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THE EFFECT OF ORGANIC FARMING SYSTEMS ON ASPECTS OF THE ENVIRONMENT

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EXECUTIVE SUMMARY

Key Conclusions

1. The crop rotations of organic systems maintain landscape diversity and biodiversity whilst the maintenance of field boundaries on organic units produces benefits to a wide range of organisms.

2. Inorganic nitrogen fertilisation and herbicide treatments of conventionally managed grassland has reduced the floral diversity of permanent pastures and maintained the low diversity of re-seeded pastures, greatly reducing their value as wildlife habitats.

3. Pesticide use is responsible for the removal of food sources for birds and mammals in the form of weeds and invertebrates, as well as removing whole populations of potentially beneficial insects.

4. The majority of water pollution incidents from farms are caused during storage and spreading of cattle and pig slurries A higher proportion of organic cattle and virtually all organic pigs are kept on solid manure systems and therefore are less of a risk.

5. The nitrogen balance of individual 'conventional' and 'organic' systems will depend greatly on the circumstances and management practices of the individual farms. Consequently it is not possible to generalise that one system is always better than the other in terms of nitrate leaching risk. With this qualification the literature does indicate that generally, organic systems offer less *risk* of nitrate leaching.

6. Organic systems are less likely to cause loss of phosphate into surface and ground waters. Both leaching and loss in eroded soil are likely to be reduced.

7. Organic management practices such as rotations, the regular use of manures and non-use of pesticides usually increase soil organic matter contents.

8. Organic practices are likely to increase earthworm numbers compared to conventional systems. The increased numbers are universally acknowledged to benefit soil fertility although such effects are difficult to quantify.

9. Soil erosion is less of a problem on organic units.

10. Accumulations of copper and zinc in soils are much reduced in organic systems because organic pig and poultry producers do not supplement feeds with these metals as growth promoters. Copper fungicides are more widely used on organic farms and their use should be carefully monitored to prevent harmful effects.

11. The practices adopted by organic farmers can reduce emissions of nitrous oxide and methane. Ammonia emissions will not necessarily be less in organic than in conventional farming.

12. Organic farmers adopt practices which benefit the landscape. They maintain and introduce features largely because they are required by the Organic Standards to do so. They introduce such management practices because they are technically necessary for successful organic production.

Introduction

A Review is presented of certain aspects of the effects of organic farming systems on the environment. When considering such effects it is important to be clear what comparisons are being made. Some studies in the United Kingdom have underestimated the differences between conventional and organic agriculture by omitting consideration of intensive conventional arable systems which predominate over much of Eastern England. Discussions focused on all grass or mixed grass/arable farms under organic or conventional management. Such comparisons may help to unravel some of the components of the systems but they frequently fail to compare a "typical" organic unit with a "typical" conventional farm.

Organic farming is defined by European and UK law. Whilst none of the required practices are unique to organic farms they must be followed on certified organic units. Conventional farmers may follow some of the same principles and practices. They are not obliged to do so and most do not. Some of the optional practices may not be introduced by all organic farmers but at the least such decisions have to be justified during an annual inspection of their operation.

The Review is presented in six sections with individual conclusions and lists of references; the sections are summarised below :-

1 The effect of organic management on terrestrial and aquatic ecosystems

Few studies have been carried out in the UK which cover the necessary length of time and controlled conditions required for conclusive results to be drawn. Most studies in the review lasted only two or three seasons and results, although appearing to favour an organic regime as being more beneficial to wildlife were often inconclusive and not statistically significant. Information on the effects of the component parts of organic systems are more helpful in demonstrating the positive effects that are likely to exist.

The design of conventional and organic systems will of necessity influence the differences in the impacts on wildlife and its habitat. The variety and rotation of crops within a system influences the landscape and ecological diversity present. The crop rotations of organic systems maintain crop diversity whilst the maintenance of field boundaries on organic units produces benefits to a wide range of organisms.

From the studies reviewed it was seen that maintenance of field boundaries and in particular traditional hedgerows, accompanied by sympathetic management, was the most significant feature of farm management practice to influence wildlife populations. Floral diversity, insect species and numbers, bird territory habitation and small mammal numbers were all higher where pesticide use along the field boundary was either removed completely or greatly reduced.

The management of field margins has a direct impact on the food chain by maintaining the invertebrate populations which support the small mammals and birds of the farmland. A large number of studies have been carried out on the impact of conventional farming on bird populations and breeding success and it would appear that pesticide use causes reduction in numbers, as does the removal of available habitat that often accompanies conventional arable farming.

There is information available on the impacts of farming regimes on the populations of soil micro-flora and fauna. They are generally enhanced by the practices commonly employed on organic farms. Conclusive evidence for the long term benefits on soil processes is more difficult to find.

Studies on small mammal populations were found to be informative, but little work appears to have been done with regard to the larger British mammals such as rabbits, hedgehogs, bats and badgers, or on reptiles. As these are heavy consumers of flora and fauna which may have been treated with pesticides or may come directly in contact with pesticides during their application, it is surprising that there is no published data on either the short- or long-term effects on individuals or populations. The impacts on mammals of the range and quantities of synthetic pesticides applied on conventional farms remains poorly understood, with little evaluation of the potential problems. Similarly there is little published information on amphibians but what there is suggests that organic systems favour increased populations.

Pesticide use, which is the factor which separates the conventional from the organic farmer in most peoples minds, was seen to be responsible for the removal of food sources for birds and mammals in the form of weeds and invertebrates, as well as removing whole populations of potentially beneficial insects. An increase in the deaths of wildlife directly attributable to the approved use of agrochemicals has been documented.

Inorganic nitrogen fertilisation and herbicide treatments of conventionally managed grassland has reduced the floral diversity of permanent pastures and maintained the low diversity of re-seeded pastures, greatly reducing their value as wildlife habitats.

2. Water pollution from agricultural systems.

Organic manures and fertilisers.

The majority of water pollution incidents from farms are caused by cattle and pig slurries. The experience of inspections on organic farms is that in practice they demonstrate few risks of pollution. Apart from the unquantifiable factor of the increased concern for the environment shown by organic farmers, there are three aspects which suggest that there will be real differences caused by the organic system per se and the way that it has to be implemented.

- A higher proportion of organic cattle are kept on solid manure systems.

- Organic pig units operate almost exclusively on solid manure systems so that the problems from slurry stores will nor arise.

- The quantity of slurry or dirty water applied at any one time is usually less on organic farms because of the quantities available and the desire to maximise the benefits to crop growth. The risk of subsequent run-off polluting water courses is thus reduced.

Nitrate leaching

It is difficult to compare directly nitrate losses from an organic and conventional system without the time and expense of setting up 'farmlets' on a research centre so that as many variables as possible are removed from the comparison. Even then, it is likely that the comparison would be confounded by rotation, since each system would operate different cropping plans appropriate to their regime. However there is sufficient evidence in the scientific literature to enable broad conclusions to be drawn and the need for further work to be identified.

Nitrogen cycling in a farming system is complex and affected by many factors. As a general guide to leaching risk, one approach might be to consider the N balance (N inputs - N outputs) of a farming system on the assumption that a large N surplus will be more predisposed to losses such as leaching. The N balance of individual 'conventional' and 'organic' systems will depend greatly on the circumstances and management practices of the individual farms; consequently, it is not possible to generalise that one system is always better than the other in terms of nitrate leaching risk. The Codes of Good Agricultural Practice also try to tighten a farm's N balance with a resultant decrease in leaching on conventional farms, as has been shown in the pilot Nitrate Sensitive Areas (MAFF 1993).

Having stated these qualifications the literature does suggest that generally, organic systems offer less *risk* of nitrate leaching:

- Organic farms are less intensive with a better N balance and there is less risk of overfertilising.. They are often operating below the crop's economic optimum fertiliser requirement (as defined under conventional management) and leaching losses are small.

- Organic systems rely on fertility building phases typically using grass / clover leys. Leaching losses from this phase are generally small, so that the average loss from the rotation will also often be smaller than from a conventionally managed rotation.

- Stocking rates and N inputs are lower than in intensive livestock systems; these intensive systems can leach substantial nitrate.

- From a practical point of view, the economics of conventional farming systems requires intensification which offers more scope for something to go wrong in the practical management of the N cycle. For example insufficient manure storage might result in untimely application, or because it is important to fertilise as close as possible to the crop's optimum, there is more risk of overfertilisation. Although Codes of Practice have been developed to minimise these risks, there will be times when they are unavoidable.

There is scope for substantial nitrate leaching losses from organic systems on some occasions. In particular the systems rely on releasing nitrate by mineralisation at a time when it can be utilised by a crop; untimely mineralisation or a crop failure will result in nitrate losses by leaching. In particular, cultivation of leys has been identified as high risk. MAFF (EPD) is funding a large programme of research on nitrogen mineralisation, and much of this will aid understanding of organic systems.

It could also be argued that there is more chance of a crop failure in organic systems due to poor control of a pest or disease. In practice such events are less common than is often imagined by the critics of organic farming. If this does occur then N will be used ineffectively and more leaching is likely to result. We also need to consider the longer-term effects of organic practices on soil fertility and 'soil health', and consequences for nitrogen mineralisation. Building up the soil organic pool through grass/clover leys and the use of bulky organic manures is ideal for soil structure and for producing a diverse biomass, and will be an important source of crop N via mineralisation. However, more information is required on the long-term effects of fertility build-up on N leaching; again the MAFF funded mineralisation research programme will go some way to understanding this. The ongoing monitoring of organic systems by Elm Farm Research Centre will help to confirm actual losses over organic rotations on a range of soil types in England.

There is scope for further work:

- The best way to compare the effects of conventional and organic systems on nitrate leaching is to model the systems. This is more cost-effective than initiating numerous field experiments to compare individual rotations.
- There is a need to understand better and quantify the concept of 'soil health', and the effects of different farming systems on it. Maintenance of soil organic matter levels is important for soil structure, erosion control and, hence, crop productivity. More information is required on the effects of farming practices on soil organic matter status, both quantity and quality.

Phosphorus

It can be concluded that organic systems are less likely to cause P loss into waters than their conventional counterparts. Soil P reserves are tending to fall on organic farms because fertiliser input is lower than offtake. This coupled with the fact that soil erosion is less of a problem on organic farms means there is less risk of phosphate rich soil being washed into watercourses.

Slurry systems are less common and organic farms do not have excess quantities of manures to dispose of. Greater care is taken to prevent run-off. Stocking rates are lower on organic farms so that any accumulation of P is minimised.

Pesticides

Organic agriculture does not involve the use of the type of pesticides which often contaminate waters from conventional systems. The few materials that are permitted are only likely to enter water through misuse near water courses or accidental spillage. Contaminated run-off is very unlikely to cause problems given the rate of use and the limited range of crops that are treated.

3. The effect of organic management on soil quality.

Soil organic matter

Increased soil organic matter levels are generally accepted to benefit crop growth through improved structure, plant nutrient supply and resilience to physical degradation. Organic management practices such as the regular use of manures and non-use of pesticides may increase soil organic matter levels. A change of rotation to one contaiming grass leys or other fertility building crops will increase organic matter content compared to continuous conventional arable production.

Earthworms

Earthworm populations are stimulated by increased increased supply of organic matter as a food source, including grass leys, non-disturbance by cultivations and lack of harmful chemicals. With the possible exception that organic farmers have limited quantities of organic manures to apply to the land compared to some conventional units organic practices are likely to increase earthworm numbers compared to conventional systems. The increased numbers are universally acknowledged to benefit soil fertility although such effects are difficult to quantify.

Soil erosion

The avoidance or the minimisation of soil erosion is a fundamental objective of organic farming. The basic system and the management practices that are adopted within it all work towards achieving this goal. Organic matter contents are enhanced, cropping practices limit the period of vulnerability, whilst cultivations and wheelings that can initiate erosion are less common on organic units.

Soil contamination

Organically approved phosphate fertilisers currently available in the UK tend to contain higher concentrations of cadmium than soluble, processed conventional equivalents. However the rates applied are much less and the net effect is in favour of the organic system. Accumulations of copper and zinc are much reduced because organic pig and poultry producers do not supplement feeds with these metals as growth promoters. Copper fungicides are more widely used in organic systems and their use should be carefully monitored to prevent harmful effects.

4. Organic livestock management - side effects of veterinary medicines.

The greater emphasis on disease prevention enables organic systems of production to use less veterinary inputs than most conventional systems. This is particularly the case for anthelmintics and for in-feed additives such as coccidiostats where clean grazing systems and reduced stocking rates reduce parasitic burden.

In most instances there is little scientific evidence to suggest that licensed products, used and disposed of correctly within conventional systems have any deleterious effect on the environment. Safeguards will be further tightened with the introduction of newer, more rigorous eco-toxicological requirements for licensing purposes.

Organic farming does not eliminate the need for veterinary treatment, either for individual animals in the case of acute disease, or on a flock/herd basis for example for ectoparasite control. In many instances organic standards stipulate the use of a different product, or the avoidance of a specific prohibited material

Some substances prohibited by organic production standards e.g. OP dips, dietary supplements of copper and zinc, and possibly the avermectins, have got implications for the environment. However, other permitted products may have higher toxicities, for example, pyrethroid preparations which are particularly toxic to aquatic life and must always be used with care.

Because of a general desire not to handle or administer perceived harmful materials, for example OP dips, 'organic' and conventional management practices have become closer in certain areas of treatment. Disposal of pyrethroid dips requires great care by all farmers.

Organic farmers may be more conscientious in their care for the environment than their conventional counterparts but they are required to use veterinary medicines when the required to safeguard the life or welfare of their stock. There is a lack of information in the public domain on the wider effects of these treatments. On balance there may be little direct environmental benefit from the adoption of an organic approach to veterinary inputs and disease control. However the possible importance of antibiotic residues in the development of resistant organisms with a link to human health justifies further study. Organic farmers only use such products to treat individual animals in response to a proven need.

5. The impact of organic management on atmospheric pollution from farms

The principle of crop nutrition in organic farming is to "feed the soil rather than the plant'. This is implemented by adding N via moderate applications of approved fertilisers and manures and through N fixation by legumes. This approach has potential for reducing emissions of nitrous oxide (N_20), which are substantially increased following large applications of mineral N fertilisers and animal slurries. This organic approach also stimulates methane oxidation in soils and thus may help to reduce atmospheric concentrations..

Ammonia emissions are related to total annual N excretion by animals and this will not necessarily be less in organic than in conventional farming. Current published data suggests losses from straw-based animal housing systems may be greater than from slurry-based ones, with less potential for abatement of emissions. However work is needed to quantify differences between systems and such studies have recently been commissioned by MAFF from IGER. In particular the size of losses from solid manures by denitrification and ammonia volatilisation have to be determined.

Methane released directly by organic stock may be greater than from conventional animals as the quantity is related to total ffood intake. This will be more than compensated by reduced emissions from the solid manure handling systems which are more common on organic farms. There is thus conflict between ammonia and methane in terms of the preferred system to minimise gaseous emissions.

Organic farms are unlikely to be the source of odour problems to the same extent as conventional units. The keeping of pigs and poultry in large intensive, indoor units on slurry based systems is not permitted under the Standards. Where pigs are kept the solid bedding systems which are used will minimise the risk of odour problems. Odour will be released when solid manure is removed from a livestock building. The subsequent composting which is often undertaken on organic farms helps to ensure that when it is finally spread odour problems are minimised. Care may be needed in the early stages of composting to ensure that the odours that can be generated at this time do not cause a problem. Organic farmers tend to spread less slurry at any one time as they are trying to maximise its fertiliser value and will often incorporate it into the soil fairly rapidly. These practices are more common on organic farms although they are not of course the sole prerogative of organic farmers.

6. Effects of organic farming upon aspects of the landscape of the United Kingdom.

This section of the review is based upon and makes critical comment of a study recently completed for the Countryside Commission.

Differences between organic and conventional systems can be inherent to the choice of system or a reflection of the farmer exercising his choice. Organic farmers tend to choose practices which benefit the landscape. They also maintain and introduce features because they are required by the Standards to do so.

Mixed organic farms contribute more beneficial features than similar conventional units. Field size, abundance of trees, hedgerow management and weeds can be beneficial at both the farm and the overall landscape levels. The impact on the landscape of converting land in intensive arable areas would be even greater as mixed systems would be introduced into what is currently a relatively uniform landscape. Although in the uplands organic farms contribute beneficial aspects to the landscape their conventional counterparts are as likely to follow less intensive practices so that the differences are small.

THE EFFECTS OF ORGANIC FARMING SYSTEMS ON ASPECTS OF THE ENVIRONMENT

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THE EFFECTS OF ORGANIC FARMING SYSTEMS ON ASPECTS OF THE ENVIRONMENT

Introduction

Organic farming in the United Kingdom is a legally defined system of production. Permitted farming practices are clearly described along with more general principles which must be observed. A comprehensive system of inspection and registration enforcement exists to ensure compliance with these specified standards. The primary standards are those laid down in EC Regulation 2092/91, but these are supplemented by the rules adopted by the UK Register of Organic Food Standards (UKROFS- the body charged by Agriculture Ministers with implementing the EC Regulation).

These Standards require management practices to be implemented which have been developed with the aim of protecting the soil, the food supply and the general environment from perceived damaging effects of modern intensive farming.

Such practices include :-

- the avoidance of synthetic agrochemicals i.e. most pesticides, and water soluble fertilisers.
- the use or rotations of different crops to aid natural fertility building and to help control weeds, pests and disease.
- the recycling of organic manures and the use of green manures to maintain and improve soil organic matter content.
- livestock management regimes intended to minimise the need for intervention with veterinary medicines and optimise manure management.
- general attention to the management, enhancement and protection of habitats and natural and traditional features in the landscape.

To the proponents of organic farming these actions clearly provide environmental gain by avoiding harmful practices and by encouraging natural processes which will regenerate and correct previous damage. There is a strongly held counter view that the harm caused by "conventional" systems is overstated and that many of the advantages claimed are not unique to organic farming. That is to say many conventional farmers undertake similar practices with comparable results.

This review considers a selection of published and otherwise generally available information on topics within the wide field of "environmental" effects. The review is divided into six sections. Each section has been written with its own introduction, conclusions and bibliography.

1. The effect of organic management on terrestrial and aquatic ecosystems

There are a wide range of effects of organic management on terrestrial and aquatic ecosystems including flora and fauna at both the macro and micro level. Amongst the aspects considered are the effects of crop sequence, use of chemicals and habitat management and creation.

2. Water Pollution from Agricultural Systems.

This section considers the impact of different farming systems on the water environment due to releases of plant nutrients, pesticides and organic manures. It includes diffuse and point source pollution.

3. Soil protection.

The impact of organic management on soil quality is discussed as determined by organic matter content, soil fauna, soil resilience to cultivation practices including effects on erosion and the accumulation of contaminants.

4. Organic livestock management - side-effects of the use of veterinary medicines.

A comparison is made between veterinary practices on organic and conventional farms. The environmental effects of different categories of medicines are considered.

5. The impact of organic management on atmospheric pollution from farms.

In recent years there has been increasing concern on the effects on the wider environment of the release of gaseous compounds from agriculture. This section considers how organic practices may influence these releases in respect of "greenhouse" gasses, ammonia which can also enrich natural habitats and compounds which cause complaints relating to unpleasant odours in the countryside.

6. Effects of organic farming upon aspects of the landscape of the United Kingdom.

The effect of organic farming on the landscape has been the subject of a recent report by Entec funded by the Countryside Commission. This report has been reviewed and a summary is given together with supplementary comments.

Scope of the review.

Each of the topics covered has an extensive literature. It was not possible to undertake a comprehensive review in the time available. Priority has been given to studies undertaken in the United Kingdom and on comparative work from elsewhere. Investigations specifically relating to organically managed systems have been used where they are available. Information from research in conventional systems has been quoted on occasions. This has usually been in order to illustrate or reinforce topics associated with organic systems but where investigations have not been done under certified organic conditions. In certain instances a more general and subjective discussion has been included on certain techniques or practices which are generally accepted to provide benefits to any farming system that adopts them. The management of animal manures to prevent water pollution is an example of this.

The review considers the impact of typical organic farming and horticultural systems when compared with standard Good Agricultural Practice as recommended in the MAFF Codes for the Safe Use of Pesticides and the Protection of Water, Air, and Soil (MAFF/HSE 1990, MAFF 1991, 1992, and 1993). Such standard systems are referred to as "conventional" in this report. As such the term includes a wide range of management systems from low to high input. Their common feature is that they are free to use all the agrochemicals that are available if they so wish and to generally manage their land as they wish within general legal and contractual requirements.

Comparing management systems.

Although organic production methods are legally defined they permit a wide range of systems to exist in practice. These extend from moderately intensive vegetable holdings to upland beef and sheep farms. When making a comparison with conventional management this is further complicated by deciding which conventional system is taken as the norm. In upland areas the introduction of organic management may have little impact on the way the farm is run. In Eastern England conversion of an intensive arable enterprise implies that significant changes will be introduced. Whilst the former may result in little if any environmental gain considerable benefits may be expected from the change of an intensive arable farm to an organic farm with a mixed grass/arable rotation.

Whilst it can be argued that as far as possible like should be compared with like this will underestimate the advantages that can accrue from a change of farming system. Some of the studies reviewed have attempted to do this. They have had varied success in achieving their stated goals. When they are successful they frequently only compare one or two aspects of the farming systems. Thus by matching farm type and rotation the effects of agrochemicals may be identified. This will completely miss the effects of mixed cropping and habitat management which are usually introduced on the organic farm. As beneficial practices are intrinsic to organic farming whereas they are only optional to a conventional system, seeking to match organic and conventional units for comparison as closely as possible will normally lead to unrepresentative results, biased in favour of the conventional system.

It is undeniable that all of the changes associated with organic farming could be made under conventional management. Change comes from the desire of a committed person to farm in a certain way (i.e. organically) or because a distinct financial advantage is expected. Under current circumstances few if any conventional arable farmers believe that such an advantage exists given the profitability of conventional arable production. Some of the benefits of organic farming are arising from the adoption of integrated systems of crop management. To date these have rarely included a move to mixed farming systems.

Organic management practices.

It has been stated above that the practices required of an organic farmer are not unique to this system. It is worth considering what options the organic farmer has in the way that he manages his land.

• Some organic practices are intrinsic to the system. They are a clear mandatory requirement of the standards and must be adopted. These include the avoidance of soluble inorganic fertilisers and synthetic pesticides, the adoption of rotations which have specific limitations on certain cropping sequences and must include fertility building crops. The livestock standards require welfare friendly housing and feeding systems such that stocking rates are limited and the keeping of pigs and poultry implies solid manure systems.

• Some organic practices which are encouraged by the standards are adopted by organic farmers because it is generally accepted that they will help to establish and maintain an organic system. These include field margin management to encourage natural predators and the adoption of manure management practices which will maximise the benefits to be obtained.

• Some organic practices which are encouraged by the standards are adopted because they are seen as part of the holistic approach to farming in the environment. Thus organic farmers are more likely to maintain or improve wildlife habitats and other traditional features of the landscape. Failure to do so could result in the loss of organic certification.

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1 THE EFFECT OF ORGANIC MANAGEMENT ON TERRESTRIAL AND AQUATIC ECOSYSTEMS

1.1 Introduction

Conventional and organic farming systems are commonly distinguished by the use of agrochemicals in crop and livestock production. If this distinction is the objective of any study comparing the systems it is necessary to exactly match the topographical features, the non-crop habitat and the enterprise type, to ensure that these factors do not bias the result and that the only variable are management inputs to the organic regime. In practice many of the other things associated with organic systems also effect wildlife and it is not appropriate to attempt to maintain a wide range of factors constant.

An interesting paper on this topic has been written in connection with the British Trust for Ornithology report, (1995) on the effect of organic management on bird populations. Stopes and Woodward, (Elm Farm Research Centre private communication) have produced a critique 'An assessment of the farm pairs in the BTO birds and organic farming study' which shows that even where great care had been taken to ensure that comparisons could be made which would isolate agrochemical inputs, close scrutiny reveals that the key criteria from the point of view of farming definition and description had not been met.

Farm size and type, overall management ,farm enterprise, rotation and proportion of arable cropping, field size, livestock husbandry, sample size and response rate were all considered. It was found that of 15 'paired' farms only 2 were deemed to be 'good' according to the study specifications whilst the remainder were deemed to be 'less adequate' because of flaws evident in the comparisons.

Other papers reviewed for this study exhibit similar flaws. In no instance was it possible to obtain an exact match for comparison purposes, however sources of information are available which are closely related to farming systems in the 'real world' enabling accurate assessments of the implications of both conventional and organic regimes.

Available literature has been accessed and relevant information extracted to produce a review of the current status of wildlife on organic holdings as compared to non-organic production units. Flora and fauna at both the macro and micro level are included, along with the effects of crop sequence, chemical inputs, habitat management and habitat creation.

1.2 Flora

1.2.1. Weeds in crops and grass

As part of the BTO study of paired farms (British Trust for Ornithology 1995) a botanical survey was carried out in order to assess the effect of management of cereal fields on the flora, and subsequent food supply for farmland birds. The survey covered three summers but only two winters(1992 and 1993). Greater plant diversity and a greater abundance of non-crop plants were found on the organic fields, although it is not stated if these results were significantly different. There was no significant difference between plant diversity and abundance between the two years. The additional species found on the organic farms were all common, widespread plants of arable fields, waste ground, gardens and hedgerows.

The Game Conservancy Trust (Moreby & Southway 1993) over 2 years sampled 59 pairs of winter wheat fields on three organic and five conventionally managed farms to assess weed and invertebrate populations in mid-June / early July. These few weeks are when arthropod food is essential in the diet of game-bird chicks. It was found that organic cereal crops had similar weed cover to conventional fields with no significant difference in the number of grass weed species, percentage cover or percentage cover of individual species. The broad-leaved weeds however showed a significantly greater cover and number of species in the organic crops.

A Danish study (Hald and Reddersen 1990) of the weeds and arthropods in 15 paired fields showed weed numbers and biomass to be significantly greater in the organic fields and the differences strongly increased during the growing season following herbicide spraying in the conventional area.

Studies on the field and margin flora of both conventional and organic fields sown to winter cereals are currently being undertaken (Rhone-Poulenc 1995) as part of a 10 year rotation. The study is now half-way and there appears to be a clear difference between the two regimes. Conventional crops have fewer weed species in them and fewer perennial species. To date there is no trend of increasing number of weed species over the years, but the numbers of perennial weeds are perceived to be an increasing problem (Noble private communication). The weed density (numbers of weeds per sq. metre) is significantly higher on the organic fields compared to the conventional but here competitiveness is thought to be low.

A number of studies by workers in Germany have been reviewed by Lampkin & Arden-Clarke (1990). They show that the abundance and diversity of wild flowers are higher in organically managed arable crops than conventionally managed ones, both in the centres of the fields and in the field margins. Comparisons of two organic (biodynamic) row crop fields with two neighbouring conventional row crop fields found 25 wild plant species in the biodynamic margins compared with 16 in the conventional field margins and 18 in the biodynamic field centres compared with only two in the conventional fields. Some endangered 'red list' species were found on the biodynamic fields but not on the conventional fields.

Monitoring of an organic farm in Wiltshire (Browning 1985) recorded a wide range of " traditional weeds" of arable crops with much reduced variation on comparable conventional fields. Similar conclusions were reported by Samuel and Guest (1990). An on-going national survey of wheat crops on organic farms in England and Wales (e.g. Yarham and Turner 1992) has also found a wide diversity of weeds. In all of these three UK studies it was unusual for annual dicotyledenous species to develop so as to compete with the crop. The main problems have been perennial weeds such as docks and thistles. This comment applies also to organic grassland where the experience with the in-bye land at ADAS Redesdale can be taken as a typical example (Young and Rushton 1994, Keatinge et al 1995). At this farm reseeding has had the major influence over the increase of clover in the in-bye swards. The improved hill pastures have shown a significant increase in clover during conversion presumably due to the withholding of inorganic nitrogen fertilisers. This is the usual result of such a change.

1.2.2. Hedgerows and field boundaries.

O'Connor (1984) pointed out that hedgerows have remained a characteristic of mixed and pastoral farming systems in the UK. Rates of hedgerow removal have been two to three times faster on arable than on mixed farms and between four and ten times faster on arable as opposed to all-pasture farms (Hooper 1970 & 1977). In virtually all the established organic systems in the UK livestock play a central role and hedges have been retained for stock management (Vine & Bateman 1981). The current UKROFS Standards (UKROFS undated) state that hedges should be retained and they also lay down criteria for managing them.

Intact hedgerows are important areas for wild flora and fauna that would otherwise be absent, or in low numbers, on farmland. Of the five to six hundred species of flowering plants that have been recorded in hedgerows, about half occur often enough to be considered as hedgerow plants. Some 30 species of shrubs, climbing plants, herbs and other plants may become locally extinct as a result of hedgerow destruction (Hooper 1970). Quantitative evidence was given by Lewis (1969) that insect diversity in a hedgerow was substantially greater than in adjoining bean and grass crops.

The loss of field margins in the form of hedgerows removes nest sites, refuges and food sources for woodland birds (O'Connor 1987). Green (1979) showed that small mammals are also dependent on hedgerows for food and cover. Bank voles and short-tailed field voles are concentrated in hedgerows and shelterbelts and changes in the numbers of these mammals will affect predatory species such as weasels (Day 1968, Tapper 1979). Raptors such as the barn owl and kestrel may be similarly affected (Glue 1967, Shrubb 1980, O'Connor & Shrubb 1986). Hedgerows on organic farms were not subject to the damaging influences of straw burning before this practice was banned. They are not subject to pesticide drift, the deliberate spraying of hedge bottoms, or the accidental spreading of fertilisers all of which are associated with conventional management (Moore 1977, Rands & Sotherton 1987).

Preliminary work has shown that those species of predatory insects considered to have the greatest potential as predators of cereal aphids i.e. rove beetles, common earwigs and ground beetles overwinter almost exclusively in field boundaries such as shelter belts, hedge banks, grass banks and grassy margins (Sotherton 1984).

1.3 Soil microflora

1.3.1. Soil Biomass and General Functions

The literature detailing the effects of management practices on soil micro-organisms is immense and the subject of many text books. As an example Domsch (1984) estimated that by that time at least 1580 papers had been written on the effects of pesticides alone. (They were then appearing at the rate of 70-80 per year.) Anderson (1978) had already produced a 120 page table on the side effects of pesticides on the microflora and microbiological processes in soils.

The total microbiological activity is commonly reported using the concept of soil microbial biomass. The size of the biomass is determined by positive influences such as food supply and negative effects such as pesticides. Whilst it is generally accepted that increasing the biomass in a particular soil is a good thing our knowledge does not permit a prediction of what is an optimum level in a particular situation. The higher the biomass the greater the overall microbial activity that can be expected.

Biomass varies seasonally at a given site according to soil conditions and the presence or absence of a crop. These seasonal variations may be greater than differences between fields under different management regimes. The biomass is particularly sensitive to the supply of food substrate from root exudates. Thus grassland soils by virtue of their perennial nature commonly support at least twice the biomass of arable land (Lynch 1984). Returning straw residues to the soil can stimulate the biomass. It has been suggested that following the ban on straw burning, organic farmers who need a greater proportion of their straw for livestock will be returning on average less straw than conventional farmers (Lampkin 1992). The increased crop biomass generated by the use of fertilisers on conventional farms can provide a greater food source from both root exudates and return of root and other crop residues.

1.3.2. Effect of organic systems.

The overall effects were summarised by Lampkin (1992) who cited a number of workers who had shown that organically managed systems have higher levels of microbial activity than conventional soils. This activity was frequently associated with specific processes concerned with the recycling of plant nutrients. He noted that many authors observe that the effects are the result of factors including soil water content, and organic carbon and nitrogen levels. As such the differences are the result of soil management practices which may be found in non-organic systems. Examples of the work cited are given below.

Fraser (1984) found that in soil treated with organic manures, soil bacterial and fungal counts and dehydrogenase activity (a measure of the overall rate of microbial metabolism) were higher than those in soils supplied with inorganic fertilisers. Untreated plots had lower microbial populations than those treated with inorganic fertilisers, which had lower populations than plots treated with organic manures (Martyniuk & Wagner 1978).

In natural soil ecosystems balanced interactions between soil flora and fauna lead to controlled, continuous mineral releases (Reichle 1977), which offers advantages over rapid increases in nutrient concentration and subsequent heavy losses from the system.

1.3.3. Mycorrhizal fungi

Mycorrhizal fungi infect the root surface of plants and have a critical influence on the effective uptake of nutrients by the plant. They are particularly important for the uptake of phosphorus (e.g. Wild 1988). As such they enable crops to grow at lower levels of soil phosphorus which can reduce the need for soluble fertilisers. Potentially soil phosphate reserves can be kept at a lower level and the risk of adverse environmental effects due to the liberation of this phosphate into the environment is reduced.

Mycorrhizae are suppressed by applications of fertiliser (e.g. Gerdemann 1975). Additions of inorganic N, P and complete fertilisers reduce the level of infection by mycorrhizae, though this effect does vary with soil type. Hayman (1987) concluded that other components of high input systems also effect this group of organisms while Sattelmacher et al (1991) concluded that the effects of pesticides, fertilisers and a narrow range of crops in the rotation acted synergistically to reduce mycorrhizal infection of rye (Secale cereal L.)

A recent comparative study in Wales (Scott et al in press) looked at the level of root infection of mycorrhizae from organic and conventional grassland soils. This was a pot study. Whilst not all the organic samples were better than those from conventional fields overall there was a statistically significant difference in favour of the previously organically managed land. The effect was demonstrated on clover and leek but not on ryegrass where nitrogen deficiency was thought to be responsible. It is interesting to note that in an earlier study Newbould and Rangeley (1984) found it difficult to reproduce under field conditions the large response of clover to inoculation obtained in pot trials. Tinker (1984) concluded that temperature was important in determining infectvity and this may explain some of these problems. He also felt that as there is a lack of host specificity that native soil fungi were likely to prove as good as introduced species.

1.3.4. Effect of pesticides.

The principles relating to the effects of pesticides on microbial activity were reviewed and discussed by Domsch (1984). He concluded that because few pesticides are so persistent and/or applied regularly that chronic effects due to long term exposure are unlikely. This is indeed the principle on which pesticide approval is conducted where absence of long term effects would be required. However acute effects after application are a possibility for some groups of organisms and it is these and possibly a more general reduction in activity that can lead to observed effects in organic systems. The confounding influences of other factors makes interpretation of effects difficult to attribute.

The recovery of microbial populations after stress may mean that a change in the balance of organisms results. Domsch (1984) listed the environmental stresses that can effect micro-organisms as :- temperature, soil moisture, oxygen supply and natural inhibitors. Measured recovery periods were frequently in the range 20-30 days. He suggested that any delay in recovery of more than 60 days could be regarded as critical. Lampkin (1992) noted that in comparative studies there are reports of a change in the balance from fungi to bacteria in systems using regular applications of pesticides. Domsch (1984) had indicated that only a small proportion , under 2 % of cases reviewed appeared to result in a long term change in activity.

It is worth noting in passing that the degradation of many pesticides involves microbial activity which is additional to that in untreated soils. This can involve the development of populations specifically adapted to breakdown a certain substance.

In an empirical analysis of the actual responses of 25 processes to 71 different pesticides in 734 experiments Domsch (1984) found that phosphatase activity, organic matter breakdown and nitrification were sensitive indicators whilst denitrification, urease activity and non-symbiotic fixation of nitrogen were insensitive. The sensitive processes were particularly affected by organic phosphate insecticides and soil fumigants.

Microbial biomass is being monitored on reduced input experiments on ADAS Experimental Centres (e.g. Jones and Johnson 1993). Measurements over 3 growing seasons showed a greater fluctuation of biomass under the plots receiving the highest level of pesticide inputs. The changes were however relatively short lived indicating that individual pesticides with a relatively short residence time can have fairly transient effects although in this work the absolute effect of pesticides was not clear because there were no nil-pesticide controls.

1.3.5. Effect of heavy metals on microbial activity.

Domsch(1984) also reviewed the effects of heavy metals. He recognised that it is the concentration of metal in soil solution that determines the response of soil organisms and therefore crude dose/response relationships to quantity of applied metal are seldom conclusive. Analytical techniques are only now coming to grips with this problem. The subject has been considered more recently by a MAFF /DOE Committee (MAFF /DOE 1993). Evidence for effects on a range of soil processes and groups of organisms were considered in relation to the existing Regulations for the application of sewage sludge to agricultural land (Cmmd 1989). Effects were noted on total microbial biomass, soil respiration, rhizobial nitrogen fixation (e.g. by clover) and on vesicular-arbuscular mycorrhizal fungi. Nitrification was only affected at relatively high metal concentrations.

Overall the results suggested that microbial function could be affected at metal concentrations found naturally in some soils and to which some might be raised by metal additions in manures and waste materials. The organic standards have always made reference to the need to limit metal accumulation in soils. The prohibition of the metal supplementation of livestock feeds for other than nutritional reasons means that accumulations will be less than from standard conventional management. (See also Section 3). The MAFF Soil Code (MAFF 1993) advises all farmers to monitor metal applications and to limit soil concentrations to those values required under the Sludge Regulations.

1.3.6. Oxidation of methane

The effects of management practices on the removal of methane from the air by oxidation in soils by micro-organisms is discussed in Section 5.

1.4. Birds

By far the greatest availability of literature supporting the case for the increased abundance of fauna on organic farms relates to avian research. A sample is considered below. Increased populations of arable weed species and insects associated with organic farming are likely to influence bird populations. Two USA studies (Ducey *et al.*, 1980 and Gremaud & Dahlgren, 1982) both concluded that the higher bird population densities found on the organic farms as compared to the studied conventional farms were linked to the greater diversity of crops and presence of grassland on those farms. In Britain, research by the British Trust for Ornithology (Anon.,1989) reported significantly higher levels of soil invertebrates available for winter feeding birds on organic farms than on conventional farms.

In Denmark significantly higher bird populations - skylarks, grey buntings, swallows, lapwings and linnets in particular were found on organic farms (Braae *et al.*, 1988).

The most recent paper available regarding the implications of organic versus conventional farming on the bird population in the UK, is that produced by the British Trust for Ornithology (1995)on behalf of the Ministry of Agriculture, Fisheries and Food, that was referred to in the introduction. As mentioned difficulties were encountered in obtaining sites that were directly comparable. In particular hedgerows which are important habitats commonly differed between paired farms.It was found that although total bird numbers and bird densities were higher on the organic farms than on their conventional counterparts, results were often not statistically significant. The project covered three breeding seasons with the intervening winters and significantly higher results were obtained for wrens, tree sparrows, redwings, bullfinches and reed buntings in at least one winter period, whilst blackbirds, blue tits, great tits and yellow hammers showed significantly higher densities in only one of the three breeding seasons.

The report goes into great detail but much of the discussion centres on non-significant results. The full report is currently under consideration by MAFF. There seems little doubt that if the study had compared typical organic and conventional lowland farms that the differences would have been greater.

A Common Bird Census has been carried out by British Trust for Ornithology volunteers at the Boarded Barns study site (Rhone-Poulenc 1995). The results from 13 species were analysed in detail - skylark, wren, dunnock, robin, blackbird, song thrush, whitethroat, blue tit, great tit, chaffinch, greenfinch, yellowhammer and reed bunting - and there was an increase from 141 to 165 in total territories held by these species.

The increase in the territory numbers in the organic study area was from 29 to 45. These figures suggest that the increase has been greater on the organic area during the conversion period than on the farm as a whole.

1.5. Mammals

1.5.1. Badgers, Foxes, Hedgehogs

The most important single item of food for badgers are earthworms (e.g. *Lumbricus terrestris*). A review of these is included section 3.2. Up to 80% of the badger diet consists of earthworms at certain times of the year (Neal 1980). Badgers, foxes and hedgehogs also require a large numbers of beetles, slugs, snails, wasps, bees, caterpillars and cranefly larvae for their day to day requirements and as these invertebrates are affected by pesticide usage it is felt that their inter-dependence should be the subject of a comparative study, however no details of any such study has been found for this review.

1.5.2. Rabbits and Hares

Radio-tracking of brown hares on a mixed farm and at nine other farmland sites have shown that hare numbers in autumn are positively associated with landscape diversity (Tapper & Barnes,1986).Hares use a variety of crop habitats at different times of the day and year, depending on food availability and local climatic conditions and this may have implications in the decline of the hare nationally (Tapper & Parsons,1984).
The importance of wild plants, including 'weeds', in the diet of hares living on agricultural land has been shown (Frylestam 1986), where a preference for wild plants as opposed to cultivated crops was shown. The availability of hare food in herbicide-treated wheat and oilseed rape crops was sufficiently limited to reduce the body weight of adult hares and their reproductive success.

Little work appears to have been carried out on the effects of differing regimes on rabbits. The only reference in which results were analysed for rabbits exposed to aphicides (Tarrant & Thompson 1992) gave results for sample sizes which were too small to be statistically interpreted.

1.5.3. Small mammals

A small mammal study was set up as part of the Boarded Barn Farms project (Rhone-Poulenc 1995) as it was felt that an increase in small mammals may be beneficial in terms of providing food for carnivores such as owls and it has been suggested that they might act as an indicator of change. They may also become a pest if their numbers increase. The common shrew, short-tailed field vole, bank vole, woodmouse, yellow-necked mouse, harvest mouse and house mouse were recorded (all vegetarian species). Results have shown that there is no significant difference in the numbers of small mammals recorded on conventional and organic fields (Brown 1995-report to BTO).

The amount of cover available makes a large difference to whether catches are made in the hedge or out in the field or to whether anything is caught at all. Management of hedgerows is crucial for the maintenance of a diverse and healthy population of small mammals. It may also encourage the yellow necked mouse and the return of the harvest mouse (Brown 1994). Planting a hedgerow on the organic dairy unit at IGER Ty Gwyn rapidly resulted in the movement of mice from woodland out into organic fields (Haggar private communication).

The woodmouse is largely restricted to cereal crops, whereas the short-tailed vole is a grassland species and substantial populations will co-exist only in areas where there is a balance of cereal and grass crops or where grassy areas often associated with hedgerows are interspersed among arable fields (Tapper 1979). Short grass is an unsuitable habitat for the short-tailed vole and large populations are not found on intensively grazed or cut leys or pastures. Short-tailed voles are an important prey item in the diet of kestrels (Shrubb 1980, Pettifor 1984), barn owls (Glue 1967), weasels (Tapper 1976,1979) and a number of other predators found on farmland (Day 1968).

The dependence of woodmice on weed seeds in cereal crops in winter (Green 1979) suggests that small mammal populations may be affected by low weed densities in these crops. Tew (1987) showed that a radio-tracked individual displayed a strong preference for feeding in unsprayed crop edges where densities of grass weeds were ten times higher than in the rest of the crop.

1.6. Invertebrates

1.6.1. General effects.

Higher numbers of insect species have been found on organic farms, due largely to the more diverse flora which is present.(Dritschilo & Wanner 1981). This is thought to be a result of higher populations of non-crop species in arable fields, a greater variety of crop species as a result of rotational and other practices, use of techniques such as undersowing and the use of flowering herbs and legumes such as chicory and red and white clovers in grassland.

This result was largely supported by the insect studies carried out during the BTO study of paired farms.(British Trust for Ornithology 1995) where species richness and diversity was assessed. Although higher numbers of insects and arthropods were detected on the organic fields, the rank-abundance curves indicated that the distributions were similar for both organic and conventional systems.

In some instances the success of natural biological control of crop pests may result in a reduced feed supply for other wildlife or the effect may be neutral. Thus the Game Conservancy (Moresby & Southway 1993) showed that conventional fields of wheat where summer insecticides were not used, had almost twice as many cereal aphids as the corresponding organic crops and also more aphid-specific parasites and predators. Organic fields in the study did have higher numbers of sawfly larvae and weevils but overall there was no difference in the total number of game chick-food insects found between the two farming regimes.

Hald and Reddersen (1990) in their study of 15 paired fields showed that the average biomass of arthropods in the organic fields was significantly higher than in the conventional fields. While the amount of insects and other arthropods showed extreme fluctuations in the conventional areas both between years and within one breeding season, it was much more stable in the organic fields. (Nohr - undated)

The carabid fauna of agrosystems was monitored at the Obere Lobau in Vienna (Kronge 1989).All fields were comparable in location, size and soil type. Cultivation differed with respect to weed control (mechanical or herbicides),disease control (none or fungicides) and manuring (green/compost/stonemeal or mineral). In both years of the trial abundance was considerably higher in organic winter wheat than in conventional. These differences seemed to be mainly due to the higher weediness, greater heterogeneity of crop density and absence of pesticides in biological wheat fields.

1.6.2. Butterflies

In 1994, a collaboration was established between the Wildlife Conservation research Unit at the University of Oxford, the Institute of Terrestrial Ecology, the SAFE Alliance and Butterfly Conservation to investigate the abundance and species richness of butterflies on organic and conventional farming systems in England. During the survey 19 species were recorded at the Boarded Barns study site (Rhone-Poulenc 1995) and preliminary analyses of data from all the sites have shown that significantly more butterflies were recorded on organic than conventional farms. Significantly more butterflies were also recorded on uncropped field boundaries than on the crop edge. Butterfly abundance differed with crop type and some butterfly species were associated with only one crop type. No significant difference between the two systems in terms of pest butterfly abundance was found.

1.6.3. Arthropods

Part of the Boarded Barns project (Rhone-Poulenc 1995) is monitoring the long term effects on the abundance and diversity of groups of polyphagous predators under the two management regimes. The findings of the 4th year of study show that there were lower numbers of beneficial arthropods trapped in conventional fields than in organic fields. The numbers of money spiders and hunting spiders caught in the conventional fields were consistently lower than in organic fields. Reasons were unclear but may be linked to the use of an autumn aphicide. The differences in the carabid and staphylinid numbers were less well defined between the two areas of the farm. Factors other than the differing regimes are currently being considered.

Several studies have been carried out with reference to arthropod numbers on paired fields (Hald & Reddersed 1990, BTO 1995 etc.) in relation to bird numbers and these have been discussed earlier - see sections 'Birds' and 'Insects'.

1.7. Soil fauna

The soil supports a vast array of living organisms from bacteria, protozoa and micro-organisms to nematodes, molluscs, earthworms, arthropods and insects. Some of these are pests, others predators or parasites of other organisms. A good soil will contain a healthy population of invertebrates which break down organic matter therefore releasing nutrients plants can utilise. A form of management therefore that encourages these invertebrates will benefit the soil and therefore the plants that grow in it (Brown 1994). See also section 3.2.

It is difficult to assess the effects of agricultural practice on micro-organisms but work has been carried out on the soil invertebrate populations (Edwards 1984). Changes such as direct drilling with no cultivation, benefit the populations of soil invertebrates but increased pesticide use and the change from organic to inorganic fertilisers has a detrimental effect.

El Titi and Ipach (1989) demonstrated increases in the population of predatory mites under reduced input, integrated arable systems. Nematode populations were also affected with a general decrease in parasitic species and an increase in beneficial predatory species. Nematode populations in an organic system have been shown to be increased by poultry manure but there were greater benefits from using FYM (Griffiths et. al. 1994).

Since 1992 a study has been in progress to highlight the differences in soil micro- and meso- fauna between organic and conventional regimes (Rhone-Poulenc 1995). The bulk of the invertebrates extracted belong to the Acari (mites) or the Collembola (springtails), with numbers of beetles, spiders, centipedes and flies also being recorded. Numbers found compare directly with those from similar cultivation practices elsewhere but currently no significant differences in the numbers present at the sampling times between the two farming regimes have emerged. The report suggests that it may be too early in the study to draw any conclusions. Sampling times are to be more confined in future years. .

The soluble salts in inorganic fertilisers can affect the soil micro-organisms and invertebrate fauna.(Marshall 1977) A reduction in faunal species composition and diversity is noted with increasing salt content, and injury due to osmotic stress in certain species such as nematodes found. It was also found that although both organic manures and inorganic fertilisers tended to increase insect populations, myriapods (centipedes and millipedes), and enchytraeid worms, some of these species were sensitive to some inorganic fertilisers.

Excessive applications of some types of organic manure can have deleterious effects on soil fauna.(Curry 1976) High rates of liquid slurry application reduced earthworm populations by half and biomass by over a third.

Soil populations of fungi, bacteria and viruses are all directly affected by fertiliser practice due to its effects on the physical and chemical conditions of the soil and on the living components of the soil environment on which the soil flora and micro-organisms depend. (Arden-Clarke & Hodges 1988). The effect can be expected to have repercussions up the food chain.

The release of nutrients from organic matter is dependent on the decomposition processes brought about by a range of soil organisms. (Coleman *et al.* 1984). Changes in the population levels of these soil organisms consequent upon agricultural practices will result in major changes in the patterns of loss, retention and flow of nutrients in the agro-ecosystem.

1.8. Amphibians.

Very little information has been published on the role of amphibians as pest control agents on farm land or of the effects of different farming systems on their occurrence in the UK. Wilkinson et.al. (1995) have reported to MAFF with a review of known information.

There seems little doubt that in the course of their normal feeding patterns, amphibians (toads, frogs and newts in the British Isles), will consume both invertebrate pests and beneficial species. When pests are common they can make up a high proportion of the diet. The potential importance of this feeding pattern is not known. Toads are commonly recommended for pest control on small organic horticultural units but there effects are not usually considered on a farm scale.

It has been estimated that the population of the common toad is 5-12 /ha on intensively managed land, 50/ha on arable farmland and between 35-150/ha in a mixed agricultural habitat which includes woodland. Similar differences have been reported for the great crested newt.

Amongst the reasons reported for these differences are the contamination of ponds and other water bodies by agrochemicals, reduction of suitable habitats for both breeding and for feeding. i.e. wetlands and hedges and woodland respectively. Eutrophication of water bodies can affect breeding success when excessive weed growth shades spawning areas.

Organic farming systems should support higher populations of amphibians by virtue of providing more favourable habitat and by reducing the negative pressures that agrochemicals can cause. There is every chance that they will repay the farmer with increased control of invertebrate pests. There is, apparently no specific information on either of these points.

1.9. Aquatic systems

1.9.1. Pesticides

Despite the very large quantities of herbicides used in arable agriculture, relatively little has been published quantifying residues of herbicides in water and the effects on wildlife (Croll 1986). Discussions on permissible levels of herbicides in water tend to revolve around the EU 'Drinking Water' Directive (80/778/EEC). The toxicity of herbicides to mammals and fish is generally deemed to be low and the critical concentrations in waters are often determined by organoleptic considerations with respect to potable water supply or toxicity to plants during overhead irrigation, within standard agricultural practice.

Kickuth (1982) describes the effect of the herbicide active ingredient Phosphonylsarcosine on the water flea. The water flea relies on a chemical, sarcosine, produced during the decay of organic matter, to lead it to its food source. The herbicide is a closely related chemical which confuses the water flea so that it can no longer detect potential sources of food, leading to eventual disruption of the food chain.

The most significant benefit in terms of fish and wildlife of a transformation to organic farming practices is the reduction or total elimination of many hazardous agricultural chemicals.(Langley *et al.* 1982). The persistence and previously wide dispersal of organochlorines from conventional farming systems has resulted in the contamination of vertebrates in aquatic environments, leading to residues in fish (De Vault *et al.* 1986) and resulting in contamination of predatory mammals e.g. otters (Mason *et al.* 1986) and fish-eating birds e.g. osprey (Prestt & Ratcliffe 1972).

1.9.2. Nutrients and manures.

Excessive agricultural runoff of phosphorus compounds are known to cause eutrophication of lakes and ponds which can destroy significant fish populations. (See section 2.4). Periodic massive algal blooms, contamination of water supplies and objectionable odours are often associated problems (Maitland 1984). Poisonous effects on surface waterways have resulted from the use of chemical fertilisers and pesticides on adjacent fields.

Organic farming methods can be expected to cause less soil erosion than conventional arable systems thus reducing sediment and nutrient pollution of water bodies (Section 3.3). Silage clamps and intensive livestock husbandry units are damaging agricultural point sources of water pollution.

High losses of nitrogen, phosphorus and potassium to surface and groundwaters are associated with conventional farming and in surface waters they can dramatically reduce the abundance and diversity of aquatic flora and fauna. Phosphorus in the waste from livestock units in rivers can cause eutrophication problems, ammonia causes fish and invertebrate deaths and the increase in organic content deoxygenates the river water by virtue of its high biological oxygen demand (BOD). See section 2.2.

1.9.3. Wetlands.

Marshes, bogs and lake and pond margins all support a wide range of plants and animals that are not found elsewhere. Five of the 19 plant species which have become extinct in Britain in the last three centuries were 'wetland' species and a further 7 are endangered. A large number of aquatic insects are also under threat and the breeding numbers of many wetland bird species such as snipe and redshank have also been reduced.

Wetlands include a variety of habitat types, including marshes, fens, bogs, watercourses of various sizes, ponds, lakes, estuaries, lagoons, wet grassland and alluvial woodland. Every EU country except Luxembourg has signed the Ramsar Convention and are required by the EU birds' directive to pay particular attention to the protection of wetlands as a means of conserving migratory species. Data on wetland habitat change is patchy (Baldock 1990), but it is clear that vast areas of wetlands have been reclaimed, leaving small relics of what must have been once extensive habitats and many individual sites remain under threat

1.10. Crop sequence

The trend towards increasing specialisation of crops and near continuous cereal cropping encouraged by economic pressures and aided by the development and use of inorganic fertilisers and pesticides on conventional farms has led to polarisation of regional cropping patterns (Southwood 1972). Grass is the predominant crop of the north and west and cereal growing predominates in the south and east.(Church *et al.* 1968, Potts 1977, Raymond 1984).

In contrast, crop rotations remain a cornerstone of organic agricultural systems on all but the permanent pasture farm. A wider variety of crops grown in an area provides greater structural diversity and therefore habitat diversity within crops and should lead to a greater diversity of wild flora and fauna. However to quantify this effect is almost impossible. Direct impacts on some bird poplations attributable to reductions in the diversity of crops grown in a given area have been shown (Murton & Westwood 1974).

As no herbicides can be used on organically grown crops, good management of a sound rotation is essential for weed control (Parish, Scottish Agricultural Colleges 1993). An 8 year rotation with a 3 year grass ley can be used to control annual weeds with undersowing helping to smother weeds and provide crop cover in winter. Accurate timing of crop drilling is essential as is roguing out of docks, thistles, wild oats and barren brome.

The Elm Farm Research Centre bulletin (1994) details the desirability of weed control on economic terms whilst pointing out that the greater diversity of non-crop species found on organic as compared to conventionally managed farms provides a range of environmental and agronomic benefits which should not be discounted. EFRC has recently embarked on a three-year EU funded research project designed to improve understanding of weeds and how to control them in organic farming systems.

By using crop rotation without insecticides, insect losses to the crop were estimated to be 1% higher (Pimentel *et al.* 1978).

On mixed farmland in Sussex, Shrubb (1980) showed that kestrels hunted clover-grass leys, field boundaries and other permanent features for most of the year but hunted the cereal fields from November to April, showing that arable and grass crops provide alternative feeding grounds at different times of the year. The grasslands provide small mammal prey and the cereal fields invertebrate prey.

One possible negative impact of rotations is the disruption to floral and faunal communities caused by the successive changes in the crops grown (Pimentel *et al.* 1983). This type of disruption is reflected in the length of time it can take to establish a given level of floral and faunal diversity in a crop e.g. low floral diversity of temporary clover-grass leys (Brotherton 1977) and the slow build up of insect populations and diversity in those leys (Purvis & Curry 1980).

1.11. Use of chemicals

1.11.1. Conventional systems.

The use of synthetic pesticides in conventional farming has one of the most significant but least quantified impacts on wild flora and fauna. The wide spectrum of activity and method of application can result in ecosystem treatment rather than specific pest treatments.

Herbicidal weed control has virtually eliminated broad-leaved weeds from cereals and other crops and whilst not being in danger of national extinction, they may be subject to local eradication. The retention of some specimens is desirable on aesthetic grounds and the seeds of a few are important food for some farmland bird species.

The Wildlife Incident Investigation Scheme in the UK, investigates deaths of wildlife, including beneficial insects, pets and some livestock where pesticides are suspected. (Fletcher *et al.*, 1993) Fish are not included. Incidents arising from deliberate abuse, misuse and approved use are looked at. The proportion of misuse (carelessness) has remained the same for 1992/93 but reported incidents arising from an approved use of pesticides increased in 1993 to 17 from only 6 in 1992. The report concluded however that when consideration is taken of the large amount of pesticide usage in the UK, these few incidents show that where pesticides are used in the approved manner, there is a negligible risk to wildlife and other animals.

Persistent organochlorines are still a threat to wildlife despite being withdrawn in 1989. Chemically they are extremely stable and are fat soluble so that they can be stored by prey animals, passing from prey to predator, and be dispersed over wide areas in bodies of migrant animals. This has resulted in depressed raptor populations, and increases of dieldrin in kingfishers (Institute of Terrestrial Ecology 1981) and in sparrowhawks and herons (between 1983 and 1986). Dead otters with potentially lethal levels of dieldrin were found in East Anglia (1982-1985). Carbamates and some broad spectrum fungicides are implicated in reduced numbers of aquatic vertebrates and invertebrates. Secondary poisoning of ground-feeding birds taking organochlorine-contaminated prey has been recorded (Davis 1966). These problems should now be on a reducing scale.

Beneficial insects are at risk from the field application of insecticides, especially when the sprayed crop is attractive to pollinating insects such as honeybees (Needham *et al.* 1966: Stevenson *et al.* 1978). Most confirmed poisonings involving bees are associated with spraying of oil-seed rape crops to control cabbage seed weevil and brassica pod midge from late May to early June (Hardy & Stanley 1984). Problems should be avoided by careful selection of pesticide formulation, timing of application and close liaison between spray operator and beekeepers. However such action cannot prevent damage to species of wild bees or other beneficial insects feeding in or on the crop.

The organophosphorus insecticides whilst being less persistent are more toxic to vertebrates. The methods of application can decimate the populations of all insect species in or close to treated crops and the newer pyrethroids and carbamates have a similar effect. The derivatives of rotenone which are permitted under organic standards for some crops and which also have a wide spectrum of activity are not cleared for use on field crops in the UK.

Some of the new foliar fungicides which are widely applied to conventionally grown cereals have a powerful insecticidal action (Lampkin 1992).

It was estimated that pesticide use on cereals had seriously depleted or currently threatened several mammalian species, 14 species of birds, 90 species of flowering plants and 800 species of insects (Potts 1988).

Due to the general environmental contamination by pesticides and the effects of spray drift it is not possible to guarantee freedom from residues in organic systems.(Lampkin & Arden-Clarke 1990)

Conventional and organic farmers stimulate biological activity by organic manuring practices, but a conventional farmer tends to suppress this activity by using pesticides (Fedoroff 1987). Nematicides are lethal to virtually all soil organisms (Edwards 1984), and soil fumigants have the most dramatic results. Aldicarb, methomyl and dazomet all reduced populations of earthworms, potworms and insects (Edwards & Lofty 1971) and the fungicides benomyl and thiophanate-methyl also resulted in dramatic reductions of earthworms (Stringer & Lyons 1974, Wright 1979).

The wide range of insecticides used in conventional agriculture have diverse effects on soil invertebrate populations (Madge 1981), some selective and some killing a range of species.

Only a few herbicides are directly toxic to soil fauna, but indirect effects result in the elimination of an important source of decaying plant matter which can reduce the available food supply for saprophytic flora and fauna. With the exception of triazines there is generally no serious effects to the soil fauna. (Madge 1981).

The potential for major impacts on non-target organisms by agrochemicals is best illustrated by estimates of the efficiency of utilisation of various pesticides. On an overall basis, Pimentel & Levitan (1986) estimated that less than 1% of the 500,000 tons of pesticide applied annually in the US reached the target organism because of reasons such as poorly controlled droplet size, exaggerated drift, consumption of only a very small proportion of a sprayed crop by pests, the small size of the pest (particularly fungi) and poor timing of applications. Of the large percentage of an insecticide which fails to reach an insect pest, a proportion may make contact with arthropod predators and parasites which prey on the pest species at which the pesticide is directed, killing a proportion of these natural enemies and potentially hindering control. Herbicides may reduce predator cover or food sources and reduce their numbers in this way.

Coaker (1977) notes many examples of pest outbreaks following the use of a variety of chemical control methods, a substantial proportion of which were due to the adverse effects on natural enemies of the pest, either by a resurgence of the original pest or by pests of secondary importance.

It has been noted that increases in the use of pesticides in a study area (Vickerman 1980), coincided with an upward trend in both cereal aphid and cereal thrip, and by downward trends in the populations of many of these pests' natural enemies, particularly carabid and staphylinid beetles, some predatory flies and some chrysomelid beetles. The populations of the pest species remained stable or increased while most non-pest species declined.

1.11.2. Organic Pest Control Strategies

Synthetic pesticides, which would undoubtedly be the major source of environmental impacts in a conventional pest control strategy are not used in organic farming systems and organic pest control strategies are based on prevention rather than cure. Minimising the potential for outbreaks, along with the maintenance of soil fertility are the guiding principles. Observation that organic farmers do not have serious problems with insect pests and disease (Oelhaf 1978, USDA 1980, Vine & Bateman 1981) are so far untested and unquantified. Vine and Bateman noted that many of the organic farmers in their survey reported that aggregations of aphids on their crops soon attracted coccinellid predators and the aphid populations never reached pest proportions. In a survey of wheat crops in England and Wales, Yarham and Turner (1992) reported low populations of insect pests in organic crops.

In organic horticultural systems, which are usually on a much smaller scale than conventional growers, pest problems tend to be limited to cabbage root fly, flea beetles and caterpillars and control is by the use of materials such as Growtect. Timing of sowings are crucial. (Lampkin 1990)

1.12. Habitat management and creation

Whereas conventional farming methods often attempt to substitute for natural production processes, organic farming attempts to enhance them, using a system which, to a larger extent, mimics natural ecosystems in terms of species and trophic level diversity.(Lampkin 1992). Organic farming is similar to the traditional, rotational farming which established the biological diversity of the British countryside and which conservation bodies wish to preserve.

The specialisation of conventional farming limits the range of non-crop habitats available to wild flora and fauna, with the decline of some farmland bird and mammal species being directly linked with this trend towards monocultures, eg. the grey partridge and the hare. Reduction in habitat and landscape diversity may be the single most important agricultural impact on wildlife (O'Connor & Shrub 1986).

Field boundaries are frequently considered to be redundant in intensive arable areas and hedge removal in the south and eastern areas of the UK is still proceeding at the rate of many miles each year. Mixed organic systems utilise and preserve these natural boundaries and their value as wildlife habitats, windbreaks and habitats for insect pest predators are seen as important components of organic farming.

Organic practices, particularly the use of short and medium term leys, can be relatively intensive and may involve the ploughing up of old grassland. Hill land improvements and drainage are also important considerations for organic producers under economic pressures (Lampkin 1992). There is a risk that old pasture will be ploughed up to produce organic vegetables, or that land containing valuable species may be drained. However organic standards (UKROFS undated) include conservation principles,a fact welcomed by the industry in general (Agricultural Supply Industry 1993). Included in these principles are that natural features such as streams, ponds, wetlands, heathland and species rich grassland should be retained as far as possible.

UKROFS standards state that "Concern for the environment should manifest itself in willingness to consult appropriate conservation bodies, and in high standards of conservation management throughout the organic holding".

Guidelines for creative management are given by the Soil Association (1995) for meadows, grassland, traditional field boundaries, hedges, moorland, heathland, wetlands and woodlands. Organic symbol holders are also encouraged to create wildlife corridors.including hedgerows, field margins and verges.'

It can be difficult to protect a wetland site on an organic unit if it is not possible to control neighbouring land use . A buffer zone is particularly useful and can prevent a wetland from becoming polluted by pesticides from run-off or spray drift or drying out if there are efforts to lower the water table in surrounding farmland. A further threat to wetland habitats comes from the use of peat in horticulture. Although peat may be used in organic horticulture alternative substrates are encouraged for plant raising systems. Most commercial substrates formulated specifically for organic use include at least a proportion of alternative materials.

Many journals e.g. New Farmer and Grower (1992), give opinions as to the effects of organic farming on habitat management by 'conserving semi-natural habitats such as old species rich pasture as well as other good wildlife habitats such as hedgerows.', however the articles are high on opinions but low on facts.

Diversity and abundance of insect species which are food for farmland birds and mammals, are increased by virtue of the less vigorous control of weeds achieved without herbicides. Undersowing of crops with a leguminous green manure can have an effect well beyond the edges of the field in question, causing significant increases in insect abundance over the whole farm (Vickermann 1978).

Organisations such as ADAS and FWAG are funded partly by MAFF to provide advice on conservation issues such as habitat management and new habitat creation e.g.ADAS (various dates). Many advisory leaflets have been produced by both organisations encouraging low pesticide regimes and the judicious use only of necessary applications. These do not include leaflets specifically about organic systems and their possible impacts on the wildlife on farms.

1.13. Reduced input systems

Although outside the official remit of this desk study, reviewing the current literature brought to light information on the trend in the last 5 years or so within the farming community, towards the more environmentally friendly practices encompassed under the umbrella term 'Integrated Farming' and a brief mention of scientific work in this area follows.

The wisdom of over-using chemicals as an insurance against crop losses has been challenged from the point of view of efficient and cost-effective crop protection. Systems of 'managed' or 'integrated' crop protection in which pesticides would be used only when necessary and targeted closely at the relevant pest, weed or disease problem have been under scrutiny since 'The Boxworth Project' was set-up in 1979. (Greig-Smith *et al.,* 1992)

This was the first study to utilise the resources of a whole farm, with single large blocks of land given over to specific treatments, either Full Insurance, Supervised or Integrated. Monitoring of pests (Hancock 1992), weeds (Marshall 1992), diseases (Yarham & Symonds 1992),crop performance and economics (Jarvis 1992), pesticide residues in drainage water (Greig-Smith *et al.* 1992), distribution of plant species in the fields and margins (Marshall 1992), effects of different pesticide regimes on invertebrates (Vickerman 1992), interactions between cereal pests and their predators and parasites (Burn 1992),changes in soil fauna (Frampton *et al.*), populations and diet of small rodents and shrews in relation to pesticide use (Johnson *et al.* 1992), exposure of rabbits to aphicides (Tarrant & Thompson 1992), the population density and breeding success of birds (Fletcher *et al.* 1992) and summer aphicide effects on tree sparrows (Hart *et al.* 1992) were all studied within the three regimes. A two year base-line period was followed by a 5 year study period.

A vast amount of information was gathered by the end of the project 1988. However throughout the study period the integrated methods appeared to be the path along which conventional farming was developing due to economic and environmental pressures. The results have provided new information about the risks to wildlife associated with cereal fields arising from high levels of pesticide use as an insurance against crop damage.

The lessons of the Boxworth Project have helped to shape the designs of two further studies, SCARAB - Seeking Confirmation About Results At Boxworth (Ogilvy *et al.*

1993), and TALISMAN - Towards A Low Input System Minimising Agrochemicals & Nitrogen. These are continuing the exploration of the ecological and economic aspects of cereal production that was developed at Boxworth.

At National and EU levels there are already a formidable array of schemes which could be described as encouraging 'low input/output agriculture' and extensification was encouraged by the May 1992 CAP reform package (Haines 1993).

In autumn 1994, Rhone-Poulenc decided to add a further element to its long-term research programme by embarking on an Integrated Crop Management (ICM) study. A further five fields at Bundish Hall Farm, close to Boarded Barns Farm will be used to compare results of an ICM regime with the organic and conventional systems already under review. Unfortunately the existing habitat on the new area is very different to Boarded Barns and comparisons will be difficult to make.

The LIFE Project, (Less Intensive Farming and the Environment),pioneered by IACR Long Ashton, as part of a European network of integrated farming systems research aims to initiate demonstration projects (Pilot Farms) relating to the transfer of technology for integrated farming systems in European agriculture. Conversion on two farms started in 1992 and prototype cropping systems, designed to be more environmentally benign have been formulated and implemented during autumn 1992/93, as part of a three year study.(Jordan *et al.* 1993, 1994). The farms are open to visitors wishing to learn more about the system and practices in force.

Farmers are being encouraged to carry out LEAF (Linking Environment And Farming) audits on their farms, geared towards a system of integrated crop management. This useful management tool offers a practical, non-prescriptive way for farmers to assess their businesses with environmental concerns in mind (Leaf 1994).The Rhone-Poulenc ICM area has as part of its' LEAF policy, agreed to plan and carry out a positive wildlife and landscape management policy which includes the need to establish a base line for beneficial insects.

A study at Lautenbach (El Titi & Ipach 1989) shows that integrated farming can provide a base for the survival of natural control agents which have reduced major pest species, offering many options in sustainable agricultural strategies which can be used in the same way.

The Nummela Project (Myllymaki 1993, Kurppa 1993) has been set up to compare conventional and reduced input regimes on soil microbes, soil fauna, epigeal arthropods and terrestrial vertebrates.

1.14. Conclusions and Recommendations

The literature search on which this current review is based reveals that despite there being a large volume of relevant documentation comparing aspects of conventional versus organic farming methods, few studies have been carried out in the UK which cover the necessary length of time and controlled conditions required for conclusive results to be drawn.

Most studies in the review lasted only two or three seasons and results, although appearing to favour an organic regime as being more beneficial to wildlife were often inconclusive and not statistically significant. Information on the effects of the component parts of organic systems are more helpful in demonstrating the positive effects that are likely to exist.

The design of conventional and organic systems will of necessity influence the differences in the impacts on wildlife and its habitat. The variety and rotation of crops within a system influences the landscape and ecological diversity present. The crop rotations of organic systems maintain crop diversity whilst the maintenance of field boundaries on organic units produces benefits to a wide range of organisms.

From the studies reviewed it was seen that maintenance of field boundaries and in particular traditional hedgerows, accompanied by sympathetic management, was the most significant feature of farm management practice to influence wildlife populations. Floral diversity, insect species and numbers, bird territory habitation and small mammal numbers were all higher where pesticide use along the field boundary was either removed completely or greatly reduced.

The management of field margins has a direct impact on the food chain by maintaining the invertebrate populations which support the small mammals and birds of the farmland.

A large number of studies have been carried out on the impact of conventional farming on bird populations and breeding success and it would appear that pesticide use causes reduction in numbers, as does the removal of available habitat that often accompanies the mono-cultures associated in particular with arable farming. The introduction of set-aside may help to redress this balance to some degree and MAFF funds conservation bodies such as ADAS and FWAG to deliver conservation advice to the arable farmer, including the best possible use of set-aside land for wildlife purposes. However attempting to maintain small pockets of non-crop habitat within a large areas of intensively farmed crops implies that conventional farming methods are generally incompatible with the conservation of wildlife.

There is information available on the impacts of farming regimes on the populations of soil micro-flora and fauna. They are generally enhanced by the practices commonly employed on organic farms. Evidence for the long term benefits on soil processes is more difficult to find.

The impact on aquatic systems was relatively poorly represented in the available literature. Much media attention is paid to the impact on fish stocks when a catastrophic spill of slurry from an intensive animal unit occurs. Manure's and pesticides can be responsible for long term chronic effects such as a loss of species diversity and subsequent downgrading of river waters.

Studies on small mammal populations were found to be informative, but little work appears to have been done with regard to the larger British mammals such as rabbits, hedgehogs, bats and badgers, or on reptiles. As these are heavy consumers of flora and fauna which may have been treated with pesticides or may come directly in contact with pesticides during their application, it is surprising that there is no published data on either the short- or long-term effects on individuals or populations. The impacts on mammals of the range and quantities of synthetic pesticides applied on conventional farms remains poorly understood, with little evaluation of the potential problems.

Similarly there is little published information on amphibians but what there is suggests that organic systems will favour increasing populations.

No information on woodlands with reference to organic systems could be found. As fertiliser and pesticide use in them is minimal effects from changing inputs are expected to be small. Sustainable management of woodlands as advocated by the Soil Association should result in improved conditions for wildlife.

Pesticide use, which is frequently perceived to be the factor which separates the conventional from the organic farmer, was seen to be responsible for the removal of food sources for birds and mammals in the form of weeds and invertebrates, as well as removing whole populations of potentially beneficial insects. An increase in the deaths of wildlife directly attributable to the approved use of agrochemicals has been documented.

Inorganic nitrogen fertilisation and herbicide treatments of conventionally managed grassland has reduced the floral diversity of permanent pastures and maintained the low diversity of re-seeded pastures, greatly reducing their value as wildlife habitats (Fuller 1987).

Relatively major changes in fauna populations due to pesticide use may remain undetected because of poor surveillance and some of the currently available pesticides may be having indirect effects which may remain undetected for years (Newton 1979).

1.15. Summary

Sufficient data has been gathered within the remit of this review to indicate that conventional farming practices and inputs pose far greater dangers to wildlife than organic practices and inputs.

Organic farming systems and to some extent 'integrated' farming methods supply alternatives which are less environmentally disruptive. The economically undesirable production of surpluses, currently managed by a system of quotas and removal of land from production under set-aside, should be addressed by further long-term studies on the feasibility and effects of alternative farming regimes. Organic farming is not a static approach to agriculture and should be allowed to evolve and adapt in the years to come.

The investigation of the very real opportunities to provide a sustainable alternative agricultural strategy alongside wildlife and habitat conservation should be instigated. This could take the form of research programmes designed to produce quantifiable, comparable information, whilst also addressing some of the current deficiencies such as the availability of data concerning mammalian, amphibian and aquatic populations.

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2. WATER POLLUTION FROM AGRICULTURAL SYSTEMS.

2.1. Introduction.

Agriculture is an important polluter of water though by no means the only industry to be implicated. Pollution may be described as coming from a "point source" or to be "diffuse". Point source pollution by manures, silage effluent or fertilisers comes from one building, store or field, and is usually readily traceable. Diffuse pollution comes from many fields and is not caused by a single event or action (MAFF 1991). Nitrate contamination of ground and surface waters is predominantly a diffuse pollution from agricultural land and this is discussed below. Phosphate and pesticides may come from both diffuse and point sources and this is also considered later in more detail.

2.2 Direct Pollution from Point Sources by Manures and Fertilisers

2.2.1. Sources of pollution.

Statistics on point source pollution incidents that are reported are published each year by the National Rivers Authority (NRA) e.g. for 1994 see NRA (1995). In 1994 only 13% of such pollution incidents were caused by farmers. The majority came from industrial sources and sewage. The proportion from these has changed little since 1987-1989 when it was 83%. The 3329 incidents arising in 1994 from agriculture was the highest total since 1988 and thus halted a steady trend of a reducing number of problems. This reduction has been the result of an advisory campaign from the NRA and MAFF and the influence of more favourable climatic conditions. However the number of most serious incidents (Category 1) continued at a low level. Only 36 were noted in the year.

There are no separate statistics which allow comparisons between organic and conventional farms. In addition to the monitoring activities of the NRA organic farmers are subject to an appraisal of their manure handling facilities during the annual inspection for Registration under the Organic Regulations. The organic sector bodies and the competent authority (UKROFS) retain the option to deregister any organic producer who is considered to consistently cause, or run the risk of causing, pollution. There have been very few cases where even a risk of causing pollution has been noted in the 6 years that ADAS have been undertaking Surveillance inspections of organic holdings for UKROFS.

Most cases of agricultural point source pollution result in the discharge of waste with a high Biochemical Oxygen Demand (BOD) into surface waters. The organic compounds are broken down by micro-organisms which take oxygen from the water in the process. In serious (Category 1) incidents all life in a river or stream can be killed. However a lot of harm can be done before this extreme situation is reached.

The ammonium content of manures and fertilisers can harm aquatic life and salmonid fish are particularly sensitive. The reported incidents do not distinguish the precise pollutant which damages the ecosystem in question. In practice more than one may be having the effect. The phosphate content of manures can also contribute to general eutrophication problems and this is discussed in more detail below. However these effects are usually more of a chronic nature rather than giving rise to an immediate or acute effect. All of the pollutants mentioned here may also have chronic effects. That is at relatively low levels of discharge they may gradually bring about a change in the aquatic environment which may not become apparent for many years or until detailed monitoring is carried out.

In a typical year most serious cases are caused by slurry (28%), silage effluent (25%) and dirty water from yards and milking parlours (19%). These proportions will vary according to the weather conditions at different times of the year.

A more detailed breakdown of the causes of total incidents is given in the following tables. Firstly the cause according to farming type in 1994.

Farm Type	% of Total Agricultural Incidents
DAIRY	55
PIGS	7
ARABLE	6
MIXED	4
POULTRY	2

The particular management problem is now shown for 1993.

Cause of pollution	Number of Incidents	
	Cattle	Pigs
SLURRY STORES	717	164
SOLID STORES	185	-
WASHINGS	610	85
RUN OFF	180	57
TREATMENT SYSTEMS	116	7
SILAGE	1006	-

2.2.2. Implications of organic management.

As mentioned above experience of organic farms is that they demonstrate few risks of pollution. Apart from the unquantifiable factor of the increased concern for the environment shown by organic farmers, there are two aspects from this table which suggest that there will be real differences caused by the organic system per se and the way that it has to be implemented.

Firstly there is the fact that organic pig units operate largely on solid manure systems so that the problems from slurry stores will not arise. Secondly there is the possibility of polluted run-off after land spreading. Such run-off may arise from a particularly heavy application of slurry or dirty water or when rain falls on recently manured ground. Such events could happen on organic farms but are unlikely. The quantity applied at any one time is usually less if for no other reason than organic farmers seldom have excess quantities of manure i.e. in excess of that recommended in the Water Code (MAFF 1991). There is also a desire to maximise the benefits to crop growth. Manures are therefore spread at times of the year when the risk of run-off is less. Manures are also less likely to be left on the surface of arable land before being turned under. On the other hand when more solid manures are applied to the surface of grassland where they may remain for longer there is a somewhat greater risk that very heavy rain may give rise to contaminated run-off.

Recorded under a category of "other incidents" are those relating to the escape of inorganic fertilisers into waters. There are around 20 such cases nationally each year. These usually relate to runoff from land or the release of nitrogenous fertilisers from storage facilities. This problem increased after the introduction of storing liquid fertilisers on farms. On occasions heavy rain can wash ammonium containing fertiliser from the surface of sloping grassland fields before it has the chance to disperse into the soil. No such problems of storage or run-off from inorganic fertilisers occur on organic units.

2.3. Comparison of Nitrate Leaching Risks from Organic and Conventional Farming Systems

2.3.1. Nitrogen cycling

Nitrogen leaching should not be considered in isolation from other processes of the N cycle; it is just one component of, and a natural consequence of, N cycling (Fig. 1). It is particularly important to note that attempts to manipulate one aspect of the cycle will have implications for other processes.

Nitrogen inputs to agricultural systems derive from the atmosphere in precipitation and dry deposition, via biological fixation and fertiliser, and from plant and animal manure residues. Inputs are either in inorganic (e.g. mineral fertiliser or the mineral fraction of manure) or organic (e.g. composted manures, plant residues) forms. Inorganic N is readily available for use by the crop but, as shown in Fig. 1, crop utilisation must compete with other processes for this N. Organic N requires mineralisation by soil microflora and fauna before it is available and can be utilised by crops.

Mineralisation and immobilisation are central processes in controlling the flows of nitrogen within the N cycle. Nitrogen is continuously assimilated into organic forms (immobilisation) and released from organic matter in inorganic forms (mineralisation). The relative rates of these two competing processes depend on many factors and determine whether there is a net release or net disappearance of inorganic N. The mineralisation of soil organic matter, of crop residues and of organic manures is crucial to liberate mineral N for crop uptake.

Much of the N cycle is driven by biological processes and the soil biomass is an important component of the overall N cycle (Powlson *et al.* 1994). The soil biomass comprises almost every class/order of invertebrate, as well as a wide range of fungal and bacterial species and types. Its size is related to soil type and management (Chaussod *et al.* 1988), so agricultural practices will influence the soil biomass and, in turn, N cycling. This concept of 'soil health' is difficult to quantify, but has important implications when comparing farming methods.

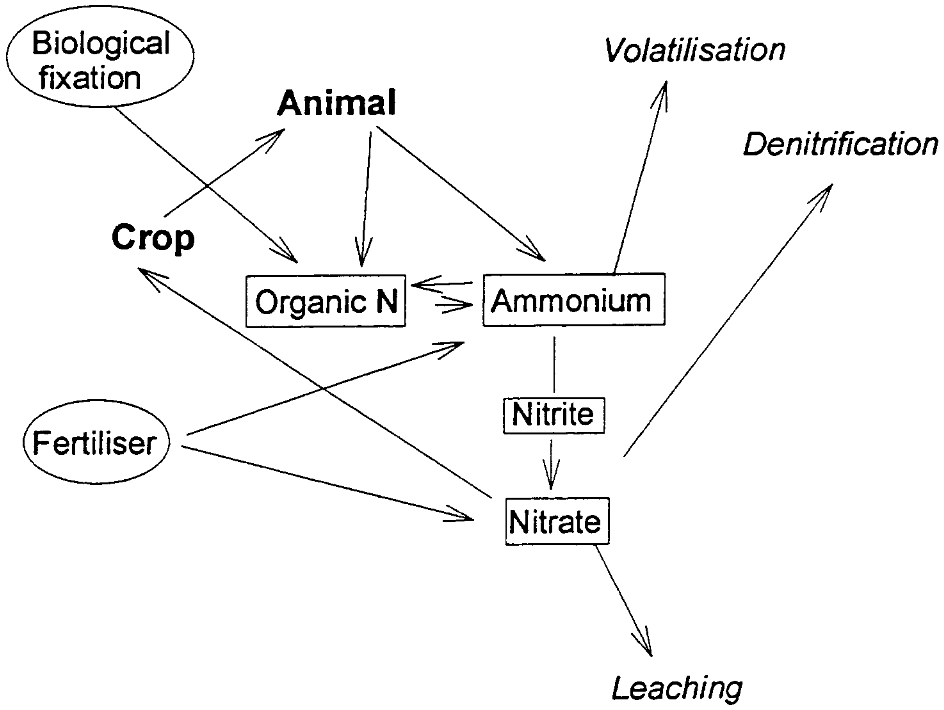


Fig. 1. The nitrogen cycle

Nitrate leaching and gaseous losses are a natural consequence of the N cycle. Strictly, they should only be considered as 'losses' if we confine our N cycle to, say, the field or catchment scale; on the global scale, the N is simply recycling. However it is the aim of good agricultural practice to manage N within the field scale as effectively as possible, which means minimising these exports. Nitrate will be lost from the soil by leaching whenever there is drainage through the soil; i.e. autumn/winter and sometimes in spring. Under anaerobic conditions nitrate can be converted to nitrogen gasses. Ammonia volatilisation is also a common loss route from surface-applied manures and decaying plant residues, although immediate incorporation into the soil alleviates the problem.

Crop demand for nitrogen fluctuates through the year, depending on the growth rate of the crop; generally, there will be a peak requirement for arable crops in spring/early summer. Total demand will be affected by the length of growing season for the crop; for example spring barley will ripen and senesce in July/August but grass will continue to take up N through into autumn.

Nitrate is generated by mineralisation throughout the year, but the rate of release varies depending on many factors (e.g. environmental - temperature and moisture - and the availability and composition of the organic substrate). Patterns of N supply tend to differ between organic and conventional systems (Atkinson *et al.* 1995); large 'pulses' of mineral N (as fertiliser) in conventional farming vs. slower release driven by mineralisation in organic systems.

All good farming systems aim to manage the N cycle to utilise N, from whatever source, as effectively as possible. Achieving synchrony between the supply of mineral N and crop uptake will minimise the 'excess' nitrate in the soil, and thus minimise the risk of nitrate leaching. It might be argued that a surplus of nitrate is only disadvantageous if there is also drainage. However, other processes (immobilisation, gaseous loss) can remove mineral N and thus decrease its utilisation efficiency. Although in this chapter we are specifically considering nitrate leaching, this single process should not be considered in isolation. Indeed, van der Werff (1993) points out that all loss processes occur in agricultural systems and that some (e.g. ammonia volatilisation from composting manure) may be greater in organic than conventional systems.

2.3.2. Rules for avoiding leaching

Guidelines which cover all aspects of good nitrogen management are available to farmers. The Code of Good Agricultural Practice for the Protection of Water (MAFF 1991) provides advice which is not mandatory. Within Nitrate Sensitive Areas (MAFF 1989), there are compulsory restrictions for those who register with the scheme. Advice from both sources aims to minimise the risk of nitrate leaching from agricultural soils, and is based on extensive research and development.

To decrease the risk of leaching, the aim should be to minimise the amount of nitrate in the soil at times when substantial drainage is likely to occur (i.e. predominantly autumn/winter and, to a lesser extent, spring; Fiege & Roethlingshoefer 1990). This principle applies to all farming systems, conventional or organic, and there are several basic rules which will achieve this aim and minimise leaching risk.

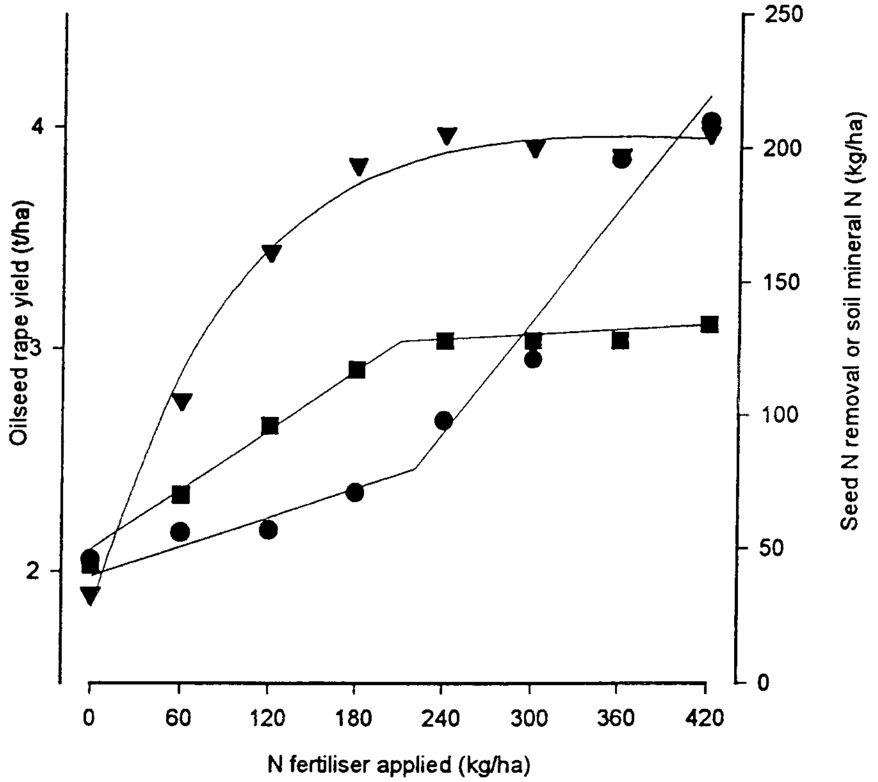
2.3.2.1. *Do not overfertilise a crop.* Recent data for a range of arable crops shows that up to the crop's optimum N requirement there are only small increases in mineral N left in the soil at harvest (and thus potentially available for leaching). Large increases can occur with fertiliser additions above this optimum(e.g. Chaney 1990; Sylvester-Bradley & Chambers 1992; Shepherd & Sylvester-Bradley 1995), as shown in Fig.2. Similarly with grass systems there is a point above which fertiliser applications substantially increase leachable mineral N (Lord 1992); the precise point will depend on grassland management, particularly N balance (i.e. fertiliser applied - N removed from the field).

2.3.2.2. *Minimise untimely mineralisation of organic nitrogen.* As stated earlier, synchrony of mineral N release and crop uptake is the ultimate aim. Cultivation in particular can cause a nitrate flush from native organic matter and incorporated crop residues; cultivation in the autumn, when crop N demand is low, therefore increases leaching risk (e.g. Stokes *et al.* 1992).

2.3.2.3. *Maintain green cover through winter.* There is much data supporting the need to maintain a growing crop through the autumn to retain N that would otherwise be leached (Prins *et al.* 1988). Consequently, leaching losses will be small from pasture provided N supply does not exceed N uptake. In arable rotations, early sown cereals can also be successful provided that they establish early to utilise N before the onset of substantial drainage (Milford *et al.* 1993). Cover crops before spring sown crops are also a very successful control measure provided they too establish early (Nielsen & Jensen 1985)

2.3.2.4. *No autumn application of mineral, or readily mineralisable, nitrogen.* Again, this avoids the over-supply of nitrate when crop demand is generally small. In particular autumn applications of slurry, with much of its N in ammoniacal form, should be avoided (Unwin *et al.* 1991).

Fig. 2. Typical relationship between applied fertiliser, crop yield (triangles), crop N uptake (squares) and post-harvest soil mineral N (circles), in this case for oilseed rape (from Shepherd & Sylvester-Bradley 1995) though the relationship is similar for most crops. The upturn in soil mineral N (leaching risk) corresponds approximately to the crop's economic optimum N rate.



2.3.3. How organic and conventional farms differ in N management.

A basic difference is that organic systems rely more heavily on recycling than on importing nitrogen (Atkinson, 1995). Organic farms do import N, not so much in feed and manure (of which small amounts can be brought on to the farm), but by using legumes to fix atmospheric nitrogen. Perhaps a much more fundamental difference between conventional intensive systems and organic farms is the *amount* of nitrogen brought on to the farm, and the resultant field N balances. This will be discussed in more detail later.

A further difference is the organic system's almost sole reliance on the mineralisation process (and hence the soil biomass) to generate plant available N. Powlson *et al.*

(1994) identified that our understanding of interactions within the biomass and between this component and other N cycling processes is poor, yet these interactions may be of increasing importance in low input and organic systems.

Stopes & Phillips (1992) list the main agronomic differences between conventional and organic farming systems, and argue that all will influence nitrate leaching in some way:

- no use of inorganic N fertiliser
- 'better' manure management
- grass, grass/clover leys
- lower stocking densities
- minimal feed imported
- cover crops
- cultivations

Each of these practices are discussed in detail below.

2.3.4. Individual management practices; effects on leaching

2.3.4.1 Inorganic N fertiliser/arable crops

Organic farming replaces mineral fertiliser with organic sources that mineralise to liberate nitrate for crop use. Manure/grass-clover residues can satisfactorily replace fertiliser N in medium or low yielding situations (e.g. Mackowiak & Fotyma, 1995), which is what most organic systems are.

Super-optimal N applications result in substantial post-harvest leaching (Fig. 2). This principal applies whatever the source of N; although most research relates applications of mineral fertiliser to post harvest residue, organic sources will ultimately be converted to nitrate with the same result if oversupply occurs. It could perhaps be argued that there is less likelihood of overfertilising in an organic system because it generally operates at lower N inputs with less risk of exceeding the crop's optimum N. However there are two provisos;

- crop yield must not be severely restricted by pest or disease and,
- N release after breaking a ley should not exceed crop need.

For example Mackowiak & Fotyma (1995) reported that they had over-supplied spring barley with nitrate deriving from mineralisation of a previous grass/clover ley and FYM application.

A benefit in terms of reduced leaching risk from organic systems is that they are often working below the crop's N requirement for efficient growth and N recovery. This has two consequences.

- There is less chance of supplying sufficient N to exceed this optimum, which is when most leaching occurs, as shown in Fig. 2.

- Second post harvest mineral N (and leaching) continue to decrease, albeit slightly, with decreasing N inputs even below the optimum (Fig. 2).

2.3.4.2. Pasture/feed inputs/stocking density.

Nitrogen cycling in grassland systems is very complex, but there has been substantial research into the processes; this is particularly so for 'conventionally' managed pasture, though the principles are equally applicable to organic systems. Grass is a good sink for nitrogen. Low input grassland leaches very little N, as shown by measurements in the Nitrate Sensitive Areas (MAFF 1993). As for arable crops, leaching risk depends on the crop's N balance. The nitrogen budget for a livestock enterprise depends on the balance between inputs (fertiliser, feed) and outputs (meat, milk), all of which will be influenced by stocking density.

The NCYCLE model (Scholefield *et al.* 1991) suggests a curvilinear relationship between N balance and N leached, rather than the two straight line approximation suggested for arable crops and shown in Fig.2. Modelling shows that grass cut for silage, if not restricted by drought, utilises N effectively, with much less leaching than from intensively grazed systems (Lord 1992). There are large leaching losses from intensively managed grazed swards because 80-90% of the applied N is circulated through the animal and returned to the pasture in urine and dung; further, the economics of the system mean that large N inputs are justified, with increased leaching as a result. Organic systems are generally less intensive with a better N balance, and thus are likely to present a smaller leaching risk.

Maize is an alternative fodder crop for many livestock enterprises, and is perceived as a large sink for N, such that the crop often receives large amounts of manure. However, this often leads to over-supply of N to the crop and, combined with its often early maturity (and so unable to utilise mineralised N), large leaching losses can result (Schroder *et al.* 1992).

Whereas the NCYCLE model was developed for beef systems, it also offers a reasonable approximation for dairying and sheep. Outdoor pigs are also an increasingly popular enterprise. As yet there is little UK information on the leaching risk associated with this system. Worthington and Danks (1994) have reported very high mineral N residues under long term pig paddocks with much lower values when the pigs were only shortly in the fields. Applying the same N balance principles as above suggests that intensively managed enterprises are likely to provide a substantial leaching risk; measurement of nitrate leaching from outdoor pigs is now under investigation through MAFF funding (B. Chambers, personal communication). If leaching losses are found to be large, then management systems will need to be developed to decrease the risk. Ensuring that the pigs are located in a field for short periods (say, 4-6 months) to minimise N accumulation, and maintaining grass cover would help to reduce the risk; management practices that are favoured in organic systems.

2.3.4.3. *Cultivations (including breaking leys)*

The mechanical disruption of the soil structure makes previously protected organic matter (native soil organic matter and crop residues/animal manure) available for degradation and increased rates of mineralisation are observed in disturbed soils (Ballesdent *et al.* 1990). Timing of cultivation can therefore affect mineralisation patterns and availability of nitrate for leaching, crop uptake or other processes. Scheller (1993) noted a large leaching risk from August cultivation if a winter crop was sown too late. Many workers have shown that delaying autumn cultivations can significantly decrease nitrate loss (e.g. Stokes *et al.* 1992).

Autumn cultivation of a large, readily mineralisable N source presents a huge leaching risk. This has implications for the breaking of leys, which is a core management tool in organic systems (Watson & Younie 1995). Torstesen (1993) noted the large leaching risk from the autumn cultivation of grass leys, for example. Even after cutting or grazing grass much of the plant material remains in the stubble and roots. The quantities increase with the age of the sward but are also affected by management (particularly the N balance). After cultivation, this macro-organic matter is relatively labile (Warren & Whitehead 1988) and large amounts of N can be mineralised, depending on age and composition of the sward.

Older swards generally mineralise more than short-term leys after disturbance, and N release and leaching risk can continue for many years after ploughing. There are many estimates of N accumulation in the literature. Young (1986) calculated that N mineralisation increased from about 100 kg/ha N after ploughing a one year ley to 280-350 kg/ha N from ploughing leys of four years or older. Francis *et al.* (1992) measured 230 kg/ha N accumulated in a three year ryegrass/clover ley. Whitehead *et al.* (1990) measured 536 kg/ha N accumulated in an eight year ryegrass sward and 602 kg/ha N for a fifteen year sward. Manure application appears to increase mineralisation on ploughing out grass. Clover contributes N by fixation, but also may have a specific effect in increasing mineralisation on ploughing grassland.

Research with organic systems has identified the transition between grass and arable as generally the most nitrate leaky phase of the rotation (e.g. EFRC 1992). Phillips *et al.* (1995) also point out, however, that up to 60% of the rotation may be in grass at any one time so that the small leaching losses from these fields will dilute the flush of nitrate from broken leys.

Even so it would be of benefit to minimise losses from this point of the rotation.

Current advice (MAFF 1991) specifically discourages the ploughing of long-term grass because of the nitrate flush, although organic systems will generally rely on short or medium term grass, typically four years or less depending on the rotation (Anon. 1992). Other advice includes disturbing the soil as little as possible when reseeding leys (rarely applicable to organic systems), and delaying autumn cultivations as late as possible without detriment to the following crop. Here, there is some conflict with organic practice since this is seen as an ideal opportunity to control weeds by cultivating several times before establishing the next crop. Watson *et al.* (1989) showed success in decreasing nitrate leaching by delaying cultivation of grass until spring, but this did delay the sowing of the next crop. Similarly Anon. (1992) decreased losses by delaying sward destruction until the spring.

2.3.4.4. *Manure management*

Animal manures vary in both their total N content and the forms of N present. Both are affected by many factors but generally straw based, composted manures have the majority of their N in organic form and slurries and poultry manure a larger proportion of readily available mineral N.

Organic manure applications can be a major source of N leaching. Ostergaard *et al.* (1993) concluded that, in Denmark, the use of animal manure increased leaching, especially when applied in the autumn. Nitrate leaching can result from the over-application of N, leaving a large post-harvest residue ('indirect' loss). This is common on conventional farms in the UK, with growers making insufficient allowance for the nutrient supply from a manure application when planning their mineral fertiliser policy (Smith & Chambers 1993). Also untimely manure applications cause leaching of the applied N ('direct' loss). Autumn applications of manures with a large proportion of readily available N should therefore be avoided. Unwin *et al.* (1991) reported large losses from autumn applications of layer manure, but much smaller losses from well composted FYM. Stockdale *et al.* (1995) similarly reported that N leaching depended on manure type (its available N content), crop cover and application time.

However, well timed applications can substitute for mineral N fertiliser. ADAS, through a large research programme, has produced estimates of the likely N supply from manure based on type and time of application (MAFF 1994). Well composted manures are typically used in organic systems. These therefore rely on mineralisation to liberate plant available N so that meeting a crop's peak N demand depends on the synchrony of mineralisation and crop need. For example Stockdale *et al.* (1992) found that potatoes (which grew later into the summer) utilised nitrogen from FYM more effectively than spring barley (a shorter growing season).

Many organic advocates argue that manure is treated very much as a valuable resource in organic systems, but as a waste product to be disposed of as easily and cheaply as possible in conventional farming (e.g. Lampkin & Arden-Clarke, 1990). One of the major problems with intensive animal units is that there is often insufficient land to spread the resultant manure at agronomically sensible rates. In these circumstances, loadings (and leaching risk) on organic farms will compare favourably. However, if farmers follow the recommended Code of Good Agricultural Practice (MAFF 1991), or adhere to the mandatory restrictions on manure use in NSAs, then leaching risk will be very much reduced.

We must also consider the longer-term effects of organic manures since the organic N can degrade slowly over several years. For example the proportion of N present in organic form in FYM can be 75-90%. Consequently, a field receiving 250 kg/ha N (the maximum recommended by the Code of Good Agricultural Practice) annually for 10 years will have received 1.9-2.3 t/ha N. This compares with a typical arable topsoil N content of about 5 t/ha. Frequent dressings of bulky organic manures, even when applied at moderate rates, can result in the accumulation of significant quantities of organic N which will be mineralised over the long-term.

The recycling of organic wastes through composting provides a more stabilised form of organic matter than 'raw' wastes, perhaps better suited to the long-term maintenance of soil organic matter. Nutrients are less readily available so that composted manures can mitigate problems of short-term pollution such as nitrate leaching (Mathur *et al.* 1990), but again the longer-term implications have to be considered. However, as a source of crop nutrients 'raw' wastes may be more appropriate (Lampkin 1990).

2.3.4.5. *Maintaining green cover.*

Retaining a growing crop through the autumn decreases leaching; hence, the advantage of undisturbed (low input) pasture. In arable rotations the use of cover crops can be successful if established early enough. Incorporation of these plants in spring will then generate some nitrate for the following crop, although the factors affecting rate and timing of this mineralisation are not yet completely understood.

2.3.5. Putting the evidence together - comparing systems.

For a true comparison of the leaching risk from conventional and organic farming we should consider the rotational aspects of nitrate leaching. The average loss from a farm is of more relevance to implications for water quality than focusing on one aspect of the rotation, since a farm or catchment will contain fields in all phases of the rotation.

There are many difficulties associated with making direct comparisons of leaching from conventional and organic systems. The main problem is that a fair comparison relies on the long-term development of contrasting rotations (Arden-Clarke & Hodges 1988) in a scientific, preferably replicated way, which is costly of time and effort. Fowler *et al.* (1993) argue that in practice it is extremely difficult to find farms or sections of farms which would allow a clear comparison to be made, because of all of the differences in soils, climate, weeds, pests, enterprise combinations, management skills and commitment. However, researchers have tried to overcome these difficulties by adopting different approaches and there is generally evidence in the literature to indicate that leaching losses are less from organic farms than from conventional farming systems.

Fiege & Roethlingshoefer (1990) measured the nitrate concentration of drainage water from two fields, one organically farmed the other conventionally farmed, over several years. The highest concentrations for both systems always occurred in winter, but the peak was less from the organic field (180 vs. 110 mg/l nitrate). The average total N loss, and N concentration from the organic field was 50-60% less than from the conventionally farmed field (50 vs. 25-30 kg N/ha/yr), thus concluding that organic farming was better for ground water protection.

Gompel *et al.* (1990) compared leaching from fields from a conventional and an organic farm in Northern Germany over two years. There were no differences in the first year (1987), because fertiliser inputs were low at both sites, but a large application of slurry to maize in 1988 (intensive system) resulted in a peak nitrate concentration of *c.* 350 mg/l, compared with 40 mg/l in the organic system. Although this work only focused on one point of the rotation, it demonstrates the risk of N oversupply from organic manures.

Vereijken (1990) studied three farming systems (organic, integrated and conventional) in the Netherlands at the Nagele Experimental Farm. The nitrate concentration of the drainage water, as an average for 1985-87, was 49.5, 43.3 and 19 mg/l for conventional, integrated and organic systems respectively. All were below the EC drinking water limit, with the organic system leaching considerably less. The rotations in this study are not standardised between management systems. Thus the organic area includes a dairy unit and grass leys whilst the conventional unit is continuous arable.

Eltun (1993) reported nitrate leaching losses from conventional, integrated and organic systems (Norway). Nitrate losses were less from systems dominated by forage than from cash crop systems with potatoes and cereals. Of the forage dominated systems, N losses were less from organic and integrated systems than the conventional approach.

Measurement of soil mineral N at the start of drainage in the autumn provides an indication of leaching risk. Brandhuber & Hege (1992) core sampled 15 fields on organic farms in Germany. They made no comparison with conventional farms but measured 'relatively low' nitrate concentrations which they attributed to good farming practices. Younie & Watson (1992) reported data from the first year of a comparison between organic and conventional 'farmlets'; soil mineral N over winter was less on the organic system, indicating less leaching risk.

Further indirect evidence of lower leaching risk from organic systems can be provided by considering a farm's nitrogen balance, although it is not always possible to ascribe N amounts to different components of the N cycle including leaching. However Kristensen & Kristensen (1993) found that organic farming systems had the lowest nitrogen surplus when comparing N cycling within 14 conventional and 16 organic dairy farms in Denmark, so that the potential N loss was 85 kg/ha less in the organic systems. Van der Werff (1993) similarly measured a much tighter N balance on mixed organic farms compared to conventional systems.

Not all studies have found in favour of organic rotations. Kristensen *et al.* (1994) compared autumn soil mineral N (i.e. leaching potential) from 550 conventional farms and 26 organic farms in Denmark in 1990. From this they concluded that adoption of organic principles would not offer groundwater protection since the soil mineral N was similar between organic (31 kg/ha) and conventional farms which used manure (29 kg/ha); conventional farms without manure presented least risk (22 kg/ha), suggesting that manure was a contributory factor. These findings were qualified however because of the small number of organic farms included in the data set. Karlen & Colvin (1992) measured the soil nitrate profiles in soil cores taken to 4.5 m depth to look at the historic effects of farming practices on leaching risk. Two pairs of fields were compared, either conventionally farmed or 'alternatively' farmed in Iowa, USA (a system broadly similar to organic farming). Differences in nitrate concentration down the profile were small and inconsistent between farming systems. It was concluded that alternative systems do not differ in leaching risk from *well managed* conventional systems.

The leaching risk associated with ploughing grass has already been identified potentially as the most nitrate leaky part of an organic rotation. However, with as much as 60% of an organic rotation remaining in undisturbed pasture in any one year (Phillips *et al.* 1995), there will be substantial dilution of the nitrate mineralised from the ploughed grass by water of low N status from the remaining fields (Watson *et al.* 1993). This is based on the assumption that the N balance of the remaining field is such that leaching losses will be small.

2.3.6. Conclusions

It is difficult to compare directly nitrate losses from an organic and conventional system without the time and expense of setting up 'farmlets' on a research centre such that as many variables as possible are removed from the comparison. Even then, it is likely that the comparison would be confounded by rotation, since each system would operate different cropping plans appropriate to their regime. However there is sufficient evidence in the scientific literature to enable broad conclusions to be drawn and the need for further work to be identified.

Nitrogen cycling in a farming system is complex and affected by many factors. As a general guide to leaching risk, one approach might be to consider the N balance (N inputs - N outputs) of a farming system on the assumption that a large N surplus will be more predisposed to losses such as leaching. Then, the N balance of individual 'conventional' and 'organic' systems will depend greatly on the circumstances and management practices of the individual farms; consequently, it is not possible to generalise that one system is always better than the other in terms of nitrate leaching risk. The Codes of Good Agricultural Practice also try to tighten a farm's N balance with a resultant decrease in leaching on conventional farms, as has been shown in the pilot Nitrate Sensitive Areas (MAFF 1993).

Having stated these qualifications the literature does suggest that generally, organic systems offer less *risk* of nitrate leaching:

- Organic farms are less intensive with a better N balance and there is less risk of overfertilising. They are often operating below the crop's economic optimum fertiliser requirement (as defined under conventional management) and leaching losses are small,

- Organic systems rely on fertility building phases typically using grass / clover leys. Leaching losses from this phase are generally small, so that the average loss from the rotation will also often be smaller than from a conventionally managed rotation.
- Stocking rates and N inputs are lower than in intensive livestock systems; these intensive systems can leach substantial nitrate.
- From a practical point of view, the economics of conventional farming systems requires intensification which offers more scope for something to go wrong in the practical management of the N cycle. For example insufficient manure storage might result in untimely application, or because it is important to fertilise as close as possible to the crop's optimum, there is more risk of overfertilisation. Although Codes of Practice have been developed to minimise these risks, there will be times when they are unavoidable.

There is scope for substantial leaching losses from organic systems on some occasions. In particular the systems rely on releasing nitrate by mineralisation at a time when it can be utilised by a crop; untimely mineralisation or a crop failure will result in nitrate losses by leaching. In particular, cultivation of leys has been identified as high risk, with longer-term grass releasing N several years after ploughing. MAFF (EPD) is funding a large programme of research on nitrogen mineralisation, and much of this will aid understanding of organic systems.

It could also be argued that there is more chance of a crop failure in organic systems due to poor control of a pest or disease. If this does occur then N will be used ineffectively and more leaching is likely to result. We also need to consider the longer-term effects of organic practices on soil fertility and 'soil health', and consequences for nitrogen mineralisation. Building up the soil organic pool through grass/clover leys and the use of bulky organic manures is ideal for soil structure and for producing a diverse biomass, and will be an important source of crop N via mineralisation. However, more information is required on the long-term effects of fertility build-up on N leaching; again the MAFF funded mineralisation research programme will go some way to understanding this.

There is scope for further work:

- The best way to compare the effects of conventional and organic systems on nitrate leaching is to model the systems. This is more cost-effective than initiating numerous field experiments to compare individual rotations.
- There is a need to understand better and quantify the concept of 'soil health', and the effects of different farming systems on it. Maintenance of soil organic matter levels is important for soil structure, erosion control and, hence, crop productivity. More information is required on the effects of farming practices on soil organic matter status, both quantity and quality.

2.4 Loss of phosphorus from agricultural land.

2.4.1. Environmental effects.

When low natural concentrations of phosphorus in water bodies are raised from agricultural sources the growth of aquatic weeds and algae is stimulated. When these die they can lead to a shortage of oxygen and fish kills. In addition the potentially carcinogenic toxins produced by some blooms of blue-green algae can pose acute health risks to humans and animals. These toxins can also interfere with water treatment processes leading to palatability problems thus incurring economic costs to the water industry.

2.4.2. Source of agricultural phosphate.

Earlier reviews on the loss of phosphorus from agriculture (e.g. Ryden et. al. 1973) have recently been updated in papers by Sharpley and Withers (1994) and Foy and Withers (1995). Although total losses from agriculture are small in proportion to the quantities cycling in the system they are sufficient to cause eutrophication of surface waters. In the British Isles the loss of P from water sheds with a mixed land use, is usually less than 1 kg/ha per year. The estimated contribution from agriculture is variable (5-90%) but can be the major contributor. Foy and Withers (1995) concluded that evidence from different continents suggests that lakes draining catchments with high input agricultural systems are likely to experience problems with nutrient enrichment.

Point source pollution by phosphorus from the incorrect handling of manure has been discussed above in as much as it occurs whenever organic loads enter water systems. Phosphorus from diffuse sources is transported in both dissolved and particulate form. Dissolved P is mainly released from soil, from vegetation or via run-off of applied manure and fertiliser. Particulate P is comprised largely of mineral soil material and organic matter removed from fields by both water and wind erosion. Therefore the higher the concentration of phosphorus in soils the greater the risk of P being transported into waters.

In studies where point sources can be identified and isolated as a source, the loss of phosphorus has been shown to be directly related to the cattle stocking rate. There is little evidence to compare losses from catchments according to different land use but Finnish studies have suggested that the proportion of land under cultivation is directly linked to the increase of P losses.

The control of releases of P into waters therefore depend on aspects of the use of fertilisers, the management of animal manures and control of soil erosion. There is evidence to indicate that soil P concentrations are not continuing to rise in Great Britain as the result of overuse of fertiliser although there are still high residues in some fields. Withers (1993) concluded that recent changes in land management such as the increase in winter cereals (leading to increased run-off and erosion), slurry based manure systems and land drainage were more important than fertiliser inputs in determining P loss in the UK.

2.4.3. Implications of organic systems.

From discussions here and in other sections it can be concluded that organic systems are less likely to cause P loss into waters than their conventional counterparts..

- Soil P reserves are tending to fall on organic farms because fertiliser input is lower than offtake.

- Soil erosion is less of a problem on organic farms

- Slurry systems are less common and organic systems do not have excess quantities of manures to dispose of. Greater care is taken to prevent run-off.

- Stocking rates are lower on organic farms.

2.5. The effect of permitted pesticides on the quality of ground and surface water

2.5.1. Introduction

Three pesticide active ingredients are permitted in organic farming systems, rotenone, pyrethrins and copper. Rotenone is extracted from Derris root and is used as an insecticide, most often referred to simply as Derris. Pyrethrins is the collective term for a mixture of six insecticidal constituents present in extracts of *Pyrethrum cinerariaefolium* and other species. Pyrethrin-based insecticides are often referred to as pyrethrum. Copper, in the form of various salts such as copper hydroxide, copper oxychloride and copper sulphate, can act as both a fungicide and bactericide. In contrast to organic farming, there are over 300 pesticide active ingredients in common use in conventional UK agriculture and horticulture, (Whitehead, 1995).

2.5.2. Occurrence of pesticides in water

Many pesticides have been detected in surface water and to a lesser extent groundwater in the UK (NRA, 1992). Although fungicides, insecticides and herbicides have all been found in the many studies on water contamination, the pesticides most commonly detected are herbicides, in particular residual soil-acting herbicides. For example, in the first report of the Drinking Water Inspectorate (DOE 1991), the four most frequently-detected pesticides in drinking water were the herbicides atrazine, simazine, isoproturon and chlorotoluron. No herbicides are permitted in organic farming systems and hence there is immediately a large reduction in the risk of water contamination from such systems, compared to conventional farming.

As far as the author is aware, pyrethrins and rotenone have not been detected in ground or surface water in the UK, though it is likely that the various monitoring bodies do not include these pesticides in their monitoring programmes. However, since other insecticides have been detected, the risk from these two warrants further consideration. The risk from copper-based pesticides presents a dilemma. Copper occurrs naturally in soil and water bodies. Any contamination from the use of copper-based pesticides could be difficult to demonstrate against the background concentration. Also, the analytical methods used in water monitoring programmes are likely to measure only elemental copper and not specifically identify pesticidal forms of the metal. Again, no reports of water contamination by copper-based pesticides have been encountered.

2.5.3. Assessing the risk of water contamination

The likelihood of a pesticide causing ground or surface water contamination is commonly assessed by considering two key properties of the chemical, its mobility in soil and its persistence or rate of degradation in soil. The more mobile and the more persistent a pesticide is in soil, the higher the risk of water contamination.

These two properties can be assessed by measuring how strongly the pesticide binds to soil or soil organic matter, usually reported as K_{oc} and how quickly the pesticide degrades to half its starting concentration, reported as half-life or $t_{½}$. The MAFF Pesticides Safety Directorate assigns the following classification to pesticide K_{oc} and $t_{½}$ values (Griffin, personal communication):-

K_{oc} (cm^3/g)	Classification	$t_{½}$ (days)	Classification
Less than 15	Very mobile	Less than 5	Impersistent
15-74	Mobile	5-21	Slightly persistent
75-499	Moderately mobile	22-60	Moderately persistent
500-4000	Slightly mobile	Greater than 60	Very persistent
>4000	Non-mobile		

- *Pyrethrins and Rotenone*

K_{oc} and $t_{½}$ values for pyrethrins and rotenone are given below. Also shown are the values for three insecticides commonly used in conventional agriculture and which have been detected in surface water, (Croll, 1988).

Pesticide	K_{oc}	$t_{½}$
Pyrethrins	100,000	12
Rotenone	10,000	3
Diazinon	1,000	40
Dimethoate	20	7
Lindane	1,100	400

Source: Wauchope *et al* (1992)

From this it can be seen that both pyrethrins and rotenone are highly non-mobile in soil. Further, pyrethrins are only slightly persistent and rotenone is impersistent. In comparison, the three other insecticides reported are far more mobile and two of them are more persistent.

Based on this evidence, the risk of water contamination from pyrethrins and rotenone would appear to be low. This view is reinforced when other factors affecting pesticide movement to water are taken into account. The risk of water contamination by a given pesticide is likely to increase as its total usage in a water catchment increases and as the proportion applied in autumn and winter increases, when field drainage restarts and reaches its peak, (Bailey *et al*, 1995). The frequent contamination of water by herbicides is partly a result of their widespread use, at relatively high rates, in the autumn and early winter. In contrast, the rates of pyrethrins and rotenone used are much lower and likely to remain so even with an increase in organic production. The time of application is not centred on autumn and winter and they are mainly cleared for, and seldom used other than on, high value horticultural crops.

- *Copper*

K_{oc} and $t_{½}$ values have not been reported for copper-based pesticides. These properties normally only being measured for carbon-based molecules and not inorganic salts. Hence there is little data on which to assess the risk of movement through soil to water. Tomlin (1994) considers that copper oxychloride is strongly bound by soil and so likely to have low mobility. He also reports that copper sulphate can be washed through the soil. When both this salt and copper hydroxide are present in soil solution, the positively-charged copper fraction of the molecules will partly be retained by the soil, as are the many other positively-charged metals in the soil solution. However, as drainage occurs, some copper movement will take place and so it is at least theoretically possible that pesticide-derived copper may reach field drains or groundwater. Whether this could be detected and its origin identified, or would be significant to water quality and the aquatic environment, is not known.

2.5.4 Limitations to current knowledge

The preceding discussion on pyrethrins and rotenone principally considers movement of these pesticides through the soil in solution. In view of their very high K_{oc} values, such movement is likely to be insignificant. However, strongly bound, non-mobile pesticides are known to reach water when carried on sediment which is moving from the soil. For example, Turnbull *et al*, (1995) detected the insecticide deltamethrin in surface water shortly after its application. Deltamethrin, a synthetic pyrethroid closely related to the pyrethrins and from which it was developed, has a reported K_{oc} of 110,700. Synthetic pyrethroids applied to water bodies are known to become concentrated in sediments (Hill, 1985).

Synthetic pyrethroids, pyrethrins and rotenone all present a toxicity hazard to aquatic fauna. Hence theoretically pyrethrins and rotenone could reach surface water and present a hazard to aquatic fauna; particularly fauna associated with sediments. The greatest risk from such contamination would be expected when these pesticides are applied at a time of year when ground cover by the crop (and thus pesticide interception) is small and sediment- bearing drainage from the soil occurs shortly after application. Where there is insufficient dilution of such drainage by other noncontaminated drainage, for example from a treated crop immediately adjacent to a water-course, localised effects on aquatic life might occur. The synthetic pyrethroids are receiving increasing attention over this aspect of their fate, but this has not included the pyrethrins.

2.5.5. Conclusions

Organic agriculture does not involve the use of the type of pesticides which contaminate waters from conventional systems. The few materials that are permitted are only likely to enter water through misuse near water courses or accidental spillage. Run-off is very unlikely to cause problems given the rate of use and the limited range of crops that are treated.

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3 THE EFFECT OF ORGANIC MANAGEMENT ON SOIL QUALITY.

3.1 Introduction

The effects of organic management on aspects of soil quality can conveniently be considered under similar headings to those in the Code of Good Agricultural Practice for the Protection of Soil (MAFF 1993).

- Soil fertility- organic matter content, acidification, soil nutrients and biological activity.
- Physical degradation- soil compaction and soil erosion.
- Soil contamination- animal manures, organic wastes, pesticides, fertilisers etc.

The concept of the well being of soil was the basis of organic production arising as it did from the farming methods developed by the founders of the Soil Association. The benefits of rotational (or ley farming) was being recognised some 50 and more years ago both within and without e.g. Stapledon and Davies (1941),the organic farming movement. The bio-dynamic movement arose in Germany from the teachings of Rudolph Steiner. Not only did he introduce the use of bio-dynamic preparations but he advocated that rotational farming should be reinstated. The benefits of rotational grass as a builder of soil fertility was demonstrated at the end of the 19th century by R H Elliot on his farm in the Scottish borders (1943).

At the beginning of the Second World War it was estimated that in England and Wales virtually two thirds of all land was down to permanent pasture despite half of this being suitable for rotational cropping (Stapledon and Davies 1941). A significant proportion of land was being continuously cropped whilst permanent grass was present on the same farm. Nearly 100,000 ha of this arable land were considered to be "completely farmed out". It was into this scenario that the wartime ploughing of grassland for food production occurred (at a rate of over half a million ha's per year from 1939-1943) and more continuous arable land was created. Within ten years the Soil Association was formed.

Soil organic matter levels are known to decline when such a change of management is introduced. Jenkinson discusses this and many other aspects relevant to this part of the review in Wild (1988). The process of breaking up permanent pastures has continued throughout the next 50 years. Statistics on this topic are now reported in rather a different way but there is now only some 4 million ha of grass more than 5 years old. Much of this is in areas of the country where grassland farming is most suitable due to soil and climatic conditions. MAFF statistics indicate that in arable counties of Eastern England such as Norfolk and Suffolk the total grassland area is only some 12% of agricultural land whilst rotational grass (less than 5 years old) only represents 2.5%.

By the late 1960's soil conditions where giving rise to concern and the MAFF Report Modern Farming and the Soil was produced (MAFF 1970). This recognised that adverse weather conditions had been a factor in the deterioration of soil structure.

Concern was expressed about the perceived low level of organic matter in some soils Damage by cultivations and treading by livestock were recognised but it was concluded that there were no serious or widespread underlying problems. It was considered that these poor conditions could be corrected by improved management practices. This view has largely been proved correct over the following 25 years. The introduction of better machinery and a great increase in autumn sown crops, have both contributed to the improvement as have farmers basic skills.

However during this time other problems have come to the fore such as increased soil erosion and decreased structural stability which can be linked to low organic matter . These are not considered by MAFF to be widespread although they can be serious where they occur and farmers are encouraged to take remedial action. (MAFF unpublished submission to the Royal Commission on Environmental Pollution.)
On a global scale "human induced degradation" at varying degrees of severity has been estimated to affect 40% of arable soils and 21% of grazing land (Oldeman et al 1991).

3.2. Soil Fertility.

3.2.1. Organic Matter content.

3.2.1.1. Total organic matter.

Total organic matter is used here to identify the gross measure of organic carbon in soils. This is distinguished from "active organic matter or biomass carbon which has been discussed in section 1.3 and is considered again below. The beneficial effects of (total) soil organic matter need no detailed description as they are well established. They were summarised in the MAFF Soil Code (MAFF 1993) as follows:-

- The amount and type of organic matter in the top layer of soil influences its physical, chemical and biological properties. In particular it affects its structural stability, ease of cultivation, water retention and release of plant nutrients.

- Changes in management can result in increases or decreases in organic matter content.

- The amount that is needed (to maintain these functions) will vary with the soil and farming system. The organic content will fall under arable farming, particularly if the amount of plant residue returned to the soil is low. Organic matter may also be reduced by erosion, by removing top soil or by deep ploughing which dilutes the top soil.

- Long-term trials show that in continuous arable systems the highest yields are only possible when positive steps are taken top maintain the level of organic matter in the soil.

This last point is of considerable significance coming as it does from work at Rothamsted where the effects of FYM in increasing organic matter have been reflected as benefiting yield over and above the effects of the plant nutrients that it contains.

Soil type is important in a number of ways in this discussion. In light sandy soils organic matter is more rapidly broken down and the near equilibrium content which can be established under a constant management regime is lower than in medium and heavy soils. Korschens reported that an annual application of 10 tonne/ha FYM increases mineralisable soil carbon by 0.2% in sandy soils but by 0.3% in loam soils. The concept of a critical organic matter content in soil which is often used to demonstrate the degraded state of UK soils must be considered in this context. The equilibrium value and hence the critical value, if such a concept exists, will vary for different soils.

3.2.1.2. Effect of organic management on organic matter content.

The organic matter content of soil is increased by the addition of animal manures, crop residues such as straw and vegetable tops, and root residues particularly of grass swards. For a given sequence of crops increasing the rate of nitrogen can increase organic matter build up (Eagle 1971). Thus an organic system operating at a low or moderate level of fertility need not necessarily be better than a similar rotation receiving conventional inputs.

The literature contains many references demonstrating that organic matter levels increase under organic management. In most cases the rotation under organic management is substantially different from the conventional systems with which the comparison is made (e.g. Reganold 1988 and Wander et.al 1994). In both cases forage crops or green manures had been introduced into continuous arable rotations. This was not the case in an Australian study of dairy pastures which looked at fields which had been converted to a bio-dynamic system for 18 years. The organic matter was 19% higher than in conventional pastures on an adjacent holding despite a reduced stocking rate. However the level in both systems was relatively high (above 6.7%) and the observed structural improvement was thought to be more the result of the reduced grazing pressure rather than the occasional application of bio-dynamic compost.

The introduction of a ley into a rotation can increase the organic matter content of the soil initially but the level will decrease again during the cropping phase. The balance between these two processes can differ from site to site. This was most clearly shown in a classical series of experiments on MAFF Experimental Husbandry Farms (Eagle 1971). The benefit from a 9 year ley was greater than from a 3 year ley. On only one of the 6 sites was the net effect of the rotation positive whilst on the remainder there was a small overall decrease. The decrease on continuous arable plots was greater. In the same way Wood (1995) quotes a New Zealand study where the organic matter content was similar in an organic and in a conventional ley/arable rotation.

Differences between sites will depend upon:-

- how close to the equilibrium organic content the system is before the changes are introduced.
- the soil type and climate.
- the extent of subsequent cultivation's.

The latter are known to stimulate organic matter breakdown and any great increase such as to create stale seedbeds or remove weeds mechanically could reduce the benefit of the organic system.

Although organic management practices may increase soil organic matter levels the impact of a change in the rotation usually associated with an organic conversion will have a greater effect on the total organic matter content of soils.

3.2.1.3. Active organic matter.

An increase in active organic matter is usually associated with increases in total content (Reganold 1988, Wander et.al. 1994, Wood 1995). This increase is associated with microbial transformations which help to form stable soil structures, release nutrients for plant uptake and breakdown contaminants in the soil. All of these three references have demonstrated increases in active organic matter under organic management systems.

Where organic conversion entails a change from arable to mixed farming the soil organic matter content can be expected to increase or at least be stabilised at a higher value than if continuous arable cropping had continued. If an all grass or a mixed grass/arable farm is converted changes may be small but advantages have been shown in some studies.

3.2.2. Soil biology

The effects of organic management upon soil organisms has been referred to in a number of places in this review. The following paragraphs consider the effects on soil fauna and in particular earthworms in view of their importance for soil fertility.

3.2.2.1. Earthworms

The importance of earthworms in the context of soil formation and maintenance of fertility is well established and has been discussed by many authors e.g. Edwards (1983), Syers and Springett (1984), Wild (1988). They redistribute organic material in soils, modify root growth and distribution, increase microbial activity and increase nutrient availability to plants. Whilst acidic fertilisers reduce earthworm activity and even suppress numbers other inorganic fertilisers which stimulate plant growth and hence increase organic matter return to the soil increase activity. The effect of earthworms on C and N cycling is the subject of a long term study established in the USA in 1991. First results of this work are currently in press and will shortly be available (Bohlen et.al. 1995).

Earthworms in UK soils have been considered as part of a review for MAFF on the effects of the predatory New Zealand Flatworm (Artioposthia triangulata) on UK agriculture (Alford et. al. 1995). Numbers of earthworms are much lower in continuos arable cultivation than under grassland, or deciduous woodland. This is the result of lack of organic matter as a food source, and the harmful effects of cultivations as well as of agrochemicals. El Titi (1989) has reported beneficial effects on earthworm numbers in an integrated agricultural system when chemical inputs were reduced but not eliminated, shallow cultivations replaced ploughing and changes were made to what remained basically an arable rotation.

Additions of organic manures generally encourage earthworm numbers e.g. Edwards (1983) Scullion and Ramshaw (1987). Animal slurries applied in large quantities, particularly to wet soils, can kill off earthworms although the longer term effect may be positive due to the organic matter applied (Unwin and Lewis 1986). Heavy metals have been shown to suppress earthworms and van Rhee (1975) and Curry (1980) reported adverse affects of copper in pig slurry on earthworm populations. On a heavy clay soil however Unwin and Lewis (1986) reported increased numbers, particularly of juveniles, when pig slurry containing 212 kg/ha copper had been applied. This had raised soil copper concentrations to close to the maximum value recommended under the Soil Code (MAFF 1993).

3.2.2.2. Earthworms in organic systems.

Given the factors that affect earthworm populations it is not surprising that the literature contains many reports of increased numbers under organic management. Lampkin (1992) quotes four German studies where comparisons between organic and conventional farms have shown increases in numbers and structural formation on the organic farms. Wood (1995) reports similar benefits from New Zealand.

Monitoring of organically farmed land in Leicestershire is showing increasing populations (Brown private communication) whilst Browning (1985 b) assessed populations on shallow chalk soils in Wiltshire. This work demonstrated a beneficial effect of leys even in conventional rotations whilst a conventional permanent pasture receiving high inputs of organic manures had one of the highest populations recorded. Organically managed fields had a greater diversity of species than any of the conventional systems. Numbers were 2-3 times greater on organic rotational fields than on conventional arable or rotational fields. The total weight of worms showed an even greater increase being nearly 4 times higher than in a conventional rotation and 15 times greater than on predominantly arable fields.

	Organic Grass/Arable	Conventional Grass/Arable	Conventional Arable	Conventional Permanent Pasture
Number of fields	11	5	5	1
Mean worm number	33	12	14	43
Range worm number	16-56	2-16	9-33	-
Mean weight g/m^2	46	12	3	17
Number of species	7	3	3	4

Earthworms have been studied at ADAS Redesdale as part of the conversion of an upland farm to organic production (Young and Rushton 1994). Whilst differences on improved hill pastures have been small, populations on the in-bye land have increased with time (1992 to 1994) under organic management and compared to an adjacent conventional pasture. A long term area of undisturbed pasture had the highest numbers and species variety and this changed little when chemical inputs were withdrawn.

Earthworms respond to increased returns of organic matter to the soil. Green manures and cover crops which are recommended practices within organic systems will provide such increases. Preliminary monitoring at ADAS Terrington has detected increases in total earthworm numbers during the period of a mulched red clover conversion ley (Cormack private communication).

3.2.2.3. Conclusion.

With the possible exception that organic farmers have limited quantities of organic manures to apply to the land compared to some conventional units organic practices are likely to increase earthworm numbers compared to conventional systems. The increased numbers are universally acknowledged to benefit soil fertility although such effects are difficult to quantify.

3.2.3. Acidification of soils.

Acidification of soils is a natural process which is frequently accelerated by human activity. The extent to which it happens depends on the composition of the soil , deposition from the atmosphere, cropping and the use of nitrogen fertilisers. Of these only cropping and the use of nitrogen could be considered as under the control of the farmer and thus potentially different between organic and conventional systems.

Nitrogen fertilisers induce acidification when excess nitrate is leached from the soil and cations such as calcium and magnesium are leached as well to maintain neutral charge in the leachate. In theory an organic system which leaches a lot of nitrate from nitrogen applied as organic manures or fixed by rhizobial associations could lose these essential cations at a similar or even greater rate than a well managed conventional rotation. However the comparison that must be made is with an equally well managed organic system. In this case losses will usually be less but as discussed elsewhere in this review (Section 2.3) the precise management system will be critical.

Organic manures, particularly those from cattle, return a significant quantity of calcium to the soil and thus a mixed farming system whether organic or conventional would be expected to have a lower lime loss at a given level of nitrogen input than where none is applied.

Although on balance organically farmed soils would be expected to suffer less lime loss than conventional units it is accepted Good Practice to maintain soil pH at optimum levels. There is thus no adverse environmental effect involved. Rather a further economic advantage to the organic farmer.

3.2.4. Soil nutrients.

The Code of Good Agricultural Practice (MAFF 1991 and 1993) recommends farmers to apply fertilisers and organic manures to meet the nutrient requirements of their crops. Also to maintain soil reserves of essential elements at optimum levels or to apply the annual dressings required for optimum growth. To this extent there should be no differences between farming systems.

Many organic farmers are not balancing inputs and offtakes of nutrients (e.g. Browning 1985 a). However the medium term effects are likely to be a reduction in economic performance rather than an environmental detriment. In fact by running down soil nutrient reserves it is possible that botanical diversity will be encouraged in both arable and grassland crops. This might be regarded as an advantage from an ecological view but may develop to such an extent that it confers dis-benefits in landscape terms. (See section 6).

It is equally fair to note that certain conventional grassland farmers are also failing to maintain soil reserves. Of more concern environmentally however are those farmers who are applying animal manures at rates that exceed crop requirements. The accumulation of phosphate that often accompanies this is a threat to water quality when the phosphate rich soil is eroded or when leaching of phosphate commences (See section 2).

3.3. Soil physical degradation.

3.3.1. Soil structure

Soils can be regarded as physically degraded when their structural condition is damaged or they suffer from erosion. The severity of the condition can be very variable but in the extreme the result may be an irreversible loss of structure or complete loss of

top soil by erosion. Less severe effects may seriously reduce crop growth by restricting root development and reducing water and nutrient availability.
Soil structure can be regenerated by natural processes but this can take many years to achieve even under grassland management which is usually advised to help bring about such an improvement (MAFF 1993).

Soils are generally more resistant to physical degradation when organic matter contents are high. Loss of organic matter can lead to structural deterioration through cultivation pressures, treading by grazing livestock under wet conditions or simply by the action of rain drop impact slaking the surface of the soil. Any reduction in soil structure which restricts the infiltration of rainfall into the soil increases the risk of surface runoff which may lead to soil erosion or under other circumstances lead to pollution by manures or fertilisers. Wischmeier and Smith(1978) estimated that for some soils in the USA an increase in soil organic matter content of one percentage point would decrease the erosion potential by approximately 10%. Earthworms can be important in maintaining infiltration both by their soil structural building capabilities but also the direct effect of their burrows in moving excess water more rapidly to deeper horizons in the profile..

Given these basic effects it is not surprising that in organic systems which have been shown above to increase soil organic matter content and/or earthworm populations, studies have identified benefits in soil structure under organic management e.g. Lampkin (1992), Reganold (1988), Lytton-Hitchins (1994).

3.3.2. Soil Erosion.

There have been few comparative studies on the effects of organic and conventional management upon soil erosion. An exception is the work reported from the North-West USA (Reganold 1988) where over a 40 year period soil erosion under an organic rotation resulted in a 5 cm loss of soil compared to 21 cm under an adjacent conventional system. The difference was the result of changed rotation, management practices and an increase in organic matter content.

As well as the basic organic practices which increase water infiltration by promoting higher organic matter contents and earthworm populations there are a number of other factors which directly contribute to reducing the risk of erosion.

3.3.2.1. Crop selection.

The increase of soil erosion in the UK has been associated with an increase in arable cropping and particularly with a shift to winter cereals. The risk has been greatly increased where this change has taken place on steeply sloping land such as in the South Downs and in East Devon. Organic farmers with their higher proportion of grassland maintain a lower risk situation.

Sugarbeet is a crop which is often the cause of wind erosion when the fine seedbeds are exposed to strong winds under dry conditions. This crop is not grown organically in the UK at the present time.

Field vegetable crops harvested under adverse soil conditions in mid-winter and maize for silage harvested in autumn, are crops which can lead to erosion following damage to soil structure by agricultural machinery. Such crops are far less common on organic farms for a variety of cultural and economic reasons.

3.3.2.2. Cultivations.

Conventional farms who rely on post emergence herbicides for weed control need to provide a fine, firm and level seedbed. This can lead to a more rapid sealing of the surface under heavy rainfall and greater risk of runoff and water erosion. For crops such as sugarbeet it can lead to wind erosion. Organic farmers are more likely to leave a rougher seedbed and to use mechanical weeders which will break-up any surface compaction which may have formed. This is true in cereals, potatoes and vegetable crops.

3.3.2.3. Wheelings.

Wheelings are commonly the focus of runoff and erosion. The tramlines which are commonly introduced at the time of drilling by conventional farmers are a particular problem. As organic farmers do not require access to cereal crops for the application of synthetic pesticides very few introduce tramlines. This is very occasionally done to assist in the application of seaweed and sulphur sprays.

3.3.2.4. Conclusion.

The avoidance or the minimisation of soil erosion is a fundamental objective of organic farming. The basic system and the management practices that are adopted within it all work towards achieving this goal.

3.4. Soil Contamination.

3.4.1. Heavy Metals.

3.4.1.1. Cadmium

The addition of heavy metals to UK soils has recently been reviewed for MAFF (Unwin and Grylls unpublished). This work confirms that after atmospheric deposition the major input of cadmium to soils in this country is from inorganic phosphate fertilisers. Fertiliser inputs were taken from an uncompleted survey of fertilisers also undertaken for MAFF(Marks unpublished data).

There is no recent data for atmospheric deposition on agricultural land although a new research project funded by MAFF has started in 1995. Previous information from monitoring studies (Cawse 1987) and more recent investigations (Osparcom 1992) suggest that average atmospheric inputs have been similar to the current input from fertilisers at around 2-3 g/ha per year. However using this value there is a discrepancy between estimated emissions to the atmosphere and calculated total deposition. One explanation for there apparently being more deposition then emissions, would be that a significant proportion of the measured deposition is actually suspension and redeposition of cadmium from earlier fallout in dust.

The offtake of cadmium in agricultural produce is less than the rate of addition. When conventional fertilisers are used there is a net addition in the absence of animal manures of 1 -2 g/ha and this is increased by around 0.4 g/ha per year by an average application of animal manure.

Organic farmers can apply unprocessed rock phosphate to maintain soil reserves. There are no legal limits in the UK to the concentration of cadmium in fertilisers. The concentration in processed phosphates has decreased significantly in the last 15 years (Fertiliser Manufacturers Association private communication). The ongoing MAFF survey suggests that the cadmium content of rock phosphate available for sale in the UK is higher than in the soluble processed products. This is probably a reflection of the source of the raw material. The multi-national fertiliser manufacturers have changed there source in recent years whilst the smaller companies dealing in rock phosphate may have tended to stay with the rather more contaminated African sources.

This does not however mean that organic farmers are applying more cadmium to their soils. It is the experience of the Organic Advisory Service (Measures private communication) and of ADAS organic inspectors that few farmers are using rock phosphate regularly. There is no data that allows an accurate assessment to be made of the difference in cadmium that is applied by conventional and organic farmers. It is however unlikely that present practices will result in average applications much more than half of those on conventional farms.

Current rotations and fertiliser practices are causing a net removal of phosphate from soils on mixed organic farms in the UK (Browning 1985 a). In the long term it is likely that organic farmers will have to apply more phosphate to maintain soil reserves. By this time it is possible that the EU will have introduced legislation to limit the concentration of cadmium in fertilisers.

Most of the cadmium in animal manures comes from feedstuffs grown in the UK. There is a small net input from imported feed and from mineral phosphate supplements. The feeding practices adopted by organic farmers mean that they use a smaller proportion of imported feed. They rely more on home grown feed and tend also to use fewer mineral supplements. These points together with the lower stocking densities found on organic farms mean that additions of cadmium are reduced. In addition the organic farmer will be buying less feed produced on other UK farms. They will therefore not be transferring as much cadmium onto their land as their conventional counterparts.

The total quantity of cadmium applied to agricultural land in sewage sludge in the UK is much less than in fertilisers. However where sludge is applied the rate of cadmium applied per hectare is much higher. The application of sludge is subject to strict monitoring to ensure that no short or long term problems can develop but as organic farmers are not allowed to use sewage sludge this source of contamination of the soil cannot occur on organic farms.

There is concern that the application of other wastes to land is not subject to the same controls as sewage sludge (MAFF/DOE 1993) although farmers are made aware of the dangers in the Soil Code (MAFF 1993). The control on organic farmers exercised by the inspection and registration process means that they are unlikely to apply contaminated waste materials as those most likely to be contaminated are not allowed under the Standards.

3.4.1.2. Lead

Apart from atmospheric deposition by far the greatest input of lead to agricultural land is as sewage sludge which is not permitted on organic farms. The quantities in fertilisers and animal feeds are negligible.

3.4.1.3. Zinc and Copper.

There are significant quantities of zinc and copper in inorganic fertilisers but they are present in amounts which mean that they are useful sources of trace elements rather than potential contaminants of the soil. The largest single source of these metals after atmospheric deposition is the high level of supplementation made to the feeds of intensively kept livestock.

Conventional rations for fattening pigs commonly contain additions of these metals in excess of 100 mg/kg. The result can be quite high rates of metal application to land in manures. As manure application is not controlled there is a risk that some conventional farmers may build up harmful concentrations in their soils. The organic farmer does not apply manures at such high rates neither are they allowed to add such supplements to their feedstuffs. Similar comments apply to the addition of zinc to conventional poultry rations.

The Soil Code cautions all farmers to avoid harmful soil accumulations of metals from manures but there is as yet no control over spreading practices. The total metal concentration in feeding stuffs is however controlled by Feedingstuffs Regulations.

3.4.1.4. Copper Fungicides

Fungicides containing copper are allowed under organic standards. Total use on UK farms was reviewed by Unwin and Grylls (unpublished). It was concluded that of the 8 tonne of copper applied annually as fungicides the great majority is currently applied in hop gardens. There is no reason to believe that the only organic hop garden in the UK receives more copper than its conventional counterparts.

The only other significant use of copper fungicides is for blight control in potatoes. Here the organic crop is much more likely to receive copper products than conventional crops. This is because synthetic fungicides are both easier and safer to use and are recognised by conventional farmers as more effective. When applied at the full recommended dose a single application will apply the equivalent of 2.5 kg/ha copper. As 3 to 5 applications may be applied in a single season total rates can be high. Organic growers are concerned at using such high rates and a number are known to use reduced rates at each time of application. They are required to minimise the number of applications under the Organic Regulations. They grow the most resistant varieties where this is consistent with an acceptable marketing policy. Virtually all potato growers grow the crop in a rotation with at least 4 years between crops. When there is a major outbreak of blight most growers are prepared to defoliate the crop early rather than embark on a costly and possibly ineffective spraying campaign. At the present time the organic crop is widely dispersed around the country and is often in areas where disease pressure from other crops is less than in intensive potato growing regions. These points all serve to reduce the risk of long term harmful accumulations of copper in the soil.

In conclusion although organic potato growers use various cultural controls to minimise the use of copper fungicides at the present time they are still likely to use more than their conventional counterparts. This means that even within Pesticide Regulations there will be a greater long term risk of copper accumulating in soils. However the surveillance provided for under organic production controls and the general concern of organic producers for their land should ensure that no long term damage is sustained.

3.4.2. Pesticides.

Pesticides are frequently mentioned as contaminants of the soil. Their effects upon soil flora and fauna has been discussed elsewhere in this report. When used according to their approvals under the relevant legislation (Anon 1986) there should not be a harmful accumulation of the active ingredient or of its breakdown products in the soil. The information that has to be submitted to obtain registration has to demonstrate that at recommended rates the material is degraded in the soil. Even when residual herbicides are used regularly any accumulations can be expected to breakdown within one or two years of applications ceasing. Indeed this is the assumption behind the period required for organic conversion.

The disposal of spent sheep dip is a potential hazard unless carried out according to recommended practice and where necessary in consultation with the National Rivers Authority. When disposed of by dumping onto soil or placed in soakaways accumulations have occurred in soils. In some instances this has resulted in an extended risk of water pollution as the active chemicals leach from the soil. Apart from the fact that organic farmers are required to use less persistent materials all sheep farmers have the same responsibilities to avoid pollution by such materials.

In terms of protecting soil from contamination there should be little difference between a "legally" managed conventional system and an organic unit which uses no persistent pesticides.

3.4.3. Excess plant nutrients.

The rates of application of animal manures by some intensive livestock producers causes an accumulation of phosphate and potash in the soil and also increases the risk of nitrate leaching. The accumulation of phosphate has been discussed in section 2.4 in respect to the risks to the environment that this can cause. Organic farmers do not have excess quantities of manure because of limited on-farm feed production and the limitations imposed on stocking rate by the standards both directly and indirectly.

Over the last 30 years when inorganic fertilisers have been relatively cheap conventional farmers have tended to apply more than has been needed by individual crops. The result has been increasing concentrations in many soils although this trend may have levelled off in recent years. This is another scenario which is very unlikely on organic farms. Indeed as mentioned above organic farms tend to be run at a net nutrient deficit.

3.5. References

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4. Organic livestock management - side effects of the use of veterinary medicines

4.1. Introduction

The main objective of organic livestock production is to adopt effective management practices which maintain animals in good health and avoid the need for chemotherapy. The emphasis is therefore on prevention and avoidance of parasitic challenge rather than on veterinary intervention. However, welfare is also an overriding consideration and conventional medicines may be legitimately employed in acute cases where animal welfare could be at risk. Prophylactic use of medication is prohibited. A combination of homeopathic and conventional approaches are frequently used on organic farms for the treatment of individual sick animals (Halliday 1991). Conventional husbandry frequently involves the prophylactic use of a wide range of veterinary products.

4.2. Limitations of this review

In considering systems of pig , milk, beef and lamb production in the UK, the health status of a particular flock/herd depends very much on individual circumstances, and disease patterns evident on that particular farm. In addition, there is increasing overlap in certain management practices applied on both organic and conventionally managed farms. Newer, alternative approaches to disease control, for example, pour-on pyrethroid preparations are gaining as much in popularity amongst conventional farmers as organic ones (Anon 1995 a). The health and performance benefits of clean grazing systems are well recognised, and such systems can be applied to advantage under conventional as well as organic agriculture (MAFF 1985). Therefore, the overall impact of organic versus conventional use of veterinary medicines is difficult to quantify in absolute terms.

Environmental risk is governed not only by the inherent characteristics of the products themselves, but also the care in their use and subsequent disposal of spent material or surplus stock. Indiscriminate disposal of a moderately dangerous product can have disastrous consequences, more so than careful handling of a more dangerous material. For the purposes of this review, it is assumed that all products are handled carefully according to manufacturers instructions.

Formal systems of assessing environmental risk cannot, and are not designed to, cover every eventuality. The information given below must be interpreted in this context.

4.3. Approach

It is beyond the scope and delivery date of this review to consider all the data currently available for every individual product used in the UK as an animal medicine.

The approach taken has been to consider what broad safeguards are currently in place, and then to focus on areas where the greatest divergence between organic and conventional management practice is likely to occur.

4.4. Use of veterinary medicines in the UK

In the UK, the animal health industry has sales of approximately £280 million (source National Office of Animal Health), compared to the equivalent in human medicine of £4.7 billion.

Of the total, 60% is made up of medicines for use in livestock, as opposed to companion animals. Just over 50% of sales are available as prescription only medicines (POM), their use overseen by a qualified veterinary surgeon.

Pharmaceuticals make up 65% of sales. Biological materials (vaccines and sera) account for 23%. Medicinal feed additives constitute 12%. Growth promoters account for 5% of total sales.

4.5. Existing legislation

Product licenses are granted by the Ministry of Agriculture, Fisheries and Food, acting through the Veterinary Medicines Directorate.

Before any new veterinary product is given marketing authorisation, it must currently satisfy three criteria:-

- *Safety* - to the consumer, the animal treated, the person administering the drug and the environment.
- *Quality*- specific aspects of purity, stability etc.
- *Efficacy* - it must perform according to marketing claims and in accordance with the product label

A fourth criteria will shortly be introduced through an EU requirement to conduct an Environmental Impact Assessment on each product. Not only will each new product have to be tested, but also existing products on the five year renewal of its licence. All products are to be considered, not only those which appear to constitute an environmental risk

According to the animal health industry there is no evidence to suggest that licensed products, used properly, constitute a risk to the environment (NOAH 1995). However, driven by the impending 'Ecotox' regulations the environmental risk associated with veterinary medicines will be even more closely scrutinised in the future. Despite the effects on specific products, some of which may (undeservedly) have to be taken of the market due to the cost of providing the additional data, the overall environmental safety of conventional veterinary medicines is likely to be improved.

Herbal and homeopathic drugs are not subject to the same controls as conventional medicines. However, controversial new proposals aim to bring homeopathic medicine within the same testing procedures. If these proposals are successfully introduced there is concern over the future availability of these 'natural' remedies.

4.6. Categories of products

In considering the use of veterinary medicines, and the likely differences between organic and conventional systems, then five main categories of veterinary products may be identified according to method of use.

- Endoparasiticides
- Ectoparasiticides
- Vaccines
- Antibiotics
- In feed additives

Enquiries have been made for this review from the National Centre for Environmental Toxiology at WRc Medmenham for information on the enviromental toxicology of a wide range of commonly used veterinary products. The search indicated that for many compounds there is little information in the public domain (Wroath private communication). Where data was available comments are included in the following sections.

4.6.1. Endoparasiticides

yThese are mainly wormers and anthelmintics, and for farm livestock represent approximately £45 million worth of sales in the UK, mainly to conventional farmers. The use of anthelmintics is likely to be one area of greatest difference between organic and conventional systems.

Under organic management use of anthelmintic is eliminated or very much reduced. Systems of management for organic grazing livestock, aim to minimise the effects of internal parasites by moderating the build up of parasitic challenge and encouraging the development of the animals own resistance to infection. For sheep and cattle, clean grazing systems have been developed integrating cropping and livestock systems to minimise the build up of host specific parasites.

Where an unacceptable level of parasitic burden is apparent, drenching is permitted (UKROFS 1994). Avermectin products are generally not used.

For reasons of stocking rate and the crop/livestock enterprises employed, uptake of clean grazing systems on conventional farms has been low. Much greater reliance is placed on the routine use of anthelmintics Three groups of products are available - levamisoles, benzidimazoles and avermectins and a common recommendation is to rotate the use of products between groups so as to reduce the potential for drug resistance.

There is little evidence available for any persistent environmental effect through the use of levamisole or benzimidazole products. However, there is a belief that avermectin products have a deleterious effect on soil invertebrates, particularly coprophagic species which come into close contact with the faecal output of treated animals, and are an important component in its incorporation into the soil. While scientific data exists demonstrating the negative effects of ivermectin on the breakdown of dung pats on the pasture, there is also data available (Wratten et al 1993) suggesting minimal effects under temperate conditions. In the aquatic environment ivermectin has been shown to have no effect on the salt water shrimp *Crangon septemspinosa* when offered in its food supply (Burridge and Haya 1993). In water 0.022 µg/l has been shown to be the LC50 for the mysid shrimp *Mysidopsis bahia* whilst the corresponding value for the larvae of the oyster *Crassostrea virginica* was 430 µg/ l (Wislocki et. al. 1989).

A half life of 10 days in soil has been put forward as a "guestimate" for Thjiophanate according to the scs/ars/ces Pesticides Properties Database.

4.6.2. Ectoparasiticides

From a total market of over £22million, sales of products for ectoparasite control account for approximately £12 million in farm animals. These products, particularly sheep dips, are widely used, high profile medication. Much publicity has been given recently to the organo phosphate based products and their possible implications for human health (Stephens et al 1995). However, the evidence to date is not conclusive.

OP products are prohibited for use on organic farms, except when there is a specific statutory requirement for their use e.g. against warble fly. Treated animals irrevocably lose their organic status when they have been used.

On organic farms ectoparasite control in cattle, sheep and pigs is generally based on various pyrethroid preparations, administered as a pour-on, or more recently as an immersion dip. In addition, a larval inhibitor (Cryomazine - Vetrazine ®) is available to prevent blowfly in sheep. No environmental data for this product has been located.

Pyrethrum is rapidly degraded by ultra violet light, and newer more stable products have been developed. Depending on the formulation, these newer synthetic preparations are more or less effective against a range of ectoparasites. For example flumethrin, (Bayticol ®) is particularly effective against mites and therefore Sheep Scab, but has little effect on blowfly.

Many ectoparasite products have the additional problem of safe disposal of spent material or surplus stock. Typically, spent sheep dip is applied at a low rate to suitable land. Pyrethroids will bind to fractions within the soil and are eventually broken down to harmless by-products. OP products are degraded by soil bacterial activity.

Products based on pyrethrum have a very low mammalian toxicity - the likely reason behind their endorsement within organic standards. However, as a common characteristic they are extremely toxic to aquatic life e.g. cypermethrin (WRO 1989), and are 1000 times more potent than OP products to brown trout (NRA private communication).Following the introduction of pyrethroid dips for blowfly control, serious pollution incidents have been recorded (Anon, 1995 b)

A WHO report (1990) indicates that synthetic pyrethroids are rapidly degraded in soils and there is little tendency for bioaccumulation in organisms. Whilst some information was locat4d for cypermethrin and a lot for permethrin and deltamethrin virtually nothing has been released on flumethrin.

Whislt information on the transformation of organophosphorus insecticides in the environmment is available effects on other organisms is less easy to find. Some data for LC50'S for fish has been located (e.g. Capel et. al. 1988, Verschueren1983).

4.6.3. Vaccines

Vaccination programmes are increasingly used in modern farming, for example for clostridial diseases in cattle and sheep, and E coli in pigs. Current research is actively pursuing the possibilities to extend the use of suitable vaccines into areas hitherto dominated by chemotherapy, for example for various internal and external parasites (Cook 1995)

While the decision by organic farmers to use specific vaccines may be more measured than their conventional counterparts, the concept of vaccination is consistent with the ethic of prevention rather than cure. Vaccination programmes are relatively common on organic farms (Halliday 1991).

Relying on the internal immune system, the use of vaccines has negligible consequences for the environment.

4.6.4. Antibiotics

Overuse of antibiotics in agriculture may encourage the development of resistant strains of microbe in the animals themselves, or possibly the development of cross-resistant in humans as a result of consuming livestock products containing high levels of antibiotics (Maynard 1995).

As a general rule, considerably less antibiotics are used on organic farms than on those managed conventionally. This is particularly the case for pigs which are kept conventionally under more intensive conditions, frequently supplemented with in feed medication. However, in more extensive sheep or cattle systems the use of antibiotics is largely restricted to the treatment of individual animals.

There is some evidence that the use of antibiotics in pig systems can affect the balance of microbes in the soil (Huysman et al 1993) when slurry is returned to the land. However, the main implications may be for the selection of antibiotic resistant microbes (Berwick 1977). There is little evidence to link the use of antibiotics and broader environmental criteria such as invertebrate life.

4.6.5. In feed additives

For conventional pig production in particular a range of medicinal products are supplied in-feed. These include antibiotics, both as growth enhancers as well as for therapeutic purposes.
Of the dietary supplements fed, copper and zinc are likely to have potential long-term effects on the environment. These and other metals have been shown to have a

persistent adverse effect on soil microflora. (See sections 1.3 and 3.4.). Their effect in water was considered in Section 2.5.

The fate of dietary copper and zinc is currently the subject of ADAS research funded under an MOU by Environmental Protection Division of MAFF.

4.7. Animal health industry - benefactor to the environment ?

There is an argument put forward by the Animal Health Industry that animal medicines have a positive effect on the environment, and in the sustainability of livestock farming.

Fit healthy animals perform well, and use less resources than unfit ones. Data provided by FEDESA suggest that if all animal health products were removed, there would need to be an increase world-wide of 54% in pig numbers, 28% in sheep, 25% in poultry and 89% in cattle to maintain total output. Greater numbers would require more land (to the detriment of natural habitats), and increase methane and the quantity of animal wastes produced.

Applied to UK agriculture, this argument would have to presuppose that all stock would continue to be kept under the same conditions as now with only medicines withdrawn. Otherwise organically reared animals must be greatly less productive and less healthy, which is clearly not the case. Neither is medication denied to stock that require it.

4.8. Conclusions

The greater emphasis on disease prevention suggests that organic systems of production inherently rely on a lower absolute level of veterinary inputs compared to conventional systems. This is particularly the case for anthelmintics and for in-feed additives such as coccidiostats where lower clean grazing systems and reduced stocking rates reduce parasitic burden.

In most instances there is little scientific evidence to suggest that licensed products, used and disposed of correctly within conventional systems have any deleterious effect on the environment. Safeguards will be further tightened with the introduction of newer, more rigorous eco-toxicological requirements for licensing purposes.

Organic farming does not eliminate the need for veterinary treatment, either for individual animals in the case of acute disease, or on a flock/herd basis for example for ectoparasite control. In many instances organic standards stipulate the use of a different product, or the avoidance of a specific prohibited material

Some substances prohibited by organic production standards e.g. OP dips, dietary supplements of copper and zinc, and possibly the avermectins, have got implications for the environment. However, other permitted products may have higher toxicity's, for example, pyrethroid preparations and their effects on aquatic life.

Because of a general desire not to handle or administer perceived harmful materials, for examples OP dips, 'organic' and conventional management practices have become closer in certain areas of treatment.

Organic farmers may, or may not, be more conscientious in their care for the environment than their conventional counterparts. Disposal of pyrethroid dips requires great care by all farmers. On balance, it is concluded that little overall environmental benefit accrues directly from the adoption of an organic approach to veterinary inputs and disease control. The importance of antibiotic residues in the development of resistant organisms with a link to human health justifies further study.

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5. THE IMPACT OF ORGANIC MANAGEMENT ON ATMOSPHERIC POLLUTION FROM FARMS.

5.1. Introduction

The gases emitted to the atmosphere by agricultural activities which are of greatest consequence to the environment are ammonia (NH_3), nitrous oxide (N_20) and methane (CH_4).

Ammonia is one of the gases responsible for acid deposition (acid rain). While not itself acidic, it is oxidised in most soils to nitric acid. The emission of ammonia is of great concern in International discussions when pollution topics are considered. In the atmosphere NH_3 reacts with sulphur dioxide to form stable aerosols, which being less reactive, can be transported greater distances than sulphur dioxide or ammonia separately, thus increasing transboundary acid deposition. Furthermore the deposition of N as ammonia to nutrient-poor habitats such as heathland encourages growth of the more vigorous species, reducing the biodiversity of the habitat.

Nitrous oxide absorbs the infra-red portion of electromagnetic radiation and has the potential to contribute to Global Warming. Nitrous oxide also catalyses the breakdown of ozone. Atmospheric CH_4 concentrations are increasing at a faster rate than carbon dioxide, and CH_4 is approximately 20 times more potent as a greenhouse gas than carbon dioxide. Since the atmospheric lifetime of CH_4 is relatively short (c. 10 years), compared with carbon dioxide (c. 120 years) policies to reduce CH_4 could help mitigate the rate of climate change faster than reduction in CO_2 emission.

5.2. Ammonia

The major source of ammonia emissions to the atmosphere is livestock excreta, approx. 84%, (Sutton et al 1995). Losses have also been demonstrated from cut herbage and from crop canopies. These are discussed below.

5.2.1. Livestock

The amounts emitted per animal are dependent upon

- The amount of nitrogen (N) excreted by the animals.
- How the excreta is handled. Ammonia losses from excreta voided in buildings are greater than from excreta voided to pastures. The types of housing, manure storage and method of manure spreading all have a further influence on the final magnitude of ammonia emission. (EMETIC 1994)

There are therefore two mechanisms by which a change to organic farming could effect ammonia emission.

- By a change in the quantity of N excreted by livestock

- Through differences in housing, manure handling and spreading manure to land.

In addition such changes may also have consequences for the applicability of techniques that have been developed to reduce ammonia emissions.

5.2.1.1 Nitrogen Content of Manures

No published studies have been located which compare the N content of excreta from organic and conventional livestock. For ruminants UKROFS standards stipulate that a minimum of 60% of the diet dry matter should be fresh or unmilled forage. The protein content of concentrates used in organic farming will often be similar to those in conventional systems, e.g. 18% crude protein for dairy cattle and 14% for beef cattle. However in many cases they will be less. For conventional farms 30% of the N intake by dairy cattle and 25% of the N intake by beef cattle is from concentrates. Thus the majority of the N intake by cattle (and sheep) comes from grass, either at grazing or in silage. This will be true also for organic ruminants. Thus the major factor determining the N excreted by ruminants will be the N concentration in the grass products they eat. This can mean that young stock fed largely forage based diets may be inefficient in digesting their intake and so receive a nitrogen surplus (Pfeiffer et al 1994).

There is less likelihood of organic stock receiving surplus N as there is less emphasis on least cost rationing when formulating concentrate feeds. This technique can result in unnecessarily high dietary intake of N. While mineral N fertilisers are not used on organic farms, grass production is maintained by N from animal manures and clover. Clover-rich swards can have N concentrations similar to that of intensive conventional grassland.

Work from the Institute of Grassland Research at Hurley, (now relocated as IGER), comparing grass forage given fertiliser N with unfertilised grass/clover swards and grass/ clover silage given 100 kg ha^{-1} N gave the following results.

	Fertiliser N kg ha^{-1}	% N in forage
Fresh grass	200	2.24
Silage grass	400	2.40
Fresh grass / Clover	0	3.20
Grass / Clover silage	100	2.80

Thus from well-managed grass / clover swards N intake by organic stock may be as great as for conventional animals on fertilised fields. The degree of similarity is likely to be greatest where organic stocking rate is similar to conventional.

Excretion of N by dairy cattle has been related to milk yield (Kirchgessner et al 1991). Thus if the productivity of organic animals is less, N excreted may also be less. In conventional farming dairy cattle are stocked at a rate of about 2.4 per ha, compared with 1.6-1.8 per ha in organic farming. A lower stocking rate will enable a reduction to be made in N inputs to grassland and hence could reduce N excretion per animal. However if stock numbers elsewhere increase to make up for reduced output per animal then total N excretion on the UK farm is likely to remain unchanged.

For pigs and poultry similar considerations apply. Their diets are composed of concentrates which will be of similar crude protein content whether organic or conventional.

Nielsen (1990) highlighted the possibilities for reducing ammonia emissions by restricting the nitrogen content of manures. This can be done to a certain extent in conventional systems for pigs and poultry by dietary manipulation including the inclusion synthetic amino-acids in the diet. The natural source of foodstuffs required under organic Standards mean that organic producers can only control the total content of the feed rather than increase the efficiency with which various components are utilised.

5.2.1.2 Emissions of ammonia during housing, grazing and after spreading manures

There are no published data comparing ammonia emissions from organic and conventional systems. The likelihood of any differences must be inferred from data published from a range of situations.

- Housing. Increasing quantities of straw bedding has been shown to reduce losses from animal houses to one half for poultry and one quarter for pigs (Hartung 1991, Valli 1994). However total losses from straw - based systems will not be necessarily be less than from slurry - based systems for two reasons.

- The greatest losses of ammonia in straw-based housing occur when the manure is moved to the store (Hartung 1991).

- Measures that have been demonstrated to reduce ammonia emissions during housing are based on modifying the scraping and flushing of slurry-based systems. Variations in the losses from different housing/management systems, all with slurry production, have been reported by Pfeiffer et al (1994). The losses from solid based systems have received relatively little research input. However 2 MAFF funded projects have recently started the Engineering Research Institute, Silsoe, and IGER North Wyke to address these problems. Increasing straw use to the extent investigated by Hartung (1991) could be impractical because of difficulties in obtaining sufficient straw. Should action be required to reduce ammonia emissions from farms as is happening in The Netherlands, there may be more scope in slurry-based systems than in solid-based ones.

As stated above, ammonia losses from excreta voided in buildings are greater than from excreta voided to pasture. UKROFS standards recommend that ruminant systems be planned to make the maximum use of grazing. It is however unlikely that dairy cattle and sheep will spend significantly more time at grass in organic than in conventional farming. There are however few organic beef animals reared and finished indoors. Should there be a significant decrease in the amount of time stock spend indoors, then there should be some reduction in ammonia emissions.

This may not be the case for pigs and poultry. While organic pigs and poultry would spend more time outdoors than conventionally-reared animals the tendency of those stock to reduce plant cover when outdoors will lessen the ability of the soil plant system to rapidly absorb NH_4-N. The potential for ammonia loss increases as plant cover decreases. Although organic pig and poultry units frequently maintain more plant cover than their conventional free range counterparts some bare ground invariably develops.

5.2.1.3. Storage

There is little published data on ammonia losses from stores. That which exists suggests losses are greater from FYM stores. Isermann (1991) reports losses of between 10 and 23% of the total N in FYM stored for between 2 and 6 months. The losses from slurry over the same period were 5-8% total N.

Losses from stored FYM have been demonstrated to depend upon not only the C/N ratio of the manure, but whether the manure is densely or loosely packed. Kirchmann and Witter (1989) found losses of between 9 and 44% of total N from aerobically stored manure but less than 1% loss from anaerobic storage. The larger losses are possible in organic farming since the aim is to compost manures and wastes. The emphasis on aeration of slurry stores in the organic standards might also mean greater losses in storage from organic slurry if this was in fact regularly practised.

There appears to be little scope to reduce storage losses from solid manures. Losses can be reduced by covering heaps, however on removing covers and handling the manure for spreading losses can be very large (B. Pain pers. comm.).

5.2.1.4. Following Spreading

Losses following spreading of solid manures are generally less than from spreading slurries. This may in part due to the ammoniacal N (NH_4-N) becoming immobilised by the straw and thus no longer being available for volatile loss. However there is also reason to conclude that the smaller losses from solid manures are a consequence of the NH_4-H content of such manures having been previously reduced by greater losses of ammonia during housing and storage.

However slurry offers greater potential for abatement of emissions by injection into grassland and injection or rapid incorporation into arable land.

Ammonia may be conserved with efficiencies of around 80% by shallow injection of slurries into the soil (UNECE in prep). In the UK around 20% of soils are considered to be too stony to allow even shallow injection (K. Smith pers. comm.) and some 50% are unsuitable over winter due to poor trafficability (K. Smith pers. comm.). This is in contrast to The Netherlands where grassland farmers on many soil types are obliged to inject their slurry and then only at certain times of the year.

In conventional farming systems opportunities to incorporate solid FYM, and slurry that cannot be injected, are limited because around 50% of FYM is produced on all-grass farms, and therefore incorporation is only possible into reseeds. Swards are re-seeded perhaps at intervals of 5 years, and normally in late summer, so the incorporation of large amounts of manure could lead to considerable losses of nitrate by leaching and nitrous oxide (N_2O) by denitrification. (See section 5.3).

Organic farms however are usually mixed, and with a greater proportion of spring crops than in conventional rotations. There is likely therefore to be more opportunity for incorporation and at times and rates that need not lead to large losses of NO_3 or N_2O.

5.2.1.5. Grazing

Ammonia losses from grazed swards have been shown to increase with increasing N application to the sward (Jarvis and Bussink 1990). This is partly due to increased stocking density, but the effect is still significant even when stocking density is constant. Swards on organic farms do not receive mineral N fertiliser and will only be given moderate amounts of N in manures. However where clover rich swards are used ammonia losses may be considerable. Jarvis et al (1989) found NH_3 losses per animal from a grass/ white clover sward grazed by beef bullocks to be about half as great as from animals grazing a sward given 210 kg ha^{-1}N. While ammonia losses per animal from a sheep grazing a grass/ clover sward were negligible, emissions from a white clover monoculture grazed by sheep were greater than from a grazed sheep pasture given 420 kg ha^{-1} N (Jarvis et al 1990).

Thus if production per animal is maintained at levels comparable to conventional farms, ammonia losses per animal are also likely to be similar. Less intensive systems will only give a reduction in total N emission if there is no increase in stock numbers to balance reduced productivity per animal.

5.2.1.5. Conclusions

• On organic farms where livestock output is similar to that on conventional farms N excretion and ammonia losses during grazing are unlikely to be different to those from conventional livestock. On less productive farms ammonia loss per animal is likely to be reduced. However this benefit will be lost if animal numbers are increased elsewhere to maintain overall output.

• There have been no studies to compare emissions from straw and slurry-based manure systems. The available data suggest that by increasing the extent of mixed farming and therefore opportunities for rapid incorporation of manures, organic farming will offer some opportunities to reduce emission following spreading of both manures and slurries. However this may be offset by greater losses during storage of solid manures and less potential for reducing emissions in animal houses.

5.2.2. Ammonia losses from crops.

Crop plants are known to release a certain quantity of ammonia to the atmosphere. The available literature was reviewed by Holtang-Hartwig and Bockman (1994). They concluded that for growing arable crops losses are highly variable between crops and seasons. Losses in temperate regions are only of the order of 1-2 kg/ha per year. This is much less than the values associated with manure management discussed above.

Whitehead and Lockyer (1989) demonstrated that grass herbage could give off 10% of the applied fertiliser nitrogen under certain conditions. As organic crops and grass usually have a lower nitrogen content such losses are likely to be less in an organic system. The higher nitrogen containing legumes that are more common on organic farms are likely to lose a similar quantity. Losses from decaying crops are greater.

The practice of cutting green manures and leaving them on the surface may result in a 14% loss of nitrogen (Janzen and McGinn 1991). This study was conducted under laboratory condition so the absolute value must be treated with considerable reserve. However with green manures a common feature on organic farms it implies that such crops should be ploughed under if possible losses are to be minimised.

This will not be possible when the crop is being grown as part of a long term fertility building ley. Especially if this is done on set-aside land where the rules of the scheme do not allow cultivation in the early months of the year. It must be remembered that conventional farmers are also required to top set-aside fields and this can also be expected to release an amount of ammonia nitrogen. Only organic farmers growing under a special derogation can sow swards containing a high proportion of legumes on set-aside land. Therefore the loss per unit area is likely to be greater on the organic unit than from the relatively low nitrogen plants growing on conventional set-aside.

There is insufficient information to decide where the balance lies in terms of overall losses between the two systems as described. It must be remembered that not all organic farmers would necessarily manage set-aside in this way. Nor for that matter would conventional ones.

5.3. Nitrous Oxide (N_2O)

5.3.1. Factors affecting N_2O emissions

The literature on nitrous oxide emissions from agriculture has been reviewed by Granli and Bockman (1994).

Nitrous oxide is produced in soil by bacteria, primarily during denitrification of nitrate which occurs when there is a relative shortage of oxygen. This will usually occur in soils when they are wet. Nitrate (NO_3^-) ions are used as a source of oxygen. The end product is principally N_2, but an amount of N_2O is also formed and the proportion is greater at lower temperatures. Around 70% of N_2O emissions (excluding natural sources) are considered to come from agriculture (Mosier 1994).

Losses occur when the soil is wet, which reduces diffusion of oxygen, and when the soil is warm, which increases bacterial activity, and when there is a source of nitrate. Nitrate may be supplied by mineralisation of soil organic matter, additions of fertilisers or animal manures. Even if N is supplied in forms other than nitrate, e.g. urea or ammonium sulphate, denitrification can occur once some of the fertiliser N has been oxidised to nitrate and if soil conditions change from dry (oxygen rich) to wet(oxygen poor). Thus weather conditions, via soil water content and temperature, greatly influence N_2O loss, and it is highly variable throughout the year. Estavillo et al (1994) demonstrated that in 1991 denitrification losses were greater after inorganic fertiliser had been applied than after cattle slurry. The following year the losses were similar.

Soil type is very important, losses being greater from soils of high clay content (e.g. De Klein and Van Logtestijn 1994). This effect is due to the poorer drainage and hence reduced aeration of clay soils compared with sandy soils. Eggington and Smith (1986) concluded the overriding factor in controlling the rate of denitrification is the occurrence of soil physical conditions that lead to anaerobic sites in the soil. Losses have also been found to be greater where crops had been direct-drilled (Colbourn and Dowdell 1984).

5.3.2. Consequences of organic farming

Because of the considerable influence of weather and soil type on denitrification, strategies to reduce N_2O emission are difficult to prescribe.

Nevertheless one of the aims of organic farming is to maintain soil productivity by improving soil structure, and hence increasing drainage and aeration. Since herbicides are not used by organic farmers direct drilling is unlikely to be practised and other minimal tillage techniques will be less common. These differences have the potential to give reduced emissions of N_2O from organic farming. Monitoring of the nitrate content of organically managed soils commonly shows lower concentrations than in conventional systems. This also implies that denitrification and hence nitrous oxide will be reduced.

Bouwman (1990) stated that emissions of N_20 are generally increased by increasing the amount of N added to soil. Measurements of N_20 loss following application of fertiliser and animal slurries show marked increases for up to 8 days after application (De Kleins & Lotgestijn 1994). However N_20 losses can be reduced by not applying large single applications of nitrate fertiliser, and in this respect organic farming could reduce N_20 emissions. It might be argued that using legumes such as clover to fix N, would lead to elevated losses of N_20. However additions to the soil plant system by symbiotic fixation, while potentially large over the season, only adds N in small increments. Colbourn (1993) found losses from a grass/clover sward to be less than from a fertilised grass sward.

The application of manures in spring when nitrate is likely to be taken up by the crop is also more likely on organic than conventional farms. However care needs to be taken that solid manures are not incorporated into wet soils as this is likely to lead to anaerobic conditions.

In addition there is concern that denitrification losses from stored FYM have been underestimated (Pain 1994), and that this may even be the dominant N loss mechanism in stored manures.

5.4. Methane

5.4.1. Generation.

The main agricultural source of methane is from microbial activity in the rumen of cattle and sheep which produce an estimated 1.14 Mt methane per annum in the UK, around 21% of total UK methane emissions.

Very few data exist on losses from farm wastes. Provisional estimates suggest that up to 0.3 Mt per year of methane is produced from slurry and animal manure, including that deposited whilst grazing.

Methane is produced under anaerobic conditions and production will increase with temperature and increasing storage time. OECD estimates that 20% of the total methane emission potential is released when wastes are stored as liquid for > 1 month and 10% of the emission potential is released when stored as solids. On this basis, methane emissions from excreta stored from any particular species for 4-6 months will be approximately 2 x higher from slurry than from solid manure.

Provisional estimates of likely emissions from dairy and pig excreta are given below.

Estimated annual methane emissions from stored excreta

	Stored as slurry	Stored as solid manure
Dairy cow (6 month housing period)	42.8 kg/cow	21.4 kg/cow
Finishing pig place	9.46 kg/pig place	4.73 kg/pig place

Methane is also produced under anaerobic soil conditions. Spreading regimes that increase the likelihood of organic manures being present in soils under such conditions will increase methane output. A principle of organic farming is to avoid large applications of nutrients that exceed the capacity of the soil and crop to absorb them. Thus the application of large amounts of manure which may lead to anaerobic conditions is less likely than on conventional farms. Soils may also act as a sink for methane (Jarvis and Pain 1992). See below.

Methane production per unit of food consumed decreases with increasing feed intake. Therefore more productive animals emit less methane per unit of output. Any effect of organic farming on methane emission from ruminants will depend upon the degree to which production per animal is maintained at levels equivalent to that produced by conventional farming.

In respect of losses from manures, solid based systems appear to release only half as much methane as slurries.

5.4.2. Oxidation in Soils

On going work at IACR, Rothamsted is investigating the capacity of soils to adsorb and oxidise methane and thus remove it from the atmosphere where it can have it's harmful impact. A preview of results has been published (Willison 1995). In continuous arable soils the capacity of the soil to oxidise methane has been shown to have been significantly reduced by the application of inorganic nitrogen fertilisers compared to both the control and plots receiving only organic manure in the form of FYM. It is not known if the effect is due to the increased organic matter content of the soil giving improved soil structure or if the microbial population of the soil has changed significantly.

Data for a long term grassland site has given unexpected results. Here plots receiving fertilisers containing ammonium have exhibited reduced capacity to oxidise methane but plots receiving only nitrate based fertilisers have shown no difference from the control.

No information on methane oxidation specifically by organic systems is has been found in the course of this review. The results from other work to date do however suggest that the management practices employed by organic farmers are likely to enhance the capacity of the soil to oxidise methane. Whether the effect will be greater than in a conventional mixed rotation using nitrate based fertilisers is not yet known but it seems quite possible.

5.4.3. Conclusions.

Direct methane emissions by organic ruminants may be greater than by conventional stock because of the tendency towards slower growth rates which result in more food being eaten per unit of production. This is likely to be more than balanced by a greater emphasis on grazing practices which reduces the quantity of manure produced and the fact that methane generation in solid manures is much less than in slurries. Soils managed organically for arable cropping are expected to maintain a greater methane oxidation potential than conventional areas. This advantage may extend to the whole rotation.

5.5. Summary of atmospheric effects.

• The principle of crop nutrition in organic farming is to "feed the soil rather than the plant'. This is implemented by adding N via moderate applications of organic fertilisers and manures and through N fixation by legumes. This approach has potential for reducing emissions of N_20, which are substantially increased following large applications of mineral N fertilisers and animal slurries. This organic approach also stimulates methane oxidation in soils and thus reduces atmospheric concentrations..

• Ammonia emissions are related to total annual N excretion by animals and this will not necessarily be less in organic than in conventional farming. Current published data suggests losses from straw-based animal housing systems may be greater than from slurry-based ones, with less potential for abatement of emissions. However work is needed to quantify differences between systems and such studies have recently been commissioned by MAFF from IGER. In particular the size of losses from solid manures by denitrification and ammonia volatilisation have to be determined.

• Methane released directly by organic stock may be greater than from conventional animals but this will be more than compensated by reduced emissions from solid manure handling systems. There is thus conflict between ammonia and methane in terms of the preferred system to minimise gaseous emissions.

5.6. Odours.

5.6.1. Source of farm odours.

The release of ammonia and methane from livestock systems is usually accompanied by other gaseous compounds formed from the microbial breakdown of the more readily degraded components of manures and slurries. When the breakdown takes place under uncontrolled anaerobic conditions the compounds produced can give rise to offensive odours. This would be typical in most slurry storage tanks and lagoons. These are often perceived as unacceptable even in a rural environment. Complaints about farm odours are recorded and reported by the Institution of Environmental Health Officers (e.g. 1994). Data for the years 1987-1990 were summarised in the MAFF Air Code (MAFF 1992) and are tabulated below to indicate the typical breakdown of the data. More recent reports have not provided an analysis of the information but in 1992/93 a total of 4916 complaints were received about agricultural practices. Eight prosecutions were taken and four convictions obtained.

	% of Justifiable Complaints
Class of Livestock	
PIGS	47
POULTRY	25
CATTLE	22
HORSES	7
Source of Odour	
SLURRY OR MANURE SPREADING	44
FARM BUILDINGS	25
SLURRY OR MANURE STORES	21
SWILL BOILING	7
SILAGE CLAMPS	4

The majority of complaints arise from intensive pig and poultry units; from the buildings in which the stock are kept, the manure and slurry stores and especially when slurry is being spread. The Air Code (MAFF 1992) provides advice to farmers on ways of minimising the problems. Although technical solutions exist for many situations these are not cost effective in relation to the profitability of the livestock system. The management techniques to reduce ammonia emissions that have been discussed above will, in general, also apply to odour control.

5.6.2. Control of odours.

Aerobic treatment of slurry as promoted under organic standards can be effective in controlling odours at the time of spreading. Care is needed that if intermittent aeration is practised in the slurry store that entrapped gases from anaerobic decomposition are not released from the system and cause problems. The cost of slurry aeration to control an odour problem may be acceptable to a farmer if it means that he can stay in business but the costs can not be justified on agronomic grounds in terms of improved fertiliser value (Berner 1990).

No critical comparisons of odour emissions appear to have been made between solid manure and slurry systems. The statistics given above do indicate that the problems are more associated with slurry. It is well established that high rates of slurry left on the surface are liable to prolong any odour emissions. Smith et al (1994) calculated that around 50% of all cattle manures in the UK are produced as slurry and 50% as FYM. This will be an important factor in limiting the number of reported problems with cattle manures. Smith (unpublished) has estimated that the total manure produced by cattle is at least 4 times that from pigs and poultry. Despite this 72% of complaints relate to these minority classes of stock.

5.6.3. Odours on organic farms.

Organic farmers are unlikely to cause odour problems to the same extent as conventional units.

- The keeping of pigs and poultry in large intensive, indoor units on slurry based systems is not permitted under the Standards.

- Where pigs are kept the solid bedding systems which are used will minimise the risk of odour problems. Odour will be released when solid manure is removed from a livestock building.

- The subsequent composting which is often undertaken on organic farms helps to ensure that when it is finally spread odour problems are minimised. Care may be needed in the early stages of composting to ensure that the odours that can be generated at this time do not cause a problem.

- Organic farmers tend to spread less slurry at any one time as they are trying to maximise its fertiliser value and will often incorporate it into the soil fairly rapidly.

These practices are more common on organic farms although they are not of course the sole prerogative of organic farmers.

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6. EFFECTS OF ORGANIC FARMING UPON ASPECTS OF THE LANDSCAPE OF THE UNITED KINGDOM.

6.1. Introduction

Unlike other sections of this report effects upon the landscape must by definition be a more inward looking, national review. The landscape of the United Kingdom is in many ways unique. Landscape integrates soil and climatic factors with the specific social and economic history not only of agriculture but of the country as a whole. Therefore studies in other countries are less relevant than for other aspects of this review. The only factor common to other situations might be the perception and aspirations of organic farmers themselves. Even these will be substantially influenced by national factors such as historical stability in land ownership and farm structural problems due to inheritance laws.

There is a lack of specific information relating to the effect of organic farming on landscape in the UK. A study by Entec (1995) for the Countryside Commission failed to locate any significant previous work other than desk studies. This section of the current review draws heavily on the Entec study as agreed with MAFF. After discussing some of the general principles involved the results of the field study that was undertaken are presented. These have been considered in the light of the limitations that are largely acknowledged in the report itself.

6.2 General aspects of landscape comparisons.

Landscape appreciation is a classic example of the saying that " beauty is in the eye of the beholder". Any assessment will be at least partly subjective and individual preference is difficult to avoid. For the Entec study landscape assessment was undertaken at two levels:-

- . Visual assessment in a landscape context.

  This was a wider scale appraisal including subjective elements in respect to the "feel" of the landscape e.g. colour and variation, and objective criteria such as number and type of hedges and trees. The appearance of the unit in the context of its overall surroundings were assessed by this method.

  Four criteria were recorded:- hedgerow type and occurrence, field size, trees and woodlands and crop type and number.

- Visual assessment in a farm context.

  This entailed more detailed recording of the attributes considered above and in addition :- weed cover, headland diversity, species in hedgerows, length of fencing and walls and anything else of significance.

Landscapes change throughout the year. Whilst some aspects may remain relatively constant, others may change significantly. The report mentions the variable impact that weeds would have according to the time of assessment. The overall impact of cropping on ground cover will be very different in winter than in mid-summer. Another example is oilseed rape. The colour of which is considered by some people to be detrimental when in flower but less obtrusive at other times. The Entec study only visited the selected farms once in the summer and the results have to be considered in this context.

6.3. Beneficial, Neutral and Detrimental features.

Deciding into which of these three categories a particular attribute falls, is itself a subjective decision. In this study the following groupings were made:-

6.3.1. Beneficial.

Diversity of hedgerow types, presence of certain hedgerow types, young and recent hedgerow trees, small fields, crop variety, recent woodland, weeds and traditional farm buildings. Of these weeds may be considered the most contentious issue. Whilst the presence of weeds in arable crops may well provide diversity to the landscape particularly when they add colour or texture farmers, including organic ones, would consider a weedy field to be an affront to good farming. This was recognised by the authors in that excessive weediness appears as a detrimental attribute.

It is one of the assumed benefits of organic systems that they encourage floristic diversity and help to encourage plants that have become less common in conventional systems since the introduction of herbicides. In practice where this happens it is despite the efforts of the organic farmers who take all precautions to keep weeds under control. To help them to do so they have better equipment in the form of mechanical weeders than did their predecessors although they can no longer afford the hand labour on which so much weed control depended in earlier times.

6.3.2. Detrimental features.

These include large fields (because they imply fewer hedges and trees), a large proportion of neatly trimmed hedges, fences, excessive weediness, and dilapidated farm buildings. In this latter category a significant number of organic units can score badly in that old caravans, corroding cars and machinery and polythene tunnels are generally seen as a blot on the landscape. Although these are found on all types of farms many organic units suffer particularly from a lack of capital resources and farmers who wish to support the concept of recycling.

6.3.3. Neutral features.

In this study farm buildings not falling into the classes described above were considered to be neutral. Again there could be considerable debate as to the true effect of modern structures. Entec argued that in most cases they are not particularly noticeable in the landscape. Crop texture which is often only noticeable from close range was also considered to be a neutral feature.

6.4. Selection of study sample.

There are a number of reasons why organic and conventional farms may have different impacts. The authors of this study recognised:-

6.4.1. Intrinsic landscape form due to region or area.

For this reason the study farms were grouped in similar areas. However this still gave problems and one of the comparisons quoted to illustrate the results at a farm level states that "the farm was located at a higher altitude......(and) had a stronger ,more upland and bleak feel. Tree cover was reduced and a sense of openness prevailed". This hardly seems a good basis for a comparison which in this case was between a long and a short term organic unit.

6.4.2. Differences in farmer attitudes and abilities.

Ability is difficult to remove from the equation whilst attitude is inherent in a farmers decision to farm organically.

6.4.3. Farm system.

Organic farms would typically have a greater range of enterprises which will immediately convey advantages. In this study an attempt was made to remove this factor by selecting similar farming types. Whilst acknowledging the problems of achieving this the report claimed that it had largely been achieved. However in the report a comment is made that " a quarter of (conventional)farms surveyed had no grass in the rotation". The organic comparisons were all either grass or grass/arable units.

6.4.4. Farm size.

The impact of farm size can be both direct and indirect. In recognising the direct effects the study only considered farms of more than 5 ha. In so doing they ruled out many of the organic horticultural units which exist in this country. Size has an indirect effect in that it affects profitability which in turn influences the money available to pursue approaches which can benefit the landscape.

6.4.5. Farm structure.

A significant proportion of organic holdings consist of a number of constituent sub-units. When these are part of a larger farm, the remainder of which is farmed conventionally, the benefits any benefits of organic management are likely to be masked. The study concentrated on completely converted farms and where these were fragmented only the area around the farmstead was considered.

6.5. Livestock systems in the lowlands.

The impact of livestock systems has received little attention in the Entec project. Perhaps surprisingly the presence of grazing livestock was not specifically considered as a beneficial feature over and above the presence of grass fields. It was not included as either beneficial or detrimental. As pigs and poultry that are kept outdoors require considerable quantities of fencing of a more or less temporary nature it is possible to argue that they might be considered to have a neutral or even a detrimental impact.

The presence of cattle and sheep was recorded on many farms in the study both organic and conventional. Pigs and poultry were encountered on 8 holdings. There is no reason to suppose that organic cattle or sheep will have a different impact than conventional ones unless there are detrimental effects due to high stocking rates. These might show as overgrazing effects on vegetation, treading damage to the soil or increased erosion. For these classes of stock the benefit would come if mixed farms can be re-established in predominantly arable areas of the country when they will complement the benefits of grass in the landscape.

Greater differences can be expected between systems if there is an expansion of organic pig and poultry production. Organic standards require both of these classes of stock to be kept out of doors to a greater extent than is practised on conventional farms. This allows for the fact that there has been a rapid expansion in conventional outdoor pig production. One quarter of the breeding herd is now kept outdoors but fattening is still predominantly an inside operation despite the current interest from the multiple retail trade in welfare friendly systems of production.

Organic pigs are likely to have a smaller detrimental impact on the landscape than conventional stock. The latter are often kept on the same field for upto 2-3 years. The result of this is that for most of the time bare soil is the predominant expression of the system. Organic stock are rotated much more frequently both to control parasitic diseases and to cash in the advantages of the fertility building conferred by the pigs.

A change to organic pig and poultry systems will lead to an increase in outdoor stock. It is open to interpretation if this will convey landscape benefits or disbenefits.

6.6. Situation if novel crops were grown on organic farms.

The impact of colour in the landscape has been mentioned above. Certain crops which have been expanding or are under investigation in recent years have the potential to add new colours to the landscape at certain times of the year, usually when they flower. There are differences between conventional and organic farms which imply that the impact of such crops will differ between the two systems. This was not included in the Entec report. The possible effect of climate change has not been included here as it has been assumed approximately neutral to the two systems.

6.6.1. Oilseed rape.

Reference was made above that growing of oilseed rape is regarded in some quarters as detrimental by virtue of the colour introduced to the landscape at flowering. This crop has not been grown commercially on organic farms in the UK because of a lack of a market for organic rape and agronomic problems relating to nutrient supply. The introduction of rape for industrial uses onto set-aside land is developing on

conventional farms. Given the opportunity for organic farmers to use set-aside to build fertility this seems an unlikely development on organic farms.
There are moves to grow spring rape under an organic regime in Finland (Hokkanen and Purainen 1995). Trials have confirmed relatively low yields unless supplementary organic manures are applied.

6.6.2. Sunflowers.

There is a market for organic sunflower oil and at the present time it seems more likely that this will be the crop that is developed further to meet demand for organic vegetable oil. There has been generally less adverse reaction to the sunflower crop in the UK. It remains to be seen if there is a major expansion of the crop on organic or conventional farms. In the short term this will depend on the development of suitable cultivars for UK conditions and a market for the crop.

6.6.3. Linseed.

Linseed has been grown on set-aside on organic farms as it is a crop which has a low fertility requirement. It is unlikely that it is a practice which will develop because of the fertility building reasons given above. The pale blue colour of the crop in flower does not appear to draw the same criticism as the yellow of rape.

6.6.4. Lupins.

A crop that is receiving considerable attention as having potential for development are lupins. These will be interesting for organic farmers as they fix nitrogen and so should have the potential to build fertility. As a grain legume they also have potential as an alternative feed for organic livestock. It is possible that the advantages may prove to be greater for organic growers but it is too early to judge. The cultivars currently under investigation are predominantly white and so would add another colour to the countryside in spring if developed to a significant extent.

6.6.5. Summary.

It seems unlikely that oilseed rape will be grown on organic farms. This would generally be regarded as beneficial to the landscape. Sunflowers and linseed are also unlikely to be grown in the foreseeable future whilst white lupins may appear to a limited extent on both organic and conventional farms.

6.7. Objectives and structure of the Entec study.

6.7.1. Objectives.

The objectives were stated to be:-

6.7.1.1. To determine whether organic farming systems affect the landscape in upland and lowland regions of England and Wales.

6.7.1.2. To determine if the length of time a farmer has been farming organically affects the extent of any impacts.

6.7.1.3. To determine if the type of farming i.e. horticulture or mixed enterprises affects the landscape differently in lowland areas.

6.7.2. Structure

The study comprised 48 farms divided into 16 groups of three. Each group comprised a conventional, a short (2-5 years) and a long (over 10 years) term organic farm. Of these groups 8 were in upland regions defined as being in a Less Favoured Area. As MAFF have found in respect of the Organic Aid Scheme this means that the farms that qualified in Wales are of a more varied nature than those in England. Of the 8 groups in the lowlands 4 were targeted at horticultural units and 4 at mixed farms.

6.8. Conclusions

Under each numbered heading the Entec conclusions are given first. The subsequent sub-paragraph offers additional comments from the authors of this report.

6.8.1. The relatively small sample size and wide variation meant that the results were not statistically significant,. All conclusions therefore must be interpreted with care. The conventional farms were considered typical of their surroundings.

None of the groups of mixed farms were in the most intensive arable areas. This is a fair reflection of the current structure of the organic sector. It does however mean that if farmers in these areas can be encouraged to convert, the potential future advantages may be greater than is implied from the overall results of the study.

6.8.2. Differences between organic and conventional systems can be inherent to the choice of system or a reflection of the farmer exercising his choice. Evidence was inconsistent but the most significant differences came from farmer choice. Organic farmers tending to chose practices which benefited the landscape.

This underestimates the requirements of the organic standards which require farmers to manage their land in a way that is sympathetic to the environment in general and to the landscape. To the extent that all farmers could exercise the same decisions the comment is of course valid. To this extent the promotion of other less intensive systems such as the Integrated Crop Management initiatives, may generate similar reactions amongst their proponents. (LEAF undated).

6.8.3. Overall the length of time that a farmer has farmed organically did not affect the degree of landscape impact.

At first sight this is perhaps a surprising finding and tends to imply that the differences due to organic systems per se may not be great. There is the *possibility that an organic farm can deliver significant benefits in a short period of time. This would be true of crop diversity and possibly, but less likely, of hedge establishment or tree planting. Alternatively it could mean that when farms are specifically purchased for an organic unit they are chosen for there existing appearance. Whilst for farms in long term ownership it is likely that the farmer would have had a sympathetic management style before organic conversion was attempted.*

6.8.4. Lowland horticultural units of both types were generally too small to have a significant effect upon the landscape.

This is another unsurprising finding. Given that many organic horticultural units are even smaller than the cut-off used in this work it implies that the current situation is of little relevance. It does not however reflect what may happen if there were to be a major expansion in organic production. There is at the present time considerable interest in the food trade to further develop organic processed foods. If this is to be successfully resourced from this country or if there is a general increase in demand for organic vegetables, then much more field scale production will be required. That is to say there will be a move away from the market garden scenario in organic growing that the conventional sector has already been through over the last 20-30 years. This implies that there could be greater impact on the landscape in future and possibly more differences between systems.
Organic horticulture will require fertility building crops which will provide variation, field sizes will be smaller than conventional systems to aid rotations, whilst a greater range of crops is also likely to be grown to aid pest and disease control

6.8.5. Mixed organic farms contribute more beneficial features than conventional units. Field size, abundance of trees, hedgerow management and weeds were beneficial at both the farm and the overall landscape levels. Although many reflect the farmers attitudes rather than inherent aspects of the organic system.

This latter statement might be considered to understate the impact of organic farms because of the design of this study. In the absence of comparative groups in the most intensive arable areas, the impact on the landscape of converting land in these areas was effectively omitted from consideration. If nothing else conversion in these situations will introduce a variation of cropping. It may also reduce field size and hence encourage grass strips between crop areas, even if widespread hedge and tree planting is not undertaken.
The study did not consider the impact of outdoor stock in any detail but the matter has been discussed above.

6.8.6. Although in the uplands organic farms contributed beneficial aspects their conventional counterparts were as likely to follow less intensive practices so that the differences were small.

This finding should come as no surprise to those familiar with farming in these areas and it is perhaps surprising that such a large part of the resources for this study were put into upland areas. This is especially so when the number of other schemes and organisations promoting care of the landscape in the uplands is considered, e.g. ESA's.

6.8.7. Overall organic farmers provide net benefits to the landscape largely because of their general awareness of the environment. Organic farming per se can have small positive effects which are most discernible on mixed lowland farms.

For the reasons given above this conclusion reflects the situation on the farms that were studied. It understates the differences between the average organic farm and the average lowland conventional farm with its predominantly arable regime. It also understate the advantages if further organic conversion is achieved in these intensive conventional areas. It is open to all farmers to introduce the changes described here as beneficial. In fact organic farmers are either required or at the least will receive greater encouragement to introduce certain of them. This all implies that the degree of benefit will continue or increase in lowland situations with an increase of organic farming. There is less reason to believe that the relative situation will change in the uplands.

6.9. References.

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