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MERLEWOOD RESEARCH AND DEVELOPMENT PAPER

No 82

ECOLOGY IN THE 1980s

I. Report of internal discussions at Merlewood:

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C O N T E N T S

1. INTRODUCTION

Mr J. N. R. Jeffers initiated a discussion on Ecology in the 1980s, posing four questions to the staff of the Institute of Terrestrial Ecology (ITE):

- What are the really important ecological issues for the 1980s?
- What aspects of ITE's present programme are relevant to these issues?
- What do we need to do to increase the relevance of our research in the 1980s?
- How can we best work on those issues with other Institutes and with the Universities?

As a first stage these questions were aired within each of the ITE Stations. Preliminary discussions in Merlewood identified a number of subjects which formed the basis of four internal workshops. These workshops provided a brief review of the subjects and raised many questions which could not be considered in any depth. The present paper provides a summary of the internal discussions at Merlewood under the subjects of pollution, agriculture, forestry and land use, the four sections being prepared by separate individuals who introduced the topics. However, the sections reflect the active participation of all the staff at Merlewood.

The internal discussion helped to identify some of the issues, and the related research, as seen by ecologists. The second stage in the discussions is to hold an open forum in which the relevance of ecological research in the 1980s will be discussed with a variety of people representing different user interests. The results of that forum will be produced in a subsequent Research and Development Paper.

The initial identification of subjects has given a strong bias towards applied research. The discussions indicated the trends in land use which are likely to occur in the 1980s and focussed attention on specific aspects which are, or could be, the subject of research. There is a danger that this approach overlooks the importance of fundamental research on the ecology of populations and processes. Experience in applied research in North America indicates that solutions to environmental problems are most satisfactory when they are derived from a long-term programme of basic ecological research. When a quick answer to a complicated question is required, it is better to rely on fundamental understanding of the processes rather than on empirical research. Therefore it is important to identify and develop the components of the basic research programme of ITE which, while of interest in their own right, can help to answer the applied problems which will arise in the future. The Merlewood discussions did not adequately consider the application of basic research, but it was examined in some detail in the discussions at Bangor Research Station and may form an important subject for future discussion.

2. POLLUTION IN THE 80s: THE DEVELOPMENT OF POLLUTION RESEARCH IN ITE

S. E. Allen

Existing and recent pollution studies in the Institute

Insecticides (studied from 1962).
- all work carried out by Monks Wood staff by the Animal Function subdivision.
  Aspects studied - distribution, effects and physiology.
  Emphasis on persistent organochlorines and residues and on similar industrial intermediates (PCB etc).
  Principal affected organism - birds.
  Some past work carried out on non-persistent organophosphorus insecticides.

Herbicides (studied from 1965).
- occasional work carried out at Monks Wood, isolated studies elsewhere (eg. Asulam at Merlewood).
  Aspects studied - distribution, effects.
  Recent studies at Monks Wood have concentrated on aquatic herbicides (eg Cyanotryn, Eulan).

Fungicides.
- very little done, mostly at Monks Wood (links with heavy metal research).

Industrial products.
- intermittant, Monks Wood staff occasionally consulted. Recent Mersey incident involving bird poisoning with tetraethyl lead can be included. Some Merlewood Chemical Section work also in this category.

Heavy metals (studied from 1968).
- most projects at Monks Wood, some small contract jobs carried out by Merlewood Chemical Section.
  Aspects studied - distribution, effects and physiology.
  Affected organisms - mostly birds and aquatic invertebrates.

Fluorine (studied from 1970).
- all research carried out by Bangor staff.
  Aspects studied - distribution, effects.
  Affected species - lichens, some grasses/herbs (Plant Biology Subdivision)
  - small rodents, foxes and avian predators (Vertebrate Subdivision).

Sulphur oxides (studied from 1974).
- shared between Bush and Brathens staff, heavy support by Merlewood Chemical Section.
  Aspects studied - distribution, intensive monitoring at Devilla, some plant damage studies (Bush).
  Affected plants - trees (mostly conifers).
  Associated pollutants also measured - NO_x, O_3.

Radionuclides (studied from 1978).
- all work being carried out by Merlewood staff.
  Aspects studied - distribution.
  Affected groups - vegetation, soil, birds.
  Main interest - transuranics.
  Research only just getting underway.

Minor pollution studies.
- Road salting (Colney, Merlewood).
  Eutrophication (Colney, Monks Wood, Craighall Road, Merlewood).
  Industrial waste disposal - Redland Purle (Monks Wood).
  Industrial spoil reclamation (Bush).
  Contract analytical/advisory work on oil pollution accidents (Merlewood Chemical Section).

Abbreviation note

Distribution - studies concentrating on geographical distribution of pollutants.

Effects - studies concentrating on effects on populations, behaviour, breeding etc.

Physiology - studies concentrating on the mechanism of uptake and physiological changes within target species.

Points identified by discussion group at Merlewood

There is a need to clearly define ITE's research interest in pollution. This should be confined to organisms and ecosystems within the semi-natural terrestrial environment. This excludes components of the marine, freshwater and atmospheric environments, except for their part in supplying or receiving pollutants to and from the terrestrial environment. Agriculture, production forestry and urban/industrial communities are not considered to be semi-natural. Because of the limit on resources, it is not considered desirable for ITE to be involved in pollution monitoring studies, except in so far as they are required in immediate support of research studies.

'New' pollutants were not predictable, but in general increasing pressures on the economy and resources must result in the release of larger quantities of pollutants, eg more nuclear power stations would ultimately lead to increasing levels of radionuclide release.

In order to be able to predict the threat of new pollutants, it is necessary to consider manufacturing processes, industrial location, application, use of products and waste materials produced. There is a need to join in early planning on disposal and use of spoil material from eg coal, by developing experience in the treatment and utilisation of toxic wastes to produce a healthy growth medium. Extension of research to investigate tolerant species, with particular attention to earlier recolonisation and the use of varieties able to withstand desiccation.

As well as threats from manufacturing processes and from the widespread use of agrochemicals there are unknown pollution hazards from the impurities present in the applied chemicals, for example dioxin which is present as an impurtiy in 2.4.5-T.

There is a need to look at the wider ecosystem implications that are involved in pollution research, in particular through the examination of distribution and movement in order to identify main pathways and sinks. Effects are of importance but there seems less justification for the use of our limited resources in examining the physiological processes involved.

ITE may have a role to play in drawing together data from separate organisations and applying an ecological understanding to help to anticipate and predict changes.

There is a need for more flexibility in project arrangement and to allow more free capacity for research response as pollution incidents occur or develop. Supplementing this type of work, a desk study should be carried out to collect data and set up models to help decide subsequent investigation routes - reference the radionuclide desk study which was particularly useful for identifying main research areas.

Most of our existing studies are concerned with pollutants in isolation (possible exception $SO_2 + NO_x + O_3$). It is important to consider synergistic effects, not only because two or more pollutants may be more damaging when acting together, but also in case a pollutant may be activated by the presence of an otherwise inert material.

Accumulation levels of pollutants differ markedly between different organisms, and pathways may be more complicated than is usually allowed for. The effect of the pollutant depends on age, health, genetic variety of target organism. This is a research area that could be developed further.

There is a need for examining fluorine pollution effects in locations away from aluminium smelters. Areas around brickworks, fertiliser plants, steel works, nuclear fuel reprocessing plants are all subject to fluorine pollution. Comparison with these other situations would allow more information to be obtained from synergistic effects.

There is a need to keep abreast of research on the effects of atmospheric carbon dioxide accumulation resulting from the combustion of fossil fuels and reduction in world vegetation cover. These effects could be enhanced in limited areas under particular weather conditions. ITE's main effort in this field would have to be as a desk study or modelling exercise.

There seems to be some scope for ITE to advise on the use of indicator species for various roles involving pollution. In testing new herbicides, advice on the suitability of representative target species could provide a better insight into the problems anticipated in field use. Similarly, we might advise on the use of 'absorbent' species suitable to serve as a filter belt around certain pollution sources.

There is a great deal of concern about the impact on the natural environment from the intensive application of fertilisers and farm slurry. Although the main affected areas are in the agricultural lowlands, there is increasing evidence of damage in upland Britain where there is more effort going into land improvement, and where the ecosystems are often finely balanced.

There is a case for developing more research to assess threshold levels of toxicity and to compare the effects of long exposure to small doses with short exposures to high doses. Studies of this type should though be related to likely exposure levels, there seems little point for us to expose target material to excessive concentrations of pollutant.

What other organisations are wholly/partly committed to pollution work in UK and how far do their programmes overlap with ITE's interest?

General review of pollution research

The Institute's interest in pollution research has progessively widened over the past fifteen years, such that now almost all the major groups of chemical pollutants that pose a threat to the natural terrestrial environment are being studied to some extent. Unfortunately, because of the complexity of the problems involved and because resources are relatively limited, research progress has not always been as rapid as one might have wished. We must therefore ask ourselves whether we are wise to commit ourselves to new lines of pollution research in the eighties before checking whether existing projects are profitable.

Our staff have now been involved in research on the persistent organochlorines for almost eighteen years. Much of the work involves monitoring their levels in avian species and in a sense the longer these tests are carried on, the stronger the case becomes for keeping up the studies. Nevertheless, since most of the chemicals have now been banned the tests could be carried out much less frequently than hitherto. It is also questionable whether so much effort should still be put into looking at the physiological changes induced when birds are treated with high doses of these insecticides. The experience of this group would be more profitably employed in looking at the effects of the new pest sprays being used by the Forestry Commission.

Herbicides

The history of research, both in the Institute and former Nature Conservancy, into the effects of herbicide application goes back nearly as far as the work on insecticides. Most of the work though, has been spasmodic arising in response to some particular environmental incident. Nevertheless there is as much interest in the effects of herbicides today as there ever was and there are undoubtedly major gaps in our knowledge about these chemicals. Before new chemicals are introduced manufacturers carry out tests in response to government regulations using selected target species, but there is no evidence that ecological opinions have been sought in the design of these experiments or choice of species. The selection of test species appears to be subjective and confined to weeds associated with particular agricultural crops.

Herbicides are usually applied by spray, some of which has been reported to drift up a mile from the point of application. In the case of aerial spraying, the spread of the herbicide must be even greater. Similarly when treating aquatic weeds the herbicide spreads through the water course and again can threaten plants at considerable distance from the treatment area.

Another aspect of herbicide use which needs examination is the question of biodegradability. There appears to be differences of opinion about the extent of breakdown of some herbicides, and in what circumstances this could occur. Many of the formulations on the market are a mix of chemicals and even if the principal agent readily breaks down this has been shown not to occur in the case of some of the other chemicals. Apart from the difference in degradability, there is concern about the toxicity of some of the chemicals included in the formulation, or present as impurities. This of course has recently hit the headlines in the case of 2,4,5T and dioxin.

These are all aspects which could be taken up by the Institute as major research subjects. To give two examples of wide spectrum chemicals which are in widespread use, one might cite Paraquot and Roundup (glyphosate). These are freely available throughout the country and no attempt appears to have been made to determine whether natural vegetation is being seriously affected. There is a need in the case of these chemicals, but also for newer herbicides, to approach the manufacturers and point out that Institute scientists have much to offer. We can advise on the choice of representative test species, the effect of age structure, seasonal influences and suitability for different situations. These are research areas which have potential for contract earnings in the eighties. There are reports that other government research organisations are taking more of an interest in the ecological effects of herbicides. We do not want to miss the boat!

Heavy metals

Of all the Institute's present pollution projects, probably the work on heavy metals is that which could be reduced with least harm. A tremendous amount of research is being carried out into heavy metal effects in the universities and some of this overlaps our own field of interest. There is some justification for ITE leaving this subject area, possibly after ensuring that some of the work is continued by NERC grant support, so that we can concentrate on those pollution research subjects where our specialised expertise and facilities are not duplicated.

Fluorine

Another area of research which needs to be reassessed is that dealing with fluorine. The considerable experience at Monks Wood which would be released by the rundown in heavy metal work could be put to good use in expanding the fluorine research. So far all the investigations have been carried out in the vicinity of one emitting source, the Anglesey aluminium plant. This suggests only a restricted range of habitats, flora and fauna are being examined. Virtually nothing has been done in the other high or intermediate fluorine pollution areas around brickworks, potteries, fertilizer plants or steel works. Extending the research studies to these other pollution zones would be especially valuable because it would introduce another array of co-pollutants. This is particularly relevant in the case of fluorine because there is some evidence that synergistic chemical effects are of particular significance. Apart from the need to consider these aspects further justification of the fluoride research programme can be sought through the exceptional build up of fluorine levels in many animals. The effects of this accumulation and the subsequent movement of fluorine in the food chain are matters which need continued support.

Sulphur and radionuclides

The considerable public interest in both sulphur and radionuclide pollution and the acknowledged threat of these pollutants to the environment means that these projects must be maintained as high priority research topics well into the eighties. Indeed because of the international concern over sulphur pollution effects this could be considered as an expansion subject. However more attention should be paid to demonstrating the effects of high sulphur levels rather than looking at its distribution. The neglect of high pollution areas in industrial England in favour of relatively clean environments in Scotland is something which needs correcting.

Fertilisers

There is another pollution threat which arises from the use of agrochemicals. Chemical fertilisers, farm slurry and partially treated sewage have been used heavily in lowland Britain for many years now but the amounts still increase. The chemicals of concern are nitrogen as nitrate, phosphate and organic matter. Most of these find their way into the ground water or into the water courses. The effects of eutrophication from this nutrient enrichment are well documented and many of our water research organisations are looking into this problem. Some of the other effects from these intensive farming practices are however receiving less attention. The direct effect of high nutrient levels on hedgerow communities and on the woods and meadows in the intensive arable areas must be considerable. Even more serious, many upland pastures are subject to heavy fertiliser application and many of the finely balanced ecological systems in the highland zone of Britain must be threatened. Perhaps this entire subject area can be coupled with the effects of clear felling as a prime research topic for the eighties.

A more immediate practical problem that stems from the intensive use of farm slurry is that of heavy metal enrichment. There is increasing evidence of the accumulation of certain heavy metals, especially cadmium, in soils subject to frequent dressings of slurry and sewage. It is open to question whether metals are moving into the surrounding natural environment.

Carbon dioxide

So far the discussion has been concerned with pollution problems with which the Institute has been associated for some time. It is true that work on excessive use of agrochemicals has not been a main line research subject but many other projects have overlapped with this problem. One entirely new research area which must be considered concerns the build up of carbon dioxide and particulates from the combustion of fossil fuels. This is a problem which is aggrevated by the vast amount of forest clearance which is worrying environmentalists the world over. There is no clear general agreement about the significance of this form of pollution, particularly on the climate resulting from the 'greenhouse' effect.

As far as the Institute is concerned the question is, whether any research effort on our part could make a useful contribution to world knowledge. In particular could we, as a biological organisation with special responsibility for a relatively small country, benefit from entry into this research area?

It is suggested that time might be profitably spent on a desk study possibly developing into a modelling exercise. This could be done using world data but with the problems of Great Britain in mind. Information on climatic trends might be assembled and the likely effect of these trends (if any) could be superimposed on the productivity and growth characteristics of our own natural communities, with possible implications for land management and use. However, the complexity of the problem is such, that it is difficult to envisage ITE ever being involved in experimental and field trials.

Other pollutants

Apart from the chemical pollutant groups already being investigated in the Institute, or those mentioned above, no other pollutant at present in use, or likely to be introduced, stands out as being a major environmental threat on a national scale. Up to recently, the heavy discharge of surfactants from industrial and domestic sources was a matter of concern. However, due to changes in formulation the synthetic detergents are now broken down more readily, although they still cause trouble locally because of their effect on aeration or because of their contribution to nutrient enrichment. The search for substitutes for the phosphate 'builder compounds' which are contained in most detergents may result in the introduction of unsatisfactory substitutes. Some time ago the use of nitrilotriacetic acid as a complex builder had toxic side effects.

There always will be the occasional incident, where a pollutant has been discharged into a water course or dumped in some rural situation, with the result that wild life or a natural habitat is threatened. The Institute must always have sufficient slack in the system to allow these incidents to be tackled if they are considered of sufficient importance. There are often considerable benefits to be gained from becoming involved at an early stage since some of our most important pollution issues have developed from what at first appeared to be minor incidents. Apart from meeting a need at the time, our continued involvement in these *ad hoc* investigations does add to our overall experience and authority in the field of pollution.

One of the most important aspects of pollution chemistry which deserves further investigation is the way that two or more chemicals either accelerate or retard the damage that may be produced by a single pollutant chemical acting alone.

Chemical synergism

This synergistic effect may result from a catalytic process or from a sequential chemical reaction. For example it has been found that fluorine can be more damaging in the presence of hydrogen chloride vapour than when acting alone. The same is believed to apply when sulphur and nitrogen oxides are present together in the atmosphere. To unravel the chemical processes involved in this copollution incidents would overstretch our present resources. However our job should be to show that these processes are occurring and to demonstrate the extent of the damage. This might mean that we have to spread our research studies to include a greater range of sites so that a different pollution mix can be examined. As already mentioned, this could be done for fluorine. Where we monitor levels of pollutants, as in the case of Devilla, we should carry out corresponding tests on target species in order to assess pollution damage in relation to the pollution mix.

Industrial reclamation

The problem of industrial reclamation can be considered as another aspect of pollution. Experimental studies on the colonisation of industrial spoil have been carried out for a number of years, particularly at Bush. We must also not overlook the practical experience gained by our nursery staff as a result of the exercise to landscape the old railway yards surrounding the new SRC/NERC headquarters building. The theoretical and practical knowledge we have in the Institute is probably more adaptable for this type of pollution research than for most others and there is a strong case for making this an expansion area in the eighties. When we move out of the present recession there is a real possibility of attracting contract money for reclamation research, and the intervening time could be used to good effect by developing our experience.

More could be done in looking at the choice of species for different industrial situations and at the cultivation of appropriate genetic varieties to resist unfavourable growth media. In most of the planting schemes carried out in the last twenty years the principal hazard has been loss through desiccation coupled with toxic effects. Far more attention needs to be paid to the selection of varieties which are resistant to draught conditions. Given the nursery facilities we have in the Institute there is plenty of scope for experimental work to solve some of these desiccation and toxicity problems. Work should also be established to develop improved growth media and to finding ways of encouraging more active soil/fauna microbial populations and in particular mycorrhiza.

Need for wider ecosystem assessment

Almost all of the pollution research projects in the Institute have developed in response to external pressures. The projects have therefore been developed to meet the immediate problem. In very few cases has sufficient time been set aside to carry out a detailed initial desk study. Experience with the radionuclide projects has demonstrated this to be a particularly valuable exercise and one that should be followed not only at the start of new research studies but at times of reassessment so that a problem can be better appreciated in perspective.

Perhaps the greatest need, which is shown by most of the Institute pollution research projects, is to look at ecosystem impact in the widest sense. There is a need to develop compartment models for entire ecosystems to take into account factors such as critical pathways, transfer rates, threshold toxicity levels, pollutant half lives and to identify temporary or permanent retention zones. With this information it would sometimes be possible to make predictions about pollution hazards and to anticipate further pollution threats.

Some specific recommendations for the development of pollution research in the 80s

1. Expand research on the ecosystem impact of herbicides.

2. Modify the fluorine programme to include other emission sources and to make greater use of Monks Wood experimental experience.

3. Expand research into the effects of intensive farming practices, especially in relation to upland Britain.

4. Develop our expertise in industrial reclamation.

5. Establish a desk study review to look at the likely effect on British ecosystems of the global build up of carbon dioxide.

6. Place more emphasis in the sulphur programme on pollutant effects and extend the research to include the higher pollution areas of England.

7. Maintain the radionuclide programme at its present level.

8. Place greater emphasis on pollution impact modelling studies.

3. ECOLOGICAL IMPLICATIONS OF AGRICULTURAL TRENDS IN THE 1980s

J. E. Satchell

Agriculture in Britain occupies 2.7% of the working population and produces only 2.5% of the gross domestic product, but as it uses 79% of the country's 24 million hectares of land, it undoubtedly has more effect on the ecology of soils, vegetation and wildlife than all other land uses combined.

Forecasting the ecological consequences of agricultural developments in the coming decade hinges on predictions of future farm practice derived as extensions of trends observed in the recent past. These have been analysed in the 1975 Government White Paper 'Food from our own resources' and subsequently in a series of short reports under the general title 'Agriculture into the 1980s' prepared under the aegis of the Agriculture Economic Development Committee. Following Britain's entry into the EEC, a further White Paper, 'Farming and the Nation'. was published in 1979. The factual information which follows is drawn mainly from these sources and from the 1979 report of the Royal Commission on Environmental Pollution, 'Agriculture and Pollution'.

One of the most marked trends since World War II is the size of agricultural holdings. Gross output per £100 of total inputs increases markedly with increases in farm size up to about 120 ha: beyond this average efficiency remains about the same. Since the average size of holding in the UK is 60 ha, amalgamation of small farms seems likely to continue but this may be inhibited by falling prices in real terms of agricultural produce, by lack of liquidity and by the increasing costs of servicing capital loans. Smaller farmers will tend to have chronic low incomes because of competition from larger enterprises. Between 1955 and 1977, the number of persons engaged in agriculture fell by 57% and there is no indication of any reversal of this trend in the 1980s.

During the next 35 years the world population is expected to double. If industrial development in the third world raises the average level of real incomes per head, food demand can be expected to more than double. In any event, competition for world food supplies can be expected to increase sharply and even allowing for some rationalisation of production between different climatic regions within the EEC, the UK policy of reducing its dependence on imported foods can be expected to continue.

Britain imports nearly half of its food. This includes tea, coffee and other commodities from hotter countries but one third of all food imports are of products which can be grown in temperate climates. Table 1 shows that, allowing for the use of cereals in animal feedstuffs, nearly half of the cost of these imports is attributable to livestock products and production.

TABLE 1 UNITED KINGDOM PRODUCTION AND IMPORTS OF AGRICULTURAL COMMODITIES IN 1977

PRODUCT	SELF SUFFICIENCY (%)	IMPORTS (£ million)	
Animals, Animal Products and Animal Feedstuffs			
Poultrymeat and Eggs	100		
Other Meat	82	974	
Butter	32		
Total Milk and Milk Products	68	460	1742
Animal Feedstuffs		210	
Live Animals		98	
Fruit and Vegetables		1108	
Potatoes	81		
Cauliflowers	92		
Tomatoes	39		2356
Apples and Pears	44		
Cereals	67	820	
Sugar	37	428	

TABLE 2 COMPOSITION (%) OF UK AGRICULTURAL OUTPUT AND EXPENSES BY VALUE 1973-76

OUTPUT	%	EXPENSES	%
Livestock and Livestock Products	66.4	Feeding Stuffs	31.8
		Hired Labour	18.2
Farm Crops	22.1	Machinery and Fuel	16.6
Horticulture	10.8	Fertiliser and Lime (before subsidy)	8.0
Other	0.7	Farm Maintenance	7.6
		Livestock and Seeds	6.0
		Interest and Rent	3.2
		Miscellaneous	8.5

Trends in Livestock Production

UK agriculture is predominantly livestock production which accounts for 65 to 70% of the value of total agricultural output (Table 2). Production of pigs and poultry has now developed to a degree of nutritional sophistication where the 'biological ceiling' of weight gain in relation to feeding has probably been reached and pig and poultry diets are likely to remain, as at present, based on wheat and soyabeans. This section of the industry is therefore likely in the 1980s to contribute to the demand for increased home production of wheat. Grass continues to provide the major part of the food requirements of sheep and cattle.

Grass

The total area of grassland in the UK in 1973 was approximately 14 million hectares, about 58% of the land area and 73% of all agricultural land. Rough grazing constituted about 6.8 of the 14 million hectares. As with other agricultural land this area is diminishing (Table 3), the loss of forage land from cattle production between 1974 and 1984 being estimated as 8.5% (Table 4).

TABLE 3 ESTIMATED LOSS OF GRASSLAND 1975-1985

	Million hectares
Loss to Cereal and Sugarbeet production	0.445
Loss to Forestry	0.330
Loss to Urban and Other Uses	0.202
TOTAL LOSS	0.977

Losses to forestry tend to be of poorer hill land, those to other uses of the most productive lowland. In Scotland, where most of the land is in the poorer grades, 26% of the land taken for urban uses from 1973-76 was in grades 1 and 2.

For the decade 1974-84, numbers of cattle are expected to increase by 5.2% and numbers of breeding ewes by 15.4% (Table 4), and taking account also of the loss of grassland area, agricultural policies can be expected in the 1980s to promote increased grassland productivity. The established methods of achieving this include improved drainage, fertilising and grass conservation.

Drainage

The MAFF Drainage survey in England and Wales 1968/69 concluded that at least 2.8 million hectares of land out of 11.0 million hectares were capable of economic drainage improvement, this being additional to the approximately equal area already improved by draining. Almost 30% of all the grass fields surveyed suffered from impeded drainage. In 1971-74 the annual rate of field drainage was 0.098 million hectares and although the rate may have accelerated since then, heavily subsidised drainage schemes are likely to continue as a prominent feature of agricultural policy in the 1980s. Initially these subsidies were taken up mainly in such areas as East Anglia where the potential returns were most obvious. In potentially less profitable areas, land draining is likely to be closely dependant on the prevailing level of economic confidence.

Fertilisers

When drainage, sward composition and basic nutrient deficiencies are corrected, herbage yield will depend mainly on nitrogen supply. Use of nitrogen fertiliser up to a level of 450 kg/ha has been demonstrated to produce a linear increase in the number of cow days/hectare provided the stocking density is correctly adjusted. Annual yields of herbage dry matter of 13,200 kg/ha are obtained in this way compared with 5,500 kg/ha with little or no N fertiliser. In England and Wales, 14% of leys and >39% of permanent grass receive no N fertiliser and the average rate on land which is dressed is 80 kg/ha. In the Netherlands, use is around 200 kg/ha. (Figure 1). The 1979 White Paper states that the UK is likely to approach self sufficiency in potash in the early 1980s and that more than adequate supplies of phosphate are expected to be available on world markets. However, depletion of the more easily accessible high grade ores combined with higher energy costs may favour the better use of animal wastes as an alternative to importing rock phosphate.

Increased use of N fertilisers is expected to make a major contribution to productivity and the UK is likely to remain a net importer of both nitrogenous fertilisers and ammonia. Figure 2 shows the Fertilizer Manufacturers' Association's estimates of the use of fertilisers in Britain in the last 50 years. P and K application rates appear to have reached a plateau but the use of nitrogenous fertilisers continue to increase steadily. The Royal Commission on Environmental Pollution quotes an estimate from a commercial source that their use could increase by 50% by the year 2000, and annual growth rate of nearly 2%, most of it goin to grassland.

Grass conservation

Hay still accounts for 76% of conserved forage in the UK but in herds of 100 cows and over hay is being replaced by silage. There is a negative correlation between dairy herd size and the use of hay. If, as may be expected, the trends toward amalgamation of small farms, larger herds and more capital intensive methods of housing and management continue, a larger proportion of grass will be ensiled and cutting will take place earlier when its nutritional value is highest. Herbicide usage is therefore likely to increase.

FIGURE 1

Average amounts of nitrogen fertiliser used on grassland in England and Wales and the Netherlands

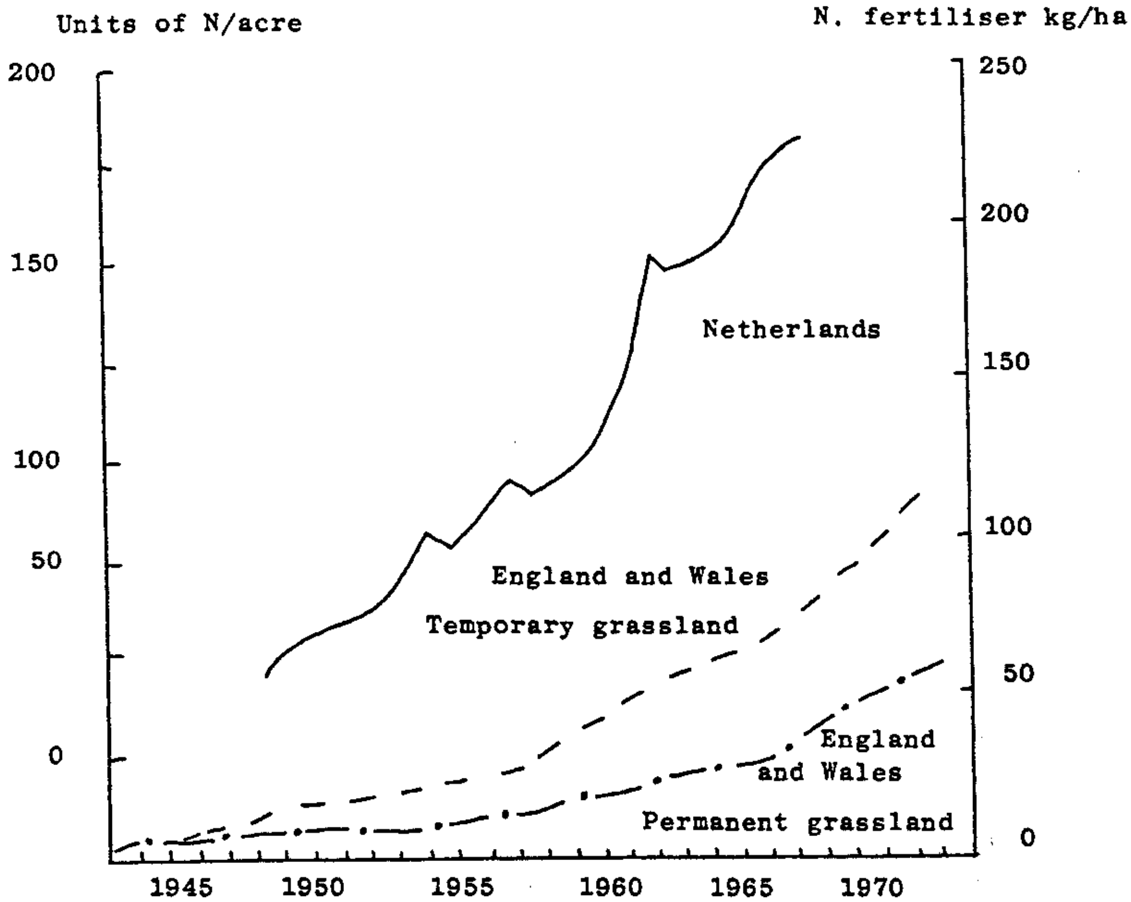
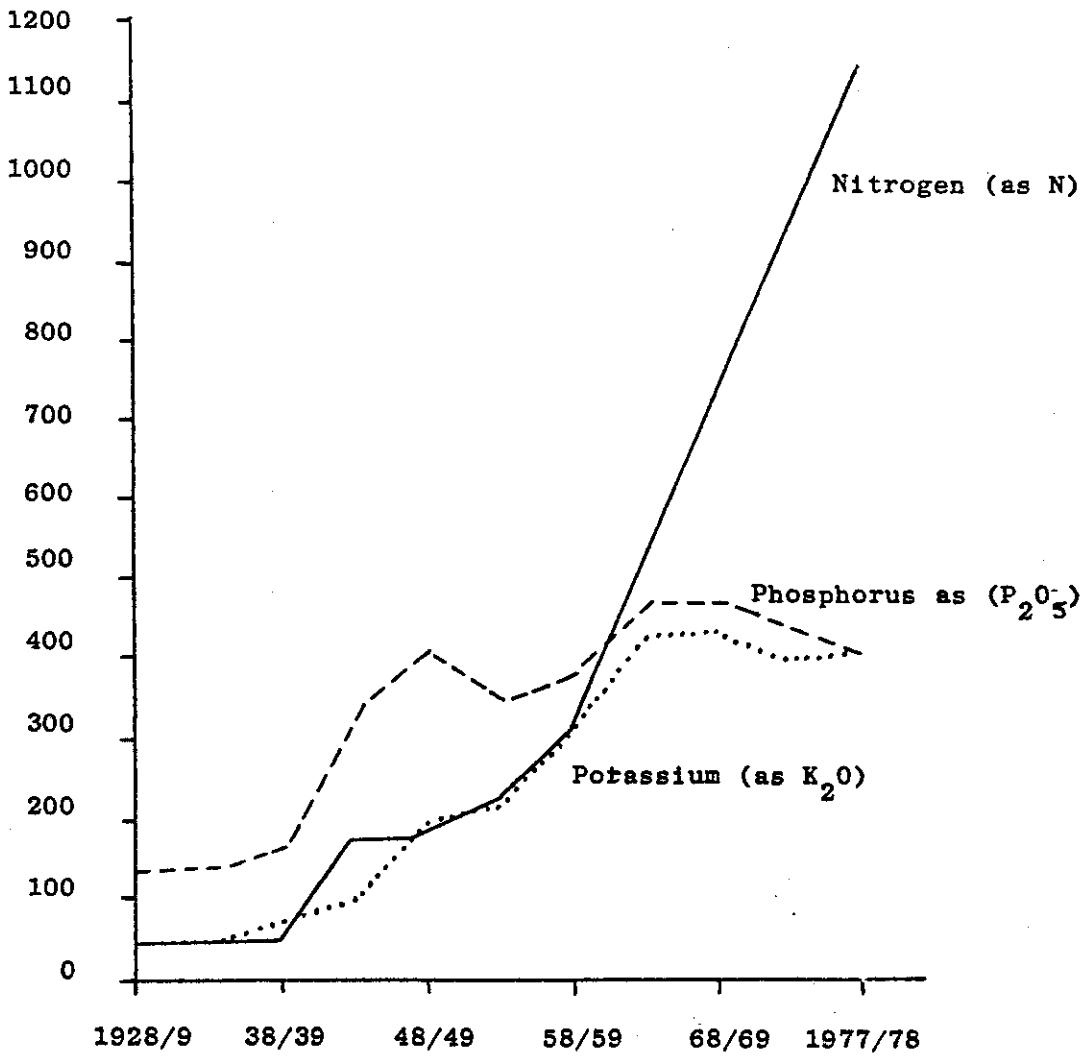


FIGURE 2

Trends in Fertiliser Usage in the U.K.



Concentrates

In the dairy sector, a trend towards calving at 2 years old has been necessarily accompanied by increased use of concentrates at all stages of the heifer's life. With beef cows, the higher nutritional planes required to improve fertility and calf production have also been achieved by increased consumption of concentrates. Feeding practices on more innovative farms are moving towards the concept of 'complete diets' in which a mixed concentrate-forage ration is offered to cattle, both dairy and beef, on an *ad libitum* basis. Sheep feeding practice has shown a small trend towards increased use of concentrates particularly with hill ewes in late pregnancy and after lambing.

Feed ingredients

Because of the highly complex digestive physiology of ruminants there is a high degree of flexibility in meeting their nutritional requirements both in respect of bulky fodders and concentrates. Feedstuff manufacturers now formulate a blend of feed ingredients from a range of materials to meet specified nutritional requirements in terms of available amino acids, metabolisable energy, minerals and vitamins rather than, as previously, stipulating specific materials and their proportions. The range available covers natural materials, processed products, by-products and synthetic ingredients, together with non-food additives. Determination of the cheapest combination of raw materials, taking into account their price and composition is carried out by linear programming and is termed 'least cost formulation'. This produces a stabilising effect on the price of compound feeding stuffs and is the basis on which it is hoped to reconcile increased consumption of concentrates with reduction in import costs.

TABLE 4 CHANGES IN U.K. LIVESTOCK NUMBERS AND FEED REQUIREMENTS

	Numbers ($x 10^6$)			Forage ($ha \times 10^6$)			Concentrates (tonnes $\times 10^6$)			Estimated Change 1974-84 (%)		
	1964	1974	Change %	1964	1974	Change %	1964	1974	Change %	Numbers	Forage	Concentrates
Cattle	11.6	15.2	+31	6.3	6.4	+2	6.0	7.5	+26	+ 5.2	− 8.6	+ 13.5
Ewes	14.4	13.9	− 4	2.3	2.0	−16	0.1	0.2	+83	+15.4	+ 0.5	+ 82.0
Pigs	13.4	15.8	+18				5.1	5.1	− 1	+15.5		+ 10.0
Poultry (aged)	320.6	463.9	+45				4.1	4.5	+ 8	+16.6		+ 34.0
Poultry (table)												
TOTAL				8.6	8.4	−2.3	15.3	17.3	+13		− 8.0 (70000 ha)	+ 18.6 (3.3×10^6)

Against this background, the Agriculture EDC Feedingstuffs Group prepared an estimate of the UK animal feed requirement in 1984. The requirement for concentrates is expected to increase by 18.6% (Table 4) and although it is anticipated that this can be met in part by increased use of rape, grain maize, sunflowers and lupins, these crops all do much better in other parts of the EEC. Increased cereal production is also planned but technological advances allowing home-grown soft wheat to be used in bread grist could reduce its availability for animal feed. Increasing food demand in the Third World may also reduce the availability of tapioca for feedstuffs and the supply of fishmeal as a cheap protein source has already fallen drastically following the cessation of Icelandic cod fishing and the collapse of herring stocks. Attention is now turning to alternatives such as alkali-digested straw and by-products of the food and drink industries and interest in the development of novel feedstuffs can be expected to intensify as these shortages increase.

Animal Wastes

Egg production increased from 8250 million in 1952 to 13900 million in 1977, and poultry meat from 86000 to 678000 tonnes during the same period. Intensive pig production increasing from 153000 to 650000 tonnes and to a lesser extent that of beef cattle added to the problems of waste disposal and utilisation. Some 170 million tonnes of undiluted excreta are produced by farm animals in the UK each year of which 60 million tonnes are voided indoors. Disposal problems have arisen as consequences not only on increased animal numbers but of the trend away from farmyard manure to slurry systems and the increasing ratio of numbers of stock housed to size of holding. Table 5 illustrates tendencies towards larger herds of dairy and beef cattle, pigs and poultry flocks in the 1960s-70s. There is no reason to suppose that maximum herd sizes have yet been reached, the number of pigs for example on Humberside is about 600,000 and in Gelderland in the Netherlands, an area of similar size, over 2 million.

TABLE 5 LARGE ENTERPRISES ON SMALL HOLDINGS

	1960	1970	1974
Dairy Herds (>100 Head on <60 ha.)	12	128	342
Beef Herds (>100 Head on <60 ha)	6	22	58
Pig Herds (>1000 Head on <8 ha: 125 ha $^{-1}$)	0	126	284
Layer Flocks (>5000 Head on <2 ha: 2500 ha $^{-1}$)	278	466	405
Broiler Flocks (>250,000 Head on <20 ha:125,000 ha^{-1})	7	11	12

TABLE 6 NUMBERS OF HOUSED LIVESTOCK FROM WHICH MANURE CAN BE APPLIED TO 1 Ha

	Dairy Cattle (housed 6 months)	Pigs (housed 12 months)	Poultry (housed 12 months)
Grass for Fodder	11.2	80	1160
Grazed Grass	4.5	35	590
Cereals	2.3	17	300
Other Arable Crops	7.5	40	580

The amounts of N, P and K animal excreta contain are not balanced for crop growth, the K and P being high relative to N. To apply the required amount of N, if no additional mineral fertiliser were added, slurry would add quantities of P likely to cause eutrophication of run-off waters and quantities of K which could be toxic to livestock. Table 6 shows the amount of manure, in terms of output per head of stock, which can be applied to land, short of producing these excesses. The two tables read in conjunction show for example that the stocking density of large pig units exceeds 125 head per hectare whereas the maximum capacity for pig excreta utilisation on grassland is that from 80 head per hectare. As large pig units are mainly located in grain producing areas the capacity is often much less than this. The excess of faeces production over land available to utilise it is even greater for poultry flocks and almost certainly applies to the largest dairy herds.

The extent to which slurry from intensive livestock units can be disposed of to other land holders depends on the costs both of transport and of alternative fertilisers. In the Netherlands, where stocking rates are much higher than in Britain, a centralised service exists by which excess slurry production is transported at subsidised rates to farmers requesting it.

Slurry is stored on most farms in tanks or open lagoons and spread on the land during the winter months. Nitrogen losses from open lagoons can be as high as 60% and further losses may occur from the land by leaching or surface run-off. There can be little doubt that slurry systems, though economical of labour, are wasteful of plant nutrients and that this wastefulness is likely to intensify as the numbers of livestock and the size of livestock units increase. The parallel trends in increased demand for, and costs of, mineral fertilisers suggest that improved utilisation of animal wastes will continue to command attention.

Sewage sludge

Related problems are presented by the use of sewage sludge as an agricultural fertiliser. In 1975 about 40% of sewage sludge production was applied to agricultural land, 22% was dumped as land fill and 28% was dumped at sea. If all sewage sludge was used on productive agricultural land it would yield the equivalent of 5% of the current use of P & N as inorganic fertilisers. Its use is constrained by heavy metal and pathogen contamination, but concern in the European Commission about pollution of the marine environment may well bring increasing international pressure against its disposal at sea. Changes in the demand for and price of fertilisers are again likely to increase interest in its utilisation.

Trends in Arable Farming

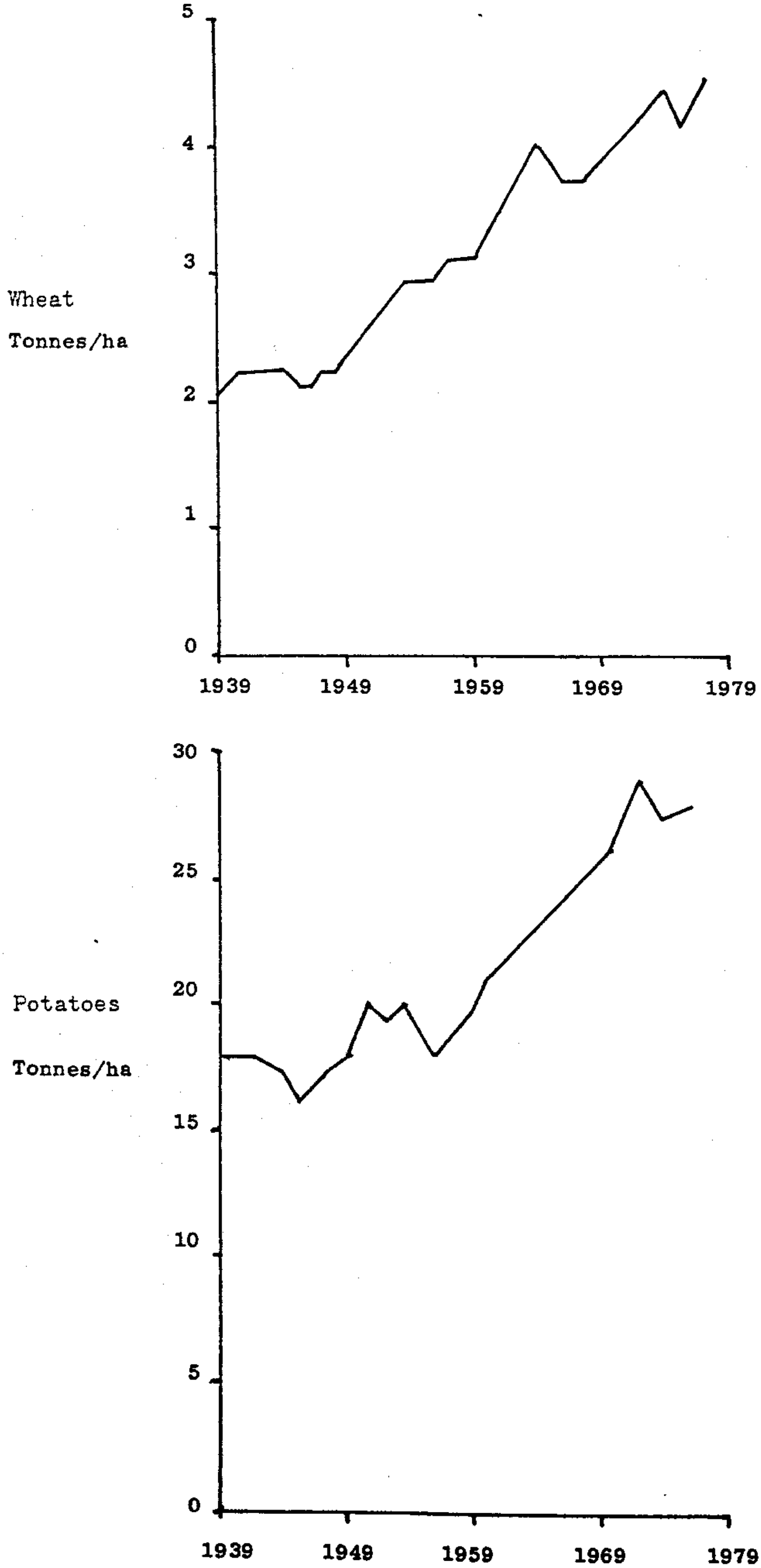
Land under arable cultivation is expected to increase by 1985 by 445000 ha for cultivation of cereals and sugar beet and to decrease slightly by losses to non-agricultural development. Political decisions within the Common Market may discourage the expansion of sugar beet cultivation in favour of importing Third World cane sugar, but since cereals account for 75% of all arable land the change in total arable area is likely to be small. On existing arable land the environment is already so drastically modified that the direction and pace of ecological change seem unlikely to alter substantially. The Agriculture EDC's Land Use Group states that land 'improvement', viz tree clearance, levelling, fencing and ditching has already been virtually completed in arable farmland.

Increased home production can be anticipated from continuation of the increase in yields obtained in all arable crops since World War II (Figure 3) and attributed to higher yielding strains and increased usage of fertilisers and pesticides.

Opinions differ on future trends in fertiliser usage. MAFF and the fertiliser industry take the view that arable crops already receive close to the recommended rates of inorganic nitrogen application and that cost benefit will restrain further increase. The ARC's Plant Breeding Institute on the other hand anticipates that nitrogen usage on cereals might increase about 150% in the next 20 years. 'Maximum yield' techniques which can for example treble the yield of potatoes by frequent application of fertiliser according to the plants' changing nutritional requirement increase nitrogen usage considerably. They are not at present generally economic however and seem unlikely to be widely practiced in the coming decade.

Minimum cultivation techniques, the replacement of ploughing and harrowing by direct drilling into the undisturbed soil, because of their substantial saving in energy costs seem likely to be considerably extended with a corresponding increase in the usage of paraquat and other herbicides for weed control.

FIGURE 3 Wheat and potato yields in U.K.



Pesticides

The development of the agrochemicals industry is illustrated by the changing number of available chemicals listed under the Agricultural Chemicals Approval Scheme, 15 in 1950, 47 in 1965, 265 in 1979, and by the number of products as formulations, 63 in 1944, 819 in 1976. Recently, the rate of introduction of new pesticides has slowed down (Figure 4); in 1956 the synthesis of 1800 chemicals led to one commercial pesticide, in 1967 the ratio was about 5000:1 and it is currently more than 10000:1.

Of the 3.7 million hectares of cereals and other arable crops, 99% was treated with pesticides in 1974 and in 1977 and in the latter year between 40 and 50% of the treated area received 4-6 applications of pesticide. During this period the weight of insecticides used increased 220% and that of herbicides 127%. Herbicides account for nearly 75% of the active ingredient used in the UK and in 'spray hectares', the product of area and frequency of application, herbicides are applied to 6.0 million hectares and insecticides to 1.1 million hectares.

The main increase in insecticide use in the 1970s was for control of cereal aphid and since the area devoted to cereal growing is expected to increase, the use of cereal pesticides will probably also increase. Resistance to pesticides, though not to herbicides, is particularly a serious problem. At least ten important agricultural pests in the UK are already known to be resistant to one or more pesticide and one or two more cases are recorded each year.

Herbicides are applied to less than 10% of grassland in the UK and if the main thrust of agricultural policy remains as at present to increase home production of livestock and the grass on which to feed it, increased use of herbicides on grassland may be a significant development of the 1980s. The gross amount of active ingredient applied may nevertheless fall if ultra-low-volume spraying and controlled droplet application techniques gain ground.

Effects on Agriculture of External Factors

Energy costs

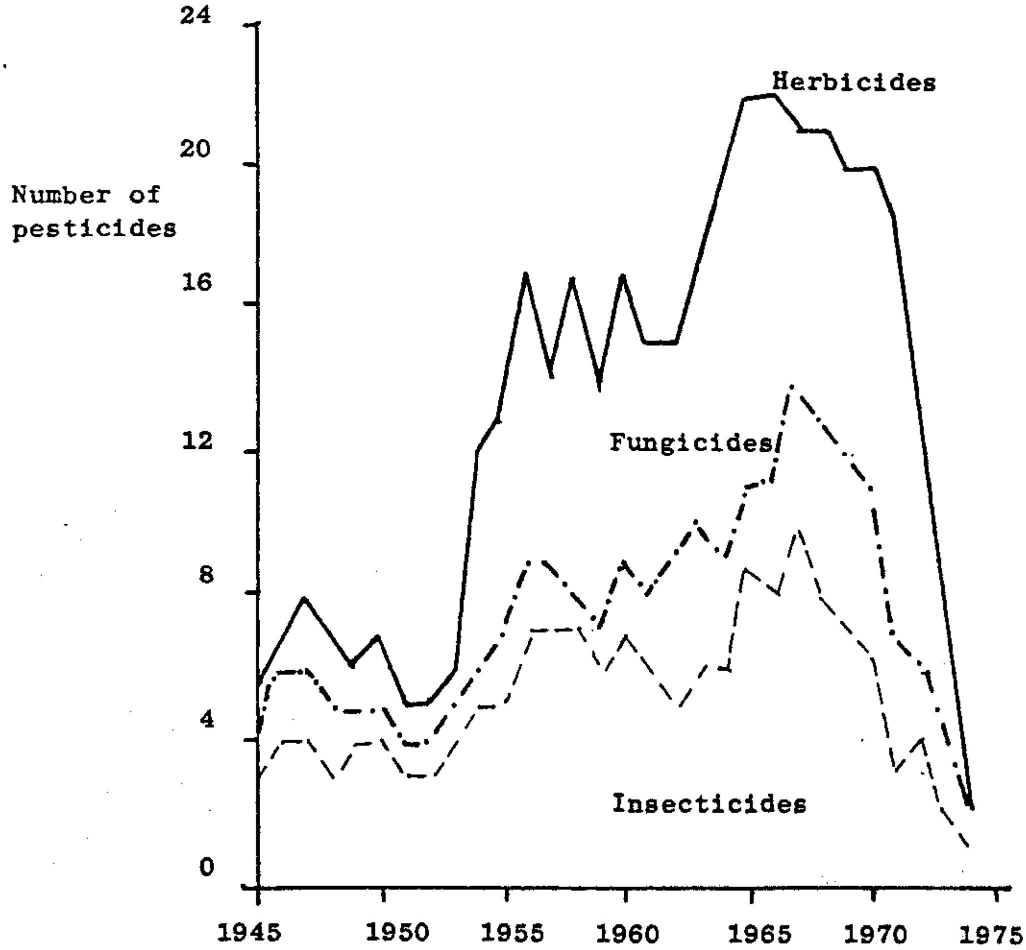
Feeding the population involves an expenditure of an estimated 16% of the total primary energy use in the UK. Agriculture uses 3.9%, processing, packaging and distribution 7.0%, and food storage and preparation 4.9%.

If the real price of oil increases by a factor of two or more by the end of the century, the best central estimate available, the rise in distributive costs and in feedstuff processing costs might result in a shift, reversing current trends, towards mixed farming so that a higher proportion of feedstuffs could be produced closer to the livestock and better use of animal wastes could reduce fertiliser requirements.

FIGURE 4

Annual introductions of pesticides 1945-75

- 3 year moving average



Alternatively, it could be argued that many techniques for increasing productivity will increase the efficiency with which overall energy inputs are used: for example, crop production where the increased yield far outweighs the energy cost of pesticide application, and animal disease control and improved reproductive performance, both of which increase food output per unit of feed eaten. Detailed analysis of the relative energy costs of production and distribution might point either to greater specialisation within EEC according to the production potential of different regional combinations of climate and soil, or to greater home production.

On the farm, the effects of higher energy costs would be felt primarily in the cost of fuel for farm operations, the cost of machinery and the cost of nitrogen fertiliser (which uses gas as a feedstock). It is not clear how large an increase in energy prices would be needed to reverse the trend towards machinery-intensive farming nor how far this could be offset by increases in machinery efficiency.

Novel energy conversion systems eg straw burning and biogas production, have been introduced in small numbers during the 1970s. Most farm scale slurry fermentors have encountered operational difficulties which suggest that management of district plants by trained personnel might more than offset the costs of transporting wastes over short distances. Rising energy costs in the 1980s together with the waste disposal problems of increasingly large livestock units may accelerate this possible development but it is likely to gain more ground as the exploitation of North Sea oil passes its peak. Production of energy crops on agricultural land, not yet commercial, may be expected to continue as a research field in anticipation of this period of acute energy shortage.

Climatic change

In so far as there is any agreement amongst climatologists concerning long term trends it is that sooner or later, to a greater or lesser extent, the climate in Northern Europe is likely to become colder and wetter. The increased reliance on home production increases the vulnerability of the UK food supplies to these adverse trends.

Increased rainfall, depending on its seasonal distribution, could raise productivity in areas suffering soil moisture deficits but would favour fungus pests, reduce the number of days suitable for grass and cereal harvesting and, on heavier soils, the days on which potato and beet harvesting machinery could get on the land. Drainage would therefore need to be improved beyond present requirements.

A concurrent fall in summer temperature would shorten the number of growing days for grass, spring sown cereals, potatoes and sugar beet and lower winter temperatures would require more livestock housing and for longer periods and a consequent increase in feedstuff requirements. In time, the wealthier nations would probably adapt their agricultural systems but the effect of a shift in climate in Britain might be trivial compared with associated changes in the tropics where the greatest increases in population are now occurring.

Political developments

The present form of UK agriculture, particularly its livestock sector, reflects the commodity price structure determined by the EEC Common Agricultural Policy. Changes in intervention prices, shifts in the relative prices paid for milk and concentrates, devaluation of the Green Pound, could separately or in combination radically alter the profitability of most of the crops grown in Britain, could change systems of production and could make or break the economics of farming. Taking together the unknowable possibilities of new discoveries and the unpredictability of energy costs, climatic change and political developments, prognosis of agricultural trends seems overwhelmingly uncertain.

Ecological Implications

Effects of land management in marginal and upland areas

1. None of the reports cited contains any suggestion of abandonment of farming on marginal land. The emphasis on home production and the increasing importance of lamb as an export suggest on the contrary an intensification of efforts to improve hill grazing by draining and fertilising. The supposed problem of maintaining upland landscapes and recreational potential under conditions of declining hill farming therefore appears unlikely to materialise in the 1980s and the emphasis placed in the 1970s on upland landscape research may therefore be less.

   This analysis depends however on many uncertain factors. Falling *per capita* consumption of butter combined with overproduction of milk under the CAP may result in a fall in real terms of the price of dairy products, but this may be offset by a reduction in New Zealand butter imports. National economic constraints may force reductions in the subsidies available for hill farming and drainage works and, with the heavy costs of capital loans, may retard the amalgamation of small farms. EEC regional support policies may on the other hand ease these constraints. New policies advocating substantial transfers of hill land to forestry may generate new patterns of integrated forestry and agriculture but these in turn may be countered by expansion of the continental market for lamb.

   One trend which shows no signs of abating is the depopulation of the rural uplands. A common pattern in recent decades has been the abandonment of the farmstead at the head of a dale, the farmhouse becoming a holiday home, and the land being run in with that of the next lower farmstead. One farming family now running the land previously employing two contributes in production statistics to increased output per man but may conceal a lower output per unit of land area. The encroachment of scrub on former dale-head grazings is a common sight throughout the hill-farming regions and it seems unsafe to assume in the financial climate of the 1980s that this phenomenon will disappear. There appears to be a clear need for monitoring changes in upland land use and their effects on vegetation as a component of landscape.

2. There is similar need for monitoring the effects of changing land use in the uplands on soil organisms and processes and the interactions of these with wildlife and conservation interests.

3. More intensive agricultural use of marginal land is likely to encounter phosphorus deficiency problems arising from the binding of phosphorus with accumulated organic matter in resistant organo-phosphorus compounds. Research aimed at increasing the rate of P circulation will remain particularly relevant to the fragile economy of hill farming.

4. The use of common land and derelict land on the urban fringe will be a focus of attention at some state in the 1980s. These two types of land have distinctive physical and biological features and act as reservoirs or islands for wildlife within intensive agricultural land and urban development respectively. The effects of commons management schemes and urban fringe developments will continue to be of interest to nature conservation and amenity bodies.

5. Land use studies in relation to production potentials of different land classes directed towards formulation of land use policies and reconcilaiation of conflicting interests will continue to be of interest. Looking beyond the 1980s, questions needing to be addressed include

   a) what yields of essential resources (food, fuel, fibre) can be sustained?

   b) what are the *per capita* requirements for these?

   c) what population levels can therefore be sustained without environmental degradation?

Ecological effects of lowland agriculture

6. The violent environmental practices of intensive lowland agriculture such as hedgerow removal, levelling etc seem to be largely complete and research interest in the associated loss of wildlife habitat seems likely to decline. The damaging effects of cereal cultivation on soil structure of heavy soils in some eastern counties also seem likely to command less interest as minimum cultivation farming expands.

7. Minimum cultivation farming has already been seen to result in dramatic increases, at least initially, in earthworm populations. Research interest in its effects on other saprovores and on soil microbiology seem likely to increase.

Effects of agrochemicals

8. None of the reports cited expresses concern over future supplies or cost of potassium or phosphatic fertilisers, but rising energy prices and the need to restrain import costs can be expected to accelerate research into P cycling and the better use of sewage and animal wastes.

9. There is a powerful concensus of opinion on the desirability of increasing nitrogenous fertiliser usage particularly on grassland. Radical changes in nitrogen demand can be expected if current research on transferring N-fixing genes to grasses and cereals succeed but as this is not anticipated within the next decade, research connected with any potential source of fertiliser N is likely to get high priority.

10. Increased application of N, organic and inorganic, can be expected to raise N concentrations in ground water leachate and surface run-off. The problem of high nitrate concentrations in drinking water was considered by the Royal Commission on Environmental Pollution to be best approached through treatment at reservoir extraction plants but, besides this, the widespread changes in limnic ecology caused by high nutrient inputs can be expected to increase. The pollution problems of increased fertiliser N application are likely to be accentuated by higher leaching rates if the proposals to increase land drainage are implemented.

11. The policy of increased crop production implies increased pesticide usage. Increased resistance to animal pesticides poses problems of integrated pest control by crop management, strain selection and varied pesticide application. Invertebrate population dynamics, phenology and mutation rates are likely to be no less interesting in the 1980s than hitherto.

12. A major increase in herbicide usage is envisaged in connection with increased cereal production, minimum cultivation techniques and grassland improvement. The effects of reducing the weed supply to herbivorous birds are likely to continue as research interests in connection with game birds and wildlife protection.

Effects of animal slurries

13. The increasing competitiveness of animal slurries over inorganic N fertilisers can be expected to generate interest in its long term effects on soil ecology, viz on soil fauna, microbiology, structure, organic matter form and content, and balance of nutrients.

14. Sewage sludge is also likely to be increasingly applied to the land and in common with the use of animal slurries will require further research on the persistence of human and animal pathogens and parasites.

15. Problems of heavy metal accumulation are likely to arise from the use of these materials, notably copper from pig slurry and cadmium from sewage sludge.

Alternative sources of protein and energy

16. Increasing demand for home produced animal feedstuffs is likely to stimulate interest in unconventional sources of digestible protein and energy. Conversion of organic wastes from farming, food processing and industrial sources either directly into animal feed or via single cell protein or via saprovores are likely to be relevant lines of research. The possibility of cropping undomesticated plant species for protein production also merits attention.

17. Research on the utilisation of organic wastes as energy sources, on the production of energy catch crops on existing arable land, and on the selection of wild species for energy cropping can be expected to continue. Energy cropping on poor land raises questions of sustainable yield and the cost effectiveness of fertiliser application. If animal manures are used to replace mineral nutrients and maintain soil organic matter the soil biology of these crops will need to be investigated. Since the species concerned are perennials, precluding cultivation, the role of earthworms in incorporating surface organic matter will need to be considered.

18. The possibility of utilising organic wastes for energy production instead of returning them to the land raises the problem of how much organic material it is necessary to apply on different soil types to maintain optimum soil organic matter levels. The complexity of the interactions between soil organic matter levels and nutrient release rates suggests that the development of agricultural energy sources requires a substantial soil science input.

The problem of uncertainty

19. Future patterns of land use are hard to predict; management techniques are developed, supplies of fertilisers, energy or feedstuffs may suddenly decrease or increase, political decisions open or close markets, climatic conditions may be extreme for a year or two. Research in the 1980s therefore needs to expect the unexpected, and to analyse sensitivity to system pertubations.

Conclusion

Home agricultural policy in the 1980s is likely to reinforce the emphasis placed in the 1970s on production of grass and reducing reliance on imported concentrates. Grass growth in the UK is limited primarily by inadequate applications of nitrogenous fertiliser. Reduction of concentrate imports requires alternative protein sources. Research on nitrogen cycling - inputs to and outputs from agricultural systems, N fixers, alternative sources, methods of utilisation, efficient recycling of nitrogenous wastes - seems likely therefore to be amongst the highest priorities for land-use orientated ecologists. In the 1990s, energy resources, land use strategies and environmental problems may be more urgent issues but nitrogen/protein could be the key key-words for ecology in the 80s.

4. FORESTRY IN THE 1980s AND BEYOND

A. H. F. Brown

Forestry has been identified as one of the major developments in land use which will affect rural Britain in the future. The main developments are along two possible lines.

Conventional view

Double the area of forest by the year 2025, mainly through continued monoculture in the uplands, using existing crop species. There will be some development of more intensive silvicultural techniques. Attention will increasingly need to focus on ecological effects of clear-felling and on the establishment of second rotation crops.

Alternative view

The area of forest will be considerably larger, perhaps extending to 30% of the land area (ie approximately quadrupling) through national and international economic forces. Extension into lowland areas will be increasingly attractive.

Currently 'unproductive' woodland could be redeveloped by coppicing for fuels and wood products.

Short-rotation energy crops from forests will become feasible and dedicated crops will be planted using non-conventional forest species and practices, again involving intensive cropping.

Whichever view is accepted, restriction on available land will force development of forest practices which incorporate other uses, particularly agriculture and amenity.

Ecological implications and research possibilities

Extension of forest area

Areas in which forest extension occurs will be mainly in the uplands and their acquisition will be determined as much by economics as by ecology. Ecology can influence selection of species for sites on the basis of their long term effect on soil conditions. In turn, this will influence long-term sustained yield and hence economics.

Extension into more extreme climatic and soil conditions will require knowledge of species response to these factors, selection of suitable species and provenances and modification of silviculture.

Extension into lowland areas will permit selection of hardwoods with fast growth characteristics either native or exotic. Associated changes in soil, vegetation and fauna need analysis, especially where exotic hardwoods are used. Soil effects may be less immediate than in the uplands.

Extension into National Parks may be made more acceptable by the use of irregular forestry ie mixed species and age - classes. This provides the opportunity for advice, experiment and monitoring. Use of agricultural land for forestry would be more acceptable if a food crop could be obtained in addition to a forest crop. This suggests grazing/forest combinations with tree species resistant to grazing and browsing. The enhanced nutrient cycling brought about by the herbivores may be an important feature of this system.

Silviculture

Selection of suitable species and provenances for use in extreme conditions of climate and soil; species with enhanced nutrient uptake through mycorrhizas, or nutrient conservative species; selection of soil improving species or mixtures of species. More intensive cropping such as whole tree logging will cause increased loss of nutrients at a time when available fertiliser supplies may become reduced.

Although this is a Forestry research area, ecology of physiological adaptation, genecology, interaction between species and between plants and soil in relation to nutrient uptake and conservation are key areas of ecological research.

Clear felling

Perturbation of the ecosystem with major change in nutrient dynamics occurs at felling, and to a lesser extent at thinning. The ecological emphasis is on the change in soil conditions and nutrient transformation in relation to different felling regimes and to varying soil and climatic conditions. Nevertheless, the extent to which, and the rate at which, the cleared areas become revegetated is important not only to conservationists but because of the vegetation's role in retaining the flush of mineralised nutrients, and hence in influencing the next crop. Conversely, excessive vegetative growth hinders crop re-establishment. The source of the vegetation (eg buried seed) and its role in nutrient cycling are obvious areas of ecological research.

Second rotations

Foresters are pragmatic, but the range of options for planting techniques - the mycorrhizal preparation of seedlings, the selection of microhabitats for planting, the interaction of ground flora and seedling - are areas in which ecological research is relevant and is not a major part of forestry research.

In addition, deer numbers have built up considerably in some forests, as a result of the cover provided by the first rotation, and pose a threat to establishment of the second.

Monocultures

The development of research on effects of mixed versus pure plantations on soil conditions and subsequent yield is a key area. This should be linked to analysis of effects of irregular forestry. Although current forest practice is conservative, the need to increase the range of options to meet new demands; to overcome the growing problem of windthrow; and to compromise with agricultural and recreational interest, indicate that mixtures and irregular forestry may become more acceptable to the forester. Many ecologists have advocated the ecological advantages of mixtures, but the rationale and practicalities need to be examined more thoroughly.

The development of invertebrate pests in monoculture requires understanding of population dynamics and the relationship of the pest to competitors, predators and their physical environment. This application of population ecology may increase in relevance. The susceptibility of monocultures compared with mixed crops to microbial diseases, and the transmission of the diseases to subsequent crops (depends partly on the crop physiology and habitat conditions) is an area in which ITE research has a potential contribution.

Energy crops

Given the possibility of economic incentive, what are the options of forest cropping for energy? What characteristics of growth are desirable to meet soil and climate demands? What are the possible combinations of species which are desirable assuming that the monoculture dangers apply also to energy forestry? What are the nutrient consequences of crop removal with short rotations and a high proportion of the crop removed especially for example in mini-rotation coppices such as those being developed in N. America and Scandinavia? Is the re-development of coppice techniques feasible, for example as a way of rehabilitating 'derelict' or 'scrub' woodlands, or in severe environments where tall tree growth is not feasible? These, and other aspects of the ecology of energy crops, are potential aspects for ITE research.

Small woodlands

The maintenance of small deciduous woodlands solely as a landscape feature may increasingly become an unacceptable luxury to the individual landowner and to society. These amenity woods will be under pressure for wood production on both commercial and informal scales, the latter, for example to supply wood-burning stoves. Research should be orientated towards developing management practices which minimise the loss of woodlands and their flora and fauna but provide valuable supplies of wood. The role of woods as shelter should also be considered. The apparent loss of regeneration capacity of small woodlands through grazing (and recreation) is a recurrent question. Do we have the answers? If we have then we have failed to communicate them. If we have not then this is an area of fundamental interest in vegetation dynamics which should be analysed further.

Conversion of native woodland to exotic conifers

Although this is now a diminishing trend, some ecological problems remain in the existing conifer plantations occupying old native woodland sites, eg the relative importance for the vegetation of soil changes compared with light intensity changes under the conifers.

Current research

The current research, and experience, at Merlewood provides an important base for further development.

The national (424) and Cumbria (362, 521, 541, 554) studies provide the basic broad definition of environmental and ecological variation for selection of sites for research, for monitoring change in land use, and for assessment of possible areas for forest development (521). The classification of forests and woodlands (1, 6, 483) are a basis for selection and monitoring of forestry developments, associated with soil classification methods (4).

Field monitoring of change in vegetation associated with conservation interests (454, 549) has developed techniques for more general application. Analysis of vegetation, fauna and soil changes in long term experiments is determining long term changes under selected conditions (9, 14, 367, 431, 633) and particular management systems (389, 417).

Changes in soil processes, and their relationships to plant growth, are increasing in emphasis, using experimental techniques and with emphasis on plant nutrients (29, 39, 61, 561, 589).

Development of work on mycorrhizas (654, 673) is strongly associated with establishment of tree seedlings under varying soil conditions, previous work on climatic and soil factors in relation to plant growth (by A. H. F. Brown, A. Millar and E. J. White) plus the experience in measurement of tree productivity (17, 329) provide a basis for understanding tree growth.

Thus the research is already relevant to many of the aspects which have been identified as future ecological issues in relation to forestry.

Merlewood is also strategically placed to work in the north of England and the Borders, where there is likely to be a considerable development of forestry.

Research priorities

ITE has a particular function in the long-term studies which are characteristic of forestry.

Working co-operation with FC and private forestry is essential because ITE does not have the necessary land and management staff for long-term forest experiments. However, some consideration should be given to the possibility of acquiring some research sites of our own.

Economic criteria will be critical in the choice of management options, however soundly based on ecology. ITE should ensure liaison with economists in Universities, FC and elsewhere.

Many of the issues raised and their ecological consequences related back to our understanding of nutrient dynamics - the short- and long-term effects of various forestry practices on the circulation of nutrients through the plant-soil system. The various conventional and alternative practices act through modification of the physical and chemical factors which affect nutrient release and uptake in the plant-soil system. The response of the system varies between different soil and climatic regimes. It is through an understanding of the responses that we will improve our ability to predict the consequences of management, and to indicate possible alternatives.

Our research has tended to concentrate on descriptions of field situations, but there is increasing emphasis on experimental work with more defined conditions away from the fields. Future work should emphasise three approaches:

Analysis and description of actual variation in forestry in the field - to determine variation, to indicate trends, to generate and test hypotheses.

Long-term experiments in forests - to provide sites for analysis of responses under selected field conditions and to test extrapolation of 'laboratory' results.

Short-term 'laboratory' experiments - to define the effects of isolated environmental (soil and climate) and management factors.

The experience, understanding and results from previous research must be synthesised to provide a clear conceptual framework (model) which a) helps to orientate the research detail, b) can be modified as a result of future research, c) can provide predictions based on 'best available information'.

The following areas of research can therefore be identified. Many will form an extension of existing work:

Factors influencing growth on extreme sites.

Effects of exotic hardwoods on soil, flora and fauna.

Effects of changing from native hardwoods to exotic conifers.

Small woodlands - their regeneration, use and the effects of grazing.

Coppicing, and the biology and physiology of coppice management.

Biology and ecology of mixtures (including soil-improving spp.) and irregular forestry, compared with even-aged monocultures.

Whole-tree cropping and its effect on the nutrient balance.

Clear-felling and the dynamics of revegetation, nutrients and subsequent crops.

Energy crops and cropping.

5. LAND USE IN THE 1980s

R. G. H. Bunce

INTRODUCTION

Originally in the Nature Conservancy there was considerable interest in the broad aspects of land use with large Reserves, such as Rhum, being acquired for the investigation of the effects of management on a resource, in this case red deer. The extensive studies on the Glen Feshie estate were comparable, with the conservation of wildlife being one objective in a multiple purpose land use system. Underlying much of this work was the idea that if land is managed well, there should be a balance between production and conservation within the same landscape. The studies on grouse and the extensive work on grazing in Snowdonia and at the Moor House NNR are examples of projects concerned with the implications of specific activities on land use.

Within the Nature Conservancy there was much discussion on the philosophy of conservation and the way it should relate to the wider context of land use. Wide differences of opinion were held both within the research and conservation branches - in strong contrast to the apparently unified approach held within the major government agencies of the Forestry Commission and the Ministry of Agriculture. Such differences have been maintained up to the present day, where the above agencies have a consistent policy in contrast to the more diffuse approach of the conservation bodies; due in part to the more straightforward objectives of production in forestry and agriculture.

When considering the research carried out in the Nature Conservancy and subsequently in the Institute of Terrestrial Ecology it is convenient to separate the research relevant to land use into two broad headings:

1. <u>Direct</u>, where the research or approach is concerned at a broad scale, with, on the one hand, patterns of land use and the implications of various changes and, on the other hand, advice on management policy that affects land use directly.

2. <u>Indirect</u>, where research is carried out mainly on the ecology of important species, groups of species or processes, which may subsequently be used in the promotion of management action which may affect land use.

Since the splitting of the Nature Conservancy in 1972 the emphasis within the Institute has been changing more towards the conservation of resources in a broader context, than more strictly with the conservation of wildlife. Such a change in emphasis seems, in part, a response to the requirements of various customers, but it also parallels the wider trend in ecology towards a greater involvement in environmental issues as opposed to the traditional studies of organisms in their natural habitats. In contrast, it seems to be generally true that the Nature Conservancy Council have become more orientated to a narrower view of species conservation - a trend parallel to the current emphasis on diversity within ecosystems.

A rapid assessment of the Institute project register showed that under 10% of the projects listed came within the broad category of direct application to land use, a further 40% were indirectly concerned and the remaining 50% had very little relevance to land use problems. Currently the major projects on land use are the Ecological Survey of Britain (424), National Land Characterisation, Ecology of Vegetation Change in the Uplands (522), The Terrestrial Environment Information System and Mathematical Modelling in Cumbria. However there are over 30 other projects such as information retrieval on Dorset Heaths (R. T. Clarke) and the study of changes in land use in historical times (J. Sheail) that are directly related to land use.

SUMMARIES OF THE PREVIOUS SEMINARS

It seems useful to provide a brief summary of the conclusion of the previous seminars concerning their relationships to land use in order to set the scene for the discussion that followed.

Forestry. The shortfall in timber was the primary factor to emerge in the future development of forestry, leading to the assumption that the area of forest in Britain will need to expand to meet demand. This is most likely to take place in the uplands, although it was also considered possible that there would be an intensification of lowland forestry with different species and practices being involved in the long term.

Pollution. It seems likely that the existing trends will continue, with current problems possibly becoming more acute due to financial constraints restricting pollution control measures. The principle of making the polluter pay is unlikely to be implemented in the present economic position. In relation to land use the disposal of animal effluents and the effects of herbicides, pesticides and fertilisers seem to be the most significant factors.

Agriculture. As with forestry, the likely trend is for increased intensification in response to a requirement to reduce British dependence on imports of food. A major factor is the degree of support provided for upland agriculture as opposed to that in the lowlands. Alterations to such support for strategic reasons would have a major impact. The involvement of EEC in relation to such policies seems to be critical.

An additional factor not covered in the above discussions is that of urbanisation. Studies of the rate of urbanisation, its pattern and trends are a vital part of any strategy on land use.

FUTURES IN LAND USE

A major conclusion to be drawn from the above factors is one of increasing competition between the major land users for the land surface which is likely to increase the degree of conflict between them. Many of the trends in agriculture and forestry rely upon both energy and nutrient subsidies provided by exploitation of non-renewable resources. As the model produced by Meadows has shown, exponential growth of various factors, when combined together shows a collapse once the resources have been used up. However, it seems most likely that there will be sufficienct feedback within the system to produce pattern of allocation of resources that is adapted to restricted supply. A major problem remains in the timescale for the development of a new equilibrium and there are wide differences of opinion about the length of time available.

The current series of conferences on land use reflect a growing concern about the way in which the conflicts are going to be resolved. The concensus to date seems to be that the major government agencies, ie the Forestry Commission, the Ministry of Agriculture, the Countryside Commission and the Nature Conservancy Council, with their counterparts in Scotland will continue to exert pressures to create their sphere of influence within the system and that the means of consultation are sufficiently well developed to ensure that a reasonable compromise is attained.

However many problems remain - notably those associated with major land owners whose estates are maintained for personal objectives, eg game conservation, which do not coincide with national requirements. The whole question of land ownership is critical to the way in which change will proceed and may well act as a major buffer against such rapid changes as are some times envisaged. The differences between hypothetical trends and what actually happens on the ground at a particular location, is a central problem that needs consideration.

It is within the terms of reference of the government agencies directly concerned with land use to be advocates of their own objectives - such advocacy has had widespread implications in land use patterns - particularly in the uplands where integrated forestry and agriculture has long been recommended but where development has proceeded separately in most cases. The adoption of a multiple land use policy has been, in the main, the concern of ecologists, whereas such integration is rare in practice. ITE could therefore perform a vital function in examining alternative patterns of land allocation and their consequences to provide an independent view of the allocation of land, because over the next decade allocation, whether determined by formal planning or by market forces, is likely to be the cause of major conflict. The agencies concerned are unlikely to accept a further party as an arbiter, however the role of ITE is not to arbitrate but to examine options and define consequences. One major problem here is the degree of political involvement that is required in land use decisions and the difficulty in the separation of ecological principles from such an involvement.

DISCUSSION AT THE SEMINAR

The major points made during the discussion are summarised below

Firstly, a major division was emphasized between:

1. The effects of treatments: where detailed studies of an organism or systems are carried out, mainly by experiment, and the results may then be used to modify land use in limited areas. The majority of work previously carried out in ITE is in this category. Government agencies were thought to be most likely to turn to ITE for this kind of work and eventual advice, since it was directly in line with a recognised pattern. A further point made was that it was essential to carry out research on the functioning of the major ecosystems, in order to provide advice in problems associated with their manipulation by man, often in connection with land use.

2. Deployment of land area: with studies of the way in which the surface of Britain, or of regions, is separated into the major land uses. In this respect much previous work was considered too imprecise, particularly regarding different types of grassland. The balances between the various uses required further study and future trends needed examination.

The monitoring of change was put forward as a major field of potential work in which ITE already had considerable experience. Such studies have three major divisions, outlined below. However a guiding principle was that such studies should be based on a range of conditions rather than as in 'one off' situations where the results could not be related to a broader pattern.

The three divisions are:

1. When? ie temporal change, where trends either in vegetation, soils or other features are followed to establish the rate of future changes.

2. Where? ie spatial change, in which the patterns of change are followed within an area to establish the relative positions of factors and their relationships between each other. The establishment of baselines was thought to be an integral part of such an approach.

3. How? ie the functional aspects, so that extrapolations may be made from known situations. Such work relates closely to the experimental approach mentioned above.

Much research currently being carried out was thought to be too isolated. In a land use context it is essential to adopt a coordinated approach, otherwise the final product will be too diffuse to have a major impact. It was considered essential therefore to have a framework, so that the component land use studies could be linked to a wider pattern. Although modelling has had only limited success in tackling problems at an ecosystem level, it has the potential to have a major role at a higher level. The problems at the ecosystem level result from the difficulty in obtaining reliable data for some compartments, whereas the type of data to be used in land use models are more robust and the relationships between variables are likely to be less complex than in an ecosystem. Practical applications of land use models should have a high priority for investigation.

There was considerable discussion concerning the role of forestry and its importance in land use changes, with integration between agriculture and forestry especially worthy of consideration. Political problems seem likely to be significant in this context; not only in terms of land tenure but also in the way government agencies interact within their different terms of reference and budgets. The grant aid for forestry and agriculture provides a mechanism for controlling development of these land uses, but in practice their application is piecemeal. It was pointed out that although the recent CAS document called for a massive planting programme, the current trend in planting was downward - presumably in response to higher land prices and limited availability. It was pointed out that there did not seem to be a definite government policy on the subject at the moment. Much the same comments applied to the land use around cities, with the pattern of development being the result of a complex series of interaction, rather than the result of a concerted policy.

The continued rise in energy costs has made the feasibility of biomass cropping for fuel worthy of assessment. In particular new liquid fuel sources are needed that can be easily fitted in to the existing technology of transport. Methanol and ethanol, and various gases, have already been used in a limited way as fuels but further development work is required to make them commercially viable. Burning of dried biomass products, either the product of energy plantations or waste material, also has potential. The latter include straw, animal waste and tree loppings and have already been shown to be capable of providing a significant contribution to energy requirements in Britain. Energy crops on the other hand need to compete with other land uses and the likelihood of a significant contribution from the present species available is less likely than the use of wastes. An essential feature of many of these potential fuels is that they need to be treated at a local level with small plants, since they are often bulky and transport costs would preclude centralisation.

The potential role of ITE in relation to impact assessment was discussed and it was considered to be particularly important that an independent view should be maintained and that statements of fact should be presented as far as possible, whatever their drawbacks, rather than judgement. Such statements could then provide the basis upon which decision makers could arrive at value judgements that were a valid appraisal of the facts of a given situation. As a research organisation ITE is in the situation of being able to stand aside from other government agencies involved in land use, since they need to represent their own objectives, eg timber production. ITE could therefore be in the situation of stating the ecological potential of an area, and the way in which land could be allocated to various land uses in order best to conserve resources as a whole. Such a strategy was thought to require probably a greater knowledge of agriculture than is currently available to the organisation, whereas knowledge of forestry is probably adequate.

PROJECT AREAS FOR FUTURE WORK

Brief headings are given below to indicate the possible areas of future work identified during the seminar. They are not in order of priority but some comments are given on their feasibility.

1. Environment impact assessment

One response to increase in environmental pressure is the production of a method of assessing the impact of a particular development situation. Part of the work of the Ecological survey of Great Britain has been designed to enable objective comparisons to be made between areas, but further work is requested on detailed applications.

Feasibility: the basis for such projects has been laid down but further development is required.

2. EEC environment programme

At the moment the Great Britain ecological survey is in advance of other European systems in providing a system of stratification for a range of land use studies. Although the EEC environment programme is well advanced, there is still the possibility of extending the principles developed to a European basis. Similarly the application of many of the multivariate techniques have potential on a European scale.

Feasibility: existing methodology would need only minor modifications for many projects.

3. Data analysis

Experience is being gained within ITE of a wide range of procedures for analysis of the environment which can be applied to other data. Such a programme would include both multivariate classification procedures and modelling.

Feasibility: sufficient experience is available on many aspects although modelling requires more extensive practical application. A problem here is the scale of finance likely to be available for analysis alone.

4. Data banking

The TEIS project at Bangor enables complex data to be stored and retrieved and has a wide potential for holding land use data. Such a development could overlap with the Edinburgh University system but there is still a high potential for future work.

Feasibility: sufficient practical experience is likely to be available to enable most likely requirements to be satisfied, with relatively minor modifications, but user requirements need to be examined to clarify further developments.

5. Land allocation

Allocation of land is a crucial issue in land use and a wide range of studies are likely to be required on the conflicts and consequences resulting from changes in land use. If government policies direct change in land use, then areas will have to be identified where changes can take place with minimal disturbance of the environment and of other land uses. Such issues are critical in relation, for example, to the current studies on energy crops.

Feasibility: linear programming has been used in one study but its application and alternative techniques need to be developed.

6. Monitoring of change in vegetation

Vegetation for its inherent interest and in its significance to land use, requires monitoring, since at the moment there is no national series of sites to follow the trends in vegetational changes. Upland vegetation is critical in this respect since it has a direct bearing on the land use adopted, eg bracken spread and grazing regimes.

Feasibility: A stratification system is now available to enable a national network to be set up. Sufficient experience has also now been gained in monitoring woodland vegetation to enable appropriate projects to be set up.

7. Monitoring of change - land use

Landscape changes have been followed on a national basis by the land utilisation surveys and have been very expensive and time consuming. However systems are now available whereby a limited set of samples can be followed in detail.

Feasibility: details of the required parameters to be followed would need to be worked out but a system could be put into operation quite rapidly.

8. Remote sensing

Very little work has been done but both traditional aerial photography and Landsat satellite imagery have potential for land use studies.

Feasibility: very little experience is available at the moment and major development work would be required.

9. Extension of land use methodology to other countries

Several parts of the projects outlined above have a ready applicability to developing countries.

Feasibility: the major problem would be adapting to widely different situations and species, as well as in the cooperation with different cultures.

10. Individual species studies

Undoubtedly over the years various critical species will require studies, in relation to management, in order either to encourage or suppress their effects. Examples of such species are bracken, red deer, earthworms and certain fungi.

Feasibility: existing methodologies and experience form a sound basis for such studies.

11. Watershed studies

The studies already going ahead on the hydrology of catchments could be extended to examine their interaction with land use.

Feasibility: considerable development work would be required in this field, with various modelling techniques no doubt being likely to be important.

12. Energy from biomass

Further information is required on the quantity and distribution of the current materials available from biomass, either on waste or primary production. The implications to land use of possible energy crops needs consideration, with the impact of alien species and the breeding of new varieties as important areas of study. Such studies interact with the section on land allocation.

Feasibility: In the main the techniques are already developed eg plant breeding. Technological problems however remain in harvesting and treatment of biomass for fuels.

6. SUMMARY

As a result of preliminary discussions, 4 major subject areas were identified as having key roles in the development of ecology in the 1980s. These subjects (pollution, agriculture, forestry and land use) were considered in discussion meetings at Merlewood and a summary is given below. Fuller details will be produced in a Merlewood R & D paper. Although the emphasis is on applied problems, it was recognised throughout that our ability to tackle the problems has to be based on fundamental ecological principles. The research on applied aspects also provides the opportunity to test and develop these basic principles.

POLLUTION

The term pollution is used to cover a wide range of existing and recent research in ITE: insecticides, herbicides, fungicides, industrial products, heavy metals, fluorine, sulphur oxides, radionuclides and minor studies on road salting, eutrophication and industrial waste disposal. From a general review of pollution research and future problems, the following research development in the 1980s is recommended:

1. Expand research on the ecosystem impact of herbicides.

2. Modify the fluorine programme to include other emission sources and to make greater use of Monks Wood experimental experience.

3. Expand research into the effects of intensive farming practices, especially in relation to upland Britain.

4. Develop our expertise in industrial reclamation.

5. Establish a desk study review to look at the likely effect on British ecosystems of the global build up of carbon dioxide.

6. Place more emphasis in the sulphur programme on pollutant effects and extend the research to include the higher pollution areas of England.

7. Maintain the radionuclide programme at its present level.

8. Place greater emphasis on pollution impact modelling studies.

AGRICULTURE

Agriculture is the major land use impacting on the terrestrial environment. Analysis of trends in management and production, reviewed from recent policy statements by the industry, covered trends in livestock production, grass management, the use of food concentrates, disposal of animal wastes and trends in arable farming. The importance of external influences, particularly energy costs, climatic change and politics, were identified.

It is concluded that home agricultural policy in the 1980s is likely to reinforce the emphasis placed in the 1970s on production of grass and reducing reliance on imported concentrates. Grass growth in the United Kingdom is limited primarily by inadequate applications of nitrogenous fertiliser. Reduction of concentrate imports requires alternative protein sources. Research on nitrogen cycling - inputs to and outputs from agricultural systems, N fixers, alternative sources, methods of utilisation, efficient recycling of nitrogenous wastes - seems likely therefore to be amongst the highest priorities for land use orientated ecologists. In the 1990s, energy resources, land use strategies and environmental problems may be more urgent issues but nitrogen/protein could be in the key key-words for ecology in the 80s.

FORESTRY

The extent to which forestry will expand is debatable. Practices are strongly influenced by economics and practical forestry is the province of the Forestry Commission (FC) and private forestry. However ITE has considerable past and present experience in the ecology of forests which should be developed and applied to problems of forest management. The main research aspects for future ITE research are identified as :

Factors influencing growth on extreme sites

Effects of exotic hardwoods on soil, flora and fauna

Effects of changing from native hardwoods to exotic conifers

Small woodlands; the regeneration, use and effects of grazing

Coppicing

Monocultures versus mixtures, including soil-improving species, and irregular forestry

Whole tree cropping and its effect on the nutrient balance

Clear felling and the dynamics of revegetation, nutrients and subsequent crops

Energy crops and cropping

LAND USE

Increasing demands by the major land users for the limited land resource will produce conflicts during the 1980s. Analysis of research in the old Nature Conservancy and in ITE shows only a small proportion of research effort has been placed on direct research concerning changing patterns of land use and their implications. More effort has been placed on indirect studies concerned with the ecology of species or processes associated with management practices. ITE has an important potential role in land use planning because of its independence from any of the major land uses. Review of the problems and of the discussion on forestry, agriculture and pollution shows the following needs in research development:

1. Environmental Impact Assessment - development of methods is needed with the National Ecological Survey providing a useful existing basis.

2. European Economic Community - the National Ecological Survey could readily be extended to cover Europe.

3. Data analysis - procedures are already developed within ITE to allow analysis of a wide range of existing data.

4. Data banking - the Terrestrial Environment Information Service shows considerable potential for development and application.

5. Land allocation - techniques, additional to linear programming, need to be developed in relation to the formal and informal planning of land use allocation.

6. Monitoring of change in vegetation - extensive date on the rate and direction of vegetation change is needed, particularly in the uplands, and could be developed from existing stratification systems.

7. Monitoring of change in land use - expensive national land utilisation surveys could be replaced by more efficient systems using the existing land classification base.

8. Individual species studies - research on some critical species, related to land use, should be developed, eg bracken, red deer, earthworms, certain fungi.

9. Watershed studies - existing hydrological research should be developed to examine interactions with land use.