

Sterling, M., Baker, C.J., **Berry, P.M. & Wade, A.** (2003). An experimental investigation of the lodging of wheat. *Agricultural and Forest Meteorology* **119**: 149-165.

Sylvester-Bradley, R. & Foulkes, M.J. (2003). Wheat varieties and diminishing UK water supplies. *Journal of the UK Irrigation Association* **31**: 9-11.

Taylor, M.C., Hardwick, N.V. & **Bradshaw, N.J.** (2003). Spatially interpolated Smith Periods and blight outbreak dates in the UK, 1998-2002. In: Westerdijk, C.E. & Schepers, H.T.A.M. [eds] *Proceedings of the Workshop on the European Network for the development of an Integrated Control Strategy for potato blight*, 2-6 October 2002, Poznan, Poland, PAV Special Report No. 9, pp. 105-120.

Taylor, M.C., Hardwick, N.V., **Bradshaw, N.J.** & Hall, A.M. (2003). Relative performance of five forecasting schemes for potato late blight (*Phytophthora infestans*) 1. Accuracy of infection warnings and reduction of unnecessary, theoretical, fungicide applications. *Crop Protection* **22**: 275-283.

Temple, M.L. (2001). *Foot and Mouth Disease proposed 20-day standstill. Estimation of the costs of the proposed ban to England's farming industry and livestock markets*. Report for Defra, London, (unpublished), 29 pp.

Temple, M.L., Emmett, B.J., Scott, P.E. & Crabb, R.J. (2001). *Economic policy evaluation of Defra's bee health programme*, Report for Defra, London, 103 pp. (http://www.Defra.gov.uk/esg/economics/econeval/beehealth/index.htm).

Temple, M.L. (2002). *Agricultural and economic aspects of a feasibility study of Oswestry Livestock Market*. Report for Advantage West Midlands, 68 pp.

Temple, M.L. & Chalmers, A. (2002). *Assessment of profitability and trends of Jersey's agricultural and horticultural industries*. Report for Jersey Department of Agriculture and Fisheries, 27 pp.

Temple, M.L., Scott, P.E., How, M., Standen, J. & Hall, W.R. (2002). *Economic policy evaluation of the Home-Grown Cereals Authority*. Report for Defra, London, 99 pp. (http://www.defra.gov.uk/farm/arable/html/adashgca.htm).

Temple, M., Angell, B., Francis, J., White, G., Doel, C., Babalis, C., **Bullard, M.**, Coates, D., Davenport, J., **Dyer, R., Elliott, J., Evans, J.**, Granger, H., Kells, A., **Lyons, H., Nicholson, N.**, Ingham, R., **Slater, J.** & Ward, N. (2003). *Mid Term Evaluation of the England Rural Development Programme*. Report for Defra, London, and the European Commission, 148 pp. (http://www.defra.gov.uk/erdp/reviews/midterm/final_report/default.htm).

Temple, M.L., Elliott, J., Scott, P.E., Tiffin, A.L., **Gittins, J. & Symonds, W.** (2003). *An economic evaluation of marketing standards - horticulture and eggs*. Report for Defra, London, 94 pp. (http://statistics.defra.gov.uk/esg/evaluation/markstan/default.asp).

Temple, M.L., Francis, J., Tiffin, A.L., **Chalmers, A., Bennett, R.M. & Martins, A.** (2003). *Economic evaluation of the agriculture development scheme*. Report for Defra, London, 79 pp, (http://statistics.defra.gov.uk/esg/evaluation/ads/default.asp).

Thorman, R.E. (2003). Make the best of nitrogen and spring spread. *Farmers Weekly*, 10 January 2003, p. 32.

Thorman, R.E., Harrison, R., Cooke, S.D., Ellis, S., Chadwick, D.R., Burston, M. & Balsdon, S.L. (2003). Nitrous oxide emissions from slurry- and straw-based systems for cattle and pigs – in relation to emissions of ammonia. In: McTaggart, I. & Gairns, L. [eds] *Proceedings of the SAC/SEPA Conference: Agriculture, Waste and the Environment*, 26-28 March 2002, Edinburgh, pp. 26-32.

Turley, D.B., Phillips, M.C., **Johnson, P.**, Jones, A.E. & **Chambers, B.J.** (2003). Long-term straw management effects on yields of sequential wheat (*Triticum aestivum L.*) crops in clay and silty clay loam soils in England. *Soil and Tillage Research* **71**: 59-69.

Van de Graaf, P., **O'Neill, T.M.**, Chartier-Hollis, J.M. & Joseph, M.E. (2003). Aspects of the biology and control of benzimidazole resistant isolates of *Phoma clematidina*, cause of leaf spot and wilt in clematis. *Journal of Phytopathology* **151**: 442-450.

Van de Weerd, H.A., Bulthuis, R.J.A., Bergman, A.F., Schlingmann, F., Tolboom, J., Van Loo, P.L.P., Remie, R., Baumans, V. & Van Zutphen, L.F.M. (2001). Description and validation of a sensing platform for the automatic classification of mice and rat behaviour. *Behavioural Processes* **53** (1-2): 11-20.

Van de Weerd, H.A., Aarsen, E.L., Mulder, A., Kruitwagen, C.L.J.J., Hendriksen, C.F.M. & Baumans, V. (2002). Effects of environmental enrichment for mice: variation in experimental results. *Journal of Applied Animal Welfare Science* **5** (2): 87-109.

Van de Weerd, H.A. & Day, J.E.L. (2002). Playtime research may boost pig performance. *Farmers Weekly*, 8 February 2002, p. 38.

Van de Weerd, H.A., Docking, C., Day, J.E.L., Avery, P.J. & Edwards, S.A. (2003). An alternative approach towards developing environmental enrichment for pigs. *Applied Animal Behaviour Science* **84**: 101-118.

Staff Publications

Van de Weerd, H.A., Docking, C., Day, J.E.L., Breuer. K. & Edwards, S.A. (2003). Longitudinal study of adverse behaviour of undocked pigs in two different housing systems. In: *Proceedings of a British Society of Animal Science symposium: The Appliance of Pig Science*, September 2003, Nottingham, p. 29.

Van de Weerd, H.A., Docking, C., Day, J.E.L. & Edwards, S.A. (2003). Behaviour of pigs with different early life enrichment in a free exploration test. In: *Proceedings of the 37th International Congress of the ISAE*, June 2003, Abano Therme, Italy, p. 91.

Van Heelsum, A.M., Lewis, R.M., Haresign, W., Williams, S.P. & **Davies, M.H.** (2001). Non-normality in carcass quality measurements and effects on the genetic evaluation of sheep. *Livestock Production Science* **69**: 113-127.

Van Heelsum, A.M., Lewis, R.M., **Davies, M.H.** & Haresign, W. (2002). Improving carcass traits in crossbred dam line lambs through selection of the crossing sires. In: *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production*, September 2002, Montpellier, France, paper 02-11.

Van Heelsum, A.M., Lewis, R.M., Haresign, W., Jones, D., Williams, S.P., **Davies, M.H. & Davies, O**. (2002). Growth and carcass characteristics of crossbred (Mule) sheep. In: *Proceedings of the British Society of Animal Science 2002*, p. 195.

Van Heelsum, A.M., Lewis, R.M., **Davies, M.H.** & Haresign, W. (2003). Growth and carcass characteristics of wether lambs of a crossbred dam line. *Animal Science* **76**: 43-53.

Van Loo, P.L.P., Kruitwagen, C.L.J.J., Koolhaas, J.M., **Van de Weerd, H.A.**, Van Zutphen, L.F.M. & Baumans, V. (2002). Influence of cage enrichment on aggressive behaviour and physiological parameters in male mice. *Applied Animal Behaviour Science* **76**: 65-81.

Walker, A.W. (2002). Scientific assessment of the welfare and performance of laying hens in furnished cages in the UK. In: *Proceedings of the International Egg Commission Poultry Welfare Symposium*, 20-21 September 2002, Seville, Spain, pp. 31-38.

Walker, A.W., Barkley, G. & Elson, A. (2003). Welfare and the egg industry: from beak trimming to furnished cages. In: Newton, J. & Williams, M. [eds] *Proceedings of the National Egg Conference*, 20 March 2003, Sutton Coldfield, pp. 18-21.

Walker, A. & Gordon, S. (2003). Intake of nutrients from pasture by poultry. *Proceedings of the Nutrition Society* **62**: 253-256.

Watson, N.J., Horrobin, C., **Riding, A.E., Slater, J.**, Åstrand, P. & Zini, E. (2001). Use of remote sensing and GIS in the Agri-Environmental measures' chain - controlling Agri-Environmental Measures in England. In: *Proceedings of Remote Sensing & Photogrammetry Society Conference*, 12-14 September 2001, London, pp. 527-536.

Webb, J., Misselbrook, T.H.M., Sutton, M.A., Phillips, V.R., ApSimon, H. & **Anthony, S.G.** (2002). A national model for estimating potential reductions in ammonia emissions and their costs. In: Venglovsky, J. & Greserova, G. [eds] *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 237-242.

Webb, J. & Todd, A. (2002). The representative soil sampling scheme. *Workshop on contamination of soils in England and Wales: problems, methods and data*, 12 December 2002, British Geological Survey, Keyworth, Nottinghamshire.

Webb, J., Anthony, S.G. & Lyons-Visser, H. (2003). Consequences for nitrate leaching and nitrous oxide emissions of ammonia abatement in the UK. In: *Proceedings of UNECE Convention on Long-range Transboundary Air Pollution Workshop on Linkages and Synergies of Regional and Global Emission Control*, 27-29 January 2003, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Webb, J., Balsdon, S. & Chadwick, D. (2003). Investigation of how ammonia emissions from buildings housing cattle vary with the time cattle spend inside those buildings. In: *Proceedings of 6th International Conference, Construction, Technology and Environment in Livestock Farming*, 25-27 March, Vechta, Germany, pp. 303-310.

Wilkinson, J.M., Hill, J. & **Hillman, J.P.** (2002). The accumulation of potentially toxic elements in edible body tissues of lambs grazing after a single application of sewage sludge. *Water Research* **37**: 128-138.

Wilkinson, M. (2002). *Feasibility of production of novel oils and extracts from crops in the West Midlands*. Report for Advantage West Midlands.

Wilkinson, M. & Weightman, R. (2002). *Feasibility study into the economic potential of oats and oat extract processing and extraction plant at Shrewsbury*. Report for Advantage West Midlands.

Williams, J.R., Chambers, B.J., Lapworth, J., Misselbrook, T.H. & Chadwick, D.R. (2003). Improving slurry nutrient utilisation on grassland farms. In: *Proceedings of British Grassland Society Seventh Research Conference*, University of Wales, Aberystwyth, pp. 11-12.

Williams, J.R., Chambers, B.J., Thorman, R.E., Misselbrook, T.H. & Chadwick, D.R. (2003). Integrated nutrient management - a new approach. In: *Proceedings of the British Society of Soil Science, and Society of Environmental Toxicology and Chemistry Conference*, 8-10 September 2003, University of Aberdeen [abstract].

Williams, J.R., Smith, K.A., Chambers, B.J. & Cross, R.B. (2002). Nitrogen and phosphorus losses in drainage water following pig slurry applications to a drained clay soil. In: Venglovsky, J. & Greserova, G. [eds] *Proceedings of the 10th International Conference of the FAO RAMIRAN Network*, 14-18 May 2002, Strbské Pleso, Slovak Republic, pp. 109-113.

Wiltshire, J.J.J. (2002). Strawberries - improved control of watering. *HDC News* No. 87, pp. 16-17.

Wiltshire, J.J.J., Tillett, N.D. & Hague, T. (2003). Agronomic evaluation of precise mechanical hoeing and chemical weed control in sugar beet. *Weed Research* **43**: 236-244.

Withers, P.J.A. (2002). An environmental soil test to determine the potential for sediment and phosphorus transport in run-off from agricultural land (DESPRAL). In: *Sustainability of Aquatic Ecosystems: Science in Support of European Water Policies*, Proceedings of an EU International Conference, 26-28 November 2002, Stresa, Lake Maggiore, Italy.

Withers, P.J.A., Royle, S., Tucker, M., Watson, R., Silcock, P., Smith, G. & Dwyer, J. (2003). *Field development of grant-aid proposals for the control of diffuse agricultural pollution*. Report P2-261/09/TR for the Environment Agency, 97 pp.

Withers, P.J.A. & Bailey, G.A. (2003). Sediment and phosphorus transfer in overland flow from a maize field receiving manure. *Soil Use and Management* **19**: 28-35.

Withers, P.J.A., Ulen, B., Stamm, C. & Bechmann, M. (2003). Incidental phosphorus loss – is it significant and can it be predicted? *Journal of Soil Science and Plant Nutrition* **166**: 459-468.

Young, C.S., Paveley, N.D., Vaughan, T.B., **Thomas, J.M. & Lockley, K.D.** (2003). Predicting epidemics of yellow rust (*Puccinia striiformis*) on the upper canopy of wheat from disease observations on lower leaves. *Plant Pathology* **52**: 338-349.

The ADAS Science Review 2003 was edited by Dr Bill Cormack and Dr Jeremy Wiltshire, ADAS Terrington.

ADAS Research Centres and Locations

ADAS Arthur Rickwood
Mepal
Ely
Cambridgeshire
CB6 2BA
Tel: 01354 692531
Fax: 01354 694488

ADAS Bristol
Burghill Road
Westbury-on-Trym
Bristol
BS10 6NQ
Tel: 0117 9591982
Fax: 0117 9591982

ADAS Boxworth
Boxworth
Cambridge
CB3 8NN
Tel: 01954 267666
Fax: 01954 267659

ADAS Cardiff
Henstaffe Court Business Centre
Groesfaen
Cardiff
CF72 8NG
Tel: 02920 899100
Fax: 02920 890054

ADAS at Defra Drayton
Alcester Road
Stratford-upon-Avon
Warwickshire
CV37 9RQ
Tel: 01789 293057
Fax: 01789 414393

ADAS East Hendred
The Old School
St Marys Road
East Hendred Oxon
OX12 8LF
Tel: 01235 438900
Fax: 01235 438909

ADAS East Malling
Oast Building
East Malling
West Malling
Kent ME19 6BJ
Tel: 01732 876662
Fax: 01732 876664

ADAS Edinburgh
Royal Highland Centre
Edinburgh
EH28 8NF
Tel: 0131 335 0326
Fax: 0131 335 3016

ADAS Gleadthorpe
Meden Vale
Mansfield
Nottingham
NG20 9PF
Tel: 01623 844331
Fax: 01623 844472

ADAS Leeds
Hollyshaw House
Hollyshaw Lane
Whitkirk
Leeds LS15 7BD
Tel: 0113 2643233
Fax: 0113 2643383

ADAS High Mowthorpe
Duggleby
Malton
North Yorkshire
YO17 8BP
Tel: 01944 738646
Fax: 01944 738434

ADAS Lincoln
Ceres House
2 Searby Road
Lincoln LN2 4DW
Tel: 01522 521301
Fax: 01522 513694

ADAS London
Room 705
Eastbury House
30 34 Albert Embankment
London
SE1 7TL
Tel: 0207 2381260
Fax: 0207 2381269

ADAS Mamhead
Mamhead Castle
Mamhead
Exeter
Devon EX6 8HD
Tel: 01626 899002
Fax: 01626 899174

ADAS Preston
16 Eastway Business Village
Olivers Place
Fulwood
Preston
PR2 9WT
Tel: 01772 703070
Fax: 01772 703311

ADAS Pwllpeiran
Cwmystwyth
Aberystwyth
Ceredigion
SY23 4AB
Tel: 01974 282229
Fax: 01974 282302

ADAS Redesdale
Rochester
Otterburn
Newcastle-upon-Tyne
NE19 1SB
Tel: 01830 520608
Fax: 01830 520451

ADAS Ruthin
Eden Court
Lon Parcwr Business Park
Ruthin
Denbighshire
LL15 1NJ
Tel: 01824 704060
Fax: 01824 707163

ADAS Rosemaund
Preston Wynne
Hereford
HR1 3PG
Tel: 01432 820444
Fax: 01432 820121

ADAS Terrington
Terrington St Clement
King's Lynn
Norfolk
PE34 4PW
Tel: 01553 828621
Fax: 01553 827229

ADAS St Ives
The Heath
Woodhurst
Huntington
Cambs
PE28 3BS
Tel: 01487 849840
Fax: 01487 849859

ADAS Wolverhampton
Head Office
Woodthorne
Wergs Road
Wolverhampton
WV6 8TQ
Tel: 01902 754190
Fax: 01902 743602

www.adas.co.uk

Produced by Impact Design & Advertising Tel 0121 707 4774