

Impacts of Agricultural Change on Farmland Biodiversity in the UK

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1 Introduction

Over the past 50 years, there has been a marked decline shown by many species closely associated with lowland farmland in the UK, which is widely considered to be a key issue in British nature conservation. Increased availability of survey data has meant it is now possible to quantify changes in biodiversity for some groups. Changes have occurred in many farming practices and these have affected biodiversity in a variety of ways. Mixed agriculture in Britain has been lost and farms have become specialised; traditional crop rotations have declined and pastoral and arable farming have become polarised. Farming has intensified; for example, wheat yields in Scotland increased by 201% during the period 1967–1999 due to more effective tillage, application of fertilisers and pesticides and plant breeding. Field sizes have increased, reducing non-crop habitat at field margins. Other changes include more autumn sowing of crops and more efficient harvesting, more non-inversion tillage, drainage and reseed-ing of grassland, a switch from hay to silage, increased stocking rates and the use of avermectin wormers.¹ This has all impacted upon wildlife species that inhabit lowland farmland landscapes. Upland farming and livestock grazing has also intensified during this time. High grazing pressure, especially by sheep, has had a negative impact upon vegetation and wildlife in many upland regions of Britain.²

Much of the focus on biodiversity conservation within agricultural landscapes has been on the conservation of rare or rapidly declining species, driven in part by the UK Biodiversity Action Plan, the Government's response to the 1992 Convention on Biological Diversity, and also by the adoption of a commitment as part of the Government's Public Service Agreement to "care

for our natural heritage, make the countryside attractive and enjoyable for all and preserve biological diversity by reversing the long-term decline in the number of farmland birds by 2020, as measured annually against underlying trends; and bringing into favourable condition by 2010 95 per cent of all nationally important wildlife sites". However, other issues of importance in the context of agriculture include whether or not increased biodiversity or species richness enhances ecosystem functions such as primary productivity and nutrient retention or ecosystem services such as pollination and biological control.³ Non-crop habitats on farmland are usually more species diverse than cropped fields or intensive grasslands, and the areas of non-crop habitat may even become islands of species richness if dispersal across suitable habitat is limited. However, over-zealous "tidying" of non-crop areas can reduce value for biodiversity and there may be a conflict here between the concept of an attractive (which for many equates with "tidy") countryside and the wish to see it populated by diverse fauna and flora.

A review of changes in biodiversity on arable farmland⁴ concluded that around half of plant species, a third of insect species and four-fifths of bird species characteristic of farmland have declined. This chapter reviews the key changes that have occurred in agriculture during the second half of the twentieth century, set in the context of evolving policies on agricultural support and their impact on the characteristic fauna and flora of the farmed landscape. It concludes by considering the most recent reform of the EU Common Agricultural Policy and the implications of the shift away from production support and towards greater provision of incentives for environmentally sustainable management. A.D. Watt *et al.* present additional related and complementary material in Chapter 6 of this volume, with particular emphasis on the wider European aspects of land use change.

2 The Post-war Intensification of Agriculture

During and following the Second World War, agricultural policy focused on maximising food production. This resulted in an unprecedented level of change and intensification accompanied by subsidies ensuring prolonged price stability throughout the second half of the twentieth century. Although highly successful, this policy has been blamed for large declines in biodiversity within both the UK^{4,5} and Europe.⁶ Farming practices became polarised, where arable farming dominated the east of the UK and grassland/livestock farming the west, whilst mixed farming and the use of grass leys declined.

The key changes in both arable and grassland landscapes have been identified.¹ In arable landscapes, the key changes that took place in the last forty years include simpler rotations and block cropping; a switch from spring to autumn cropping; more efficient harvesting and sealed grain storage; and recently, more non-inversion tillage. On grasslands, key changes in the last forty years include more drainage and reseeding; a switch from hay to silage; a move away from dicotyledonous fodder crops and barley grown for fodder to

intensive grass and forage maize; increased stocking rates; and the introduction of avermectins. In the lowlands, there was a trend to larger, specialised farms with large fields and fewer hedgerows and increased use of pesticides and fertilisers.

2.1 Land Drainage

Land drainage grants were introduced in 1940 and abolished in 1987. The area of land drained reached a peak of 100 000 ha year⁻¹ in the 1970s. Most land drainage was undertaken to improve extensively managed or rough grassland but 40% was carried out for conversion to arable cropping. Remaining wet grassland habitats have also been affected by the drainage of adjacent arable land.⁷ Wet grasslands support distinctive plant communities and often contain rare species that are adapted to local conditions. Land drainage has also impacted upon wetland bird species, such as waders. Four bird species in particular have been affected: lapwing (*Vanellus vanellus*), redshank (*Tringa tetanus*), curlew (*Numenius arquata*) and snipe (*Gallinago gallinago*). Other species such as the starling (*Sturnus vulgaris*) have also been affected, as drier land alters the availability of soil-surface invertebrates.⁸ The decline of the water vole is probably partially due to widespread drainage and canalisation of rivers.⁹

Drainage is often the first step in the process of improvement, followed by intensification of farming on drained land, including reseeded, ploughing and fertiliser application. This intensification has had subsequent impacts on biodiversity. More rapid and denser grass growth of competitive species as well as higher stocking densities may occur in the case of managed grassland. These changes alter the habitat properties significantly, reducing both grazing opportunities for wildfowl and the range of seed resources available for use by granivorous birds.¹⁰ Drainage of wetlands can also reduce soil penetrability for probing birds and access to the soil surface may be reduced by more vigorous spring plant growth, reducing access for breeding birds.¹¹ Declines in bird species as a result of land drainage have occurred in both the lowlands¹² and the uplands.¹³

Although land drainage may have negative impacts upon biodiversity, particularly for rare wetland communities, ditches and drains themselves can provide a rich habitat within arable landscapes and can be final refuges for species that have declined due to field drainage.

2.2 Decline of Mixed Farming and Changes in Crop Rotations

The polarisation of farming, with arable farming now dominating in the east and grassland in the west, has reduced the diversity of habitats and resources associated with mixed farming. Agricultural intensification has brought about a change in the range and rotation of crops being grown. Management practices, vegetation structure and duration to harvest have altered. This has potentially had an impact upon biodiversity; however, more research is required to

understand the scale at which changes are likely to have had a negative impact upon populations. A loss of crop diversity is often cited as one of the key factors in the decline of the brown hare (*Lepus europeus*),^{14,15} although hares are still relatively common on arable farms.¹⁶

The separation of pastoral and arable farming systems has led to declines in bird populations, and grassland management in arable landscapes would improve habitat diversity within farmland.¹⁷ Equally, it is also suggested that the presence of arable habitat within grassland landscapes can be vital to the survival of key granivorous species such as grey partridge (*Perdix perdix*), skylark (*Alauda arvensis*) and corn bunting (*Miliaria calandra*) in grassland regions, in order to prevent local extinctions.¹⁸

The increasing availability of a large variety of pesticides and fertilisers, combined with the rising price of cereals, has led to grass leys (*i.e.* temporary grassland), once an important part of the arable rotation, being less popular as a means of controlling weeds and insect pests or for maintaining soil fertility. The introduction of fungicides has allowed many farmers to dispense with “break crops” such as grass or roots, previously used to control cereal fungal diseases. As a consequence of these changes, some arable weeds have declined, whereas others, such as barren brome (*Anisantha sterilis*), have increased. Weed species composition and diversity within different crop types will depend upon the management, *e.g.* fertiliser, pesticide and harvesting/cutting requirements of that particular crop type. For example, oilseed rape often has a higher level of broadleaved weeds than cereals, because they are more expensive to control and the yield benefit does not justify the additional herbicide cost. Sugar beet is sown in late spring so is more likely to contain spring-germinating species such as fat hen (*Chenopodium album*), a key bird food species.¹⁹

Thus, reduced habitat heterogeneity in all types of farming landscape is likely to have been an important factor in biodiversity losses over the last forty years as mixed farming has declined. However, mixed rotations, including arable crops and grassland grazed by livestock, are still key components of most organic farming systems.

Other changes in cropping practices have also had detrimental effects on biodiversity. For example, the decline in cultivation of fodder crops such as turnips in favour of field beans and, more recently, the increase in the growth of forage maize at the expense of barley in southern and western England have not been beneficial to bird populations. Changes in cropping practices may not always have a negative impact upon all species, however. For example, wood-pigeons (*Columba palumbus*) declined as clover was no longer sown on winter stubble during the 1960s, but increased in numbers when an alternative winter food source became available: the young leaves of autumn sown oil-seed rape.⁸

2.3 Fertiliser

The use of inorganic nitrogen fertiliser has doubled during the second half of the twentieth century.²⁰ This has had important implications for biodiversity,

particularly for plant species and associated fauna. Increased fertiliser use, often in conjunction with reseeding to competitive ryegrass (*Lolium perenne*), has resulted in major losses of botanical diversity in the majority of UK grasslands.¹ One of the most important factors affecting plant diversity is nutrient availability and thus the productivity of a habitat. Since the 1940s inorganic fertilisers have increasingly been used, which allow greater concentrations of nutrients to be applied with a quicker release time into the soil, though reliance on inorganic fertilisers reduces the amount of organic matter in the soil and may affect soil chemistry.⁴ Inorganic fertilisers promote rapid growth of a few competitive species, reducing light levels within the crop and preventing the growth of other plants.²¹ Along boundaries and hedgerows, misplaced nitrogen fertiliser can alter the nutrient balance, encouraging the growth of nitrophilous annual weeds such as cleavers (*Galium aparine*) and common nettle (*Urtica dioica*).²²

The stimulation of grass growth by fertiliser in grasslands renders the sward unsuitable for ground-nesting birds, and eliminates many broad-leaved plant species through competition.⁸ Loss of plant species has indirect effects on birds too, as insect diversity and abundance is reduced. Rapid growth in spring stimulated by nitrogen allows early and more frequent cutting, so that birds do not have time to complete breeding before cutting destroys nests.

Other nutrients, such as phosphorus and potassium, can also lead to changes in plant species in treated fields. In trials conducted in a species-rich hay meadow on a Somerset peat moor, phosphorus was more important than nitrogen in determining both biomass production and plant species change.²³ Grazing levels after cutting, along with fertiliser inputs, also contributed to botanical change. Liming, in order to reduce the acidity of soil before cultivation, has probably contributed to the decline of corn spurrey (*Spergula arvensis* L.) and corn marigold (*Chrysanthemum segetum*).²⁴

2.4 Pesticides

Highly toxic organochlorine pesticides used during the 1960s and 1970s have now been withdrawn following the well-documented decline in biodiversity that resulted from direct impacts of their use.²⁵ Screening of pesticides for toxicity to non-target organisms combined with risk assessment has reduced risks to such species; for example, the number of poisoning incidents involving wild mammals and pesticides has decreased over the last 10 years, from 20 in 1996 to 12 in 2005. In 2005 only two mammal deaths were caused by the approved use of pesticides, rodenticides in both instances.²⁶ This reflects the generally lower toxicity of modern products, improved education and tighter controls governing their use.

Today, indirect effects of pesticides (*i.e.* effects operating through the food chain) are of greatest concern for vertebrates; in particular, from broad-spectrum herbicides and insecticides. Broad-spectrum pesticides, insecticides especially, have a major long-term effect on non-target invertebrates,²⁷ many of

which are important as biological pest-control agents or as important links in the food chain of farmland faunal groups.²⁸ In particular, the application of broad-spectrum pesticides in agricultural systems has decreased bee populations dramatically.²⁹

Herbicides impact upon bird populations by either (1) reducing the abundance of, or eliminating, non-crop plants hosting arthropod foods for birds, particularly during the breeding season, or (2) depleting or eliminating weed species, which provide food for herbivorous or granivorous species.³⁰ Herbicides reduce butterfly abundance indirectly when they cause the loss of larval food-plants and nectar or pollen sources for adults, particularly in boundary vegetation.

In addition to the toxicity of the pesticide itself, the timing of pesticide application, the indirect effects of the pesticide and impacts on non-target species are all important to invertebrate survival. Pesticides may reduce invertebrate abundance through direct toxicity, but also indirectly by restricting food supply or altering habitat. Pesticides are now routinely screened for side effects against non-target invertebrates for the purpose of registration.

The direct impact of pesticides on different invertebrate groups is highly dependent upon the timing of application. For example, autumn applications tend to drift into field boundaries more because crop and marginal vegetation heights are lower³¹ and may therefore contact invertebrates over a larger area.

The importance of indirect effects of pesticides on birds was first identified for the grey partridge.^{32,33} Pesticides (insecticides and herbicides) were shown to be important in limiting chick survival by reducing the supply of invertebrates important in chick diet, and the implementation of conservation headlands, whereby invertebrate densities were increased by restricting use of these pesticides at the edges of cereal crops, was shown to increase chick survival.^{34,35} In a review of indirect effects of pesticides,³⁶ grey partridge was considered to be the only species for which such effects had been conclusively demonstrated, though there was circumstantial evidence for a number of other species. Corn bunting brood condition and the probability of nest survival were both correlated with the abundance of insect food close to the nest and, furthermore, the abundance of chick-food was negatively correlated with the number of insecticide applications.³⁷ More recent studies have shown similar results for yellowhammer (*Emberiza citrinella*).^{30,38,39}

The exposure of mammals to pesticides can be very variable, depending on how the pesticide is applied and the feeding behaviour of the mammal species,⁴⁰ and though the short-term impacts may be measurable, long-term effects are unclear.⁴¹ Species that frequent arable land, such as badgers (*Meles meles*), bank and field voles (*Clethrionomys glareolus* and *Microtus agrestis*) and deer are likely to suffer exposure to agrochemicals.⁴²

Use of pesticides continues to increase in intensity: the area of arable crops increased by 3% between 1994 and 2004, but the pesticide-treated area increased by 42%, though the weight of pesticides applied had decreased by 4%.⁴³ This increase in area treated despite a decrease in area grown reflects an increase in average number of sprays applied to each crop, plus an increase in

the number of products used. The average number of pesticide sprays applied to a crop has increased from four in 1994 to over five in 2004. Also the number of products used increased from an average of seven products per crop in 1994 to almost eleven in 2004. On grasslands, pesticides are used less intensively, though herbicides may be used to control some broad-leaved weeds in order to maximise grass quality for livestock grazing.

Arable weed seedbanks have been significantly depleted by intensive herbicide usage over the last fifty years, so that some plants once termed “weeds” are now species of conservation concern in the UK.⁴⁴ Chickweeds (*Stellaria*), knotgrass and persicarias (*Polygonum*) and goosefoots (*Chenopodium*) are important food sources in the autumn and winter for a large number of granivorous bird species on farmland, such as linnet (*Carduelis cannabina*) and tree sparrow (*Passer montanus*).^{19,45} These particular weeds are generally less competitive in winter cereals; thus more selective herbicide use could help to maintain these species. However, between 1970 and 1995 the spectrum of activity of herbicides on weed taxa increased from an average of 22 to 38 taxa.⁴⁶

The impacts of the increased use and efficiency of herbicides are exacerbated by improved seed-cleaning techniques and the development of increasingly competitive, nitrogen-responsive crops, acting to minimise weeds and reduce availability of seed foods. The timing of herbicide applications may also be important; spraying with herbicide in the spring/summer had the greatest impact on plant populations, particularly in terms of a decrease in broad-leaved weed occurrence.⁴⁶ During recent decades herbicide use has increased and switched gradually from spring/summer applications to autumn/winter applications, reflecting the trend towards autumn-sown crops over the last 30 years, though follow-up spring applications are often also made.

Pesticides are likely to be one of the most important factors influencing gross levels of abundance of farmland plants.⁴⁷ Many of the plant species that remain common on farmland either have prolific and persistent seedbanks or are resistant to or difficult to target with herbicides.⁴

2.5 Field Size and Hedgerows

Increased mechanisation and the demand for productivity in the latter twentieth century led to increased field sizes and subsequent hedgerow loss. Hedgerows were removed to allow the use of large machinery in arable cropping and because their role in stock control became redundant with the loss of livestock from arable farms.⁴⁸

Hedgerows and field margins are important habitats for a range of wildlife.^{49,50} Thus the removal of hedgerows is likely to have had a significant impact upon biodiversity. Hedgerows both facilitate and restrict invertebrate movements and flight activity.⁵¹ For example, butterflies disperse along linear features such as hedgerows, but may also perceive them as barriers to movement.⁵² Hedgerows can also restrict the movement of beetles, causing

aggregations around field boundaries.⁵³ It has been shown that hedgerows are particularly associated with the presence of bee species.⁵⁴

Hedgerows are important habitats for a number of species of bird, including yellowhammer.⁵⁵ Hedgerow removal or abandonment of hedge management, excessive cutting of hedgerows, incorrect timing of hedgerow cutting, filling or clearing of ditches and other intensification that has impacted upon field margins such as cropping or grazing right up to the field edge, have had a long-term impact on hedgerow bird species.⁵⁵

Hedgerows are important mammal habitats in the agricultural landscape, as a source of food and shelter and as corridors of movement between other habitats; over 20 mammal species are known to live or feed in hedgerows. Hedgerows are also important to predators and can provide one of the most prey-rich habitats for species like the weasel.⁵⁶

Cutting or flailing during the autumn, when fruit is setting, or in the winter can lead to the loss of important food resources for small mammals. Reduction of hedgerow size due to an intensification of management and the resulting loss of food and cover has been implicated in the decline of the common dormouse (*Muscardinus avellanarius*).⁵⁷

Large scale losses of hedgerows have occurred as a result of agricultural intensification and, although this loss appears to have been halted and new plantings undertaken, the ecological value of these new hedgerows, particularly compared to ancient hedgerows that have been lost, has yet to be assessed.⁴⁸

2.6 Autumn Sowing

Winter cropping has increased at the expense of spring-sown crops over the past 40 years due to the availability of higher-yielding cereal varieties capable of overwintering. The percentage of spring-sown wheat and barley declined from over 70% in 1968 to less than 20% in 1998.^{58,59} Key differences in associated flora and fauna occur between winter-sown crops (cereals and oilseed rape) and spring-sown crops (potatoes, sugar beet and maize); for example, spring root crops have lower abundances of beetles and spiders.^{22,60}

The increase in autumn tillage has changed the composition of weed communities and reduced stubble feeding grounds over winter.⁵ The reduction in the presence of winter-stubble is highly significant, as areas of winter-stubble positively influence national trends in breeding and population recovery of key farmland bird species such as skylark and yellowhammer.⁶¹ Winter cropping has resulted in the loss of breeding habitat for ground-nesting birds such as lapwing⁶² and skylark,⁶³ which prefer the more open structure of spring-sown crops.

Tillage, particularly ploughing, can cause high mortality in populations of soil dwelling Diptera (two-winged flies) larvae.⁶⁴ Ploughing also has a strong negative impact on spiders,⁶⁵ with autumn cultivation being damaging,⁶⁶ and is also reported to be detrimental to moths⁶⁷ and Hemiptera.⁶⁸ Symphyta (sawfly) abundance has declined rapidly due to increase in autumn cultivation, which destroys over-wintering larvae.⁶⁹

An increase in area of winter-sown cereals may have had an adverse impact on the harvest mouse (*Micromys minutus*). Modern cereals grow and ripen quickly and so are ready to harvest in late summer, which corresponds to the peak breeding season of the harvest mouse. The loss of nests and young in cereals, combined with a reduction in rough grassy areas which can also provide suitable nesting habitat, has probably contributed to the decline of the harvest mouse on farmland.⁷⁰

A change to winter cereals from spring cereals leads to a reduction in weed density and species diversity and, in the UK, a change to autumn cultivation may have contributed to the decline of spring-germinating species such as cornflower (*Centaurea cyanus*), corn marigold and red hemp-nettle (*Galeopsis angustifolia*).

Earlier harvesting of crops may limit the breeding season of late nesting bird species, for example, corn bunting.⁷¹ Modern, efficient combine harvesters leave less wastage and grain remaining in stubbles after harvest, which, when combined with the effects of more efficient weed control, further reduces the availability of food for seed-eating birds and other seed predators over the autumn and winter period.¹

2.7 Management of Grassland

Grassland management can have major impacts upon feeding and nesting bird population dynamics within the field in the UK. Intensification of grassland management has led to increased vegetation density and homogenisation. Longer vegetation in grassland systems can enhance food supplies for several farmland bird species (e.g. Tipulid larvae).⁷² Conversely, sparse vegetation benefits aerial hunters such as kestrels (*Falco tinnunculus*).⁷³ Of the 20 species included in the Farmland Bird Index, it has been suggested that 15 of these species are likely to benefit from shorter swards for foraging and predator detection, for at least part of the year.⁷⁴

For some species (e.g. lapwing, starling, barn owl (*Tyto alba*)) mosaics of short and long vegetation may provide the optimum conditions.⁷⁴ It is suggested that ideally these mosaics should be varied temporally as well as spatially (managed as short-term leys mixed with permanent pasture), with low-intensity cattle grazing over the autumn and winter, to maximise the range of bird habitat available.⁷⁵ Similar conclusions were reached in a modelling study of coastal grazing marshes, indicating that the heterogeneity of grass sward height was more important in determining species presence than mean sward height. Complexity of the grass sward and surface topography favoured the presence of ground nesting birds.⁷⁶

Agricultural improvement of grass swards has resulted in higher yields, allowing more frequent cutting and higher grazing densities. The conversion of rough grazing, the switch from hay to silage and the loss of temporary grassland in rotation may have impacted upon birds by reducing insect food supplies.⁷⁷ Grassland intensification is detrimental to butterfly populations.

Ploughing and reseeded old pastures with rye-grass (*Lolium*) swards eliminates all known larval food plants of British butterflies,⁷⁸ and pasture improvement coupled with high stocking levels destroys the structural and botanical diversity of swards, which is needed to support a high diversity of butterfly species.⁷⁹

In upland regions, many areas of grassland have been ploughed and reseeded with high-yielding grass species in order to improve fodder quality. However, these grasslands are generally dominated by perennial rye-grass, which can withstand frequent defoliation and disturbance and responds to high levels of nitrogen use.¹⁰ Plant species diversity is therefore low, as few broad-leaved forbs can survive within these swards. The ploughing and reseeded of unimproved pasture combined with the input of inorganic fertiliser have caused a massive loss of botanical diversity in grassland.⁸⁰

2.7.1 Cutting Management. Since the 1970s there has been a trend towards silage rather than hay for winter stock feeding. Grassland grown for silage usually consists of highly fertilised reseeded swards. Silage has higher moisture content than hay and so mowing for silage can begin as early as mid-March and can be repeated every few weeks until the autumn. This allows little time for both grass and forb species to flower and set seed and little opportunity for seed to enter the seed bank.¹⁰ In contrast, hay is usually cut in mid to late summer, allowing many plants species to set seed. Moreover, seed is released during handling and transportation and dung from hay-fed stock also contains large quantities of seed, which may be deposited back onto grassland with a possibility of germination. Because of earlier and more frequent cutting, seed set is largely prevented. Sources of food for birds and other animals are thus reduced. Silage cutting, with fast cutting machines, occurs at a time of year when leverets (young hares) are using the grass fields for feeding and cover, resulting in potentially high mortality levels.⁸¹

2.7.2 Grazing Management. Uplands and lowlands have undergone a large increase in sheep stocking densities in recent years, which has clearly impacted upon the habitat structure, sward height and composition of grasslands. The number of sheep in the UK increased by 3% between 1984 and 2005 whereas the number of cattle declined by 20% over the same period, though the rate of increase for sheep would probably have been higher and the decline less for cattle without the Foot and Mouth Disease outbreak in 2001. The effects of grazing upon biodiversity are complex and depend upon the type of stock, stocking rate and timing of grazing.¹

Livestock type can alter the structure and species composition of the sward. Sheep tend to bite off vegetation close to the ground; often selecting plants low in the grassland profile and so produce very short swards. They can be selective feeders, avoiding tall plants and tussocky areas and often selecting flowers over grass stems. Wethers (castrated rams) are less selective grazers and have a lower mineral requirement than lambs or ewes and so will often feed on coarser and less palatable vegetation.⁸² Cattle, however, are less selective feeders than sheep

and cannot graze as close to the ground so that longer swards are maintained.²⁰ Also, cattle avoid grazing close to dung-pats, so the longer grass around these results in a more structurally diverse sward.

Timing of grazing can also be important. In one study, species richness of a lowland neutral sward was increased by sheep grazing in spring or winter, provided that spring grazing was followed by only light summer grazing,⁸³ whereas in another, species diversity, richness and original species composition in a meadow were maintained by autumn and spring grazing.⁸⁴ Grazing in spring and summer can be useful in the control of scrub or undesirable weeds but can be detrimental to early flowering plants such as the fritillary (*Fritillaria meleagris*). In the autumn, most plant species have finished flowering and set seed, and winter grazing probably has little effect on most grassland herbs, though poaching (*i.e.* breaking of the sward by livestock trampling, particularly a problem under wet conditions) is possible under heavy grazing, and the low nutritional quality of the grass may require the supplementary feeding of stock.²⁰

Grazing acts upon plant communities through defoliation, trampling, deposition of dung and urine and poaching, all of which can alter the relative abundance of species and their competitive abilities. Grazing by animals usually results in greater plant species richness; the sward is kept open, allowing the establishment of forb species in the gaps.¹⁰ However, too little or too much grazing both can have an adverse effect on species diversity. Low grazing levels can lead to patches of tall rank vegetation and deep litter layers, both of which hinder establishment of forbs, whereas heavy grazing produces short, dense swards with little production of seed.

Reductions in pastoral bird populations have been linked to increases in stocking densities of sheep.⁸⁵ High stocking densities have reduced seed and insect availability to birds through reduced sward height and plant diversity (such as loss of heather (*Calluna vulgaris*) moorland), impacting upon almost all species of open upland habitats.⁸ The value of the sward as nesting and wintering habitat has deteriorated under these conditions and short, uniform swards are poor for shelter and protection from predators.^{2,20} Direct impacts of higher stocking densities include increased defoliation intensity and trampling, which destroys bird nests and young.²⁰ Key species affected include ground-nesting birds such as black grouse (*Tetrao tetrix*) and red grouse (*Lagopus lagopus*).⁸ A recent study of lowland grasslands indicates that such intensification may only affect specific insectivorous birds during the summer (for example, buntings, skylark, whinchat (*Saxicola rubetra*) and red-backed shrike (*Lanius collurio*)) and intensification may in fact be beneficial to several species in winter (such as carrion crow (*Corvus corone*) and jackdaw (*Corvus monedula*)) as soil invertebrates are increased.⁸⁶ Studies also show that more intense grazing of moorland favours skylarks and the fragmentation of heather favours meadow pipits (*Anthus pratensis*).⁸⁷

Field voles, which have declined over the last 40 years,⁴ are very dependent on rough grassland, though if this habitat is not grazed it can revert to unsuitable scrub, and if it is grazed too much, the sward can become too short

to attract voles.⁸⁸ The loss of unimproved and rough grassland and heavy grazing has also adversely affected pygmy shrews (*Sorex minutus*) and common shrews (*Sorex araneus*),⁸⁸ and unimproved and ungrazed pasture has been found to be strongly associated with high numbers of brown hares.^{89,90}

2.8 Heather Burning

In uplands, burning of heather has become widely practised as a method of promoting fresh growth. Where red grouse shooting is common, burning is on a small scale in rotation to create a heather mosaic; however, where sheep are dominant burning is large scale and more frequent.

When sensitively managed, burning of heather helps to remove the accumulation of older, woody areas of the plant and also helps to stimulate seed germination and shoot regeneration. These shoots provide a good food source not only for sheep grazed in upland areas, but also for grouse. However, repeated burning can lead to a loss of moorland flora and wildlife habitat, fire-resistant species such as bracken (*Pteridium aquilinum*) can be favoured and, when burning is undertaken in conjunction with heavy grazing, grass species such as purple moor-grass (*Molinia caerulea*) may replace heather.⁹¹ Only a few mammal species such as the red deer (*Cervus elaphus*) and the mountain hare (*Lepus timidus*) are primarily associated with upland habitats and only the latter appears to be affected by the practice of burning to encourage heather regeneration. Sheep grazing can also result in the loss of heather and the spread of coarse grasses and the sheep themselves compete directly with the hares for food and cause disturbance to feeding hares.⁹²

2.9 Grain Storage and Animal Housing

Keeping animals inside yards and/or sheds and off pasture fields can have impacts on biodiversity, as grazing may improve floral and faunal diversity both in terms of species and structure. For example, it has been found that keeping cattle inside can result in fewer ground and dung beetles present as prey for bat species.⁹² Keeping animals indoors during the winter can reduce food sources for birds that feed on the grains provided for the livestock, for example, corn buntings. Also, the elimination of rickyards and other sources of grain around farmyards in mixed farmland has reduced the availability of food for corn buntings, with the highest impact during the breeding season,⁹³ and has removed an easy source of rodent prey for barn owls.⁹⁴ Tidiness and hygiene around farmyards and “bird-proof” storage facilities also limit food availability for birds; it is believed such measures may be responsible for the recent decline in the rural house sparrow (*Passer domesticus*) population.⁹⁵

Another factor leading to a reduction in grain availability in the field is the efficiency of modern combine harvesters, producing less waste and resulting in lower densities of grain left in the stubble after harvest. In conjunction with efficient weed control practices and the effects of keeping animals indoors (see

above), food availability for seed-eating birds and other seed predators is much reduced over autumn and winter.

2.10 *Veterinary Medicines*

Veterinary medicines are widely used to treat disease and protect the health of animals. Release of veterinary medicines to the environment occurs both directly (for example, the use of medicines in fish farms) and indirectly, via the application of animal manure containing excreted products to land. There is a need to explore the links between fertiliser inputs, predation rates, anti-helminthic (worming agents) treatments for livestock and bird habitat suitability in grasslands,²⁰ and also the implications of veterinary medicine use for biodiversity in uplands.

Pasture invertebrate assemblages are potentially threatened by modern livestock endo-parasite control practices. The best-studied group of endo-parasitic treatments, in terms of potential environmental impacts, are the avermectins, which have been widely used for the past twenty years. While these chemicals offer very effective endo-parasite control, they do not decompose well and remain active in cattle dung at least five weeks after treatment.⁹⁶ Avermectin residues are excreted in the faeces of treated animals and, being insecticidal, may reduce the numbers and diversity of invertebrates associated with dung, many of which are important prey items for birds.²⁰ A large number of birds feed on insects within cow dung (for example starlings, rooks (*Corvus frugilegus*) and jackdaws) particularly in winter when other food sources are scarce and in spring when beetles emerge (coinciding with nesting).⁹⁷ Direct effects of avermectins on birds are not evident; however, indirect effects may be caused by a reduction in dung insects, which would have greatest impact at critical times of year, such as during the breeding season or when chicks begin to forage. In addition to direct mortality, avermectins cause non-lethal effects such as reduced invertebrate fecundity. This could depress sensitive populations of dung beetles such as *Aphodius* spp.⁹⁸

Dung, particularly that from cattle, is an important source of invertebrate prey for several bat species.⁹⁹ For bat species such as the lesser horseshoe (*Rhinolophus hipposideros*) and Natterer's (*Myotis nattereri*), dung-associated dipterans are an important food source and, for larger species such as the serotine (*Eptesicus serotinus*), dung beetles are particularly important in the diet in late summer and autumn when the young bats are preparing for hibernation.⁹⁹ A shortage of suitable prey could have serious consequences for these bat species.

2.11 *Supplementary Feeding*

Supplementary feeding of livestock, particularly of sheep on upland areas, is often carried out over the winter months when the nutritional value of the vegetation is low. In such instances, instead of spreading their grazing over an

area, flocks tend to concentrate around the sites where supplementary feed is put out, leading to a degradation of the upland heather vegetation.^{91,94} Hay is often placed upon areas of old heather to prevent it from blowing away, but this also leads to a concentration of trampling and grazing on vegetation least able to withstand it. Urea-based feed blocks can also stimulate the sheep to eat more roughage, which is usually taken as heather,⁹¹ and this can also contribute to the decline of the vegetation. Ideally, supplementary feeding on heather moorlands should be given on areas of coarse grass or dead bracken, away from heather stands.

3 Recent Changes in Agricultural Practices

Since the zenith of high productivity farming in the 1980s, a number of changes have occurred, which have been largely driven by successive reforms of the European Common Agricultural Policy (CAP). Accumulation of surpluses plus a need to reduce burgeoning expenditure led to a reduction in incentives to maximise output per unit area, coupled with falls in prices for many agricultural commodities. This led to changes in production techniques designed to increase efficiency and reduce costs, with the aim of optimising, rather than maximising, output and an increased emphasis on sustainability of production. At the same time, interest has grown in alternative enterprises to supplement the traditional crop and livestock products of agriculture.

In addition, a growing realisation of the impacts of intensification upon biodiversity and other environmental attributes led to a gradual but increasing emphasis in agricultural policy upon environmental protection and biodiversity conservation, including the introduction and development of a number of “agri-environment” schemes, which provide payments for environmentally beneficial management. In parallel to these developments, a growing public awareness of the negative effects of intensive production and concern about the health implications of production methods has increased the market for food produced from agricultural systems perceived to be environmentally benign, such as organic farming.

3.1 Farming Systems

Although organic farming has been practised for several decades, interest has grown in recent years because of the perceived benefits for human health and the environment. In recognition of this, Government incentives for conversion to organic farming were introduced. In England, The Organic Aid scheme was launched in 1994 and superseded by the Organic Farming Scheme in 1999. This has now closed, to be replaced by the Organic Entry Level Scheme. Equivalent schemes in other parts of the UK are the Organic Aid Scheme in Scotland and Organic Farming Schemes in Wales and Northern Ireland.

Concerns about the sustainability of intensive production methods also led to an increased interest in the development of “integrated” farming systems,

which continue to utilise pesticides and inorganic fertilisers that are largely avoided by organic farmers, but aim to minimise the use of these inputs through integration with cultural control of weeds, pests and diseases, avoidance of nutrient losses and improved efficiency of nutrient use. Guidelines for Integrated Crop Production were drawn up in 1993,¹⁰⁰ based on the IOBC definition of integrated farming which can be summarised as “a farming system that produces high quality food and other products by using natural resources and regulating mechanisms to replace polluting inputs and to secure sustainable farming”.

Early studies comparing the effects on biodiversity of organic and conventional farming were often inconclusive, but in recent years evidence for biodiversity benefits from organic farming has grown. It is hard to define exact elements of organic farming that give rise to specific benefits; however, in general, the combination of mixed crop and livestock farming, varied crops, low chemical pesticide and inorganic fertiliser use, smaller fields and a larger proportion of field boundaries, which is characteristic of organic systems, tends to improve their suitability as habitat, particularly for birds.^{101,102} There is a general consensus that greater abundance and/or species richness of birds is found on organic rather than conventional farms, particularly for skylark, blackbird (*Turdus merula*) and greenfinch (*Carduelis chloris*) populations.¹⁰²

Total bat activity and foraging activity both were found to be significantly higher on organic farms¹⁰³ and the activity levels of small mammals were found to be higher in organic than in conventional fields.¹⁰³ In both studies, increased food abundance as a result of sympathetic management, particularly of hedgerows, was cited as the likely factor influencing mammal biodiversity.

Organic farming has been reported to benefit ground beetles (carabids),¹⁰⁴ spiders⁶⁵ and butterflies,¹⁰⁵ although other studies found no significant differences between butterfly populations on organic and conventional farms¹⁰⁶ and that species richness of carabids was higher on conventional farms than on organic farms.¹⁰⁷ Other invertebrate orders such as staphylinid beetles have been found to be more abundant in conventional fields.¹⁰⁴ Possible explanations for this are that staphylinids, a group of highly mobile beetles, may avoid pesticide applications more easily than other less mobile groups, that the higher crop density in conventionally managed fields creates a more humid microclimate which suits this group, or that some of the groups with which staphylinids compete are less abundant in conventionally managed fields. The authors of a study which concluded that organic farming can result in a more vigorous carabid fauna in terms of species richness and activity suggested that effects of herbicides/pesticides and different levels of weediness between conventional and organic farming may have accounted for this difference.¹⁰⁸

Within grassland systems, any differences between organically and conventionally managed pastures were less marked, though it appeared that organic permanent pasture contained more typical grassland species and a greater species richness, especially of forbs.¹⁰² Hedge bottom vegetation also had higher species diversity on organic than on conventional farms. This is likely

to be due to the lack of herbicide drift and higher rates of immigration from the greater species pool available in surrounding areas on organic farms.¹⁰²

Integrated Farm Management also promotes more environmentally sensitive approaches to farming (see <http://www.leafuk.org>) and is perhaps more economically viable for the majority of farmers. Even fewer studies are available that assess the performance of integrated farming in comparison with conventional farming for biodiversity, than for organic farming. There is some evidence that integrated farming systems may benefit seed-eating birds such as chaffinch (*Fringilla coelebs*) and yellowhammer in particular and, in general, bird numbers have been found to increase.¹⁰⁹

Conservation Grade is an emerging farming system. Farmers have to take 10% of their land out of food production and devote it to habitat creation so that wildlife can be protected. This builds upon Integrated Farm Management practices, providing further benefits for wildlife.

Many researchers advocate mixed farming as key to the success of programmes to sustain farmland bird populations in the UK.^{74,110} Heterogeneous landscapes, mixed cropping and crop rotation, grassland within arable landscapes (or arable cultivation within grasslands) and conservation areas are important elements which can often be implemented as options within agri-environment schemes.

Overall, it has been found that other aspects of agricultural practice, such as crop type and the location of the farms assessed in the studies, tend to be more significant than the differences in the farming practices themselves.¹¹¹ Individual farming practices in time and space within each farming system are what really define the benefits to all organisms, including birds, although the structure of the farm defined by the farming system may facilitate key beneficial practices (for example, small fields and more extensive boundaries on typical organic farms).

3.2 *Reduced Cultivation Systems*

There has been renewed interest recently in reduced forms of cultivation, variously known as minimal cultivation, non-inversion tillage, conservation tillage, eco-tillage and, in its extreme form, as direct drilling or no-till. The common factor is the absence of ploughing (*i.e.* soil inversion), formerly considered essential for weed control and to bring fresh soil to the surface to provide a seedbed. Improved cultivation machinery combined with effective non-selective herbicides (in particular glyphosphate) has made it possible to establish many crops without ploughing, thus providing savings in both time and cultivation costs. Additional benefits are improved soil structure and reduced erosion risk. Conservation tillage is thought to provide better cover for ground-nesting birds compared to conventional tillage or where tillage is used to control weeds.¹¹² Higher densities of birds and higher productivity by nesting passerines have been observed in some North American studies, but there have been few studies into the effects of this form of tillage on farmland

birds in northern Europe to date.^{112,113} However, a recent UK study found that gamebirds, skylarks and granivorous passerines all occupied a greater proportion of fields established by non-inversion tillage than by ploughing in the late winter period, though there were no differences early in the winter.¹¹⁴

Numbers of earthworms generally increase under reduced tillage systems, but results of studies on arthropods are often conflicting or inconclusive.¹¹² It appears that different species may respond to cultivations in different ways, but that large species are more vulnerable to cultivations than smaller ones. Minimal cultivations can exacerbate slug problems, thus increasing the need to apply molluscicides. The effects of different forms of soil cultivation and seedbed conditions at the time of sowing upon slugs have been well documented.¹¹⁵ The more thoroughly the soil is worked, the more effective cultivations become at reducing slug numbers,¹¹⁶ while direct drilling of land has been reported to give the highest slug numbers.¹¹⁷

Many plant species found in arable crops are annuals, which are able to grow and set seed in the time between the sowing of the crop and the post-harvest cultivation. Many of these seeds can remain dormant in the seedbank for several years and species with long-lived seeds such as the common poppy (*Papaver rhoeas*) have persisted on arable land, whereas species like the shepherd's needle (*Scandix pecten-veneris*) that have shorter-lived seeds have declined.⁸⁰ The introduction of reduced cultivation systems means that seed is not buried during cultivation and has led to the increased abundance of some perennials and annual grass weed species such as black-grass (*Alopecurus myosuroides*).¹¹² and may encourage the establishment of species whose seeds are dispersed by wind, such as perennial sow-thistle (*Sonchus arvensis*).²⁴ However, this system of cultivation may also result in the decline of arable dicotyledons with persistent seedbanks, which benefit from soil inversion.²⁴

3.3 Set-aside

Set-aside land was introduced in 1988 as a supply control measure to limit overproduction of cereals and other arable crops. The generation of environmental benefits was not one of the original objectives of set-aside; nevertheless it was hoped that it might improve habitat for farmland birds by encouraging broad-leaved plants and improve arthropod and seed availability. However, natural regeneration may produce dense vegetation with a limited arthropod fauna, depending upon soil type and situation. Even sown grasses may produce a cover of limited value.²²

In 1992, rotational set-aside was introduced, which led to the creation of more desirable habitats that are more beneficial to farmland biodiversity, depending also upon the seeds that are sown: cereals, brassicas and red clover (*Trifolium pratense*) benefit insects, for example.¹¹⁸ The most commonly adopted management for rotational set-aside is to allow fields to regenerate naturally a cover of vegetation without any input of agrochemicals.¹¹⁸ It has been found that a typical, naturally regenerated set-aside field, in the first

season of establishment, generally develops a mixture of crop volunteers and opportunistic arable plants with much bare ground. The vegetation on non-rotational set-aside continues to develop into a perennial grass sward after another 1–3 years, due to natural succession following the cessation of soil disturbance. Studies have shown that most species prefer set-aside land as habitat in summer and winter compared to other cropped areas,^{119–121} skylark in particular.¹²²

Set-aside and fallow land has been associated with higher numbers of hares, probably because these areas create habitat diversity within the agricultural landscape, increasing the variety and amount of food available and providing cover throughout the year.^{15,123} The positioning of set-aside may be important; blocks of set-aside were used by wood mice (*Apodemus sylvaticus*) and strips adjacent to margins were avoided, possibly due to the increased risk of predation in the area close to the hedgerow.¹²⁴ Management practices, such as sowing with a grass seed mix, mowing and length of time left *in situ*, can all be a positive influence on the attractiveness of the area to small mammals like the field vole.¹²⁵

In addition to natural regeneration and sown grass swards, set-aside can also be sown to “wild bird cover” (defined as an unharvestable mix of at least two crop groups, *e.g.* cereals and brassicas) and non-food crops. Wild bird cover can be a valuable source of food for seed-eating birds in winter.^{126,127} Non-food crops are usually grown to produce oil for industrial use (*e.g.* oilseed rape, linseed) or energy crops (see below). Where non-food crops are of the same type as those grown for food, production systems, and hence impacts on biodiversity, are essentially the same.

3.4 Energy Crops

A number of novel crops have been investigated as potential alternatives to those currently grown. Some have achieved commercial success, *e.g.* borage, but so far these have remained “niche” crops, grown on a very limited area. However, one class of novel crops has the potential to cover significant areas of farmland in the near future, *viz.* crops grown as a source of renewable energy, in order to reduce reliance on fossil fuels and help meet targets to reduce greenhouse gases. Thus, substantial increases in the area of non-food “energy crops”, such as *Miscanthus*, short-rotation coppice and oilseed rape, are likely in the near future.

Annual arable crops such as wheat, barley, potatoes and sugar beet, which are all used to produce bio-ethanol, and oilseed rape grown as a source of biodiesel, are likely to contain the same invertebrate communities as conventional crops.¹²⁸ A number of studies have found that oilseed rape is preferred by some bird species to other crops such as wheat and barley.¹²⁹ However, any changes in crop varieties or management, particularly in the use of insecticides and herbicides, could lead to changes in biodiversity and insect communities; an increase in these agrochemicals may directly reduce insect populations and

the presence of food and cover, whereas a decline in chemical inputs could lead to an increase in arable weeds and greater insect numbers and diversity.¹²⁸ Overall, it is suggested that there will be little difference in the environmental impact of growing annual crops for bio-fuel instead of food. There is only likely to be a negative impact if they are grown on current set-aside land.¹²⁹

Perennial energy crops are relatively undisturbed, allowing the development of varied ground vegetation, particularly in the field margins.^{130,131} The most common bio-energy crop in the UK is willow short rotation coppice (SRC). A study of the insect species associated with British trees¹³² found that five native species of willow in Britain supported 450 phytophagous insects and mites, so there is potential for willow SRC to increase the insect diversity of an area as compared with conventional arable crops. These SRC plantations may be beneficial not only to those invertebrates that live on the trees themselves, but the development of a varied ground flora, particularly in the field margins left unplanted by trees, may also encourage a range of insects. In a four-year project comparing vegetation within willow short rotation coppice with the previous land use of arable farming, the coppice supported a richer plant community in each year of the study.¹³¹ In pre-commercial SRC studies in the UK, overall bird density and species diversity were higher compared to arable crops and managed grassland.¹³³ This is perhaps because they are broadly similar to traditional coppice woodland that is attractive to many bird species, although the management systems are quite different, resulting in differences in flora and invertebrate communities.¹²⁸ In general, willow SRC has been found to contain more bird species than poplar SRC and the more complex structure increases biodiversity.¹³⁴ SRC could also provide cover in winter for birds in open areas of farmland and create new areas of suitable habitat for some woodland, scrub and ruderal vegetation species (plants characteristic of highly disturbed ground) in farmland. These areas also provide greater cover and food resources for small mammals such as the wood mouse and are likely to provide a valuable refuge, particularly in the winter when vegetation cover in arable fields provides little protection from predators. However, planting large areas of woody crops on marginal wet grassland in the UK could damage breeding wader populations (such as lapwing, snipe, curlew and golden plover (*Pluvialis apricaria*)) or other birds requiring a more open landscape (such as skylark, yellow wagtail (*Motacilla flava*) and corn bunting).

Perennial grasses also have the potential to be grown as bio-energy crops, but little research on the biodiversity implications has been carried out to date. In one study perennial grass biomass crops were found to support a greater floral diversity than arable fields, due to no or low inputs of agrochemicals,¹³⁰ though poor *Miscanthus* growth probably encouraged better weed establishment. *Miscanthus* is, at present, the most widely grown bio-energy grass in the UK, but as it is non-native, it is unlikely to support any specialist invertebrates, though two Lepidopteran species (butterflies and moths) have been identified as possible pest species.¹²⁸ The implications of planting *Miscanthus* on bird populations are unknown, as there are no significant areas of crop upon which to base research in the UK.¹³⁵ The crop structure is unlikely to be suitable for

nesting by open-field ground-nesting birds, except early in the breeding season when the crop is short. It may be suitable for bird species characteristic of tall, rank grassy or ruderal vegetation, such as reed warblers (*Acrocephalus scirpaceus*). Studies of switchgrass crops in North America show that grass energy crops are likely to be suitable breeding habitat for a range of birds.

3.5 Genetically Modified Crops

No genetically modified crops have yet been grown commercially in the UK, but such has been the level of concern at their potential introduction that no discussion of agricultural changes on biodiversity would be complete without some consideration of their potential impact.

Although a wide variety of traits can potentially be introduced into crops through genetic modification, most research to date has been carried out on genetically modified herbicide tolerant (GMHT) crops. A major five-year study known as the 'Farm Scale Evaluations' (FSEs) was carried out from spring 2000 to investigate the potential impacts in comparison with conventional varieties.¹³⁶ As part of this research, arable weeds in fields of conventional crops of beet, maize and spring oilseed rape were compared with those under GMHT cropping. Overall, weed diversity in all three crops showed little difference between GMHT crops and conventional crops. Biomass and seed rain were higher in GMHT maize crops but this difference was not detectable in the seed bank. However, the biomass and seed rain were lower in GMHT beet and rape, the seed bank was found to be 20% lower, and it is possible that if this loss was sustained for several years, there could be a detrimental effect on arable weeds in GMHT crop fields.^{137,138} Growing a conventional crop within a GMHT rotation could help to replenish seedbanks, though changes in herbicides available and their application timing and rates within conventional crops may also affect arable weeds in the future.^{137,138}

The FSEs only compared crops managed in a standard manner. In a study comparing different approaches to managing GMHT crops, it was found that if the management of a GMHT sugar-beet crop was altered by the application of an early overall spray or band spraying, viable seeds in the soil were present at higher levels than in conventional crops, with no loss of yield.¹³⁹ Spraying a GMHT crop of fodder beet with glyphosphate later than recommended also had beneficial effects on weed biomass, again without any loss of yield.¹⁴⁰ However, weeds less sensitive to the herbicide glyphosphate could flourish at the expense of other species, with long-term effects on weed populations.

The growth of GMHT crops could lead to an increase in very broad-spectrum herbicides, which will make weed management cheaper and simpler. This might bring environmental benefits in terms of the decreased use of persistent herbicides. Conversely, weed control in GMHT crops may be so efficient that some arable weed species might disappear completely¹³⁷ and there may be increased damage through spray drift to adjacent habitats such as hedgerows and ditches.⁷

Among invertebrates, herbivores and their natural enemies, and also pollinators, generally responded in relation to the weed biomass; where this was higher, abundance of both these groups was greater. Detritivores (springtails, Collembola) always occurred at higher densities in GMHT treatments, probably as a result of the later herbicide treatment increasing food resources for this group at the time of assessment.¹⁴¹

4 Measures to Benefit Biodiversity on Farmland

4.1 Agri-environment Schemes

Concern over the impact of agriculture on biodiversity and the landscape led to the development of agri-environment schemes, through which farmers were paid to manage land in an environmentally sensitive manner. Environmental measures under the Common Agricultural Policy (CAP) were originally supported under Regulation 797/85, article 19. In the 1992 reform of the CAP, member states were required under the accompanying measures (Regulation 2078/92) to develop agri-environment schemes, with 50% of funding provided by the European Community (75% in Objective 1 areas). Under the Agenda 2000 reform, agri-environment schemes were supported under the Rural Development Regulation 1257/1999 (Chapter VI) and were the only measure under this regulation which member states were compelled to implement, as part of their Rural Development Plan.

The forerunner of agri-environment schemes in the UK was the 1985 Broadland Grazing Marshes Conservation Scheme. This was followed in 1987 by the first tranche of Environmentally Sensitive Areas (ESAs), each supporting specific management practices directed towards the conservation of the wildlife and landscapes characteristic of the area. Eventually, 22 ESAs were established in England, covering some 10% of agricultural land. Environmentally Sensitive Areas were also established in Scotland, Wales and Northern Ireland. However, there was a need for a vehicle to promote environmentally beneficial management outside ESAs, and in 1991 the Countryside Stewardship Scheme was launched. Equivalent schemes were established by the devolved administrations in Scotland (the Countryside Premium Scheme, replaced by the Rural Stewardship Scheme in 2000), Wales (Tir Cymen, succeeded by Tir Gofal) and Northern Ireland (the Countryside Management Scheme). The ESAs were absorbed into single national schemes in Scotland, Wales and Northern Ireland, but were retained in England until the end of 2004, when they were closed to new entrants.

In addition to these major schemes, there were schemes to support organic farming (see Section 3) and a number of smaller schemes limited in scope and timescale with various objectives (*e.g.* the Moorland Scheme, the Habitat Scheme and the pilot Arable Stewardship Scheme, among others).

Agri-environment schemes have also been developed in other European countries, both inside and outside the EU. However, these have varied in their

objectives and targets. For example, in Switzerland and the Netherlands, as in the UK, wildlife and habitats have been the priorities, but in Denmark and Germany reduction of agrochemical emissions has been the aim of most schemes, and in France the programme concentrates on the prevention of land abandonment.¹⁴²

Concern about the effectiveness of agri-environment schemes led to a call for more scientific evaluations.¹⁴³ A review of the value of schemes in conserving biodiversity concluded that in most of the 62 evaluation studies discovered, the research design was inadequate to assess reliably the effectiveness of the scheme.¹⁴² The authors concluded that there were insufficient scientifically robust evaluations to allow a general judgement of the effectiveness of agri-environment schemes in Europe. In spite of this, supporters of agri-environment schemes point to examples of successes where targeted action has been coupled with effective monitoring.^{144–146} Furthermore, at least in the UK, many of the prescriptions adopted are based on research which has already demonstrated positive benefits.^{63,126,147,148}

English agri-environment schemes have been through a period of change in recent years.¹⁴⁹ The Policy Commission on the Future of Farming and Food, chaired by Sir Don Curry¹⁵⁰ recommended a new approach, the development of a “broad and shallow” scheme, to run alongside and complement a more demanding “narrow and deep” scheme, similar to the existing Countryside Stewardship. The 2003 reform of the CAP, with an increased allocation of funding to environmental measures and the opportunity to raise additional funds through “modulation” (top-slicing subsidy funding), provided an opportunity to re-structure agri-environment schemes to encourage greater participation and the Curry proposals were translated into the Entry Level and Higher Level of the Environmental Stewardship scheme, launched in 2005. The Entry Level Scheme is open to all farmers and landowners and operates on a points-allocation system: applicants can choose options from a menu, each of which is assigned a number of points per unit area, length, *etc.* All those who reach a threshold number of points are guaranteed entry and payment of a flat rate per hectare of land entered into the scheme. Thus, for the first time, the majority of farmers will be involved in a scheme to encourage positive environmental management.

4.2 Cross-compliance

Cross-compliance, *i.e.* the imposition of conditions on the receipt of subsidies, was first introduced in the 1992 “McSharry” reform of the CAP, in the form of conditions on the management of set-aside to protect environmental features, minimise nutrient losses, *etc.* The UK also applied conditions to livestock headage payments to control overgrazing, but other member states did not implement cross-compliance conditions at that time.

Under the 2003 CAP reform, cross-compliance became mandatory and receipt of payments is now conditional upon compliance with a range of

measures. In England, for example, these include a requirement to complete an Environmental Impact Assessment before ploughing permanent pasture, the maintenance of land in “Good Agricultural and Environmental Condition” (GAEC), compliance with Statutory Management Requirements (SMRs) and certain public and animal health measures. Good Agricultural and Environmental Condition standards include measures for soil management and protection and maintenance of habitats and features, including uncultivated land, forestry, Sites of Special Scientific Interest (SSSIs), overgrazing and supplementary feeding, heather and grass burning, uncropped land, stone walls, hedges and watercourses and felling of trees, among others. These provide a baseline standard of environmental management, upon which land managers can build through membership of agri-environment schemes if they so wish.

5 Changing Agricultural Policy and Implications for the Future of Farmland Biodiversity

The most recent round of CAP reform has signalled a fundamental shift in the agricultural support mechanisms. The key element of the reform package was the “decoupling” of subsidies from production, such that the amount received by farmers would no longer be linked to the output from their land. Instead, they would receive an annual single payment, determined either in relation to previous payments (historical model), or in relation to the area farmed (regional model). In reality, options to retain some level of coupling remained and so the extent of decoupling varies between EU member states. The UK and Ireland have opted for a fully decoupled approach (apart from a small element of cattle payments in Scotland), but most other member states have retained some coupled payments.

In addition to the decoupling of subsidies, there was an intention to raise the level of support for environmental measures, as illustrated by the mandatory implementation of cross-compliance conditions and agri-environment schemes in all member states (though most commentators believe that levels of funding for the latter are still lower than optimal).

In England, 90% of payments were historic initially, gradually shifting to 100% regional payments by 2012. “Regions” are Severely Disadvantaged Areas (SDAs), separated into moorland and other SDA land, and all other non-SDA land. The Single Payment Scheme (SPS) replaces 11 previous schemes; however, there are still some anomalies such as the dairy sector, where guaranteed prices and production quotas were still important elements of the support regime initially and reforms were planned to be staged over several years. Scotland and Wales have opted entirely for historic payments, whilst Northern Ireland has a hybrid system.

Further complexities abound, but the underlying principle is that support payments will no longer influence decisions on what and how much to produce from farmland. This increased flexibility may be manifest in a number of ways

and will be influenced by a variety of factors. Market prices will have a stronger influence than previously, but farmers will also have the option of not farming the land at all for one or more years, provided it is retained in “Good Agricultural and Environmental Condition”. Thus there could be large swings between years, not only in what crops are grown, but in how much of the land is cropped at all. Set-aside was retained as a policy in the reformed CAP and, as the SPS covers a wider range of crop types than the old Arable Area Payments Scheme, the number of farms with a set-aside obligation will be extended. For example, set-aside will now be required in conjunction with land growing horticultural crops such as fruit, vegetables and potatoes, temporary grass less than five years old, and many perennial crops. Management rules are similar to those existing previously, though with increased flexibility in some areas.

What will these changes mean for biodiversity? Much depends on the relative profitability of different enterprises and market forces are notoriously difficult to predict in anything but the short term. A recent analysis¹⁵¹ indicates that the following changes are likely:

- Sheep will become more common in lowland areas and less common on open moorlands.
- Beef cattle will decrease in numbers in the uplands, but may increase at least temporarily in traditional dairying areas.
- Dairy farms will continue to decline in numbers and those surviving will be larger.
- In more productive arable areas, larger scale block-cropping of wheat and rape with simplified rotations will become more dominant. There will be more fallow but less sugar beet.
- The area of maize will continue to increase.
- In less productive arable areas, some land will grow novel or energy crops, some will fall into disuse, or will be diverted to other land uses or built development.
- There will be continued increase in non-commercial farmland management, e.g. “hobby farms”, horse grazing and leisure activities.

Outcomes for biodiversity will depend on the relative strengths of these trends and other factors, such as the level of incentives to grow energy crops. Cross-compliance and the Entry Level Scheme (or its equivalent under devolved administrations) should provide environmental benefits, but the extent of the benefits accruing has yet to be tested.

After a long period of relative stability, during which levels of productivity reached hitherto unprecedented levels, agriculture in the UK and elsewhere in Europe is now undergoing a period of rapid change, stimulated by a series of reforms in the CAP support systems since the early 1990s. The countryside of the future could look very different from that existing at the end of the twentieth century. Elements could include, for example, large areas of energy crops, such as short-rotation coppice and *Miscanthus*, areas of unmanaged “fallow” land, areas of intensive crop and milk production, novel crops and new combinations of land uses. Some of the potential developments may

threaten biodiversity on farmland, but there are also many opportunities to integrate biodiversity conservation with the agriculture of the future.

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