MAFF environmental research and development.

SCIENTIFIC RESEARCH AND DEVELOPMENT

THE ENVIRONMENT

MAFF ENVIRONMENT matters

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MAFF ENVIRONMENTAL RESEARCH AND DEVELOPMENT

Farms and woodland cover nine tenths of our country. As well as producing most of our food, and providing a small but increasing amount of our timber, they offer us all a great deal of pleasure and enjoyment. Indeed, people have rightly come to expect farmers and foresters to be environmental managers as well as production directors and businessmen. The same goes for our fishing community.

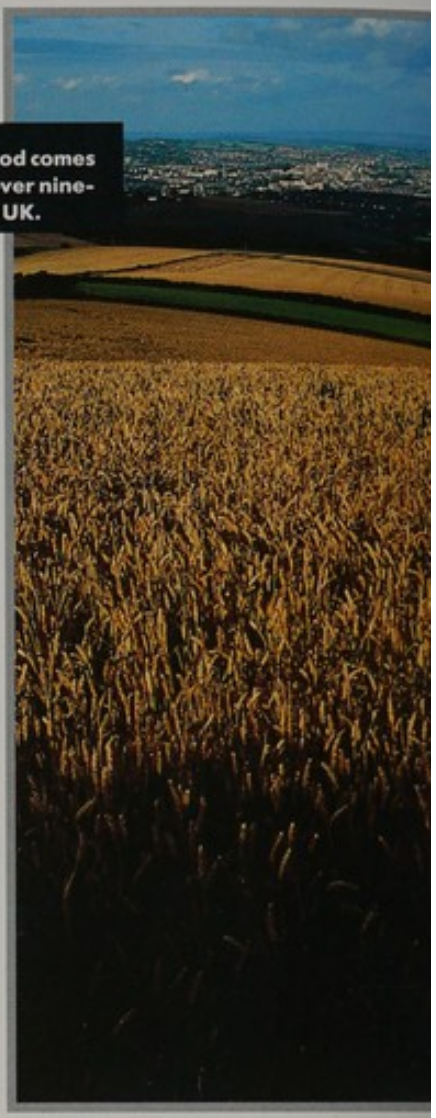
We recognise this dual responsibility in our policies for the countryside and for marine resources, which are firmly based on the integration of economic and environmental aims, the conservation and improvement of landscape, habitat and the marine environment, and on the protection of the land from flooding and erosion. If they are to succeed as we would wish, our policies need to be supported by the best possible understanding of the interaction of man and the environment, both in the immediate and the longer term.

To secure that understanding, MAFF will be spending about £50 million in 1991/92 on environmental research and development (R&D). This publication is a brief guide to what we are doing and how we make the knowledge that we gain available to all who can benefit from it.

I hope that you will find this resumé useful and that it will encourage you to take an even closer interest in our programme of environmental R&D.

Trumpington

THE BARONESS TRUMPINGTON
Minister of State
Ministry of Agriculture, Fisheries and Food



More than half our food comes from the farms which cover nine-tenths of the land in the UK.

THE RESEARCH AND DEVELOPMENT STRATEGY

MAFF's environmental research and development (R&D) strategy is principally determined by the policy requirements of the Ministry, which range from the improvement and more effective enforcement of statutory controls to the promotion of alternative uses for land at a time of surplus agricultural production.

The R&D is not 'science for science's sake' but a managed programme which plays an essential role in the formulation and evaluation of policies as well as in their practical application. To ensure that the work is closely integrated with existing policies, as well as anticipated future problems, the officials responsible for policy formulation have the budget for the R&D. Decisions on the content of the programme are taken in consultation with the Ministry's Chief Scientists as well as other professional and scientific experts.

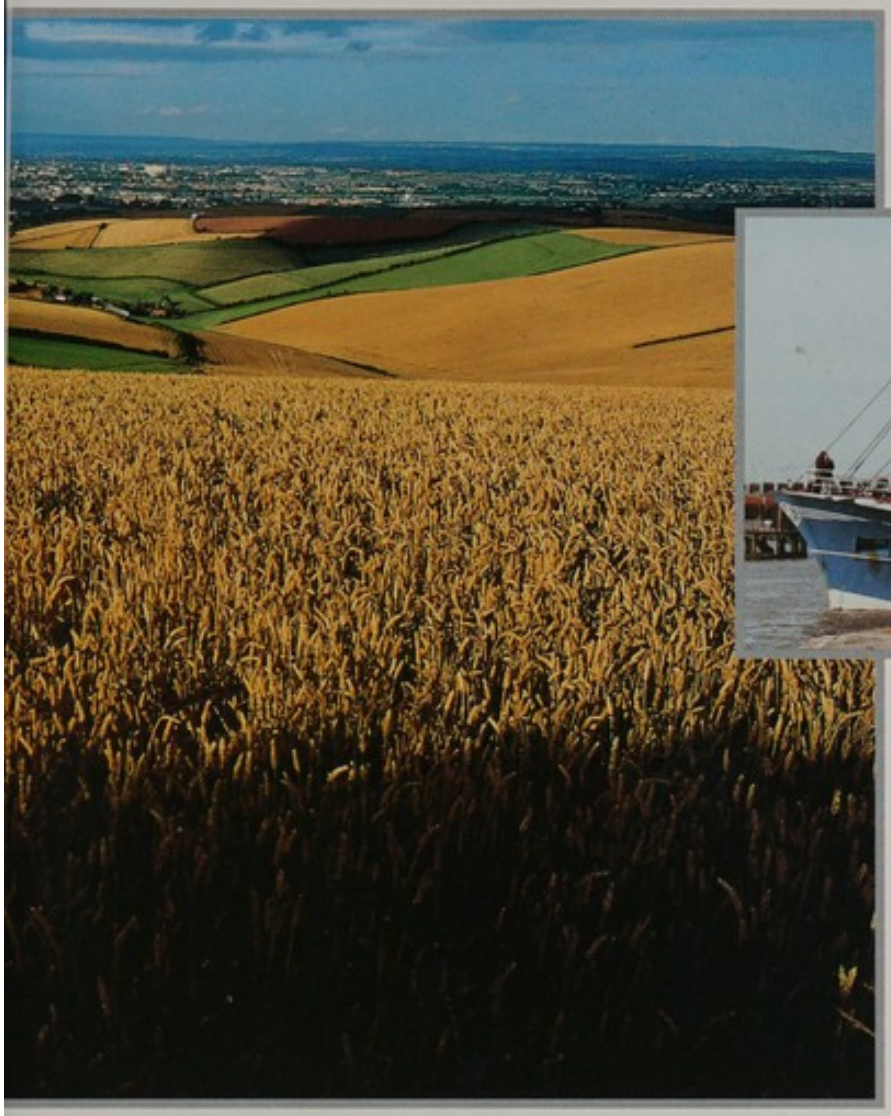
The Ministry also undertakes work in the general public interest, and supports strategic research to underpin the development of new technologies and techniques.

Much of the environmental R&D funded by the Ministry is commissioned with outside organisations, including the Agricultural and Food Research Council (AFRC), the Natural Environment Research Council (NERC) and other institutes and academic bodies. In addition, MAFF's Agricultural Development and Advisory Service (ADAS) and the Central Science Laboratory – including its Experimental Husbandry Farms (EHFs) – undertake work for the Ministry. The Royal Botanic Gardens at Kew carries out basic research under a grant-in-aid from MAFF.

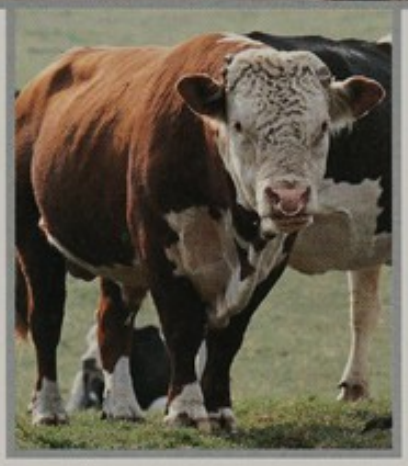
Environmental R&D is highly labour-intensive. Much of it is based on painstaking fieldwork and observation, often involving the making of measurements over many years. It may also involve detailed and sophisticated laboratory analyses and experiments aimed at interpreting the field results.

Other Government departments also undertake environmental research. It is therefore important that the various programmes are properly co-ordinated. To ensure that the national programme is balanced and comprehensive, the United Kingdom Agriculture Ministers and the Chairman of the AFRC are advised by the independent Priorities Board for Research and Development in Agriculture and Food.

In addition, the private sector carries out environmental research. If the maximum benefits are to be derived from both public and private R&D there must be clear lines of communication between them. To achieve this, the Priorities



Over half a million people depend for their livelihoods on farming, fishing and forestry.



Board is assisted by six Advisory Sectoral Groups (ASGs) which scrutinise research programmes and requirements in different areas and provide opportunities for the exchange of ideas and opinions on research needs. The Advisory Group on the Environment Sector includes representatives of the Department of the Environment, the Natural Environment Research Council, the National Rivers Authority, the Forestry Commission, and conservation and environmental organisations as well as the Agriculture Departments and the AFRC.

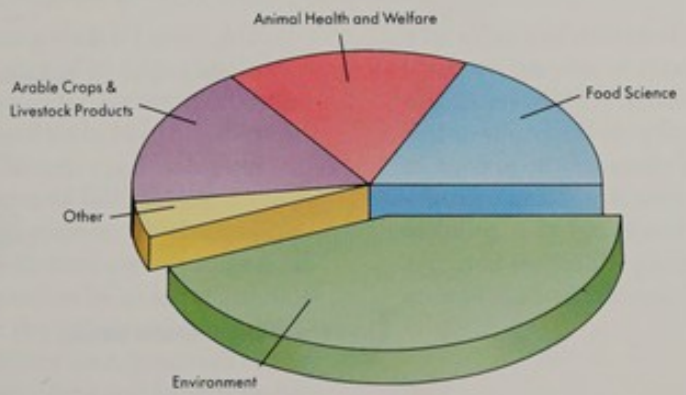
Of course, the Ministry is also liaising with our EC partners in order to pool information and avoid duplication of R&D effort.

MAFF is responsible for:

- *the protection and enhancement of the countryside and fisheries;*
- *the safety and quality of the nation's food supplies;*
- *the protection of the land against flooding and coastal erosion.*

The Ministry undertakes a comprehensive, balanced and far-sighted programme of environmental research and development to inform and guide its policies.

Breakdown of MAFF expenditure on research & development: 1991/92.



Protecting the rural environment, water supplies and rivers, soil and the land, the air, fisheries, the marine environment; and farm woodlands and set-aside, pest and pesticides, genetic conservation and modification, climate change, and flood and coastal defence.

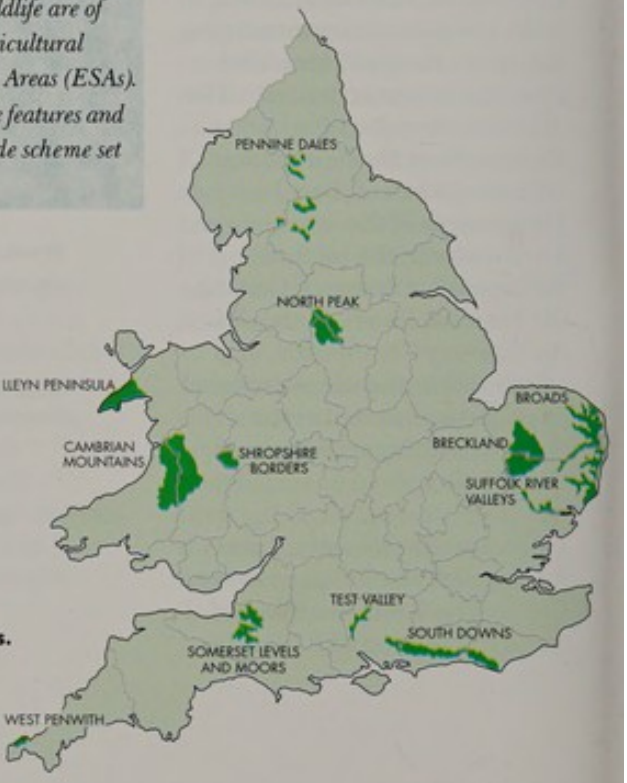
PROTECTING THE RURAL ENVIRONMENT

Field barns and stone walls are important landscape features in the Pennine Dales ESA.

The countryside has undergone significant changes since 1945, many of them due to the modernisation and intensification of farming techniques. These led to a reduction in semi-natural habitats and in biological diversity. From the 1980s, however, there has been increasing concern over safeguarding the rural environment, a concern which the Ministry seeks to meet by encouraging landowners, farmers and growers to protect and enhance the countryside by modifying their farming practices.

The Ministry's R&D strategy for protecting the rural environment is designed primarily to provide the scientific basis for the development and evaluation of the Ministry's policies for protecting and enhancing the countryside. This programme currently costs about £1.6m a year. Much of the work is focused on issues arising from the operation of the Environmentally Sensitive Areas (ESAs) which have been designated across England and Wales.

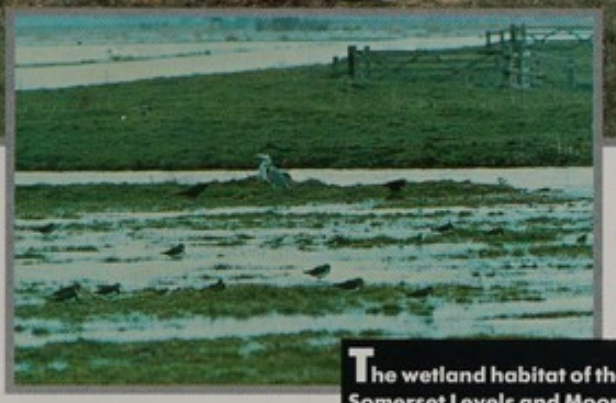
Twelve localities in England and Wales where the landscape and wildlife are of special importance, but particularly vulnerable to the impact of agricultural intensification, have been designated as Environmentally Sensitive Areas (ESAs). In these Areas, farmers are paid to retain and enhance the landscape features and habitats. These ESAs now form part of a European Community-wide scheme set up on the Ministry's initiative.



The ESAs of England and Wales.

Properly managed heather burning regenerates old stands of heather.

Work at Redesdale EHF examines the effect of grazing pressure and seasonal grazing on the regeneration of heather which can be seen here with the height and health of the heather.



The wetland habitat of the Somerset Levels and Moors ESA is an important area for birds.

Heather Moorland

One of the most important projects in the rural environment programme concerns the damage done to heather moorland. Damage can occur naturally, as it did in the North York Moors National Park in the drought year of 1976, for instance. Here, fires started accidentally were followed by heavy rain, leading to serious soil erosion. The soil surface then had to be stabilised to allow the heather to recover. The Ministry's R&D, some of it undertaken in collaboration with the National Park Authority, is designed to see if the methods used there can be applied successfully elsewhere.

Damage to moorland has also occurred as a result of intensive grazing on hill farms. At a number of its Experimental Husbandry Farms, including Redesdale in Northumberland, the Ministry is developing systems of hill pasture management, which combine the efficient use of indigenous vegetation by grazing animals with the preservation of the structure and dynamics of the native plant and invertebrate communities.

The effects of different stocking levels on the rate of recovery of degraded heather are examined within plots and on a farm scale, alongside other factors like seasonal grazing, burning and topping. A range of techniques are used within the plant and animal studies. On one farm site

The Agriculture Act 1986 places an obligation on Ministers to achieve a balance between:

- *the promotion and maintenance of a stable and efficient agriculture industry;*
- *the economic and social interests of rural areas;*
- *the conservation of the natural beauty and amenity of the countryside; and*
- *the promotion of the enjoyment of the countryside by the public.*

PROTECTING THE RURAL ENVIRONMENT

the botanical work alone requires the collection of 26,000 separate pieces of information each year. Aerial photography and computer-based analysis are used as well to determine the range of factors influencing recovery.

This project is of great importance in determining what strategies to use for the regeneration and maintenance of upland heath communities.

Species Diversity
Modern farming techniques have reduced the range of species in the rural environment. A series of R&D projects is therefore exploring the impact of such techniques and examining ways in which the variety of species can be extended.

At Swavesey Fen in East Anglia, a database of hydrological and farm management information is being built up in order to determine the effect of varying water levels on the diversity of flora and fauna.

On the Somerset Moors, the AFRC Institute of Grassland and Environmental Research (IGER) is studying the changes in the botanical composition of species-rich grassland due to the sustained application of fertiliser. In the first stage of the study, fertiliser treatment will continue across a series of plots of land so as to establish a base measurement. Then the plots will be divided, with fertiliser being completely withheld from half of them. Finally, some plots will be subject to a variety of treatments to encourage greater botanical diversity. These

Work on the inoculation of bracken with myco-herbicides.

Swavesey Fen Catchment

Monitoring water levels and flora and fauna helps us to understand the effects of changing agricultural practices.

An uncropped strip in Breckland has resulted in picturesque and diverse flora.

include physical disturbance of the grassland to produce space for the germination of species in the 'seed bank' present in the soil, and the introduction of seeds from adjoining areas which have received no fertiliser.

Current grassland management practices are designed to produce high grass yields and optimum levels of animal output by using high inputs of fertiliser and intensive grazing management. Consequently, about 90% of the grassland in England and Wales has come to be dominated by perennial ryegrass. Introducing species-rich grassland, on the other hand, may reduce overall grass yield and as a consequence reduce animal output and profitability. We need to know more about the precise effects on costs and how these can be minimised. So IGER is undertaking a project which aims to provide costed options for the management of species-rich grassland.

Field Boundaries

The intensive use of pesticides and fertilisers has been widely blamed for causing serious damage to the semi-natural habitats, such as field edges, associated with farmland. At the same time, many farmers regard these areas as reservoirs of weeds and pests. It is, therefore, important to develop a full understanding of the impact of farming on diversity and inter-species competition in the flora and fauna of semi-natural habitats. The Ministry is funding studies of non-crop habitats with the aim of developing management strategies which will benefit wildlife while maintaining weed control efficiency.

FARM WOODLANDS AND SET-ASIDE

In order to counter the problem of surplus agricultural production, the Ministry has introduced a number of schemes designed to provide farmers with an alternative source of income and to reduce the production of certain foodstuffs. Among these are the Farm Woodland and the Set-aside Schemes. Both have significant environmental implications and are the subject of environmental research and development work as well as monitoring and evaluation.

The development of farm woodlands is supported by an R&D programme currently costing around £1.7m a year. The main objective is the development of cost-effective methods of establishing and maintaining woodlands on land that has previously been under arable cultivation.

When trees are planted on land previously under arable cultivation, the soil is so fertile that, unless there is proper weed control, the saplings will be overwhelmed and the plantation will fail. The R&D programme is investigating a variety of ways of controlling weeds, including different plantation layouts, the use of wide uncultivated strips between tree rows, and the planting of grass or wild flowers to inhibit weed growth. Rabbit populations are increasing nationally, so work is also in progress on effective methods for countering rabbit damage to trees and to other crops on the farm.

Other aspects of farm woodland R&D include studies of novel forms of tree production and systems which combine the planting of trees with farming.

The effects of woodland plantings on the discharge of water and nitrate from former arable land are also being studied.

Planting broadleaved woodlands on farms is likely to reduce the quantity of water discharging by surface and subsurface drainage. In time, it should also reduce nitrate leaching; partly because the trees themselves will take up nitrate and partly because there is little soil disturbance under established woodland. To test these assumptions, the ADAS Field Drainage Experimental Unit at Cambridge is examining changes in local hydrology and drainage water quality where trees have been planted after intensive arable farming.

Set-Aside

Research and development in support of the Set-aside scheme includes trials on the Ministry's Experimental Husbandry Farms to study the management options for set-aside land and their implications for the spread of pests, weeds and diseases. Research is also taking place on the effects of nitrate leaching and on the husbandry requirements of crops that might subsequently be grown on such land.

Set-aside

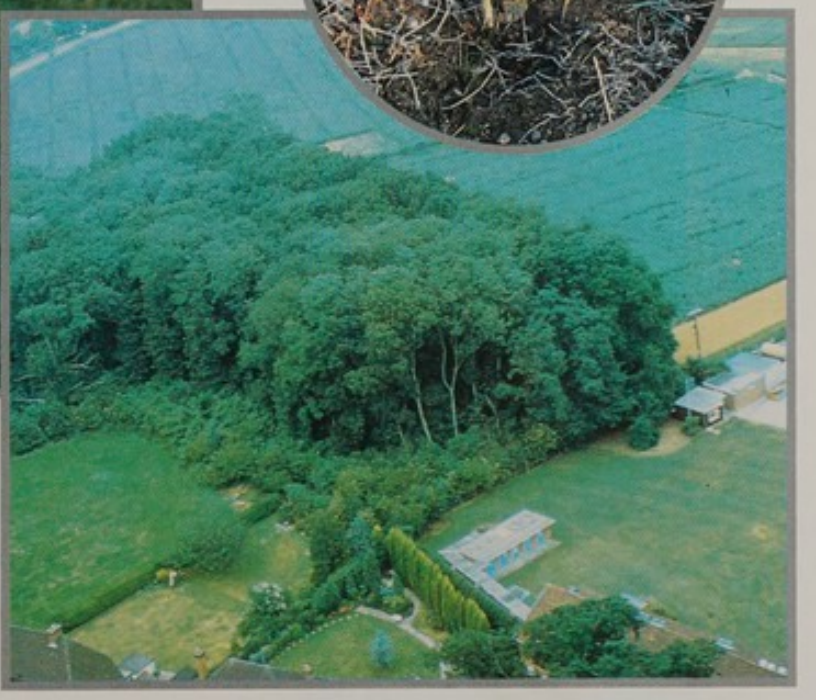
Set-aside is a European Community scheme under which farmers receive compensation when they withdraw at least 20% of their land from arable production. The scheme provides farmers with an alternative source of income while they adjust to the effect of price reductions. It also imposes a number of environmental obligations, including restrictions on the use of fertilisers and pesticides and a requirement to maintain certain environmental features. In seven counties in the east of England, the Countryside Commission offers additional incentives to farmers who manage their set-aside land in ways which bring specific environmental benefits such as the creation of wildlife habitats. The Ministry is considering developing a similar scheme on a nationwide basis.

Farm Woodland Scheme

MAFF is encouraging the planting of trees on better quality land which might otherwise be used to grow crops which are currently in surplus. Grants for this purpose are paid under the Farm Woodland Scheme which particularly encourages the planting of broadleaved woodlands.

Experiments at Boxworth EHF (below) and Drayton EHF (top left) test the effects of managing set-aside land in different ways.

Damage by rabbits to saplings can be a great problem and nuisance to farmers.



The scope for grazing ewes and lambs together with the planting of ash trees is being studied by IGER at North Wyke, Devon.

PROTECTING WATER SUPPLIES AND RIVERS

Long term classical experiments on the Broadbalk field at IACR have helped to improve our understanding of the nitrogen cycle on farmland.

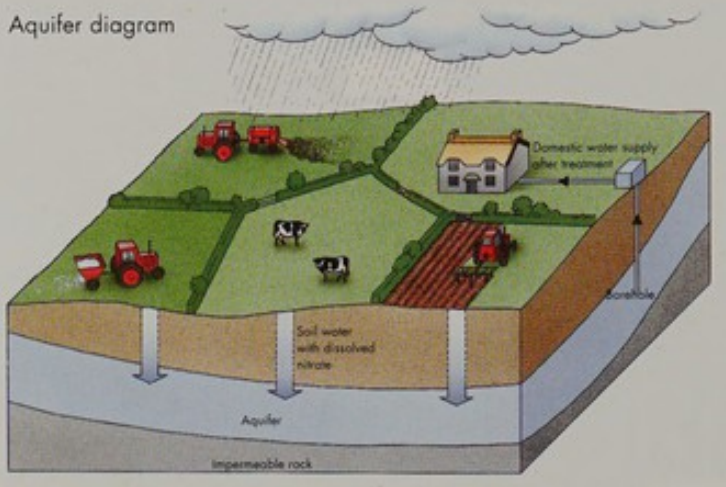
The Government is committed to achieving further improvements in the quality of Britain's drinking water supplies and rivers. In addition to work on the effect of pesticides (see pp.16–19), the Ministry's R&D in this area concentrates on two principal issues: the contamination of groundwater and surface water by nitrate leaching and by farm wastes.

Nitrate Concentrations

In a few parts of Britain, nitrate levels in drinking water are close to or above the European Community limit of 50mg/l, partly due to nitrate leaching from farm land. The Ministry is currently spending over £6m a year on R&D to help tackle the problem. It is taking both a strategic approach, designed to enhance understanding of nitrogen cycling in agricultural soils, and carrying out shorter term work which has the aim of showing how best to reduce leaching through the use of autumn cover crops and optimum applications of chemical fertilisers and organic manures.

Models of the nitrogen cycle, or parts of it, help us to understand the processes by which nitrate is taken up by crops or leaches to water supplies. At present, several models of parts of the cycle exist – notably for leaching and crop uptake. These are by no means perfect and the Ministry is therefore funding work at the AFRC Institute of Arable Crops Research and elsewhere to gain sufficient understanding of nitrogen cycling in farmlands to allow better models to be developed.

Aquifer diagram



On many arable farms, maintaining crop cover over the winter is the single most effective way of reducing nitrate leaching. Soils always contain some nitrate in the autumn, and if this is not taken up by a crop it is likely to be washed out of the soil over the winter. The problem can be reduced either by establishing a winter cereal or winter rape crop or, if a spring planted crop is planned, by sowing a cover crop in the autumn to be ploughed down in the early spring. Work at

To help reduce the amount of nitrate leaching from farmland, ten pilot Nitrate Sensitive Areas (NSAs) – covering some 14,000 hectares – have been designated in England under the Water Act 1989. In the NSAs, farmers qualify for annual payments towards the cost of major changes in their farming practices to reduce the risk of leaching. Both they, and farmers in a further nine advisory areas, also receive free individual advice. The NSAs are being monitored by ADAS and the National Rivers Authority.

These clamps show the different levels of effluent produced under different methods of ensiling.

To minimise water pollution from farm waste, the construction of waste storage facilities must meet statutory requirements.

The Water Act 1989 makes it an offence to pollute watercourses and the maximum fine on summary conviction has been increased from £2,000 to £20,000. New regulations require farm waste facilities to meet minimum standards and 50% grants are available for their construction or improvement. In addition, ADAS provides individual advice on pollution control and the Agriculture Departments of England and Wales have published guidance.

the Gleadthorpe Experimental Husbandry Farm, Nottinghamshire, and elsewhere is demonstrating the effectiveness of cover crops in reducing leaching. This could result in the preparation of guidelines on the optimum use of cover crops to minimise leaching while ensuring minimal effects on subsequent spring-sown crops.

Farm Waste

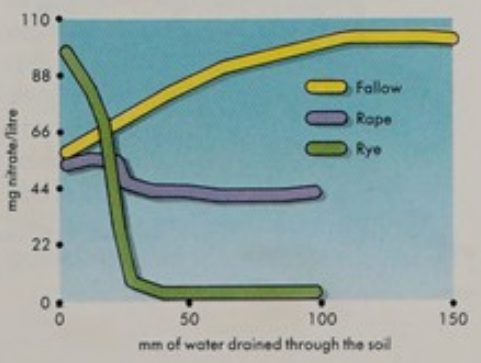
Pollution from farm waste, such as silage effluent and animal slurries, can pose a major problem to aquatic life. Undiluted slurry is up to 100 times more polluting, and silage effluent up to 200 times more polluting, than raw sewage. In both cases the materials' demand for oxygen depletes the supply in the watercourse.

The Ministry is currently spending over £1m a year on R&D aimed at reducing water pollution from farm waste. This has three main aims: developing practical and cost-effective methods for reducing the production of silage effluent and slurry; improving the containment of wastes; and developing improved outlets for wastes, including recycling.

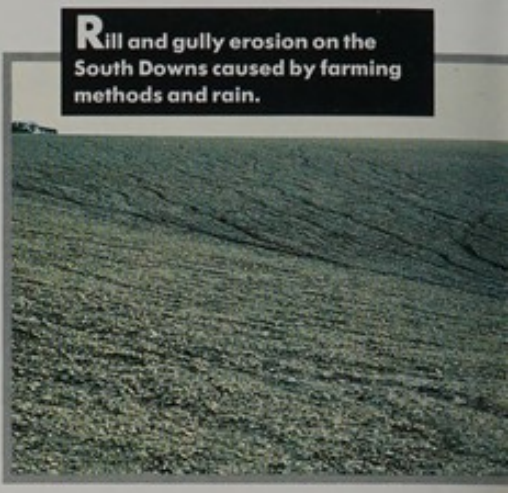
Research funded by the Ministry with AFRC and ADAS is demonstrating the best techniques for storing and utilising animal manure so that it can be more confidently substituted for applications of mineral fertilisers. This will lead to more efficient use of the nutrients and organic matter in the manure and convert a waste disposal problem into a benefit for the farmer and the environment.

ADAS and the AFRC Institute of Grassland and Environmental Research are currently examining ways of reducing silage effluent pollution, for example by studying the effects on effluent generation of the factors involved in silage production. These factors include the influence of fertiliser levels, the time that the crop is cut, and the period it is left to wilt in the field. In another project, they are investigating storage methods and looking at the use of additives and absorbers, such as polymer gels, as means of containing the effluent; and at making silage in polythene covered bales, rather than in large clamps, which lightens the pressure on the fermenting material and hence reduces leakage.

Nitrate concentration in drainage under different cover crops



PROTECTING SOIL AND THE LAND



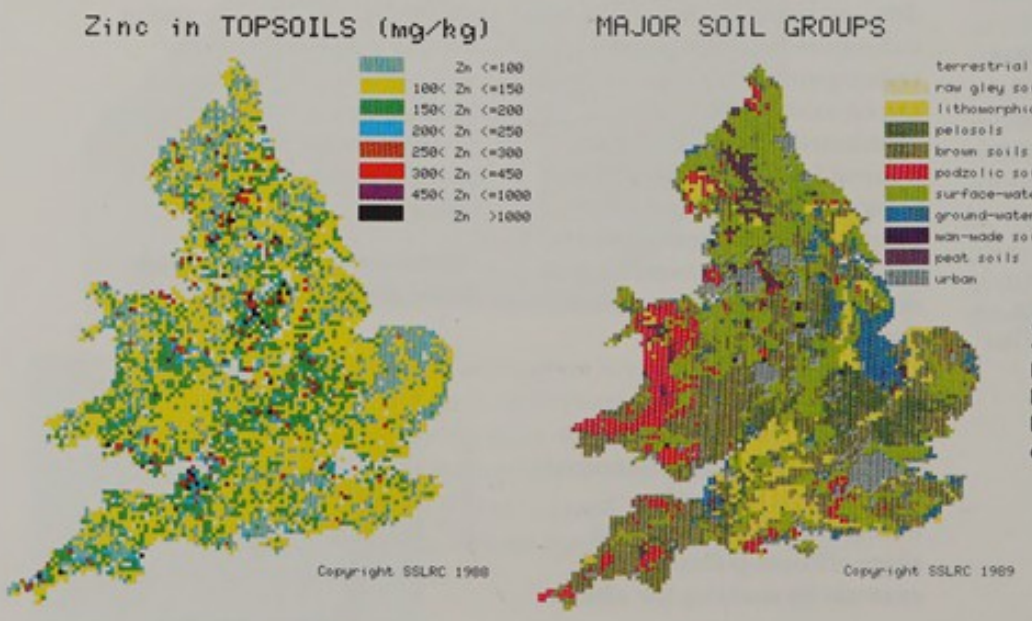
Rill and gully erosion on the South Downs caused by farming methods and rain.

Changes in soil fertility could have significant long term effects on the viability and competitiveness of farming in the United Kingdom. Therefore, in line with its responsibilities for land use policy and for encouraging sustainable agriculture, the Ministry is undertaking R&D on the effects of various farming practices on soil quality. The programme is costing around £1.5m a year.

For many years the Ministry has funded the Soil Survey of England and Wales – now the Soil Survey and Land Research Centre (SSLRC) – to record and map the soil types in England and Wales. This has produced large amounts of detailed information, much of which has been converted into a form accessible by computer. This information supports policy and R&D work not only on soil fertility but also on issues such as nitrate and pesticide leaching and on the disposal of farm waste. One area of particular importance is the database on levels of heavy metals in the soil, which was produced by collaborative work between SSLRC, ADAS and the AFRC Institute of Arable Crops Research. This provides a valuable yardstick by which to assess present and future concentrations.

Heavy Metals

All plants and animals have metals as a component of their tissues. The important nutrient metals such as calcium, magnesium and potassium tend to be the less dense (and therefore lighter) metals. Other metals such as lead, cadmium, copper, chromium, zinc and mercury are denser and are known as heavy metals. Some of the heavy metals are required by living organisms in minute quantities, but at high concentrations most of them are toxic to plants or animals. The methods for measuring heavy metals are very sensitive, and most soils have a measurable content of heavy metals.



Soil survey information for England and Wales which has been collected over many years has been collated into a form accessible by computer.

Considerable quantities of soil have moved by water erosion within this potato field.

The heavy metals contained in sewage sludge used as an organic manure pose a potential threat to soil fertility and human health. Over 50% of Britain's sewage sludge is spread on agricultural land and, while it can benefit the soil, its heavy metal content can damage the soil organisms essential for crop growth and can also be transmitted along the food chain through ingestion by cattle.

Sludge disposal to agricultural land is controlled by Regulations which are backed by a Code of Practice. Amongst other things, the Regulations set maximum permissible concentrations for heavy metals in soils to which sludge is applied. The limits are kept under review. To assist in this, the Ministry is funding work at the AFRC Institute for Arable Crops Research into the effects of heavy metals on the interaction between legumes and microorganisms. Clover and other legumes such as peas and beans are believed to be most at risk from heavy metals because of their symbiotic association with nitrogen-fixing microbes. The project has yielded valuable information on soil protection and further work will be carried out by the AFRC and ADAS both on this and on the impact on crop growth and yield.

A further threat to the land is presented by acid rain, which can break down soil components, reducing the soil's productivity and leading to the leaching of potentially toxic elements into watercourses. R&D is in progress at the AFRC Institute of Arable Crops Research and a number of individual farms to identify and quantify the impact of acid rain, especially in areas of high deposition and low natural soil acidity.

Sludge disposal to agricultural land is controlled by Regulations which are backed by a Code of Practice.

Soil Erosion

Soil erosion by water is not a severe problem in the UK but has become more widespread in the last 20–30 years as a result of the expansion of arable cropping, larger fields and widespread use of permanent wheelways in crops. The Ministry is funding a project designed to measure erosion in a small but widespread selection of sites and to devise methods for its control which can be incorporated into national guidelines.

PROTECTING THE AIR

Farming activities can cause air pollution, in particular through the burning of crop residues and the housing of livestock which can produce offensive odours. The Ministry currently spends nearly £1.5m a year on R&D aimed at the prevention of such air pollution.

Crop Residues

The burning of straw and other crop residues has caused great public nuisance as well as some environmental damage, and the practice will be prohibited after the 1992 harvest. The main alternative to burning straw is to plough it into the soil, but this is not always easy.

In order to minimise the problem, the Ministry is collaborating with the AFRC Institute of Arable Crops Research on long term studies aimed at identifying the most effective ways of using straw in a range of soil types and geographic locations. The work includes burying different varieties of straw chopped to different lengths in different types of soil to investigate the way in which the straw breaks down and over what periods of time. The studies are also evaluating the effect of straw incorporation on soil nitrogen levels, as incorporation could have a role to play in reducing nitrate leaching.

Investigations are also under way to minimise any environmental problems that may be caused by alternatives to burning. For example, ploughing in straw is likely to mean more grass weeds. This could in turn lead to greater herbicide usage with its consequent potential risks, especially for watercourses.

Besides the Ministry's R&D work on crop residues, the Department of Energy's Energy Technology Support Unit is conducting R&D into the possible commercial use of straw as a fuel.

The Environmental Protection Act 1990 introduced a number of new and improved powers to tackle air pollution:

**to control the most polluting processes, which include some related to agriculture such as rendering of animal by-products, a new system of Integrated Pollution Control has been introduced. Authorisation to operate these processes must be obtained from the local authority or Her Majesty's Inspectorate of Pollution and operators must comply with detailed process guidance notes;*

**to deal more effectively with complaints of nuisance from odours, including farm odours, strengthened powers have been given to local authorities; and*

**Ministers have been provided with the power to prohibit the burning of crop residues, to make exemptions to that prohibition and to control permitted burning.*

Straw and stubble burning will be banned by 1993. ADAS is continuing to research into alternative methods of disposal, such as ploughing in of straw.

Concentrations of odour and ammonia are analysed and pilot scale studies of the aeration of pig slurry are carried out at the Silsoe Research Institute to develop odour control techniques.

Chemical Emissions

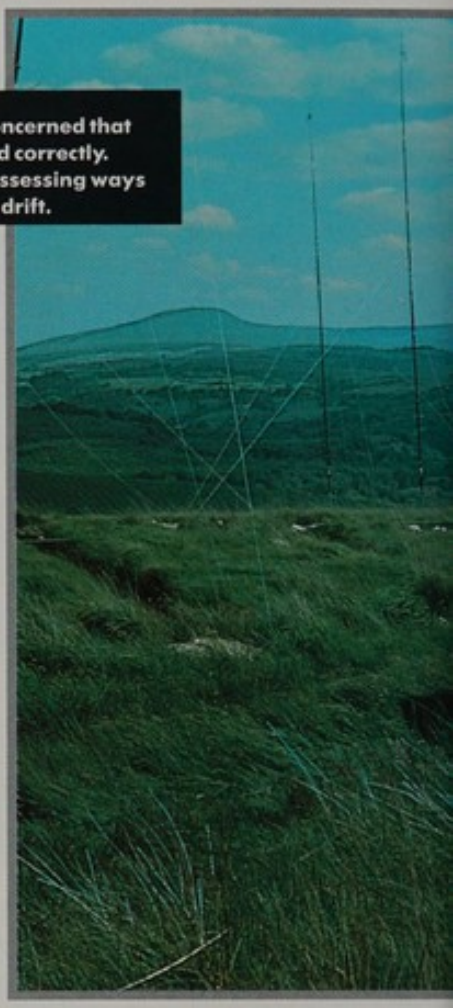
Ammonia and oxides of nitrogen (NOx) can be emitted from soils, mineral and organic fertilisers, and from farm wastes, which can also give off methane, a major greenhouse gas (see pp.26–27). Ammonia and NOx emissions can lead to localised acid rain. The extent to which nitrogen depositions from the atmosphere can contribute to the nitrogen supply in nearby soil is demonstrated by the evidence of cereal plots on Broadbalk Field at the AFRC Institute of Arable Crops Research in Hertfordshire, which have not received any fertiliser since 1844, yet still produce crops and have an estimated nitrogen input from the atmosphere of about 40 kg per hectare each year.

Nitrate R&D (see pp.10–11) includes work on rates of nitrous oxide emissions from cultivated and fertilised soils.

Odours

Farm wastes can give rise to problems of odour, which may cause a nuisance. To ensure that appropriate guidance is given to farmers on the best practice in controlling odours from wastes, suitable odour control techniques, including slurry aeration processes, are under development.

PESTS AND PESTICIDES

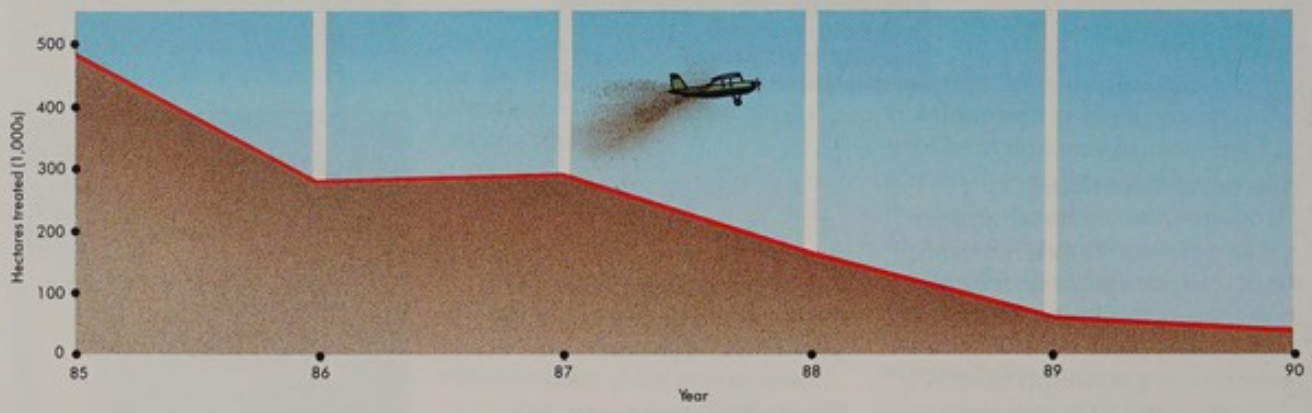


The Ministry is concerned that pesticides are used correctly. Researchers are assessing ways of avoiding spray drift.

Pests and diseases can take a heavy toll of food supplies, both on the farm and in store. Insects, moulds, weeds and rodents can reduce output by as much as 30%; and rabbits alone eat crops worth over £100m every year. It is for this reason that more than 99% of the farm holdings in this country, producing arable or vegetable crops, use pesticides.

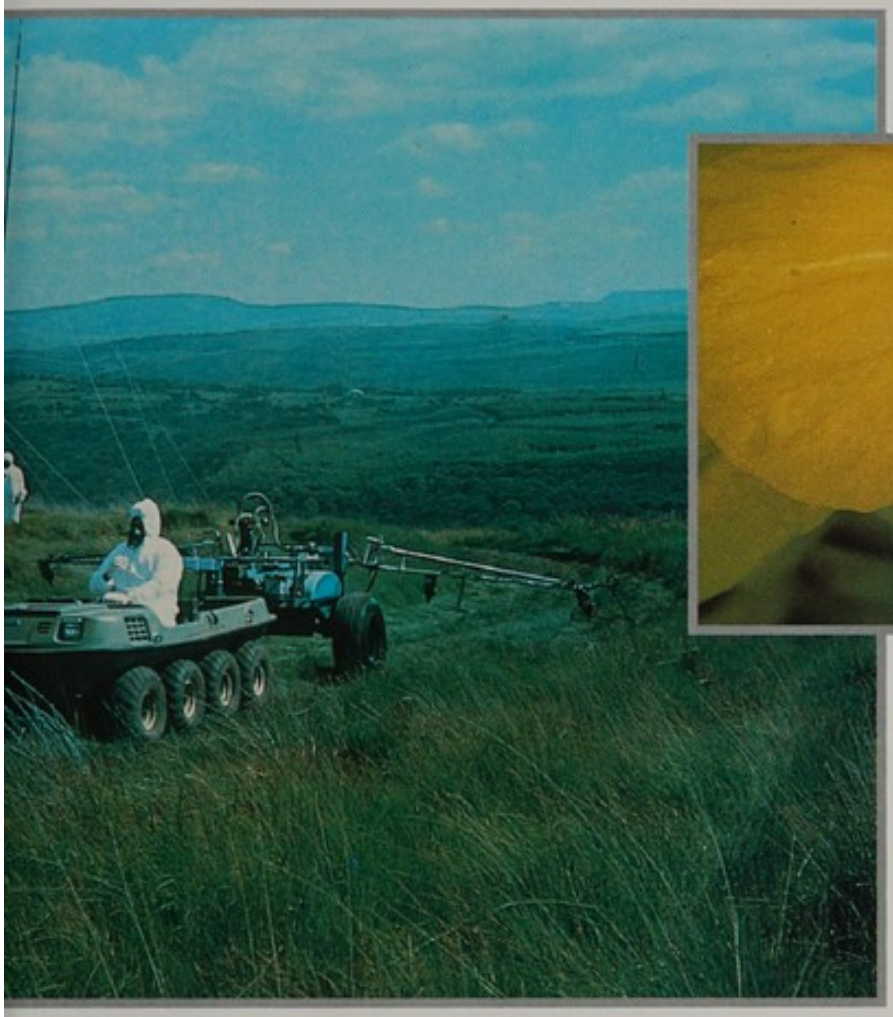
It is the Ministry's policy to ensure human and environmental safety by reducing the use of pesticides to the minimum compatible with the efficient production of wholesome agricultural and horticultural produce.

Aerial application of pesticides



The Ministry is responsible for the statutory regulation of agricultural pesticides – a responsibility it shares with the Departments of Employment, Environment, Health, Scotland and Wales. Strict controls exist over the advertisement, sale, supply, storage and use of approved pesticides. Before approval is given, Ministers in all six departments must be satisfied that a pesticide may be used without risk to consumers, operators, animals or the environment. Ministers are advised by the independent experts of the Advisory Committee on Pesticides. In addition, all pesticides are subject to review at any time if significant new evidence of concern arises. The agrochemical industry covers the full cost of the regulations, including the monitoring of food and surveillance of wildlife. This is done through a levy, which amounted to £5m in 1990, and through fees paid for registration activities. The Ministry is also responsible for licensing activities in connection with vertebrate pest control under the Wildlife and Countryside Act 1981.

Aerial application of pesticides has reduced significantly – by over 90% since 1985. Total tonnage of all pesticides used has also dropped – by 17% since 1979 and 13% since 1988.



By using a microelectrode inserted into the antenna of the cabbage seed weevil and exposing the antenna to individual volatile compounds released by the rape plant, it is possible to discover which components of rape scent are most attractive to the weevil, and to study their influence on insect behaviour.

Research and development into pesticides and crop protection constitutes the largest item in the Ministry's environmental R&D programme. It has an annual budget in excess of £20m and involves some 170 projects. Much of the work is directed towards providing support for the statutory pesticides regulations; the rest towards achieving safer and reduced pesticide use, and more humane controls on vertebrate pests, such as rabbits and foxes. Here are a few examples of the projects currently underway.

Increasing Pesticide Efficiency

Pesticide use can be reduced by improving the efficiency of pesticide performance. One way of achieving this is by being able to identify and predict those situations where field, crop and weather conditions do, or do not, require pesticides to be applied.

To develop reliable forecasting systems for fungal diseases in wheat and barley, the Ministry is funding a programme of complementary laboratory and field experiments which examine the complex range of factors involved in crop damage. These include the role of rain splash transport of spores and the effects of nutrition and wheat variety on disease.

Pesticide efficiency will also be increased if strategies can be established to prevent resistance to pesticides developing. Researchers are therefore currently studying the factors which cause some pests to develop resistance. The research involves the peach-potato aphid, *Myzus persicae*, which is the main vector of economically important viruses of sugar beet and potatoes, and the fungus *Septoria tritici* which destroys the leaves of cereal crops.

PESTS AND PESTICIDES

Integrated Pest Control
Another way in which the use of pesticides can be reduced is to develop alternative forms of pest control. This is the case, for example, with the major pests of glasshouse crops which, because of resistance to pesticides, have now become almost impossible to control by chemical means alone. Integrated Pest Management (IPM) involves the incorporation of biological methods into pest control programmes. As well as research on arable crops, work is currently being funded at Horticulture Research International's Efford and Stockbridge Experimental Husbandry Stations which aims to extend the range of glasshouse crops responsive to IPM treatment. One aspect of the project is the development of basic methods of culturing or rearing promising new biological control agents, such as parasitic insects and insect pathogenic fungi.

Reducing Environmental Hazards
In order to minimise the effect of pesticides on the environment, greater understanding is needed of their non-target side effects.

The Ministry is supporting work to refine the methods employed to detect the impact of pesticides on wildlife and the nature of the consequent effects. For example, ADAS and Reading University are developing immunological assays for the improved detection of the effects of pesticides on serum enzymes in birds and mammals; and, using aviary experiments, are examining the possible behavioural effects on birds of sub-lethal exposure to pesticides, including increased vulnerability to predators.

Pesticides can leach through soils and drainage systems to both surface and groundwaters. To improve guidelines to minimise this, a project is being funded to monitor and model the process whereby pesticide residues are transported in plot studies, lysimeters and small catchments under a range of agricultural systems. Some of the studies focus on small discrete clay catchments, in order to address the impact of different farming practices on the diffuse leaching of pesticide residues to surface waters. The movement to groundwater is being addressed through lysimeter studies. A lysimeter is a column of soil enclosed within an open-topped container buried in the field. Any solutions leaching through the soil column can be collected and chemically analysed.

The Boxworth Project
The Ministry has funded a unique seven year farm-scale project at the Boxworth Experimental Husbandry Farm in Cambridgeshire involving over 100 man-years of effort. The experiment aimed to determine the environmental effects of pesticide use in intensively produced cereals and to monitor the economics of alternative pesticide regimes.

The project compared three levels of pesticide use. The high level was designed to 'insure' against the worst possible levels of crop infestation and involved pre-planned preventive applications of insecticides, herbicides and fungicides. At the 'Supervised' level, treatments were only applied if pests, weeds or diseases exceeded thresholds of economic damage. And in an 'Integrated' System, the 'Supervised' approach was combined with additional modifications in husbandry, for instance, the use of resistant varieties to reduce further the input of pesticides.

As part of the Boxworth project the effect of different levels of pesticide use on non-target wildlife, like this dormouse, was monitored.

Work at Boxworth EHF showed that farmers could reduce levels of pesticides and increase gross margins.

The 'Full Insurance' regime gave the lowest incidence of pests and diseases but produced harmful effects on populations of some non-target species, including beneficial species like beetles and spiders, with the result that the aphids and other pests, on which they prey, were more likely to flourish.

The 'Supervised' regime, on the other hand, did only limited damage to non-target wildlife while producing the best gross margins of the three systems, yielding (at 1989 prices) an average of £477/ha, compared with £443/ha for the 'Full Insurance' treatment and £423/ha for the 'Integrated' System.

Many other studies are carried out at Boxworth on birds, small mammals, soil organisms and plants.

GENETIC CONSERVATION AND MODIFICATION

The Ministry conducts R&D into two areas involving fundamental genetic material. On the one hand, it is working to preserve rare genetic material by funding the Royal Botanic Gardens at Kew to help in the conservation of the world's botanic resources. On the other, it is supporting R&D which is designed to ensure that genetically modified organisms (GMOs) may be used safely.

Conservation at Kew

The Royal Botanic Gardens carries out work of world importance on the conservation of biodiversity. The Ministry's total annual funding of the work at Kew includes £6m for R&D. Field studies in South America, Africa and South East Asia are cataloguing the immense and threatened diversity of the tropics; laboratory studies are examining the potential of the world's plants for new medicines and crops. Kew's Seed Bank holds an internationally important collection of seeds with special emphasis on wild plants from the increasingly degraded arid lands.

In addition to being a public showplace for botany and horticulture to over 1,300,000 visitors a year, and a resource for public and professional education, the 'Living Collection' undertakes the vital role of propagating critically endangered species. Among the plants grown are specimens representing the last known individuals of their species. The information and the techniques developed at Kew will be of crucial importance in future re-introduction programmes.

The 'Living Collection' also manages a natural reserve at Wakehurst Place, a demonstration of the important role which botanic gardens can play in the conservation of native flora and natural habitats.

Conservation of Plant Genetic Resources

In addition to the Seed Bank at Kew, MAFF funds other collections of plant genetic resources which contribute to the international effort to conserve ex-situ genetic material which may be needed for breeding programmes in the future. Collections include the Vegetable Gene Bank at Horticulture Research International, Wellesbourne, the Pea Gene Bank at the John Innes Centre for Plant Science Research, and the National Fruit Collection at Brogdale.

Globularia sarcophylla – a very rare plant endemic to the Canary Islands, propagated by Kew's micropropagation facility and returned to the Islands.

Genetically Modified Organisms

Genetic modification techniques have not yet made a significant impact on the agriculture and food industries but they are expected to be of key importance in the future. Already a few enzyme preparations produced from genetically modified organisms (GMOs) have been cleared for food use as has one genetically modified yeast, whilst clearance has been given for trial plantings of a number of genetically modified plants.

It is important to recognise that genetic modification could possibly present risks to human health and the environment. In order to provide effective safeguards for the use of GMOs, the Government is drawing up regulations which will implement the European Communities' Directive 90/220 on the deliberate release of genetically modified organisms into the environment. The principal effect of the regulations will be to require anyone proposing to release or market GMOs to first carry out an environmental risk assessment regarding them and, where necessary, obtain consent for the proposals.

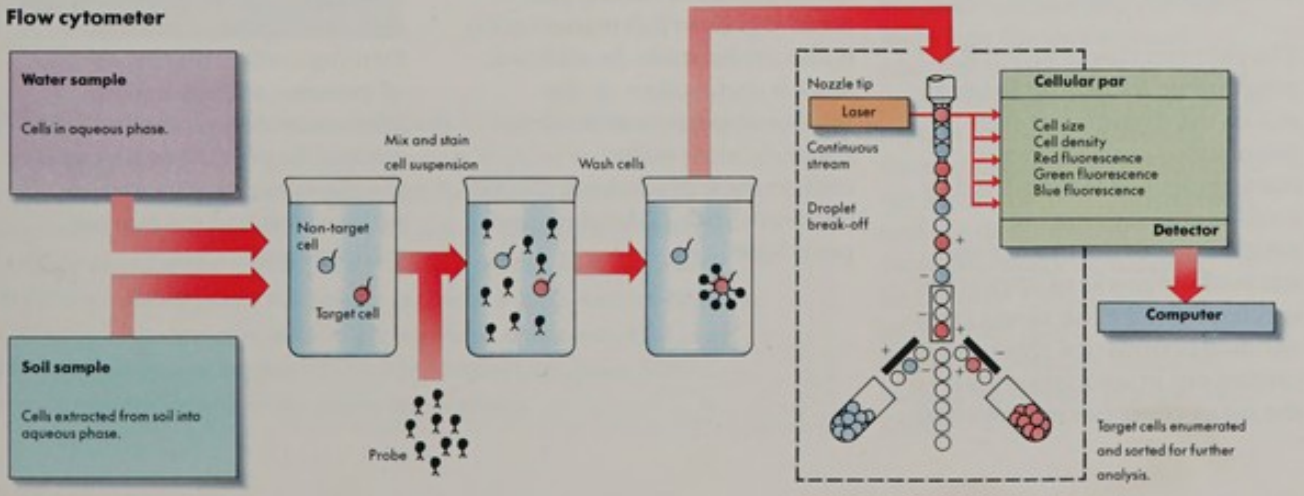
Kew is making a major contribution to the world's botanic resources.

The Ministry's R&D on GMOs is designed to provide reliable scientific information for the preparation and consideration of environmental risk assessment. Already the programme, costing about £¼m in 1991/92, includes seven projects to seek information on the possibility of plant genes spreading through pollen or through viral activity in plants resistant to known viral pathogens; to assess the risk of gene transfer in environments where GMOs might be used agriculturally; and to develop techniques for the detection and quantitative assessment of microorganisms in soil at release sites.

The programme is being developed in close liaison with other funding organisations including the Department of the Environment and the AFRC. It also takes account of the work of PROSAMO (Planned Release of Selected and Modified Organisms), a consortium of nine companies, the Department of Trade and Industry and the AFRC, which funds research in this area.

A flow cytometer can be used to measure the population dynamics of a microorganism after it has been released in the soil. After sampling the soil, the microorganism is marked with a specific probe which enables the cytometer to count that organism alone. This can be used to help assess the risks associated with releasing genetically modified microorganisms.

Flow cytometer



PROTECTING FISHERIES

The Ministry has responsibilities for conserving marine fish stocks, assisting the conservation and management of salmon and freshwater fisheries, controlling fish diseases and carrying out work on a range of aquaculture issues. In 1991/92 it is envisaged that £4.7m will be spent on R&D in these areas.

Conservation of Fish Stocks
The conservation and management of fish stocks involves a series of decisions about the quantity of fish which can be caught as well as a wide variety of other issues including the type of gear which may be used in particular fisheries or seasons. Many of these decisions fall within the European Community's Common Fisheries Policy as well as our own national and local regulations. It is in order to make the decisions necessary for successful fisheries conservation and management that the Ministry carries out fisheries research and development work.

The fisheries conservation R&D programme focuses on fisheries stocks, the dynamics of fish populations and fisheries management. It is supported by a substantial monitoring programme of the catches and status of the stocks of important species. Because fish stocks cross national boundaries, this work is carried out in association with the many countries interested in the various stocks and co-ordinated on an international basis to make maximum use of the scientific resources and data available.

Biological and modelling projects designed to increase our understanding of the nature of fish populations and of recruitment into fisheries are an important part of the R&D. The migratory and reproductive behaviour of fish are studied to increase our understanding of both the geographical and the seasonal distribution of the stocks, as well as the variations in spawning success and in recruitment to commercial fisheries.

Other studies are directed at factors affecting the survival of larvae, its implication for the recruitment of young fish to fishable stocks, and the interaction between different species, including the predation of one on another. The development of fishing gear to achieve greater fish conservation is also under study. In addition, work is undertaken on the relationship between seals and fisheries, and on the conservation of whales and small cetaceans such as dolphins and porpoises.

Salmon and Freshwater Fisheries
The Ministry is responsible for providing the framework within which the National Rivers Authority (NRA) carries out its statutory duty of managing and conserving salmon and freshwater fisheries. An active R&D programme is centred at the Ministry's Lowestoft Laboratory. At the international level, scientific advice is provided to the International Council for the Exploration of the Sea and, through the European Commission, to the North Atlantic Salmon Conservation Organisation.

Fish Cultivation
Considerable resources have been invested in research into the genetics, nutrition and husbandry of farmed fish, particularly salmonids. Much of this research has now been completed successfully and its results transferred to our thriving aquaculture industry. Current work on fish cultivation is exploring the possibility of farming certain marine species of promise, such as halibut, lobsters, and some shellfish species. Important new aspects are the interactions between aquaculture and the marine environment.

Electronic tagging provides vital information on the migratory behaviour of fish. Here a plaice with an acoustic tag is being released at sea prior to tracking by the research vessel.

Fish surveys conducted from MAFF research vessels indicate the distribution and abundance of different age groups of commercial species, such as cod and haddock, and provide essential data for fish stocks management.

The fish farming industry has expanded rapidly over the last 15 years and there are now more than 800 fish and shellfish farms in England and Wales. Since 1985 all such farms have had to register with the Fisheries Departments. Registration forms an important part of the controls designed to prevent the introduction and spread of serious diseases of both fish and shellfish, controls which have helped to ensure that farmed and wild fish stocks have remained free of the serious salmonid diseases, viral haemorrhagic septicaemia (VHS) and infectious haemopoietic necrosis (IHN). The Ministry's fish disease R&D provides essential support for the disease control process.

Controlling Fish Diseases

R&D on the control of fish diseases includes two principal projects. One involves assessing the possible impact of the introduction and spread of shellfish diseases and parasites, including the threat posed by non-native species. The second seeks to improve the detection of certain serious diseases of farmed fish, the identification of the means of their transmission, and the development of new rapid diagnostic techniques. In October 1990, it was announced that a new fish diseases laboratory would be built at Weymouth at a cost of £10m.

PROTECTING THE MARINE ENVIRONMENT

Uncontrolled disposal of waste to the sea would damage marine life and, because fish can accumulate pollutants, it could also create hazards to human health. The Ministry has a statutory responsibility to protect the marine environment against pollution and will spend some £3.5m in 1991/92 on relevant R&D.

Among the many different projects in the programme are assessments to determine the effects of pesticides, including anti-fouling paints and other novel pollutants, on marine and freshwater species so as to ensure that hazard evaluations are as comprehensive as possible. Past work on the anti-fouling paint TBT led to a ban on its use on small boats. Bioassays are under development for assessing the toxicity of dredged spoil dumped at sea and to act as indicators of water quality. A study is being undertaken to determine whether the disinfection of sewage can make the effluent toxic to marine life.

'Smart' bottom lander system being deployed to study fine sediment dynamics.

The programme includes projects to quantify the extent to which natural estuarial extraction processes prevent river-borne nutrients from reaching the sea; and to investigate the speed with which areas of seabed dredged for sand or gravel are recolonised with marine flora and fauna.

The Ministry makes major use of computer programs of processes in the marine environment. As new procedures become available, MAFF is improving its models of the movements of contaminants in the North Sea and developing techniques for studying the extent to which contaminants bound in sediments are transported. In the same way, work is in hand to refine the existing models of the environmental processes which affect the dispersion of radionuclides discharged by the nuclear industry.

MAFF research vessels monitor many aspects of the marine environment.

Marine environmental protection naturally demands international collaboration and the current focus for this is the North Sea Task Force set up by the Ministerial North Sea Conference to assess scientific aspects of the marine environment. MAFF is playing a key role by linking in its North Sea monitoring and research programmes. Among the assignments for which the Ministry has assumed responsibility are definitions of quality assurance and quality control procedures for nutrient analytical methods in marine waters and the development of a standard oyster embryo bioassay for general use as an environmental indicator.

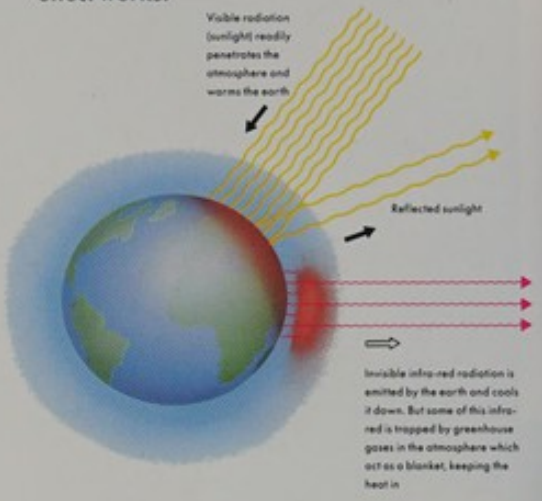
MAFF supports a wide ranging research programme into marine water resources.

Computer models of the movement of contaminants in the North Sea are being developed and continually improved.

The disposal of waste at sea is regulated through a licensing scheme under the Food and Environment Protection Act 1985. No waste disposal is licensed if it would cause harm to the marine environment. The Ministry also seeks to minimise sea disposal by requiring that wastes be disposed of on land if this is practicable. In conjunction with the Department of the Environment, MAFF also controls the nuclear industry's discharges of radioactive waste to the sea by pipeline, and it is consulted on proposals for the discharge of other wastes and on applications to dredge the seabed for sand and gravel. The Ministry is responsible for advising on the marine environmental implications of nuclear emergencies and incidents such as oil and chemical spills at sea.

CLIMATE CHANGE

How the greenhouse effect works.



Global warming, due to the greenhouse effect, on the scale currently modelled by the Inter-Governmental Panel on Climate Change, could have a profound effect on agriculture in the United Kingdom. In order to address the potential implications, three questions require answers.

- How might climate change affect the type and location of the crops which can be grown in the UK, and their relative profitability?
- Are there steps that could be taken to protect the viability of this country's farming under such conditions?
- Are there steps which might be taken to reduce agriculture's contribution to greenhouse gas emissions?

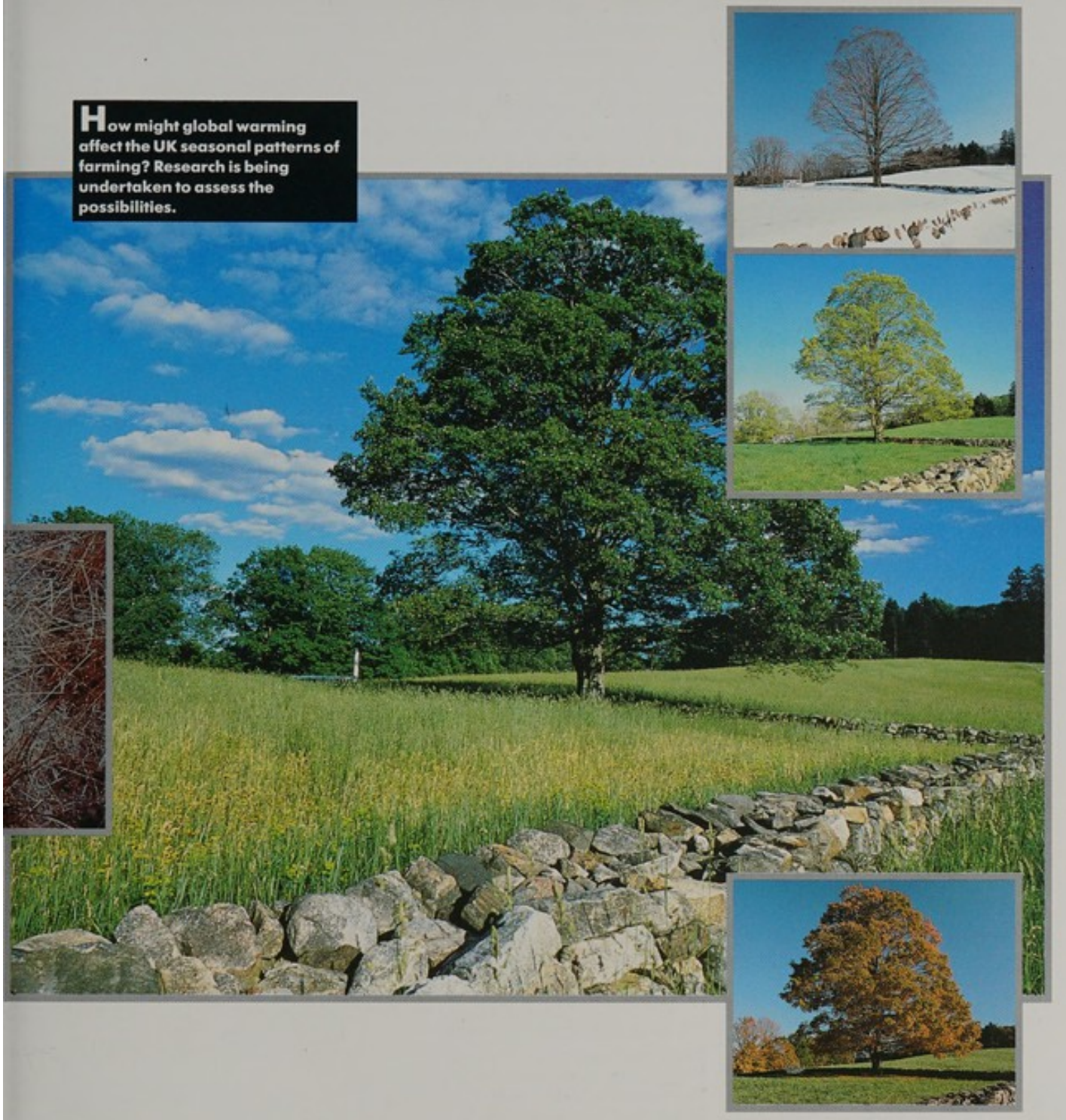
The Ministry is already conducting research into these issues. In 1991/92, the programme, costing nearly £1m, will concentrate on the potential impacts of climate change on agriculture, and on the control of greenhouse gases such as methane and nitrous oxide. Further research, based on the outcome of this work, will be directed at response measures.

A main aim of the programme is to provide preliminary estimates, at a national level, of the likely scale, extent and rate of impact of climate change on soils, crops, pests and diseases.

Agriculture is thought to contribute around 20% of methane emissions in this country: cattle are the main source.

The Institute of Grassland and Environmental Research at Aberystwyth is breeding drought resistance into ryegrass.

Computer models are used to predict the impact of climate change on crop growth and development. However, these models have been constructed using data from experiments conducted under current conditions and the predictions are extrapolations outside the models' known areas of accuracy. Work is planned at the AFRC Institute for Arable Crops Research to test the predictive ability of such models. This will be done by growing plants in combinations of conditions that could prevail in the future, measuring various crop parameters and processes, and comparing these with the predictions from the models. If the measurements are



How might global warming affect the UK seasonal patterns of farming? Research is being undertaken to assess the possibilities.

significantly different from the predictions then the reasons for this will be investigated and the models altered accordingly.

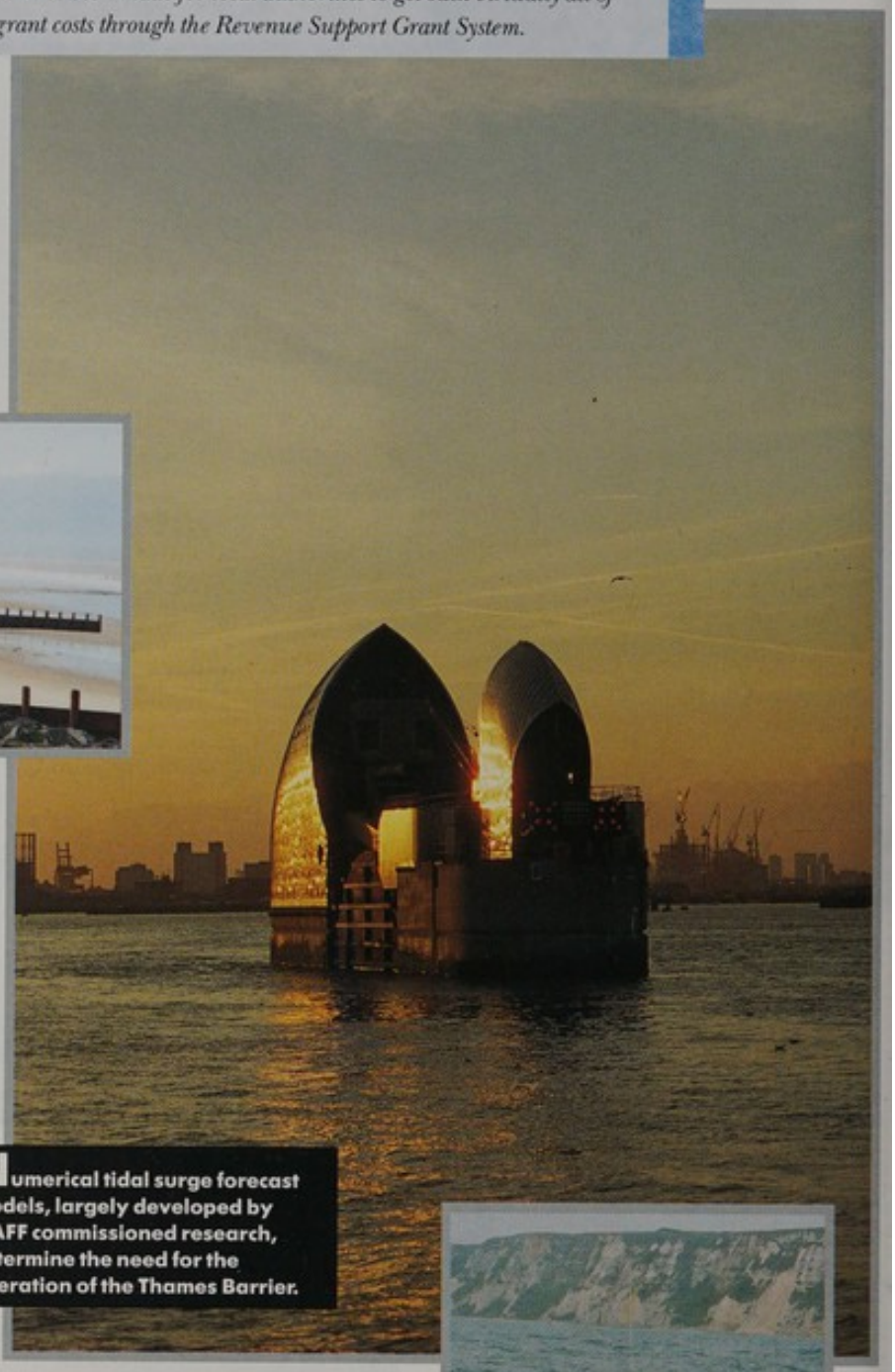
Agriculture contributes around 20% of the methane emissions in this country and, weight for weight, the impact of methane on the greenhouse effect is 21 times that of the most common greenhouse gas, carbon dioxide.

However, methane persists in the atmosphere for an average of only 10 years, compared to a much longer atmospheric lifetime for carbon dioxide. Enteric fermentation is a major source of agricultural methane, with a large proportion deriving from farm animals, particularly cattle, and much of the remainder from the anaerobic digestion of farm wastes.

Methane is a natural product of the ruminant digestive system and is released into the atmosphere as the animals belch. The ADAS Feed Evaluation Unit is conducting research aimed at gaining increased understanding of the function of the rumen, the first compartment of the stomach of ruminants; and of the effects of different types and levels of diet on methane production.

The Ministry is responsible for ensuring that flood and coastal defence work in England is adequate. It grant aids a substantial proportion of the capital works programme implemented by the drainage and coast protection authorities and, in recent years, funds for these works have been increased significantly, particularly for the improvement of the defences along the east coast. Also, special arrangements have been made for local authorities to get back virtually all of their net-of-grant costs through the Revenue Support Grant System.

FLOOD AND COASTAL DEFENCE



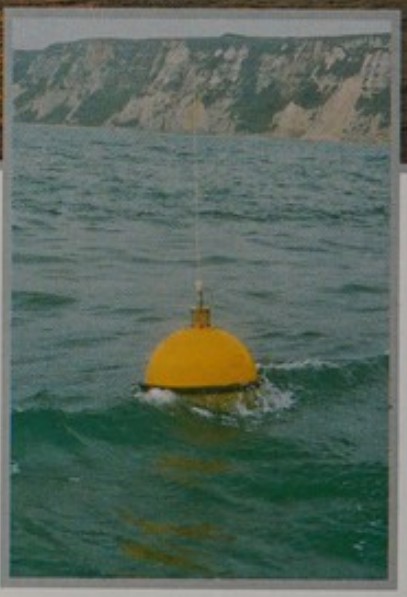
Numerical tidal surge forecast models, largely developed by MAFF commissioned research, determine the need for the operation of the Thames Barrier.

Flooding by rivers and the sea and the erosion of the coastline by waves and weather can endanger life and property. Measures are taken to alleviate inundation of the land and to avert the permanent destruction of the coastline. The Ministry funds R&D on flood and coastal defence to the value of some £2.5m a year to ensure that investment is properly targeted.

The basis of the Ministry's approach is the study of coastal processes and river flows, particularly at their extreme limits, and the recording and analysis of this data. Research work is carried out on the Ministry's behalf by contractors such as the Natural Environment Research Council, HR Wallingford, universities, polytechnics and other research establishments.

The programme is also designed to assist in planning strategies to respond to changes in weather patterns and sea level rises which might result from global warming. Over half the R&D budget in this area is directly relevant to the effects of global warming.

Among the projects concerned with global warming are a study of the changes in sea level around the United Kingdom, and a broad valuation of the assets, especially the environmental resources, to be found in the coastal zone and their sensitivity to a range of possible sea level rises.



Waverider buoys provide data for calibrating prediction models to assess, among other things, possible extreme wave conditions due to climatic change.

Where to find out more

If you would like further information about MAFF's Environmental Research and Development work or on any of the subjects or projects covered in this brochure, please write to:

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BRUCE COLEMAN (LANDSCAPE ONLY) JOEL PHOTOGRAPHIC ZEFA

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