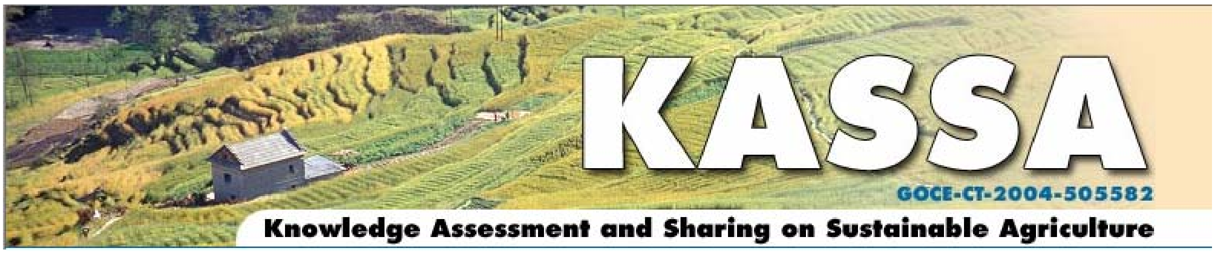

Deliverable 1.1 – Appendix A8

Alternative agricultural systems in the United Kingdom

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The KASSA Consortium assembled 28 contractors from 18 countries.
KASSA has been implemented through four regional "platforms": Europe, the Mediterranean, Asia and Latin America.
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Partners of the European platform:

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CONTENT

Note

While a wide range of research papers have been consulted for the preparation of this report, extensive sections of this paper have been based on the comprehensive publication: *A Review of Research into the Environmental and Socio-Economic Impacts of Contemporary and Alternative Arable Cropping Systems* by R A Wadsworth, P D Carey, M S Heard, M O Hill, S A Hinsley, W R Meek (CEH Monks Wood) D J Pannell, V Ponder, A W Renwick (CRER, Cambridge), K L James (Northmoor Trust, Abingdon) of the Centre for Ecology and Hydrology (CEH) at the Natural Environment Research Council (February 2003).

Recommendations

The main recommendation of this report is that there should be a holistic approach to the comparison of the alternative farming systems and a major programme to compare the systems is required. Such studies should be conducted at multi- and interdisciplinary levels and should not only concentrate on farm-scale effects but go beyond to consider landscape scale effects, also.

Before such studies are commissioned, a scoping study should be put in place to determine the criteria to be evaluated (e.g. economic parameter, number and abundance of species, inputs and their effects, rural employment, social indicators, sustainability indicators etc.) and be set to ask rigorous questions that can be answered.

There is a need for the results of such research to be disseminated quickly to national and local government, the general public and - above all - the farming community. External farming and environment organisations etc. could be very useful in this role. Agricultural education establishments, in the UK, around Europe – and indeed the whole world - need to be aware of all new developments.

The United Kingdom

Land & Climate

The United Kingdom (UK) is divided politically into four devolved regions/countries: England, Scotland, Wales and Northern Ireland. The total land area of the United Kingdom is 241,590 sq km with mostly rugged hills and low mountains in its western and central part and level to rolling plains in the east and southeast. The population 60,270,708 (July 2004 est.) is concentrated in the urban areas in particular the South East of England. The climate of the United Kingdom is mild relative to its latitude. The mildness is an effect of maritime influences, especially of the warm Gulf Stream. This current brings the prevailing south-westerly winds that moderate winter temperatures and bring the depressions which are the main day-to-day influence on the weather. The western side of the United Kingdom tends to be warmer than the eastern; the south is warmer than the north. The mean annual temperature is 6° C (43° F) in the far north of Scotland; 11° C (52° F) in the south-west of England. Winter temperatures rarely drop below -10° C (14° F), and summer temperatures rarely exceed 32° C (90° F). More than half of the days are overcast

The sea winds also bring plenty of moisture; average annual precipitation is more than 1,000 mm (40 in). Rain tends to fall throughout the year, frequently turning to snow in the winter, especially in Scotland, the mountains of Wales, and northern England. The western side of Britain is much wetter than the eastern: average rainfall varies from more than 5,000 mm (196 in) in the western Highlands of Scotland, to less than 500 mm (20 in) in parts of East Anglia in England.

Relative to its size, the scenery of the British Isles is very diverse and can change dramatically within short distances. This diversity reflects in part the underlying rocks, which is due to a highly diverse geology ranging from crystalline rocks of Pre-cambrian and later age and Lower Carboniferous to Cambrian in the north and west (Scotland and north England). This largely produces acid soils which through the influence of climate tend to be mostly podzolic. In southern and eastern England the soils derive from the Triassic and Permian, Jurassic, Cretaceous and Tertiary epochs and Quarternary drifts with pH mostly above 6. This gives the Britain a wide variety of soils the benefits of which are however limited by the predominant climatic conditions. All of the United Kingdom with the exception of the area of England roughly south of a line drawn between the Thames and Severn estuaries was covered in ice during the Pleistocene ice age, and glaciation shaped its most spectacular scenery, including the English Lake District, the loughs of Northern Ireland, the Welsh valleys, and most of Scotland, including her lochs. Human activity has also played a key part in creating the landscape, including the southern downlands of England, the Norfolk Broads, the Fens, and the moorlands of northern Scotland.

See: Soil Information and its Application in the United Kingdom: An Update http://eusoils.jrc.it/ESDB_Archive/eusoils_docs/esb_rr/n06_soilresources_of_europe/PDF/UK04.pdf by Michael G. Jarvis; Soil Survey and Land Research Centre, Cranfield University, Silsoe.

Land Cover

The proportions and geographical distribution and of land cover and farm types show a marked spatial pattern of distribution (see Figure 1) that are determined by a range of climatic and geo-morphological factors. However, a general summary would be a change from the areas of pasture in the west to an increased emphasis on arable crops towards the east. This is a combined reflection on the geo-morphology, soil properties and climate. There is some distinct regional pattern to production of certain crops e.g. maize and soft fruit, while in some cases the necessary infrastructure, such as processing factories, means that sugar beet is also restricted to the central south-east of England.

As the UK (Köppen Type Cfb.) climate is greatly modified in the West by the Gulf Stream, annual precipitation is ostensibly different between the wet west and the much drier east of the country. There are local constraints on agronomic practices for example; shorter growing seasons in the North can restrict the planting of winter crops. In Aberdeenshire in the east of Scotland, the proportion of spring-sown crops increases inland and with increasing altitude. The increasing climatic constraints moving northwards can reduce the potential benefits offered by certain management options recommended for reducing environmental impacts, such as establishing cover crops.

Table 1 shows the basic types of land cover in the UK.

Table 1: Land Cover in England

Built up	12.3%
Arable land	30.7%
Managed Grassland	31.4%
Semi natural	12.5%
Woodland	10.6%
Other	2.4%

Source: Countryside Agency: State of the Countryside 1999
http://statistics.DEFRA.gov.uk/esg/publications/auk/2004/chapter7.pdf

Description Of UK Agricultural Context

71.1% of the land area of the UK is used for agricultural purposes, arable land is 23.46% of whole. A significant proportion of the land area is rough hill or low mountain. Approximately 1.8% of the workforce is employed in the agriculture sector (includes spouses of farmers, partners and directors), down from 2.8% in 1984, the % of national gross value added (current prices) provisional fig for 2004 is 0.8%, down from 2.9% in 1973. These statistics show the result of a long term decline in farming’s importance within the national economy.

The UK average farm size is 68.9 hectares which is the largest within the EU, however census results exclude non-intensive holdings below 6 hectares. This figure should also be understood in a context of considerable regional variation, for example the average farm size for Northern Ireland being 36 hectares. There appears to be a movement toward both the extremes of the farm size range, with growth in the number of small part time holdings and continuous size increases in large scale enterprises.

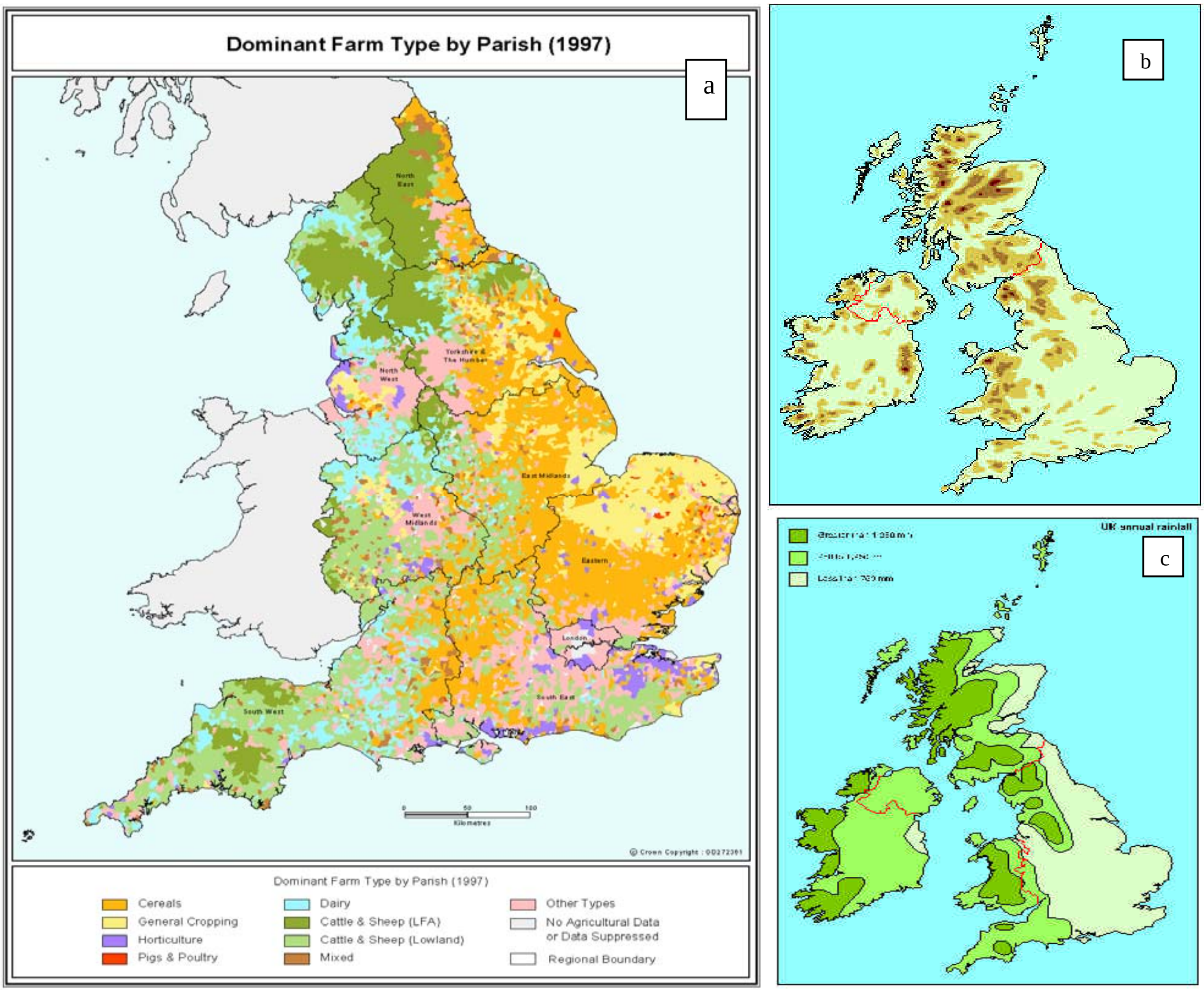
In the organic sector (2004 Figs) the UK average farm size is 174 hectares. This breaks down as: England 100 hectares, Wales 94, Scotland 537 hectares and Northern Ireland 40 hectares. These figures should be interpreted bearing in mind the dominance of extensive livestock grazing on rough hill land within the UK organic sector.

The UK agricultural industry is now administered and legislated for by the Department of Environment, Food and Rural Affairs (England and Wales http://www.DEFRA.gov.uk/), Department of Agriculture and Rural Development (Northern Ireland http://www.dardni.gov.uk/) and Scottish Executive Environment and Rural Affairs Department (Scotland http://www.scotland.gov.uk/topics/agriculture).

Specific information relating to organic production within the UK can be found at:

England & Wales	http://www.DEFRA.gov.uk/farm/organic/default.htm
Northern Ireland	http://www.ruralni.gov.uk/bussys/organic/
Scotland	http://www1.sac.ac.uk/cropsci/external/orgserv/

Figure 1: **Distribution Of a) Farm Types (Data From), b) Relief And c) Annual Precipitation** (>1250mm – dark green, 750-1250mm light green, <750mm – white) http://www.DEFRA.gov.uk/esg/work_htm/publications/cs/farmstats_web/datamap_links/search_menu.asp#maps



Agricultural Land Classification within the UK

England and Wales

Within the countries of England and Wales the "ALC" system of classification is used by DEFRA (the government Department for Environment Food and Rural Affairs) see http://www.defra.gov.uk/environ/landuse/alcleaflet.pdf. The ALC gives a high grading to land which allows more flexibility in the range of crops that can be grown (its 'versatility') and which requires lower inputs, but also takes into account ability to produce. The ALC system classifies land into five grades, with Grade 3 subdivided into Subgrades 3a and 3b.

- Grade 1 (excellent)
- Grade 2 (very good)
- Grade 3: 3a (good)
- 3b (moderate)
- Grade 4 (poor)
- Grade 5 (very poor)

The 'best and most versatile land' is defined as Grades 1, 2 and 3a by policy guidance. This is the land which is most flexible, productive and efficient in response to inputs and which can best deliver future crops for food and non food uses such as biomass, fibres and pharmaceuticals. Current estimates are that Grades 1 and 2 together form about 21% of all farmland in England; Subgrade 3a contains a similar amount.

Details of the system of grading can be found in: 'Agricultural Land Classification of England and Wales: revised guidelines and criteria for grading the quality of agricultural land'. (DEFRA Publications, 1988). Maps can be purchased from DEFRA at http://www.defra.gov.uk/corporate/publications/pubcat/map.htm

Scotland

The system of land classification which has operated in Scotland for some 40 years (A+, A, B+ etc.) is superseded by a system of Land Classification for Agriculture (LCA) based on the work of the Department of Soil Survey of the Macaulay Institute for Soil Research, and now merged with the HFRO and titled the Macaulay Land Use Research Institute.
The land classes in the new LCA and a brief description of each are shown in Table 2, below.

Classes 1, 2 and 3.1 of the new system equate broadly to classes A+, A and B+ of the former system and may likewise be described as "prime quality land".

Maps covering land capability climate and soil typology for Scotland are available for purchase from Macaulay Research Consultancy Services at http://www.mluri.sari.ac.uk/MRCS/gis/gis2_map.html

Northern Ireland

Northern Ireland also has its own classification system which is similar to the above.

Table 2: Scottish Land Classes In The New LCA And Their Description

Class	Description
1.	Land capable of producing a very wide range of crops.
2.	Land capable of producing a wide range of crops.
3.1	Land capable of producing consistently high yields of a narrow range of crops and/or moderate yields of a wider range.
3.2	Land capable of producing a moderate range of crops. Average arable land.
4.1	Land capable of producing a narrow range of crops. Below average arable land.
4.2	Land capable of producing a narrow range of crops. Marginal arable land.
5.1	Land capable of use as improved grassland. Land is well suited to improvement.
5.2	Land capable of use as improved grassland. Land is moderately suited to improvement.
5.3	Land capable of use as improved grassland. Land is marginally suited to improvement.
6.1	Land capable of use only as rough grazings. Land has high grazing value.
6.2	Land capable of use only as rough grazings. Land has moderate grazing value.
6.3	Land. capable of use only as rough grazings. Land has low grazing value.
7.	Land of a very limited agricultural value.

Concepts & Practices

General Overview Of The UK Research Projects In The KASSA Inventory

The projects included in the UK inventory, are very diverse in range, nature and also their broader intentions, varying from tightly focussed laboratory or field experiments dealing with specific issues, to large projects examining whole systems of production over many years with multiple criteria of assessment. In addition, there are projects that approach the subject of sustainable land use and agriculture from the point of view of research disciplines other than agricultural science, such as ecology, law, economics, and other social sciences.

There are immediately perceivable subject areas in which research projects seem to be most numerous:

- Strategies for the control of pathogens, pest species and weeds with minimum inputs.
- The maintenance of soil fertility without artificial inputs.
- The reestablishment of genetic robustness/appropriateness in crop and livestock varieties and breeds.

Reduced and Zero Tillage does not seem to be an area of extensive interest to UK researchers certainly insofar as its application within the UK is concerned. This is not surprising given the general view of the farming community resulting from the heavy arable soils of the country and the often wet growing season with rapid weed growth. Minimum tillage with its cost advantage has some interest where soils are sufficiently dry and stable in structure (see http://www1.sac.ac.uk/info/External/About/publicns/TN/Tn553.pdf). In the context of the UK's traditional agriculture; poor soils of hill, heath and moor land have been used as permanent grazing in extensive systems, several projects seek to improve the efficiency and sustainability of this usage, either through improved management or choice of livestock better adapted to local conditions. This area of production is also very important in terms of conservation.

Another traditional system of grassland management once common in Britain was the water-meadow, a system of permanent grass on alluvial soil subject to annual controlled flooding, using a system of sluices, very few remain and of those that do many have a neglected infrastructure. Related naturally flooding wet-meadows and non-flooding dry hay-meadows have also been greatly reduced in number since world war two. These pastures usually cut for hay later than grass lays are of great importance to bio-diversity and conservation, being the habitat of many threatened species, in particular flowering perennial plants. See *(Hampshire County Council's "The Conservation of Water Meadows Structures" 2002* *http://www.hants.gov.uk/environment/historic-environment/watermeadows.html).*

In the British Isles, attitudes to genetically modified organisms seem to be extremely polarised. At the populist level, simple absolutist hostility to GMOs exists. At more sophisticated levels within the fields of ecology, the environment and sustainable development, the concept of GMOs per se may be viewed more positively; however a widespread distrust exists with research, development and testing to date often being seen as commercially motivated in a direction that is the antithesis of sustainability. EU regulations also state that there is no place in organic agriculture for GMOs. The projects included that have GMOs as a principal focus, are Elm Farm Research Centre's (EFRC) *A Review of Knowledge of the Potential Impacts of GMOs on Organic Agriculture. Final Report to DEFRA. Project Reference: OF0193.October 2002*, and Cambridge Research for the Environment's (CRE), *Legal and economic evaluation of the release of genetically modified organisms into the environment* http://www.landecon.cam.ac.uk/environment/index.htm . *HGCA Project Number: 2085 Botanical and rotational implications of genetically modified herbicide tolerance in winter oilseed rape and sugar beet link to publication details at www.hgca.com.*

Within the organic agriculture movement GM crops are seen as a major threat to future viability through contamination although the whole concept of sustainability and what constitutes a sustainable agricultural system is not something on which there appears to be as yet any true consensus. The whole issue is often highly politicised and researchers, like everyone else, are influenced in their approaches by what economic and other ideologies they hold or work under. For example, organic farming and sustainability are not necessarily synonymous although the assumption that they are is sometimes made within the organic farming movement.

A dichotomy is observable with most projects falling into one of two groups, those focussed on developing sustainable U K production and land use and those intended to benefit food producers in developing countries. Although physical differences of climatic and other environmental conditions are of course extremely relevant, it is noticed that often different orders of questions are asked and different types of solution found premised on cultural and socio-economic criteria. Here as elsewhere we perhaps see a lack of any true consensus on what actually constitutes objective sustainability. See http://www.uea.ac.uk/env/cserge/research/51.htm *Sustainable Development Inside and Outside the European Union.*

Description Of Alternative Agricultural Systems Design & Management In The UK, Their Dissemination And Driving Forces & Constraints

Overview

Agricultural systems are multi-functional within landscapes and economies. They not only produce food and other goods for farm families and markets, but also contribute to a range of valued public goods, such as clean water, wildlife, carbon sequestration in soils, flood protection, groundwater recharge, and landscape amenity value. Arable cropping systems also have developed and continue to change in response to economic and social pressures while concern for the state of wildlife and the quality of soil and water has led to further pressures on the way that crops are farmed. There is therefore an ongoing debate about the future of arable farming – not only in the UK but also in European and global context.

Table 3 provides an indication of how easy it would be to convert particular conventional farm types into organic systems.

Table 3: A comparison of the ease of conversion for several different types of farm

Lowland mixed farm	✓✓✓✓✓
Lowland, all-grass farm, low N input	✓✓✓✓✓
Lowland, all-grass farm, high N input	✓✓✓
Upland mixed farm	✓✓✓✓
Hill/upland all-sheep farm	✓✓✓
All-arable farm	✓

Each of the terms *'No-Tillage'*, *'Reduced Tillage'*, *'Conservation-'* and *'Organic Farming'* encompass a wide range of agricultural practices and farm types.

While strictly-speaking *'No-Tillage'* and, *'Reduced Tillage'* are systems driven by the need for improved economies rather than an improvement in the environmental aspects of farming, *'Conservation'* and *'Organic'* agricultural practices pursue the goal of an increasing 'naturalness' of farming and seek to make the best use of nature's goods and services as functional inputs. This is achieved by integrating regenerative processes (such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests) into food production processes. It minimises the use of inputs that damage the environment or harm human health. It builds on farmers' knowledge and skills, and seeks to make productive use of social capital, namely people's capacities for collective action for pest, watershed, irrigation, and forest management.

Many commercial organisations assess the pressures they are under by performing a PEST (Political/Legal, Economic, Social and Technological) analysis. Most of the pressure for change on the arable agriculture sector could also be put within this framework. The primary forces (pressures) driving change in arable landscapes relate mainly to the intensity with which resources are used. In arable systems this means the way that nutrients and biocides are applied, tillage is performed, etc.

The CEH Report (see Note above) reviews a series of studies to identify differences between contemporary and five alternative arable cropping systems in relation to their environmental (see also Environmental Impacts) and socio-economic impacts (see also Socio-Economic Impact). They were also assessed in terms of their profitability and levels of input usage based on existing knowledge, which is compared with alternative cropping systems in the UK and elsewhere.

No-Tillage / Reduced Tillage

One of the early proponents of the concept of No-Tillage goes back to Ed Faulkner in 1943 in the USA and Professor A. Trewavas FRS of the University of Edinburgh (http://www.scientific-alliance.org/opinions/opinions_members_write/benefitsnotill.htm and http://www.agbioworld.org/biotech-info/articles/biotech-art/orgfarmperspective.html) states that all of Faulkner's claims have been established by measurement and that they indicate the benefits of no-till agriculture over organic and conventional ploughing technologies. He continues to state that: "…ploughing is the most damaging soil treatment and no-till agriculture is most easily introduced with Herbicide Tolerant (HT) crops to avoid weed problems. GM HT crops are the simplest way to introduce no-till agriculture. Organic farmers need to plough not only to remove weeds which accumulate in organic fields (weed seed density has been shown to be three fold higher) but to mineralise nitrate and possibly phosphate".

He continues: "No-till has not been greatly used in the UK. DEFRA have issued two booklets describing case histories and indicating that clay soils are best for no-till. (Booklets are "A Guide to Managing Crop Establishment" produced by the Soil Management Initiative and "A Guide to Better Soil Structure" by National Soil Resources Institute). This booklet contains maps that suggest much of southern and midland England are suitable for no-till. There have been experiments some 30 years ago in Scotland on no-till but cold soils may have been a problem in its introduction. Blackgrass was also a problem but that is now controllable with glyphosate. However this would seem to be an area for further research to be undertaken."

It further appears that most research references in No-Tillage systems originate in the United States. However, the issue appears to be gaining interest in the UK as an Internet extension information service on research in No-Tillage systems is provided by Nottingham University in the UK(http://agrifor.ac.uk/text/browse/cabi/56f87b27cbfcb8bfc7a659c43c087d45.html); a website still under construction is promoting No-Tillage principles in the UK (http://www.eco-till.co.uk/). Other websites promote No-Tillage or Reduced-Tillage systems are virtually exclusively supporting the use of chemical herbicides or GMOs.

Conservation Agriculture

According to the European Conservation Agriculture Forum (ECAF), conservation agriculture refers to several practices which permit the management of the soil for agrarian uses, altering its composition, structure and natural biodiversity as little as possible and defending it from degradation processes (e.g. soil erosion and compaction).

The policy of conservation agriculture in UK forms part of the European Conservation Agriculture Federation strategy that brings together eleven national associations[1] which promote soil management and "best practice" aspects of conservation agriculture among Europe's farmers. ECAF was conceived to encourage the maintenance of agrarian soils and

[1] ECAF was constituted in Brussels on 14th January 1999, as a non-profit making association, subjected to the Belgium laws with the following members: Belgium, Denmark, France, Germany, Greece, Italy, Portugal, Slovakia, Spain, Switzerland and the United Kingdom.

their biodiversity in the context of sustainable agriculture and elevate knowledge between its member associations and respective farmer audiences. The main focus for encouragement is the investigation, development, and teaching of all aspects of conservation agriculture. Conservation agriculture has an increasingly prominent role to play in world agriculture as farms seek to develop Integrated Crop Management (ICM) systems that benefit the environment and enhance farm profitability. Conservation agriculture refers to soil management practices which minimise the disruption of the soil's structure, composition and natural biodiversity, thereby minimising degradation, erosion, and water contamination. At national level the UK, as an ECAF's member, aims to:

- improve technology transfer to farms;
- promote agricultural and environmental policies supportive to sustainable soil management;
- research, develop, evaluate and promote soil management systems to improve crop production and protection of the environment;
- improve information exchange in the research, policy and practicing communities;
- collaborate with other international and national organisations that have related to conservation agriculture objectives.

The development of modern intensive farming practice in the UK since the 1950s has brought widespread and profound changes to the soils, landscape and the environment, in general. The relationship between conservation and agriculture, which depends on the continuation of traditional land use practices, has eroded as government policy encouraged increased output through the use of grants and subsidies, which has taken no account of nature and other conservation objectives.

Despite its recent declining economic role (in 1999 agriculture's direct contribution to the national economy declined to less than 1% of Gross Value Added), farming still occupies more than 70% of the land area of the UK, and modern agriculture has had a profound impact on the countryside, affecting soils, water, landscapes and wildlife.

Current conventional tillage methods are a major cause of severe soil erosion and loss, which is accelerated by wind and water. Every time a farmer tills land to control weeds, the soil structure is destroyed and becomes more vulnerable to erosion. The way soils are cultivated today needs to be changed.

With regard to ecological changes effected by cultivation in the UK, figures reveal that since the WW2 Britain has lost:

95% of traditional hay meadows;
99% of lowland heaths;
80% of chalk downland;
80% of limestone grasslands;
80% of fens and mires;
90% of lowland ponds;
50% of ancient lowland woods;
150,000 miles of hedgerows.
Since the establishing in the UK of the British Nature Conservancy Council (1949) and later a national network of *Sites of Special Scientific Interest (SSSIs)*, a sectoral approach to rural land use policy was followed with each major land use direction - agriculture, forestry and

nature conservation - following independent paths. The integrity of the extensive SSSI system (covering 1,366,067 ha or 6% of Britain's land surface by the early 1980s) weakened as land use in rural areas intensified[2].

What should be done to improve this situation? Appropriate policy strategy and practical measures in technological means will transform conservation agriculture today. Following the advance changes within the framework of the Common Agricultural Policy and ECAF's conservation agriculture strategy, and the gradual improvement of the National Agriculture and Forestry Conservation Grants Scheme[3], including the enhancement of the Conservation Plans, Agri-Environment and Rural Stewardship Schemes[4], make it possible to reverse the "status quo" in the UK conservation agriculture. The further promotion of sustainable agricultural practices, such as integrated plant nutrient systems - which use recycled animal and vegetable waste and other techniques to cut down on fertiliser use, and integrated pest management using pest-resistant crop varieties and natural pest control methods, as well as pesticides, are supposed to change the current situation. No-till/conservation agriculture, improved (more efficient) water use and water pollution control technologies are also helpful to improve soil conditions. A supplementary expansion of aquaculture and forest plantations may help to protect soil, to save biodiversity and natural resources with respect to the countryside environment, and to provide high standards of conservation agriculture and food quality.

Today, the active steps to conserve the countryside and agriculture, including hedgerow legislation and reasonable policies to increase the percentage of woodland cover, as well as different schemes to promote environmentally sensitive farming, are gradually having a positive effect. Biodynamic Organic Agriculture courses seek to provide *"…an opportunity for the next generation of farmers to learn to grow food and to sustain human future; to support sustainable agriculture with idealistic farmers who can put those ideals into practice; to train farmers who can work with the land and the landscape in ways that are healthy for us, wildlife and for the land itself"* (Farmland conservation/agriculture and biodiversity, 2004).

Source:

1. Countryside Commission 2000, http://www.workingforwildlife.org.uk/conservation/; http://www.fao.org/waicent/ois/pressne/presseng/1998/ pren9842.htm.
2. UK Joint Nature Conservancy Council, Report 2002.
3. Farmland conservation/Agriculture and biodiversity, 2004, http://www.defra.gov.uk/farm/conservation/biodiversity.htm
4. The History of Conservation Legislation in the UK. Nature Conservancy Council, 1989, http://www.naturenet.net/status/history.html.
5. What is ECAF? http://www.ecaf.org/Whatis.htm...
6. Viewpoints: Food for all? Sustainable practices and the right policies, J.Schmidhuber, BBC News, 27 November 2004

Sustainable Agriculture

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[2] The Introduction of the Wildlife and Countryside Act 1981 through a combination of regulation and financial incentives places the Council in a stronger position to persuade landowners not to proceed with land use change which would damage conservation interests.

[3] including separate Statutory Instruments for England and Wales, Scotland and Northern Ireland.

[4] such as Environmentally Sensitive Areas, the Countryside Stewardship Scheme and the Rural Stewardship Scheme (in England and Scotland) and 'Tir Gofal' (in Wales), The Woodland Grants Scheme, Farm Woodland Premium Scheme.

Sustainable agriculture relies more on agro-ecological and organic approaches to food production. This is not to say that modern agriculture cannot successfully increase food production. The central questions today are:

- to what extent can farmers improve food production with cheap, low-cost, locally-available technologies and inputs, and
- to what extent can they do this without causing environmental damage?

The matching of major (N, P and K) and all other nutrient supply with crop demand is central to the concept of sustainability within all agricultural systems. For this to be achieved it requires a certain synchronicity between soil processes that supply nutrients and it can be argued that this becomes increasingly critical for ‘organic’ compared to ‘conventional’ managed systems. Watson et al., (2002a) suggest that one of the fundamental differences between management of organic and conventional systems is the way in which problems are addressed. Conventional agriculture often relies on short-term solutions e.g. application of soluble fertiliser and pesticides.

Organic Farming

A commonly held perception is that organic farming is synonymous with a reduced intensity of production accompanied by wide-ranging environmental benefits. While this must be true for certain aspects, such as the elimination of pesticides, those associated with nutrient cycling and loss may not be as straightforward.

Compared to conventional farming systems, organic systems use an approach, which is strategically different as it relies on longer-term solutions (preventative rather than reactive) at the system level. The extremely low solubility of ground rock phosphate allowed in organic farming compared to the high solubility triple supper phosphate used in conventional systems is a good example for this difference in approach.

Organic farming systems can be grouped into four main categories and these have recently been summarised by Watson et al. (2002a) and references cited therein.

- *Mixed systems* – commonly employ a ley/arable rotation, with soil fertility being built-up during the ley phase where livestock and fodder production provide an income. The length of ley period depends on factors such as soil type and inherent fertility, livestock type and climate.
- *Livestock systems* – where crop rotations are impractical due to soil/land type, climatic constraints or conservation issues, the use of long-term or permanent grassland is acceptable within organic regulations provided soil fertility is maintained through nutrient recycling, with minimal external inputs.
- *Stockless systems* – often developed in situations where specialist conventional arable farms lack the necessary basic infrastructure (fencing, water supply and housing) required for livestock production. Soil fertility is maintained through use of green manures, grain legumes and the import of manures, composts and other acceptable fertilisers.
- *Horticultural systems* – encompasses a wide range of systems from field vegetable production to fruit and protected cropping (glasshouse/polytunnels). Intensive horticultural systems often are the ones most dependent on imported nutrients and

those with a high nutrient demand and susceptibility to pests and diseases. Perennial fruit crops offer a particular challenge for maintaining soil fertility.

Comparable farm types exist within conventional farming and in addition include intensive pig and poultry livestock categories. The recent trend towards intensification and specialisation has meant that the ‘mixed farm’ category has declined while the ‘arable’ and ‘livestock’ systems have increased. There are various economic and logistical reasons for this change, but it has had consequences for the regional and farm scale nutrient cycle. In particular, the farm level separation of arable and livestock systems means that areas of feed production have become geographically separated from the resulting livestock waste. The resulting nutrient imbalance for stockless arable systems is only sustained through the use of fertiliser. The historical and current context is described for the UK phosphorus (P) cycle by Withers et al. (2002) and Northern Ireland, where nitrogen (N) and potassium (K) is also included by Foy et al. (2003). This trend has developed against the background of a strong West-East spatial climatic and geo-morphological component that has specific agronomic impacts (see section I-2). The accumulated nutrient surplus within agricultural land is considered to represent a significant potential risk to the wider environment, although the precise nature of this relationship is complex.

These developments and changes in agricultural production systems have had several consequences, one of the most obvious being the breakdown of traditional crop rotations, it is not unusual to see either large areas of mono-cropping which are repeated annually and no longer include any pasture-based break crop. While there are potential implications for soil physical properties and pest/disease build-up, intensive arable systems have been shown to be able to be extremely nutrient efficient, although they rely almost totally upon imported fertilisers. Areas with intensive livestock production, on the other hand, can suffer from nutrient surpluses and contamination of the local environment.

Crop rotation is a major feature of systems managed organically and usually includes a clover/grass ley (1-5 years) that represents the ‘build-up’ phase through N fixation followed by a period of cash crops during which nutrients become depleted. The objective is to balance or be in slight surplus for N over a complete rotation. An average of 83 kg N ha^{-1} yr^{1} has been recently calculated as the surplus for 88 organically managed farms located in 5 temperate regions (Watson et al., 2002b). The comparable P and K farm-scale balances were more variable showing both deficits and surpluses and averaged 3.6 and 14.2 kg ha^{-1} respectively (see Table 4). While excessive surpluses represent a potential environmental risk, deficits if prolonged represent a real concern from an agronomic perspective. Growth limitations caused by a deficiency of individual nutrients can reduce the utilisation efficiency of other nutrients.

Providing a balanced nutrient supply that matches plant requirements remains a key aspect of agricultural production, and represents a major challenge to organic farms. Yields are typically lower in organic systems ranging between <50% to 95% of conventional yields probably due to N limitation which itself is due to the difficulty of matching supply with demand. While N has a range of sources, atmospheric deposition, biological fixation and mineralization of organic matter, sources of P and K are more restricted with a variable amount originating from soil mineral weathering and transformation of organic matter. These factors are discussed in section II-2-3 and have been recently reviewed (see Öborn et al. 2003 and related papers) in that issue.

The ratio of legume/ley to cash crop varies depending upon the overall system and soil type. Ploughing up the ley and cultivation stimulates N mineralization, usually high N demanding crops (wheat or potatoes) follow the ley; spring crops follow this as the available N declines. It also represents the time where nitrate leaching is possible, so timing of cultivation is very important. The length of ley can directly influence the build-up of organic matter. Ploughing up of different aged leys (2 – 10 years) resulted in the release during the first autumn of 34 – 328 kg N ha^{-1}, with no clear relationship between ley age and N loss (Shepherd, 1993). Cultivation also allows the mixing in of surface applied manures. Rotations also help reduce the build-up of pests and diseases.

Table 4: Farm-scale nutrient surpluses (Input-Output) kg ha^{-1} yr^{-1} for 88 organically managed farms summarised by farm type (taken from Watson et al., 2002b).

Farm type	n	Mean	Range	n	Mean	Range	n	Mean	Range
		Nitrogen			Phosphorus			Potassium	
Arable	2	25.6±24.4	1.2 – 50.0	1	-6.0		1	57.0±	
Beef	5	112.0±25.6	18.4 – 164	4	-1.8±1.4	-6 – 0	4	3.0±3.4	-4.5 – 12.0
Dairy	67	82.1±6.7	2.1 – 217.0	56	3.1±0.9	-6.5 – 36.0	58	9.6±2.0	-26.5 – 58.0
Horticulture	3	194.2±100.7	91.0 – 395.6	3	38.9±26.0	1.7 – 89.0	3	122.0±88.0	-23.0 – 281.0
Mixed	8	54.6±8.6	21.0 – 91.6	6	-2.4±1.3	-6.9 – 4.0	3	-2.2±1.2	-4.4 - -0.3
Mean		83.2			3.6			14.2	

The organic farming movement in the UK was established under the guides of the British Soil Association more then half a century ago. By April 1999 it included more than 240,000 hectares of land that was registered and managed organically by 1.356 producers, representing 1.2 percent of the total agricultural land and 0.7 percent of the farmers. One quarter of this organically managed land had gained full organic status by April 1999 and was therefore able to produce organic food.

Table 5 shows the areas of organic and in-conversion land and organic land as a proportion of the total agricultural area varying between regions.

Table 5: Organic & In-Conversion Land (Jan 2004). Data from DEFRA

	In conversion	Organic	Total (ha)	Total agricultural area1[1] (ha)	Percentage of total area
England	36,904	222,026	258,920	9,177,389	2.8
Wales	8,027	50,219	58,246	1,458,825	4.0
Scotland	20,382	352,180	372,562	5,520,500	6.7
Northern Ireland	825	5,057	5,882	1,073,887	0.5
UK	66,137	629,482	695,619	17,212,512	4.0

[1] Excludes common grazing land

The remaining 180,000 hectares was classed as being ‘in conversion’. 79 percent of the 60,000 hectares classed as fully organic were grassland (permanent pasture, temporary leys and rough grazing). In addition to this the vast majority of the land classed as in conversion will also be in grass, due to the requirement for fertility building during the conversion period. Only 21 percent or 12,600 hectares of organic land was classed as ‘cropped’ (arable, horticultural and fruit production). Whilst the area of organic crop production has grown significantly, it is not increasing as fast as the area of grassland.

The proportions of various crops and pasture for the UK are shown in Table 6.

Table 6: Organic And In-Conversion Land Use In The UK (Jan 2004)

	In conversion	Organic	Total (ha)	Percentage of total area
Cereals	7,016	35,079	42,095	1.4
Other Crops	4,065	17,864	21,929	2.1
Fruit & nuts	213	1,330	1,543	4.4
Vegetables	1,985	12,341	14,326	4.2
Herbs & Ornaments	66	232	298	2.1
Temporary pasture	10,700	67,302	78,002	7
Set aside	2,326	4,620	6,946	1
Permanent pasture (inc. rough grazing)	38,512	482,037	520,549	5.2
Woodland	686	4,816	5,503	1.1
Non cropping	252	715	967	n/a
Other	228	681	909	n/a
Unknown	88	2,465	2,552	n/a

Data from DEFRA

Farming systems that include livestock fit organic rotations best.
(from SAC http://www1.sac.ac.uk/cropsci/external/orgserv/)

England's Organic Sector: Prospects for Growth - Action Plan
(from DEFRA: http://www.DEFRA.gov.uk/farm/organic/actionplan/prospects.htm)

There are considerable differences in terms of the scale and type of organic production within the UK. In England the government funded Organic Conversion Information Service has received about 7,000 enquiries on organic production since its launch in July 1996, with the majority of these enquiries coming from dairy and livestock farmers. By April 1999 organically managed land in England accounted for 135,000 hectares of which almost 100,000 hectares was in conversion. Organic farming in Wales by January 1999 included 3,182 hectares of fully organic land with an additional 2,149 hectares in conversion. Currently organic production is concentrated in West and South Wales with relatively few producers in North or Mid Wales. Over 80 percent of the agricultural land is classed as Less Favoured Area, with livestock enterprises predominating. Of the farmers converting to organic production in Wales, it is estimated that 65 percent can be categorised as beef and sheep and 15 percent as dairy. The remainder represent mixed livestock and cropping farms with some horticulture[5].
In Scotland, the rate of conversion of farmland has been higher than in any other part of the UK. By April 1999 over 100,000 hectares (2.5 percent of total agricultural land) was licensed and managed to organic standards. Over 70 percent of the land in conversion and

[5] A key feature of the strategic review of food & agriculture by the Welsh Development Agency was the adoption by the National Assembly for Wales of a policy initiative for organic farming. Policy tools include an action plan ("Welsh Agri-food Action Plan for the Organic Sector", adopted in March 1999) to establish a national centre of excellence, integrated strategies for market development and the extension of production and processing capabilities. A target to achieve 10 percent of agricultural output produced organically by 2005 has been set.

about 90 percent of the land with full organic status in Scotland is classed as hill or rough grazing, maintaining extensive livestock production. Less than 2.5 percent of this land is used for arable or horticultural cropping, compared with over 10 percent for the UK as a whole. In Northern Ireland organic production is still at a very small scale compared to the rest of the UK. Only 200 hectares is under organic management, with an additional 100 hectares in conversion. The limited growth in organic production in Northern Ireland is partly due to the limited distribution of processing infrastructure. Considerable effort is being made to develop the organic sector further in the region. Substantial growth is expected in the near future with more than 20 producers, representing 600 hectares contemplating conversion.

The first set of organic standards in UK were published as guidelines by the Soil Association in 1967, and the Soil Association Organic Marketing Company, now Soil Association Certification Ltd, was set up in 1973 to inspect and certify organic food. Today, the Soil Association standards are the most widely recognised with over 70 percent of the organic food in Britain coming under their inspection system, although there is a total of five approved inspection bodies. This was later superseded, by the government-led UK-register of Organic Food standards; which is responsible for implementing the Council Regulation (EEC) 2092/9 on organic production in the UK. It is challenging the government to set a target of 30% organic production by 2010.

Currently, the Ministry of Agriculture, Fisheries and Food spends over £ 3 billion (approx 4.3 billion Euros) each year on supporting agriculture, but only three percent is spent on the agri-environment budget within the programme of the Organic Farming Scheme[6]. Only eight percent of the agri-environment budget is currently spent on organic farming (£ 6.2 million; 9.0 million Euros). This works out at 0.2 percent of the total UK spending on agriculture. Despite increasing attention being paid to environmental and food safety issues, in practice the pursuit of cost efficiency, global competitiveness and free market policies are still the dominating concerns[7]. In the Organic Food and Farming Report (2003) further strategy changes and specific policy tools were recommended to achieve environmental goals through efficient land use, rigorous environmental controls, and innovations in pollution prevention and technology.

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5. UK Action Plan to Develop Organic Food and Farming in England. August 2001: UKOFS statistics of the organic sector. http://www.defra.gov.uk/farmorganic/stat.htm
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Genetically Modified Organisms

[6] Compare to the average eleven percent in the EU.

[7] In Scotland funding is provided by the Scottish Executive Rural Affairs Department (SERAD) which is the equivalent of the Ministry of Agriculture. Changes to the SERAD Organic Aid Scheme that is in operation from 1999-2000, relate to the payment rates have been proposed to the EU and approved by the Scottish Parliament.

In the UK Genetically Modified Organisms (GMO) are restricted under the EU Council Directive 90/220/EEC on the Deliberate Release into the Environment of GMO. Releases for research trials or marketing of GMOs are subject to the Environmental Protection Act 1990; the GMOs (Deliberate Release) Regulations 1992 (amended 1995, 1997, 2002) and Environmental Information Regulations 2004. These regulations apply to experimental field trials and commercial agriculture. For 'contained use' (in laboratories and factories) the GMOs (Contained Use) Regulations 2000 (SI 2000/2831) applies[8]. The risk assessment process is covered by the GMOs (Risk Assessment) (Records and Exemptions) Regulations 1996 and the GMOs (Deliberate Release and Risk Assessment) Regulations 1997. The legislation aims to ensure that the possible risks of GMOs to human health and the environment are properly assessed and controlled. GMOs can only be released when consent has been given, on the basis that the GMOs pose a low or effectively zero risk to human health and the environment. The main UK bodies concerned with regulating and monitoring GMOs are the Department of the Environment, Food and Rural Affairs (DEFRA); the Food Standards Agency; and the Health and Safety Executive that lay down a set of common environmental and human health safety measures in relation to the release and marketing of such organisms.

GM crops are not new, either in the UK (where they have been planted in field tests since 1987) or internationally (where in 2000 they were being grown commercially on over 44 million hectares in 14 countries). However, Farm Scale Evaluations (FSEs) have led to a wider-scale growing of GM crops, and the prospects of their commercial release in the UK for the first time have sparked a wide scale criticism, both from environmental organisations and from the general public. These evaluations, established in 2000 as a result of concerns expressed by government agencies and NGOs, are three-year trials of GM herbicide tolerant crops. During this period the biotechnology industry agreed to refrain from GMO commercial growing in the UK. In October 2002 the UK Government announced the coming into force of the English GMOs (Deliberate Release) Regulations, 2002. The regulations are widely tipped as paving the way for commercial release of those crops currently grown in FSEs, which are herbicide-tolerant spring and winter oil seed rape, sugar beet and forage maize.

A report commissioned by DEFRA in January 2003 stated that “In the period 1998 to 2000 gene flow was detected from GM trials into adjacent OSR (Oil Seed Rape) crops”. The report concluded, “if transgenic oilseed rape is grown on a large scale in the UK, then gene flow will occur between fields, farms and across landscapes”. That conclusion coincided with the recent report from the European Environment Agency on GMO crops (2002), which also judged that under current farming practice, contamination between the transgenic crop and the non-GM wild relative is inevitable. This could lead to vigorous hybrids developing and establishing across the countryside displacing natural populations through competition

[8] There are also regulations, which aim to protect people against health risks from GMO in food. These are the GM and Novel Foods (Labelling) (Scotland) Regulations 2000, the GM and Novel Foods (Labelling) (England) Regulations 2000 and the GM and Novel Foods (Labelling) (Wales) Regulations 2000; GMOs (Deliberate Release) (Scotland) Regulations, 2002 and the GMOs (Deliberate Release) (Wales) Regulations, 2002. In Northern Ireland the legislation for GMOs is contained in the GMO (1991 Order) (commencement No.1) Order (Northern Ireland), 1994; and the GMOs (Contained Use) (Amendment) Regulations (Northern Ireland) 1994 (Amended 2001), the GMOs (Deliberate Release) Regulations) Northern Ireland, 1994 Amended 2003, the GMOs (Deliberate Release and Risk Assessment) (Amendment) Regulations Northern Ireland, 1997, the GMOs (Risk Assessment) (Records and Exemptions) Regulations (Northern Ireland), 1996 and the GM and Novel Foods (Labelling) Regulations (Northern Ireland) 2000.

and thus reducing biodiversity. In the case of herbicide tolerant crops report also predicts that "plants carrying multiple resistances will become common" and "weeds may become more difficult to control with herbicide treatments".

Consequently, the UK Agriculture and Environment Biotechnology Commission (AEBC) and the Government's own GM watchdog stated that: *"They* [FSEs] *cannot be as widely interpreted… before commercialisation can proceed. Additional information, and consideration of a wide range of viewpoints, must be the factors in the eventual decision".* The Government's advisors on GM releases to the Advisory Committee on Releases to the Environment (ACRE) reviewed the report DEFRA and advised that: *"ACRE's risk assessment of GM oil seed rape has always assumed some gene-flow will occur and that this does not itself constitute a risk to human health or the environment. It was concluded that the extent of gene flow was entirely within expectations".*

In 21 July 2003 the UK Government Science Review on food safety unsurprisingly reported that human health is at a "very low" risk from the current generation of genetically modified (GM) crops. On the matter of biodiversity, the report is clear: "*Unquestionably, the largest gap in our knowledge is the impact that GM Herbicide Tolerant cropping would have on biodiversity."* It also admits that for pest resistant GM crops: "*Agronomically realistic ecological studies comparing the impacts on biodiversity of the use of GM pest resistant crops with conventional insecticidal crop treatments should be undertaken for any GM pest-resistant crops that are being considered for commercial release in the UK. This research will be needed in future if we are going to introduce [GM] crops into commercial release, especially for industrial end-use.* "

Despite the continuing discussion, the precautionary principles of GMOs release are already incorporated into the UK legislation. The Regulations on GMOs require notifying the appropriate Minister or the Secretary of State (HSE) of all premises where GMOs are used and notification is required when certain higher risk activities are being carried out. Regulations specify the types of activity requiring consent, and the nature of the information required in an application; they can also provide for exemptions in particular circumstances. Consents which have been granted can be subject to conditions or to time limitations, and can be revoked.

Advice on whether a release should be given consent is provided by the ACRE. Applications for consent to release GMOs fall into two categories, the first is 'standard', and such applications are discussed in full by ACRE, and the second is 'fast track', and are dealt with by the ACRE Secretariat. There are three different types of fast track application. Firstly, low hazard GMOs which do not need special control measures. Secondly, releases which are considered low risk if appropriately managed, and, lastly, repeat applications, relating to types of release which have previously received consent. An application for release must contain detailed information on the GMO and possible effects of the release or unexpected spread of the GMO. The widespread release of a GMO through sale to users (e.g. to farmers to plant economic crops) requires a consent for marketing. It is very important that standards of occupational and environmental safety and containment are maintained, this means emergency plans are carried out and there is sufficient notification of accidents, so that the health and safety of persons and the environment outside the premises are protected.

Sources:

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Assessments of Impacts

Environmental Impacts

The state of the environment within arable cropping systems is described by reference to:

- Biodiversity – distribution and abundance of plants and animals;
- Social and economic conditions – employment and profitability (and to a lesser extent with externalities like pollution and energy efficiency);
- Landscape structure – field size, diversity of activities
- Genetically modified organisms

General Trends

During the past fifty years the remarkable increases on food production have come at considerable environmental and human health cost (cf *Conway and Pretty, 1991; *Campbell and Cooke, 1997; *MAFF, 1998; *Pretty, 1998; *EPA, 1999). The changing state of arable plants and animals is a cause of widespread concern to land managers and conservationists. National monitoring and long-term studies of birds, butterflies, beneficial invertebrates and annual arable flowers have shown serious declines in some species associated with arable farmland in the late 20th century (*Aebischer, 1991; *Donald, 1998; Sotherton, 1998; *Asher *et al.*, 2001; *Baillie *et al.*, 2001).

Declines in biodiversity, therefore, coincided with an increase in the intensity of agricultural production. Several factors played a part in causing these declines (*O'Connor & Shrubb, 1986; *Potts, 1991). Farming became more specialised, with arable increasing in the east of the UK and decreasing in the west. Fertilisers and crop-protection chemicals were improved and applied in increasing amounts. Non-cropped habitat was removed to enlarge field sizes. Crop rotations were simplified with an increase in winter cereal production. Subsidies were created by European and national governments to pay farmers to remove hedges and drain wetlands to increase agricultural production.

In 1999, the Government published the White Paper Achieving a better quality of life, which contained a draft set of 150 indicators of the sustainability of lifestyles in the UK. Fifteen of the proposed indicators were identified as 'headline' indicators, and one of these was based on population trends of breeding birds. The Government has pledged to reverse the long-term trends in woodland and pertinent to this project, farmland birds. In particular, DEFRA has published a Public Service Agreement target to reverse the long-term decline in the number of farmland birds by 2020. Although a series of policy initiatives have been launched to help farmland birds, meeting this target will be a significant challenge.

Currently farmland birds are considered the headline indicators for arable cropping systems although the debate about what is a valuable indicator of biodiversity continues.

Limits To What Has Been Studied

Although studies of the biodiversity of field margins are relatively numerous, the effects of cropping system on the field interior have received less attention. European studies (of which very few come from the UK) tend in the main to focus on organic versus contemporary systems, whilst studies examining the biodiversity effects of type, depth or intensity of cultivation are much commoner in the USA and Canada. In order to infer generalities from American studies one must make the assumption that the arable faunas of both temperate North America and Europe react similarly to changes in cultivation.

In both European and American studies there is a tendency to focus on the epigeal arthropod fauna, especially carabid beetles (Moreby *et al.*, 1994), with transect surveys of butterflies also popular. Other taxa are relatively underrepresented.

It is generally assumed that increasing the abundance and species richness of soil organisms has a positive effect on soil functioning and crop growth. However, there exists much functional redundancy in soil ecosystems, and soils often function adequately with reduced overall species diversity.

It is very difficult to perform manipulative field-scale experiments with the soil biota, because of the scale and complexity of interactions and the difficulty of sampling the soil itself. Hence, we do not know the exact role of each group of organisms (e.g. the mites and collembola) in relation to soil functions (i.e. increasing nitrogen availability, increasing soil porosity etc.). A number of groups of soil animals are also multi-functional, such as the earthworms, which affect the biological, chemical and physical attributes of the soil matrix. Very little work has been carried out for arable systems (under any management) in the field to mechanistically describe the role of defined groups on soil function in a quantitative, ‘model-friendly’ manner.

There is evidence of direct and indirect effects of agricultural practices (chemical and physical) on organisms for a range of taxonomic groups. For example: birds, arthropods and earthworms are all detrimentally affected by pesticides; plant and earthworm abundance are affected by nitrogen input; and reduced tillage causes increases in weeds and invertebrates, and reduces earthworm mortality. Therefore, in most cases a reduction of chemical inputs and a reduction in severe soil disturbance will have ecological benefits.

Different arable cropping systems affect the landscape in different ways. This is especially important for birds, mammals and insects that move around in the countryside. Ecological benefits are shown to accrue from mitigation measures such as arable margins, beetle banks, conservation headlands and wild bird cover. These mitigation measures are normally carried out with the assistance of agri-environment scheme payments.

Large scale uptake of planned agri-environment schemes is likely to have widespread positive effects on fauna and flora but these effects might not necessarily be large on a per field scale.

According to one key report, organic farming of crops is relatively profitable. Although it has lower yields than conventional systems, these are compensated by higher prices. There are some concerns about whether the economic analysis has fully captured the costs of switching to different rotations in organic farming (e.g. including costly years of manure crops to maintain soil fertility) since the study was based on small samples in single years.
Low input systems and integrated arable systems were both variable in their economic performance. Their economic returns compared well with conventional systems in some situations but not in others. There is scope for additional economic modelling to broaden the knowledge base about the performance of these systems in different circumstances.

Reduced tillage currently has limited economic potential in the UK. Farmers have been reluctant to adopt it. Large capital investment is required at the beginning so it is unsuitable for small farms.

Precision farming has been evaluated positively in the one major UK study, but a more sophisticated economic analysis from Australia raises suggests that the UK study may have overstated the likely benefits.

Implications for farm labour were identified, the most important of which are a likely increase in labour demand in low input systems and a requirement for more skilled labour in some systems.

Carbon Cycle & Greenhouse Gases Emissions

A special issue of Soil Use and Management (2004, volume 20) provides a comprehensive summary of 'soil as carbon sinks'. King et al. (2004) described the potential for soil organic carbon sequestration, energy savings and the reduction of the emission of greenhouse gases for a range of changes in the management of tilled land and managed grassland in England. The greatest carbon sequestration and saving contribution was associated with increasing the proportion of permanent woodland. Changes to tillage practices, increased use of permanent conservation field margins and increased return of crop residues also was predicted to have significant effects. Interestingly a large component of the likely saving on CO_2 emissions came from the reduced energy use.

Erosion Mitigation

Under certain circumstances soil erosion can be significant, especially where soils have little over winter crop cover. The extent to which soil erosion occurs is highly location and management dependent, being related to soil type and properties, such as organic matter content, gradient and rainfall intensity. Reducing the degree of preparation of seed beds can help to reduce erosion risk, although this might have implications for germination and crop establishment. Often erosion has been demonstrated to be extremely localised, developing from compacted areas such as headlands and tramlines. Erosion is a size selective processes with finer sized materials being transported further distances. There is also often an inverse relationship between particle size and the concentration of potential contaminants. Examples of this can be found within recent DEFRA funded research on P (see http://www.iger.bbsrc.ac.uk/DEFRA_Phosphorus/index.html). http://www.DEFRA.gov.uk/environment/land/soil/pdf/soilerosion-lowlandmanual.pdf

Tillage

Weeds

Reduced tillage has been very successful in reducing erosion and nutrient losses on some soils, but results are very variable. In all cases of reduced tillage there is the possibility that weeds will become more prevalent (and hence may require control by non-mechanical means). Reduced tillage is generally not successful on poorly drained soils, on soils with high organic matter content, or soils that compact easily or where crusts form.

Invertebrates

In reviews, Kromp (*1999; carabids), Paoletti & Hassall (*1999; woodlice) and Sunderland & Samu (*2000; spiders) all indicated that reduced tillage led to increases in their respective taxa. Two studies from Europe (Krooss & Schaefer, 1998; Germany; Baguette & Hance, 1997; Belgium), seem to support many American studies such as those by Neave & Fox (1998) and House (1989), which found greater arthropod diversity and/or abundance in reduced tillage regimes. A third, a German study by Wick *et al.* (2001) found no effect of tillage on carabids. Buntin, Hargrove & McCracken (1995) found no effect of tillage amongst foliage-inhabiting arthropods, and both Marasas, Sarandon & Cicchino (2001) in Argentina, and Gallo & Pekar (2001) in Slovakia found that reduced tillage favoured predatory species relative to ‘pests’.

Earthworms

Plots at the Rothamsted Experimental Station in the UK that have grown the same crops since 1843 showed that the largest earthworm populations occurred under continuous cereals, with much lower populations under root crops and the lowest of all under fallow (Edwards & Bohlen, 1996). The main reason for this is that cereals leave considerable litter residues, which are usually ploughed into the soil, encouraging the build-up of organic matter and hence earthworm populations. In contrast, root crop residues decompose quickly and leave little organic matter in the soil. Food supply is limited and subsequent earthworm numbers are low. This finding was supported by Fraser & Piercy (1998) who compared earthworm numbers under different stubble management regimes over a 4 year period. They found that after 4 years, earthworm densities in plots where stubble was burned or removed had a population density of approximately 150 individuals per m^2, whereas plots with residue incorporation had 400 individuals per m^2. They also noted that under-sowing barley with clover seed brought about a large increase in earthworm density, with numbers increasing from 150 individuals per m^2 before clover sowing to over 1000 individuals per m^2 afterwards.

Tillage has an immediate impact on earthworms themselves (through injury or direct mortality) and on their habitat, but the severity of effect is dependent on the mode of tillage practiced by the farmer. There exists conflicting evidence regarding the effect of tillage on earthworm abundance and diversity. For example, Doube, Buckerfield & Kirkegaard (1994) found no significant decline in earthworm abundance after one to two years following conversion of pasture to various types of crop. However, increasing the depth and frequency of tillage decreases the density of earthworms. Gerard & Hay (1979) compared deep ploughing (30-35 cm, furrows 45 cm apart), normal ploughing (15-20 cm, furrows 22.5 cm apart), tined cultivation (12-30 cm deep, tines 22.5 cm apart, two to three passes) and no-tillage in two experimental UK soils. Earthworm population density (numbers m_{-2}) decreased with increasing ploughing severity, from 120 in no-tillage, through 70 and 60 in normal tillage and tined cultivation to 55 under deep tillage. Curry, Byrne & Schmidt (2002) studied the effect of severe tillage on earthworm populations and found that earthworm population density dropped from 319 to 40-82 individuals per m^2 in a wheat to potato conversion after intensive cultivation (grubbing, ridging, bed-tilling, de-stoning and ridging). Furthermore, after mechanical potato harvesting at the end of the season, populations declined to virtually undetectable levels and showed little sign of recovery over a year later.

Due to the negative effect of conventional tillage on earthworm populations, conservation tillage is now widely practiced as a means of reducing damage to earthworms themselves and to their habitat. In the United States, Kladivko, Akhouri & Weesies (1997) studied 14 paired no-till/conventional sites and found that 8 no-till had higher earthworm population densities, 4 had roughly equal numbers and 2 had lower populations, when compared to contemporary practice.

Intensity of Land Use

Earthworms

The most fundamental form of management alteration in arable systems is conversion from contemporary to organic farming. Blakemore (2000) compared earthworm densities between a contemporary arable field, requiring inorganic fertilisers and pesticides with an organic ley-arable section (8-10 year rotation of corn, root-crop, and grass ley) supporting stock and found densities of 100.0 and 178.6 individuals per m^2 respectively. Blakemore also noted that earthworms preferred organic soils when placed in choice chambers (headcounts of 96 to 73 organic/contemporary). Even larger differences were found by Pfiffner & Mader (1997) who studied earthworms in a Swiss experiment running continuously since 1978. They found that earthworm population densities in 1991 under wheat were 130 and 350 individuals per m^2 for contemporary and organic treatments respectively. This difference has been sustained in recent years and now both biomass and abundance are higher in organic treatments, compared to contemporary by a factor of 1.3 to 3.2 (Mäder *et al.*, 2002).

Intermediate 'sustainable' treatments can also augment earthworm population densities. Schmidt *et al.* (2001) compared earthworm communities in a contemporary winter wheat monocropping system and a low-input intercropping system in which successive crops of winter wheat were direct-drilled into a permanent white clover sward. The wheat-clover system supported a higher population density than the mono-cropping system (548 to 194 individuals per m^2) and also showed higher species diversity (between 1 and 5 more species were found in the wheat-clover system compared to the mono crop). Length of time since conversion from contemporary methods is one of the most important factors determining population size, as shown by the UK LIFE (Less Intensive Farming and Environment) project. The study compared earthworm abundance and diversity between contemporary and integrated treatments from 1990 to 2000. Within the project, Hutcheon, Iles & Kendall (2001) found no significant differences between treatments in terms of earthworm population density or biomass over the first three years of the experiment. Thereafter, differences were found, with higher biomass and density found on the integrated treatment, but for selected species only. Numbers of *Allolobophora chlorotica, Lumbricus festivus,*
L. rubellus and *L. terrestris* averaged over all years were significantly greater in the integrated management treatment, whereas there were no consistent differences for *Aporrectodea caliginosa* or *A. rosea*. Species diversity was also consistently higher under integrated management.

Other Soil Organisms

When considering soil bacteria and fungi, the relationships between soil treatment, total microbial biomass, species diversity and soil function are of fundamental importance. Breland & Eltun (1999) found that microbial (bacterial + fungal) carbon biomass was approximately 50% higher under 'ecological' (i.e. integrated) farm treatments, compared to contemporary treatments. However, whereas N mineralization was slightly higher under ecological as opposed to contemporary treatments, the rate of carbon mineralization was equal in the two systems. Carpenter-Boggs, Kennedy & Reganold (2000) found that biodynamic treatments increased soil biomass C and a range of soil functions dehydrogenase activity, basal soil respiration and soil C mineralised in 10 days) when compared to contemporary treatments amended with mineral fertilisers. A study into the functional role of microbes in arable soils demonstrated that microbial species diversity can be greatly reduced, but soil function can still remain. Griffiths *et al.* (2001) decreased biodiversity (via dilution) in a conventional arable soil in laboratory microcosms by 15, 40 and 60%. This treatment could mimic the effect of stressors such as fungicides. They found no consistent effect of biodiversity on a range of soil processes measured (incorporation of thymidine and leucine, potential nitrification, nitrate accumulation, respiratory growth response, community level physiological profile and decomposition). Neither was there a direct effect of biodiversity on the variability of the processes, nor on the stability of decomposition when the soils were perturbed by heat or copper. The biodiversity of, and inter-relationships within, the microbial communities was such that the experimental reductions had no direct effects on soil function. These papers show soil microbial communities are inherently variable (Smit *et al.*, 2001), but that soil function is usually maintained under stress as there are many species remaining in niche space which are 'waiting in the wings' to take over the role of microbes dominant under previous management regimes.

Hendrix, Guo & An (1995) found large differences in mycorrhizal community dominance, diversity, equitability and species richness associated with different crop types. Interpreting the functional significance of these differences is extremely difficult as definitive experiments have not been carried out to quantify the relation between microbial diversity and crop productivity in the field. One of the few studies related to this was carried out by van der Heijden *et al.* (1998). In a field plot experiment simulating a North American old-field system they established 70 macrocosms, inoculated with varying numbers of mycorrhizal species and planted with mixed grass/herb species. They found that plant biodiversity; nutrient capture and productivity increase significantly with increasing mycorrhizal diversity.

Alvarez, Frampton & Goulson (2001) analysed collembola communities in winter wheat fields in the UK and found few systematic differences between contemporary, integrated and organic systems. However, a small number of consistent, though not significant treatment related abundance trends were noted, i.e. 1) *Entomobrya multifasciata* and *Isotomurus* species were more common in contemporary treatments then others, 2) *Isotoma viridis* and *Isotoma notabilis* were higher in organic fields and 3) for *Sminthurinus elegans* and *viridis*, variation was explained by interactions between treatment and area. Also, organic fields had the most equitable community structure, equitability being an attribute which has been linked with ecosystem resilience and sustainability (Naeem *et al.*, 1995). Interestingly, organic and contemporary systems did not differ from each other, but integrated differed from both.

Bouwman & Zwart (1994) showed that the protozoan biomass (dominated by amoeba) in a Dutch system (the Lovinkhoeve Experimental Farm) under integrated management was significantly higher than under contemporary, but this is difficult to explain as bacterial biomass remained the same in the two treatments. They suggest that bacterial production rate may be higher under integrated management. Also, soil physical properties (soil organic matter content, soil moisture etc.) differed under the treatments, with higher organic matter content under integrated management. These factors may provide more favourable habitat for protozoa. Differences in nematode activity were not significant. About 30% of N mineralization in Lovinkhoeve was due to the bacterivores.

Birds

Agricultural intensification converts farming into an industrial process with little regard for the environmental effects of increasing production (Chamberlain *et al.*, 2000; *Donald, Green & Heath, 2001; *Pain & Pienkowski, 1997; *Schifferli, 2000). Landscape-scale effects (habitat loss and fragmentation, loss of landscape connectivity, loss of diversity and the creation of monoculture, loss of habitat quality, direct poisoning and loss of food supplies) are discussed below. Other effects, notably the change from spring to autumn sowing with the concomitant loss of winter stubbles, have received much attention from ornithologists. Loss of stubbles reduces the availability of winter food supplies for a large number of farmland bird species (Moorcroft *et al*., 2002; Robinson & Sutherland, 1997; Whittingham & Markland, 2002). Autumn sowing also changes the characteristics of crop structure in relation to the timing of breeding (Donald & Vickery, 2001). Autumn-sown crops, especially cereals, become unsuitable as nesting habitat for certain species, especially Skylark *Alauda arvensis,* earlier in the season, resulting in an early end to breeding and a reduction in the number of broods that can be raised (Donald & Vickery, 2000). Birds attempting to compensate for unsuitable crop height and density by locating nests on the edges of wheel marks may also suffer higher predation rates, but results concerning predation differ between studies and may depend on a range of factors (e.g. characteristics of local predator populations, availability of alternative prey, local and larger-scale landscape structure) which may vary widely between sites (Wilson *et al.*, 1997).

Different crops offer different foraging opportunities for birds, in relation to crop type itself, weed and invertebrate abundances and physical access. Where nesting habitat is limited, crop rotation, in conjunction with field sizes and monoculture methodology may affect foraging efficiency, especially if a particular crop type is being exploited (Holland *et al.*, 2002; Moorcroft & Wilson, 2000; Moreby & Southway, 2002; Morris, Bradbury & Wilson, 2002). Rotational set-aside may have similar effects, but management of set-aside is likely to be more important (Henderson & Evans, 2000; *Sotherton, 1998). For example, spraying, mowing and ploughing should be timed to minimize impacts on breeding birds. Predation may also be a problem with set-aside, especially where lack of alternative habitat results in high nest densities (Donald & Vickery, 2000).

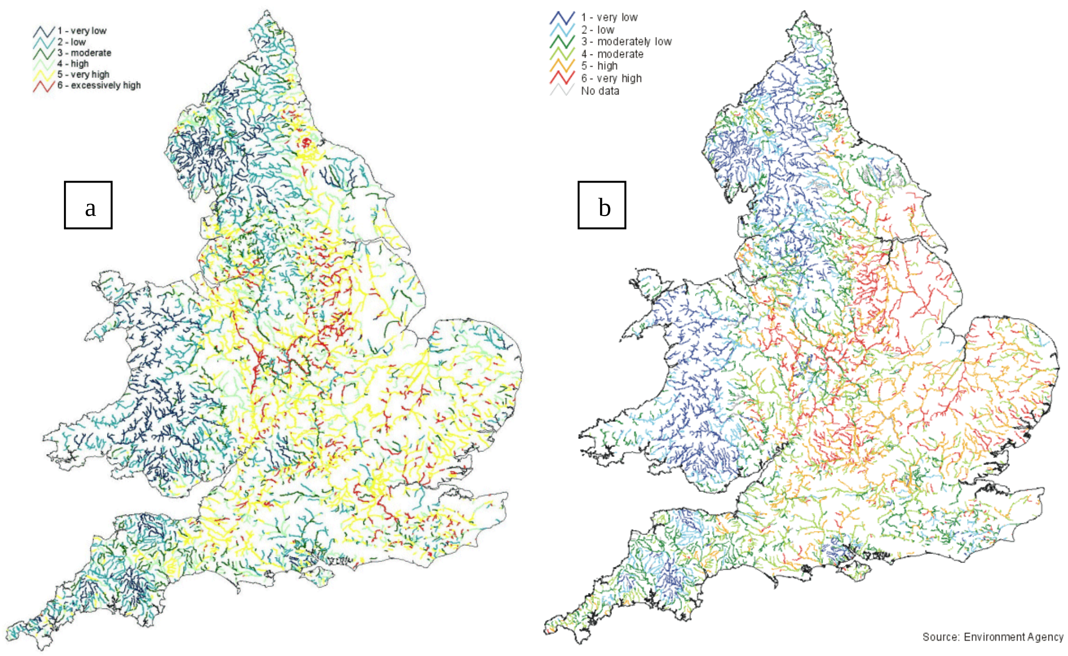
Pollutants In Soil And Water

There are a wide range of potential pollutants that arise from agriculture. Environmental impacts vary from nutrient enrichment, eutrophication and damage to semi-natural ecosystems as well as direct health implications arising from nitrate and/or pathogens in drinking water (Reid et al 2003), the build-up of potentially toxic elements in soil.

The rates of N release from crop residues and organic waste is very difficult to predict and control (Stopes et al., 2002). Ploughing and cultivation is usually associated with a flush of nitrate, the peak concentration would be expected to decline with time during the arable cropping phase. The timing of cultivation, period of fallow and crop type will influence the potential leaching. Crops such as potatoes have a heavy demand for N although the early establishment phase and deeper cultivation can increase the susceptibility to nutrient loss and erosion. A comparative study of nitrate leaching from similarly cropping organic and conventional farms showed little difference or slightly less loss from the organic farm (Stopes et al., 2002). The yields of organic systems averaged 60% and 55% and nitrate leached averaged 96% and 46% of those in conventional systems for wheat and other cereals respectively (Stopes et al., 2002). When losses are expressed on the basis of food product, organic systems tended to be less efficient. The measurements were all associated with a large amount of variability.

Further information relating to specific environmental issues for different types of water bodies can be found at
http://www.DEFRA.gov.uk/environment/water/marine/internat/ospar.htm,
http://www.sepa.org.uk/data/bathingwaters/ and http://www.groundwateruk.org/

Figure 2: Relative concentrations of phosphorus (a) and nitrate (b) in rivers of England and Wales (data from the Environment Agency. See Soil Use and Management 2000 volume 16 for a special issue 'Tackling Nitrate from Agriculture').



A considerable amount of information exists for the various water body types as shown for riverine phosphorus and nitrate concentrations in Figure 2. Differences in the spatial patterns of these two parameters are related to the major sources and processes responsible for there formation. High concentrations of nitrate, typical of the eastern region, are in part related to the regular cultivation associated with crop production. The significance of population density and sewage treatment effluent is more apparent for phosphorus.

• In 2000, agriculture accounted for 27% of serious and significant water pollution incidents – the largest single source. This compares with 17% caused by the water and sewage industries themselves (*Policy Commission on the Future of Farming and Food, 2002*).

Nutrient Inputs

Weeds, Invertebrates and Birds

Fertilisers have an essential role in agricultural ecosystems. Nutrient inputs are obviously designed to favour crop growth and hence certain 'weed' species may be suppressed by dense crops, quite apart from any adverse effects of high nutrient levels *per se*. Similar effects may also occur due to vigorous growth of relatively few weed species which can exploit such conditions, leading to loss of plant species diversity which may in turn affect invertebrate abundance and diversity (Kleijn & van der Voort, 1997; Wilson & Tilman, 1993). Dense growth of crops can also impede access to the crop and ground by foraging birds, and may be particularly problematic for young precocial chicks (e.g. partridges, pheasants, lapwings; Shrubb & Lack, 1991). Such problems may be exacerbated during cold, wet weather; chicks attempting to forage in, or negotiate, dense, wet crops may risk becoming soaked and chilled, although no evidence for such effects was found in one study of set-aside and permanent pasture (Poulson, Sotherton & Aebischer, 1998). Similarly, nests of altricial young under such conditions may take longer to dry out and re-warm, increasing risk of chilling to eggs and chicks. Agricultural chemicals also contribute to eutrophication of freshwater, estuarine and shallow coastal habitats, but the consequences are not always harmful. Depending on initial conditions and the degree of pollution, productivity may increase to the benefit of certain bird species (*Newton, 1998).

Earthworms

Edwards & Lofty (1982) studied the effect of different combinations of N fertiliser (farmyard manure, inorganic, liquid and solid sewage sludge and sewage cake) on earthworm populations in a wheat crop. They found a strong positive correlation between inorganic N addition and earthworm abundance over an application range of 0 to 300 kg N ha^{-1}, with plots that received both inorganic and organic N having highest earthworm populations (95 individuals m^{-2}, 110 g m^{-2}). However, the relationship between N addition and earthworm population density is not always clear-cut. Ma, Brussaard & Deridder (1990) found positive relationships between N addition rate and earthworm biomass for only 2 out of 6 fertilisers tested (organic-coated urea and ureaformaldehyde) in a grassland ecosystem. In the other treatments, 3 out of the other 4 formulations reduced soil pH with increasing N addition rate (by approximately 2 pH points over 7 years) creating sub-optimal habitat for earthworm populations.

Pesticides

Invertebrates

To say that pesticide application has an adverse effect on invertebrates (whether by direct mortality or the death of their food plants) is something of a truism (*Rudd, 1964), supported by numerous studies. Non-target species are often affected (*McLaughlin &

Mineau, 1995). Nevertheless, some authors also found that a few individual (usually common) species could become more abundant after pesticide application. It is usual for studies to find that organic systems result in greater densities of both arthropods and their favoured food plant groups than contemporary systems (e.g. Mäder *et al.*, 2002 for carabids staphylinids and spiders; Feber *et al.*, 1997 for non-pest butterflies; Hald, 1999 for food plants), although effects are often taxon-specific.

Earthworms

Not all pesticides are alike, and they vary in toxicity to earthworms; a field application of 10 kg ha^{-1} of Endrin would have a much greater effect than an equivalent application of Paraquat (*Edwards & Bohlen, 1992). In the context of this review, the most useful measures of the effect of pesticides on earthworms are population survivorship and reproduction parameters.

The most commonly used survivorship measure is the LC_{50}[9]. A large literature exists quantifying earthworm mortality in response to differing pesticides and exposures. Mostert, Schoeman & van der Merwe (2000) undertook such a study with three different pesticides and the earthworm *Eisenia fetida*. Vulnerability to adverse effects varied greatly between different pesticide products (e.g. after 21 days an Imidacloprid exposed population experienced the same mortality as a control population, whereas chlorpyrifos increased mortality by 24%). Pesticides also affect reproduction, which has a direct effect on population sustainability. Panda & Sahu (1999) exposed earthworms to single or double doses of malathion (producing soil concentrations of 2.2. and 4.4 mg kg^{-1}) and found decreased cocoon production relative to controls. However, they also found that 105 days after exposure, the earthworms resumed normal growth and reproduction, thus indicating that the timing of pesticide application under field conditions is crucial when predicting the effect of pesticides within an ecologically relevant context. A large-scale field-based investigation into the effects of reduced pesticide use on soil biota was carried out across three farms in the UK during the SCARAB project. Conventional levels of pesticide application were compared to a treatment with a 50% reduction. The treatments began in 1990 and results up to 1994 showed no ecologically significant differences between conventional and reduced pesticide plots in terms of earthworm numbers or species diversity. Substantial differences between farms were noted, but these were largely explained by differences in climate, soil type, crop type and cultivation technique (Tarrant, 1997).

Birds

Pesticides have been shown to have both direct and indirect effects on the abundance of chick-food for game and non-game bird species. Reduction in food for chicks is an important factor in the decline of farmland birds (*Campbell & Cooke, 1997; Potts, 1986).

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[9] LC50 (Lethal Concentration 50) is the amount of a substance that, over a specified period of time, is expected to cause death in 50% of a defined animal population.

The loss of raptors (and also fish-eating birds and seed eaters) due to poisoning by organo-chlorine pesticides (withdrawn from sale and banned) is one of the best documented incidences of direct pesticide effects on birds (e.g. Newton, 1986; Ratcliffe, 1970). Other pesticides known to represent a direct hazard to birds include alkyl-mercury compounds (withdrawn from sale and banned), carbamates and organophosphates; other problematic compounds include pyrethroids, polychlorinated biphenyls (banned but will still be released to the environment from a variety of sources, even though production has been stopped) and certain second generation rodenticides (some are restricted to professional use only) (*Newton, 1998). With respect to the latter, control of rodent pests on farmland can result in secondary poisoning of raptors and other species via the ingestion of poisoned (both live and dead) rats and mice (*Burn, Carter & Shore, 2002; Newton et al., 1999). Molluscides may also pose a hazard to some bird species. Evidence of population scale effects is currently lacking, but secondary poisoning is again a hazard (Dolbeer, Avery & Tobin, 1994; Shore et al., 1997). Indirect effects of pesticides on birds via their food supply is also well established, the best documented example being the widespread decline of the Grey Partridge *Perdix perdix* (Potts, 1986; Potts & Aebischer, 1995). No other species have been studied in such detail, but declines in other farmland birds are also likely to be linked to reductions in invertebrates, weeds and seeds due to pesticide use. Various studies have indicated links with both reductions in breeding success and problems with winter food supplies (Brickle et al., 2000; *Burn, 2000; Campbell et al., 1997; Evans et al., 1997; Moorcroft et al., 2002; *Sotherton & Self, 2000). Pesticide usage may also damage bird breeding success by reducing the availability nesting cover, by direct destruction of nests by machinery during application and by exposing existing nests to predation following the collapse of vegetation cover after spraying.

Genetically Modified Organisms (GMO)

Concern about GMOs relates to their effects on biodiversity and the contamination of foodstuffs. In terms of biodiversity, in 1999, the government asked an independent consortium of researchers to investigate how growing one kind of genetically modified (GM) crop might affect the abundance and diversity of farmland wildlife compared with growing conventional varieties of the same crops. It needed the results of this study to help decide whether to allow such GM crops to be grown commercially in the UK. In the largest ever field trials of GM crops in the world, the researchers compared GM and conventional varieties of four crops. The crops were winter-sown oilseed rape, spring-sown oilseed rape, beet and maize. The GM crops had been genetically modified to make them resistant to specific herbicides; they are called herbicide-tolerant (GMHT). In 2003, the team reported that there were differences in the abundance of wildlife between GMHT and conventional spring & winter rape, beet and maize. Growing conventional beet and spring rape was better for many groups of wildlife than growing GMHT beet and spring rape. There were more insects, such as butterflies and bees, in and around the conventional crops because there were more weeds to provide food and shelter. There were also more weed seeds in conventional beet and spring rape crops than in their GM

counterparts. Weed seeds are important in the diets of some animals, particularly farmland birds. The researchers stress that the differences they found do not arise because the crops have been genetically modified. They arise because these GM crops give farmers new options for weed control. That is, they use different herbicides and apply them differently. The results of this study suggest that growing such GM crops could have implications for wider farmland biodiversity. However, other issues will affect the medium- and long-term impacts, such as the areas and distribution of land involved, how the land is cultivated and how crop rotations are managed. These make it hard for researchers to predict the medium- and large-scale effects of GM cropping with certainty. The researchers stress that the differences they found do not arise because the crops have been genetically modified. The North American experience with oilseed rape and the devastation of organic rape production should serve as an impetus to Government to bring in prudent guidelines for separation distances as quickly as possible.
The report has 27 recommendations, which include concern expressed about possible contamination by gene flow and pollen spread of non-GM crops and insistence that the issue of liability be settled before any GM crops are allowed to be commercially grown in the UK. Moreover, liability should lie with the industry and not with farmers. It also states that biodiversity levels have slipped intolerably over the last fifty years and British Government has a duty to attempt to regain some of that lost ground, establishing a benchmark for biodiversity in conventional crops, at the less intensive end of the spectrum and organic crops. It is against this benchmark that future trials should assess innovatory practices and regimes in conventional agriculture. Furthermore, the Government and its advisory bodies are considered to be guilty of setting too low the level of harm. (Select Committee on Environmental Audit Second Report 5 March 2004). See also under Biodiversity.

Biodiversity

Ecological Impacts Of Arable Agriculture

This chapter makes an assessment of how arable agriculture has had an impact on ecological processes on the farmed land. The chapter is structured to show how each of six different factors (pesticides, nutrient inputs, tillage, intensity of land use, landscape structure and mitigation measures) have affected different taxa.

The important economic effects of ecological impacts are discussed in chapter Socio-Economic Impact under Key Findings - Ecological Impacts.

Fauna & Flora

Different arable cropping systems affect the landscape in different ways. This is especially important for birds, mammals and insects that move around in the countryside. Ecological benefits are shown to accrue from mitigation measures such as arable margins, beetle banks, conservation headlands and wild bird cover. These mitigation measures are normally carried out with the assistance of agri-environment scheme payments. (CEH)

Conventional farming in the UK has brought about considerable change in terms of the endemic flora and fauna, for example (Carruthers, 2003):

- Two-thirds of England's hedgerows were lost between the 1950s and the 1990s. Hedgerows were removed at a rate of 18,000 km per year between the 1980s and 1990s.
- Populations of almost all species of bumblebee have declined since the 1960s. Of the three species specifically studied, one is now considered extinct.
- More than nine-tenths of wildflower-rich meadows have been lost since the 1940s, plus one half of heath land, lowland fens and valley and basin mires, and one third to one half of lowland woods and hedgerows.
- Populations of nine species of farmland birds fell by more than one half between 1970 and 2000

Landscape Structure

Birds

In some studies, the structure and biodiversity of the surrounding landscape, or the crop type, were found to have more effect on field-inhabiting invertebrates than the farming system itself. The fact there is in most cases no attempt to quantify this variable may be significant.

3.31 Many species of farmland birds are highly mobile in the landscape and thus have the potential to access resources on a scale of kilometres rather than meters. Therefore, the overall abundance of resources and their patterns of distribution in the landscape will influence bird survival and performance (Eybert, Constant & Lefeuvre, 1995; Frey-Roos, Brodmann & Reyer, 1995; Mason, 1998). Resource abundance will itself be influenced by landscape structure, for example, small patches may be more vulnerable to extreme weather conditions and other edge effects which act to reduce patch resource potential (*Murcia, 1995). The location of patches will influence the costs of their exploitation in terms of time, energy and risk (Hinsley, 2000). Thus patches with good resources may be under-exploited if the costs of getting there outweigh the benefits. For breeding birds, estimation of costs will include consequences for parental, as well as chick, condition and survival (Hõrak, 1995;
Rytkönen, Koivula & Orell, 1996). Similarly, in terms of risk, exposure of patches may increase losses to predators and good patches may be under-exploited if their use incurs too high a predation risk (Newton, 1967; Suhonen, 1993). Therefore, landscape structure in general (not just that of the resources themselves) will influence bird usage. Factors associated with arable land-use likely to directly affect bird populations via landscape

structure include field size, availability and condition of field boundaries, especially hedgerows, and the availability and condition of other semi-natural habitat, including gardens and individual trees.

Birds will do best under any system that:

- Maximises the availability of semi-natural habitat in farmland (e.g. correlates with smaller field sizes);
- Maximises the quality of the semi-natural habitat that is available (e.g. minimal pesticide/herbicide usage, sensitively managed hedges of a range of structures, use of field margin habitat, conservation headlands etc.);
- Minimises the isolation of patches of semi-natural habitat;
- Supplies diversity in terms of both the semi-natural habitat available, and the
- crop types; and
- Supplies temporal diversity as well as spatial/physical diversity (e.g. so that food supplies and cover are not suddenly altered/removed at the same time over a large area).

In general, the concept of greater habitat diversity being associated with greater overall biodiversity and population viability is well established (*Wilson, 1992). Similarly, the benefits to birds of mixed farming are well known (e.g. Aebischer & Ward, 1997; Burel *et al.*, 1998; Evans *et al.*, 1995; Hurford, 1997; *Lack, 1992; *O'Connor & Shrubb, 1986; Robinson, Wilson & Crick, 2001). The minimum requirements of breeding birds are nest sites and foraging areas and for many species of farmland birds these are not located in the same habitat types. Similarly, requirements in winter differ from those of the breeding season, increasing the range of resource diversity required for population persistence. Any agricultural monoculture, be it arable or grassland, reduces habitat diversity and has the potential to damage bird populations. The effects of monoculture may operate temporally as well as spatially, for example causing rapid changes in resources availability depending on the stage of crop development or cultivation (*Holland *et al.*, 2002).

Habitat quality influences bird performance and survival, but in many cases is difficult to quantify in terms meaningful the organism in question (Dias, 1996). Overall species diversity (Boecklen, 1986; Mills, Dunning & Bates, 1991), breeding success (Hinsley, Rothery & Bellamy, 1999), territory occupancy (Matthysen, 1990; Newton, 1991) and survival (Hinsley, Bellamy & Newton, 1994; Watkinson & Sutherland, 1995) have all been used to quantify quality; in general, abundance alone is not a good measure of quality (Brawn & Robinson, 1996; Van Horne, 1983; Vickery, Hunter & Wells, 1992) and in extreme cases, the habitat currently occupied by a species may be a consequence of exclusion from preferred sites rather than the result of choice (Caughley, 1994; Newton, Davis & Davis, 1989), i.e. making the best of a bad job. Transient availability of nesting habitat may offer opportunities to some species, but will be of less (if any) value to sedentary species and specialists whose requirements include later/mature stages of vegetation.

Transient foraging habitat should be of use to a wider number of species, especially if widely available across the landscape. Factors influencing habitat loss include increasing field sizes and poor management (e.g. repeated ploughing of roots). Factors influencing quality (most of which have the potential to be positive as well as negative if properly managed) include patch size, management of woodland edges, hedgerows, field boundaries, ditches and tracksides, management of set-aside, spray and fertilizer drift, grazing by livestock, leaching of chemicals etc. into waterways and alternative uses of semi-natural habitat such as for recreation, shooting and game rearing.

Soil Microbiology

There is some evidence of greater biomass activity (basal respiration rate) and enzyme activity is greater during the grass-clover leys, than with arable cropping (Watson et al., 1996). It would be expected at activity increases dramatically during the ploughing and cultivation stage immediately after the ley phase. Periods of ley are likely to stimulate the population of mycorrhizal fungi (arbuscular) with associated benefits for plant nutrition, reduced soil borne diseases and improved soil structure (Mäder et al., 2000). Differences in microbiological communities in soils under different management practice (organic vs conventional) were subtle rather than dramatic (Shannon et al., 2002). There was a suggestion that soils under organic production had a greater physiological diversity. Accumulation of potentially toxic elements has been shown to have continuing effects on soil microbial biomass-carbon and population 40 years after the treatments were stopped (Abaye et al., 2005).
The earthworm population is affected by practices that perturb the soil or change organic inputs. Differences in earthworm numbers between organic and conventionally managed farms were inconsistent (Scullion et al., 2002). A conversion from conventional and organic farms has shown some benefits for floral diversity and number and species of butterflies (see http://www.sussex.ac.uk/Units/gec/pubs/briefing/brief-17.htm).
Mitigation Measures

Concerns about these losses in biodiversity led researchers to investigate how farmland habitats can be manipulated and managed to benefit wildlife. For example, conservation headlands were designed as a game management measure to prevent further declines in grey partridge (Sotherton, Rands & Moreby, 1985). Many of these mitigation methods have since been incorporated into agri-environment schemes which were introduced in the late 1980s to encourage farmers to restore and recreate habitats for wildlife on farmland (Haines-Young *et al.*, 2000; Anon., 2001, 2002).

Results of the most recent Countryside Survey indicate the length of hedges, which declined in England and Wales up to the 1980s, now appears to be increasing (Haines-Young *et al.*, 2000). Furthermore, cereal field margins are considered such an important habitat that they are now a Biodiversity Action Plan (BAP) Priority Habitat. The BAP target is to maintain, improve and restore by management the biodiversity of some 15,000 ha of cereal field margin in the UK by 2010.

Permanent field margins have received considerable research interest in terms of their role in the conservation of biodiversity associated with farmland. Many taxa have been shown to rely almost exclusively on field margins or hedgerows for at least part of their life cycle, including shrews and voles (Tew, Todd & Macdonald, 1994); farmland birds such as yellowhammer and whitethroat (Bradbury *et al.*, 2000; Stoate & Szczur, 1994) and arthropod predators of cereal pests (Sotherton, 1984, 1985). In a recent study by Meek *et al.* (2002) butterfly, bumblebee, carabid, spider, millipede and harvestman abundance was significantly higher in sown field margins and margins left to regenerate naturally compared to where the field margin had been conventionally cropped to the field edge. Feber *et al.* (1997) also found that non-pest butterfly abundance was greatest over uncropped field boundaries compared to the crop in both organic and contemporary faming systems. Whilst there is a substantial amount of evidence to show that where these mitigation measures are implemented within either contemporary or sustainable systems there are likely to be significant benefits to biodiversity (*Marshall & Moonen, 1998; *Marshall & Moonen, 2002), very little research has investigated whether there are any differences in terms of their effectiveness between different farming systems. Differences between farming systems in terms of intensity of management of cropped areas, pesticide use, crop rotation and quality and quantity of non-cropped habitat could all play a role in the effectiveness of these mitigation measures.

Organic farming is often cited as a model of sustainable farming, with sympathetic field margin management forming part of the 'whole farm' approach towards sustainability. The majority of research investigating the effectiveness of field margins between systems has focused almost wholly on comparing organic with contemporary farming the latter being perceived to be less sustainable.
Feber *et al.* (1997) investigated butterfly abundance on eight pairs of organic and contemporary farms in areas bordered by Dorset, Shropshire, Lincolnshire and Essex. Organic field margins were significantly richer in non-pest butterflies than field margins on contemporary farms. Reasons for this were unknown but may have reflected management differences between the two systems such as lack of spray drift or cropping pattern, or a greater abundance and diversity of food plants in organic boundaries. In another study conducted on 22 pairs of organic and contemporary farms across England and Wales, Chamberlain, Wilson & Fuller (1999) suggested the quality of field boundaries for farmland birds was greater on organic farms. Organic farms tended to have taller, wider hedges and field boundaries containing more trees which was thought to explain the higher densities of birds found using field boundaries on organic farms. Recent reviews have also suggested that the quantity and quality of non-cropped habitat on organic farms is greater than that on contemporary farms and field boundaries on organic farms support a higher level of wildlife (*Azeez, 2000; *Bartram & Perkins, 2002). However, Bradbury *et al.* (2000) showed that yellowhammer territories are associated with hedgerows and wide uncultivated grassy field margins but found no difference in breeding success between four organic and five intensively managed farms in the midlands and south of England.

These studies suggest that organic field boundaries are of superior quality and support higher biodiversity than contemporary boundaries. However, this has only been shown for a limited number of taxa and some of the studies were only carried out on a small number of farms. Further large-scale research is needed to test the generality of these results.

It is common for all farms other than organic to be labelled ‘conventional’ and to be seen as unsustainable. However, there has been an increase in the popularity of ‘integrated’ farming whereby farmers strive to reduce pesticide inputs. As with organic farming, management of field margins and other non-cropped habitats forms part of the ‘whole farm’ approach. Research is required to investigate whether there are any differences in terms of effectiveness of field margins between ‘integrated’, organic and ‘conventional’ systems. Obtaining a definitive answer to these questions is inherently difficult. Quantity and quality of non-cropped habitat and dominant farming type surrounding a particular study area may affect the colonisation of field margins by flora and fauna at that site. Furthermore, the effectiveness of field margins for biodiversity may differ with the length of time under which a farm has been organic or less intensively managed.

Conservation Headlands And Field Margins

Concerns about the decline of grey partridge in intensive arable farmland resulting from the direct and indirect effects of pesticides on invertebrate chick food first led to the concept of conservation headlands. Studies in the UK, Sweden and Finland showed that cereal headlands left unsprayed with herbicide and insecticide supported higher densities of weeds and arthropods, including those species important in the diet of game bird chicks (Chiverton & Sotherton, 1991; Sotherton *et al.*, 1985; Chiverton, 1994; Helenius, 1994). Furthermore, partridge and pheasant chick survival was higher on farms where unsprayed margins were implemented (Sotherton *et al.*, 1985; Chiverton, 1994). Following this research numerous studies have shown that conservation headlands also benefit non-game species (*Marshall & Moonen, 1998; *Marshall & Moonen, 2002). Research conducted in England and the Netherlands has shown that higher numbers of individuals and species of butterfly are found in unsprayed compared to sprayed headlands (de Snoo, van der Poll & Bertels, 1998; Dover, 1997; Sotherton *et al.*, 1985) and foraging activity by butterflies is higher in unsprayed headlands (Dover, 1997) also found that whereas spring emerging butterflies in fields without conservation headlands were associated with the pre-existing hedgerow margin, in fields with conservation headlands they were associated with headlands. However, Kells, Holland & Goulson (2001) in a study in the UK found greater numbers of foraging bumblebees in uncropped margins left to regenerate naturally than in conservation headlands. Where fertiliser was also excluded from conservation headlands in the Netherlands, Kleijn & van der Voort (1997) showed that endangered arable weeds can benefit as a result of increased light penetration. In another study in the Netherlands de Snoo *et al.* (1994) found that unsprayed headlands were visited more frequently than sprayed headlands by *Motacilla flava flava* (blue-headed wagtail) but no effect was found for *Alauda arvensis* (skylark) or *Anthus pratensis* (Meadow pipit). In a three-year study on two farms in Oxfordshire unsprayed headlands were preferred to sprayed headlands by the wood mouse *Apodemus sylvaticus*. Increased food availability in terms of higher weed and insect abundance was thought to influence this behaviour (Tew *et al.*, 1992).

All of these examples suggest that conservation headlands can benefit a wide range of taxa on intensive arable farmland. However, there has been no documented research to investigate whether there are any added benefits in terms of the effectiveness of conservation headlands where pesticide inputs are carefully controlled across the whole of the farm for example in integrated systems.

Beetle Banks

Many key invertebrate predators important in the control of cereal aphids over-winter almost exclusively in field boundaries, particularly on raised grassy hedge banks (Sotherton, 1984, 1985). Beetle banks aim to increase the proportion of over-wintering habitat for these invertebrates, and so enhance predator densities within cereal fields during spring and summer.

Studies in the UK (Hampshire & Leicestershire) and Sweden showed that beetle banks sown with tussock forming grasses support higher densities of predators than bare ground or banks sown with matt-forming grasses or left to regenerate naturally (Collins, 1999; Thomas, Wratten & Sotherton, 1991, 1992; Chiverton, 1994). These authors also showed that beetle banks sown with tussock forming grasses could support densities of predators similar to or greater than that found in contemporary field margins. Furthermore, in an experiment in Leicestershire, Collins *et al.* (2002) showed that invertebrate predators emigrating from a beetle bank significantly reduced numbers of cereal aphids in an adjacent crop of winter wheat.

More recently the value of beetle banks for other taxa has been examined. Beetle banks sown with tussock forming grasses on a game estate in Leicestershire were found to provide ideal nesting habitat for harvest mice (Bence, Stander & Griffiths, 1999). A study of 22 beetle banks and contemporary field margins from five farm estates in Hampshire & Wiltshire also found beetle banks to be a valuable source of chick food for farmland & game birds (Thomas, Goulson & Holland, 2000, 2001). Murray, Wilcox & Stoate (2002) showed that beetle banks were used as foraging habitat by skylarks significantly more than un-managed set-aside and broad-leaved crops. Moreover, although newly established beetle banks are generally less botanically diverse compared to contemporary field margins, diversity increases with age and banks over a decade old can be nearly as diverse as contemporary margins (Thomas *et al.*, 2002).

All these studies were either carried out on single estates or a small number of estates, covering a limited geographical area. There have been no direct comparisons of the effectiveness of beetle banks either in terms of wildlife conservation or for biological control across different farming systems. Nevertheless, it has been hypothesised that intensity of insecticide regime may affect carabid abundance and subsequent colonisation of beetle banks (Collins, 1999; Thomas *et al.*, 1992). Thomas *et al.* (2001) sampled invertebrates from beetle banks on farms managed for game and other environmental benefits; they found little variation in abundance between sites. However, once the experiment was extended to include a wide range of farm types invertebrate abundance differed significantly between farms. The authors suggested that this was due to differences in pesticide management between farms. These results indicate that further research is warranted to investigate the effectiveness of beetle banks under different farming systems particularly in terms of predatory invertebrates and the role of these habitats in biological control.

Wild Bird Cover

Wild bird cover mixtures were originally designed to provide habitat for game birds and are based on cereal or kale based mixtures. Cereal mixtures were designed to provide brood-rearing cover whilst kale provides winter cover. The majority of literature on wild bird cover comes from studies conducted on the Loddington estate in east Leicestershire where the aim is to integrate game and wildlife conservation with viable commercial farming. In a four-year study on this estate Boatman & Bence (2000) showed that set-aside sown with wild bird cover provides nesting and foraging habitat for pheasant and skylark and this habitat was preferred to all or most other available habitat on the farm. Murray *et al.* (2002) also showed that set-aside managed as wild bird cover is an important foraging ground for skylark and yellowhammer. Kale set-aside was used more by skylarks whereas cereal-based set-aside was better for yellowhammers. Butterfly transects carried out on the estate revealed that wild bird cover yielded more observations of butterflies than any other habitat (Boatman & Bence, 2000). Other studies conducted on the estate have shown that wild bird cover constitutes the main feeding habitat on the farm for seed-eating birds during winter and is a preferred habitat of brown hares (Boatman & Bence, 2000; Boatman, Stoate & Watts, 2000; Stoate & Leake, 2002). Following this research a three-year experimental project was conducted at Loddington, Leicestershire and two other estates in Norfolk and Hertfordshire to examine the value of a wider variety of crops which could be sown as a food source for birds in winter (Boatman & Stoate, 2002). Annual crops tested were barley, borage, buckwheat, fat hen, forage rape, linseed, millet, mustard, quinoa, sunflower, triticale and wheat. Biennial crops were kale, teasel, chicory and evening primrose. This research indicated kale and quinoa mixtures sown on set-aside would benefit the widest range of birds and addition of teasel would benefit goldfinches. However, larger buntings require cereals and addition of linseed would broaden the range of species attracted to this mixture. These mixtures also provide good foraging and nesting habitat for birds in summer (Boatman & Bence, 2000; Murray *et al.*, 2002). A variety of mixture types are therefore likely to provide the greatest conservation benefits for birds in both summer and winter.

This research has only been carried out on a small number of farms and covers a fairly limited geographical area. Much of this work has also been conducted on farms where there is a history of environmentally conscious management to encourage game. Further research is needed to test the effectiveness of this mitigation method under different farming systems.

The influence of agri-environment schemes

Agri-environment schemes began in the late 1980s with the first of the Environmentally Sensitive Areas (ESAs). Although hedgerow management and the reversion of whole arable fields to grassland were addressed from the beginning it was not until the introduction of the Countryside Stewardship Scheme (CSS) and the later tranches of ESAs that arable margins, and beetle banks were introduced on a large scale.

A sample of 51 CSS agreements were evaluated by a combination of desk study, survey and expert opinion against five criteria: agreement negotiation, appropriateness, environmental effectiveness, compliance and side-effects (Carey, 2000). Of relevance to this review were environmental effectiveness and compliance. The vast majority of the 51 agreements were expected to provide environmental benefit ecologically as they would provide habitats for invertebrates and small mammals and would provide protection for hedgerows and ditches. In some cases where management was to allow natural regeneration on light soils or where wildflower mixtures were sown there was expected to be benefit for flora and the nectar-feeding insects dependant on them. In the very great majority of cases it was expected, and indeed there was evidence that farmers would comply with the conditions of their agreement and carry out the management on the arable margins. The survey has not been repeated to see whether the expected benefits have materialized.

Currently a new agri-environment scheme is being devised by DEFRA and its advisors. In addition to the existing agri-environment measures it is expected that there will be a new entry tier for farmers with simple and proven management tasks to be carried out. For arable farmers this is likely to include field margins and buffer strips alongside streams and hedges as well as hedge management and the protection of trees.
If uptake is even close to the target then this new scheme is likely to have a large effect on the ecological quality of arable fields but more importantly the arable landscape. The effects will be widespread but as yet it is difficult to gauge how large the effects will be either on the countryside as a whole or even on a field per field basis.

A continuing debate within and outside DEFRA concerns whether agri-environment schemes provide ‘value for money’. In many cases the calculations for the savings to society of agri-environment over contemporary farming have not been carried out. Most economic activities affect the environment, either through the use of natural resources as an input or by using the `clean' environment as a sink for pollution. The costs of using the environment in this way are called externalities, because they are side effects of the economic activity and their costs are not part of the prices paid by producers or consumers. When such externalities are not included in prices, they distort the market by encouraging activities that are costly to society even if the private benefits are substantial (EEA, 1998; Brouwer, 1999; Pretty et al, 2000). Until the calculations are made on the true costs of farming on the environment are made including externalities (e.g. the cost of a pair of skylarks) it will be difficult to fully assess how one arable cropping system compares with another. There is a range of local, regional and global impacts. Atmospheric transport especially of nitrogen and carbon compounds, some of which originate from agriculture, means that origins of contaminants can be separated spatially from the point of impact.

Agronomic Impacts

Soil Physical Properties

Generally soil structural properties would be expected to be improved through the addition of organic matter (green and livestock manures and composted wastes) and the accumulation of litter and roots and especially polysaccharides that occurs during the ley phase. Recently formed organic matter is especially important for soil structural development, aggregate stability. The quality and quantity of organic patter added to soil is extremely important (Shepherd et al., 2002). Continuous cultivation is known to result in a reduction of soil organic matter and reduced aggregate stability and loss of soil structure. Recently a Soil Action Plan has been published for England (http://www.DEFRA.gov.uk/environment/land/soil/pdf/soilactionplan.pdf) see also

http://www.environment-agency.gov.uk/subjects/landquality/776051/775200/775473/?lang=_e). These consider a wide range of issues relating to the long-term sustainable management of soil. Guides are available for maintaining and improving soil structure. http://www.DEFRA.gov.uk/environment/land/soil/publications.htm#soilcode

Trafficability

Soil trafficability is highly soil and climate specific – whereby the majority of soils in Britain are of a clayey nature and which – given the high rainfall particularly in the western areas of the British Isles can lead to severe access problems to fields. Reduced soil organic matter contents and structural degradation can also reduce the number of 'machinery days' available. Although somewhat speculative, if there is a change occurring within the seasonal climatic pattern it may increase the frequency of wet years. This would influence trafficability and the period of time required for recovery of soil structure, particularly for crops such as potatoes. Localised areas that suffer heavy trafficking such as headlands, gates, feed areas and tram lines further represent significant sources of potential surface runoff and erosion.

Soil Resistance To Root Penetration

Ploughing and subsequent cultivation is widely practiced in the UK as this allows regular mixing of the topsoil to reasonable depths – whereby no-tilling is not usually practiced in the highly-mechanised, 'industrial' approach to farming on the mostly heavy soils of Britain. Apart from specific cases where plough pans have been allowed to develop and in those areas with heavy trafficking, most soils allow good root penetration.

Soil Water Fluxes & Content

As most soils in the eastern lowlands of the British Isles are based on clay and silt, drainage is of considerable importance. This also applies to the usually poorer soils of the western highlands which are often based on peat.

Reduced amounts of soil organic matter has occurred in some soils under tillage. This can reduce the water holding capacity of soils and lower potential yields. There are possible implications in soil water management and climate change, if either the amount, distribution or intensity of precipitation changes. Reduced surface infiltration rates caused by deterioration of soil structure would result in a faster runoff response and large volumes of overland flow. This situation could increase soil erosion and the loss of associated contaminants and contribute to flooding downstream.

Soil Chemical Properties

A considerable amount of information is known about the chemical properties of UK soils (see http://www.afsni.ac.uk/Research/Project.asp?Project=ga9831 for a recent summary of data available for Northern Ireland).

Nutrient Dynamics (N, P, K)

There are two aspects that relate to nutrient supply, timing (synchronising nutrient supply with nutrient demand) and a balanced supply, both of which present major challenges to organically managed systems. While fertilisers have been formulated to have a wide range of nutrient concentrations and high solubility, livestock and manures, the main source of nutrients on organic farms, is much less predictable with respect to its composition and nutrient availability.

The calculation of nutrient balances is increasingly used as an indicator of efficiency. While it is relatively straightforward to quantify the amounts of major nutrients added in compound fertilisers, it is much more difficult to determine accurately the two main sources in organically-managed soils i.e. manures and biologically fixed nitrogen. Not only is the total amount difficult to quantify but also the rate to which nutrients become available to plants. The species/chemical form that nutrients are present in is very different and much more variable in manures. The amount of N fixed depends upon factors such as legume species and planting density, age, and external environmental conditions (temperature, moisture). Estimates of N fixation vary widely up to 500 kg ha^{-1}. Potassium is one of the major elements that can show a negative farm balance within organic systems. Recently Fortune et al. (2004) tested the supply of various mineral and organic forms of K using a grass/clover mix.

Manure management is important in most agricultural systems and especially in organic ones where it often represents the main source of nutrients. Importation of manures from non-organic farms is allowed provided it originates from ‘ethical’ sources and livestock that have not been fed on a diet containing genetically modified organisms. While composting can reduce the level of diseases and weed seeds present in manure, it also reduces the availability of nutrients present.

It is considered that despite the difference emphasis on sources and management of nutrients the underlying processes related to nutrient cycling are essentially similar (Stockdale et al., 2002) it is the relative emphasis that differs between systems.

An *Annual Survey of Fertiliser Practice* provides comprehensive information on inorganic fertilizer, lime and also organic manure use in mainland Britain. It was based on an annual sample of about 1500 farms, selected from the Agricultural Census and stratified by farm type and size and have been recently summarised (Chalmers, 2001). http://www.statistics.gov.uk/STATBASE/Source.asp?vlnk=873&More=Y

pH

There is some evidence that soil pH values have declined over the 25-year period of *The Representative Soil Sampling Scheme of England and Wales*, which started in 1969 (Skinner and Todd, 1998). Mean soil pH values under arable and ley-arable cropping changed little, but under grassland they fell by 0.3 units. Wales and the West Country had the lowest pH values; these regions together with the Northern region were also found to have declining pH values.

CEC

The CEC and base saturation is usually adequate in most UK soils. The loss of CEC with decreasing organic matter may represent an issue, especially if there is some link with aggregate stability and dispersitivity. Maintaining an appropriate K/Mg balance for pasture is important.

Pathogens

All livestock manures represent a major source of pathogens, and inappropriate spreading and poor storage and management around farm buildings can increase the risk of contamination. There are local health implications for private water supplies and possible downstream effects, such as bathing waters. http://www.environment-agency.gov.uk/yourenv/eff/water/213925/bathing/?lang=_e . Research funded by DEFRA and SEERAD have demonstrated for a number of catchments, that significant loadings of faecal indicator organisms can originate from agricultural sources and add to those from other human sources (such as effluent from sewage treatment works and septic tank overflows).

Crop Yields

Watson et al. (2002a) state that the total value of UK organic production in 2000/01 was £97 million. The approximate distribution of certified organic land is 81% rough grazing and permanent pasture, 9% is temporary ley, 7.5% is in arable production and 2% is used for horticultural crops.

Berry et al. (2002) discuss some of the reasons why organically managed systems yield less than conventional systems. It is often considered that N is commonly limiting despite often positive N balances and considerable amounts being added through manures and fixation. They suggest there is a problem with synchronising the timing of N transformation processes and plant requirement. This could be particularly problematic for early developing crops, such as winter wheat.

Cover Crop And Residue Management

Various fodder or green manure crops are used in addition to white clover-grass leys, these include, other types of clover, lucerne, vetches, lupines and trefoils, the relative success depends upon climatic and soil constraints. The use of cover and catch crops can be advantageous to all farming systems as it helps to reduce nitrate leaching and conserves nutrients. Types of catch crops include mustard, stubble turnips and rye.
The composition and amounts of nutrient contained within crop residues vary widely, but can be substantial for some vegetables. The composition, especially lignin content and C:N ratio influence the potential rate of decomposition and mineralization (Berry et al., 2002). The scope for using cover crops is considerable, with the potential to reduce NO_3 leaching (Lord et al., 1999).

Weed Management

Generally continuous cultivation is not encouraged in Organic systems, crop rotation helps with reducing weed populations. Using crops having different growth characteristics requiring different timings of cultivation can help reduce weed populations (Liebman and Davies 2000).

Pest And Disease Management

Reduced incidents of pests and diseases are usually associated with increasing time between susceptible crops within the rotation (Clark et al., 1998). Appropriate composting can reduce the amounts of pests, diseases and weed seeds introduced by application of manures.

Selection of Varieties

There is probably scope to make improvements to the choice of crop varieties available, since most have been selected to perform under conditions typical of conventional agriculture. Foulkes et al. (1998) suggest that modern varieties of winter wheat were less efficient at utilising soil N when grown under conditions of high N availability. Further Information may be obtained from the Rural Economy & Land Use programme (RELU) http://www.relu.ac.uk/.

Socio-Economic Impact

The success of modern agriculture in recent decades has often masked significant externalities (actions that affect the welfare of or opportunities available to an individual or group without direct payment or compensation), which affect ecosystem services and human health, as well as agriculture itself. Environmental and health problems associated with agriculture have been increasingly well documented, but it is only recently that the scale of some of these costs has come to be appreciated (Pretty 2002).

Farming is widely understood in terms of its economic performance, and public perception of farming is defined by the following UK statistics (Carruthers after DEFRA):

• Total income from farming (2002) - £2.36 billion
• Contribution to national economy (2002) – 0.8%
• Public expenditure (2002/3 forecast) - £3.12 billion

Environmental Health Costs

A conservative estimate by researchers at the University of Essex of the external environmental and health costs of farming in the UK put the bill at around £1.5 - 2.0 billion per year, broken down as below.

Table 7: Estimated Annual Costs (£) Of Environmental And Health Impacts Of UK Agriculture (*after Pretty, Agri-Culture, 2002)*

Impactor	Estimated Cost
Water pollution	231 million
Atmospheric pollution	444 million
Soil damage	96 million
Biodiversity and wildlife losses	27 million
Hedgerows and drystone walls	99 million
Human health costs (inc BSE & CJD)	777 million
TOTAL	**1,674 million**

Organic Farming as a "Brand"

Within the fields of economic development and the wider political sphere, there is a concept that has some currency, that organic/conservation agriculture can (and should) be developed as a "brand" serving a small specialist market while the bulk of food production continues to follow the now conventional model. This concept is based on an analogy with the systems of production of manufactured consumer goods (as for instance, most people wearing mass produced clothes manufactured at minimal cost while a few wear hand tailored garments.) Such an analogy appears fallacious as it does not take into account the intrinsic difference in context between primary production and manufacturing. Farming operates within a direct context of natural phenomena to a greater degree than any form of secondary production. One significant effect of this is the degree to which the chosen methods of one farmer can impact on neighbouring holdings.

Part of the thinking behind the niche market concept, mentioned above, is the assumption that non-conventional systems necessarily have lower yields per hectare. If lower yields are indeed inevitable in sustainable systems the question still needs to be asked if this inevitably means lower returns on investment, which in turn raises the question of how costs are to be calculated – e.g. should we continue only to count costs born directly by the producer? Ultimately someone has to meet the costs of "un-sustainability". Niche-marketing in the case of organic produce has assumed a premium on sales, being dependent on increasing demand, but recent increases in the supply of organic produce have removed much of this advantage.

Organic farming is under the same market pressure of low prices, as conventional farming, to increase in scale, to compensate for lower unit profits with larger acreages and livestock numbers. The "brand" concept of organic food may be compatible with a more industrial scale production but is sustainability. Even the organic "brand" image is threatened by growing consumer scepticism arising from imported organic food and comparatively intensively produced products; for example supermarket-sold organic and free-range eggs, that are still bad eggs (in terms of taste) compared to eggs from traditional extensive methods. *(See: "Getting Connected" John Harvey article on 2004 conference 'Re-connecting the public with agriculture' in Organic Farming; Issue 81; Spring 2004; page 22-23)*

The UK Organic Market

The UK organic market has increased rapidly over recent years with growth rates of 30 to 50% per annum. Sales in 2000-2001 amounted to £802 million, up by 33% on the previous year. 2001-2002 sales are predicted to be up a further 20% to over £950 million. By the end of 2001 organically managed land accounted for 2.5% of all English farmland, over the whole UK, 3.9% is under organic management (taken from DEFRA http://www.DEFRA.gov.uk/farm/organic/actionplan/prospects.htm). Secretary of State, Margaret Beckett MP proposed that the sector could experience a three-fold increase - taking it from 3% of UK agriculture to around 10%. Others propose a more ambitious target of 30% of production and 20% of the retail food market organic by 2010 (http://www.sussex.ac.uk/Units/gec/pubs/briefing/brief-17.htm has some comparative economic data).

Growth rates have been dramatic, but organic still represents a small proportion of the total food and farming sector and many factors influence supply and demand. Predicting and managing growth in these conditions is difficult, a few more producers in one sector can result in a significant increase in available organic product; exchange rates and better conditions in some countries make organic products cheap to import.

The market for organic food is a vital component for delivering the benefits of organic production, but reliance solely on the market ignores the public good elements. Though organic can be regarded as a 'niche' food sector, from a policy point of view, organic farming is an agri-environmental scheme - with taxpayer support justified through the 'public' goods delivered. No other agri-environmental measure expects environmentally friendly farming to be supported by the market. Why should a small minority of consumers be expected to pay for all the benefits that accrue to society from organic production?

In a consumer-led market experiencing rapid growth, there has been a tendency to ignore the importance of market development as a component of the policy mix, which has tended to focus on supply-push policies. Under prevailing conditions, demand-pull policies are also important; supply-push policies for agri-environmental outcomes can have a disproportionate impact in some sectors and less in others - market imbalance and instability can be the result.

The Organic Action Plan for England aims to identify what is required to ensure stable and strategic growth for the organic sector whilst increasing farmers' share of the market for organic produce currently imported.

The following section provides an overview of the policy actions required to achieve sustainable growth of the organic sector, as far as possible from our own resources.

The prospects for growth of the organic sector depend on many factors - including the state of conventional farming and the continuing market for organic food. Six priorities for action are relevant to the whole sector:

1. Appropriate support for organic conversion and organic stewardship - valuing the wide-ranging benefits of organic farming;
2. Strategic development of the production base to overcome imbalance in the sector - between arable, horticulture and livestock, animal feed and seed production;
3. Infrastructure development to facilitate local and independent production, processing and marketing, as well as provision of better, shorter supply chains into multiple retailers;
4. Market development - informative labelling and generic promotion, supportive retail chains, public procurement;
5. Information for producers and processors that is relevant, timely and reliable - through research, knowledge transfer and demonstration;
6. Public awareness - using organic farming to connect the public with the farming community through the promotion and branding of organic food.

Rapid Expansion Of Organic Produce Supply Base

Table 6 shows the different types of land use on England's organic farms. Compared with the organic-UK as a whole, England has a higher proportion of organic arable, temporary ley, vegetable crops and orchard, whilst only half of the total area of organic farmland is rough grazing and permanent pasture in England, substantially less than in the UK as a whole.

In December 2001 (UKROFS data), almost 4000 managed 680,000 Ha of land organically (39% of this is in conversion and 61% fully converted) - equivalent to 3.9% of UK farmland and an increase of 29% year-on-year. The majority (90%) of organically managed land is grassland, most as rough grazing and permanent pasture. Overall, England accounts for 32% of organically managed land (converted and in conversion) in the UK; Scotland 60%, Wales 7% and NI 1%. Table 8 shows the increase in organic production in England and the UK between 2001 and 2003.

The area of fully converted land increased rapidly during 2001 as conversion completed on large areas of land entered into the new Organic Farming Scheme in 1999, by December 2001 almost 50% of the organic area in England had converted through the OFS. In April 2002 a total of 1,750 OFS agreements covered 158,735 Ha. In England the area producing organic crops and livestock increased by a factor of 2.6 and in Wales by 3.4 between 2000 and 2001. This sharp rise in availability of organic product has inevitably led to real marketing difficulties for farmers in some sectors, with considerable pressure put on organic prices and leading organic producers to sell a proportion of their milk, potatoes and livestock as conventional rather than organic.

Further expansion of the sector in England will depend on and contribute to developments in Scotland, Wales and NI, as well as other countries in Europe. Most importantly, expansion must be closely linked to the development of the organic market. Effective co-operation from the producer and through the supply chain is essential to ensure security. This has been very clearly demonstrated in those sectors where a rapid increase in supply has not found an organic market.

Cost Of Production - Returns Through The Supply Chain

The recent marketing problems in several organic sectors are not only the consequence of sudden increases in the supply base (a 'boom and bust' cycle), important though this undoubtedly has been. Current exchange rates make the problem worse, with imported products more profitable to retailers; additionally costs of production of many organic products are lower and conditions for growth better in other parts of Europe and the world than in the UK.

The financial return to each partner in the supply chain, from farmer to retailer, varies in each sector and with the specific product supply chain. Producer costs and prices are generally relatively transparent with the organic price paid to the farmer nominally reflecting the increased costs of the stringent organic production system (falling organic prices are significantly eroding returns to producers). However, returns to other parts of the supply chain are not transparently considered, why should a consumer pay 25-30 p more for a litre of organic milk when the producer, responsible for the organic part of the process can not even get a 10 p per litre premium? Better understanding of the costs and returns to all parts of the supply chain is essential to underpin secure and sustainable supply chain relationships.

There is immense pressure on retailers to import organic produce in a bid to bring down prices to consumers - this has resulted in downward pressure on prices paid to organic farmers in England and the rest of the UK, consequently a proportion of producers have barely covered their production costs. This is clearly unsustainable and the position has been made worse by the buying behaviour of some supermarkets, which has provided little or no security to UK producers; whilst there has been little effective co-operation, and even hostile competition amongst organic farmers. With conventional farmers facing the hardest conditions (including the Foot and Mouth crisis) and lowest prices ever, there is a further downward pressure on prices - the organic sector is similarly affected.

This has led many in the organic (and conventional) sector to emphasise the need for a fair and sustainable price that reflects the full cost of production and provides an adequate return to the producer. However, defining organic production costs at enterprise and whole system level is not straightforward. Costs can vary widely between regions, farms, over seasons, with the level of technical and management ability as well as with the level of investment and the availability and cost of labour. The organic farmer may also be subject to greater variability in yield and quality - being more dependent on climate, soil type, nutrient management and the technical and husbandry ability of the organic farmer compared to the conventional. Further work is needed to define a fair price and to determine commercially viable contracts that provide security and flexibility to all parties.

Whilst current exchange rates prevail, providing sustainable prices and attractive markets for UK producers is a priority. We must find ways to emphasise the importance of the origin of a product; defining and communicating the benefit of buying from UK producers is central if a greater share of the organic market is to be captured by our farmers. This in turn will ensure that we all benefit from the 'agri-environmental' outcomes of the policy measures.

Prospects for Growth

With the dramatic growth rates of the organic sector to date, continued increase in production and market share seem inevitable, but the rate and limits to growth vary by sector and are inevitably hard to predict or control. The situation in other European countries, as well as around the world will be of continuing importance where import of organic food to the UK continues. However, with effective communication and enforcement of a retail policy focussing on supply from our own resources, continued and sustainable growth could be secured even in the face of significant increase in production in other countries, many of which are traditionally orientated around export of their production.

Support for organic farming is primarily justified because of the agri-environmental or public benefits achieved through the production system. For this support, and to ensure that any growth is sustainable targets for growth across all sectors must agreed and linked to effective action for market development.

Since it is inevitable that the organic consumer will pay a higher price for organic than conventional products, it will become increasingly important that better information is provided to existing and potential consumers as to the benefits (from an agri-environmental point of view) of organic farming. This will be one part of a more co-ordinated approach to marketing that is clearly essential if the organic opportunity is to be captured.

Organic farming is not evenly spread throughout the countries of the UK, and is also regionally patchy, whilst the market also varies, reflecting demographic differences. The majority of organic farmers are in the southwest region of England. The prospects of growth overall, and in specific sectors is closely linked to the regional variation within and between the countries of the UK. England has many advantages for organic sector development and these must be fully exploited.

The proportion of the UK organic market supplied from imports amounts to approximately 70%, in contrast roughly the same proportion of conventional food in the UK is supplied from UK producers. There is clearly an opportunity to supply a considerably greater proportion of the demand for organic food from our own production base, not only will this support an expanding sector, also it will ensure that the agri-environmental benefits of organic production accrue to the UK. Table 6 shows estimates for the proportion of conventional and organic farm products supplied by UK producers in 2003.

Horticulture

The most important organic category for many consumers, fruit and vegetables must be supplied year-round, whilst retailers place an emphasis on cosmetic quality and obviously price. Fruit and vegetable production in the UK is generally rather ignored by policy, and the sector has never received the level of support seen in other areas of agriculture. Furthermore, many types of fruit and vegetable either can't be produced in the UK or are not suited to year round production. Consequently imports of organic fruit and vegetable crops predominate, whilst existing intensive conventional horticulture systems can be rather hard to convert to organic management.

To avoid uncertainties, a commitment to purchase UK organic fruit and vegetables will provide an important opportunity for growers in England where there is already a significant area of horticulture and top fruit production with some of the best conditions in the UK.

Even where crops can be grown in the UK, we are still importing substantial amounts of organic produce. This is particularly true in the case of fruit, where the costs of the establishment of organic orchards can be particularly high. However, there have been considerable increases in some organic vegetable crops (for example organic potato production has increased rapidly over the past few years) leading to supply exceeding demand during the year, particularly where imported produce has been available at a competitive price. Table 9 shows the area of key organic fruit and vegetable crops in England in 2002.

This opportunity will require a co-ordinated approach to exploit if a 'boom and bust' cycle is to be avoided. The importance of this is emphasised by key production issues in organic horticulture - notably organic seed production and crop quality (including pest and disease management) demand research and development. Furthermore, the 25% increase in horticulture land completing conversion over the next year (mostly in England) will require effective and co-operative supply management.

Livestock

Generally hill and upland conversion has been over-represented, with a disproportionate rate of conversion relative to the lowland. This has resulted in insufficient availability of lowland organic farms able to finish the large numbers of cattle and sheep - particularly with the large areas of hill and upland due to complete conversion over the next year. This is particularly relevant for England, where there has been little conversion of farms appropriate for stock finishing (often largely arable farms in central and eastern England) where there might be considerable agri-environmental benefit arising from organic management.

Table 8: Market share of home-grown produce in conventional and organic sector (2001- 2003)

Sector	**Current UK* conventional market share** **%**	**Current UK* organic market share** **%**
Dairy	99.6	65
Meat – Cattle Sheep Pigs Poultry **Average**	71.5 65.5 58.5 80.0 69.0	55
Eggs	87.5	90
Arable Cereals	87.0	60

Human Cereals		20
Fruit Vegetables **Average**	8.0 65.0 36.5	15
Baby Food	?	50
Total home-grown	**74.7**	**30**

*Conventional data based on volume (tonnes), organic data based on value (£)
Source: Action Plan Group estimates derived from DEFRA, Soil Association, and HDRA

It is only over the past five years that a significant premium for organic livestock products has been achieved, and this has been mainly because conventional prices collapsed - previously, organic livestock producers relied on conventional prices, only organic crops commanded a higher price than conventional. Marketing problems have emerged for livestock farmers, with buyers using lower conventional prices to 'talk down' the organic price, whilst the retail price to the consumer has remained little changed.

Table 9: Area of organic fruit and vegetable crops in England - April 2002

Crop	England organic Ha
Potato	1,252
Cabbage & other brassica	555
Onion & leek	219
Carrot	127
Top Fruit	811
TOTAL	**2,964**

Source: Certifying Bodies

Effective organic marketing of the whole animal - not only the best cuts and joints - is also increasingly important, but appropriate organic markets for the cheaper cuts rely on large volumes, keen prices and good service. Thus although headline prices for organic meat may be high, the farmer must sell the whole animal reducing the return.
For organic dairy producers a sharp rise in organic milk supply in 2000-2001 led to fierce competition, whilst the conventional milk price was also falling whilst demand had not increased in line with supply. The lesson from the organic milk story must be applied to

the developing supply side surplus of beef and sheep to avoid a further fall in organic farm incomes in an already hard pressed sector.

Organic poultry production has reached higher levels of penetration than other livestock, however, maintenance of this position, as well as continued development will depend on the resolution of key issues of standards - relating to feed and production system for both egg and poultry meat production.

As in other production sectors co-ordinated supply chain management of organic livestock will be crucial to success.

Arable

With the overwhelming proportion of organic land in grass, and most in permanent and rough grazing, it is not surprising that there is a relative shortage of organic arable production, particularly in view of the importance of arable crops for livestock feed and human consumption.

Table 9 shows the area of key arable crops in England in 2004. The strategic development of this sector must be carefully managed, but the potential benefits (both in terms of crop production and in provision of suitable organic farmland in a ley-arable organic rotation suited for finishing beef and sheep) could be substantial. Although England has the largest proportion of conventional arable land in the UK (42%), organic arable production in England is significantly underrepresented (13%). However, England already has almost double the proportion of organic arable land compared to the UK whilst there is more than three-times the area of organic temporary ley. Clearly there is scope for achieving higher levels of UK production of cereal and pulse crops, and England organic arable production could contribute to this substitution of imports. More importantly the organic conversion of these types of farm would also secure considerable benefits for England from an agri-environmental point of view.

Table 10: Area of organic arable crops in England - April 2002

Crop	**England organic Ha**
Wheat	6,501
Oats	2,335
Barley	3,021
Triticale	1,753
Beans & peas	2,887
TOTAL	**16,497**

Source: Certifying Bodies

Costs & Profitability

General Insights

Studies are considered in respect of the differences between contemporary and alternative systems rather than their absolute levels of performance. Where possible, three criteria are used to compare the systems:

- Yields and profitability
- Input usage and environmental impacts
- Social impacts

There is a vast literature studying different aspects of farming systems around the world, and this literature provides some general insights that are relevant to socio-economic, social and environmental impacts of different cropping systems. There are many different factors that influence the farm-level profitability of particular systems or system elements. Pannell (1995) grouped them into five categories:

(a) Short term profit factors (e.g. crop yields, output prices, input costs)
(b) Dynamic factors (short to medium term) (e.g. impacts on subsequent crop yields due to current fertilizer use, weed control, tillage method, crop disease)
(c) Sustainability factors (e.g. pesticide resistance, soil degradation)
(d) Risk factors (e.g. yield variability, price variability, system flexibility, the farmer's attitude to risk)
(e) Whole-farm factors (e.g. machinery capacity, finance availability and cost, labour, the farmer's objectives, knowledge and experience.

As a result of variation in these five factors, the economic performance of particular farming systems or system elements often varies widely among farmers in a region, and even more so between farmers of different regions. This means that caution is needed in drawing general conclusions about the performance of any particular system. As a generalisation, given sufficient time and experience, commercial farmers are reasonably successful at identifying which systems are suitable for them under current conditions (*Lindner, 1987). *It is not wise to expect that scientists or others without considerable [practical] farming experience and highly detailed site-specific knowledge of a farm can prescribe practices that would be more successful at meeting a farmer's personal objectives than the farmer's or his agronomic advisor's own choices* (quote highlighted by writer of the present paper).

When considering different possible rates of application of farming inputs to a crop, there is often a reasonably wide range of input levels either side of the economic optimum that give only slightly lower profits (Anderson, 1974). In other words, there is often a wide margin for error, and scope for flexibility in choosing input levels, without substantially reducing profits.

As market prices and/or the level of price support under the CAP vary, economically optimal input levels will vary accordingly (*Dillon, 1977). While price support remains high, there is a tendency for low input systems to be relatively economically disadvantaged, particularly in those systems that do not attract market premiums on account of their environmental or health benefits. However, as noted above, the actual economic performance depends on a multitude of factors and it is possible for low input systems to compete economically if they have other advantages to offset their typically lower yields.

Where a relatively profitable farming system generates adverse impacts on the environment or human health, more is required than simply quantification and communication of those impacts in order for farmers to act decisively to reduce those impacts. Specifically, legal or financial tools are needed to create incentives for change (Cary & Wilkinson, 1997; Pannell, 1999).

Work is currently being carried to identify the "economic footprint" of farm systems; however, results of that analysis are not yet available.

Gross margins for individual crop or livestock enterprises can be a misleading indicator of their profitability within the farming system, or their different levels of profitability in different systems. For example, livestock may appear unprofitable if viewed as an individual enterprise, but provide complementary benefits to the cropping enterprise by rotational benefits of including pastures (Pannell, 1987), or by providing a degree of weed control. Legume crops or green manure crops may provide nitrogen to subsequent cereal crops (Gladstones, Atkins & Hamblin, 1998). In such cases, gross margins should be compared for whole rotations, rather than individual crops.

Farm Incomes

Total income from farming (TIFF) has fallen to its lowest level since entering the Common Agricultural Policy. In the short-term, financial pressure on farms is the result of a combination of events, which have led to the very steep decline in farm incomes since 1996. Farm incomes in the UK are now as low (in real terms) as at any time in the last thirty years. Incomes have fallen by 60% since 1995 (after doubling between 1990 and 1995). This steep fall in incomes reflects a combination of adverse factors, i.e. an exchange rate which is high by historical standards; weak world markets in a range of commodities; and the effects of the BSE crisis, foot & mouth disease and other food scares.

The fall in incomes has affected all types of farms and all regions in the UK, although to different degrees. For some farmers, the impact of the downturn has been cushioned by other sources of diversified income. At least 25% of full-time farmers in England have diversified incomes and for these farmers this diversified income is worth slightly more, on average, than the income earned from farming. But diversification is far easier in some areas than in others; in particular, in more accessible parts of the countryside or in areas with leisure potential (Farm Income_2005 on http://statistics.DEFRA.gov.uk/esg/reports/repfi.pdf).

Estimates of net farm income and cash income for farm businesses in the UK in 2004/05 are provided by the annual Farm Business Surveys conducted in England, Wales and Northern Ireland and the Farm Accounts Survey in Scotland. A new classification of farm types was introduced in 2003/04 which has caused some changes to nomenclature. Further details on farm classification may be found at http://statistics.DEFRA.gov.uk/esg/pdf/farmclass.pdf . The lower size threshold for the Farm Business Survey was also changed from 8 European Size Units to 0.5 Standard Labour Requirements (in annual full-time equivalents).

- Average net farm income for full-time farms is expected to decrease by 29 per cent overall between 2003/04 and 2004/05. Cash income is expected to decrease by 5 per cent.
- Incomes for dairy farms are expected to remain broadly similar or increase slightly compared to last year. Output on dairy farms will be bolstered by the introduction of the dairy premium in 2004, although this is partially offset by higher costs.
- The decreases in net farm income and cash income for LFA cattle and sheep farms between 2003/04 and 2004/05 are mainly due to a small fall in livestock output combined with a similar increase in costs. Output has fallen due to lower prices for some classes of cattle and sheep whilst inputs such as fuel, fertiliser and depreciation have increased.
- Incomes on cereal and general cropping farms are forecast to be considerably lower for 2004/05 compared to 2003/04. This is due to lower commodity prices from the 2004 harvest, particularly cereals and potatoes, as well as increases in key inputs such as fuel, fertiliser and agrochemicals. Revenue from arable area payments is also expected to have fallen in 2004/05.
- Incomes on pig farms are forecast to decrease reflecting a slightly lower pork price over the twelve months and higher costs. Specialist poultry incomes however are expected to rise, largely due to the increased value of eggs.

Direct Margin

Pressure on farming arises especially from the income situation - on one hand leading to a dual structure of large commercial farms dominating the production of food, and the majority of farms which partly support pluri-active and pluri-income farm households. The latter survive mainly through off-farm work, but also through diversified policy supports, on-farm activities, and pensions and social welfare supports. This is added to by increasing demographic changes, and especially differential migration in terms of age and skills – as well as a reproduction-failure, i.e. no succession is ensured where farms are small or poorly located.

Changes also are evident in upstream and downstream industries to agriculture which are increasingly oligopolistic, with global sourcing, relying on contracts with large commercial farms.

Consumers demand greater food safety, animal welfare codes, labelling and traceability, often leading to greater bureaucratic requirements while Environmentalists and environmental legislation are concerned with pollution of water and air, biodiversity, and landscape changes. Pressures are also being exerted from recreational and general interests demanding greater access to land, especially in Less Favoured Areas (LFAs) and there is a demand on farmers to change their operational ‘productivist’ paradigm towards a more holistic approach to farming (i.e. sustainable agriculture, conservation farming, organic farming).

Increasing global competition and changing agricultural, regional and rural policies and practices regarding public services including transport, telecommunications, housing, health, education which often impact particularly severely on rural areas, and especially the less well-off and less mobile people (JM Bryden, 2000).

As biotechnology will lead to productivity increases through factor saving effects (labour, land, energy, water), not only is it expected to accelerate the trend towards fewer and larger farms, but will also aggravate existing surpluses in certain agricultural commodities. Thus, biotechnology is capable of exerting a considerable influence on agricultural employment. Even in highly industrialised countries with low rates of agricultural employment, concern about expected negative employment effects of agriculture biotechnologies has stimulated the rise of countering powers to limit their application. (JM Bryden, 2000).

Low-input systems

Research into low-input arable systems was initiated in the UK at the end of the 1970s after a decade of increasing pesticide use in cereals. This period had seen a decline in invertebrate populations in cereal crops in Southern England and a link was considered possible.

The general conclusion that can be drawn from the UK studies into low-input arable systems is that reducing pesticide rates is likely to be economically viable in certain crops, notably cereals. However, profitability is influenced by numerous factors such as cost of inputs, market value of the crop, rotation system, location, soil type and agronomic factors. Furthermore, a high level of site-specific management and knowledge are of prime importance. Reducing input levels is likely to become increasingly financially viable if the economic squeeze on arable crop prices tightens.

Input Usage And Environmental Impacts

All of the systems in this category involved moderate reductions in pesticide use. Other inputs where maintained at levels comparable to contemporary practice.

No studies of the implications of Low-Input Systems for energy use and greenhouse gas emissions were identified in the review.

Social Impacts

No social impacts of the low input systems were identified in the research reviewed. Considering the nature of the systems, it appears likely that any social impacts from adoption of these systems would be minor.

Strengths and Weaknesses

A strength of the Low-Input Systems is that, of the systems examined here, they are the most similar to contemporary practice, and so their adoption may meet with less resistance from farmers (provided benefits from their adoption can be demonstrated to farmers). On the other hand, the Low-Input Systems involve only modest changes in farm management, and so may be seen by the community as generating only low external benefits.

Key gaps in information

Information gaps exist in:

- The optimal design of systems for a balance between profit and reduced pesticide use. The systems examined in the field studies reviewed represent a very small set from the full range of possibilities. It may be that other systems not yet studied would provide greater reductions in pesticide use while maintaining or increasing profits. Further exploration of this possibility would require computer modelling to integrate pest/pesticide responses within a detailed economic framework. If this work successfully identified more profitable systems with lower pesticide use, it could enhance their uptake by farmers, and guide further field research into areas where it is most likely to make a difference.
- The applicability of economic conclusions to a wider variety of farm types and locations. There are many different farm types and farming environments that differ in a variety of ways from the sites used for the reviewed trials. The differences would particularly affect economic conclusions, even if the biological conclusions were reasonably consistent. The type of bio-economic model suggested above in 4.24 could be useful for extending the range of situations for which conclusions can be reached about the economics of Low-Input Systems.

Integrated Arable Farming Systems

Interest in Integrated Arable Farming Systems (IAFS) or Integrated Crop Management (ICM) in arable crops has grown since the late 1980s, both in the UK and in Europe. Growing economic, environmental, political and social pressures have forced a reappraisal of arable production systems. IAFS is considered by many to be a viable option for sustaining agricultural production and farm incomes and safeguarding the environment. The interest in IAFS also stemmed from the limited success and adoption of Integrated Pest Management approaches despite their environmental benefits and cost saving potential. It was hoped that a more integrated approach that addresses economic, political, agronomic, sociological and environmental aspects of arable crop production would be more likely to attract wide farmer uptake.

Reduced Tillage Systems

Reduced tillage systems, otherwise known as ‘conservation tillage’, ‘minimal tillage’ or ‘low tillage’ have been defined in a Home-Grown Cereals Authority research review as: ‘Sustainable cultivation systems which are less expensive than traditional systems; they may be less energy demanding, and/or quicker and/or have a lower labour demand’ (Davies & Finney, 2002).

Reduced tillage has had a relatively low uptake in the UK and Europe, with an estimate of less than 1-2 per cent of European agricultural land cultivated using this system (European Conservation Agriculture Federation, undated). Uptake of the system is however, growing worldwide. The USA has pioneered reduced tillage and the US government has provided a high level of support for its use under various Farm Bills. Much research and development of reduced tillage techniques has taken place in the USA. In 1997, 37 per cent of 120 million hectares were cultivated using reduced tillage or no-tillage techniques in the USA. It is also widely used in Australia, Canada, Brazil and Argentina (European Conservation Agriculture Federation).

Reduced tillage techniques practised in Europe fall under the following categories:

- direct drilling, whereby no cultivation takes place prior to drilling
- shallow tillage, where the soil is tilled to a depth of less than 100 mm without inversion
- Deep tillage, where the soil is tilled to a depth greater than 100 mm without inversion (Davies & Finney, 2002).

Reduced tillage is not suitable for all soil and specific problems are associated with the system, which may discourage farmers from adopting it or may influence their choice of reduced tillage techniques. Soil compaction, straw incorporation and grass weeds are all problems commonly experienced (Ball, 1990). In the UK, the most favourable sites for reducing tillage operations are those with stable, well-drained soils in lower rainfall areas (Davies & Finney, 2002).

Relevant Projects

The need to reduce costs has renewed interest in the technique in Europe. There are also significant environmental advantages, specifically in terms of reducing soil erosion. However, research into the economic and social aspects of reduced cultivation systems in the UK and Europe has been limited. Numerous studies have been undertaken in the USA, but differences in soil conditions, climate, farm size, crops grown and rotations make USA produced data of limited relevance in the UK. For this report, the review by Davies & Finney (2002) was particularly valuable.

Yield and Profitability

The low uptake of reduced tillage methods in the UK and Europe sends a strong signal that these methods are unlikely to be as beneficial to farmers in these environments as they are in the USA and elsewhere where adoption has been high and rapid.

Yields achieved by reduced tillage systems are influenced by various site-specific factors such as soil characteristics and cropping patterns. Furthermore, any yield benefits associated with reduced tillage may not be evident for a number of years (at least 10 years on some soils and under certain climatic conditions). Yields may also be dependent upon the type of reduced tillage system adopted (Uri, 1999). The general rule is that the shallower the tillage, the greater the savings in costs, but the greater the risk of reduced yields. It is nonetheless generally accepted that reduced yields are not a necessary the consequence of reduced tillage systems and they can be avoided by the adoption of the most suitable system for the site (Davies & Finney, 2002). Long-term field experiments have shown that long-term average yields are usually similar to those achieved by conventionally tilled systems where the soil is ploughed and drilled (Ball, 1990).

Costs savings are important factors in the decision-making process for most farmers considering reduced tillage systems. Costs can be saved in terms of labour, machinery and energy. As little research has been undertaken into the economics of reduced tillage systems in the UK, there is little data available on cost savings relative to contemporary systems. One exception is a study undertaken at the Scottish Centre of Agricultural Engineering (SCAE) in the 1980s, in which reduced tillage systems were compared with a conventional plough and drill system (Ball, 1990). It was calculated that direct drilling incurred only 28 per cent of the total costs of the contemporary system for establishment of cereal crops, while the result for shallow plough/shallow cultivation and drilling was 85 per cent, and for broadcasting and shallow cultivation, 54 per cent.

The most important cost saving is in the reduction of energy use. More details are given below under ‘Input usage and environmental impacts’.

Labour savings are also reported to be significant, although this is largely dependent upon farm size and the reduced cultivation system used. More details are given below under ‘Social impacts’.

Although there may be initial high capital costs incurred in the purchase of reduced tillage machinery, in the long term machinery costs may be lower due to lower depreciation and maintenance costs. Wear on parts of reduced tillage equipment, particularly discs, should be low compared with contemporary systems. High initial machinery investment costs suggest that reduced-tillage systems may be more suited to larger farms. It is suggested by Davies & Finney (2002) that farms should be at least 450 ha for maximum benefit and that farms smaller than 250-300 ha would be most efficiently cultivated with a plough based system. It is possible that contractors will be able to carry out the work on smaller farms.

Input Usage and Environmental Impacts

In the SCAE study, energy use for direct drilling was 29 per cent of contemporary systems, 74 per cent for shallow plough/shallow cultivate and drill and 46 per cent for broadcast and shallow cultivate of the energy demand of the contemporary system (Ball, 1990). In a report by the European Conservation Agriculture Federation, it was estimated that energy consumption could be reduced by 15 - 50 per cent in reduced tillage systems compared to contemporary systems. The same report stated that energy productivity is increased by between 25 and 100 per cent (*European Conservation Agriculture Federation, 1999). Net energy input for a plough based system is usually in the region of 200-360 MJ/ha for a plough based system, 100-230 MJ/ha for reduced tillage and 80 MJ/ha for direct drilling (Davies & Finney, 2002). Where soils compact or seal over reduced tillage can increase runoff and erosion (*Guerif *et al.*, 2001; Kingery *et al.*, 2002; Quine & Y. Zhang, 2002; Van Muysen & Govers, 2002).

In the USA, considerable benefits to society have been made by converting highly erodible land to reduced-tillage systems, in terms of damage prevention to water facilities such as drinking water supplies, water storage, irrigation, and recreation (*Uri, 1999). Less disturbance of the soil also reduces atmospheric emissions. There do not appear to be any published studies estimating reductions in soil erosion from reduced tillage in the UK. Although there may be some benefits in this category, it seems unlikely that they would to be on the scale measured in the USA.

Social Impacts

The use of larger machines, which achieve cultivation at high work rates and low-energy input, will reduce labour requirements. In the SCAE study, time required was 29 per cent for direct drilling, 65 per cent for shallow plough/shallow cultivation and drilling and 20 per cent for broadcasting and shallow cultivation relative to the time demand of the contemporary system.

Strengths and Weaknesses

A possible strength of reduced tillage is that the very high levels of adoption in a number of large agricultural producing countries may provide opportunities for the UK to benefit from lessons already learnt elsewhere. Specific tillage technologies might be adapted for UK application, or different systems for integrating reduced tillage into an overall crop management system might be observed.

The outstanding weakness of reduced tillage in the UK is the failure so far to identify a system that is sufficiently effective and profitable to attract wide adoption by farmers.

Key Gaps In Information

Given the low adoption of reduced tillage in the UK, there has been little incentive for research into the technique, so there are numerous knowledge gaps. There may be a ‘chicken and egg’ problem here, with widespread adoption depending on increases R&D to develop improved systems. On the other hand, it might be judged that the existing evidence is sufficiently discouraging not to warrant greater investment in R&D for the time being.

For three of the alternative arable cropping systems (low-input systems, integrated arable farming systems and organic farming), a significant body of UK and European research is available for review. For these areas, the information available is not comprehensive, but an indicative picture emerges about them. A number of key information gaps are also identified. For two of the alternative systems (reduced tillage systems and precision farming systems), much less UK and European research has been carried out. Research from countries outside Europe is cited to complement the local results, but for both these systems, the potential for confident conclusions for the UK is lower.

Table 11 summarises the review of each of the five alternative cropping systems compared against conventional cropping.

Table 11: Summary Of The Review Of Each Of The Five Alternative Cropping Systems Compared Against Conventional Cropping (comments are relative to contemporary practice).

	Low-input systems	**Integrated arable systems**	**Reduced tillage systems**	**Precision farming**	**Organic farming**
Key projects	Boxworth SCARAB TALISMAN RISC	LIFE LINK:IFS FOFP RPMS	Davies & Finney, 2002	Godwin *et al.*, 2002; Pannell & Bennett, 1999	Offerman & Nieberg, 2000 Padel & Lampkin, 1994
Extent/quality of evidence	***	****	*	*	***
Economic Performance	• Variable. • More likely to be attractive for cereals and if output prices are low	• Profits vary widely between studies • Similar to conventional on average	• Cost savings recorded, but apparently outweighed by other negative	• UK study says good potential • Detailed overseas study indicates caution needed	Profitability high for crops - weaker for livestock

	Low-input systems	Integrated arable systems	Reduced tillage systems	Precision farming	Organic farming
			aspects		
Social Impacts	• Minor	• Requires more skilled management. • Perhaps higher overall labour demand	• Lower labour use if reduced tillage uses larger machinery	• Unchanged or perhaps slightly lower labour demand. • Need for new skills.	• Often includes livestock, perhaps leading to increased labour demand
Environment	• Moderate reductions in pesticide use	• Significant reductions in inputs	• Reduced energy inputs • Reduced soil erosion	• Significant reductions in inputs such as pesticides and fertilisers may be possible	• Almost no synthetic chemicals used • Lower greenhouse gas emissions
Ecological impacts	• Some benefits to many taxa	• Some benefits to many taxa	• Benefits especially to soil fauna	• Benefits to many taxa in areas not targeted by inputs	• Benefits to many taxa across all cropped areas
Strengths	• Most similar to contemporary practice, so easier to adopt	• Avoid some problems experienced with organic farming	• Lessons from successful adopting countries may be possible	• If successful, reduced inputs without loss of profit	• Currently substantial price premiums and substantial reductions in intensity
Weaknesses	• Only modest Environmental benefits	• No price • Premiums • Need high-level management • Higher risks initially	• Evidence of low adoption suggests poor technical effectiveness and economics in the UK	• Expensive to purchase/run • Doubts about economic benefits if properly evaluated	• Weed Management • Maintenance of soil fertility
Key gaps in information	• Applicability of economic results to other farm types and locations • Optimal design of systems to balance profit and pesticide use	• Labour implications • Applicability of economic results to other farm types and locations • Optimal design of integrated systems	• Relatively little R&D into the technique conducted in the UK so far	• Sophisticated analyses of the economic potential for precision technologies • Bio-physical information necessary to conduct such analyses	• Impacts of policy changes • Marketing and Processing • Labour implications • Effects of livestock on crop profits. • Whole-rotation

Organic Farming

Organic farming has recently attracted considerable interest from policy makers both in the UK and within Europe. This has principally been due to the surge of interest in organic produce and the compatibility of the principles of organic farming with EU CAP legislation aimed at redirecting agriculture to respond to market needs and towards more sustainable practices.

Although this has prompted some comprehensive studies of the socio-economic performance of organic farming, information is lacking in certain areas, including the impacts of future policy changes and issues related to the development of the marketing and processing of organic produce. For the purpose of this study, data for arable crops only is limited. By their very nature, organic farms tend to have a diversity of enterprises and usually have livestock incorporated into the system. This makes direct comparisons of organic arable systems with other arable systems problematic.

A range of useful sites related to organic farming have been brought together at
http://www.DEFRA.gov.uk/farm/organic/related-websites.htm;
http://www.europa.eu.int/comm/agriculture/qual/organic/facts_en.pdf;
http://www.europa.eu.int/comm/agriculture/qual/organic/brochure/abio_en.pdf
international papers http://orgprints.org/

Relevant Projects

A range of studies is referred to in the review. Particularly noteworthy is that of Offerman & Nieburg (*2000) who provided a comprehensive and detailed set of analyses of the economic of organic systems. Their study covered all EU countries and three non-EU countries: Norway, Switzerland and the Czech Republic. It was based on a literature review and on data collected by experts in each country. Indicators of organic farms used in the analysis were compared to comparable contemporary farms in each country and these ratios were compared between countries and studies, thus reducing problems associated with comparing data from countries with different economic circumstances.

Table 12: Organic Producers, Processors and Importers (Jan 2004).

	Producers and growers	Processors and/or Importers [1]	Total
England	2,570	1,630	4,200
Wales	610	109	719
Scotland	687	169	856
Northern Ireland	150	33	183
UK	4,017	1,941	5,958

[1] Processors and importers include abattoirs, bakers, storers and wholesalers. The recorded location depends on the address registered with the Sector Bodies and so larger businesses

may be recorded at their headquarters.

Yield and Profitability

Data taken from various European countries indicates that there is wide variability in organic crop yields, both between farms and between countries (*Offerman & Nieburg, 2000; *Padel & Lampkin, 1994). Factors that contribute to yield variability include climate, crop rotation, soil quality and the time the land has been under organic management. Most of those factors influence both organic and contemporary crop yields. In European organic arable systems, yields are generally lower than contemporary systems. Cereal yields are typically 60-70 per cent of yields from conventionally produced crops (*Offerman & Nieburg, 2000).

Offerman & Nieburg (*2000) found that, over a number of European countries, organic potato yields range from 38 to 82 per cent of contemporary yields and yields of pulses average around 20 per cent lower than contemporary production, although in the UK, pulse yields were eight percent higher than contemporary yields. Organic production of oilseeds and beets is comparatively small and little data is available (*Offerman & Nieburg, 2000). In a seven-year study conducted in the UK by CWS comparing organic farming systems with contemporary systems, organic winter wheat yields were 68 per cent of contemporary yields, winter oats were 81 per cent, winter beans were 72 per cent and peas 61 per cent (Leake, 1999).

It has been observed that yields from organic crops tend to increase over time as the land has been organically managed for longer (Byström, Jonsson & Martinsson, 2002; Leake, 1999). In addition, the trend of average yields from organic production overall has been increasing (*Mühlebach & Mühlebach, 1994; *Padel & Zerger, 1994). However, this has been at a slower rate than the increases occurring under corresponding contemporary systems (*Mühlebach & Mühlebach, 1994; *Padel & Zerger, 1994). Specific causes of yield increases are often difficult to determine as they typically result from a combination of factors potentially including: improving soil quality; improving management skills and knowledge; and research and development, leading to improvements such as disease-resistant, higher yielding seed (*Offerman & Nieburg, 2000; *Padel & Lampkin, 1994). These factors are potentially relevant to both organic and contemporary yields. The gap between organic and contemporary yields may change overtime as legislation limits the intensity of contemporary arable production, or as developments in technology increase yields of either organic or conventionally grown crops.

The lower yields achieved by organic crops in comparison with those grown conventionally are due to the non-use of inorganic fertilisers and synthetic pesticides. However, this is compensated financially by lower input costs and price premiums received.

Data on total costs of organic arable production for 1995/96 set them at 80 per cent of the total costs of contemporary systems, with fixed costs at 86 per cent and variable costs at

66 per cent (*Offerman & Nieburg, 2000). Low variable costs are due to the significantly lower usage of inputs such as fertilisers and pesticides, although the costs of organic seed are likely to be higher than those of conventionally produced seed. Although fixed costs are generally lower, this can vary according to labour input and how much of the labour input is unpaid family labour.

Organically grown products generally attract price premiums (except in periods when the organic market for a particular commodity is over-supplied). The level of price premium received depends largely upon the marketing channel. Direct marketing to the consumer tends to bring the highest premiums. However, arable crop commodities tend not to be marketed directly. Data from some EU countries show that less than 10 per cent of organically grown cereals are marketed directly. Organic potatoes are unusual in that direct marketing can account for more than 40 per cent of total sales (*Offerman & Nieburg, 2000).

Price premiums vary considerably, both between commodities and between countries, depending on the demand and supply of organic and contemporary produce within each country (*Padel & Lampkin, 1994). Wheat can be sold for premiums of 50 to 200 per cent in Europe. In the UK, the premium for milling wheat between 1994 and 1997 was 75 to 100 per cent. In 2001 the UK premium was 200% but had dropped in 2002 to approximately 100% Prices of potatoes can be highly variable due to the high level of yield fluctuation. In the UK, the average price premium for potatoes varied over time between 75 per cent and 775 per cent during the period 1994-1997 (*Offerman & Nieburg, 2000).

Crop prices 2002

Profitability of arable crop production on organic farms is shown in much available data to be considerably higher than contemporary farms, particularly for arable farmers (e.g. Institute of Rural Studies, 2000). (Relative profitability of organic livestock farming is generally found to be lower). In the UK between 1992-1997, organic arable crop farms achieved profits averaging around 30% higher than those from contemporary farms (*Offerman & Nieburg, 2000).

Table 13: Cropping Prices 2002

Crop	***Organic***	***Conventional***
Milling wheat	£155	£74
Feed wheat	£135	£61
Feed barley	£120	£61
Malting barley	£160	£70
Triticale	£125	no prices
Oats	£120	£54
Beans	£180	£70
Peas	£190	£83
Lupins	£200	no prices
Soya	£240	no prices

Source: Organic Soil Association Survey, Conventional Farmers Weekly

This result should be treated with caution for a number of reasons. Firstly, it was calculated from data drawn from surveys involving only small numbers of farms. Secondly, prices for both contemporary and organic arable commodities have changed since the studies underlying that conclusion were conducted and more up-to-date economic comparisons are not available. Thirdly, arable enterprise profitability will be influenced by the mix of crops grown. It will generally not be possible to grow a high nutrient demanding crop such as wheat as frequently in an organic rotation as in a conventional rotation. Other less demanding and less profitable crops may need to be incorporated instead, reducing the overall profitability of the organic system relative to contemporary systems. For example, nutrient building, green manure crops may be incorporated into the rotation, particularly in systems with no livestock (Leake, 1999). These would enhance the profitability of subsequent cereal crops in the rotation, but at the cost of sacrificing income in the year of the green manure crop (*Padel & Lampkin, 1994). This highlights that it is important to evaluate organic cropping in the context of whole rotations rather than as individual crops (see General Insight). Offerman & Nieburg's (*2000) result that organic crops give profits 130 per cent of contemporary crops is based on data for whole farms, although the data is taken for individual years and not averaged over whole rotations. If large enough samples of farms were surveyed over enough years, the approach would provide a reasonable comparison, but we have already noted above the small number of farms included in the comparisons.

Input Usage and Environmental Impacts

Levels of artificial pesticides in organic systems would, of course, be lower than in contemporary systems. In the case of nutrient inputs, organic systems use different sources (e.g. non-synthetic fertilisers, green manure crops). We examined evidence on whether there are differences between contemporary and organic systems in the overall levels of nutrient inputs. Mäder *et al.* (2002) found that nutrient input into organic systems were 34-51 per cent lower than in contemporary systems. Stolze *et al.* (2000) concluded from a review of European literature that nitrate leaching from organic farming is lower or similar to levels from contemporary farms. However, when calculated for production units, nitrate leaching from organic farms was similar to or higher than that from contemporary farms. Cobb *et al.* (1999) calculated that 25 per cent less leaching of nitrates occurred from organic systems than from contemporary systems. All of these references refer to organic and contemporary systems in general and not to arable farming specifically.

Potato blight poses the most serious risk in growing potatoes by organic methods. At present it is permissible to use Burgundy mixture to control blight but doubts about the practice of repeated applications of copper to soils may soon mean that the EU imposes a limit or ban its use in the future.

It is believed that most pests and diseases can be controlled largely by crop rotations (*Litterick *et al.* 2002) including mixed farming. Several DEFRA funded research programmes are currently investigating this topic.
Energy use is divided into direct and indirect energy. Indirect energy use is highest in contemporary arable systems and makes up the largest proportion of energy due to the use of fertilisers and pesticides. In organic production direct energy accounts for the highest proportion of energy use where crops are dried.
Transport costs tend to be higher for organic crops due to fewer certified organic grain facilities. Consequently organic grain has to be transported longer distances on average (*ADAS Consulting Ltd, 2000).

Studies of relative energy use of organic and contemporary systems have most commonly found that organic arable systems use less energy than corresponding contemporary systems for single crops or part rotations. In a study commissioned by MAFF, better energy ratios were achieved by individual crops in organic production systems than in contemporary systems (*ADAS Consulting Ltd, 2000). In a study undertaken in Switzerland, organic systems were found to require 20 to 56 per cent less energy to produce a crop dry matter unit (Mäder *et al.*, 2002). A study commissioned by the German government also showed that energy used, per hectare, in organic crop production in 1991/92 was 65 per cent lower than contemporary crop production systems (*Köpke & Haas, 1996). However, when whole rotations were compared by ADAS Consulting Ltd (*2000), the organic system that exclude livestock had poorer energy ratios due to the inclusion of annual fertility building crops and winter cover crops, which had no direct outputs. It is not clear whether the results of the other energy studies cited above would also be less favourable for organic systems if a whole-of-rotation approach were to be applied.

In a German study that compared energy ratios in organic farming systems with integrated systems for a cereal/root rotation, very little difference was found in energy efficiency (*Hülsbergen & Kalk, 2001). The integrated system used more fossil fuel per unit area but less energy was recovered from the organic system due to lower yields.

Comparative studies have been undertaken into the greenhouse gas emissions from organic and contemporary arable systems. In the study by Köpke & Haas (*1996) it was found that organic systems had more efficient carbon dioxide budgets than contemporary systems due to higher levels of carbon dioxide assimilation in organically managed soils. The high humus content of organic soils reduces carbon losses that otherwise occur through wind and water erosion. However, some nitrous oxide emission levels from organic arable systems have been shown to be higher than contemporary arable systems, particularly during the first year after a ley has been ploughed up (Ball *et al.*, 2002).

Social Impacts

Evidence suggests that organic farming in general has a positive impact on rural employment (*Jansen, 2000). In the EU, organic farms use 10-20 per cent more labour than contemporary farms (*Offerman & Nieburg, 2000). Estimates have been made for the potential for organic farming to increase employment opportunities in the UK. Estimates have been made that 5,521 full time equivalent jobs (Hird, 1997) and 12,000-18,000 (*Jenkins & McLaren, 1994) additional jobs would be created if 10 per cent of UK agriculture was converted to organic. This would be likely to increase the demand for seasonal labour which is already difficult to meet.

It is not clear how the figures for organic crop production would vary from these published figures for organic production in general. On one hand, it might be expected that organic arable farming systems would be more labour intensive in certain respects; there may be more time spent in pest prevention, and planning and observing may be more time consuming. However, there may be less time spent on agrochemical application. Organic farms tend to carry out more processing and direct marketing. However, this is generally only the case with arable crops where field scale vegetables are grown.

There is some evidence available from a study in Switzerland which calculated the relative labour demands of contemporary and organic crops (Näf, 1995). Wheat was found to require 28 per cent more labour relative to contemporary cropping methods, while the corresponding increases were 36 per cent for barley and 34 per cent for potatoes (Näf, 1995). Lampkin (*1994) suggests that higher labour costs may be associated with labour-intensive high-value organic crops such as potatoes and carrots. However, Lampkin also suggests that higher labour usage in organic enterprises may be due to low levels of capital available for investment in mechanisation, rather than an intrinsic requirement for greater labour. In view of this, and recognising that arable farming has relatively low labour intensity compared to other farming enterprises such as horticulture, the potential impact on rural employment from conversion of crop production to organic methods is probably of relatively minor significance.

Strengths and Weaknesses

The outstanding strength of organic production is the availability of substantial price premiums for organic produce, due to consumer preferences in favour of its complete avoidance of synthetic agrochemicals. Whether the price premiums are sustainable in the long term is unknown.

A weakness is the difficulty of maintaining low weed numbers in the absence of those chemicals. Pernicious weeds may cause significant yield losses and reduce the quality of the crop, or mean the crop requires additional processing (to remove weeds seeds etc.). However, some species of arable weeds are desirable from a biodiversity perspective.

The need to maintain soil fertility without use of synthetic fertilisers also means that costly practices such as green manure crops may be required, reducing the overall profitability of the system.

Key Gaps In Information

Essential gaps of information exist in:

- The impacts of future policy changes on the economic attractiveness of organic systems to farmers.
- A range of issues related to the development of the marketing and processing of organic produce.
- Socio-economic data and analysis specific to arable crops (most organic systems include animals).
- The interaction between crop and livestock elements in determining the economic performance of organic systems. Livestock systems viewed separately appear relatively unprofitable, but may enhance the profitability of the crops and thereby the system as a whole (see General Insight 8, para. 4.2).
- Economic comparisons of organic farming and contemporary farming based on whole rotations rather than individual crops. Separate gross margins are likely to overstate the economic performance of organic cereal crops and understate the economic performance of livestock in organic systems.

Key Findings - Ecological Impacts

The ecological impacts of agriculture already have been discussed in chapter Biodiversity under Ecological Impacts Of Arable Agriculture. Furthermore, the different arable cropping systems exert different pressures on the natural environment, but these differences do not form a continuum. Further findings are:

Pesticides

Organic systems usually result in greater densities of both arthropods and their favoured food plant groups compared to contemporary systems.

Pesticides do have a detrimental effect on earthworms but reducing pesticides by 50% had no effect on earthworm numbers or diversity

Adverse effects on non-target species are documented for a number of species.

Pesticides exert impact on bird populations by direct mortality and also indirectly by reducing plant and invertebrate food supplies and destroying habitat.
Table 14 below summarizes the main differences between the systems.

Further findings are:

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Table 14: Differences In Pressures Exerted By Each Arable System

	Organic	**Integrated**	**Contemporary**
Use of Pesticides	No synthetic chemicals allowed without derogation	Only applied when needed	Insurance applications may be applied to prevent disease
Use of Nutrients	No synthetic fertilisers allowed; organic fertilisers can be applied liberally	Applied to maximise efficiency of use	Applied to maximise financial return, some precautionary applications
Tillage	Often intensive especially to control weeds	No-till and reduced till depending on circumstances	Generally annual ploughing
Economic advantage in increased field size?	Variable	Yes	Yes
Economic advantage in simplified landscape?	No - need to maintain some livestock within system	Variable	Yes
Strengths	Reduced inputs	Reduced inputs, reduced tillage	None
Weaknesses	Increased tillage	None	Known to cause reduction in biodiversity
Key gaps in information	No proof yet whether there is benefit to wildlife	No proof on whether there is benefit to wildlife	Little information on how contemporary compares with organic or other cropping systems

Nutrient inputs

The use of fertilizers may change plant species composition in favour of species, which can tolerate, or prefer, such conditions, thus reducing diversity and food supplies for birds.

Increased nitrogen inputs increase earthworm density.

Tillage

Reduced tillage tends to lead to weeds becoming more prevalent.

Reduced tillage usually leads to an increase in invertebrates, although there may be no effect on carabids or foliage-inhabiting arthropods.

Reduced tillage may favour predatory species relative to ‘pests’.

Tillage injures or kills earthworms. The severity of the effect depends on the type and depth of tillage.

Intensity Of Land Use

Soil fauna show few systematic differences between contemporary, integrated and organic systems but organic fields have the most equitable community structure.

Protozoan biomass was significantly higher under integrated management possibly due to higher organic matter content.

Maximising agricultural output via intensification has damaged farmland bird populations across Europe (and beyond).

Variation in soil biota between farms under similar management may be larger than variation between contemporary *versus* integrated *versus* organic treatments due to large-scale process such as climate and soil type. Management sometimes explains only a relatively small amount of variation in soil biota abundance and diversity.

In general, the biomass and diversity of earthworms is higher under organic and integrated management than under contemporary, but the trend is highly variable with many notable exceptions.

Landscape Structure

The structure and biodiversity of the surrounding landscape may be more important to field-inhabiting invertebrates than the farming system itself.

Bird survival and performance depends on the availability, in both space and time, of a range of resources and thus a greater diversity of land-cover has more potential to supply all requirements than could be expected of monoculture.

The effects of habitat loss are obvious in the concomitant reduction in resources, but bird population survival and performance will also be affected by the quality of the habitat that persists, including its temporal availability.

Crop rotation, and the location and management of set-aside, may influence bird populations at a local level in relation to the spatial distribution of crop types and nesting habitat, and also at a larger scale, especially in winter, in relation to food availability.

Mitigation Measures - Margins, Beetle Banks, Conservation Headlands And Wild Bird Cover

Field margins beetle banks, conservation headlands and wild bird cover are of benefit to a wide range of taxa.

Organic field boundaries generally support a higher abundance of wildlife.

The quality and quantity of non-cropped habitat is often higher on organic farms, however, further research is needed to test the generality of these results.

No studies were found to compare the relative value of conservation headlands, beetle banks or wild bird cover for wildlife in relation to different whole farm approaches.

Further studies are needed to investigate differences between ‘integrated’, organic and ‘contemporary’ systems and for a wider range of taxa.

Comparing the effectiveness of mitigation methods for wildlife between different farming systems is inherently difficult. Factors such as quality and quantity of non-cropped habitat and dominant farm type in the surrounding landscape of a study site may also influence results.

Agri-environment schemes with arable margin options were predicted to be environmentally effective. A new scheme with high uptake should have wide-scale positive effects but those effects cannot yet be quantified.

Key-Findings - Socio-Economic Impacts

Low Input

In trials yields were consistently lower in low input cropping when compared to contemporary cropping. Profitability in low input cropping was sometimes higher, the same or lower than contemporary cropping.

Reducing pesticide rates is likely to be economically viable in certain crops, notably cereals.

Input use fell in all trials but only moderately.

There was limited impact on indicator organisms.

As there is little change to current practice this may lead to higher uptake.

There are likely to be low external benefits.

Integrated Arable Farming Systems

Yields tend to be lower under IAFS than contemporary cropping.

There was no statistical difference between gross margins between IAFS and contemporary cropping.

Risks are considered higher with IAFS especially until the farmer gains experience and therefore guidance to farmers is required.

Inputs in IAFS decreased by an average of 52% for fungicide, 48% for herbicide, 40% for insecticides and 17% for fertilisers (para 4.43). IAFS show potential for lower energy use.

A strength of IAFS is that mainstream agrochemicals can still be used and a weakness is that there is no niche market.

Organic

Organic cereal yields are typically 60-70% of contemporary yields. Yields do tend to increase the longer land has been organic.

Organic arable crop farms achieved profits averaging around 130% of profits from contemporary farms although this value must be treated with caution as it is not based on whole rotations.

Evidence suggests that organic farming has a positive effect on rural employment.

A strength of organic production is the price premium (para. 4.74), whilst weaknesses are weed control and soil fertility.

Reduced tillage

The low uptake of reduced tillage methods in the UK and Europe sends a strong signal that these methods are unlikely to be as beneficial to farmers here compared to those in the US.

Farms should be at least 450 ha for maximum benefits from reduced tillage.

Energy consumption is greatly reduced by reduced tillage systems.

Precision farming

It is economically beneficial to apply nitrogen, herbicides and pesticides in a spatially variable manner.

Highly positive results for precision farming should be treated with caution.

The ecological impacts of the different cropping systems have not been fully quantified but the generality that fewer chemical inputs and less severe soil disturbance are beneficial to fauna and flora has been substantiated in most cases. The degree to which each of the cropping systems reduces inputs and disturbance must be considered. The impacts of each cropping system will be modified by mitigation measures that are currently employed and whether they are equally employed by farmers undertaking the different cropping systems. Another pertinent question is how is the uptake of mitigation measures are likely to change in the near future.

Overall, it seems that organic farming of crops is relatively profitable in the current climate (up to 2002). Although it has lower yields than contemporary systems, these are compensated by higher prices. We have some concerns about whether the economic analyses of arable cropping have fully captured the costs of switching to different rotations in organic farming (e.g. including costly years of manure crops to maintain soil fertility in crop production years) since the studies are based on small samples in single years. It remains to be seen whether the system would remain profitable without the extra subsidies paid for it.

Low input systems and integrated arable systems were both variable in their economic performance. Their economic returns compare well with contemporary systems in some situations but not in others. There seems scope for additional economic modelling to broaden the knowledge base about the performance of these systems in different circumstances. There is a difficulty in making predictions as economic conditions can change very quickly.

Reduced tillage appears to have limited economic potential in the UK. Precision farming has been evaluated positively in the one major UK study, but a more sophisticated economic analysis from Australia raises concerns that the UK study may have overstated the likely benefits.

Implications for farm labour were identified, the most important of which are the likely increase in labour demand in low input and organic systems and the need for more skilled labour in precision farming systems.

Labour

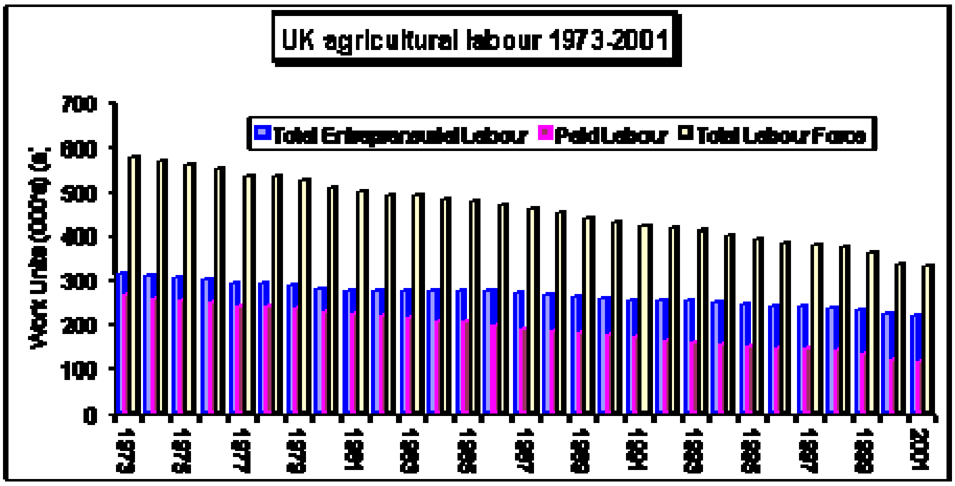
In the post-WW2 period there has been the rapid and continuous decline in agricultural employment, in the position of farming and farming families within rural society, and the changing political consensus around issues of agricultural subsidies and other support structures. In addition, there have been major changes in the industries upstream and downstream from agriculture. These are now more oligopolistic or even monopolistic in character

Despite the changes in agriculture and related industries, rural population and employment in the UK has generally increased over much of the past 20 or even 30 years. New rural economic opportunities have arisen. Many but by no means all of these are related to a growing demand for tourism and recreation. Partly too, this growth is linked with a new interest in the natural environments and cultures of rural areas, sometimes referred to as rural amenities.

It is clear from the trend for Total Factor productivity in the UK Agricultural Industry since 1995 has been approx. +5%, while labour productivity has risen by approx. 18%. Figure 3 below shows that the number of people working on farms has been declining for a long period of time. There has, moreover, been a move from full-time working to part-time working within the industry. Whilst the number of full time workers has declined since 1985, there has been a corresponding increase in the number of part-time workers from 21% of the total in 1984 to 29% in 1997. The proportion of seasonal and casual workers has remained relatively stable over this period.

The trend for Total Factor Productivity in the UK Agricultural Industry since 1995 has been approx +5%, while Labour Productivity has risen by approx + 18%.

Figure 3: UK Change of UK Agricultural Labour



Source: DEFRA (2002) a = full time equivalent
http://statistics.DEFRA.gov.uk/esg/statnot/jun_eng_labour.pdf

Total labour force for 2003 has reduced further to 354,381 (from the DEFRA June Agricultural Census
http://farmstats.DEFRA.gov.uk/cs/farmstats_data/trends/hist_trends_chart.asp?trend_id=2472

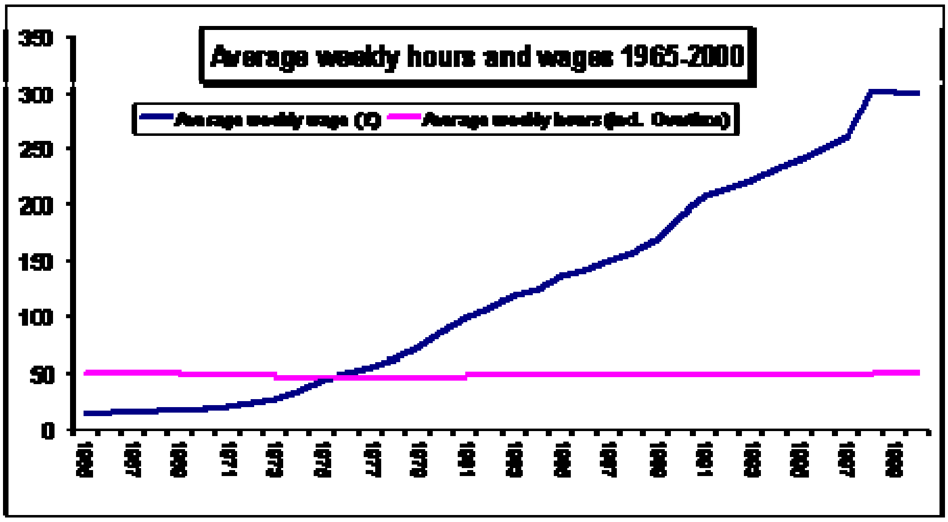
Agricultural Wages

Individual pay rates are a matter of negotiation between employer and employees subject to the terms and conditions stipulated by the Agricultural Wages Board.

Agricultural wages are underpinned by minimum levels set by the Agricultural Wages board and usually fluctuate within a fairly narrow range of between 70 and 80% of average manual workers earnings. The apparent difference in agricultural workers and other manual workers earnings may be accentuated slightly because the value of ‘benefits in kind’ (housing, fuel, milk etc.) received by agricultural workers is not always fully reflected in the recorded earnings figures.

The *Farmers Weekly* in December 1999 suggested that the average age of farmers in the UK was 58. The distribution of people employed on farms across the EU has remained approximately stable between 1985 and 1997 (Source: EC Farm structure survey 1999).

Figure 4: Average Weekly Hours Worked And Wages Paid For Whole Time Men In England And Wales



Ref: University of Reading (http://www.ecifm.rdg.ac.uk/maclab3.htm)

Whilst the number of full-time farmers and farm workers continues to fall, the overall labour numbers have increased, with significant increases in part-time working. Overall there is a 3.7% increase in total farm labour. Within this, the headline figures are:

- Full-time Farmers, Partners, Directors & Spouses (FPDS) have fallen by over 2% and simultaneously part-time FPDS have risen by over 6%. The trend of switching from full-time to part-time is continuing, with more immediate family members being involved some way in farm work.

- Salaried managers have increased by nearly 30%. This is likely to be a combination of more limited companies, and the consolidation of the industry, meaning fewer, larger farms requiring more managerial staff.
- Regular full-time male and female workers have fallen by 4% and 3% respectively, whilst regular part-time male and female workers have increased by 13% and 3% respectively. This again follows the pattern of switching from full-time to part-time work.
- Casual and Gang labour has increased by 10%, with male workers making up the majority of this increase.

The headcount figures do not necessarily provide the best indicator of the labour input on a holding. For example a very small ‘spare time’ holding with a few sheep or chickens might contribute two part-time farmers to the national total, a similar contribution in terms of numbers to much larger, economically significant businesses. Because smaller farms are more numerous than larger ones, over 50% of the national total of part-time farmers comes from the smallest size group, even though this group is responsible for only 4% of agricultural production. Further, consolidation of the industry may mean staff working part-time across a number of holdings, but being recorded as one headcount on each of the individual holdings, which could lead to an increase in overall numbers.

As a consequence of this we have also produced results excluding the very small ‘spare time’ holdings. Spare time is defined as holdings whose standard labour requirement (SLR) is less than 0.5 or equivalent to up to 950 hours of labour input per year. SLR is a theoretical measure of the labour input needed for a holding, based upon the type of agricultural activity
on the holding. For example a holding with 1 SLR (1900 hours) is equivalent to having 365 sheep or 95ha of wheat. These results for the economically significant farms show that total labour has also increased since 2003, by 3.3% overall. Of the overall increase of 13,000 in total labour:

- The very small (both spare time and part time) and small holdings (up to 3,800 hours of input per year) contribute almost 10,000, the bulk of which is for part-time farmers on cereal, lowland cattle & sheep, specialist grass & forage and specialist horse holdings.
- Salaried managers have increased by 3,300, which is spread fairly evenly across all holding sizes.
- 3,700 are due to increases in casual and gang labour, a third of which is on very large holdings.

(from: Farming Statistics, Department For Environment, Food And Rural Affairs, Labour Results - Agricultural And Horticultural Census: 3 June 2004 England).

A strong sense of community has traditionally been the stuff of the countryside. People felt they belonged. Rural communities are still regarded as more vibrant and there are several drivers that could maintain of reconstruct communities. Working against these are powerful forces of social fragmentation (Countryside

Agency, The State of the Countryside 2020, published 2003). Jules Pretty attributes this social fragmentation in the countryside to the modernization of agriculture. He further maintains that the social costs of modern agriculture and rural development have been significant and far-reaching as the environmental costs. Horizontal networks within communities have diminished, often replaced by vertical links to distant organizations. Farmers have fewer direct contacts with local people, and as a result trust and confidence have declined. Opportunities for informal and formal horizontal exchanges have fallen, and so norms of cohesive rural societies gradually have eroded (Jules Pretty, The Living Land, 1998).

Sociological Impact

There is little research conducted to date solely on sociological factors inducing evolution and the social impact of organic farming, conservation agriculture and GM crops. In various papers the need for more research into the social implication of organic farming has been identified.

Main Themes:

Social change: Change in lifestyle: consumers are more health-conscious and therefore impose a greater demand on organic food supplies.

- Decline in traditional family farms and the need for new markets is illustrated in the growing number of organic farms and/or conversion farms. Agri-environmental policies and growing consumer demand have stimulated conversion to organic farming.
- Research showed that there is a growing consumer resistance to genetically modified food stuffs as there are so far unknown risks to health involved. (REF)
- Pressures on rural areas and farmers have been identified as:

    - ✓ Demands from environmentalists and environmental legislation regarding pollution of air and water, biodiversity and landscape changes
    - ✓ Consequent pressures on farmers worldview, which are often productivist, from the above, which demand a different worldview
    - ✓ Demographic changes and differential migration in terms of age and skills

Ongoing and as yet unpublished research deals with the following subjects:

- ✓ Research into the socio - economic impact of organic farming which will explore the key hypothesis that organic farming provides an additional benefit to the rural economy and therefore rural development over and above conventional agriculture. It will also explore the benefits to employment patterns and social networks.

- ✓ Identified need for research (identified through stakeholder consultation):

  - Lifestyle changes
  - Health and diet needs (of an ageing population)
  - Studies that characterise the key economic, social and environmental drivers for business decisions of land managers
  - Recreation and tourism: positive and negative effects of demand on rural areas and farming for recreational needs and their social and economic effect

An interesting research project by the Consultative Group on International Agricultural Research (CGIAR) which aimed to understand how agricultural technologies influence and are influenced by livelihood strategies, vulnerability contexts and social relations involved seven case studies of different types of agricultural research in Bangladesh, China, India, Kenya, Mexico and Zimbabwe. One of the key insights of this study appear of interest for Britain also as they showed that: "The adoption of technologies depends on whether they are expected to increase or decrease vulnerability, whether the poor[10] have the pre-requisite assets, and the level of trust in mediating / disseminating institutions" (Ruth Meinzen-Dick; Michella Adato; Lawrence Haddad; Peter Hazell).

As a more sustainable agriculture seeks to make the best use of nature's goods and services, so technologies and practices must be locally-adapted. They are most likely to emerge from new configurations of social capital, comprising relations of trust embodied in new social organisations, and new horizontal and vertical partnerships between institutions, and human capital comprising leadership, ingenuity, management skills, and capacity to innovate. Agricultural systems with high levels of social and human assets are more able to innovate in the face of uncertainty.

[10] Read 'farmers' in the British context

Conclusions & Proposals

Significance Of The Knowledge Generated

The collection of research projects/publications for KASSA has been undertaken under time constraints, with the result that the data so far collected represents only a limited part of UK research with significance for sustainable agriculture.

A large body of knowledge has been generated by UK research projects. This knowledge base suggests that much more could be done in developing agricultural sustainability as well as minimising the negative impacts of farming on the environment. The technologies and methodologies, needed to achieve adequate levels of sustainable production, exist or are well progressed in their development.

In the context of UK agriculture, the historical development of the last half century has seen huge changes: declining numbers employed, increased mechanisation, and increased chemical/pharmaceutical inputs. Resulting from these factors, and changes in macro-economic conditions, has been a move away from the patterns of mixed farming toward a greater focus on monocultures, an ever smaller number of products produced within given farms and regions. Some projects (including *The Stockless Arable Organic Project* (*Nos OF0318 and OF0322*) at ADAS Terrington, funded by Defra, http://www.stocklessorganic.co.uk/stockless/ do suggest the possibility of arable-only organic farming albeit with a diverse range of crops compared to some conventional arable enterprises. However, overall the research would seem to suggest one of the requirements, of organic farming in particular and sustainability in general, is the recreation of greater product diversity, including in most cases a reintegration of livestock and arable systems.

In the overall field of conservation and enhancement of biodiversity some of the most important projects are those like the University of Oxford Dept of Zoology's project: The *Sustainable Farming Initiative: Whole Farm Conservation Plans* (see http://www.wildcru.org/research/farming/WFCP.htm) that works at a landscape scale. Such projects have a significance for conservation based funding systems (see http://www.wildcru.org/research/farming/relu.htm). Britain is a comparatively de-forested and heavily cultivated country with extensive built environment. A major threat to many of its wild plant and animal species arises from being trapped in isolated, man-made habitats. Single location/farm-based conservation initiatives do little to address this issue.

During the last 50 years various aspects of agricultural practices and land management have changed. While there has been little change in the total area of land farmed, yields have increased. In particular there has been a tendency for intensification and specialisation of production systems. There have been a range of associated agronomic and management factors that have also changed and include, livestock free farms, loss of traditional crop rotations, increased reliance upon fertilisers and pesticides, greater use of slatted housing and collection of slurry and a trend towards autumn sown arable crops. These changes have had and continue to have various direct and indirect effects on the local, regional and global environment. These include reduced biodiversity and annual nutrient surpluses, especially for many livestock systems, which have resulted in accumulation of nutrients within soil. There is also growing awareness that livestock farming, including run off from areas of hard-standing can contribute potentially significant quantities of faecal indicator organisms and pathogens with implications for drinking and bathing waters. Farm practices continually change and the wider implications of recent CAP reforms are likely to cause more changes.

The following section has been taken directly from a recent report produced for SEERAD (Custodians of Change: Report of Agriculture and Environment Working Group http://www.scotland.gov.uk/library5/agri/aewg-04.asp). The group were asked to examine the environmental issues that will impact on farming and food processing businesses over the next five to ten years and these represent their priorities.

From our analysis of impending legislation, climate change and the current impacts of agriculture on the environment, it is concluded that diffuse pollution, biodiversity and landscape will be issues of major importance over the next 5-10 years but of these the mediation of diffuse pollution should take priority over the next 5 years. These priorities are inter-linked; diffuse pollution reduces biodiversity, land cover changes impact on the landscape and landform focuses or disperses pollutants.

The Cultural Limitations on the Impact of Research

What impact the empirical knowledge generated by these and similar projects can have is likely to be limited by many factors. Chief amongst these is good faith on the part of legislators, administrators, and those involved in agri-business and the market. The achievement of a sustainable economy in primary resources is perhaps not as yet the first priority in most spheres of influence. It is unrealistic to believe that sustainable non-environmentally damaging agricultural production is achievable without some change to an economic culture predicated on continuous growth and increase in consumption, or an economic culture whose terms of reference always seek to minimise the value of primary products at the farm gate and maximise the value added in the stages between producer and end user. Much existing control, legislation and regulation, at all levels and whatever its ostensible intention, curtails sustainable modes of production and favours a non-sustainable “conventional” methodology of production. For example, seed registration regulations that have the incidental effect of limiting the diversity of varieties allowed for cultivation have the consequence of outlawing varieties with a local adaptive quality.

Many UK farmers are themselves autonomously pursuing strategies of marketing that attempt to circumvent the hegemonous economic system, these are of their nature limited in scope, for instance the number of producers who can retail their own products (farmer’s markets, organic vegetable box schemes, farm shops etc.) are limited to those able to produce commodities in an end user state who are located reasonably close to centres of population. A paradigm shift at the macro social scale is required before the knowledge generated by many research projects can fulfil its full potential impact.

Discussion

One obvious change required beyond farm level in order to increase sustainability and lessen environmental impacts is a reversal of the tendency toward centralisation in the processing and distribution of agricultural products.

Many communities in rural regions, in the recent past, were supplied with perishable commodities: eggs, milk, cheese, butter, vegetables etc. by, often small scale part-time local producers. Such near-subsistence level systems are often portrayed as inefficient because they did not generate significant cash turnover. They may be perceived otherwise if we view them in the context of the economy of the whole community, judge them by the terms of reference of sustainability and contrast them with a present situation where in more remote areas obtaining fresh food can involve consumers in long car journeys. In the Scottish context even the Scottish executive definition of "accessible rural" can mean a one-hour round trip to a community likely to have a supermarket, (see *Figure 2. Scottish Executive 8-fold Urban Rural Classification* http://www.scotland.gov.uk/library5/rural/seurc-03.asp) and these estimated drive times are very optimistic, and would require ideal weather conditions. In much of the Highlands and Islands of Scotland one can need very long journeys indeed to access fresh food.

In relation to the above, it seems significant that much of the research focussed on developing economies seeks to improve the methods and circumstances of subsistence-level producers and those creating small surpluses for local distribution. In a third world context they are seen as exemplars of sustainable production. If this is true in Africa and Asia, it surely is also true in Europe?

Without denying the role played by factors such as rural de-population, we need to accept that much has actually been done that has discouraged, small-scale, local production and distribution. Over the last three decades the writer has personally known many such small producers, both smallholders/crofters and larger farms where a small flock of poultry was kept or small quantities of cheese made as an ancillary enterprise. The reason most often cited for cessation of their production is the inability, or perceived inability, to comply with an ever-increasing burden of regulation and even the difficulty of knowing what regulations they need to comply with. Ironically most of this regulation was intended to protect against bio-hazard in response to threats that became significant in the context of industrial scale production and processing. Declines in profit and even losses are important but not as important as they would be to larger corporate enterprises. Eventually as enough individuals cease their activity related local infrastructures and networks of exchange disappear, often the area will be left with a near total dependence on tourism or even without a full-time resident population.

Whether we consider the destruction of artisanal production and self-sufficient rural communities to be incidental or intentional we need to consider if it is something we wish to perpetuate and spread to those areas that still have a degree of self-contained local economy.

A random perusal of the letters page of any of the farming papers in the UK indicates the extent to which farmers feel persecuted. Chief amongst the perceived enemies of farmers is of course the ever more complex burden of regulation and its accompanying often apparently incongruous bureaucracy - but the ‘environmentalist’ can come a close second and is also the provoker of yet more rules, regulation, extra costs and paperwork.

If sustainable agriculture is to be achieved there is still a battle for hearts and minds to be fought within parts of the farming community. Given the investment over the last sixty years that has gone into promoting the principles of high chemical input, high yield, cheap food-producing systems by governments and commercial interests, this is not surprising. Recently, within British society the cultural gulf between those who work in the country and those who work in the town has widened, there is a raised degree of antagonism. On both sides there is insufficient distinction between conservation initiatives based on scientific premises and initiatives based on cultural prejudices and the sentiments of an urban population increasingly divorced from the realities of the production of their food. Many see little distinction between the terms: ‘sustainable’, ‘ecological’, ‘organic’, ‘conservation’, ‘environmental’ and ‘green’. All these expressions and their derivatives can raise a spectre of an exclusively urban agenda determined to turn the countryside into a theme park wilderness for urban visitors and holiday homes, with no awkward indigenous inhabitants.
As an example, an illustrative quote from ‘The Scottish Farmer’ letters’ page for 20/11/04: *“The Greens*[11] *offer no new paradigm, no framework of explanation such as Darwinism or Cartesian rationale […]. They merely wish to reverse the progress of science in the West and deny its fruits to the Third World. They are the 21st century inheritors of the mantle of darkness which periodically engulfs the human race in superstition, mumbo-jumbo, ignorance and misery...”*. While this writer is extreme, his fears and misconceptions are not that unusual.

If the search for sustainable agricultural production is to be successful, a new, positive paradigm appears to be necessary. There is a need to emphasise the potential gains in food quality and variety, and an improvement in general quality of life and environment, the potential for sustainability to reverse rural decline and deprivation for those who live and work in the countryside.

There are of course farmers who are less sceptical with regard to the premises of the principles of sustainability, this does not necessarily mean they trust official policy with regard to sustainability, after all government ministries had a major role in creating the systems now considered unsound. Farming is a chosen or inherited lifestyle, different to most occupations in the extent to which people will persist in businesses irrespective of their profitability. Many work in other occupations to maintain a farm through lean periods, and/or diversify into other non-agricultural farm based enterprises. From personal contacts the writer recognises that many are desperate to find a way forward and

[11] Colloquial expression for political parties or individuals with a ‘green’ agenda as stated in the paragraph above.

are willing to consider most suggestions, however, whatever path is followed, they ultimately want and need to produce food, and require a viable profit margin between the production costs and the sale price of their produce.

An objective model of sustainability needs to acknowledge that what happens after food leaves the farm in terms of processing, storage and transport may often have a far greater impact than methods of production. Carrying organic vegetables thousands of miles by air to places where they can easily be grown can surely not be as sustainable as local produce - whatever its method of production. It is also necessary to acknowledge and quantify the differences in sustainability between conventional methods, many conventional extensive methods may actually involve no more inputs and be as or more sustainable than those with the legal designation of organic.

The aspect of food that impacts the consciousness of us all, every day is its taste not its safety. Unfortunately food quality in terms of taste does not follow a neat line between organic and conventional systems, the divide is often more noticeable between intensive and extensive production, or between fresh local food and old food from far away.

The concept of de-coupling support from production in the recent CAP reforms introducing the "Single Farm Payment" is intended to encourage rational, market based, decision making and to increasingly be a payment for land management as opposed to bulk production. It is central to the government's '*Strategy for Sustainable Farming and Food'* (see http://www.defra.gov.uk/farm/sustain/default.htm) whether it succeeds in increasing sustainability is yet to be seen. According to an article in (Farmers Weekly, Dec31-Jan6 2005, page12) the decoupling is *"…driven by World Trade Organisation demands and EU enlargement."*

If the end effect is that much UK production is abandoned as uneconomic, within the terms of reference of global trade, thus increasing the need for imported commodities, will this contribute to sustainability seen from a scientific and global perspective? (see: http://europa.eu.int/scadplus/leg/en/lvb/l11089.htm different systems will apply in the devolved U.K. administrations see: http://www.defra.gov.uk/farm/capreform/ and http://www.scotland.gov.uk/Topics/Agriculture/CAPRef/SFPS/Introduction and http://www.countryside.wales.gov.uk/fe/master.asp?n1=408 and http://www.ruralni.gov.uk/bussys/dard_consultation.htm).

Complementary Research Required

Some aspects of research could be usefully targeted:

- Nutrient composition, availability and patterns of release from various livestock wastes.
- Establish the value of farm level nutrient balances and especially what represents an acceptable surplus for each of the major nutrients. This should require some

adjustment for farm type, soil type and sensitivity of the surrounding environment.

- Quantify terrestrial sources and sinks of nutrient and faecal indicator organisms at farm and catchment scale.
- Evaluate the efficiency and value of remediation practices at the farm and catchment scale. Remediation measures might include natural/constructed wetlands, buffer strips, hedges, and fencing of stream banks. Assess there cost-effectiveness.
- Greater emphasis on cross discipline projects such as the current Rural Economy and Land Use (RELU) Programme (co-funded by the Economic and Social Research Council, the Biotechnology and Biological Sciences Research Council and the Natural Environment Research Council).
- Evaluate prospects of current CAP reforms for changes in farming practices.

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