Natural England Research Report NERR030

Environmental impacts of land management

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This report details work carried out by Natural England to establish the factual basis behind decisions on a number of systems of land management.

A summary of the findings covered by this report, as well as Natural England's views on this research, can be found within Natural England Research Information Note RIN030 – Environmental impacts of land management.

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Preface

This report is aimed primarily at policy makers, academics, practioners from the land management sector, non-governmental organisations and the interested public. It looks at a number of common aspects of farm, forestry and game management, and summarises the published research that lies behind our current understanding of their environmental impacts.

Summary

The farming, forestry, and game industries have had a profound impact on the English landscape and its wildlife through history. This has been through modifying natural habitats and natural resources, investing in features such as hedgerows, water control structures and drainage, thereby affecting underlying natural processes, leading to landscapes and wildlife that favour species typically dependent on open habitats, early succession and regular disturbance. The variation in the natural environment and differences in the history of how people used the land has resulted in very diverse and distinctive landscapes across England.

Farming, forestry and game management are still the key influence on the character and ecological quality of our rural landscapes, and the way their business practices develop continues to shape landscapes and to change its appearance, character and ecological condition. Modern farming systems and technology allow those managing land to have a much more profound effect on our landscapes and natural processes than was possible in earlier periods. There is a need to design in delivery of landscape character and wildlife and to ensure practices avoid adverse impacts on environmental resources and ecosystem services. It is no longer possible to rely on benign alignment between commercial practices and delivering the desired outcomes for landscapes, wildlife and natural resources.

There is common ground: all these industries depend on a healthy natural environment for their respective harvestable products. Landscapes in good ecological condition, that support wildlife and deliver essential ecosystem services also depend on a healthy natural environment and natural resources in good condition. We believe it should be possible to design in delivery of distinctive ecologically resilient landscapes and enable commercially successful businesses in these sectors. Sympathetic management of natural resources is essential for both, and for the long term sustainability of land based businesses. This report provides a basis from which we can move forward by looking at a number of management systems or activities prevalent in these sectors to identify those that can benefit the natural environment and those that may be environmentally unsustainable. It does not focus on management for delivering landscape and wildlife. This report analyses a number of common aspects of farm, forestry and game management, and summarises the published research that lies behind the current understanding of their environmental impacts. It will examine our understanding of how management practices affect the natural environment, and the results will provide the basis for identifying where climate change will lead to significant changes in the impacts and the risks in future.

Our rural landscapes are largely formed from land managed by farming, forestry and game management businesses in both the lowlands and uplands. These areas are also important for a range of other services, such as water purification, carbon sequestration, and flood mitigation. They also provide a home for biodiversity and a space for recreation and relaxation within a richly detailed landscape. We need to ensure we maintain, and sometimes restore, these services as core elements of successful land based businesses.

The management operations which the report assesses are:

Cultivations

Good soil management involves more than ensuring that loss through erosion is minimised. Soil is a potential carbon sink, a habitat, and a store of nutrients. Soil condition and management has a major impact on water retention, the risk of local floods and the quality of water resources. Sympathetic management involves maintaining or enhancing levels of organic matter, and ensuring that the structure is not damaged. There is increasing evidence that the vast array of organisms living in the soil have the potential to improve soil function. Lack of attention to the loss of soil organic matter can depress fertility, harm soil structure and biodiversity, and potentially increase greenhouse gas emissions. Cultivating in such a way that minimises disturbance of the sub-soil habitat is a possible way of improving structure and productivity, whilst minimising risk of erosion and release of carbon.

Lowland drainage

Historically drainage has made huge changes to the lowlands, providing suitable conditions for intensive cropping and livestock systems. Ponds have also been widely lost, in part because of reductions in mixed farming and in part because drainage has made them less reliable as water sources. Whilst this has seen the loss of the majority of our lowland wetlands, some habitats have evolved with the activity, and have become part of our familiar landscapes. Farming that depends on drained landscapes is incompatible with extensive wetlands. It is possible to incorporate habitats within drainage systems that support some wetland species if designed in and managed accordingly. There are clear tensions between intensive agriculture on drained landscapes, biodiversity, and natural resource management.

Pesticide use in agriculture

Modern agriculture includes highly effective control on weed species and crop diseases. For many systems, this ability is a key factor in terms of profitability. Farmland biodiversity can be affected both directly and through secondary effects such as the loss of insects or weed seeds which otherwise would have contributed to supporting farmland bird populations. There have been significant gains from the replacement of persistent pesticides that accumulate at the top of food chains, but the effectiveness of modern pesticides is such as to affect food sources for farmland wildlife.

The management and use of nutrients in both the arable and livestock sectors

In order to maintain productivity, crops require nutrients. These can be delivered in organic or inorganic form. Recent data show that many of the nutrients applied to cropland and grasslands are not taken up by the growing plants, but are leached into water courses, affecting downstream habitats, as well as drinking water supplies. Fertiliser application benefits a few, aggressive plant species, often at the expense of other flora and fauna, increasing productivity, but depressing biodiversity. Nutrients from livestock (manures and slurries) are generally more beneficial to soils, increasing organic matter, but they also have a price in terms of ammonia, nitrous oxide and methane emissions, respectively a polluting gas, and two potent greenhouse gases.

Intensive grassland production for grazing livestock

Growing the quantity and quality of forage required for intensive lowland livestock farms requires intensive management. Production of silage from grass and maize can have a detrimental effect on species diversity (plants and birds), and needs to be carefully managed to preserve soil function and stability. By contrast, where such systems cannot compete with the profitability of arable farming, grasslands, sometimes with valuable assemblages of plant and animal species are under threat from destruction, or lack of grazing.

Pastoral systems in the uplands

Upland agriculture has always been more marginal than in the lowlands, consequently maintaining a subtle balance of agricultural and natural processes is difficult, and sometimes unpredictable. Most of the upland area is pastoral, which includes moorland grazings, as well as inbye land (valley land, or land near the farm steading) which can include valuable habitats such as species-rich hay meadows, and wet grasslands. Relatively recent grazing management on moorland areas has often involved high stock numbers, and a resulting loss of dwarf shrub habitat. There has been considerable financial pressure for farmers to intensify on the inbye land. Hitherto, agri-environment schemes have provided a financial incentive to reduce stocking rates and maintain traditional practices (such as hay making). We are now increasingly looking to the uplands as a vital area for carbon sequestration, and regulation of water quality and quantity, and we expect grazing managers to be part of that process.

Habitat management for shooting interests in the lowlands and the uplands

In the lowlands the shooting industry is closely linked with agriculture: some of the management of woodlands and field margins owes itself to maintenance of habitat and cover for gamebirds. This can benefit farmland birds, many of which profit from the planting of game cover, and enhanced field margins as well as from gamekeepers activities. In the uplands, shooting over moorlands is a major land use, and the landscape we know is almost entirely shaped by grazing and management for game (mostly grouse) shooting. Moorland drainage and burning are two key management tools of the gamekeeper, both of which are currently subject to considerable research. Drainage as practised in the past caused considerable damage to peat bogs, and water supplies. Currently steps are being made to reverse this damage. Heather burning can be a useful management tool, but if not carried out in sympathy with the vegetation and the location, can be harmful to habitat and wildlife.

Biomass crops

A relatively small area of land is currently being used to produce biomass crops such as Short Rotation Coppice, and Miscanthus. The industry is comparatively young, and it is not yet clear what effect larger plantations might have on the natural environment, and on the wider landscape. Current indications are that, particularly where Short Rotation Coppice and Miscanthus replace arable crops, there are potential benefits to soils, water quality, and to wildlife, even before gains in carbon emissions are considered.

Woodland planting

New woodland has a high potential for environmental benefit, but its creation (whether by planting or natural regeneration) does involve some major changes in surrounding and underlying habitats. These need to be carefully assessed, to ensure that valued features (environmental and historic) will not be lost, that there are not undesirable landscape impacts, or damage to local habitats or biodiversity. By contrast woodland creation in the right places leads to improvements to the soil, through root growth and litter deposition; to the atmosphere, through carbon sequestration and pollutant ‘scrubbing’; to water quality and storage through better infiltration into the soil, and interception of sediments and nutrients; and also to biodiversity.

Tree felling

Felling can be a highly disruptive and destructive activity, with heavy machinery exposing and destabilising soils and plant assemblages. Carried out with care it is a highly sustainable operation, which is part of a long history of similar management that has contributed to the development of valued landscapes and habitats. At present only part of the annual increment from English woodland is being used so the annual rate of felling could be increased substantially, with opportunities to increase open ground (both temporary and permanent) within woodland or forest areas. Properly managed this need not prevent an increase at the same time in the amounts of dead timber, providing potential habitat for fungi, invertebrates, birds, and other species.

Withdrawal of management

In England, particularly in lowland areas, the abandonment of traditional land management practices almost inevitably leads to encroachment of scrub, and the development of woodland. As with woodland planting, this can have a detrimental effect on open ground habitats and species, but it may also provide considerable environmental gain in the longer term. Land may become unmanaged through neglect, or by design. All land in England has been shaped by human activities, so any change in that status will inevitably lead to considerable change. Only a few, relatively small areas of land have had management withdrawn as part of a deliberate policy, and there is relatively little documentation of the longer term changes. Where land has been abandoned or neglected in the past some valuable habitats have become fragmented or lost.

A number of the management techniques, or systems assessed in this report can have a damaging or a beneficial effect on natural resources, depending on how, when or where they are practised. This report aims to identify the key issues and natural processes associated with these activities, without being prescriptive. This will allow land managers to make a more informed assessment of the environmental consequences of the management systems they operate.

Much of the evidence presented in this report focuses on damaging effects of management activities. This is largely a reflection of the research that has been carried out in the relevant areas. Land management that has been successfully integrated with natural processes and habitats has generally been less closely researched, and often tends to be specific to local conditions rather than being more generally applicable.

This report will examine our understanding of how management practices affect the natural environment. It will provide robust information that can help policy makers, land managers and others in their work to address the complex and challenging task of developing environmentally sustainable land management practices.

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1 Introduction

1.1 Over time our use of land and the natural resources that land provides, has shaped and re-shaped our environment, leaving us with the English landscapes and semi-natural habitats that are so valued today. The use of land has also shaped the patterns of settlements, buildings and other elements such as transport routes in rural areas leaving us with todays rural landscapes. Each has its own history with evidence from different time periods giving each a distinctive character. Our landscapes today reflect this diversity of historical pathways which range from recreational landscapes such as the New Forest to transformed landscapes such as the Fens. Today, about four-fifths of our land area is used for agriculture or forestry. These industries now use systems and techniques that directly affect the character of our landscapes with the potential to change them rapidly and to affect the condition of the underlying natural resources. We need to incorporate as an integral part approaches that will maintain the desired character of the landscape and the condition of the natural resources used and affected by modern agriculture and forestry.

1.2 This report sets out the evidence for impacts, both positive and negative, of a number of management activities routinely carried out by operators in the farming, forestry, and game management sectors. The aim is to understand how current routine practices impact on natural resources - water, soils, air - and the ecosystem services our landscapes support. Farming, forestry and game management businesses themselves depend on these natural resources and the ecosystem services they provide, so there is a direct interest in understanding how their activities affect their future as a result of these impacts. Society as a whole also benefits from ecosystem services provided by rural landscapes and has an interest in understanding the degree to which these are at risk as a result of current practices, and in supporting changes that will secure these services into the future.

1.3 The report is a presentation of the evidence around activities that are part of mainstream commercial operations, rather than a discussion of optimal management of key landscape features and habitats. The evidence presented should be used as the basis for developing improved practices and policies to support adoption of systems that deliver ecosystems services into the future. In the light of this, the challenge is to develop practices that reduce impacts that can be adopted by commercially viable farming, forestry and game management businesses and to integrate the management required to deliver our landscapes, wildlife and other ecosystem services valued by society. This report provides evidence to underpin the developments required.

Managing key natural resources - identification and management of impacts

1.4 There are two main ways in which farming, forestry and game management impact on the environment:

- Direct impacts on the immediate environment where they are practised and on the surrounding areas: for example, effects on the soil, watercourses, wildlife and habitats.
- Direct and indirect impacts on the wider environment: for example greenhouse gas emissions, flood control or mitigation, and cultural development.

1.5 This report presents evidence about those management activities that may have a significant impact on the main natural resources:

- habitat
- species
- water
- soils
- air
- landscape.

1.6 The industry sectors on which the report concentrates are:

- farming
- forestry
- game management.

Natural and semi-natural habitats

1.7 Many semi-natural habitats in England were created through farming, forestry and game management practices over time. We have seen significant reductions in the areas of these habitats in recent decades. Those that remain are under pressure from inappropriate management and possible destruction. The diversity and quality of these habitats is one of the main elements of biological diversity that the UK government has committed itself to protecting. Healthy habitats are essential to maintaining species and genetic diversity, and to delivering ecosystem services relating to soils, water, air and climate, as well as being significant elements in our landscapes and having aesthetic and cultural value for a high proportion of the population.

Individual species

1.8 Individual species can be comparatively robust in their ability to survive change, but equally, they can be extremely sensitive to specific influences. In many cases a seemingly minor activity, which could be avoidable, may be a critical trigger for the decline of one or more species. The Farmland Birds Index (an indicator of the health of farmland wildlife) shows a decline in the overall numbers of 19 key farmland species, which has been shown to be closely linked with the development of modern agricultural practices. This trend continues, despite positive measures being implemented which encompass a number of management systems.

1.9 Conversely, management for gamebird production has been a major contributor to the continued presence or dominance of some species (such as grouse and heather moorland) where other activities such as grazing by livestock might have led to their demise.

Water

1.10 Water has often been overlooked as a vital commodity in this country. Environment Agency maps show that south east England, and parts of East Anglia are already described as ‘water stressed’, due largely to rising population demands, and reduced summer rainfall. Although use of water for irrigation in agriculture is relatively small it can have important local impacts.

1.11 More importantly agriculture has a huge impact on water quality: while there are currently programmes in place which are addressing nitrate and phosphate pollution in England, 60% of nitrates, and up to 40% of phosphates in water are attributable to agriculture. Inappropriate use or disposal of pesticides is also a significant issue, again attributable largely to the agriculture industry which now has in place a number of initiatives to address this. All these forms of pollution are not acceptable in domestic water supplies, they can also unbalance and critically alter natural ecosystems, compromising important habitats, and threatening the future of individual species.

1.12 Whilst the way land is managed can exacerbate flood events, it can play a key role in flood mitigation. Changes in vegetation cover and soil function can affect soil water retention. Land drainage in the uplands and lowlands may speed water through a catchment - possibly exacerbating flash-flooding - but in many cases it can increase infiltration, and improve storage potential. Despite these benefits, land drainage has been a key component in the loss of our wetlands.

Air

1.13 Air quality is affected by land managers in a more complex way. There is increasing pressure to modify activities which add to greenhouse gas emissions, and aerial nutrient deposition.

1.14 Agriculture is the biggest source of ammonia emissions in the UK. Nearly 90% of ammonia emissions in the UK come from agriculture - mostly livestock manure and slurry. The net effect of carbon dioxide emissions from agriculture is not easy to calculate: growing crops absorb CO_2, but the manufacture of inorganic fertilisers releases large quantities of the gas. Use of organic or inorganic nutrients, and management of soil organic matter will determine the carbon budget of most agricultural products. Forestry in general is seen as being effective at sequestering CO_2, whilst wood products can substantially reduce or offset the carbon costs of a number of diverse products and activities.

1.15 Methane and nitrous oxide are much more potent greenhouse gases than CO_2. Agricultural emissions of both have been reduced in recent years, though for different reasons: methane is emitted by grazing livestock, and by slurry. A reduction in livestock numbers over the past ten years has reduced total emissions, though a bigger reduction in other non-agricultural sources has resulted in a rise in the proportion of total emissions due to agriculture. Nitrous oxide emissions from agriculture have reduced by over 20% since 1990, largely due to a reduction in the use of inorganic nitrogen fertiliser.

Soils

1.16 Soils are crucial to forestry and agriculture, and the good management of them is crucial to freshwater and coastal fisheries. Whilst the cost of poor forestry and agricultural management of air and water quality may not have an immediate effect on the land manager, the management of soil does.

1.17 Soil is not only the growing medium for crops and timber, but soil organic matter is also a major sink for carbon, and, if not managed correctly, a potential major source of CO_2 emissions. Soils are often extremely complex ecosystems, whilst potentially being host to equally complex ecosystems above ground. A change in physical conditions within the soil (such as drainage or ploughing) may destroy much of the mycorrhizal and bacterial activity, so that attempts at above-ground habitat restoration on that area are hampered by the below-ground changes. The ability of soils to hold water is also vital to our water supplies, and to flood management.

1.18 Below-ground conditions may also be crucial to the preservation of archaeological evidence, and hence our understanding of local, possibly national historical heritage. These can be seriously affected by drainage, cultivations, or scrub and tree root development.

Landscape character

1.19 The distinct, recognisable and consistent pattern of elements in a landscape make one place different from another and give it its ‘sense of place’. It results from a combination of geology, landform, soils, vegetation, land use, field patterns and human settlement.

1.20 The historic and present day activities of farming have both formed and shaped the character of the English landscape. Recent trends in agriculture, including increasing crop and livestock specialisation, a decline in mixed farming systems; and increasing intensity and mechanisation, have led to a dramatic loss of semi-natural habitats and increasing landscape homogeneity, with a decline in many of the features that once characterised individual localities.

1.21 The impact of forestry on the landscape is most significant in relation to planting new areas with trees. Historically, this has been significant, particularly in the uplands where conifer plantations were established. Stronger controls are now in place and many existing plantations are being removed or converted to mixed broadleaf woodlands as they reach the end of their commercial life. Even broadleaf woodland creation can transform landscape character and needs to be undertaken sensitively. Management of existing woodland is often important in maintaining the existing character of wooded landscapes.

2 Cultivations - tillage operations

Context

2.1 Arable crops are a major source of food in this country (Defra calculated that in 2007 74% of 'indigenous' food consumed in the UK was home-grown).[1] Approximately 3.7 million hectares are under arable rotations in England (including temporary grass crops).[2] This amounts to just under half of the agricultural land in England (land classified as 'tillage', set-aside, and bare fallow comprised 45% of croppable land in 2007).[3] Increasingly this area is being looked to for the provision of fuel as well as food.

2.2 The green areas on the map at Figure 1 show land identified as arable or horticultural land in England.

Current industry practice

2.3 Almost all arable food crops are rotational, requiring annual sowing, involving some tillage to provide suitable growing conditions for seeds. Tillage is also used to remove weeds, mix in soil additions like fertilisers and manures, and shape the soil into rows and furrows for planting and irrigation.

2.4 Soil texture and structure are the main physical factors which influence the tillage method used: clay or other heavy soils can be difficult to break down into a seed bed, with a narrow 'window' of optimal weather conditions, and are more suited to ploughing; on light soils which can be worked with lighter equipment, excessive tillage can lead to 'slumping' as the inherent soil structure is destroyed. Tillage operations in adverse conditions can result in soil compaction, smearing and development of plough pans.[4]

2.5 Minimum tillage, conservation tillage or zero tillage, are terms given to growing annual crops with minimal or no disturbance to the soil. These techniques involve reducing cultivation depth and can avoid the use of the plough, instead relying on non-inversion of the soil. As cropping systems are largely influenced by soil structure and soil fertility, it is recognised that minimal or zero tillage can help increase yields overall, build soil organic matter and improve use of soil nutrients.[5] Recent research carried out for Defra shows that over the long term, organic matter gains may be marginal.[6] At the same time the presence of crop residues on the surface can reduce erosion[7] and benefit farmland birds by providing a source of invertebrate food[8] and increasing habitat for earlier nesting.[9]

2.6 Zero tillage is practised on approximately 111,000 ha[10] in England (extrapolated from 3% of UK arable area).

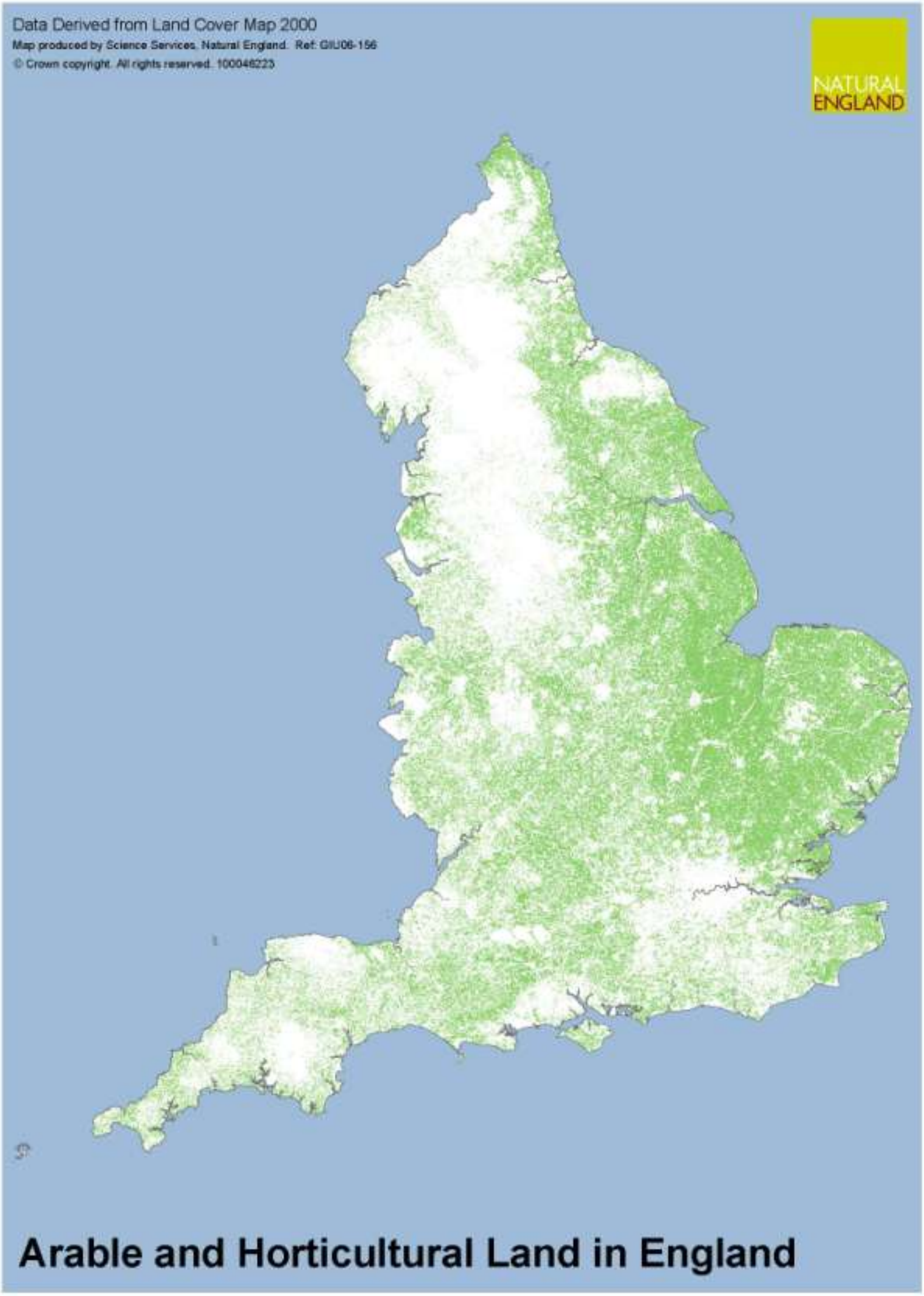

Figure 1 Land identified by Land Cover Map 2000[11] as arable or horticultural land in England

Industry trends and pressures

2.7 Cultivating fields and establishing crops can demand 20-50% of the total fuel requirement[12] on an arable farm. Changes in tillage practice to reduce fuel cost and emissions can have a positive effect on the high overall demand on fossil fuels (potentially compounded by a high fuel requirement for the manufacture and transport of fertilisers and crop sprays). Increasing use of biodiesel, which can be produced on-farm potentially reduces the fossil fuel demand.

2.8 There is strong financial pressure at present for farmers to increase production. In already highly efficient systems such as those common in England, these pressures are likely to increase the incentive to bring more land into cultivation. A large amount of land that was put into compulsory set-aside, often the least productive parts of holdings, is now back in production following the introduction of a 0% set-aside requirement. Provisional figures for 2008 indicate that arable land currently set-aside dropped to 30% of the 2007 area.[13]

2.9 Cultivated soils are prone to erosion for a number of reasons, particularly on sloping or steep land. Working across a slope can counter rill formation and reduce runoff. On steeper slopes (>7%) it may be impractical or dangerous to do so. Location-targeted buffer strips are effective in intercepting or impeding surface flow. Best practice advice is to use a substantial (6 m wide) buffer strip at a maximum of 200 m apart on slopes over 5%.[14] The restrictions within the Soil Protection Review as part of Cross Compliance require farmers to make assessments of erosion risk with regard to soil type and slope. As a result many managers prefer to avoid crops requiring cultivations in these conditions.

2.10 For current incentives, advice and regulation for cultivations, see Annex I to this chapter.

Plate 1 Tractor undertaking a combined cultivation operation

Key impacts

2.11 Tillage methods and systems have changed as more powerful machinery has been produced, enabling soils to be worked more quickly and deeply, and finer seed beds to be produced. In some situations cultivation systems which are machinery intensive, and which bury trash more efficiently have effects which impact on the wider environment such as the dramatic decline in farmland birds[15] and the amalgamation of fields by removing hedgerows (a practice now controlled under the Hedgerows Regulations 1997[16]).

2.12 Conventional tillage involving mouldboard ploughing can lead to unfavourable effects such as soil compaction and degradation of soil aggregates, negative impacts on soil microbes, arthropods and invertebrates, and loss of organic matter.[17] Soil microbial biomass has been shown to improve soil structure and stability, thereby reducing soil erosion.[18] The loss of organic matter has further implications: the organic matter is a source of nitrogen and carbon, and can enhance plant uptake of phosphates from the soil.[19] Where organic matter breaks down and there is little or no plant uptake, the nutrients that are not incorporated into the soil complex can be released either into the atmosphere as CO_2[20] or into rivers and groundwater (phosphates and nitrates). Unless the soil is adequately aerated, zero tillage systems can emit higher levels of N_2O than conventional tillage. This is due in part to the anaerobic decomposition of surface trash, which would have been incorporated into the soil under ploughing.[21]

2.13 Some organic farming systems need more tillage than conventional systems to allow incorporation of manures to build organic matter and retain fertility,[22] and to germinate and desiccate weed seeds and plants. These greater fuel demands are generally offset by not using artificial fertilisers.[23] The build-up of organic matter in the soils also benefits soil structure and drainage.[24]

2.14 In some conditions, crops can be grown successfully for some time with little or no tillage.In English conditions use of this method is limited, and can over several years lead to weed, disease and compaction problems.[25] Research also suggests that, where periodic ploughing is required, there is little long-term gain in carbon storage, as the bulk of the accumulated organic matter breaks down rapidly after ploughing.[26]

2.15 Establishment of winter crops using conventional tillage and autumn sowing (burying weeds and seeds from the previous crop) has been shown to be a contributory factor to the poor survival of important farmland bird species. This removes most of the food sources of overwintering graminivorous birds, and the established crop is unsuitable for many ground nesting species in the spring. Leaving land for spring crops as overwintering stubble is preferable for wintering birds,[27] as well as for minimising erosion risk, particularly where soil surface compaction is removed or a cover crop is established.[28]

2.16 Reduced tillage techniques reduce the number of fieldwork passes. This is advantageous in terms of the scale of crop management possible, easing the workload and labour costs, and improving timeliness of operations. It can also reduce the use of fossil fuels and minimise soil erosion in many circumstances.[29] It may also help to reduce pesticide and nitrogen leaching by virtue of maintaining or increasing soil organic matterthroughout the soil profile.[30]

2.17 For further factual background to this section see Annex II to this chapter.

Summary of impacts

Biodiversity

2.18 Cultivation of fields in sub-optimal conditions can lead to formation of 'plough pans' and subsequent surface waterlogging. Soil fauna are generally more abundant in soils which have good porosity and are not waterlogged. Biodiverse soils have been shown to benefit several species of farmland birds.

2.19 The power available for modern arable cultivations has made it possible to till and reseed fields in the autumn without relying on weathering to break down soils. Deep ploughing has reduced the need for fallow periods in crop rotations. Both these advances have allowed chages to cropping patterns which have reduced the prevalence of winter stubbles, which are of key importance for overwintering farmland birds.

2.20 With minimum or zero tillage systems, the presence of crop residues on the surface can reduce erosion and benefit farmland birds, by providing a food source and encouraging earlier nesting. Arable wildflowers may be dependent on soil disturbance patterns which have a particular frequency and depth. Higher levels of pesticide applications, which are sometimes necessary to control greater weed burdens as a result of using minimal tillage, also serve to endanger these plant populations.

Resource protection

2.21 Soil function can be heavily affected by tillage where it is carried out in sub-optimal conditions - untimely, excessive or inappropriate working can lead to structural damage, reduction in soil biota, loss of nutrients and organic matter (to air or water), and soil erosion. Effective subsoiling can improve surface drainage, improving rooting depth and soil porosity.

2.22 Cultivation of any sort involves operations which modify both above- and below-ground habitats. These operations can lead to the release of stored carbon by exposing soil organic matter to oxidation.

2.23 Cultivation tends to increase the rate of mineralisation of organic nitrogen and some leaching of mineralised or plant nitrogen is inevitable if land is ploughed. This can be minimised by ensuring the subsequent crop establishment follows immediately after cultivation. Minimal-tillage can reduce the level of mineralisation.

2.24 Poor soil structure can lead to significant surface run-off, leading to high sediment loads and phosphate levels in receiving waters. Water quantity can also be affected where compacted or sealed soils result in less infiltration and, potentially, more run off during high rainfall events and lower soil moisture / lower stream flows later in the season.

Greenhouse gases

2.25 The high power demand of modern tillage operations is an important contributor to CO_2 emissions from agriculture, as is the degradation of soil organic matter which is exposed by tillage.

2.26 On sites in England where there is a periodic need to plough, reduced tillage systems only deliver moderate Carbon storage over the long term, as ploughing releases most of the accumulated C. In organic systems, the dependence on manures to provide soil fertility may compensate for the breakdown of soil organic matter and release of carbon. On poorly aerated soils reduced tillage can result in increased N_2O emissions.

Landscape

2.27 The soil disturbance caused by tillage can impact on buried archaeological remains. Damage to archaeological remains is most serious where previously uncultivated areas are ploughed, but even on existing arable land impacts will arise where continued 'same depth' cultivation leads to compaction and a reduction in the protective layer of ploughed soil.

2.28 Farms have become more specialised to maximise efficiency. A more efficient arable system has led to the loss of a large proportion of old hedgerows and field boundaries, as the need to reduce headland cultivations and increase work rates has become more important. This has resulted in more homogenous cropping and the impoverishment of some soils where organic matter has been lost.

Annex I Current incentives, advice and regulation

- GAEC for Soils involves taking action to maintain soil organic matter levels, to reduce the chances of soil erosion (water and wind) and reduce damage to soil structure through field operations in excessively wet conditions.[31]
- The Soil Protection Review (part of GAEC for Soils) requires farmers to make an assessment of the risk of operations and management to soil erosion, and to take action to minimise these impacts and mitigate any damage done.[32]
- Advice on some soil management issues is available through a number of publications by Defra,[33] the Environment Agency,[34] [35] and the England Catchment Sensitive Farming Initiative.[36]
- Ancient Monuments and Archaeological Areas Act 1979. Operations likely to affect an archaeological monument scheduled under this act must obtain written consent. This is needed to change use from pasture to arable; to plough up pasture to renew grass; to carry out deeper than normal cultivations, and to use a subsoil plough or improve drainage.
- Where there are archaeological remains under arable land, Environmental Stewardship options can be used to revert these areas to grassland. More specific historic environment options are available, including arable reversion by natural regeneration, where normal grassland establishment techniques would cause damage, and minimising depth of cultivations where it is not feasible to stop arable cultivation or crop establishment by deep drilling.

Annex II Impacts of arable tillage on environmental sustainability

Table 1 Impacts of arable tillage on environmental sustainability

Habitat quality and diversity	• Homogeneity of cropping systems has resulted in a reduction in habitat and weed species diversity.[37]
Species abundance and diversity	• Many arable wildflowers rely on landscape complexity, less prevalent in modern arable agriculture.[38] Over 80 arable wildflowers are listed in the 2005 Red Data Book of Endangered Plant species.[39] • Some species of carabid beetle and earthworms enhance soil porosity as they move through the soil profile. This improves the soil aeration and also increases the amount of organic matter moved from the surface into the soil profile. Ploughing has been shown to reduce earthworm populations[40] and change the assemblage of carabid beetles, though not necessarily the abundance (some favour ploughed 'blank' soil).[41] • Soils under min-till and no-till systems have higher invertebrate populations.[42] • Increased soil fauna resulting from reduced or zero tillage can have a beneficial effect on several species of farmland bird, which depend on high soil fauna populations.[43] • Bird populations have been shown to be affected by seasonality of cultivation. The increase in autumn sowing of crops (at the expense of spring growing) is one of the major causes of the decline in numbers of farmland birds.[44] • In the Higher Level Stewardship scheme, options can be used for reverting arable land to grassland for a range of target features including 'great crested newt, chough or cirl bunting'. There are also options for the creation of foraging and nesting habitats for both widespread and range-restricted farmlandbirds, as well as BAP species such as brown hare.
Water level control	• Soil water conservation can be enhanced with conservation tillage systems. The type and amount of crop residues present, and the agro-ecological zone directly influence the amount conserved.[45]

Table continued...

Sediment loads in water	• It has been estimated that agriculture is responsible for 75% of the sediment in watercourses,[46] although a study on the river Sem suggests that only about 25% of silt comes from agricultural topsoils, with some 18% from road verges and the majority coming from channel banks and subsurface sources.[47] • Soil can be protected from rainfall by establishing a good crop cover, for example by sowing winter cereals early in the autumn, or using reduced cultivation systems that retain crop residues on the soil surface.[48] The establishment of permanent green covers on at risk field slopes and margin areas is highly effective in reducing sediment transport.
Nutrient loads in water	• Eroded soil can be a major source of phosphates in water. Well established ground cover can be effective at taking up nutrients, and stabilising soils. [49] • Cultivations enable release of mineralised and plant nitrogen. Where it is not taken up by reseeded or catch crops this causes N leaching.[50]
Pesticide control in water	• Cultivations are a potential source of pesticide leaching. Conservation tillage generally involves higher pesticide use and possible increased leaching due to increased soil macropores.[51] • Conversely, improved soil microbial activity under conservation tillage can contribute to the increased breakdown of pesticides in soils.[52]
Greenhouse gases	• Cultivated soils emit carbon with the oxidation of organic matter. Emissions vary according to soil and climatic conditions.[53] • Tillage is a major source of GHG emissions from machinery. Approximately 20% of the total energy required for non-organic oilseed rape production is for tillage. Increased cultivations required for pest control and organic matter incorporation in organic systems may increase the tillage requirement to over 50% of the total energy involved[54] (although the total energy budget in organic production is lower than in conventional production, which has a high energy demand from the manufacture of fertilisers).[55] • Compacted soils emit higher levels of N_2O. This is largely due to reduced plant uptake of mineralised nitrogen.[56] Where soil is poorly aerated, zero-till techniques tend to increase N_2O emissions above the levels of conventional tillage.[57]
Soil stability (erosion)	• Cultivations are a major source of eroded soil in watercourses (some mitigation is now required by GAEC seedbed requirements).[58] • Improved soil structure allows better infiltration of water.[59]

Table continued...

Soil function	• Tillage operations in adverse (wet) conditions can result in soil damage and loss through compaction, smearing, and development of plough pans.[60] • Poor soil structure arising from damaging tillage can lead to patchy crops from uneven germination, poor growth and greater susceptibility to seedling diseases. Improved structure encourages mycorrhizal activity, which can have beneficial effects on soil and plant condition.[61] • Clay or other heavy soils can be particularly difficult to break down into a seed bed, with a narrow 'window' of optimal weather conditions.[62]
Landscape character	• Tillage activity is potentially highly destructive to sub-soil structures such as archaeological remains.[63] In the Higher Level Stewardship scheme, arable options can be used to protect archaeological remains. • Between 1984 and 1990 it was estimated that 23% of hedgerows had been lost through removal or neglect.[64] There was an estimated 6.2% decrease in hedgerows between 1998 and 2007. This was mostly through neglect[65], Hedgerow removal has been controlled by the Hedgerows Regulations[66] since 1997.

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Case study: Autumn cultivations

Within the last 30 years there has been a strong shift away from mixed cropping on arable land to sowing predominantly winter crops. These are crops which are sown in the late summer or autumn, emerging within weeks of sowing, to lie dormant over the winter before resuming growth in the spring . Despite clear visual evidence that winter crops are more prevalent, the change in area from spring sowing to winter sowing over the period in question is not clearly documented in the UK. This is largely due to the Agricultural Census not differentiating between winter and spring sown wheat (although the change in area of winter sown barley and oats is identifiable)

In agricultural terms it makes good sense to grow winter crops: the gross margins are generally higher than for spring sown crops, and there is a greater buffer against the risk of bad weather conditions at establishment, and at harvest. Cultivating soils after the summer is potentially less likely to present problems than on soils which are more likely to have been saturated throughout the winter. Ensuring some sort of ground cover may also be an important way of controlling nitrate leaching.

The table below outlines the differences in average gross margin between spring and autumn sowing for wheat, barley and oilseed rape (OSR).

Table 2 Economics of winter cultivations - comparisons

Crop	Yield t/ha (Winter sown)	Yield (Spring sown)	Gross Margin Winter sown	Gross Margin Spring sown
Wheat	8.5	5.75	547	346
Barley	6.6	6	270	272
OSR	4	2	601	249

Assumptions: Wheat at £95/t; Barley at £ 80/t; Oilseed Rape at £225/t; Fertiliser at £220/t[1]

It has been shown that the change from spring to winter cropping has contributed to a serious decline in farmland birds.[2] There are a number of reasons why winter crops are less suitable for farmland birds:

- Stubbles are potentially rich in seeding weeds and waste grain, which can support high densities of seed-eating birds. These are dramatically reduced in autumn sown crops.
- Many ground-nesting species require open, sparsely vegetated ground for nesting. Autumn sown crops are too advanced in growth in the spring for species such as Lapwing, Stone Curlew, and Skylark.
- The earlier harvesting of autumn sown crops can present problems for late-nesting birds such as Corn Buntings, which nest on the ground in mature cereals.[3]

Both Entry Level Stewardship, and Higher Level Stewardship currently include an option for provision of overwintered stubbles, which can be moved round the farm according to field cropping patterns.

Plate 2 Wheat stubble showing seeds and chaff

Research suggests that the provision of areas of winter fallow (available as an option within Environmental Stewardship) can be beneficial for farmland birds, although other research indicates that there is a degree of species variation in terms of preference for ‘clumped’ or ‘isolated’ sites.[4] Minimal tillage systems appear to improve foraging opportunities for wintering birds in autumn sown crops,[5] although the benefit may be variable over a longer time period.[6]

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3 Lowland water level management and drainage

Context

3.1 Water level management in the lowlands is integral to agriculture and biodiversity in England. Ditch and drain systems can be used to raise or lower water levels in fields, and thus control water levels according to the needs of different land uses.

3.2 The scale and extent of past drainage activity has meant that the majority of our most valued wetland habitats are in fact partially drained systems, for example the Somerset Levels and Moors. At one time the Moors were a complex mix of raised bog, swamp and wet woodland. The area has now lost much of that diversity, but retains considerable value for biodiversity with large areas of species-rich wet grassland and fen, both UK Biodiversity Action Plan (BAP) priority habitats.

3.3 Throughout history, drainage has contributed to the loss of extensive areas of wetlands. Whilst drainage has taken place in stages since Roman times, most of the major field drainage effort in the lowlands has been carried out in the last 200 years.[1] Extensive programmes of drainage were carried out between the First and Second World Wars, to provide employment, as well as to 'reclaim' marginal land for more intensive agricultural production.[2] Between 1971 and 1985, grant aid was available for drainage, and applications were made for works on approximately 1,020,000 ha of farm land in England (of which approximately 20% was for renewal or modification of existing systems).[3]

3.4 Around 40% of wet grasslands have been drained since the Land Drainage Act of 1930[4] and, in Eastern England, approximately 7000 km^2 of wetland are thought to have been drained.[5] Eighty-eight per cent of the land in the fens is cultivated and accounts for almost half of the Grade 1 (most productive) agricultural land in England.[6]

3.5 Approximately 4900 ha of lowland wetland and rivers Sites of Special Scientific Interest (SSSI) are affected by adverse drainage or water-level management. Nearly 7550 ha of lowland neutral grassland SSSI are affected in a similar way.[7]

3.6 No comprehensive mapping is available to show the extent of drained land in England. A map showing the extent of drainage operations between 1971 and 1980 can be accessed at the website for Wetland Vision.[8]

Current industry practice

3.7 Over time, the development of new technologies such as windmills and motor-powered pumps hastened the process of reclaiming land for agriculture. Land drainage for land 'reclamation' is now a high-technology operation involving laser levelling, high-speed trenching and pipe-laying tools.[9]

3.8 Raising or maintaining a high water table and allowing periodic flooding was used historically in some areas to raise nutrient levels in water meadows, to protect valley grassland from frost and for simple irrigation in the summer, using sluices and gravity-fed channels.[10] Coastal and floodplain marsh water levels may be kept relatively high in the summer months to maintain suitable moisture for grass growth. Some floodplain land has been reverted to grazing marsh by raising water levels.[11] Full ditches also serve as 'wet fences', keeping livestock in place.

3.9 Drainage of lowland peat has provided some of the more productive arable land in the UK. Reducing soil moisture levels and lowering the water table exposes the organic matter in peat soils to oxidation, releasing carbon dioxide. Ploughing of drained peat soils exacerbates the oxidation and thus loss of organic matter, lowering the land surface and reducing the agricultural value of the land.[12] Peat is not a renewable resource and cannot be farmed in this way indefinitely. It is estimated that two thirds of the remaining deep fen peat under current drainage and cultivation management will have been lost by 2050.[13]

3.10 Since 1984 grant aid from the Government has shifted from field drainage to flood mitigation and prevention - often involving the use of river valley land as short term 'storage' areas for flood water.

Industry trends and pressures

3.11 With climate change predictions of warmer wetter winters, more storminess and more potential for flooding, there is growing interest in how land may be used for other purposes such as flood mitigation. Land which is susceptible to frequent flooding is generally unsuitable for high value crops, however fertile it may be (see Table below).[14] This land has potential for the creation of wetland or wet grassland habitat and may be appropriate for use as a 'storage' area to buffer peak flows from high rainfall events. These areas are not necessarily permanently wet enough to contribute to a rewetting programme.[15] Irregular summer flooding can itself pose risks for biodiversity objectives on wildlife sites that are dependent on active drainage.

Table 3 Land use according to flooding and soil moisture conditions[16]

	Drainage	Short duration flooding	Medium duration flooding	Long duration flooding
Winter flooding only	**Rapid**	Arable, pasture, hay meadow, woodland	Hay meadow, pasture, woodland	Pasture, woodland
	Moderate	Hay meadow, pasture, woodland	Pasture, woodland	Pasture, woodland
	Slow	Pasture, woodland	Pasture, swamp, woodland	Pasture, swamp, woodland
Flooding at any time of year	**Rapid**	Hay meadow, pasture, woodland	Pasture, woodland	Swamp, woodland
	Moderate	Pasture, woodland	Pasture, swamp, woodland	Swamp
	Slow	Pasture, swamp, woodland	Swamp, pasture	Swamp

Table after J. Morris, Cranfield RELU study

3.12 Currently, requirements for water level management reflect the need for productive land and for natural habitat creation or reversion. Some drainage systems are failing as they silt up or collapse over time, resulting in some areas getting wetter again. More natural communities can potentially start to develop again.[17] This raises the question of whether drainage should be restored to retain the wet grassland (in favourable condition for the features that developed during a past period of more intensive management), or whether it should be returned to wetter conditions (under the natural hydrological regime), allowing a new suite of interest features to develop.

3.13 For current incentives advice and regulation for land drainage, see Annex I to this chapter.

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Plate 3 Large drainage dyke in the fens

Key impacts

3.14 Drainage has contributed to the loss of extensive areas of wetlands in the past. The continuing damaging impact of drainage and water level management on wetland habitats is demonstrated in the area of wetland SSSIs currently in unfavourable condition as a result of these activities. An extensive programme of development and implementation of water level management plans for SSSIs aims to restore water levels through management of drainage systems and, where necessary, through changes to agricultural practices to accommodate such changed drainage patterns.[18]

3.15 Some wetland habitats can continue to survive in partially drained systems where they are maintained by the careful hydrological management of the landscape. For example, the wet grassland of the Halvergate Marshes in Norfolk (SSSI, SPA, SAC, Ramsar site) is maintained by a sophisticated water level management system and extensive pastoral farming.[19] The Ouse Washes SPA and SAC (between the Old and New Bedford rivers in Cambridgeshire) have an extensive system of ditches, with high summer water levels in the dykes maintained to support important freshwater plant and invertebrate communities.[20] In addition, they take flood water from the rivers, helping to control flooding within the catchment. The Somerset Levels host a multiplicity of habitats and species and thus require complex and sophisticated water level management.

3.16 Whilst the lack of subsidy on drainage operations has dramatically reduced the amount of new land drainage that is being carried out, a change in the value of some crops or agricultural products might make it worthwhile for agricultural production to restore existing areas of drainage.

3.17 Some lowland agriculture on drained land is reliant on pump drainage. The cost of the energy expended pumping the water from these areas must be balanced against the agricultural productivity of the soil. Where soils are not robust, the inherent fertility of the land is likely to decline as the organic matter is oxidised, and more of the low-nutrient underlying mineral material is incorporated into the plough layer. Ultimately in these cases, pump draining the land may become uneconomical. Some conservation action within wetlands is also reliant on maintaining major engineering works and structures such as large bunds and pumps, which may not be sustainable in the long term, but are necessary to maintain high water levels within drained systems while longer-term solutions are found.[21]

3.18 Drainage ditches can be valuable habitats. Excessive ditch clearance can harm these habitats, although excess vegetation can impede water flow and increase the local flooding risk. Internal Drainage Boards have recently agreed to produce joint Biodiversity Action Plans by April 2010, in partnership with Natural England and Defra, to improve management of drainage channels.[22]

3.19 Where these soils have a high organic matter content (such as in the Fens) drainage and cultivation cause the peat to oxidise, releasing carbon dioxide.[23]

3.20 Wetland drainage can lead to peat dessiccation and wastage. This wastage leads to the loss of organic materials (wood, leather, textiles) and environment indicators (pollen, wood, leaves, seeds and soil fauna that were trapped as the peat formed) that are important aspects of the historic environment.

3.21 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

3.22 Water level management and drainage have played a large part in the loss of around 90% of the area of wetland that was present 1000 years ago. The overall impact of such drainage has been the reduction in area and fragmentation of wetland habitats and loss of the species associated with them. The impact has been caused directly by insertion of drainage channels and, indirectly, through a general lowering of the surface water table. A lowered water table can result in the simple modification of hitherto wet habitats and the deterioration of fragile organic archaeological remains that would otherwise be preserved by waterlogging.

3.23 Around 12,450 ha of lowland SSSI wetland and grassland is affected by adverse drainage or water level management.

3.24 In some cases, water level management has contributed to the development of some wetland habitats that we value today, as a by-product of their agricultural use. These areas may still support extensive agricultural systems, such as hay meadows and pasture, for example the Somerset Levels and the Derwent Ings, and these continue to support highly valued habitats and species. In fact, much of the interest in these systems represents relict communities and species from the original wetlands.

Resource management

3.25 Water levels have been manipulated for centuries, controlling both flooding and drainage.

3.26 High-value crops and some terrestrial habitats are generally sensitive to surface water and are thus dependent on effective drainage systems.

3.27 Field drainage can have considerable long-term effect on soils, ranging from increased permeability in heavy soils, due to better root penetration, to desiccation and oxidation in soils high in organic matter. Field drainage can lead to the rapid drainage of land, leading to increased peak flows in water courses down stream.

3.28 Flood alleviation is not necessarily directly related to presence or absence of efficient field drainage, although the use of agricultural land as ‘storage’ areas for peak flows has been used as a way of alleviating flood risk in higher priority areas, for example Exminster marshes in Devon.

Greenhouse gases

3.29 Globally, wetlands are most likely the largest natural source of methane to the atmosphere, accounting for approximately 20% of the current global annual emissions. Climate and related biological interactions that presently control the distribution of wetlands and their methane emissions are expected to change during the next 50-100 years.

3.30 Desiccation of organic matter in the soil due to drainage can be a major source of carbon emissions. High levels of carbon are released into the atmosphere where peaty soils are allowed to dry out.

Landscape

3.31 The landscape we know today is inextricably linked with the history of drainage operations. Some landscapes are particularly valued for the way drainage has affected them, and a number of historic landscapes are being recreated by raising water levels to earlier levels.

Annex I Current incentives, advice and regulation

Commonly, there are four levels of management on land drainage:

- **Environment Agency:** Have powers to undertake works on main (arterial) watercourses (designated 'Main Rivers'), critical ordinary watercourses and embankments. Management of major sluices such as Thames Barrier, Denver Sluice.
- **Internal Drainage Boards (IDBs):** Have powers for works on ordinary watercourses, tidal sluices and pumping stations to provide drainage best suited to the local catchment land use.
- **Local Authorities:** Have powers for works on ordinary watercourses outside IDB and Main River areas.
- **Landowners:** Responsible for the drainage of their own land into main watercourses, and for water. Landowners have a duty to pass drainage water on and not obstruct flows from upstream.

Other regulation:

- Environmental Impact Assessment (EIA)[24]: the EIA regulations are designed to prevent improvements (an increase in productivity) to uncultivated land which may be affected by 'projects' such as drainage.[25]
- Countryside and Rights of Way Act,[26] and Habitats Directive[27]: aim to prevent 'operations likely to damage' habitats and species on SSSIs and other designated sites.

Management incentives

Agri-environment schemes (especially wetland-dominated Environmentally Sensitive Areas, such as the Broads and the Somerset Levels) and the Higher Level Environmental Stewardship Scheme all have options for the creation, maintenance and restoration of wetlands and capital items for water management works. These all involve raising water levels, and some options involve allowing periodic inundation during the winter months.

There are currently no options specifically for drainage operations in agri-environment schemes, although grants may be given for maintenance or restoration of existing drainage channels or water control structures in order to provide the required water level management regime. Water level management must not compromise neighbouring land.

There are currently no direct grants for drainage works which are not linked to agri-environment outcomes. Ditch maintenance options within Entry Level Stewardship are designed to allow periodic clearance, with the minimum disturbance to habitats.

Annex II Impacts of lowland drainage on environmental sustainability

Table 4 Impacts of lowland drainage on environmental sustainability

Habitat quality and diversity	• Since 1870, between 40,000 and 80,000 ponds are thought to have been lost, around 40% of wet grasslands have been drained since the Land Drainage Act of 1930 and, in Eastern England, as much as 7000 km² of wetland are thought to have been reclaimed.[28] In the lowlands, a number of Biodiversity Action Plan (BAP) habitats are directly dependent on appropriate water level management: • Grazing marsh: Requires periods when ditches contain standing water (fresh or brackish) at or near field level, and damp conditions in fields through winter, spring and early summer.[29] • Fen: There are a number of fen types, all of which may be affected by drainage and changes in the availability and source of ground and surface water.[30] In general, fens require high water levels i.e. at or above surface throughout or at least for the majority of the year. Biodiverse reedbeds require open areas of standing water throughout the area. • Raised bog: Surface vegetation is dependent on rainfall, but bogs only develop where very high water levels are maintained, so can be dried out by drainage in the surrounding area or within the bog itself.[31] • Purple Moor Grass and rush-pasture: Requires high water levels near or at the soil surface.[32] • Lowland wet meadows (MG4, MG8): Dependent on natural river flooding and maintenance of relatively high water levels (particularly MG8) to maintain character.[33] All these priority habitats have specific water level requirements which are in conflict with most forms of intensive agriculture.

Table continued...

Species abundance and diversity	• Surveys by the Wildlife Trusts for Bedfordshire, Cambridgeshire and Northamptonshire and Peterborough have shown that the network of fenland drainage ditches is valuable habitat for the water vole. Studies have shown that on average 70% of Internal Drainage Board drains within a study areas have positive signs of water vole.[34]
	
	• Other species that potentially benefit from re-wetting, or raised water levels:[35]
	  • Mammals: for example; otter.
	  • Invertebrates: for example; Norfolk hawker, Southern damselfly.
	  • Birds: for example; Curlew, Lapwing, Redshank, Bittern, Yellow wagtail.
	  • Amphibians: for example; Grass snake, Great crested newt.
	  • Molluscs: for example; Large-mouthed valve snail.
	  • Wetland plants: for example; Greater water parsnip, Cut-grass.

Water level control	• Intensive arable and livestock farming require high standards of drainage i.e. a relatively low water table, whereas extensive farming or high value wildlife and wetland sites either depend on, or can function with higher water levels, often at or near land surface. • Washlands can help control flooding at local catchment scale[36], but not necessarily throughout catchments.[37] • Efficient field drainage may move water (which can contain a high silt and nutrient load) off the fields more rapidly than naturally drained land. Undrained soils will reach field capacity more quickly and any subsequent rain will run off the surface.[38] • Use of buffer strips can reduce run-off flows and intercept silt and nutrients, although these need to be appropriately sited and managed.[39] • Drainage operations are rarely cost effective on livestock farms, where the main benefit would be to raise stocking rates. To raise the stocking rate from 1.75 cows/ha to 2 cows/ha would improve annual Gross Margin by £150/ha.[40] Cost of draining 1 ha is approximately £2500.[41]
Sediment loads in water	• Impeded drainage (either from a high water table or soil compaction - depending on soil type) can lead to excessive surface flow. Where soils are exposed through lack of vegetation cover, such as on arable land where no cover crop has been established post-harvest, erosion can result.[42]
Nutrient loads in water	• There can be impacts of diffuse pollution where aquifers become the sink for nutrients - these ultimately feed through into natural groundwater seepage. This is seriously enriching some lowland fens and rivers.[43] • Crops in waterlogged conditions are less able to take up soil nutrients. This can contribute to nutrient leaching.[44]

Table continued...

Pesticide control in water	• Aquatic pesticides may be used by land managers to maintain clear flows in watercourses.[45] These can affect local ecosystems and habitats downstream. • Poor vertical drainage in arable fields can raise the risk of pesticides moving into watercourses via surface flow.[46]
Other pollutants	• Land drainage can result in ochre in the watercourse as a product of oxidation of peat soils. This is acidic and can be harmful to aquatic life.[47]
Greenhouse gases	• Methane emissions from high water content; high organic matter soils stop emitting methane almost immediately after drainage.[48] • Waterlogged soils emit higher levels of N_2O. This is largely due to reduced plant uptake of mineralised nitrogen.[49] • A drained and cultivated peatland has been estimated to emit 125 t CO_2e/ha/yr. Rewetting this land is likely to reduce the overall emissions to 15 t CO_2e/ha/yr in the short term and, in the longer term, this is estimated to reduce further to represent a modest sink, absorbing 1.5 t CO_2e/ha/yr.[50] • Wetlands limit decomposition of organic matter, resulting in consequent build up and development of organic matter, which acts as a carbon sink.[51] • Drainage and cultivation causes these peat soils to oxidise into carbon dioxide, resulting in loss of peat depth at rates of up to 30.5 mm[52] each year and typically releasing between 47[53] and 118 t CO_2/ha/yr.[54]
Soil stability (erosion)	• In soils of very high organic matter content (such as in the Fens), drainage can desiccate soils, resulting in considerable loss from erosion over time.[55]
Soil function	• Well drained soil is less likely to become compacted from livestock treading or the passage of machinery. This makes it more suited to intensive cropping systems, by extending the period during which cultivations can be carried out. Thirty-seven per cent of the vegetables produced in England are grown in the Fens[56] due to productive soils and extensive drainage systems. • Eighty-four per cent of our deep fen peat has already been lost[57] and it has been estimated that, if drainage and cultivation continue, two thirds of the remaining peat will have been lost by 2050.[58] • Soil which is not waterlogged is likely to have improved microbial activity and nutrient availability.[59] • An indirect effect of drainage on soil organic matter is through making land available or more suitable for arable cropping. Tillage of soils reduces soil organic matter through desiccation and oxidation.[60,61]

Table continued...

Landscape character	• Natural drainage is more likely to reflect landform, in terms of presence and location of habitats and traditional field boundaries. • Drainage systems and construction have played a major part in the history of some parts of the country for example; work creation between the wars,[62] fenland 'reclamation'. • Climate change may dictate that river channels and sea defences will need modification, or removal, depending on whether there is a requirement to maintain existing features and/or communities. • Archaeological remains in wetland areas are especially fragile and vulnerable. Maintaining high water tables can be of paramount importance in preserving wetland remains.[63]

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Case study: Water abstraction for agriculture and horticulture

Water abstraction is cited as being a contributory cause of unfavourable condition on more than 4000 ha of SSSI, covering 55 sites.[1]

Nationally, agriculture accounts for a very small proportion of total water abstracted. Just under half of this total is taken from surface waters, the rest being abstracted from groundwater.

Irrigation in the Anglian region accounts for the major agricultural and horticultural use (more than the agricultural and horticultural use for the whole of the rest of England), but this is still only about 4% of all water abstracted within the region. In other regions such as the South West, agriculture and horticulture account for less than 0.5% of all water abstracted. Clearly, this is closely related to rainfall, and also farm type within the region. Nationally, water for irrigation and other agricultural purposes (such as dairy washing), accounts for just under 1% of all abstracted water.[2]

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Plate 4 Potato field and irrigation reel

Currently, irrigation is primarily used by potato growers and producers of horticultural crops such as soft fruit and vegetables. A small proportion of water abstracted by agriculture is used, for example, for washing down milking parlours and dairy equipment. Since April 2005, usage amounting to less than 20 m^3 per day has not required a licence and thus is less likely to be accurately recorded. Most small to medium dairy enterprises would be likely to use less than this quantity.

One of the main concerns with agricultural water use is that it is predominantly abstracted at a time of year when water levels are already low. In some areas this has led to conflict with SSSI objectives, and failures to achieve target condition for some sites.

The prospect of increasing competition for water, and possibly drier summer conditions due to climate change, has led a number of farmers, particularly in the eastern part of the country, to construct their own reservoirs. Cranfield University reported that in 2005, of those holdings which used irrigation, 42% of them had reservoir storage capacity. In that particular year, rainfall was such that only half of the reservoir capacity was used.[3]

A criticism of many irrigation processes is that the water is not targeted, which is wasteful, and can lead to nutrients and soils being washed into watercourses. As soils become wetter, water infiltration rates reduce, and the likelihood of runoff increases. A NFU survey in 2007 suggested that scientific scheduling is used on 60% of the irrigated area.[4]

Currently Natural England and the Environment Agency are further developing Catchment Abstraction Management Strategies (CAMS), which are designed to provide a consistent approach to local water resources management, and to help to balance the needs of water users and the environment on a catchment scale.[5]

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4 Use of plant protection products in agriculture

Context

4.1 Plant protection products, referred to here as pesticides, are chemicals used for controlling agricultural pests and diseases; these include herbicides (weed control) fungicides and insecticides. UK legislation, such as the Control of Pesticide Regulations 1986, has now been replaced by a suite of European Regulations which separate pesticides by the sector in which they are used, for example plant protection products (crop pesticides); biocides (non-crop pesticides, but including rodenticides and insecticides for use in livestock housing); and veterinary medicines (including ectoparasiticide treatments such as sheep dips and fish farm medicines, which can contain insecticides). In some cases the same active substance may be registered as a plant protection product, a biocide and a veterinary medicine. The scope of this chapter is limited to use of pesticides on farm crops.

Current practice

4.2 Conventional arable farming has a high economic dependence on pesticides to deliver the productivity and quality of crop required.

4.3 Crops in most modern agricultural systems are grown in monocultures, often with high rates of fertiliser usage. This renders them susceptible to a wide range of pests and diseases. High populations of weeds in crops can reduce yields through competition and can cause problems at harvest time by contributing to higher moisture levels in grain. A wide variety of fungal diseases can, in severe cases, result in a near total loss of crop if not treated, for example blight in potatoes. Infestations of insects such as aphids and other pests can result in up to 80% of a crop being lost.[1] In 2006 in the UK, 18,257 t of active substance of plant protection product were used on a total of 44.2 million hectares.[2]

4.4 There are two main strategies which contribute to the reduction of pesticide usage: the approach promoted by the Voluntary Initiative, which aims to ensure that best environmental practice is undertaken in the use of pesticides; alternatively, the approach used in organic farming, which is to control crop pests and diseases by use of sustainable crop rotations, maintenance of biodiversity, high soil microbial activity and the use of selected crop varieties.[3] This requires great care and attention to detail, and generally entails reduced yields from crops. It is argued that it is a more sustainable form of agriculture, using natural processes and predators to control diseases and pests.

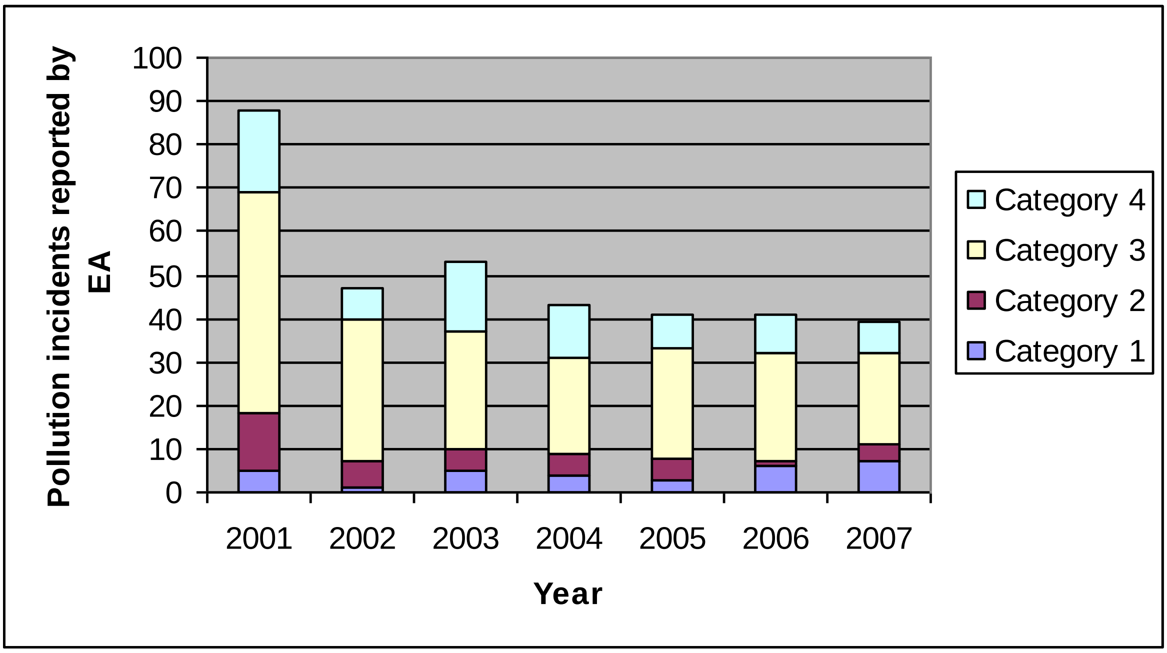
Industry trends

4.5 There is an overall trend towards tighter regulation of the use of pesticides because of their potential impacts on the environment and human health.

4.6 In global terms, farmers in the UK achieve a high level of crop output per hectare. Crops that are harvested in the UK are closely linked with the use of pesticide sprays. Legislative changes in the EEC restricting approved products and their usage could result in a reduction in productivity of approximately 25%.[4]

4.7 In 2006, Defra published a new code of practice for using plant protection products.[5] This drew together and updated the Code of Practice for the safe use of pesticide on farms and holdings, the parts of the approved code of practice for the safe use of pesticides for non-agricultural purposes relating to amenity and forestry situations, and the voluntary code of practice for the use of pesticides in amenity and industrial areas. Considerable research effort continues to be put into analysing and assessing the use of pesticides to control crop pests, weeds and diseases, and their effects on wildlife.[6]

4.8 The Environment Agency (EA) reports yearly on pollution incidents, which include point source and diffuse pollution incidents involving pesticides. Surface- and ground- waters are also monitored and the EA reports annually on environmental quality standard failures and on their surface water and groundwater indicators. In 2006, the pesticides in surface water indicator showed that in 6.49% of samples, pesticide concentrations were >0.1 ug/L. This represents a reduction from 2005 (7.98%), but is still above the level reported in 2004 (5.43%).[7] Figure 2 shows the change in number of the different severities of pollution incidents involving pesticides and biocides between 2001 and 2007. Category 1 is the most serious type of incident, Category 4 the least serious recorded. The overall drop in cases is not mirrored by the number of Category 1 (most serious) cases.



Source: Environment Agency[8]

Figure 2 Pollution incidents involving pesticides and biocides between 2001 and 2007

4.9 Pesticides are a cost to agriculture and the majority of farms only use them where the financial returns make it worthwhile. In 2001, proposals were put forward by the farming and crop protection industry to minimise the environmental impacts of pesticide use.[9] This Voluntary Initiative provides advice to farmers on training requirements for operators, and the Environmental Information Sheets outline best practice for use and application. It also helps farmers to minimise chemical applications, both in quantity and in frequency, by assessment and recognition of infestation or disease thresholds beyond which crop yields and economic margins are adversely affected.

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Plate 5 Boom spraying winter wheat

4.10 For current incentives, advice and regulation for pesticide use, see Annex I to this chapter.

Key impacts

4.11 Pollution incidents are generally localised in nature but, given the widespread use of pesticides, impacts can add up to having a pervasive effect across a large area. Localised incidents may affect a number of species or the community at the location. Direct impacts on populations are generally low, except where these occur at single locations, or where pollution incidents involving individual chemicals are more frequent and co-locate with susceptible species. Recovery will normally occur. It can take a considerable time dependent on the nature of the incident and the species affected. In 2006 in England and Wales, the Environment Agency reported that there were six Category 1 incidents (the most severe) in water, land and air which involved pesticides and biocides (see Figure 1). Indirect impacts of pestcides can have much greater effect on populations.

4.12 Deleterious effects on wildlife can be ascribed to a number of reasons:

Deliberate misuse / illegal use

- Local populations of rare species, including some birds of prey, are at risk from the misuse or deliberate abuse of plant protection products. In 2006, of the 390 incidents reported to the Wildlife Incident Investigation Scheme, 111 incidents were due to pesticide poisoning, of which abuse accounted for 67 incidents.[10]

Accidental pollution

- Wildlife and semi-natural habitats including watercourses, hedgerows and important nature conservation sites can be damaged by pesticide drift, run-off, leaching or over-spraying, which are all considered as accidental pollution. Of the 111 pesticides poisoning incidents reported in 2006 involving wildlife mortality, only two resulted from approved use of pesticides.[11]

Secondary and indirect effects

- There remain areas of significant uncertainty in pesticide environmental risk assessment. These include: sub-lethal effects; in-combination effects; direct impacts on non-target plants and invertebrates; and indirect effects. The wide use of pesticides, together with other changes in farming practice, has contributed to significant declines in the numbers and diversity of insects and wild plants in farmland.[12] By affecting their food supply, this indirect effect of pesticide use is a major factor contributing to serious declines in the populations of certain farmland birds.[13]

4.13 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

4.14 Crop pesticides affect biodiversity through two routes: deliberate reduction or removal of species which are detrimental to crop production, and unintentional effects on non-target areas or species, either by accidental application, for example spray drift, or by the removal of food or prey for another species.

4.15 The wide use of pesticides, together with other changes in farming practice, has contributed to significant declines in the numbers and diversity of insects and wild plants in farmland. By affecting their food supply, this indirect effect of pesticide use is a major factor contributing to serious declines in the populations of certain farmland birds.

4.16 Movement of pesticides by leaching or run-off in soils and spray drift can result in detrimental effects in a number of non-target habitats, but without specific monitoring, it can be difficult to identify specific spraying activities with a species or habitat decline.

4.17 A high dependence is placed on chemical sprays to help control invasive alien plant species. Control of species such as Japanese Knotweed by mechanical means has proved relatively ineffective.

Resource protection

4.18 Water quality can be adversely affected by use of plant protection products, even when used at the recommended dosage, and in the correct manner.

4.19 Soil microflora and fauna are adversely affected by some pesticides, altering their function and potentially affecting the soil's function as well.

4.20 The residual effect in soils and water of chemical sprays is of major concern in the licensing process of new products.

Greenhouse gases

4.21 Use of pesticides does have a cost in terms of greenhouse gases, but it is not clear how this compares with alternatives such as mechanical weed control or reduced yields.

Annex I Current incentives, advice and regulation

There is a considerable amount of legislation surrounding the use of pesticides in agriculture. All pesticides sold, supplied, used, stored or advertised in the UK must first be approved. Approval of agricultural pesticides is the responsibility of the Pesticides Safety Directorate and for non-agricultural pesticides it is the responsibility of the Health and Safety Executive.

The following include some key legislation relating to pesticide use:

- Plant Protection Products Regulations (1995).[14]
- Control of Pesticides (amendment) Regulations (1997).[15]
- Food and Environment Protection Act (1985).[16]
- Biocidal Products Regulations (2001).[17]
- Veterinary Medicines Regulations (2008).[18]
- EU Groundwater Directive (2006).[19]
- Water Framework Directive 2003[20], the English legal instrument of the European Water Framework Directive (2000).[21]
- Cross Compliance - Restrictions on the use of plant protection product (SMR 9).[22]
- Cross Compliance - Protection of hedgerows and watercourses (GAEC 14).[23]
- Wildlife and Countryside Act (1981)[24] and under the Countryside and Rights of Way (2000) Act Application of products to designated sites such as SSSIs may be considered an Operation Likely to Cause Damage which is an offence under this legislation.[25]

The EU is also developing a Sustainable Use Directive as part of its Thematic Strategy for Pesticides. The sustainable use of pesticides is designed to ensure that there is less reliance on pesticides as a primary means of crop protection through: production methods (such as integrated pest management and organic); good product selection and the best management and practice in use and disposal of pesticides therefore minimising the risk to non-target species.

Other advisory instruments relating to pesticide use are:

- *The Code of Good Agriculture Practice for the Protection of Water*.[26] This is a statutory code under the Water Resources Act 1991 which is currently under review alongside the Soil and Air Codes.
- The Groundwater Protection Code: use and disposal of sheep dip.[27]
- Linking Environment and Farming.[28]
- The current England Catchment Sensitive Farming Delivery Initiative (ECSFDI) provides a 'toolbox' to give advice on meeting some elements under the programme of measures in the Water Framework Directive.
- The Voluntary Initiative.[29]
- Use of low inputs of plant protection products is incentivised under Environmental Stewardship and other agri-environment schemes.

There are a large number of other advisory initiatives produced by bodies such as RSPB, FWAG and others.

Annex II Impacts of plant protection products in agriculture

Table 5 Impacts of plant protection products in agriculture

Habitat quality and diversity	• There are potential major effects through spray drift and accidental applications. Field margins can act as effective buffer zones to mitigate the effects of spray drift.They can also be of value in themselves, providing habitats for vertebrate and invertebrate species, as well as wild flower diversity.[30] • Water habitats can be affected either through spray drift, or through vertical and lateral movement of pesticides through the soil, and into drainage and groundwater systems.[31] • Potential habitats for rare arable wildflowers are likely to be affected by the application of residual and topical herbicides.[32]
Species abundance and diversity	• Poisoning of wildlife using chemicals is still an issue in the UK today. Poisoning is of low risk to individual wildlife populations, but is a continuing risk for individuals.[33] • Species can be affected directly, for example by the release of an insecticide such as sheep dip affecting a crayfish population downstream,[34] but they can be affected by secondary exposure (such as raptors taking rodents that have ingested rodenticide, or rodents eating grain treated with pesticide).[35] • A national decline in farmland and freshwater species abundance or diversity may not be attributable to the use of a specific pesticide.Agricultural processes which rely on pesticides are a key cause of the decline in farmland bird populations, due to the loss or decline in abundance of seed-bearing weed species and insect species.[36]
Sediment loads in water	• Sediment can act as a carrier for pesticide into water, although this is not thought to be the major route of entry for pesticides into the aquatic environment.[37]

Table continued...

Pesticide levels in water	•	Pesticides can enter water by point-source such as spillage, or drain outfall or more diffuse pollution such as leaching through soil fissures.[38] Observation of best practice identified in the Voluntary Initiative[39] should mitigate these occurrences.
Soil stability (erosion)	•	Measures to increase stability, such as contour tillage, may reduce run-off and therefore reduce pesticides entering surface waters.[40]
Soil function	•	Soil microbial activity can play an important part in the degradation of pesticides, but this activity can also be affected by pesticides. The process can vary considerably within an individual field.[41]
	•	Soil micro-organism breakdown of organic matter can be affected by the use of agrochemicals. The processes are complex and not well understood.[42]
Greenhouse gases	•	There is discussion around whether the greenhouse gases emitted during the manufacture and transport of pesticides are more significant than those emitted by the extra fuel consumption required where mechanical hoeing is carried out. There is currently no conclusive evidence.

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5 Nutrient management - crops

Context

5.1 Naturally, nutrients essential to plant growth become available through animal deposition (dung and urine), atmospheric deposition, 'fixation' by certain plants, or by the weathering of minerals within the soil.

5.2 Most agricultural and horticultural crops show predictable increased growth and productivity in response to applied fertilisers.[1] Major nutrients such as nitrogen (N), phosphorus (P) potassium (K), sulphur (S) and magnesium (Mg) are commonly applied as inorganic fertiliser, along with lime which is used to buffer both the natural acidity of many soils and the acidifying effect of nitrogen fertiliser.

5.3 Eutrophication of semi-natural habitats and watercourses from agricultural run-off affects approximately 17,800 ha of SSSIs in England.[2] Maps produced by the Environment Agency show that regions where arable farming is dominant (Anglian, Midlands and Thames) have the highest proportion of river length with excessive nitrate and phosphate levels.[3]

Current practice

5.4 In agricultural terms, maintaining soil fertility to meet crop requirements is a key element to successful and profitable crop management. Agricultural crops show predictable responses in development and yield to the addition of nutrients. Fertiliser recommendations are based on identifying a particular crop's economic optimum (the point at which the increase in value of the crop is no greater than the increase in the cost of the nutrient).[4] In the case of phosphates, movement through the soil does not take place easily, so it has often been seen as expedient to apply more than is needed by the plant.[5]

5.5 The value of inorganic nutrients for agricultural production is invariably calculated in economic rather than environmental terms. With increasing pressures, both regulatory and/or financial, good nutrient management is becoming increasingly important. Organic fertiliser (particularly farmyard manure and slurry) is often undervalued and on many farms a product that can save cash outlay is wasted.[6] See also chapter on 'Nutrient and pollution management - intensive livestock'.

5.6 Organic farming systems are equally demanding of nutrients if economic yields are to be achieved. Nutrient supply to organic farming systems relies on the bulk of the nitrogen coming from biological fixation by legumes and on phosphate supply being mediated by mycorrhizal (fungal) associations with the roots of most crop plants.[7] Livestock wastes (farmyard manure (FYM) and slurry) are also used as nutrient inputs and also, occasionally, external nutrient sources such as rock phosphate.

5.7 Of the farms surveyed in Defra's Farm Practices Survey (2007), nearly 24% of those who grew crops did not have any nutrient management plan.[8]

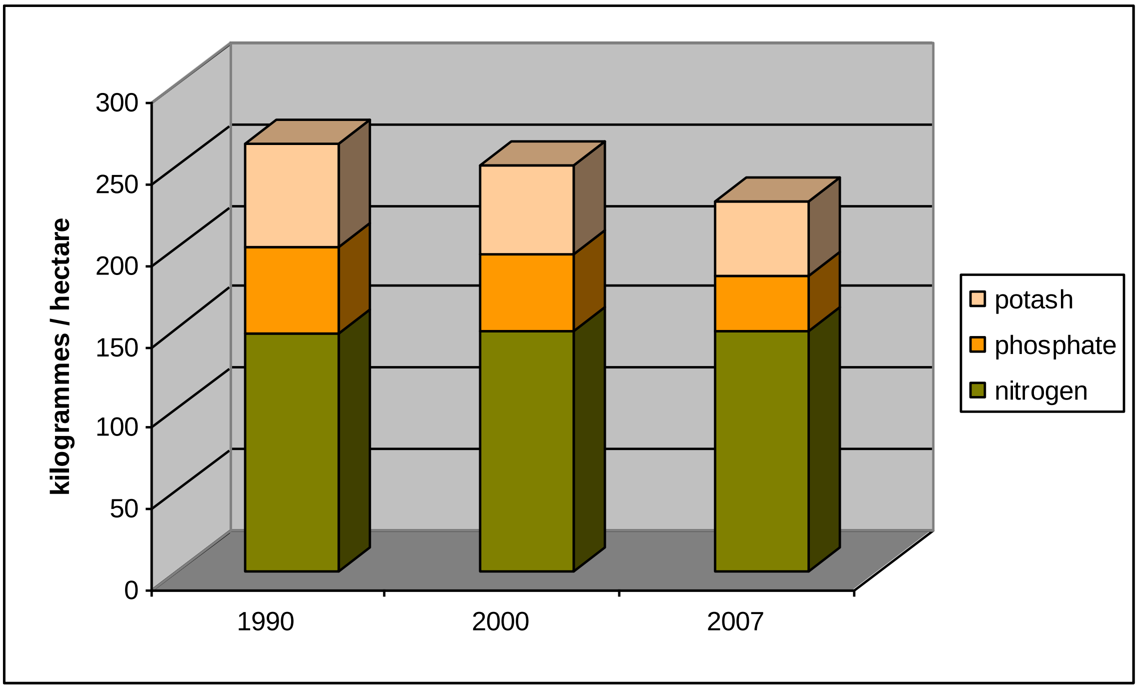
Industry trends

5.8 In environmental terms, good nutrient management ensures that a wide range of factors are taken into account prior to producing a fertiliser recommendation. These factors include nutrients from the soil supply, recent applications of organic manures, previous cropping, reduced winter rainfall and the estimated yield and quality parameters. Soil type has a strong influence on the natural availability or ability to retain nutrients,[9] thus appropriate quantities, rates and timings of nutrient application can vary considerably across individual catchments and even holdings. Therefore, responsible fertiliser and manure use must be based on a field-by-field knowledge of nutrient inputs and off-takes so that nutrient balances can be calculated. Taking full account of all inputs helps minimise the environmental impact.

5.9 A wide range of manures/wastes (organic and inorganic) may be applied to land for example, FYM, slurry and poultry manure, sewage sludge, composts, paper wastes, recovered gypsum, incinerator ash and other products. These have a lower cost (financial and environmental) in terms of production but are less consistent in their content and generally release their nutrients more slowly, making them more difficult to use effectively and efficiently.[10] The practical difficulty of achieving high rates of nutrient supply in organic systems is one factor contributing to arable cash crop yields that are typically between 20% and 40% lower, and forage crop yields 20% lower than on conventionally fertilised farms.[11] Some waste products (such as sewage sludge) cannot be used on organic land.

5.10 Fertiliser prices have risen sharply over the past year and land managers have responded by looking for ways to further reduce waste, after a number of years of reduction of fertiliser use. This has involved either a reduction in quantity used, or a more effective targeting of what is used, and in some cases both. An improvement in river water quality throughout much of the country has coincided with this change.[12]

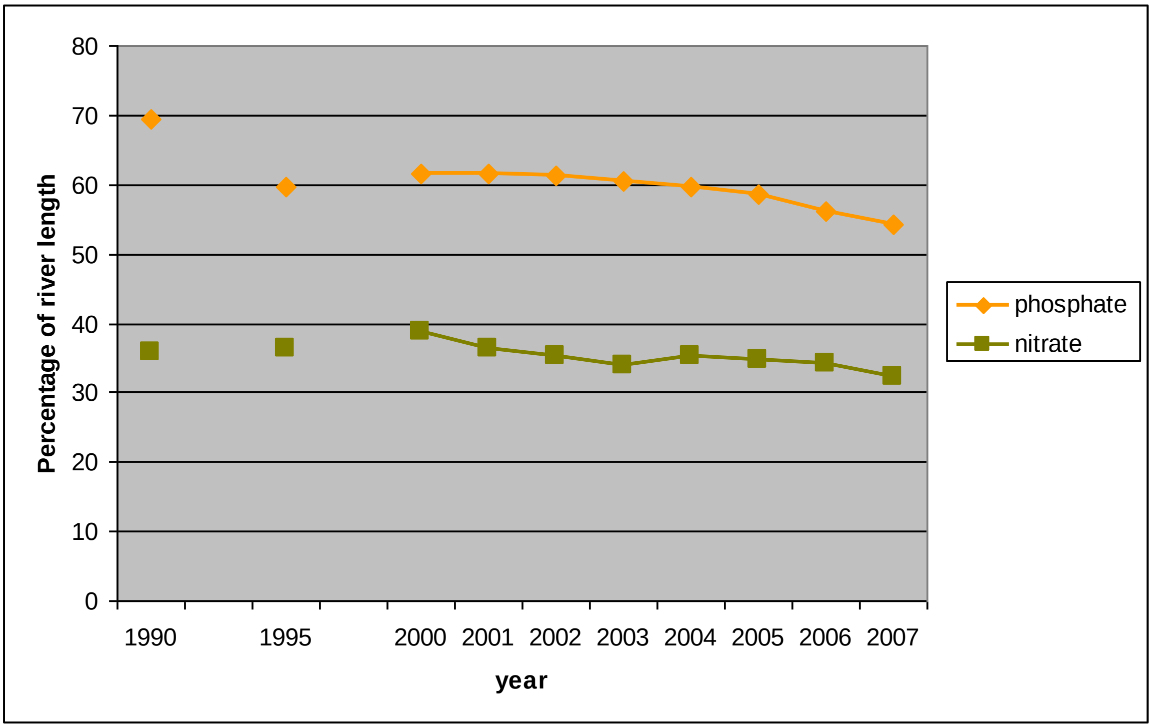
5.11 Figure 3 illustrates the reduction in fertiliser used on arable crops, particularly phosphates, since 1990.



Source: British Survey of Fertiliser Practice[13]

Figure 3 Average fertiliser use on arable crops in England, 1990-2007

5.12 Figure 4 shows that the reduction in fertiliser use nationally can be correlated with the reduction of river length identified by the Environment Agency as having 'high levels of nutrients'.[14]



Source: Environment Agency[15]

Figure 4 Indicator - Rivers with high levels of nutrients in England, 1990-2007

5.13 For current incentives, advice and regulation for nutrient management, see Annex I to this chapter.

Key impacts

5.14 Native plant species and assemblages respond unevenly to the addition of nutrients.[16] In semi-natural habitats such as grasslands,[17] and for many arable wildflowers,[18] the deposition of additional nutrients can allow some species to out-compete others, and can also compromise disease or pest resistance, resulting in medium to long-term habitat modification or loss.[19]

5.15 Nutrients which are not taken up by plants or absorbed into the soil biomass are diffused either aerially or in water. Problems involving nutrients being released by agriculture and affecting semi-natural habitats and native species are centred around excessive levels of nitrogen (as nitrate, nitrite or ammonium) and phosphorus (as phosphate), which enter watercourses and groundwater, and airborne nitrogen (as nitrous oxide and ammonia).[20]

5.16 In many agricultural systems, the application of fertilisers to crops results in nutrient movement beyond the crop edge or rooting zone. This has a nutrifying effect on hedgerows, boundary habitats[21] and the plant communities of receiving waters, where nitrates and phosphates are transported through the soil profile or by surface flow. Most manures and waste products are applied for their value in terms of additional nitrogen or organic matter. The nitrogen/phosphate ratio in these materials is generally such that it can lead to over-application of phosphate. Whilst phosphate is generally held in the soil, it can also reach a level of saturation, beyond which it will leach through, resulting in contamination of water-courses.[22] A further disadvantage of using manures and waste products is their potential to contain heavy metals, which can accumulate in the soil[23]. See also chapter on 'Nutrient and pollution management - intensive livestock'.

5.17 Cultivations can be an important source of mobilised nitrates, as mineralised nitrogen in the soil is released.[24]

5.18 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

5.19 Research has shown that inorganic fertiliser has a negative effect on many native grassland and arable plant species and assemblages. This can have a long-lasting effect due to the slow transport of phosphorus out of soils.

5.20 Increased deposition of nutrients on natural and semi-natural vegetation will result in a change in species composition, either due to the increased growth of some species, or because of an increase in susceptibility of other species to disease or climatic extremes, for example frost hardiness.

5.21 Habitats such as woodlands, wetlands and semi-natural grasslands adjacent to intensively cropped areas can be affected by nutrients in surface or groundwater.

5.22 Nutrient deposition into watercourses and groundwater can affect rivers, standing water, and coastal and marine waters. Aquifers can also carry nutrients in groundwater to fens, affecting their botanical structure.

Resource management

5.23 Regions where arable farming is dominant (Anglian, Midlands and Thames) have the highest proportion of river length with excessive nitrate and phosphate levels.

5.24 Excess nutrients in the soil can be dispersed aerially as greenhouse gas (N_2O) or ammonia, which can result in nitrogen deposition elsewhere, or they can be transported in water, leading to eutrophication in water and loss of aquatic flora and fauna.

5.25 The use of buffer zones at field boundaries and of catch crops are two key ways to minimise nutrient leaching and volatilisation. The rapid incorporation or injection of organic manures is an important method for mitigating ammonia emissions.

5.26 The rise in price of inorganic fertilisers is likely to increase the pressure on land managers to minimise in-field losses, by tailoring applications more closely to crop needs and by enhanced soil management.

Greenhouse gases

5.27 Nitrous oxide is released at manufacture and mineralistation of inorganic fertilisers. Carbon dioxide is released at manufacture, transport, and application of inorganic fertilisers (particularly of nitrogen fertiliser). Methane may also be released where organic fertilisers are used. See chapter on ‘Nutrient and pollution management - livestock’.

Landscape

5.28 Current global trends suggest that the pressure on productive agricultural land is unlikely to diminish in the future, leading to a probable intensification in crop production and pressures to increase the area of cultivated land.

Annex I Current incentives, advice and regulation

There are various drivers forcing agriculture to move towards better control of nutrient losses to water and air. They include the Water Framework Directive, legislation protecting special wildlife sites and international carbon emission obligations.

Agri-environment arable-reversion options stipulate zero nutrient input where a high diversity of native plant species is part of the objective. There are other options which incentivise the use of low inputs.

The Code of Good Agricultural Practice[25] provides an industry standard for soil water and air management.

The current England Catchment Sensitive Farming Delivery Initiative (ECSFDI) provides a ‘toolbox’ to give advice on meeting some elements under the programme of measures in the Water Framework Directive.

A number of regulatory instruments are applicable to the use of fertilisers and crop nutrients:

- *Wildlife and Countryside Act (1981)[26] and the Countryside and Rights of Way (2000)[27] Act*. Application of nutrients to designated sites such as SSSIs may be considered an Operation Likely to cause Damage which is an offence under this legislation.
- *EU Groundwater Directive 2006.*[28]
- *Water Framework Directive 2003*[29], the English legal instrument of the European Water Framework Directive (2000).[30]
- *Nitrate Pollution Prevention Regulations 2008*.[31]
- *Nitrate Vulnerable Zone* regulations[32] (currently applied to nearly 70% of England and Wales).

Annex II Impacts on environmental sustainability of crop nutrient management

Table 6 Impacts on environmental sustainability of crop nutrient management

Habitat quality and diversity	• Low nutrient status is important where maintenance or recreation of semi-natural habitats is the objective. Species rich grasslands and lowland heath both require low levels of nitrates and phosphate. These habitats can be adversely affected by nutrients entering the system.[33] • In current conventional agricultural systems, nutrients not taken up by crops, or held in the soil leach into the water, or (in the case of ammonia and N_2O) are released into the atmosphere, from where they may disrupt the equilibrium of nutrient cycles in other habitats. This can result in some species out-competing others, thereby changing or degrading the habitat.[34,35] • Nitrates and phosphates can be taken up by algae and some aquatic plant species, which are then able to proliferate vigorously and seriously affect habitats and water quality downstream, and into the sea.[36] • Semi-natural habitats downwind or downstream from an area of nutrient release can be adversely affected, generally by a disruption of the species balance, or the incursion of new species.[37]
Species abundance and diversity	• Serious eutrophication can result in the majority or all aquatic life in affected waters being killed, due to the massive oxygen demand of developing algae.[38]
Sediment loads in water	• Phosphates get into watercourses via movement of soil particles to which the phosphate is bonded. It is therefore an important consideration in the downstream effects of erosion. Phosphates can also move in soluble form, and movement can be overland flow, subsurface flow, through drains etc.[39]

Table continued...

Nutrient loads in water	• Nitrates enter water mostly through leaching, which can come from inorganic fertiliser, organic manures, and also can be released by legumes such as clover. Phosphates enter water predominantly via physical removal when attached to eroded soil particles, though some can arrive in solution.[40] • High concentrations of nitrates in water occur mainly in the central and eastern regions of England,[41] which coincides with the predominance of arable farming. • It is estimated that between 25% and 40% of the phosphates in water courses is due to agricultural run-off and soil erosion (lower than previously estimated).[42,43] • Polluted waters may take a significant time to return to an accepted nutrient status.[44] • Nitrates which are not taken up by plants can leach into groundwater. This can take years to flush out, and can be transported a long way from the original source of the discharge.[45] • Nitrate release by organic matter is gradual, unlike inorganic fertiliser. When it forms part of organic matter it is less susceptible to leaching in high rainfall events, but release is generally gradual and can be more difficult to match to crop requirements.[46] • Between 1990 and 2006 the percentage of rivers of good biological quality in England rose from 60% to 71%. In 2006, 66% of English rivers were of good chemical quality, compared with 43% in 1990.[47]
Greenhouse gases	• CO_2 and N_2O are released during the manufacture of inorganic fertiliser.[48] • N_2O is a bi-product of the nitrogen cycle, released by the denitrification of ammonium nitrate fertiliser, manures and slurries. It is a GHG which is approximately 310 times more potent than CO_2, although it can break down over time in sunlight.[49] • Organic fertilisers can release large quantities of methane if not managed properly.[50] • More than 50% of the total anthropogenic N_2O emissions in the UK come from agriculture.[51] • N_2O emissions from agriculture in England have decreased by almost 22% since 1990, mainly due to a reduction in fertiliser use.[52]
Air quality: other pollution	• Organic fertilisers are a common source of odour nuisance. • Application of organic manures (particularly slurry and FYM) can result in high losses of N as ammonia (*c.*40% for slurry, 70% for FYM).[53]

Table continued...

Soil function	•	The use of heavy machinery to apply nutrients in the form of inorganic and organic fertilisers can lead to problems of compaction, particularly in the spring.[54]
	•	The chemical make-up of the soil can be affected by fertiliser application in terms of its pH, as well as changes in terms of possible addition or loss of elements and compounds.[55]
	•	Chemical and physical changes to soils, such as acidification caused by application of inorganic fertilisers, and heavy metal contamination from fertiliser and organic matter can affect soil microflora and fauna.[56] [57]
	•	Crop uptake of mineral nitrogen may not be much greater than 50%,[58] although some nitrogen may become immobilised in the soil biomass, for example micro-organisms, fungi, bacteria.
Landscape character	•	Nutrient use has enabled land managers to intensify production. This has involved a change in agricultural landscapes, particularly where it has allowed poorer land to be used for economic production. For example, in Breckland, acid heathland has been ploughed since the Second World War and intensively managed. Now much is in irrigated vegetable production,[59] on ALC Grade 4 land.

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Case study: Precision farming

Precision farming is a relatively new application of Global Positioning System technology developed over the last twenty years. It enables farmers to map to a relatively high degree of accuracy variations in crop yield within individual fields. Where these variations are closely related to permanent or long-term physical features, there is the potential to adjust fertiliser and spray inputs accordingly. This has the advantage of targeting products better to where they are needed most, and also avoiding waste where crop uptake is in some way limited, allowing potential nutrients to be washed away.

The initial cost of such technology can be high - it requires harvesting equipment which measures and maps grain flow as it is being harvested, and automatic steering systems for tractors, to ensure that the correct fertiliser or spray dosage is applied in the correct place. Possible prices range from £4500 to £16,000 for an integrated system, depending on the accuracy required, and whether it is retro-fitted to existing equipment. Early calculations suggest that low-cost systems could be worthwhile for arable areas over 80 ha, and for higher cost systems, areas may need to be 250 ha or more.[1]

Currently crop yields are predominantly mapped using equipment on the harvesting machinery which measure changes in yield through the field at the point of harvest. This is a relatively cheap way of mapping crop information, but variability in yields over a field may have a number of potential or actual causes, for which better fertiliser targeting may not be the answer.

Potentially crop treatments need not be based on data collected from previous harvests, but they can be determined from remote sensed images, using hyperspectral data for the estimation of various biochemical parameters of vegetation, such as leaf chlorophyll and nitrogen concentrations.[2] Use of such imagery is currently costly, and the scale of operation required to see benefits valuable enough to offset these costs may mean that relatively few enterprises are likely to adopt the technology in the short term.An even more targeted use of agro-chemical products could further reduce pressures on the natural environment.

In the Lincolnshire Coastal Rivers Catchment, farmers have become engaged in issues around resource protection through their interest in minimising unnecessary spray and fertiliser applications[3] This has led to an improved awareness of resource protection relating to farming activities, many of which can be immediately addressed by use of precision farming systems. Where expensive products such as fertilisers are being more effectively targeted, there are clear opportunities to improve financial margins.

The use of precision farming technology has thus far been directed predominantly at symptoms and criteria relating to growing crops. It could be argued that soil condition and function is also worthy of attention, and could render some chemical-based treatments unnecessary.

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6 Nutrient and pollution management - intensive livestock

Context

6.1 Agriculture is the biggest single source of ammonia in England (approximately 90% of the total annual emissions).[1] Almost all of this comes from livestock farming: 13% of emissions stem from inorganic fertilisers, of which nearly half is applied to grasslands; the remainder comes from manures and slurries, stemming from intensive units.[2] Organic manures are a source of organic and mineral nitrogen (N). Mineral N is largely present in manures as ammonium N, and can volatilise into ammonia gas. Ammonium N in the soil can be converted into nitrate N which can leach into watercourses, or be lost as gaseous nitrous oxide (a greenhouse gas) and nitrogen.

6.2 Ammonia gas, deriving from the breakdown of excreted urea, can also be released directly into the atmosphere from manure stores and livestock buildings.[3]

6.3 Intensive livestock production in the context of this chapter covers animals kept predominantly in housed environments, where all fodder and bedding requirements are delivered to the animal. Housing poultry[4] and livestock[5] in large numbers allows considerable production cost savings, but involves higher ammonia emissions per head.[6] Dairy units can also be regarded as intensive livestock units, and are considered here alongside pig and poultry units.

Current practice

6.4 Livestock manures are applied to 48% of grassland but only to 16% of arable land in the UK.[7]

6.5 Current intensive systems tend to concentrate manure and slurry outputs. The trend towards polarisation of farming enterprises in different regions, rather than 'traditional' mixed farming, often leads to logistical problems around their disposal, resulting in some areas where no manures or slurries are applied, and other areas where they may be seen as a surplus. This can often lead to water contamination through nitrogen leaching, or the mobilisation of phosphates. Table 7 provides a summary of potential nutrient output from livestock.

Table 7 Typical values for nutrient production by housed livestock

			Output during housing period (kg)		
Type of livestock	**Housing period (% of year)**	**Undiluted excreta (t or m^3)**	**Nitrogen (N)**	**Phosphate (P_2O_5)**	**Potash (K_2O)**
Dairy cow	50	9.6	48	19	48
Growing/fattening cattle	66	6.2	31	12	31
Breeding sow + litter	100	4.0	19.5	20	16
100 laying hens	97	4.1	66	54.5	36

Source: MAFF (2000)[8]

6.6 Permanent housing is the dominant method of keeping and rearing pigs and poultry - 73% of chicken eggs produced in England are from housed accommodation. Most of the 3100 holdings producing broilers involve housed birds as well.[9] Approximately two thirds of pigs in England are housed for the whole of their lives.[10]

6.7 Typically these facilities are the source of large quantities of manure, as a result of the high numbers of animals involved. This can be an agricultural asset in terms of the nutrients and organic matter that it contains. It can also be a problem in that some of the nutrients can be in highly concentrated form and prone to volatilisation, and there can be an accumulation of heavy metals (particularly from pigs and poultry).[11]

6.8 It has been estimated that 40-60% of farmers do not include slurry or manure nutrients in their fertiliser calculations.[12] Grassland farmers have been reluctant to rely on the nutrient value of slurry on grasslands, although here the necessity of avoiding contamination of silage with faecal matter and avoiding a poor fermentation due to excessive nitrogen content of the herbage are important contributory factors.

Plate 6 Slurry spreading on arable land

6.9 In recent decades there has been a consistent under-estimation of the nutrient (and thus financial) value of manures and slurries, as well as the effect they have on local habitats and their effect on the wider environment. Targeted use of pig slurry could save up to £100/ha in annual fertiliser costs for an integrated arable unit.[13]

Industry trends

6.10 A large proportion of nutrients deriving from animal manures and slurries is lost to the atmosphere before it can be made available for crop uptake.[14] Despite this, some holdings within nitrate sensitive catchments struggle to cope with the quantities produced. Other holdings, where restrictions are less onerous, have continued to add to the high levels of water-borne nitrates, which are leached through their soils.[15] From 1 January 2009, the area of Nitrate Vulnerable Zones extends to approximately 70% of the country.[16]

6.11 Despite an annual reduction of 1% in dairy cow numbers nationally since 2005,[17] there has been a 6% rise in the number of dairy herds of over 200 cows since 2000 and, nationally, since 1996, average herd size has increased by approximately 20 cows.[18] Dairy cows are a major source of ammonia,[19] methane,[20] slurry and dirty water (milking parlour and yard washings).[21]

6.12 Despite the high visual impact of extensive pig and poultry units, they comprise a very small proportion of their respective industries. It has been estimated that extensive pig units only occupy approximately 7500 ha nationally. In 2007, the number of breeding pigs kept extensively had reduced by 7.5% from the 2006 level.[22] Numbers for all poultry during the same period increased by 32% to 12,255,000 birds (extensive poultry units were not recorded separately).[23]

6.13 Stored slurries are a potentially useful source of methane, though the high capital costs for installing such a system has put many farmers off investing. The initial capital cost for a digester and combined heat and power unit suitable for a 300 dairy cow unit could be in the order of £1000 per cow.[24]

6.14 For current incentives, advice and regulation for nutrient and pollution management, see Annex I to this chapter.

Key impacts

6.15 The main nutrients released from intensively reared or housed livestock are nitrogen (as ammonia, nitrous oxide and nitric oxide) and phosphates. Potash is also produced from animal housing and associated manure/litter storage and spreading, but generally does not have such a potentially damaging effect on the environment. Manures from pig and poultry units can have a high heavy metal content, which may build up over long periods of time, affecting soil function.[25]

6.16 Oxidation of ammonia in soils has an acidifying effect, with the extra nitrogen impacting ecosystems through eutrophication.[26] Aerial deposition of nitrogen from ammonia affects the resilience of native species such as heather,[27] whilst other families such as lichens and mosses can die off under high nitrogen deposition.[28]

6.17 Recent research has shown that the value of applications of manures and slurries to grassland and crop land extends beyond simple nutrient enhancement: whilst the level of soil organic carbon may be enhanced to an extent (depending on existing C levels and management), the addition of organic matter to the soil can be highly beneficial in terms of soil structure, drainflow and run-off.[29] Additionally, this can improve nutrient uptake by crops. The use of crop nutrients from manures can also offset CO_2 emissions resulting from inorganic nitrogen fertiliser manufacture and transport. An application of 8 t/ha (fresh weight) of broiler litter, with crop available nitrogen of 75 kg/ha, can yield a saving of 83 kg carbon per hectare.[30]

6.18 Storage and spreading manure can involve the emission of large quantities of ammonia, which has an acidifying effect on ecosystems. Nitrates which enter the soil but are mobilised before they can be taken up by plant growth may be released to the atmosphere as nitrous oxide, which is a potent greenhouse gas.[31] Slurry placement or injection systems have been shown to reduce ammonia emissions, and consequently nitrate loss at application and later stages.

6.19 Enteric emissions of methane, as part of the digestion process of ruminants, have been identified as potentially a major source of a potent greenhouse gas. Agriculture (predominantly dairy farming) is estimated to contribute 43% to the UK's emissions of methane.[32] Currently a number of methods are being evaluated to modify the digestion processes of cattle and sheep, such as: selective breeding, diet manipulation, and vaccination.

6.20 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

6.21 Oxidation of ammonia in soils has an acidifying effect, with the extra nitrogen impacting ecosystems through eutrophication. This, and the aerial deposition of nitrogen from ammonia, affects the resilience of some native plant species and can cause die-off of some mosses and lichens.

6.22 Increased deposition of nutrients on natural and semi-natural vegetation will result in a change in species composition, either due to the increased growth of some species, or because of an increase in susceptibility to disease or climatic extremes, for example frost hardiness, of other species.

6.23 Habitats such as woodlands, wetlands and semi-natural grasslands adjacent to areas of nutrient production can be affected by atmospheric deposition, surface flow or leaching.

6.24 Nutrient deposition into watercourses and groundwater can affect rivers, standing water and coastal and marine waters. Aquifers can also carry nutrients in groundwater to fens, affecting their botanical structure.

Resource protection

6.25 Intensive livestock production involves the associated production of large amounts of waste products, predominantly manure and urine. These are potentially major sources of gaseous products such as ammonia and methane, as well as nitrates and phosphates. These have a potential value as crop nutrients.

6.26 These products can also have profound negative effects on soils and water quality, as can heavy metals contained in the waste products.

6.27 Ammonia emissions can combine with oxidised nitrogen and sulphur to form particulate matter which can have a detrimental effect on human health.

Greenhouse gases

6.28 Use of manure and slurries can improve soil fertility for agriculture and offset CO_2 and N_2O emissions resulting from the manufacture and transport of inorganic fertilisers.

6.29 Storage of manures, particularly slurries, can be a major source of methane. Whilst it is possible to capture and use this gas for power generation, the equipment for its production, storage and use requires a high capital outlay.

Annex I Current incentives, advice and regulation

- *The Water Code*[33] (voluntary code of practice).
- *Nitrate Vulnerable Zone Action Programme*.[34] Compliance is also required for this under Cross Compliance Statutory Management Requirements.[35]
- *Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations (as amended).*[36] *1991* regulates new or substantially modified slurry stores. Pre-1991 stores are exempt structures but the Environment Agency may require them to be improved if they believe there is a risk of causing pollution. Handling slurries is only regulated through facilities in and around the farmyard being part of the slurry storage system. The regulations do not currently apply to solid manure stores that are sited away from the farmyard.
- *Environmental Permitting Regulations*[37] legislation covers ammonia emissions. It also regulates manure spreading to land with a requirement for slurry to be spread using band spreaders or shallow injectors, rapid soil incorporation (on arable land), housing design, covering of slurry stores and management. An Environmental Permit is issued by the Environment Agency for large pig and poultry units.
- *Feeding Stuffs (England) Regulations, 2005*[38] controls the levels of Zinc and Copper used in pig diets, to minimise risk of heavy metal contamination in land-applied manures.

Annex II Impacts of livestock nutrient management on environmental sustainability

Table 8 Impacts of livestock nutrient management on environmental sustainability

Habitat quality and diversity	• Intensive livestock units are known to emit ammonia. This can result in the acidification or eutrophication of semi-natural habitats downwind.[39] • Nutrient enrichment of grasslands and other habitats has been shown to reduce botanical diversity.[40] [41] • Increases in the levels of atmospheric N have been blamed for habitat degradation in upland areas (notably on blanket bog) and some nutrient-poor lowland habitats.[42]
Species abundance and diversity	• High nutrient status of soils can allow aggressive plant species to out-compete those more tolerant of low fertility.[43] • Light levels of FYM application (12 t/ha or less) may have no detrimental effect on species abundance and composition, but this appears to depend on whether there has been a history of fertiliser use. Where there is no history of fertiliser use, applications may need to be as low as 6 t/ha to avoid change in plant communities.[44] • FYM may favour some soil diversity by increasing mycorrhiza and the ratio of fungal/bacterial biomass.[45] • Nitrogen deposition from ammonia has a direct negative effect on the survival of lichens and other heathland species such as heather and *Polytrichum* mosses.[46]
Nutrient loads in water	• Nitrates may be leached as a result of applications at inappropriate times, or of excessive quantities applied due to underestimation of N content of slurries and manures.[47] • High concentrations of N and P in water have been recorded following rainfall after manure applications.[48] • Where manures are applied for their value in terms of additional nitrates, the nitrate/phosphate ratio is such that it can lead to over-application of phosphate, which is not held in the soil, and can result in contamination of water-courses.[49]

Table continued...

Pesticide control	• There is evidence that manures from livestock treated with ivermectins can have an adverse effect on field springtail and enchytraeid populations[50]. Fears have been expressed that bat populations may be affected by reduced insect populations, but as yet there is little evidence to support this view.
Other pollutants	• Copper and zinc has been routinely fed in the pig industry as a growth promoter. This is controlled by the Feeding Stuffs (England) Regulations, 2005 . Long-term applications of pig slurry can lead to an accumulation of copper and zinc in soils and standing crops.[51] • Point-source pollution incidents in water involving organic waste are predominantly from agriculture (2005 data).[52] These are potentially destructive to wildlife as they involve high biological oxygen demand.[53]
Greenhouse gases	• Nitrous oxide (N_2O) is a potent greenhouse gas.Emissions from the livestock industry (livestock manures and forage area) are the largest source of N_2O in the UK.[54] Emissions from grassland are higher than arable land because of the high rates of fertilisers applied, higher rainfall and more compacted soils - all favourable conditions for N_2O emissions.[55] • High levels of methane emissions are possible from unmanaged slurry.[56] • High levels of methane are emitted by the digestive systems of ruminants. Where nationally 43% of methane emissions are derived from agriculture, manipulation of ruminant production, and digestion has been identified as a potential contribution to the UK's meeting it's targets under the Kyoto Protocol.[57] • Incorporation of organic matter into soils can increase carbon sequestration, although, as organic matter accumulates, the amount of carbon sequestered annually reduces.[58] • Use of organic fertilisers such as manure and slurry can offset CO_2 and N_2O emissions resulting from the manufacture and use of inorganic fertilisers.[59]
Air quality: chemical	• Ammonia emissions from livestock sources contribute to high levels of N deposition. This can lead to soil acidification and eutrophication on some semi-natural habitats.[60] • Application of slurries (particularly sprayed) can lead to over half of the nitrogen content being lost to the atmosphere as ammonia.[61] • 90% of total UK ammonia emissions reported for 2005 were from agriculture (286 kt).[62]

Table continued...

Air quality: particulates	•	Ammonia reacts with sulphur and oxidised nitrogen in the air to form ammonium particles. This provides 20-35% of the inorganic fraction of PM 1.0 and PM 2.5, having significant impact on human health.[63]
Soil stability (erosion)	•	Large-scale outdoor pig units operate on only 7500 ha nationally.[64] Whilst they have the potential to cause erosion, environmentally sustainable production can be an important added value to the output of the enterprise.
Soil function	•	Incorporation of manures improves soil structure.[65]
	•	Appropriate timing of application can be difficult, given the need to apply slurries when soils can support heavy machinery, whilst ensuring maximum nutrient uptake by the growing crops (early spring through to early summer).[66] Soil compaction can result in raised N_2O emissions due to impaired soil function.[67]

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7 Grazing livestock in the lowlands

Context

7.1 Approximately 2.4 million hectares of land in lowland England are used for grazing livestock production. Just over 95,000 ha are classed as semi-natural grasslands (excluding woodlands).[1] Nearly 65,000 ha of that area are Sites of Special Scientific Interest (SSSI).[2]

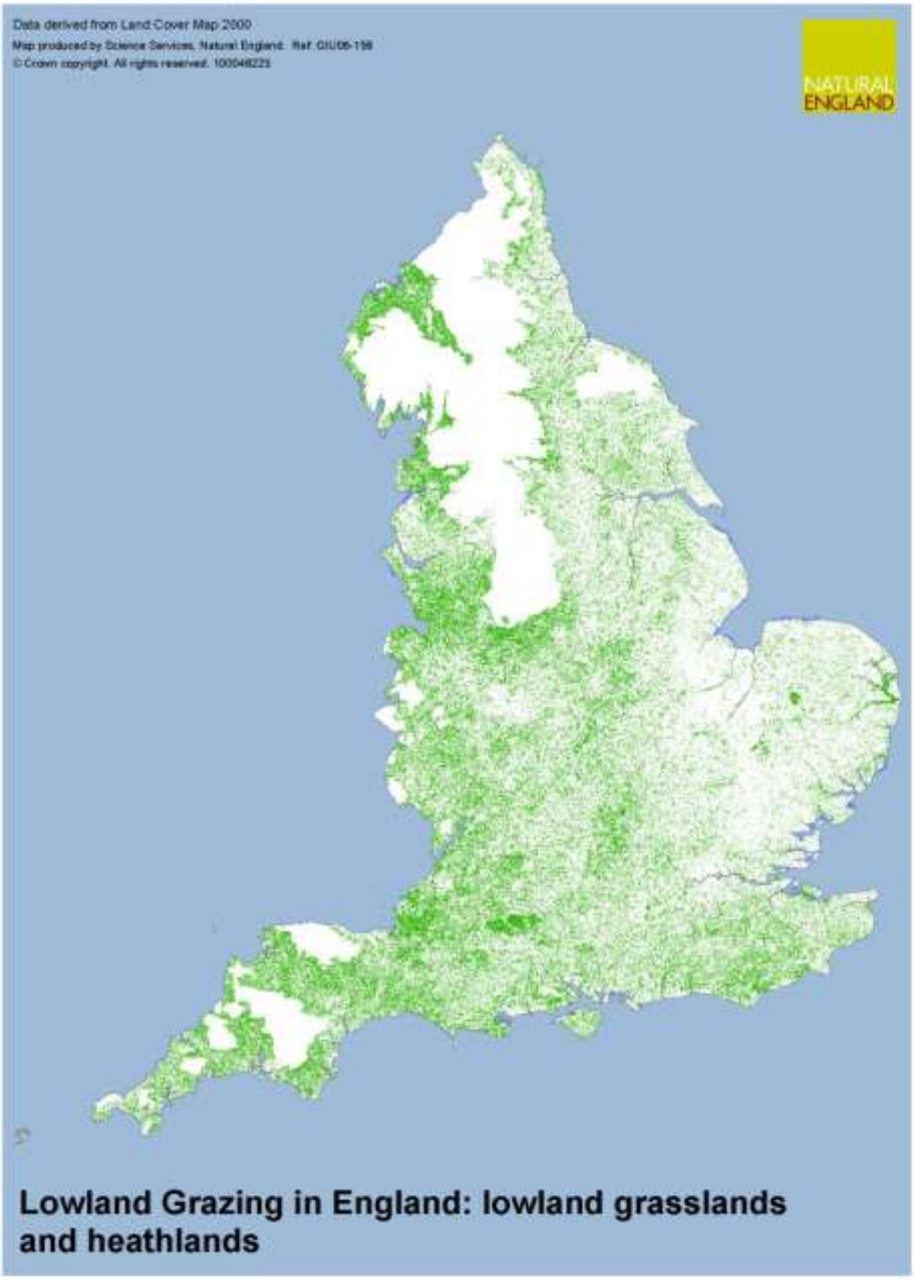

Figure 5 Lowland grazing outside Less Favoured Area

7.2 The map above shows the extent of land classified as grassland, heathland or rough grazing in the English lowlands.

Current industry practice

7.3 Management for lowland grazing livestock enterprises is generally closely associated with high stocking rates, short-term grass leys, high rates of inorganic fertiliser use and the disposal of large quantities of slurry. The average stocking density over all lowland forage area is 0.58 livestock units (which equates to one medium sized suckler cow) per hectare.[3] The average stocking rate on a lowland dairy farm is 2 livestock units (two dairy cows) per hectare.[4] This stocking rate would present manure disposal problems in a Nitrate Vulnerable Zone.[5] Permissible rates for manure application will be raised in autumn 2009, to allow an equivalent of approximately 2.5 cows per hectare.

7.4 The majority of ruminant livestock utilise grassland for much of the year. Typically, dairy and suckler cows are housed for approximately 24 weeks over the winter period. Sheep are housed on average only for six weeks over the lambing period.[6]

7.5 Overwintering requires conserved forage. This is viewed as a key product in lowland livestock enterprises. Production of large quantities of forage is usually dependent on high nutrient inputs and, in the case of grass silage, can mean multiple ‘harvests’ with early initial cutting dates. Effluent from silage is potentially a serious water pollutant. Stringent regulation has resulted in a marked reduction in such pollution events.[7]

7.6 Currently, a large proportion of arable crops such as maize or whole-crop silage, wheat (50%) and barley (over 60%)[8] is used in the livestock sector as a way of providing relatively cheap energy and protein.[9]

Industry trends and pressures

7.7 Land in the English lowlands is generally more versatile than in the uplands so the mix of farming enterprises is more able to change according to the economic climate. Between 1990 and 2006, lowland sheep and beef numbers rose by 18%, whilst dairy cow numbers dropped by 43%.[10] The area of wheat and oilseed rape increased, although total combinable crops decreased slightly.[11] Recent rises in the price of milk have maintained some degree of financial competition with arable crop production.[12] Livestock production is still dominant in those lowland areas where arable cropping is more marginal due to terrain or climate - largely in the north and west of England.

7.8 There has been a gradual polarisation of farm types, so that mixed farming (arable with livestock) has become less common, with arable farming predominating in the midlands and eastern part of the country, and livestock farming predominating in the west.[13]

7.9 In the lowlands, some areas of semi-natural vegetation developed as part of a traditional grazing system. These areas may typically have provided winter grazing to stock from elsewhere. In many predominantly arable areas of England there are insufficient suitable grazing livestock, and as a result undergrazing of conservation areas can be an issue.[14] Keeping stock in these areas, apart from having an economic function, can serve as a major habitat management tool through conservation grazing.

7.10 Livestock may be kept in lowland areas for a number of other reasons: they may be seen as a useful means of converting arable by-products into a more valuable commodity. Many arable farms buy large numbers of young (‘store’) animals for overwintering on fields which have been sown with late-sown or catch crops, thereby creating a short cropping break, which also has the benefit of adding a certain amount of fertility in the form of dung and urine. Grazing animals on such crops can result in severe soil run-off during bad weather if not managed sensitively.[15]

7.11 Many of the traditional lowland livestock enterprises, particularly where livestock have been used as a break from an arable rotation, have been phased out as land managers have found the increasingly small margins uneconomic, particularly given the comparatively high labour costs.

7.12 Since 2002, nitrogen fertiliser use on grasslands has reduced from an annual average of 89 kg/ha to an average of 65 kg/ha in 2007. Total phosphate applications had reduced from an average of 20 kg/ha in 2002 to 14 kg/ha in 2007.[16,17] The value of slurry and farmyard manure has increased in recent years as in the past it was often overlooked by land managers, both as a source of crop nutrients (high P, K and N values)[18] and as a potential source of energy (methane). The nutrient value and organic matter from farmyard manure can augment arable fertility on mixed farms. Some farmers on intensive livestock holdings have difficulties using all the solids and liquids on the holding within the constraints of Nitrate Vulnerable Zone (NVZ) requirements and the Codes of Good Agricultural Practice.[19]

7.13 With the higher cost of straw and milder winters, stock are being out wintered for longer, with the potential to cause soil compaction[20] and run off problems.

7.14 For current incentives, advice and regulation for lowland grassland farmers, see Annex I to this chapter.

Key impacts

7.15 Land which has been relatively extensively grazed for many years can develop a flora that largely reflects the management system. The habitats which have developed can be diverse and significant. Lowland semi-natural habitats dependent on livestock enterprises include lowland calcareous grassland (53,945 ha), lowland meadows (20,378 ha) and Purple Moor Grass and rush pasture (8734 ha).[21]

7.16 The loss of grazing from these areas (due to poor economic returns, lack of infrastructure, or the high demand in labour) may result in high risk to local or even national biodiversity as the growing conditions provided by grazing are difficult to reproduce by other means. There is therefore a case for maintaining lowland grazing in these areas irrespective of market returns on the basis that they provide a public benefit. Agri-environment funding is available to provide a financial incentive in many such cases.

7.17 The use of rotational crops for livestock may result in a loss of longer term grass leys. These leys have a higher biodiversity value than arable land, above and below ground,[22,23] and store carbon in soil organic matter, which is preserved through lack of cultivation.[24,25] Hay, which is generally cut later in the growing season, is now less common, despite being the most easily transported, largely because of its dependence on good weather during harvesting and its comparatively high labour demand.

7.18 Modern high-output forage systems have a high potential for risk to the environment from loss of semi-natural habitat and release of nutrients into surface and ground water. Agriculture is a source of over 60% of nitrates, up to 40% of phosphorous and approximately 25% of silt in UK waters.[26] It is also responsible for 85% of ammonia emissions, particularly from the dairy sector.[27]Since 2000 there has been a gradual reduction in nitrate and phosphate levels in English rivers.[28]

7.19 Early cutting dates for silage have been shown to have a detrimental effect on the breeding success of most ground nesting birds.[29] High nutrient input and early cutting dates have contributed to the loss of traditional hay meadow habitats.[30]

7.20 For further factual background to this to this chapter, see Annex II.

Summary of impacts

Biodiversity

7.21 Many important lowland ecosystems, including coastal areas, are dependent on low intensity grazing to maintain the desired vegetation mix and structure. Economics and lack of local infrastructure have often resulted in difficulties securing animals for this purpose. Sometimes referred to as undergrazing, this can result in loss of important habitat.

7.22 The pressures on biodiversity in the lowlands have increased as the agricultural sector has responded to economic forces by concentrating on intensive production. In the livestock sector, the drive to produce large quantities of high quality conserved fodder has resulted in areas of dense, heavily fertilised grasslands, which are cut early in the season, reducing botanical diversity and displacing or killing ground nesting birds.

Resource protection

7.23 In recent years, fertiliser use has been reduced, along with a reduction in stock numbers. There has also been increased focus on sources of agricultural pollution. Since 2000, the industry's record has improved in terms of point-source pollution incidents involving livestock. Agriculture is still a significant source of water pollutants and a major contributor of ammonia emissions.

7.24 Lowland livestock farmers are increasingly reliant on rotational crops such as maize (see Maize Production Case Study) and wheat for whole-crop silage. This has a potential negative effect on carbon sequestration, soil stability and biodiversity, above and below ground. The exception to this is where overwintering birds may benefit from whole-crop barley stubble.

Greenhouse gases

7.25 Ruminant livestock emit large quantities of greenhouse gases, principally methane, which can be managed as a fuel but, given high capital costs and modest returns, is more commonly not managed at all.

7.26 Grasslands can sequester carbon from the atmosphere, but this is largely released if they are ploughed up in a rotation. Intensive grasslands (both cut and grazed) are also the largest source of N_2O emissions across all agricultural systems.

7.27 Ammonia emissions are considered in the chapter on 'Nutrient and pollution management - intensive livestock'.

Landscape

7.28 Many lowland landscapes, such as the downs of southern England and the grazing marshes and lowland meadows of the Broads and Upper Thames, are dependent on extensive grazing.

7.29 Earthworks and other archaeological sites generally survive best on grazed land. Despite this, they can be seriously damaged by erosion by stock and around access routes. The maintenance of appropriate stocking levels to avoid erosion and control the spread of scrub is essential for the continued conservation and public appreciation of historic earthworks.

Annex I Current incentives, advice and regulation for lowland grassland farmers

Incentive

Environmental Stewardship and the earlier Environmentally Sensitive Area and Countryside Stewardship schemes incentivise a number of activities to enhance biodiversity on grasslands:

- A reduction or cessation of fertiliser applications on potentially high value grasslands.
- Late cutting dates for traditional hay meadows and making of field dried hay, to encourage seed setting.
- Creation of species-rich hay meadows.
- Field operations such as chain-harrowing limited to prevent damage to ground nesting bird populations.
- Maintenance of structural heterogeneity to encourage waders.
- Raised water levels to restore or recreate wet grassland habitats.

The Catchment Sensitive Farming (CSF) initiative provides free advice to farmers and land managers on all issues relating to water management and soil protection on land within river catchment areas.

Regulation

- *Wildlife and Countryside Act* - protection of vegetation on designated sites from overgrazing or undergrazing.
- *Countryside and Rights of Way Act* - prevention of Operations Likely to Damage.
- *Cross Compliance - GAEC 9*- overgrazing and supplementary feeding damage of semi-natural habitats.
- *Environmental Impact (Agriculture) regulations* – protection of unimproved grassland from agricultural improvement
- Cross Compliance also requires that nationally there should be no net loss to permanent grassland from the national extent in 2003.[31] As yet this condition has not been required, as census results show no overall loss.
- Water Framework Directive - overarching water quality requirements.

Annex II Impacts of lowland grazing livestock production on environmental sustainability

Table 9 Impacts of lowland grazing livestock production on environmental sustainability

Habitat quality and diversity	• Grazing has a direct effect on habitats though defoliation, trampling and deposition of dung and urine. This can be desirable or undesirable, depending on the objective for the habitat. Historically, areas of lowland SSSI have deteriorated through inappropriate grazing. • Undergrazing is currently an important factor in degradation of semi-natural lowland habitats.[32] • Grazing has been used in many areas as a tool for maintaining or restoring habitats. This requires careful management and monitoring.[33] • Extensive outwintering of livestock can produce large areas of bare ground, which provide useful winter feeding opportunities for overwintering birds.[34] Findings are variable, suggesting that more intensive trampling may have the opposite effect.[35,36] This area is still being researched. Such outwintering may be considered in breach of Cross Compliance regulations relating to damage to sites from supplementary feeding. • Lack of profitability in grazing enterprises has resulted in grassland being ploughed up for arable production. Defra census indications are that this is predominantly rotational (short term) grass leys.[37] Habitats which have been created (directly or indirectly) by and are maintained due to lowland livestock enterprises are: • Culm grasslands • Lowland wet grassland • Calcareous grassland • Lowland wet and dry heath • Lowland acid grassland • Wood pasture • Orchards • Lowland meadows. Lowland priority habitats which are threatened by inappropriate livestock management: • Wood pasture • Lowland meadows • Chalk Downland.

Table continued...

Species abundance and diversity	• The environmental impacts of outwintering livestock are currently being researched through a number of nationally funded projects. Early indications are that light damage to topsoil and vegetation resulting from treading (poaching) by extensively outwintered cattle can benefit some birds and possibly encourage botanical diversity.[38] Key lowland species which have benefited from livestock enterprises are: • Low growing forbs, for example Early Marsh Orchid and Marsh Gentians proliferate where grazing maintains space for recruitment and an open sward in lowland wet heath.[39] • Overwintering birds which can benefit from whole-crop silage stubbles, particularly whole-crop barley, where grass and maize silage fields are of less value.[40] Key lowland species which are threatened from lowland livestock are: • Ground nesting birds which have been adversely affected by grass silage production - earlier (and repeated) cutting dates and fewer seeds in the fed product.[41] • Traditional pasture and meadow plant species - outcompeted by intensive grassland methods.[42]
Water level control	• In some circumstances, it can be advantageous to livestock farmers to maintain a high water table, to ensure good herbage growth throughout the season.[43] • Drainage operations are rarely cost effective on livestock farms, where the main benefit would be to raise stocking rates. To raise the stocking rate from 1.75 cows/ha to 2 cows/ha would improve annual Gross Margin by £150/ha.[44] Cost of draining 1 ha is approximately £2500.[45]
Sediment loads in water	• A study in the River Sem suggests that about 25% of silt comes from agricultural topsoils, with some 18% from road verges and the majority coming from channel banks and subsurface sources.[46] • Where grazing exposes or destabilises soil, it becomes prone to run-off, erosion and transfer of sediments to watercourses. This can be a particular problem where livestock concentrate at foddering sites during the winter.[47] • Hedges and ungrazed field margins can act as buffer zones against run-off.[48] • Maize crops present a high risk in terms of soil run-off due to extensive periods of low ground cover and the need to harvest late in the year, often in sub-optimal weather conditions.[49] • Poor yard drainage from housed livestock can result in high volumes of dirty water run-off.[50]

Table continued...

Nutrient loads in water	• Run-off from areas of compacted or poached soil can add to phosphates and nitrates entering the water.[51] • High application rates of slurry and inorganic N, such as on intensive dairy farms, can result in nitrate leaching.[52] • Since 1984, there has been a 50% reduction in the use of nitrogen fertilisers on grassland in England[53] (20% since 1998).[54] This bears little relation to Environment Agency data on nitrate concentration in rivers, which has stayed relatively stable since 1995[55], suggesting either that nutrient runoff is largely due to organic fertiliser applications, or that the livestock industry is not the main source of nitrate pollution. • Currently, agriculture accounts for approximately 60% of the nitrate in river water.[56] • Between 1990 and 2006, the percentage of rivers of good biological quality in England rose from 60% to 71%. In 2006, 66% of English rivers were of good chemical quality, compared with 43% in 1990.[57] • Traditional hay meadows are low impact on water quality, being managed using very low nutrient inputs.[58]
Pesticide control in water	• Sheep dip is potentially a major pollutant of water. See Sheep Dip Case Study for more information. • There is evidence that manures from livestock treated with ivermectins can have an adverse effect on field springtail and enchytraeid populations[59]. Fears have been expressed that bat populations may be affected by reduced insect populations, but as yet there is little evidence to support this view.
Other pollutants	• Water quality may be affected directly through introduction of bacteria such as *Cryptosporidium* and *Giardia*, generally via the faeces of grazing livestock. This is a particular issue with cattle.[60] • Silage effluent has very high Biological Oxygen Demand (BOD). Milk has a higher BOD than silage effluent.[61] Both are specifically recorded by the Environment Agency in their data on pollution incidents in watercourses.[62] • Recorded pollution incidents from the livestock industry show that the highest percentage stems from slurry stores and tanks. Other major sources are: land run-off, yard washing and silage effluent.[63] • Nationally, between 2001 and 2007, recorded pollution incidents involving silage effluent fell from 79 to 32. Incidents involving slurry fell from 690 to 283.[64]

Table continued...

Greenhouse gases	• Grazing can affect air quality through direct emissions of methane from grazing ruminants and emissions of ammonia and nitrous oxide from dung and urine. Optimal grazing is likely to have a net benefit in terms of C sequestration, but there is considerable variation between systems and soils.[65] • Uncovered slurry stores as well as livestock themselves were the source of nearly 38% of all methane in the UK in 2006 (most recent data).[66] • Grasslands in the UK (both for cutting and for grazing) are the major source of agricultural N_2O emissions. Grassland produces on average almost three times as much N_2O per hectare as arable crops.[67] • N_2O emissions from agriculture in England have decreased by almost 22% since 1990, mainly due to a reduction in fertiliser use.[68]
Air quality: pollutants	• Livestock housing, slurry storage and slurry application are major sources of ammonia from agriculture.[69]
Soil stability (erosion)	• Grazing affects soils through physical compaction or erosion associated with trampling. This is usually associated with exposure and/or destabilisation resulting from removal of vegetation and physical disturbance from hooves or scraping/rubbing.[70] • Growing maize for silage involves extended periods of bare soils and often vehicle access (for harvesting), when soils are wet and prone to rutting and smearing, both of which are a high erosion risk.[71]
Soil function	• Grazing livestock can affect the soil chemically and biologically, through deposition of nutrients (as dung and urine), and through the effect on vegetation, which can change plant litter inputs, soil microbiota and the temperature regime.[72] • Surface compaction and poaching caused by maintaining stock on wet soils, and compaction caused by heavy machinery used in silage operations, especially when ground conditions are wet, can significantly depress yields by reducing microbial activity, nutrient mobility and water infiltration.[73] • Late harvesting of maize can involve adverse weather conditions, which may lead to extensive rutting, smearing and soil compaction.[74] • High levels of inorganic fertiliser use can reduce soil mycorrhizal activity, which depresses competitive ability of some herb species. This can affect overall biodiversity.[75]
Landscape character	• Grazing has affected landscape through our development of landscape scale structures to enable the management of the grazing livestock. This has led to distinctive patterns of field boundaries and agricultural buildings.

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Case study: Maize production

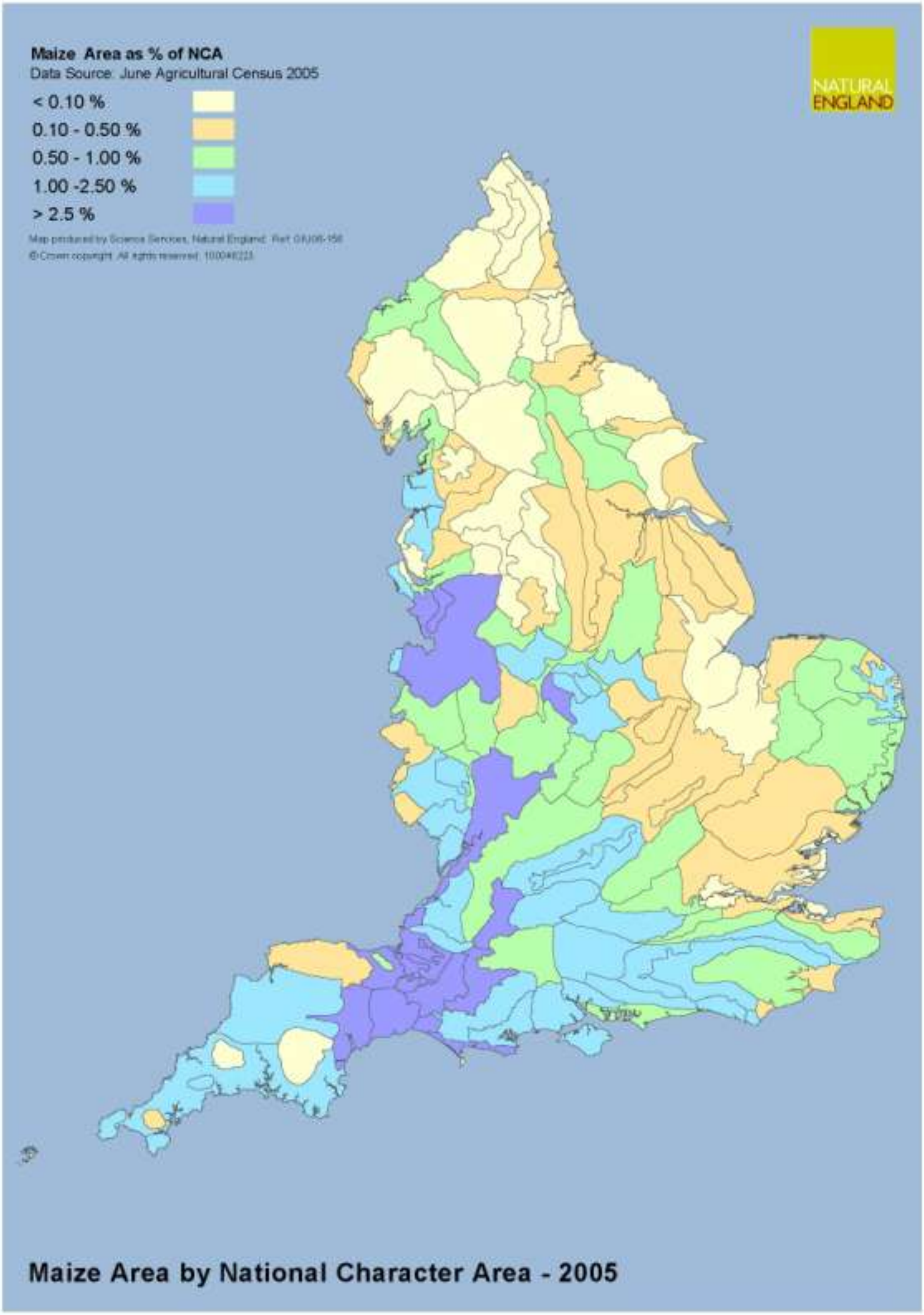

Figure 6 Maize 2005

Over the last 20 years the use of maize for wholecrop silage has become more widespread, due to its comparatively high yields and potential for high intake by livestock.

The area of maize grown for silage in England has increased from approximately 21,000 ha in 1980 to approximately 118,500 ha in 2005.[1] The total reported land area used for arable silage in 2003 was 38,000 ha.[2] Since 1980 the area of permanent grassland (grass leys over 5 years old) in England has stayed relatively constant (3.1 million ha), whilst short-term leys have decreased, suggesting that in the last 25 years, silage from maize and arable crops has mostly impacted on rotational, rather than permanent grassland.[3]

The map above shows the distribution of maize production in England. A warmer climate could result in further spread northwards.

Maize production has the potential to present some serious environmental problems: biodiversity is affected due to cultivations at establishment, and the use of residual sprays to avoid weed competition. The crop has a high nutrient demand, often addressed by heavy applications of slurry and farmyard manures, as well as inorganic fertilisers. Soils are exposed to erosion for an extended period during the crop's development, and harvesting (in late September or October) presents a high risk of soil structural damage from smearing and compaction in wet conditions.[4] Because of the relatively late harvesting, most cropped maize fields are left uncultivated until the spring. If there is no undersown crop, the soil is likely to be exposed to further erosion risk.

A number of mitigating strategies have been developed to reduce some of the negative effects of the crop. Key among these is control of soil erosion and runoff. A number of techniques can be used to achieve this, two of which have particular potential to reduce biodiversity losses: a buffer strip around the crop can not only reduce soil and nutrient runoff, it can be a useful source of seeds and invertebrates throughout and beyond the growing period. Undersown crops, or late-sown cover crops can provide similar benefits, and provide better soil stability and retention of nutrients after harvest.

Maize is considered to be a 'lazy rooter', often developing a shallow root system, particularly where there are ready supplies of surface nutrients. Attention to potential soil compaction before sowing not only reduces erosion and run-off risk, it allows the maize crop to develop a strong root system which is better able to utilise existing soil nutrients, thereby reducing the requirements for heavy additional applications.

Use of such simple strategies can reduce costs to farmers and improve environmental performance. These measures are amongst those being advocated and adopted under the England Catchment Sensitive Farming Initiative.[5]

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8 Grazing livestock in the uplands

Context

8.1 Approximately 2.2 million hectares of land are classified as Less Favoured Area (LFA), with 1.6 million hectares classified as Severely Disadvantaged Area (SDA). Extensive sheep and beef cattle farms account for the predominance of farm types in the LFA (46%).[1] Most of the SDA land is suitable only for grazing. Currently only 7.2% of farms in the SDA are classified as dairy, accounting for 9% of English dairy cows.[2]

Current industry practice

8.2 The husbandry of grazing livestock is an integral part of English upland agriculture. Animals, plant species, landscapes and husbandry systems have adapted, or have been adapted, over hundreds of years by both economic, and natural processes.[3]

8.3 Livestock grazing in upland England is mainly for the production of meat, breeding stock, and fibre (wool). In upland regions, grazing is the major agricultural land use, largely because the more difficult terrain and poor soils are not conducive to other forms of production. The continuation of grazing systems may also be strongly influenced by family or local tradition.

8.4 Forage for livestock in the uplands comprises moorland and rough grazing, suited predominantly to beef and sheep rearing (and, in some areas, native ponies), and more modified enclosed land. Much of the enclosed land has relatively shallow soils, less suited to regular cultivation. Combined with a higher annual rainfall and a shorter growing season than in lowland areas, these factors make upland areas less suitable for intensive production.

8.5 Livestock farming in the uplands does not just have a value to be measured in terms of biodiversity and rural economy. The predominant appearance and cultural history of the uplands involves livestock - from native breeds, walls and farm buildings to place names.

8.6 In a minority of situations, livestock may be grazed with the primary purpose of maintaining upland biodiversity, managing vegetation or supporting target species in grazed ecosystems (‘conservation grazing’). Many conservation grazing projects involve maintaining cattle on hill and moorland. Because the grazing habits of cattle are less selective than sheep, and they will eat coarser vegetation, their loss from upland areas could result in detrimental changes to many semi-natural habitats.[4] These projects provide multiple benefits - traditional agricultural outputs, the maintenance of a traditional agricultural infrastructure and the maintenance or enhancement of biodiversity and landscape. An example of such a project is the Limestone Country Project in the Yorkshire Dales.[5]

8.7 The map at figure 7 shows grazing land within the English Less Favoured Area.

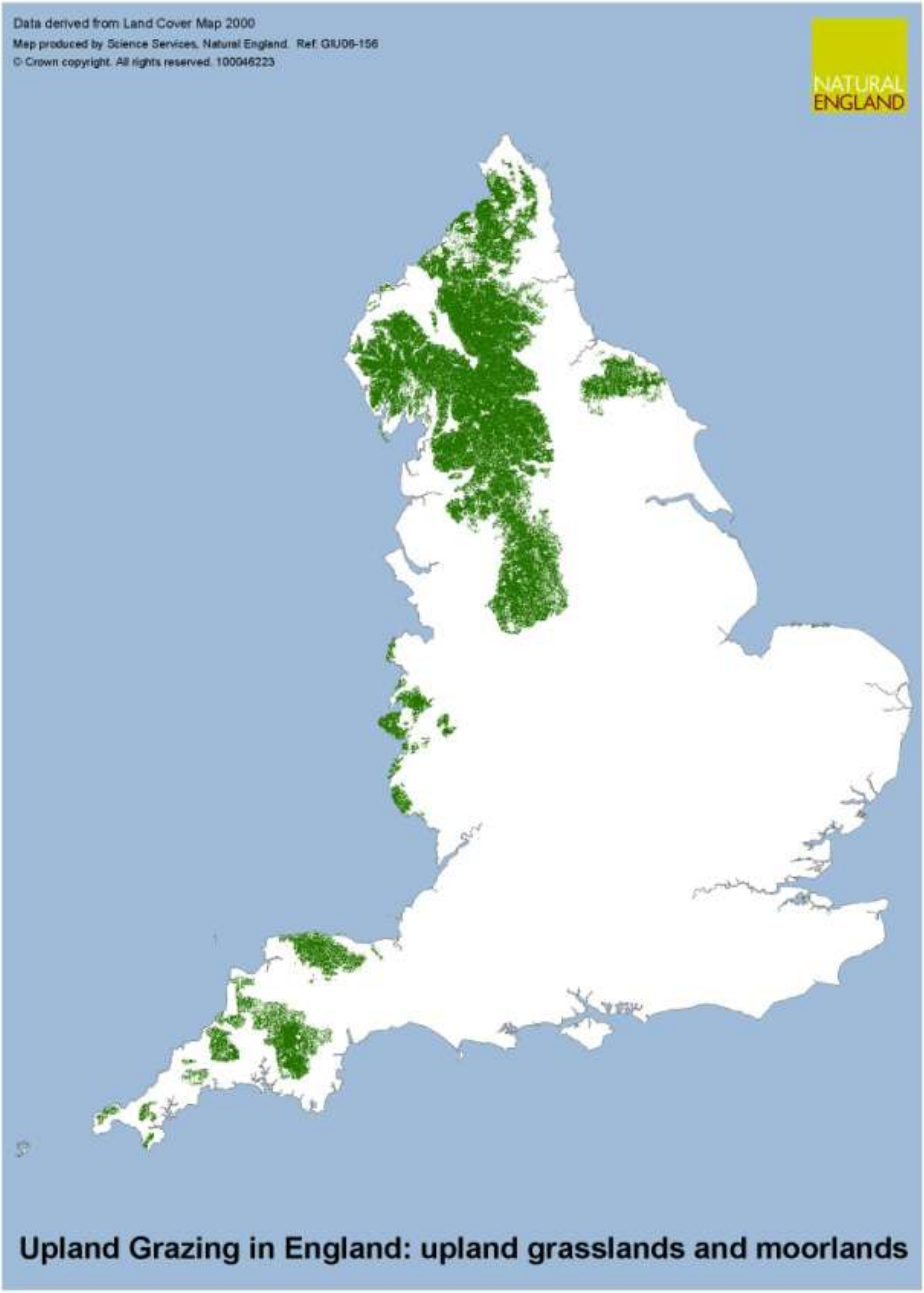

Figure 7 Area classified as grazing land within the Less Favoured Area

© Natural England

Plate 7 Cattle on a conservation grazing project

Industry trends and pressures

8.8 Some graziers, predominantly in the uplands, have rights to keep animals on common land. The land is often of low agricultural productivity, but can be comparatively high value in terms of biodiversity. Common grazing is used, with supplementary feeding, as an additional forage area, freeing the more productive 'inbye' land for periods of intensive husbandry, such as tupping, lambing, calving, fattening, and production of conserved forage. Historically, the semi-improved inbye land dictated overall stock numbers on a holding (typically it comprised about 10% of the total grazing area). After the introduction of headage payments in the 1970s, hill livestock numbers increased dramatically,[6] often disproportionately to the available inbye area. It became financially viable to outwinter hardy sheep and cattle breeds on the hill grazings, increasing problems of overgrazing and localised problems of trampling and nutrification where foddering takes place.

8.9 Since CAP reform in 2005 there have also been reductions nationally in sheep and beef cattle numbers.[7] Predictions of changing farming practice following these reforms suggest that there will be substantially less grazing activity in the uplands, with particular declines in cattle grazing. As yet there is little documented evidence to show that the changes in subsidy payment are having a direct and substantial effect on livestock numbers in the uplands. Nationally livestock numbers have declined, in many cases since before 2005,[8] Figures from the draft report by Defra's Agricultural Change and Environment Observatory Programme show a 9% reduction in upland beef cow numbers between 2004 and 2008.[9]

8.10 An economy in which livestock could not be supported in these areas would involve a major change in amenity and culture and would challenge long established perceptions of the upland landscape. Ultimately, in this scenario, natural processes would replace livestock grazing as the main influence on the landscape, leading to the development of woodland and other semi-natural habitats.

8.11 For current incentives, advice and regulation for upland grazing managers, see Annex I to this chapter.

Key impacts

8.12 Through its influence on plant community composition, agricultural grazing in natural ecosystems has encouraged habitats which are predominantly comprised of grazing tolerant or resistant plant species. The history of grazing, burning and drainage on moorlands has resulted in many habitats becoming dominated by a few stress-tolerant and less palatable plant species. Thus moorland ecosystems used for grazing have become strongly anthropogenic, and often species-poor,[10] despite having a high landscape value. On the inbye land, physical conditions and traditional management methods have resulted in relatively nutrient-poor grasslands which can be particularly species rich and of high conservation value - upland hay meadows.[11] These have developed from cutting and removal of hay every year, modest applications of farmyard manure and grazing in autumn and spring.

8.13 Growing conditions in the uplands are often difficult and heavy grazing can lead to suppression or loss of a number of plant species. Where vegetation is heavily suppressed, bare patches can develop and erosion can result. Very high levels of grazing can lead to large areas being affected by erosion, though moderately high levels of grazing can mobilise the same quantity of material, though over a smaller area. Where low levels of grazing do cause erosion, it is generally only on paths, or treading (poaching) in localised areas.[12]

8.14 Heather is a key component of many extensive upland vegetation types.[13] Under excessive grazing, stands of heather tend to fragment and become dominated by coarse grasses.[14] Whilst grassy vegetation produces more biomass than heather,[15] it is poor feed value in the winter months. Extending the period of use of moorland habitats through supplementary feeding leads to potential habitat change in small areas due to nutrification through dunging and local overgrazing where stock congregate.

8.15 Low levels of grazing can enhance habitat heterogeneity, whilst maintaining or enhancing biodiversity.Determining the appropriate level of grazing for a grazing unit containing a number of different vegetation types has proved to be technically challenging, particularly when economic sustainability is considered as well.[16]

8.16 A move to less hardy, but more productive ‘upland’-type animals could result in reduced pressure on hill grazings, but increased pressure on the inbye land.

8.17 The majority (95%) of England’s blanket bog resource is uncultivated and is used primarily for sheep grazing and grouse shooting; land uses which may be accompanied by moorland drainage to produce more heather and provide better grazing. The drained peat has become degraded through oxidation[17] and the loss of peat-forming sphagnum has resulted in the degradation of a major carbon sink.[18] Restoration of water levels is effective in reducing peat degradation and enhancing biodiversity.[19] Often such a programme is carried out in conjunction with a reduction in grazing. See chapter on ‘Drainage and burning management on moorlands’.

8.18 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

8.19 Upland livestock production is the means by which some upland habitats, now highly valued, have been created and maintained, for example upland hay meadows. Hay production led to the development of a grassland type rich in plant species, of which some notable examples remain. These are dependent on a low soil nutrient status, and on cutting dates considerably later than intensive lowland grasslands. To a large extent, where these conditions have been maintained, it has been by traditional upland livestock management systems. Silage production has been behind much of the loss of botanically diverse upland meadows.

8.20 Much of the subsequent degradation of habitats such as heather moorland has been due to suppression, by grazing, of the heather, herbs and other dwarf shrubs, which have been replaced by more resilient grasses.

8.21 The degradation of upland heather habitats (blanket bog and dry heath), which accelerated from the late 1970s into the 1990s, has been directly linked to an increase in livestock numbers, largely stemming from CAP headage support.

8.22 Reductions in grazing in upland areas have been achieved through agri-environment schemes, the enforcement of Cross Compliance requirements, the removal of headage payments and poor returns on livestock products; these factors have contributed to some areas becoming undergrazed. Habitat recovery has been varied, depending on the degree of degradation and the alternative management introduced.

8.23 Bracken encroachment has been blamed both on overgrazing and on undergrazing in the uplands. There is little evidence to support either claim.

Resource protection

8.24 Upland soils can be fragile and relatively easily mobilised. Grazing and treading by high numbers of livestock have been implicated in the erosion of peat and other upland soils.

8.25 Moorland gripping, when combined with grazing, has had a number of serious negative impacts: the resulting destabilised soil has increased the sediment loads and colouration in water running off moorlands. It has been blamed for the increased risk of flash flooding due to diminished water retention, and the resulting desiccation of peat bogs has led to an increase in carbon emissions.

8.26 Pressure of grazing is closely related to erosion of upland soils, both in extent and volume.

Greenhouse gases

8.27 Drainage to improve grazing on peat moorland has resulted in large areas of degrading peat, turning a small carbon sink into a potentially major carbon source.

Landscape

8.28 Upland pastoral agriculture is a major means of maintaining upland landscapes as we know them.

Annex I Current incentives, advice and regulation for upland grazing managers

There are a number of statutory controls relating to grazing. These mostly proscribe allowing undesirable change to semi-natural vegetation due to excessive grazing and are linked to farm payment and incentive schemes. Grazing on some designated sites and sites under agri-environment agreement may be carefully controlled to allow specific types of habitat to generate or regenerate:

- *Wildlife and Countryside Act*[20] *and Countryside and Rights of Way Act*[21]: provides for owner/occupiers to be notified of operations that need consent. Introduction or a change in grazing levels would require consent.
- *Cross Compliance - GAEC 9*:[22] protection of semi-natural vegetation from overgrazing and unsuitable supplementary feeding. This is a requirement of the Single Payment Scheme.
- Standards of Good Farming Practice: these apply to holdings with land under agri-environment schemes.

Management incentives

For reduction of grazing livestock numbers (principally sheep) include:

- Environmentally Sensitive Areas (ESA)
- Wildlife Enhancement Schemes (WES)
- Sheep WES
- Countryside Stewardship
- Environmental Stewardship.

For maintaining cattle:

- ES cattle supplements.
- Marketing initiatives (for example: Limestone Country project).

Annex II Impacts of upland livestock production on environmental sustainability

Table 10 Impacts of upland livestock production on environmental sustainability

Habitat quality and diversity	• Grazing has a direct effect on habitats though defoliation, trampling and deposition of dung and urine. Historically, large numbers and areas of upland SSSI have been brought into unfavourable condition through excessive levels or inappropriate timing of grazing. Currently, nearly 42,000 ha of upland SSSI habitats are in unfavourable condition due to inappropriate grazing levels.[23] • Winter foddering on upland grasslands and moorland leads to areas of nutrient enrichment, poaching and localised overgrazing.[24] • Grazing has been used in many areas as a tool for maintaining or restoring habitats.[25] This requires careful management and monitoring. • Lower stocking rates associated with ESA prescriptions for the management of semi-natural rough grazing have maintained existing heather (*Calluna vulgaris*), but have not prevented localised over-grazing and concomitant under-grazing of less desirable species.[26] • Where habitat is heavily degraded by overgrazing, reduction in grazing may result in an increase in aggressive, undesirable species.[27] Habitats which have been created (directly or indirectly) by, and are maintained due to upland livestock enterprises are: • Upland hay meadows (developed through management for hay).[28] • Upland calcareous grasslands (appropriate grazing maintains desired sward heights).[29] Upland SSSI habitats which are threatened by inappropriate livestock management: • Dwarf shrub heath - 12,069 ha overgrazing, 607 ha undergrazing.[30] • Blanket bog - 22,042 ha overgrazing, 765 ha undergrazing.[31] • Fens marsh and swamp - 174 ha overgrazing, 74 ha undergrazing.[32]

Table continued...

Species abundance and diversity	Key upland species which have benefited from grazing livestock include: • Golden plover (short vegetation within heather moorland and blanket bog, created by grazing or burning, for nesting and enclosed grazed pastures for foraging).[33] • Heather (*Calluna*) (appropriate stocking discourages scrub development, and keeps grasses in check).[34] Species which have been adversely affected include: • Salmon (soil deposition in rivers affects redding sites).[35] • Black grouse (excessive grazing of traditional feeding and nesting sites).[36]
Water level control	• Soil compaction caused by treading reduces water infiltration, and therefore may increase surface flow, increasing risk of flooding downstream.[37]
Sediment loads in water	• Where grazing exposes or destabilises soil, it becomes prone to runoff, erosion and transfer of nutrients to watercourses.[38] • A large amount of moorland drainage was carried out to 'improve' productivity for grazing. This has predisposed extensive areas to serious erosion, with associated high sediment loads.[39] • There is a high cost to the water industry of sediment and colouration removal, due to erosion. A proportion of this is due to the effects of erosion caused by livestock.[40]
Nutrient loads in water	• Nutrification of water from upland agriculture is generally low,[41] reflecting the prevalence of less intensive production systems.
Pesticide control in water	• Sheep dip is potentially a major pollutant of water. See Sheep Dip Case Study for more information.
Other pollutants	• Water quality may be affected directly through introduction of bacteria such as *Cryptosporidium* and *Giardia*, generally via the faeces of grazing livestock.[42] This is a particular issue with cattle.
Greenhouse gases	• Grazing can affect air quality through direct emissions of methane from grazing ruminants, and emissions of ammonium and nitrous oxide from dung and urine. Low densities of livestock on extensive grazings means little impact from methane per hectare, particularly where storage of slurries is avoided.[43] • The draining and drying out of peat bogs has resulted in the oxidation of organic matter, and release of stored carbon.[44]

Table continued...

Soil stability (erosion)	• Grazing affects soils through physical compaction or erosion associated with trampling. This is usually associated with exposure and/or destabilisation resulting from removal of vegetation, and physical disturbance from hooves, or scraping/rubbing.[45] • Gripping to 'improve' moorland productivity through drainage has resulted in high levels of peat erosion.[46]
Soil function	• Soil can be affected chemically and biologically by deposition of organic matter and nutrients through dung and urine, and through the effect on vegetation, which can change plant litter inputs, soil microbiota and the temperature regime.[47] • Outwintering and feeding livestock can have a damaging effect on soil structure, particularly where treading has led to deep mud.[48]
Landscape character	• Landscape scale structures (walls, barns) enable the management of the grazing livestock. A large proportion of the upland areas of England owe their appearance to their use for rearing grazing livestock. This appearance may change over decades, but it is recognised as being highly characteristic of many upland National Character Areas.[49] • Reduction of grazing in the uplands has given rise to fears that historic features may become obscured or destroyed by root growth of scrub species. There is currently little evidence to support this scenario.

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Case study: Sheep dip

Sheep are prone to parasitism from a number of ectoparasites, several of which are capable of carrying potentially lethal diseases, or are a direct cause of serious welfare problems.

Failure to treat sheep against scab mites, ticks, lice and biting flies can encourage disease such as louping ill (which also affects grouse), loss of condition and death. Most sheep owners treat stock prophylactically. On some holdings where ticks are a major problem (particularly moorlands), dipping may take place four or more times during the summer and autumn. In recent years there has been no statutory obligation to dip sheep against scab mites, but flock managers have recognised the welfare benefits to their stock, and the majority of flock owners still dip their flocks.

Historically, there have been a number of ways of dealing with sheep ectoparasites, such as washing, tarring, spraying, injections, and dipping. The simplest effective method of controlling the majority of skin parasites is dipping, largely because the dip penetrates the natural water-repellent barrier created by wool, and has a relatively long period of residual activity. Treatment by dipping is also the most effective treatment against all major ectoparasites. Systemic treatments such as injection or pour-ons, whilst having the benefit of reduced risk to water quality, are not effective across such a broad spectrum.

In the past, use of sheep dip has had a direct effect on watercourse quality, not only in areas where sheep are produced, but also in areas where wool is processed, where dip residues on the wool fibres could be washed out and released into watercourses.[1]

Release of sheep dip into watercourses, either via dipped sheep, or poor disposal of spent dip has caused substantial environmental harm, due to its high level of toxicity, which can affect considerable lengths of watercourse, and sometimes substantial parts of a catchment.[2] In 2005, there were nine Category 1 (the most severe) pollution incidents involving sheep dip.

Problems caused by sheep parasiticide treatments can be categorised into three broad areas:

- Those which harm humans who are involved in the dipping/treatment process, or who come into close contact.
- Those causing environmental damage to aquatic invertebrates caused by dip products entering watercourses.
- Those causing mortality in soil-dwelling invertebrates which process or use sheep dung which has been affected by systemic products or through direct disposal of spent sheep-dip to land.

In 2006, the National Farmers Union launched its Stop every Drop[3] campaign to raise awareness of the potential pollution dangers associated with sheep dipping, and to promote best practice. This was supported by the Environment Agency and the Veterinary Medicines Directorate. Also in 2006, licenses permitting the sale of cypermethrin-based dips were suspended. In that year there was only one Category 1 incident involving sheep dip.

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9 Drainage and burning management on moorlands

Context

9.1 Moorland is a cultural landscape that is at least partly anthropogenic in origin as a result of forest clearance and grazing. It is also a product of the climate and underlying soils and geology. Open moorland landscape is typical and characteristic in upland England. It covers a variety of different habitats and soils - including blanket bogs, heaths, grasslands and rocky outcrops. These can frequently occur together in a mosaic but their management requirements and the impacts of management will be widely different. Approximately 773,000 ha of land in England are currently within the Moorland Line, which comprises "*Land with predominantly semi-natural upland vegetation, or comprised predominantly of rock outcrops and semi-natural upland vegetation, used primarily for rough grazing; including enclosed land such as allotments, ffridd or reverted in-bye.*"[1]

9.2 Past land management practices undertaken on moorlands have been dominated by drainage to reduce or remove waterlogged conditions, with the intention of increasing 'productive' vegetation. This was carried out with the intention of increasing livestock production as well as of improving conditions for grouse. Burning is a major habitat management tool on many moorlands, contributing to the value of the area in terms of grouse production, and in terms of its distinctive landscape.

9.3 The major socio-economic activities on moorland in England are: livestock production; game shooting (mainly for red grouse); recreation and tourism. Moorlands are also important areas for the supply of drinking water and increasingly identified for the generation of wind energy. In the future, the ability of certain soils and vegetation types to store carbon may also have an economic value.[2] In the past, drainage was also carried out on moorlands for the establishment of forestry stands and improved grazing. This practice has been discontinued.

9.4 Grouse moor management is a substantial source of income to some areas of the uplands: estimated net income on grouse moors from shooting is approximately £67/ha - not taking into account likely income to service industries in the area. Nationally this is worth £12 million.[3] Sheep grazed at a low level (one ewe per hectare) on a similar area might be expected to yield a net income of around £25/ha, excluding any agri-environment payment.[4] Research has shown that lower stocking rates (down to 0.25 ewes per ha) could be more profitable.[5]

9.5 Around 80,000 ha[6] of moorland SSSI is classified as being in unfavourable condition as a result of burning. Approximately 10,000 ha of SSSI moorland is in unfavourable condition due to inappropriate drainage. There are approximately 283,000 ha of moorland managed for grouse in England,[7] of which 180,000 ha are SSSI.[8]

Current practice

9.6 Active drainage ('gripping') of moorland areas is now a relatively minor activity. Whilst some grips are maintained (for example in the north Pennines), more conservation effort is being put into grip blocking, to prevent erosion, to prevent degeneration of peat, and to restore upland wetland habitats. Burning is carried out to improve palatability of the vegetation for grouse and livestock, and to provide a variety of heather age and structure for red grouse to feed, nest and shelter. Grazing by livestock and game species is the third key management activity. This is discussed in more detail in the chapter on 'Grazing management in the uplands'.

Heather and grass burning trends and pressures

9.7 Adequate areas of heather which have been burnt and have regenerated are vital to grouse management. Without large areas of fresh growth and cover in which to nest, the grouse will not be productive enough to warrant driven shooting.[9] Burning of heather moorland is predominantly carried out to provide a mixture of heather ages and structure for supporting grouse for game shooting - young shoots for feeding and deep heather for nesting cover and shelter. The frequency and extent of heather burns nationally is currently being researched using satellite imagery. Current research shows that approximately 23% of upland heath and 11% of bog in England has been burnt within the last 7.7 years.[10] This can be extrapolated to approximately 114 km^2 of dwarf shrub heath burnt annually, with the average period between burns on all such habitat at 20 years.[11]

9.8 Other vegetation, for example coarse grasses such as Purple Moor Grass, is burnt by moorland managers to remove litter and encourage fresh growth for grazing livestock.[12] This can increase the dominance of the coarse grasses in the long term, especially if the burns are hot and if the ground is burnt frequently.[13] The area covered by this activity is being researched but is not yet known.[14] The legal period for burning vegetation in the uplands is 1 October - 15 April. Within this period, gamekeepers and livestock managers burn heather and grass as part of the management of the moor. In addition to the legal burning season, the Regulations also prohibit various types of burning which may create a high risk of soil exposure and erosion.

Moorland drainage trends and pressures

9.9 The digging of drainage channels (grips) in upland peat in an attempt to dry out the land is now uncommon, but government grants from the 1950s to the 1980s provided funding for the use of grip-producing machinery on a large scale.[15] There are no accurate figures for the full extent of moorland gripping in England, although regional data taken from aerial photographs of upland areas in England and Wales indicate that over 50% of the land had been drained in some areas. Approximately 1.5 million hectares of upland blanket peatland have been drained since the 1930s.[16] It has been estimated that within the North Pennines AONB there are 9300 km of grips.[17]

9.10 There is little evidence that gripping was of much value agriculturally and it is seldom carried out today. Current practice is largely centred on the blocking of grips, to recreate wet areas and to control soil erosion by rewetting peatlands and restoring vegetation.

9.11 Currently, a number of important projects are under way throughout England and the rest of the UK to block existing grips, to restore the soil wetness and create conditions to allow peat forming species to thrive and return to a situation which captures and stores carbon. In some very degraded areas significant restoration activities have been required, including grip blocking at a landscape scale, along with stabilisation and re-seeding of bare soils, for example the Sustainable Catchment Management Programme.[18]

9.12 For current incentives, advice and regulation for moorland managers, see Annex I to this chapter.

Key impacts

9.13 Moorland habitats are varied and will be impacted differently by management. There are strong links between different economic activities, with some land management practices impacting on others. For example, management for grouse will also affect grazing use of the moor by livestock, and both have an effect on water quality.

9.14 Unless carefully managed, drainage, burning and grazing on moorland areas can all reduce the diversity of the vegetation and the associated fauna, although in different ways. Drainage and burning may affect *Sphagnum* communities, and these activities can also allow heather to dominate at the expense of other species.[19] Grazing can suppress dwarf shrub cover, allowing coarse grasses to predominate where heather stands become fragmented. Research suggests that where heather is restored from grass-dominated moorland, there can be an increase in invertebrate abundance and diversity.[20] Changes in bird populations may result, but these are also closely linked to other moorland management practices such as predator control.[21]

9.15 Recently, there has been considerable concern that the gripping and burning management of peat moorlands has contributed to large-scale degradation and drying of peatlands.[22] The drier conditions have led to the loss of peat forming plant species such as *Sphagnum* mosses. Where the peat surface is exposed, such as through excessively hot burns, desiccation and erosion can result, with associated water sediment and colouration problems. Research has shown a correlation between an increased frequency of soil piping within peat soils on peatland with grips and on areas dominated by heather. This produces more rapid subsurface erosion and carbon loss.[23] Where grips have been blocked, there is some evidence that this slows water release into the catchment. Depending on where this occurs, it can mitigate flooding further downstream.[24]

9.16 The cost of removal of peat colouration from water for domestic use is currently borne by water companies and, ultimately, consumers.[25] Drainage can also cause direct damage to archaeological sites and can alter the hydrology leading to a loss of peat and palaeological deposits.[26]

9.17 Peat oxidation and the consequent release of carbon to the atmosphere has been strongly associated with moorland gripping. As peat dries out, so it is able to decompose; this releases CO_2. There have been estimates of carbon losses of 3-10 t C/ha per year where peat has been drained.[27] The blocking of grips is a necessary and critical precursor of restoring the hydrology and functioning of these peatland systems.[28] Grip blocking is effective in rewetting peat soils in the long term, although it is calculated that there is some time lag before the peat reverts from greenhouse gas source to greenhouse gas sink, and the rewetting can result in increased methane emissions.[29]

9.18 Extensive grazing, cool, managed burns on longer rotations, limited or no burning on blanket peats and a reversal in the drainage of moorland areas can lead to landscapes which are richer in biodiversity.[30] They can also make a significant contribution to better water quality,[31] and climate change mitigation.

9.19 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

9.20 Drainage and burning both have high potential for impact on biodiversity, either as individual activities or in combination.

9.21 Burning alters the vegetation composition and structure of moorland habitats and, where intensive, can significantly reduce biodiversity interest and species diversity. Where associated with drainage on peat, it can remove peat forming vegetation and prevent further accumulation of peat.

9.22 A variety of vegetation species and structure favours a wider range of invertebrates, birds, mammals and reptiles and amphibians. Sustainable burning of heather on mineral soils can increase plant species diversity, providing the burning regimes are not intensive. Where intensity is not severe, it is also associated with creation of patches which are favoured by some Biodiversity Action Plan (BAP) priority species, for example golden plover and curlew. Management for red grouse can lead to significantly improved chances of having black grouse, and some species of breeding waders on the moor[32], though current evidence does not differentiate between the effects of habitat management and predator control.

9.23 An increase in the frequency or intensity (temperature) of the burn is likely to result in greater negative impacts on biodiversity. Where there are large-scale fires and hot temperatures, all vegetation can be destroyed, soils (especially peat soils) can be badly damaged and animal life may be affected.

9.24 Burning carried out in March and April has the potential to destroy nests and nesting birds, even during the legal burning period.

9.25 Drainage of moorland, especially blanket bog, has significant impacts on the biodiversity through altering hydrology, reducing soil wetness and, consequently, vegetation composition and structure. These impacts can be exacerbated by burning and inappropriate grazing.

Resource protection

9.26 Peat soils can be destabilised through drainage and burning. Exposed peat soils can be broken down, contributing to colouration and sediment in the water run-off.

9.27 Poorly functioning blanket bogs and peats lose their ability to hold up water within the catchment. Where little or no vegetation is present, there is also little impediment to surface water flows following periods of rain. These surface flows can be significant.

9.28 Managed burning along with other fire prevention measures can reduce wildfire risk (through, for example, fuel load reduction), potentially minimising the damage caused by very hot burns. Whilst burning over peat soils carries a relatively high risk, increasing soil wetness and reduction of heather cover on peat soils can reduce wildfire risk.

Greenhouse gases

9.29 Moorland drainage (or ‘gripping’) at regular intervals dries out peat soils allowing oxidation, which releases large quantities of stored carbon in the form of CO_2, potentially turning a substantial carbon sink into a major carbon emitter. The drying of the peat is unsuitable for the survival of peat forming species, most notably *Sphagnum* mosses, which need waterlogged conditions. The loss of Sphagnum mosses therefore reduces the carbon storage function of peats.

Landscape and recreation

9.30 Regular burning (in combination with grazing) creates or maintains spatial, compositional and structural diversity of the open heathland element of our upland landscape.

9.31 Drainage and burning affects both landscape (through removal of trees and scrub) and the recreational use of that resource.

9.32 When burning and drainage activities impact on peat they can also cause the loss of historic information such as the pollen record (sometimes going back thousands of years) and archaeological remains that are preserved either above or below the soil surface.

Annex I Current incentives, advice and regulation
Management incentives

- There are capital grants to aid grip blocking where rewetting is considered favourable to enhance agri-environment objectives such as biodiversity and the historic environment.
- Similarly, agri-environment payments can be made to fund burning management where it is considered of benefit, particularly for biodiversity or the historic environment. This requires the production of burning plans, which may also identify areas to be excluded from burning management.
- Graziers on grouse moors can benefit from payments under the Single Payment Scheme, and from Hill Farm Allowance and Upland Entry Level Stewardship. Moorland owners can be recipients of Entry Level Stewardship, Higher Level Stewardship and Wildlife Enhancement Scheme payments.
- Agri-environment payments may also be available to fund other restoration works such as soil/peat stabilisation and revegetation.

Regulatory

- *Heather and Grass etc (Burning) Regulations 2007 (No.2003):* primary legislation governing moorland burning. The Heather and Grass Burning Code[33] (which is voluntary) outlines good practice on planning where to burn and how to burn safely and responsibly.
- *Wildlife and Countryside Act 1981*: moorland burning and drainage on SSSIs requires consent from Natural England.
- *Wildlife and Countryside Act 1981, and Conservation (Natural Habitats etc.) Regulations 1994*: regulate against destruction of protected animals, plants and habitats.
- *Ancient Monuments and Archaeological Areas Act 1979*: Scheduled Monuments must not be damaged by burning activities.
- *Highways Act 1980*: burning must not cause interruption or danger to road users.
- *Health and Safety at Work etc. Act 1974, and Management of Health and Safety at Work Regulations*: burning operations must not endanger anyone, including the public.
- *Environmental Protection Act 1990*: smoke emissions must not cause a nuisance, or be prejudicial to health.
- *Cross Compliance - GAEC 9* conditions,[34] in particular those relating to soil protection may be applicable.

Annex II Impacts of moorland habitat management on environmental sustainability

Table 11 Impacts of moorland habitat management on environmental sustainability

Habitat quality and diversity	• Routine burning reduces the botanical diversity of the moorland being burned. Regular burning can particularly favour heather and Purple Moor Grass over other species such as *Sphagnum* mosses and woody species. For Red Grouse, the purpose is to maintain a heather dominated moorland, while burning for grazing livestock - previously practised on a much larger scale, can lead to a grass dominated landscape.[35] • Burns that become uncontrolled covering large areas increase habitat homogeneity, by reducing age diversity in the heather. They may also burn into non-target areas, such as bracken, affecting the breeding habitat of such Red-list birds as Twite, Ring Ouzel, Whinchat and Merlin.
Species abundance and diversity	• Some species of bryophytes are thought to be uncommon as a result of their sensitivity to burning, for example *Sphagnum fuscum*.[36] • Burning on moorland is permitted at a time when potentially substantial numbers of ground-nesting birds may already be nesting, for example golden plover, hen harrier, redshank, short-eared owl.[37] • Insects that normally thrive in pools and boggy wet ground, can no longer survive when these are affected by drainage schemes. This has had a consequent impact up the food chain on birds and small mammals that feed on these insects.[38] • Data suggests that the habitat conditions created by blocking grips can be of high value to grouse chicks and upland wader populations by providing an important invertebrate food source.[39] • A wide variety of different moorland habitats and vegetation structure has been shown to favour a greater range of birds and invertebrates.[40]
Water level control	• Draining has been shown to increase the sensitivity of blanket bog to rainfall with earlier and higher peak flow rates per unit.[41] • Some research suggests that selective grip blocking can reduce some flood risk but in some places can increase it, depending on which grips are blocked and the balance between connectivity and storage.[42,43]

Table continued...

Sediment load in water	•	Where burns have removed too much surface vegetation, or where they have been carried out on steep ground, there is a high risk of erosion.[44] • Artificial drainage of moorland can generate large quantities of eroded material (up to 5.8 × 10^3 kg carbon per km^2 in addition to any erosion related to the ditch channel incision).[45] • There is some evidence that changes in wind velocity over the moorland following burning plays a role in soil erosion.[46]
Pesticide control in water	•	Bracken spraying on moorland using Asulam has been closely controlled by the Environment Agency, due to the high risk of spray residues entering watercourses. The use of Asulam in this context is currently under review.
Other pollutants	•	Eroded peat can cause discoloration of water, the removal of which is a major cost to the water utilities. One water utility has estimated that a catchment management programme to address moorland erosion, largely caused by inappropriate drainage and peat degradation, would reduce water colouration to acceptable standards, saving approximately £800,000 p.a.[47]
Greenhouse gases	•	Recent research has shown that the proportion of exposed peat surface resulting from new heather burning was consistently identified as the most significant predictor of variation Dissolved Organic Carbon concentration.[48] • Over half the carbon within *Calluna* which is burnt is lost into the atmosphere.[49] • Active peat moorland (fully vegetated) can sequester carbon at rates between 0.2 and 0.7 t C/year.[50] • Degraded peat, and peat which is drying out, becomes mineralised, and is a major source of carbon released into the atmosphere (up to 100 t C/km^2 per year in the Peak District).[51]
Soil stability (erosion)	•	Burning of gullies leads to a high risk of formation of erosion features.[52] • Burning is closely associated with erosion of peat soils, in particular through the exposure of burnt areas to the atmosphere and rainfall.[53,54] • Gripping is directly related to high levels of peat and mineral soil erosion in the uplands. In some areas this has led to substantial loss or destabilisation of peat 'caps'.
Soil structure	•	Increases in the numbers of sub-soil pipes has been associated with gripping, with these contributing to the loss of particulate organic matter. The older the grips, the greater the number of soil pipes.[55]

Table continued...

Landscape character	• Controlled burning leaves a very obvious and recognisable signature on the landscape. • Grips form an obvious feature in the landscape, particularly when they have been dug in the standard ‘herring-bone’ fashion spaced at 22 m intervals. • Archaeological evidence within the peat such as pollen records and other carbon-based material can be destroyed where desiccation and erosion take place.[56] • The construction of tracks to aid moorland management can have significant impacts, not just on biodiversity, but also have a detrimental impact on wild moorland landscapes.[57] They may also open up access to sensitive parts of the moor, possibly increasing fire risk.

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Case study: Bracken

Bracken is seen by most land managers as an invasive weed. In fact it can be an important habitat, and has become a strong landscape component in some areas (such as the Lake District), particularly for its colour as it dies back in the autumn and early winter.

Originally bracken was a predominantly woodland species,[1] but in England it has become a vigorous and invasive competitor on uncultivated ground. It can have strong negative impacts where it encroaches on vegetation such as semi-natural grasslands and heathlands. Its rhizomes can also disrupt below-ground archaeological deposits, and obscure sites.[2]

Bracken also has some biodiversity value: the high brown fritillary,[3] and the pearl-bordered fritillary,[4] use bracken litter for overwintering their eggs; both are Biodiversity Action Plan priority species. It is also an important habitat for ground-nesting Twite, Ring Ouzel, Whinchat and Merlin, four Red-listed birds of conservation concern, and BAP priority species.

Where bracken grows in dense beds, it smothers ground vegetation, and forms a deep litter layer, which is not populated by other plant species. It is toxic to livestock: cattle can develop internal haemorrhaging, associated with bone-marrow damage,[5] and is not usually grazed. Key livestock impacts on it are: increase of extent by suppressing other vegetation (through grazing), or decrease of extent by trampling and exposing the rhizomes to frost - this is generally only effective in small areas such as feeding sites, where the effect can be concentrated. There is no conclusive research to show that reduction of grazing pressure causes an increase in bracken spread, despite common belief.

The Countryside Survey in 2007 indicates that between 1998 and 2007 there was a reduction in bracken 'broad habitat' cover in Great Britain, from 318,000 ha to 263,000 ha. This does not necessarily reflect eradication of bracken over 55,000 ha - rather a change in the overall bracken cover in that area.[6]

Land managers are often keen to treat bracken . Its invasive habit means it can hinder heather growth and thus reduce grouse habitat, it can reduce the area available for grazing, and it can make good habitat for ticks, providing a potential reservoir of Lyme disease, and Louping Ill. Most treatments involve spraying with asulam or glyphosate, with follow-up treatments, though there is some evidence that regular cutting (twice a year) is effective.[7] Spray treatment is relatively expensive (up to £280/ ha),[8] and involves vigilance in subsequent years - requiring regular follow-up treatments. It is now likely that Asulam will be withdrawn from the market for use on bracken, removing a key tool in its control.

The regeneration of vegetation after bracken eradication can be problematic, particularly where there is a deep litter layer. Here the soil is unstable, and the establishment of other vegetation may take some years. In the intervening period it is prone to erosion, and has little habitat value.

A number of small enterprises have been set up to compost harvested bracken for use as a garden soil conditioner, potentially replacing the unsustainable use of peat.[9]

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10 Management for lowland gamebirds

Context

10.1 It has been estimated that approximately 500,000 people shoot live quarry in the UK, the majority of which involves gamebirds (including grouse in the uplands) or other bird quarry species.[1] Many in the game industry consider that management for sport shooting provides a substantial contribution to conservation management, although this may depend on the activity in question.

10.2 In lowland England gamebird shooting involves mainly three species (grey partridge, red-legged partridge and pheasant). Red-legged partridge and pheasant are non-native species, and are typically reared and released in large numbers. This is often associated with specific management activities aimed at supporting the resulting high populations.

10.3 It is estimated that shooting influences land management activity over approximately 9 million hectares in England (upland and lowland).[2] Active management of habitats and wildlife, primarily to provide gamebird shooting is carried out over around 1.2 million hectares.[3] Wildfowling clubs manage approximately 105,000 ha of foreshore, marsh and wetland for shooting in the UK, of which 90% coincides with SSSIs.[4]

Current practice

10.4 Various estimates suggest that between 20 and 30 million gamebirds are reared and released in the UK each year (the majority in England), some 60% of which are imported as eggs or chicks. Birds shot in the lowlands comprise approximately 80% pheasants and approximately 14% red-legged partridges.[5]

10.5 Non-gamebird quarry species (mainly ducks, waders and geese), are also shot for sport, and some species are shot as agricultural pests, notably the woodpigeon.

10.6 Wildfowling often involves the shooting of birds from wild populations rather than being based on rear and release. However, the ranges of certain species, including the non-native Canada goose and the native greylag goose have been deliberately extended for the purpose of providing stock for shooting, and large numbers of mallard are reared and released for shooting each year.[6]

10.7 Much land management undertaken for gamebirds is associated with driven shooting where high densities of birds are required in order to provide adequate sport. In contrast, rough shooting involves the ‘walked-up’ shooting of small numbers of a range of different game species. It can still require habitat management to maintain viable numbers of quarry species. Wood pigeon can only be shot under the terms of the relevant Natural England general licence - it isn’t legal quarry. Shooting wood pigeons therefore has to be associated with land management measures, such as preventing serious damage to crops, for it to be legal, and only once other satisfactory (non-lethal) solutions have been shown to be ineffective.

10.8 The specialised land management practices carried out to enhance red grouse populations for shooting on upland moorland, including burning, are covered in a separate chapter ‘Drainage and burning management on moorlands’.

Industry trends and pressures

10.9 Game shooting and wildfowling are traditional activities and have influenced the nature of the English landscape for hundreds of years. Game shooting has increased markedly in popularity from the Victorian era, with an associated increase in the intensity of management and hence greater potential for influencing landscape and biodiversity.[7]

10.10 Historically, gamebirds and waterfowl were shot primarily to provide food for the table, particularly in poor rural areas. Now, this activity is undertaken mainly as a sport or hobby, although most of the edible birds shot are retained or sold for human consumption. To ensure that sufficient birds are available for shooting, the wild stock is often supplemented by birds reared on the shoot and then released into the wild. This is especially the case for driven game shooting where large numbers of birds are flushed over lines of guns. Wildfowling and rough shooting generally involve the shooting of only small numbers of birds, and the attraction of the pastime is often as much about spending time in the countryside as it is about hunting birds.

10.11 The leasing of shooting rights is considered a viable source of income for many landowners. It has been calculated that the full-time equivalent of 49,000 people work on activities directly related to shooting (620,000 individuals are estimated to be involved).[8] In 2004, approximately £850 million was spent providing sporting shooting,[9] although these figures include pest control, deer stalking, target shooting and clay pigeon shooting, in addition to the shooting of birds for sport. It is estimated by the industry that £250 million per year is spent on management activities that provide benefits for conservation - equivalent to 2.6 million work days.[10]

10.12 Lower intensity shooting, including wildfowling and rough shooting, has little commercial value except potentially where pest control is involved.

10.13 For current incentives, advice and regulation for lowland gamebird management, see Annex I to this chapter.

Key impacts

10.14 In general terms, sport shooting in the lowlands has had a positive effect on the landscape. Many hedgerows, field margins[11] and small woodlands[12] are maintained more for their sporting value than for their biodiversity interest, although the practice can be beneficial in both aspects. Many land managers with shooting interests plant small areas of game cover to provide food and shelter for partridges and pheasant. These crops provide a useful food source for farmland birds such as sparrows, finches and buntings when winter cropping regimes may have reduced other feeding opportunities.[13]

10.15 In many cases woodlands are beneficially managed and maintained to support the shooting interest. This can have influence the structure of the woodland habitat. Woodlands used for gamebird rearing tend to have a more open aspect,[14] which can benefit other woodland species such as ground flora, birds and invertebrates. Where excessive ground feeding is practised, the natural ground flora can be adversely affected through increased nutrification, disturbance and the introduction of non-woodland species.[15]

10.16 The maintenance of hedgerows and field margins for gamebird provides buffer zones to mitigate surface water, sediment and nutrient flow,[16] but also benefits birds and other wildlife through the provision of food, shelter and nesting sites.[17]

10.17 There is little published evidence that quantifies the effect on native species of releasing such large numbers of non-native gamebirds into the wild on an annual basis. Whilst artificial food sources provided for gamebirds may benefit some native farmland birds, competition for natural food is thought likely to be detrimental to many species. There is a lack of published research on this topic.

10.18 Control of common predators, such as foxes, mustelids and corvids, and of rats has been shown to be beneficial to some other ground nesting birds.[18] The control of rats with highly toxic modern rodenticides can lead to accidental secondary poisoning of birds of prey and predatory/scavenging mammals.[19]

10.19 Raptors can benefit from shoots, in that there is generally a source of birds which have died after being winged, and a high mortality of reared game chicks, which can provide a food source, particularly for scavengers like the red kite and buzzard. This can have a harmful side-effect in that a number of dead kites have been found with high lead levels, due to the ingestion of lead shot.[20] Instances have also been recorded of wading birds, and game birds being adversely affected by lead shot ingestion.[21]

10.20 Shooting on, or adjacent to, wetland sites supporting concentrations of waterbirds can result in disturbance which causes birds to expend extra energy in making escape flights and reduces the time available for feeding. This can reduce survival rates, particularly if disturbance events are frequent and birds are in poor condition, for example during a period of severe winter weather.[22] [23]

10.21 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

10.22 A number of lowland habitats have been preserved and enhanced in order to provide suitable conditions for gamebirds and quarry species. This can also provide valuable habitats for species of conservation concern, a wide range of wildlife, including species of conservation concern such as farmland birds.

10.23 Some semi-natural habitats can be damaged by operations associated with game rearing such as the inappropriate siting of release pens.

10.24 Whilst many raptor populations have increased in recent decades, the illegal persecution of birds of prey is still a problem in some areas. Birds of prey may also be adversely affected by secondary poisoning from the lead used in shotgun cartridges and from highly toxic modern rodenticides.

10.25 Disturbance to waterbird concentrations by shooting and other recreational activities is a concern on some designated sites.

Landscape

10.26 Many areas of wildlife habitat on farmland have been preserved by land managers because of their value for sporting activities. This is likely to have had a considerable effect in maintaining landscapes and non-game species.

10.27 Shooting is a legitimate reason for limiting access on some land.

Annex I Current incentives, advice and regulation

- The firearms required for shooting are subject to controls overseen by the police and have become tighter in recent years. A shotgun certificate is required in order to own and use a shotgun for shooting gamebirds and other quarry. The use of firearms for shooting is controlled by the Firearms Act 1968[24]
- The requirement to hold a game licence to kill or take game and the requirement for a local authority licence and an excise licence in order to deal in game were removed by the Regulatory Reform (Game) Order on 1 August 2007 [25].
- The shooting of gamebirds and other quarry species is restricted to open seasons as set out by the *1831 Game Act*[26] (and related legislation) and the *Wildlife and Countryside Act (1981).*[27]
- *The Wildlife and Countryside Act (Part 1)* prohibits the intentional killing of wild birds and the use of certain methods of control. The shooting of some 'pest species', such as woodpigeon and magpie, is authorised year-round through a system of general licences issued by Natural England.
- It is illegal to use lead shot when shooting over SSSI land (the Environmental Protection (Restriction on the use of lead shot) (England) Regulations 1999).
- Regulations have recently been introduced to allow the imposition of movement restrictions on birds should this prove necessary to prevent the spread of diseases such as avian influenza. It is possible that this could impact on the importing of gamebird chicks for rearing and release in future.
- Natural England consent is required in order to carry out shooting and many of the associated management activities on designated sites. It may be refused where it could result in adverse impacts on the interest features of the site. For example, through excessive disturbance to waterbird concentrations or damage to woodland vegetation.
- A number of organisations provide a considerable quantity of advice for shooting interests. For example, the British Association for Shooting and Conservation; the Game & Wildlife Conservation Trust; and the Countryside Alliance. The Code of Good Shooting Practice[28] is a voluntary code overseen by a steering committee comprising representatives of all the major shooting organisations. The code sets out a framework for sustainable shooting.

Annex II Impacts on environmental sustainability of management for lowland game birds

Table 12 Impacts on environmental sustainability of managing for lowland game birds

Habitat quality and diversity	• Typical habitats actively provided or managed by lowland shooting interests:[29] ◦ Conservation headlands ◦ Hedgerows ◦ Stubbles/cover crops ◦ Beetle banks ◦ Woodlands ◦ Flight ponds ◦ River banks. • Lowland farmland is often managed to encourage gamebirds, including the maintenance of hedgerows, unsprayed field margins and headlands, game cover-crops and seed-bearing crop mixtures.[30] • There is some evidence that woodland structure in woods managed for pheasant shooting in England is more open, with a denser field layer and is able to support higher breeding densities of some bird groups, for example, certain warblers.[31] • The siting of pheasant release pens in ancient/semi-natural woodland of high conservation value, including woodland SSSIs, can result in damage to ground flora.[32]

Table continued...

Species abundance and diversity	• The control of generalist predators such as corvids, foxes and stoats by gamekeepers can result in increased breeding success for some species of ground nesting birds of conservation value.[33] • The maintenance of semi-natural habitats for gamebirds and other quarry species, and the provision of artificial food for gamebirds either directly as grain, or indirectly through game-cover crops and the retention of cereal stubbles, can benefit other birds of conservation importance. This includes a suite of declining farmland birds such as sparrows, finches and buntings.[34] These habitats are also favoured by grey partridge,[35] for which shooting interests are putting considerable effort o reverse its decline. • The mortality through shooting of the native Grey Partridge (a Red-listed species) has been reported to be six times higher through shooting than through predation.[36] • Wounded gamebirds, which subsequently die, can provide a food source for some native mammals and birds of prey, for example buzzard and red kite, although this has on occasion given rise to secondary lead poisoning in birds of prey.[37] There are some recorded instances of the ingestion of lead shot by waders, and gamebirds.[38] • Shooting on or adjacent to wetlands with important waterbird concentrations has, in a small number of cases, reduced site populations through direct mortality and, more often, through disturbance.[39 40] Other leisure activities may have a similar or additive effect, for example walking, boating and bait digging.[41] • Some species that predate gamebirds can be controlled legally. Illegal control of protected species can result in population declines. The illegal killing of hen harriers and goshawks to protect gamebirds is preventing population recovery of these rare species.[42,43] • Introduced, non-native gamebirds may compete for food with native farmland birds. There is limited evidence suggesting that intensively-reared birds could spread disease to native species, although this has not been well studied.[44]
Water level control	• The raising of water levels to create lowland wetlands and wet grasslands is beneficial to some wildfowl and wading birds.[45] This is not generally undertaken primarily for game shooting purposes.
Sediment loads in water	• Field margins maintained as nesting/feeding habitat for gamebirds can help to prevent sediment from arable fields entering adjacent watercourses by acting as buffers.[46]
Nutrient loads in water	• Field margins maintained as nesting/feeding habitat for gamebirds can reduce nutrient run-off from arable farmland when situated adjacent to watercourses by acting as buffers.[47]

Table continued...

Pesticide control in water	•	Management prescriptions to reduce pesticide use on arable crops, for example conservation headlands under Environmental Stewardship, may be taken up to provide habitat for gamebirds, with a resulting reduction in pesticide run-off into watercourses.[48]
Other pollutants	•	Medication is widely used to prevent disease in intensively-reared gamebirds. Concerns have been raised that this could contribute to the development of immunity to antibiotics and even have implications for human health when birds enter the food chain, but this is a little-studied area, with scant evidence. The Veterinary Medicines Directorate monitor chemical residue in game meat for human consumption to ensure the safety of human health.
	•	Modern rodenticides are often used to control rats in areas where supplementary food is provided for gamebirds. This can result in secondary poisoning of birds of prey and mammal predators/scavengers; when they feed on poisoned rodents.[49,50]
	•	Lead is still used in shotgun cartridges. This is legal for shooting terrestrial birds though it is illegal for shooting waterbirds.[51] Waterbirds can be poisoned through direct ingestion of lead and birds of prey are subject to secondary poisoning when feeding on shot prey.[52]
Landscape character, and access	•	The varied, 'patchwork' landscape of lowland England has been heavily influenced by the maintenance of woodland and hedgerows to encourage gamebirds. Continued management of field margins, hedgerows and woodlands is undertaken in some areas for game shooting, enhancing the landscape character.[53]
	•	The perceived threat to gamebirds from disturbance by people and their dogs means that public access is often strictly controlled on estates where game rearing is important. CRoW 'open access' land may be closed to the public for up to 28 days each year to allow shoots to take place.

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Case Study: Predator Control

Predator control is practiced by land managers principally to try to avoid losses of livestock on farms, and game animals and birds where there is a shooting interest. Predatory species controlled in this way range from foxes and mustelids (such as mink and stoats), to corvids (such as crows and magpies). Control of raptors is illegal unless carried out under license. To date no such licenses have been issued. The subject is still highly contentious where there is the belief that raptors are reducing numbers of potentially valuable gamebirds, or affecting the breeding success of other scarce native species.

Moorland managed for red grouse supports higher numbers of certain species of bird than moorland not managed for grouse.[1] Specific research which clearly demonstrates the impact of predator control on upland birds is limited. This is likely to be a reflection of differences in habitat quality, type of management and predator control. It is not possible from research to date to determine the precise contribution that predator control may play. Conversely there are a number of species which are less abundant on grouse moors, particularly certain raptors. A report assessing hen harrier nesting success between 2002 and 2008 shows that very few nesting attempts on grouse moors are successful and this is likely to have limited their distribution and expansion in England.[2]

In order to test whether predator removal by moorland gamekeepers improves the numbers or breeding success of moorland birds other than red grouse, the Game and Wildlife Conservation Trust have recently concluded an 8 year Upland Predation Experiment based at Otterburn, Northumberland. The project adopted an experimental approach using four plots each of 12 square kilometres. Two plots retained the same regime for the whole period, one where fox and crow populations were managed (keepered) and one where they were not (unkeepered), whilst the other two switched half way through the experiment from keepered to unkeepered and unkeepered to keepered, allowing an assessment of breeding success on the same plot with and without predator control. A final analysis of the experiment is currently being completed. Provisional findings outlined by the Game and Wildlife Conservation Trust[3] suggested waders and meadow pipits show a tendency for greater breeding success on sites with predator removal, though the trend in numbers of breeding pairs is not yet clear. Black grouse and grey partridges also show a tendency for better breeding success in the presence of predator removal, but the low numbers of these species means that the analysis may not be conclusive.

Reviews of a large number of studies into predator control have concluded that whilst killing predators frequently increases breeding productivity (and hence, for game species, the surplus of birds available for shooting in autumn), this does not necessarily translate into an increase in the size of the breeding population in subsequent years.[4]

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11 Energy crops - biomass

Context

11.1 European Union targets for use of renewable energy are that 20% of our energy use will come from renewable energy sources by 2020. Electricity consumption in England in 2006 totalled 271,010 GWh.[1] Biomass has a lower calorific value (i.e. less energy per tonne) than coal or gas, but typically produces 77g CO_2 eq/kWhe, compared with 1054g CO_2 eq/kWhe produced by coal.[2] Even after carbon emissions associated with cultivations and fertiliser usage are calculated, greenhouse gas emissions for biomass production are significantly lower than those for fossil fuel. For example 66-99% lower than for current coal-fired power generation.[3]

11.2 Energy crops can be used in different ways: ‘biomass crops’ such as Short Rotation Coppice (SRC), Short Rotation Forestry, tall perennial grasses such as *Miscanthus*, and by-products such as straw from annual crops, provide carbohydrate for direct combustion; oil-bearing crops (oilseed rape, sunflowers) and carbohydrate or sugar-rich crops (wheat, sugar beet) are used to produce biodiesel and ethanol respectively, to replace hydrocarbon fuels. This chapter is concerned with biomass crops in particular. Biofuel crops that are suited to production in this country are based round grain and oilseed production and, in that respect, husbandry methods are not likely to differ substantially from production of similar crops for human or animal feed.

11.3 Between 2001 and 2007, some 5783 ha of *Miscanthus* and 1676 ha of SRC were planted under the Energy Crops Scheme in England.[4] It is not clear whether these areas have remained under energy crops after the agreement period elapsed but Defra’s Farm Practices Survey (2008)[5] found that 12% of farmers surveyed stated that they were growing energy crops (which may include crops for liquid biofuel production), with 24% considering growing them in the future.

Current industry practice

11.4 SRC is planted at high density (approximately 1m spacing) and harvested at 3 year intervals. Its productive life is between 15 and 30 years (up to six harvests), after which time the roots are grubbed out.[6] *Miscanthus* is planted as rhizomes, and is harvested anually in autumn or winter from its second year onwards. It has a productive lifespan of approximately 15 years, after which it can be treated with herbicide and the land cultivated to destroy any remaining rhizomes..

11.5 Currently an increasing amount of chopped material is pelleted before transport, effectively trebling the bulk density of the material, and increasing transport efficiency.[7]

Industry trends and pressures

11.6 To provide 1500 MW of ‘renewable’ electricity capacity around 125,000 ha of land would be needed for energy crops.[8] Biomass crop estimates to supply future UK demand suggest that it will include 450,000 ha of SRC and *Miscanthus* (the remainder to come from 700,000 ha of oilseed rape and 350,000 ha of wheat and sugar beet).[9] Drax power station plan to generate 500 MW from biomass co-firing facility.[10] Current UK targets are for SRC area to increase to 16,000 ha which will provide 215 kt of biomass.[11] The current target area for *Miscanthus* is 5000 ha, providing 64 kt of biomass.

11.7 For current incentives, advice and regulation for production of biomass crops, see Annex I to this chapter.

Key impacts

11.8 For conventional crops, such as oilseeds, wheat or sugar beet, agricultural operations such as fertiliser and agrochemical spray applications are unlikely to differ substantially when destined for bioenergy applications. See chapters on 'Nutrient management - crops', and 'Use of plant protection products'). Where conventional crops are replaced by perennial biomass crops, fertilisers and herbicides are only used at establishment, and after cutback,[12] due to the difficulties in application during other growth stages.

11.9 Depending on the scale of planting in the locality, establishment of SRC or *Miscanthus* may provide an increase in landscape heterogeneity, which has potential advantages in terms of bird and invertebrate diversity[13] (depending on the previous land use), but the overall effect would depend on the habitat that is replaced. Where grasslands are ploughed out it would potentially impact local biodiversity, soil carbon and water quality through nutrient release.[14]

11.10 The crop structure of SRC provides suitable habitat for several key UK farmland bird species and passerines (mainly tits, finches and warblers) characteristic of scrub, woodland and ruderal vegetation.[15,16] Bird species associated with open farmland habitats such as skylark and lapwings do not use SRC as breeding habitat except possibly following establishment or after the winter cut.[17] Surveys show that many of the species that use areas of SRC are concentrated round the edges of the crop.[18]

11.11 It has proven to be difficult in practice to source all the biomass required within the immediate vicinity of co-firing facilities, and as a result much has needed to be imported. Transport to end users has been shown to have very little impact on the overall GHG balance.[19]

Plate 8 Short Rotation Coppice, showing density of the growing crop

11.12 Soils under biomass crops are vulnerable at harvest time, where heavy equipment may be used under wet ground conditions.With SRC the extended period between harvests, and the development of large root systems, should allow some stability and recovery. At other times, the leafy cover and fallen leaf material are considered to be effective in reducing erosion and soil run-off.[20]

11.13 At present, the area used for energy crops has been predominantly under arable rotations, as evidenced by the lack of change in area of medium and long term grasslands.[21]

11.14 Energy crops are a relatively new element in the landscape and may have an impact on landscape character, depending on where and how they are grown. The impact of any planting will depend on the character and quality of the recipient landscape, the scale and form of the planting, and the ability of the landscape to absorb change.[22] This will often be site-specific and may be positive or negative. For example, in some open landscapes, SRC can obscure key historic features and views, whereas in lowland agricultural landscapes it has the potential to add structural diversity and interest. Enclosure, openness and landform type will all have an influence. Cultivation has the potential to disturb archaeological remains and damage can arise from planting processes, root growth, hydrological impacts and harvesting.[23]

11.15 Where crops are established in previously cultivated ground, impacts may be no greater than for conventional cereal planting, although associated works, such as the widening or removal of historic gateways, erecting new fences etc., may impact directly on archaeological remains or their setting.

11.16 Where SRC is planted, research indicates a higher water demand[24] than traditional arable crops. There is little evidence at present to suggest that this has a deleterious effect on water tables. In models of bulk planting of catchments, hydrologically effective rainfall (the rainfall that enters the catchment as runoff, or infiltrates groundwater by deep percolation) can be reduced by 75-90% by SRC or 50-60% by Miscanthus.[25]

11.17 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

11.18 There is little hard evidence on the wider effects that energy crops will have on biodiversity. Were a high percentage of land to be required for energy crop production, it would put pressure on some semi-natural habitats, particularly given the current concerns that the area of land used for food production should not be reduced.

11.19 Short Rotation Coppice (SRC) can contain a greater diversity of wildlife than conventional arable crops, particularly small birds - although these are more likely to be woodland species than birds of open farmland.

11.20 Where biofuels are being derived from crops such as oilseed rape and wheat, it is unlikely that there will be a major departure from current growing methods and associated impacts on biodiversity. Unless there is a mechanism which values the product on the carbon costs of production, it is likely that intensive (high input, high output) management will be the popular option.

Resource protection

11.21 Research indicates that despite the release of nitrates at establishment and ‘grubbing up’ of short rotation coppice, overall nutrient losses into the soil are less than under conventional arable cropping.

11.22 Crops such as SRC are not ploughed or harvested annually, which benefits soil structure in comparison with conventional arable land use, and their low agrochemical requirement is advantageous in terms of risk from run-off and leaching.

11.23 If non-arable land is converted to biomass crop production, this would lead to losses of soil carbon. This has implications for soil structure and erosion as well as for greenhouse gas emissions.

Greenhouse gases

11.24 The drive behind energy crops is based on reducing emissions from carbon-based fuels. There is strong debate over whether conventional arable crops for processing into liquid biofuels deliver acceptable C savings. Biomass crops have come under less scrutiny, but are targeted to provide carbon savings of over 190 kt C annually.

11.25 Low fertiliser and agrochemical requirements in biomass crops also contribute to greenhouse gas savings.

Landscape

11.26 The expansion of arable areas into *Miscanthus* and SRC production will affect the landscape, though gains and losses will depend on individual location and shape of plantation, and any infrastructure associated with the local production of biofuels, such as storage areas.

Annex I Current incentives, advice and regulation

- The UK Renewable Energy Strategy, as agreed by European Union Heads of Government in 2007, commits us to a binding target of 20% of EU's energy (electricity, heat and transport) to come from renewable sources by 2020.[26] It also has a further domestic goal to reduce carbon dioxide emissions (one of the main greenhouse gases) by 20% below 1990 levels by 2010.[27] To contribute to meeting these targets, the UK encourages delivery through the Energy Crops Scheme[28] and Energy Aid payments.[29]
- In the UK, grant funding for energy crops originally required biomass crops to be grown as close as possible to the end user, usually within 25 miles.[30] This has proven to be logistically impossible and the limit no longer applies.
- Several economic and policy drivers may lead to the development of large, relatively uniform areas of bioenergy crops. These include economies of scale, the demands of large scale users and the need to minimise transportation costs.
- The local planning system does not cover the impacts of planting bioenergy crops on the character of the local landscape. The Energy Crops Scheme (ECS), which provides establishment grants for SRC and *Miscanthus*, can be used as a mechanism for ensuring that new plantations are established with consideration for environmental issues.

Annex II Impacts on environmental sustainability of biomass crop production

Table 13 Impacts on environmental sustainability of bioenergy fuel crop production

Habitat quality and diversity	• Habitats might be affected or lost where biomass crops are inappropriately sited. This includes open farmland habitats (arable or pastoral) that are important for nesting and feeding birds, as well as more marginal, semi-natural habitats Crops such as Short Rotation Coppice (SRC) can be grown on land unsuited to other arable production (Agricultural Land Classification grades 4 and 5).[31] This could entail a higher impact on semi-natural vegetation, which has not been affected by other agricultural intensification. • Some successional plant communities can become relatively stable in long-term plantations,[32] despite current crop establishment guidelines involving relatively heavy use of herbicides.[33]
Species abundance and diversity	• SRC can contain a greater diversity of wildlife than conventional arable crops, particularly small birds[34], although the species assemblage would not be the same as for open farmland.[35] • SRC can support a relatively high diversity of flora,[36] although its establishment on species rich habitats would still be damaging.
Water level control	• High yielding biomass energy crops such as SRC use more water resources than conventional arable crops.[37] This may affect the local water table.
Sediment loads in water	• Crops such as *Miscanthus* and SRC are established or harvested over the autumn or winter period, increasing the erosion risk.[38] • Deep rooting of biomass crops improves water infiltration and reduces surface run-off.[39] • Grassy or woody crops are usually effective buffer areas against erosion from other sources.[40]

Table continued...

Nutrient loads in water	• Oil Seed Rape (OSR) grown for biodiesel and cereals for bioethanol will receive virtually the same nutrient application as conventional foods crops, with little or no change to the risk of nutrient load to water.[41] • Some cultivars of *Miscanthus* are associated with nitrogen-fixing bacteria, which can reduce substantially external nitrogen requirements.[42] Grubbing out such crops can release nitrates into the groundwater. • The normally low level of nitrogen mineralisation is increased in soils during the disturbance involved in establishment and grubbing out.[43]
Pesticide control in water	• The practicalities of spraying pesticides on a SRC crop preclude their use during most of the growing period. Some use may be made for weed control at establishment, which may potentially enter watercourses, depending on the persistence of products used.
Other pollutants	• Heavy metal contamination resulting from application of sewage sludge can be taken up by willow; ash disposal after burning requires consideration.[44] • Relatively high levels of pest damage can be tolerated, unlike in conventional arable crops.[45] This entails less pesticide application.
Greenhouse gases	• Where grassland is ploughed up to establish biomass crops, the carbon released may take decades to offset.[46] • The precise balance between the lock up of greenhouse gases within the biomass of energy crops and the release of gases from the use of inputs to grow, transport and utilise them is under debate. • Low bulk density of the chopped material is a limiting factor for all modes of transport.[47] This is offest where material is pelleted before transport. • Comparatively low demand for inorganic fertilisers leads to low overall GHG emissions per hectare of crop during cultivation.[48]
Air quality: odour	• Organic fertilisers are a common source of odour nuisance. • Application of organic manures (particularly slurry and farmyard manure (FYM) can result in high losses of N as ammonia (*c.* 40% for slurry, 70% for farmyard manure).[49]
Soil stability (erosion)	• Energy crops such as *Miscanthus* and SRC are established and harvested over the winter period. This may have detrimental effects on sloping ground or vulnerable soils.[50]

Table continued...

Soil function	•	The use of heavy machinery to harvest the biomass crops in winter can lead to problems of compaction on some sites.[51]
	•	Deep rooting of biomass crops improves water infiltration and reduces surface run-off.[52]
Landscape character	•	There is considerable opportunity to impact both positively and negatively on landscape through the design and scale of bioenergy crop planting. As yet such plantations are on a comparatively small and fragmented scale.

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12 Woodland creation

Context

12.1 England has approximately 1,127,000 ha of forest or woodland, of which 10% is classified as 'young stands'.[1] Woodlands classified as small (under 2 ha) comprise 14% of the total woodland area. Farm woodlands in England comprise 305,400 ha (27%) of the total woodland area.[2]

12.2 Within the UK, 5.1% of the total forest area is designated Sites of Special Scientific Interest (SSSI); this represents 23% of the total ancient and semi-natural woodland resource.[3] Plantations on sites of ancient woodland comprise 13% of all woodland area.[4]

12.3 The areas quoted for woodland plantation exclude short rotation coppice. See chapter on 'Energy crops - biomass'.

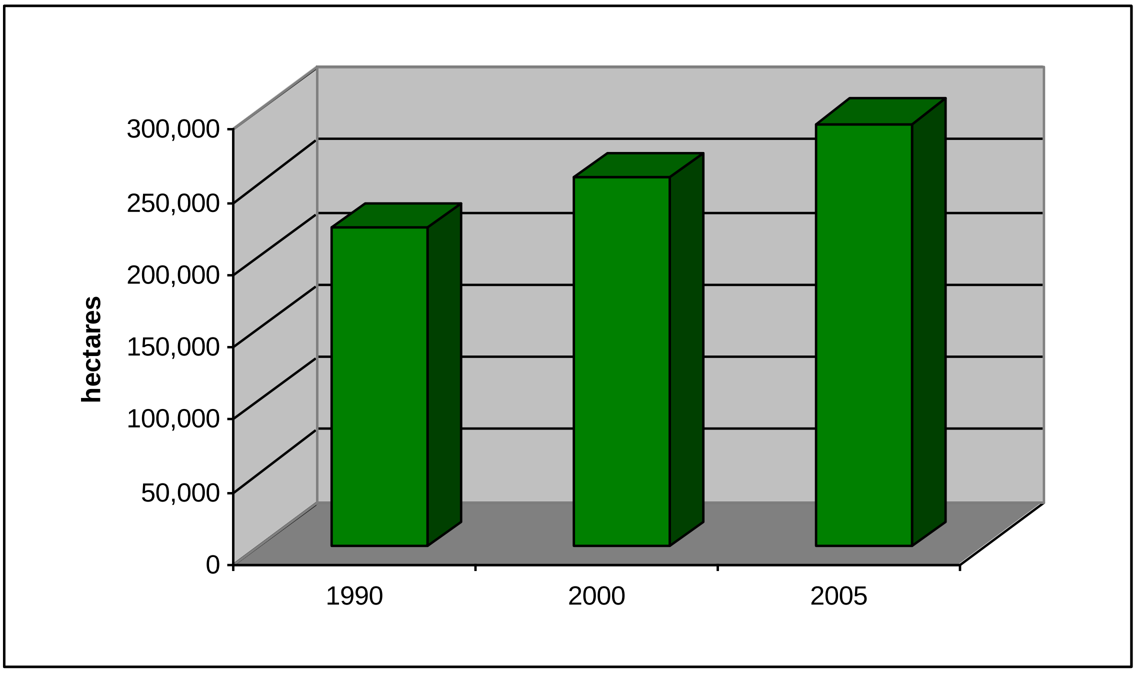
12.4 Current policies and objectives for forestry in England are set out in the Government's strategy for England's Trees, Woods and Forests.[5]

Current practice

12.5 Woodland planting may be carried out to meet a number of specific objectives, for example wood production, game management, biodiversity, recreation, landscape, shelter. These objectives will shape the desired extent, location, structure and composition of the new woodland and, ultimately, its future management. In turn, these factors can influence the likely impact (positive or negative) of the woodland creation on the environment.

12.6 The total area of forest and woodland in England is increasing at a slow rate, and percentage forest cover is still amongst the lowest in Europe: forest cover for the whole of Europe is 44.3% of land area; the United Kingdom has 11.8% cover. England had 8.6% forest/woodland cover in 2006, compared with 8.4% in 2000.[6]

12.7 In the years up to 2005, recorded farm woodlands increased both in size and extent. The number of holdings with woodland rose from nearly 35,000 in 1990 to nearly 39,500 in 2005 (although some of this may be due to changes in recording). Within that same period, the area of farm woodland has increased, and the proportion of farm area which is woodland has also increased slightly (2.7% in 2000 to 3% in 2005).[7] Figure 8 below illustrates the change in area of farm woodland from 1990 to 2005.



Source: Defra[8]

Figure 8 Area of farm woodland, 1990-2005

Industry trends

12.8 During the afforestation boom of the 1970s, between 20,000 ha and 30,000 ha were being planted each year in the UK. Changes in forestry policies, and to the support for new planting in the 1988 Budget, led to a much reduced rate of planting overall in Great Britain. It also led a shift towards more small-scale woodland planting and more emphasis on the woodland creation in the lowlands, for example in the Community Forests and National Forest.[9] As a result of the changes in policy, UK planting has dropped to about 10,000 ha per year. In England currently, new woodland creation is around 3200 ha (including estimates for natural colonisation and areas planted without grant-aid). More than 95% of this area is broadleaved.[10,11]

12.9 The map at Figure 9 shows the extent of forestry and woodlands in England.

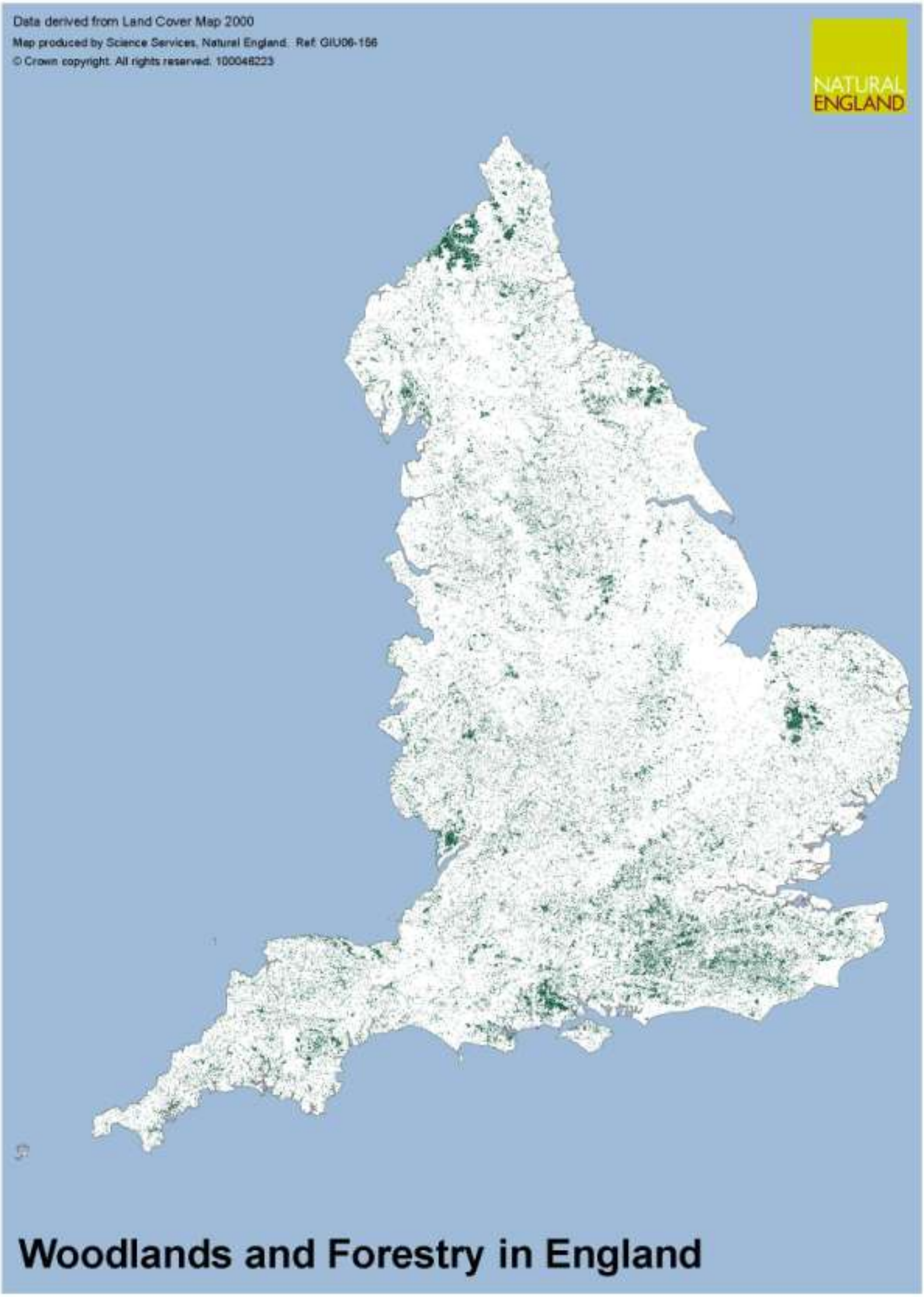


Figure 9 Areas of woodland and forestry in England

12.10 This level of activity is insufficient to meet the current Habitat Action Plan targets,[12] even if it were all focused on biodiversity objectives, let alone other objectives. In that respect, an increase in planting/woodland creation over the next 5-10 years is needed and is supported by the recent Strategy for England's Trees, Woods and Forests.[13]

12.11 Over recent years, there have been further shifts in emphasis arising from a number of concerns and needs:

- Too much of the new planting was as very small (<2 ha) blocks that would not deliver effectively on the objectives in the Strategy for England's Trees, Woods and Forests,[14] in particular because the contribution to future wood production was being ignored.
- The planting should contribute to reducing the impacts of habitat fragmentation, including, for example, as part of climate change adaptation strategies.
- The role of new woodland in carbon sequestration strategies should be explored.
- There should be specific woodland creation targets as part of the woodland habitat action plans under the Biodiversity Action Plan (BAP).
- There is a revival of interest in energy crops as a component of new woodland creation (including both short rotation coppice and short rotation forestry).
- There is interest (but little action to date) in allowing more spread of woodland by natural regeneration.

12.12 For current incentives, advice and regulation for woodland and forest managers, see Annex I to this chapter.

Key impacts

12.13 Some impacts may only develop, or may become more significant, as the new woodland becomes mature. Others, related to activities directly connected to planting, such as removal of grazing from pasture land and soil compaction and disturbance from planting,[15] will be more immediate.

12.14 Many local Habitat Action Plans recognise that woodland creation can encroach on locally important areas of open ground, but it is generally agreed that woodland creation has a positive role to play in the wider landscape. Trees have a number of important functions which are generally beneficial for natural resource management:

- Root systems can penetrate deep into the soil. This is beneficial in terms of soil microbial activity,[16] allowing increased organic matter and thus carbon content, as well as being beneficial in terms of water and flood management, reducing surface flow by allowing increased water infiltration. The transpiration of the leaves can also reduce water levels.[17]
- Root systems also serve to stabilise soils, and can intercept sediment and nutrients from agricultural land. Planted along watercourses, woodlands can make excellent buffer strips against farmland.[18]
- The tree canopy can actively 'scavenge' nutrients and pollutants and particulates from the air, although there is also the possibility that much of this can be washed off the leaves by rainfall and enter the soil or watercourses.[19]

12.15 The Environment Agency has produced a draft report which considers in detail at the effects and interactions of woodlands and water.[20]

12.16 Young plantations generally need to be fenced against livestock and deer. As a result, the understorey can become densely vegetated. Whilst this may be detrimental for open ground species, the increased vegetation can be beneficial in terms of increased organic matter in the soil and increased carbon storage.[21] Trees planted on highly organic soils such as peat are likely to have the opposite effect, as they tend to lower the water table and encourage oxidation of the desiccated organic matter.[22]

12.17 Tree plantation on most soils contributes to carbon sequestration, by locking up carbon in the wood itself and adding to the soil organic matter. Younger trees tend to do this more rapidly, in conjunction with a vigorous understorey due to the more open canopy[23] and the greater annual increase in woody material. In the longer term more carbon is stored in mature woodland.

12.18 Apart from providing habitat which is of benefit to woodland specialist species, woodland creation can also be advantageous, to varying degrees, to woodland edge species and those that prosper in habitat mosaics with varied landscape structures.[24] Woodland specialists are likely to benefit most where woodland creation is adjacent to existing ancient woodland and uses natural regeneration of trees and shrubs native to the site.

12.19 During the mid-part of the twentieth century, woodland creation (primarily the establishment of large-scale conifer plantations) was a major cause of damage to wildlife sites and to treasured landscapes such as heaths, moorlands and, in particular, blanket bog.[25,26,27] A new policy framework is being developed to support the restoration of these habitats.[28]

12.20 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

12.21 The increase or creation of entirely new woodland habitat can serve to consolidate or extend the range of key species.

12.22 In the wrong place, woodland creation can have a direct negative impact on other habitats: developing woodland may also impact adjacent land, for example, by providing a seed source on lowland heaths, lowering the water table on wetlands or creating potential niches for other (potentially invasive) species to colonise. Continued management after the initial planting is important for maintaining or enhancing woodland structure and composition.

Resource Protection

12.23 Water infiltration into the soil is improved as a result of root activity, resulting in increased flood mitigation capability (although planting on peat would, through the same process, lead to soil degradation).

12.24 Largely because of the management required in young woodlands, vegetation cover is usually dense and can act as a buffer against soil and nutrient movement.

12.25 Access and other disturbance during the planting process can give rise to short-term soil compaction, erosion and sedimentation in watercourses.

Greenhouse gases

12.26 Where the woodland is created either by planting or natural regeneration, carbon sequestration takes place; the rate of net sequestration tends to be higher in young, fast-growing crops than in mature/old-growth stands, although the total carbon stored (standing crop) is higher in the latter.

12.27 Air quality may be improved by the ‘scavenging’ effect of tree canopies, although the accumulation of pollutants and particles can affect the soil where these are washed off leaves by rain.

Landscape

12.28 New plantations can enhance the landscape if well designed and well located but can detract from landscape quality if poorly sited.

12.29 Root development can adversely affect historic structures.

12.30 Some of the above impacts (such as landscape effects or root infiltration) may become significant after a period during which the woodland develops, while others (such as carbon sequestration or soil disturbance at establishment) may reduce over time.

Annex I Current incentives, advice and regulation

- Standards and guidelines have been introduced to improve the implementation of planting proposals, supported by Forestry Commission and other grants.[29,30]
- Most planting and much woodland creation by natural regeneration is supported by the Forestry Commission, either directly or else through being covered as part of an approved management plan. It will be expected to comply with the UK Forest Standard and associated guidelines.[31] Where woodland is created under Higher Level Stewardship agreement, similar standards should be applied.
- Proposals for woodland creation above a certain size (5 ha, or 2 ha within sensitive areas) may also be subject to *Environmental Impact Assessment (EIA)*.[32]
- Local planning authorities are consulted on licence applications to the Forestry Commission via a public register of proposals.[33]
- New planting/woodland creation within SSSI (including Special Areas of conservation (SAC) and Special Protection Areas (SPA)) will normally require agreement (assent/consent) from Natural England.
- Planting affecting scheduled ancient monuments would be subject to consultation with English Heritage.
- Planting and management of trees within development sites may be required as conditions of planning consent.
- Other conditions may be required if the planting is associated with woods covered by the UK Woodland Assurance Standard - a voluntary certification scheme.[34]

Annex II Impacts of woodland creation on environmental sustainability

Table 14 Impacts of woodland creation on environmental sustainability

Habitat quality and diversity	Depending on the composition of the new woodland, there can be creation of woodland priority habitats and species under the UK BAP. Woodland creation may contribute to the following effects: • Expansion of habitat for woodland species more generally. • Changes to the habitat conditions in the land immediately around the woodland, for example by the introduction of a new seed source.[35] • Loss of use of land that could otherwise be open habitats. A number of local Habitat Action Plans recognise this, for example Sussex, where chalk grasslands are an important local feature.[36]
Species abundance and diversity	• Encouragement of predatory species into an area, for example even small blocks of woodland near to important wet grassland sites can harbour foxes and corvids, which may have a detrimental effect on wader nesting success).[37] • Planting to produce structural heterogeneity is important to maintain habitat for the wider breeding bird community.[38] • Increase in potential for movement of many plant and animal species through improved permeability of the landscape.[39]

Table continued...

Water level control	• The extent, composition and location of woodland cover affects water yield from a catchment compared with other types of vegetation cover.[40] • The quantity and quality of run-off may be either increased or decreased by woodland creation, depending on circumstances. In the lowlands, trees often reduce the water table through increased transpiration/interception losses compared with shorter growing crops.[41] • In the uplands, tree cover may encourage greater rainwater infiltration compared with former sheepwalk[42] and slow the rate of run-off in some circumstances. • Appropriately sited woodland can help to alleviate downstream flooding by slowing the rate of water movement.[43] • Water levels may also be affected by changes in field drainage, either those put in to assist woodland creation or as a consequence of changing former agricultural drainage.
Sediment loads in water	• Poorly designed roads or soil preparation for planting can lead to increased soil erosion and sediment loads in streams, particularly on slopes.[44] The Forestry Commission has produced guidelines to minimise this. • Under woodland creation near water courses, there are likely to be changes to the nature of bankside vegetation composition and structure and effects on channel stability. Vegetated cover should lead to greater soil stability.[45] Vegetation abundance is likely to be increased unless heavy shading trees (such as conifers) are used.
Nutrient loads in water	• Water chemistry will be changed as a consequence of changes in water flow patterns and increased scavenging of nutrients and pollutants from the atmosphere. Afforestation was a major contributor to stream acidification during the 1970s and 1980s[46] and this is taken into account in current water guidelines. • Where woodland is planted to replace farmland, there is the likelihood of lower nutrient inputs.[47] • Woodland strips along watercourses may help to buffer streams against agricultural run-off.[48]
Pesticide control in water	• Pesticide use in forests tends to be limited to the immediate period of woodland establishment.
Other impacts	• Reduced water temperature where streams become shaded.[49,50]

Table continued...

Greenhouse gases	• Woodland creation results in increased sequestration in most instances (except where trees are planted on highly organic soils) compared with lower growing vegetation. Sequestration in the tree tends to be highest in relatively young fast growing stands. Carbon build up may also occur in the litter and soil layers.[51]
Air quality: chemical	• Increased scavenging of nutrients and pollutants from the atmosphere.[52]
Air: particulates	• Increased scavenging of particles from the atmosphere.[53]
Soil stability (erosion)	• In the short term, there may be some increased soil disturbance during ground preparation but, in general, soil erosion is reduced and stability tends to be improved under woodland.[54]
Soil structure	• There are likely to be changes in soil-carbon levels (generally increases on mineral soils, and decreases in wet peat soils because of increased peat decomposition).[55] • Where planting is for commercial purposes (entailing felling at maturity), carbon release from the soil may be greatest immediately after felling, due to increased disturbance and reduction of carbon input from litter. In continuous cover systems this is likely to be reduced.[56] • Potentially, there is reduced soil compaction in the longer term and increased water infiltration compared with previously grazed sites.
Landscape character	• New woodland may either strengthen or damage landscape character, depending on the landscape. The principles behind good landscape design and fitting in new woodland are well-documented and set out in the relevant guidelines.[57] • Tree roots can disrupt the historic environment, both by physical displacement and by disrupting pollen records as organic soils become dried out.[58]

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13 Tree felling and woodland clearance

Context

13.1 The nature of British, but particularly English, woodland has been shaped by centuries of clearance and management of what woodland did survive.[1,2] Usually management contributes to maintaining and enhancing the environmental values of a wood, but sometimes there is the potential for conflict. Our woodland has for the most part been managed through different felling regimes in the past; the environmental impacts of current felling operations tend to be site-specific, depending on factors such as topography, scale, shape and location of felled areas, the extent of soil and vegetation disturbance, and the restocking methods and species used.

13.2 There are about 1,127,000 ha of woodland in England,[3] much of which may contribute to landscape, historic, biological and social values, as well as to wood production. Non-timber values tend to be highest for ancient and broadleaved woodland.[4]

13.3 Within the UK, 5.1% of the total forest area is designated SSSI; this includes 23% of the total ancient and semi-natural woodland resource.[5] As of June 2009, a total of 6,554 ha of forest and woodland SSSI (approximately 11%) are in unfavourable condition due to inappropriate management.[6] Lack of management has been identified on a number of these as being the contributory factor.

13.4 Current policies and objectives for forestry in England are set out in the Government's strategy for England's Trees, Woods and Forests.[7]

Current practice

13.5 Currently, only about 25% of the annual wood increment from native woodland (approximately 60% from conifer forests) is harvested.[8] Some increased felling could have potential benefits in terms of increased open space in the woods, although it would not be desirable for the whole of the annual increment to be cut because of the environmental value of both fallen and standing dead wood.

13.6 Felling contributes to the value of woodland, directly, through providing returns from the wood harvested, and indirectly through affecting the structure of the woodland; this in turn may influence game shooting, landscape, access and biodiversity.

13.7 In most instances where there is felling within a woodland, there is a presumption that the area will be restocked (through planting or natural regeneration). The Forestry Act (1967)[9] includes a presumption against deforestation, and the UK is party to various international conventions designed to reduce deforestation and promote expansion of forest cover (United Nations Framework Convention on Climate Change, Kyoto).[10] An exception is where there is clearing of trees to restore open habitats. A new policy framework for this is in development.[11]

13.8 Felling systems have been classified by foresters in various ways,[12] but here the following groupings are used:

- 'Traditional management' covering coppicing and pollarding.
- 'Commercial forestry', as widely practised now, is based on clear-fells (>0.5 ha, but usually several or many hectares) or, less often, group-fells (0.1-0.5 ha).[13,14,15]
- 'Continuous cover', a term used for systems where the gaps created are about the size of one or two individual trees (<0.25 ha) although they may, in shelterwood systems, be widespread across a stand.
- Felling of individual trees outside woods, usually as an incidental part of other activities, for example hedge management, part of planned development or for safety reasons, where there is a perceived serious risk from falling branches or main trunks.

Industry trends

13.9 Prior to the mid-nineteenth century, the timber demand was mainly for small broadleaved poles;[16] now our main needs are for coniferous timber and wood products, and approximately 85% of what we use is imported.[17] Mature straight single stems that can then be cut to size are valued more than a large number of small stems; hence the shift from traditional coppice regimes to the various high forest systems.

13.10 A potential major new market for small/poor quality broadleaved wood may be wood-fuel. The Government Wood-fuel Strategy[18] has the target of harvesting 2 million tonnes by 2020, a renewable source of energy sufficient to meet the needs of 270,000 homes, or the equivalent of a reduction in CO_2 emissions from fossil fuels of 400,000 tonnes carbon per annum.

13.11 Coppicing usually involves small patch cutting (usually <3 ha), of relatively young growth; hence short rotations (<30 yrs), with restocking by stump regrowth.[19] A similar system, but involving harvesting between eight and 20 years is used in short rotation forestry, which is designed for energy generation from biomass. Unlike short rotation coppice, only the stem wood is extracted for use; the bark and side shoots are left in situ.[20] Short rotation coppicing of willow and poplar is considered in the chapter on 'Energy crops - biomass'.

13.12 Felling with no restocking, primarily for biodiversity purposes, has taken place over about 4300 ha on the Forest Enterprise (FE) estate.[21] In addition, about 3900 ha has been felled without a restocking condition outside FE land between 1997 and 2005. Most of these applications were for small areas, but many of the larger examples were on Sites of Special Scientific Interest (SSSI) and hence also likely to be restoration projects.[22] There is also an ongoing but unknown amount of (generally) small-scale clearance for development.

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Plate 9 Felled pines for habitat enhancement

13.13 For current incentives, advice and regulation for woodland and forest managers, see Annex I to this chapter.

Key impacts

13.14 There are numerous possible variations and intermediate forms of felling system. Despite claims sometimes made that one or other system is 'close to natural', none of these systems necessarily produces the structure and composition of woodland that would exist under natural woodland dynamics.[23]

13.15 Many habitats have evolved with the management systems that have been used at their location.[24] The impact of felling (including individual tree management and coppicing) on the woodland appearance, historic, and nature conservation values depends on the size of the individual coupes (areas cut/to be cut), how they are distributed in space and time, when the cutting takes place, what is done with any cut material (including extraction methods) and how the cut area is restocked (if at all).[25] The significance of the impact also depends on the history and composition of the stand. What is appropriate in one site may not be in another.

13.16 Felling may be driven by conservation objectives; the most appropriate system to adopt will then depend on the woodland structure that is sought. In Thetford, clear-fells provide large areas of open ground that are used by wood-larks and nightjars;[26] in many ancient woods there are species associated with open space and dense young growth which is well-provided by coppice;[27,28] in other sites maintaining closed humid conditions (such as can be achieved with continuous cover) may be best for dead wood associates or ground living bryophytes. Species that depend on dead wood would profit more from a management system which encourages standing deadwood to be left in situ.

13.17 There are areas where woods and forests may be cleared to restore open habitats such as heathland or grassland, as part of the Biodiversity Action Plan (BAP) process. Under current forestry policies (including commitments under international conventions), there is a general presumption against such clearance unless there are other strong benefits.

13.18 Between 1997 and early 2005, there were 44 applications to restore large areas (>20 ha) of open ground by tree removal. Of those, 43 were driven by biodiversity objectives (40 of which were on SSSIs), and only one was for landscape considerations. There may also be small-scale clearance for development purposes.

13.19 The greenhouse gas budget of mature woodlands is complex and much can depend on the soils. Mature trees can compress peaty soils and contribute to a lower water table. Removal, for example, of conifers on peat soils can allow the water table to rise, restoring some of the peat function and eventually carbon sequestration in the peat. This may in part be offset by the increased production of methane due to increased waterlogging.[29]

13.20 Poorly managed felling can result in movement of soils by erosion. Release of nutrients depends on the rate of breakdown of the litter layer, whether harvest residue (brash) is removed, and the vegetative growth that establishes after timber extraction.[30,31]

13.21 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

13.22 Clearance of woodland may be encouraged for biodiversity purposes where the potential for creating a high-value non-woodland habitat outweighs the benefits of the current/future woodland habitat.

13.23 Tree removal can affect some microclimates, for example shading over streams.

13.24 Many woodland habitats and species benefit from the variety of structure that is created through the felling and restocking process in managed woodland.

Resource protection

13.25 Increased pressure to take account of sustainability issues, including use of wood as a fuel, is likely to lead to more felling in future.

13.26 Felling trees is not *per se* an important contributor to carbon emissions. Following felling there may be some increased loss of carbon from more rapid litter breakdown, but the carbon taken up by the felled trees remains within the timber until that is broken down.

13.27 Removal of trees from peat soils can allow the water table to rise, slowing peat oxidation and contributing to reduction in rates of soil carbon loss.

13.28 The pattern and scale of felling, and the extraction process, are key factors in the associated soil erosion and compaction risks.

Greenhouse gases

13.29 Mature trees hold large quantities of carbon but sequester comparatively little.

13.30 Timber extraction may only represent a comparatively small return of carbon to the atmosphere: wood does not release CO_2 until it decomposes or is burnt. The oxidation of leaf litter and surface soil biomass in felled areas will add to net emissions in the short term. Where regrowth or restocking does not take place, there is a potential net loss of 50 t C/ha.

Landscape

13.31 Tree felling or clearance can be damaging to landscape but, equally, the removal of ill-sited trees or unsuitable tree species may contribute to an overall enhancement.

Annex I Current incentives, advice and regulation

Regulation

- *Forestry Commission guidelines*: The Forestry Commission has produced a range of advice covering potential impacts to habitats, soil, water, historic environment and landscape arising from tree and woodland management.
- *Woodland felling*: Most felling within woodland needs a licence from the Forestry Commission, either directly or else through being covered as part of an approved management plan.[32] Local planning authorities are consulted on licence applications to the Forestry Commission via a public register of proposals.[33]
- *Environmental Impact Assessment (EIA)*: If the land is to be cleared, for example to restore heathland, the felling is likely to require EIA determination.[34]
- *Tree Preservation Orders(TPOs)*: The felling of individual trees does not normally require a licence, but individual trees/less often woods may be subject to TPOs that further limit management activity without prior consent.[35]
- *Development control*: Retention and management of trees within development sites may be required as conditions of planning consent, and the Forestry Commission are a non-statutory consultee on planning applications that affect ancient woodland. Local Authorities are expected to take account of the value of ancient woodland and veteran or aged trees for biodiversity in considering development proposals under PPS9.[36]
- *Wildlife and Countryside Act (as amended)*[37] and *Countryside and Rights of Way Act*[38]: Felling within SSSIs (including Special Areas of Conservation (SAC) and Special Protection Areas (SPA)) will normally require agreement (assent/consent) from Natural England.
- *Historic Monuments*: Felling affecting scheduled ancient monuments would be subject to consultation with English Heritage.
- *Biodiversity Action Plan (BAP)*: Most broadleaved woodland falls within the categories listed as priority habitat under the BAP. It therefore falls within the biodiversity duty placed on public bodies under the Natural Environment and Rural Communities Act.[39]

Incentive

- *Grant Schemes*: Support for woodland management under various grant schemes may be conditional on limitations on felling procedures. Work is expected to conform as a minimum to the Forestry Commission's UK Forestry Standard[40] and associated guidelines for Biodiversity, Soils, Water, Historic Environment and Landscape (currently under revision).[41]
- *Voluntary Certification Schemes*: Other conditions may apply if the woods are covered by the UK Woodland Assurance Standard - a voluntary certification scheme.[42]

Annex II Impacts of tree felling on environmental sustainability

Table 15 Impacts of tree felling on environmental sustainability

Habitat quality and diversity	Depending on the size of individual coupes and their spatial and temporal distribution, so different groups of species will be favoured or disadvantaged by different felling systems: • Habitats and species of ancient and broadleaved woodland tend to be favoured by traditional management (such as coppicing) or systems that provide analogous structures.[43] • Where remnants of the former open habitats survive or are to be restored from plantation, large-scale fellings may be more successful in maintaining/encouraging these than small-scale felling because they increase the size of the open habitat patches and reduce the potential for recolonisation.[44] • Continuous cover systems, with their small-scale fellings, are unlikely to provide suitable habitat for the open space specialists, but will favour closed canopy species.[45] • Minimum intervention stands in which no felling occurs will benefit natural processes and the accumulation of dead wood.[46] • Increased management could be a risk to species that depend on shady conditions, tall canopy trees and dead wood, which have tended to increase in the last 50 years.[47 48] • Felling of individual trees tends to be most significant outside woodland because the individual trees themselves, particularly veteran trees, are critical to the interest, for example in orchards, hedges and parkland.[49]
Species abundance and diversity	Different types of felling favour different species. In addition, some species may be favoured by small amounts of disturbance,[50] although major disturbance of the woodland floor tends always to be damaging: • For species requiring open conditions (such as some woodland butterflies), the aim should be to concentrate coupes such that there is easy movement between them[51]; for species which avoid coupes (such as dormouse), felling should be small-scale and dispersed.[52] • Species that depend on decaying wood and old tree habitats will also be increasingly disadvantaged as the degree of wood removal increases. Specialist dead wood species tend to remain limited to the sites where they have occurred for centuries.[53]

Table continued...

Water level control	• The extent, composition and location of woodland cover affects water yield from a catchment compared with other types of vegetation cover.[54] • In the lowlands, trees, particularly conifers and energy crops, often reduce the water table through increased transpiration/interception losses compared with shorter growing crops.[55] • In broadleaved woods, felling may lead to temporary rises in the water table because of reduced transpiration.[56,57] • In the uplands, tree cover may encourage greater infiltration compared with former sheepwalk,[58] and slow the rate of run-off in some circumstances. Felling therefore can lead to increased or faster run-off. • Appropriately sited woodland may help to alleviate downstream flooding by slowing the rate of water movement.[59]
Sediment loads in water	• Badly organised felling and extraction can lead to increased soil erosion and sediment loads in streams, particularly on slopes; this should be minimised by adherence to Forestry Commission guidelines. Buffer strips may help to trap eroded soils and surface flow.[60,61]
Nutrient loads in water	• Water chemistry may be changed in the short term as a consequence of changes in water flow patterns. • Reduced scavenging of nutrients and pollutants from the atmosphere following felling may entail increased loads reaching water courses.[62,63]
Other pollutants	• Risks from spillage of fuel/lubricants for machinery should be minimised through following best practice. • Removal of tree cover will affect water temperatures and hence conditions for fish.[64,65]

Table continued...

Greenhouse gases	• Reduced sequestration in the short term through harvesting of mature stands should be offset by future growth if the land is restocked.[66] • Mature stands store large amounts of CO_2, and net sequestration is significant.[6768] Younger, more vigorously growing stock sequester more per unit area.[69] • Where trees are felled and the area not restocked, the net effect on carbon stocks depends on the nature of the replacement vegetation and the soils, but will typically represent a loss of about 50 t C/ha.[70] • Cut material remains as stored carbon in the timber products; these may off-set CO_2 emissions from fossil fuels, where the wood is used as fuel, but does contribute to increased CO_2 emission where felled material is burnt on site (in the short term) or left to decay (longer term). Burning material on site may also result in significant emissions of methane and nitrous oxide[71] - powerful greenhouse gases in their own right. • There may be an increase in carbon released to the atmosphere from increased oxidation of the litter layer, or organic matter in underlying soils from increased soil surface temperatures.[72] • Removing (conifer) woodland from peatlands/highly organic soils will raise water tables and reduce rates of soil carbon loss.[73]Methane and nitous oxide emission will increase at the same time.[74] The greenhouse gas balance of the activity is complex and will vary from site to site.
Air quality - chemical pollutants	• There will be reduced scavenging of nutrients and pollutants from the atmosphere immediately following felling.[75]
Air quality - particulates	• There will be reduced scavenging of nutrients and pollutants from the atmosphere immediately following felling.[76]
Soil stability (erosion)	• Some ground disturbance is inevitable during tree felling and the subsequent extraction; the extent of disturbance depends on the scale of the felling, how it is organised and the extraction methods used. This can be minimised by adherence to Forests and Soil Conservation guidelines.[77]
Soil structure	• Reductions in organic matter in litter layers through increased decomposition in felled areas.[78] • Compaction to the soil from use of heavy machinery, particularly along roadsides or log stacking areas.[79] • Trash left from short rotation forestry has been shown to improve some soils, through added biomass and increased soil biological activity.[80]

Table continued...

Landscape character	• Felling patterns can reinforce or, conversely, damage local landscape character.[81] The most appropriate scale of felling depends on the scale and nature of the landscape and whether this is being considered from outside or inside the wood/forest. Thus, small-scale fellings may work well from the point of view of a walker within the wood but, in a distant view, add nothing to the visual diversity of the scene. Large-scale fellings may work well in bold large-scale landscape panoramas, but seem out of place to the walker going through them. • The rate of change is also critical to the landscape impact of felling patterns; the same total area felled over several years may have a different impact to where the felling is done all at the same time. • Loss of individual trees in open landscapes can also have significant effects on landscapes, cf. the change in character of much of the lowlands following the loss of hedgerow trees over the last 40 yrs.
Historic features	• Ancient trees, and specimen trees in historic parkland, may have historic and landscape value in their own right..[82] • Felling can be beneficial in removing trees that may be causing (or will cause in future) damage to or obscuring other historic features above or below ground.[83] Equally, ill-planned felling and extraction may damage such features.

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14 Withdrawal of management

Context

14.1 This chapter considers the implications of a significant drop in the level of agricultural activity across a block of land (several hundred hectares in the lowlands, several thousand hectares or more in the uplands). Withdrawal of forestry management has not been included here because:

a) it is already part covered in the chapter on 'Tree felling and woodland clearance'.
b) it tends to lead to less immediate changes - there may already be long periods in a forestry cycle when little is done.
c) withdrawal of forestry management is less likely to lead in the short to medium term to large-scale changes in the nature or composition of forest habitats and species, unlike the case for agriculture.

14.2 Management has been withdrawn for 'rewilding' purposes on only a small number of areas in England, and only relatively recently. Many of the anticipated impacts are slight at present. Most of the evidence for this chapter has been extrapolated from experience in other countries, or from an understanding of natural processes.

14.3 Where management has been withdrawn due to 'abandonment', evidence is also sparse within an England context. True abandonment would imply that no farming or forestry activity is being carried out, and that no support payments are being drawn from Defra. Thus, the land may not be identified on the Rural Land Register under any management category. For this reason it is not possible to give an accurate estimate of the area that has been left unmanaged.

Current practice

14.4 The vast majority of England is a cultural landscape shaped by thousands of years of human activity.[1] The wildlife and habitats that we value have survived in association with often long-established management regimes, from chalk grassland and coppice woodland to grazed uplands. Past and continuing management has developed the scenery that people associate with particular regions - the stonewall patterns of Derbyshire, the Chalk downs, the Cotswold beechwoods; and we value the traces of former land-use as part of the historic environment. For most of the land, most of the time, farming and forestry have been the dominant activities shaping its appearance and composition.

14.5 Significant withdrawal of agricultural and forestry management might be part of a deliberate policy for some: landowners, including Natural England on some of its reserves, have chosen to allow more 'natural' habitats to evolve, to explore how past and present management do affect the landscape and wildlife. On a relatively small scale there are already various woodland and some upland areas that have been under minimum intervention (no active management) for some decades.[2]

Industry trends

14.6 There has been discussion on taking a 'minimum intervention' approach forward on a larger scale - sometimes referred to as 'rewilding'.[3, 4] Often such discussions are associated with the use of free-ranging large herbivores[5, 6, 7] and possible species re-introductions.

14.7 There is also the possibility that agriculture might be scaled down/withdrawn from some areas of land due to lack of profitability, or the inability of the land manager to integrate a particular area into any of the surrounding enterprises. This is already a concern in some parts of the continent and possibly in parts of the English uplands.[8] An analogous process is happening on parts of the coast in England through managed re-alignment,[9] where similar questions arise over the benefits and dis-benefits of completely removing agricultural (and sea-defence) management and leaving the future of such areas to natural processes. It could be argued that this is a very deliberate form of management.

14.8 For current incentives, advice and regulation for landowners, see Annex I to this chapter.

Key impacts

14.9 In the majority of cases, habitats will not revert to their original wild state, but will develop from their current starting point. Some of the changes resulting from allowing 'natural processes' a freer rein may lead to more diverse and interesting, albeit different, landscapes and wildlife.[10] There could be benefits for carbon storage and the creation of new areas for access and recreation.

14.10 One aim of deliberate 'minimum intervention' is the development over large areas of new mosaics and species assemblages. Even if conventional farming is withdrawn from such areas, domestic stock may still be used as replacements for the lost natural herbivores.[11, 12] Although the driving force has come from the biodiversity side, there may be potential benefits in carbon storage, recreation and tourism from such areas. There may also be potential improvements in water quality and flood mitigation deriving from enhanced interception of agricultural inputs[13] and increased vegetation cover,[14] respectively.

14.11 The alternative situation is where farming is significantly scaled down or abandoned for other reasons - including changing agricultural support, changes in the market for livestock or breakdown of local communities or ways of life. Historically, this happened between the 1920s and 1980s on some of the Dorset heathlands due to military use during the war, poor agricultural profitability and fragmentation caused by development.[15] Areas subject to such true abandonment are difficult to identify on a national scale. There are some places where the intensity of production has been substantially reduced so that some indication of the implications of complete withdrawal can be identified. In practice, most examples stay just within the definition of extensive agricultural systems because of the reliance in part on agricultural grants for support. An example of this is the Knepp Estate in Sussex.[16]

14.12 The various potential benefits from agricultural withdrawal may be translated into direct benefits to the landowners through reduced costs (where enterprises are currently unprofitable), new sources of income (perhaps increased tourism) or grant support, for example for biodiversity gains.[17,18] There might be some benefits to water companies from reduced agricultural nutrients in water supplies. There are also potential increased costs/reductions in income - the direct loss of production income, and loss of Single Farm Payment if Good Agricultural and Environmental Condition rules are compromised, for example GAEC 12: Agricultural land which is not in agricultural production.

14.13 Environmentally, there are potential gains and losses which are likely to be site specific. A number of scenarios have been considered, for example in upland areas some less productive land may become abandoned, allowing managers to concentrate activities on more accessible and productive land in the valley bottoms. Whilst this might serve to enhance many moorlands in the short or medium term, it could have a detrimental effect on traditional hay meadows and other high value grasslands, which might become more intensively used as a result. In the early stages, for example, more management may be needed to get the landscape into a state such that there is more chance of the positive benefits emerging early on.

14.14 Current farm support payments and potential margins from active management are such that large-scale withdrawl of management in the lowlands, at first sight, seems unlikely. In some areas (particularly eastern England) livestock enterprises are only marginally viable and the land that was traditionally grazed is not worth using for arable land, or is protected from conversion to arable under Environmental Impact Assessment (EIA) regulations[19]. These areas are already in danger from the impacts of the loss of grazing, with the resulting loss of grassland habitats. There are also several high profile examples, for example the Great Fen Project in Cambridgeshire and the Knepp Castle estate in Sussex where, while the land is still under some management, this is moving away from farming in a conventional sense.

14.15 While reduced agricultural input may seem more likely in the uplands - Wild Ennerdale (Cumbria) provides an example of movement in this direction[20] - the land may still be very actively managed. For example, much of the moorland area of the North Yorkshire Moors, traditionally a sheep producing area, is now ungrazed due to the increasing difficulty of keeping sheep profitably on such land.[21]The relatively high financial value and level of interest in shooting has resulted in largely maintained levels of heather management by other means such as burning and bracken control programmes.

14.16 For further factual background to this section see Annex II to this chapter.

Summary of impacts

Biodiversity

14.17 Where management is withdrawn from agricultural land, there will be changes in terms of biodiversity. Whether these are judged to be desirable or unacceptable will depend on the particular area concerned, as well as the particular changes that ensue.

14.18 With the substantial removal of grazing, it is most likely that grassland and heathland areas will develop areas of scrub, ultimately becoming dominated by trees. Where this involves, for example, high nature value grassland or lowland heath, or the loss of mosaic habitats[22] currently maintained by low intensity farming, the result could be a loss of habitat of greater biodiversity value.

Resource protection

14.19 The reversion of arable land to grassland, scrub or woodland would have a positive impact on water quality (nutrients, pesticides and sediment), flood mitigation and freshwater habitats. This would largely derive from the increase in organic matter, immobilising soils and nutrients.

14.20 Increased tree cover may lower the water table, having a detrimental effect on lowland wetlands and raised bogs.

Greenhouse gases

14.21 Organic matter such as dense vegetation acts as a carbon sink.

Landscape

14.22 Landscape character would change to a more wooded aspect. Access may be enhanced or restricted, with areas becoming less accessible over time due to dense growth.

14.23 Key issues in managing the impacts are likely to be the area over which agricultural withdrawal takes place; the habitat(s) to be lost, whether the withdrawal is complete or whether some low-intensity use continues and how, or whether, the transition to the future state is managed.

Annex I Current incentives, advice and regulation

For the most part, the regulatory framework is based around limiting proposals for action[23]; it deals less well with situations where the cessation of activity (in this case farming) is the cause of potential changes.

- *Statutory designations*: On Sites of Special Scientific Interest (SSSI), including Special Protection Areas (SPA) and Special Areas of Conservation (SAC), where Natural England considers that management is needed to maintain favourable condition, then changing (stopping) various forms of management, including grazing, could fall within the definition of Operations Likely to Damage, an offence under *Wildlife and Countryside Act (1981)*[24] and the *Countryside and Rights of Way (CRoW) Act (2000).*[25]
- Changes that were considered damaging to scheduled ancient monuments would be subject to consultation with English Heritage.
- Any detrimental changes to water quality or quantity following from a change of land-use would need to be considered by the Environment Agency. The Catchment Sensitive Farming (CSF) Initiative provides free advice to farmers and land managers on all issues relating to water management and soil protection on land within river catchment areas.
- *Cross Compliance*: Land currently receiving Single Farm Payment must comply with GAEC requirements. 'Eligible land which is not in agricultural production' must be managed to avoid scrub encroachment and weed infestation unless it is being managed as part of a habitat creation programme (GAEC 12).[26]
- *Animal health and welfare*: If free-ranging herbivores are involved, then welfare legislation applies, particularly but not exclusively to domestic stock should these be seen to be suffering. In the event of a major animal disease outbreak, for example foot and mouth, any large herbivores would be subject to emergency control measures. This is currently the situation with wild animals, for example with respect to foxes and rabies.
- *Forestry incentives and regulation*: It is unclear whether, if trees were to spread naturally over an area as a consequence of reduced grazing, this might also require an EIA from a forestry point of view if no grant were involved. A forestry EIA determination would be required[27] (depending on the extent and location of the spread) if grant were sought for the regeneration. Compliance with the UK Forestry Standard and Guidelines (see chapter on 'Woodland Creation') would then also be needed.[28]

Annex II Impacts on the environment of abandonment or rewilding

Table 16 Impacts on the environment of abandonment or rewilding

Habitat quality and diversity	Removal of management can have a number of potential effects on existing habitats, depending on previous management, location and habitat type: • Depending on grazing levels, there is potential loss of open habitats (grassland, heath, some moor, fen and bog) or changes in their structure and species composition.[29] • There may be creation of new habitats/habitat mosaics and shifting patterns of habitats. • There is potential for initial increased uniformity of habitat, particularly on small sites, because of similar successional trajectories; but with greater potential heterogeneity over longer periods and timescales. In the same way, much common and downland scrubbed up after the decline of rabbits in the 1950s. • There is potential for increased fuel load if large areas of bracken or on some sites mature heather develop, leading to more intense wildfires, for example Fylingdales Moor in 2003.[30]
Species abundance and diversity	• There may be losses of species from current locations, but opportunities for others to increase abundance or range. • There is potential for spread of invasive species currently checked by agricultural management (such as Himalayan balsam).
Water level control	• Increased retention of rainwater and consequent flood mitigation further downstream.[31] • Natural channel development.
Sediment loads in water	• Changed and probably reduced erosion patterns, with increased and more complex vegetation cover along watercourses. Vegetated cover should lead to greater soil stability.[32]

Table continued...

Nutrient loads in water	• Reduced chemical inputs to catchments leading to less risk of chemical contamination of water bodies, plus increased buffering of runoff and filtration of nutrients.[33]
Pesticide control in water	• Depending on whether the unmanaged land was arable or grassland, there is the likelihood of lower nutrient inputs.[34]
Other pollutants	• Potential risk of bacterial contamination of water courses from dead animals if fully 'natural grazing ' were adopted. This is unlikely given current welfare legislation. In addition, stocking levels are likely to be lower than under agricultural grazing, with consequently fewer contamination risks.
Greenhouse gases	• Gradually increasing carbon sequestration on most sites, but potentially increasing fire risk.
Soil stability (erosion)	• Reduced cultivation, drainage and impacts of heavy stocking should lead to reduced erosion risk under normal conditions.
Soil structure	• Reduced organic matter degradation and disturbance due to cultivations should allow a build-up of organic matter and nutrients within the soil matrix.[35]
Landscape character	Landscape character is likely to change in positive and negative ways: • Development of new landscape features, for example natural water channel development (meanders etc), more scrub and native woodland. • Landscape heterogeneity is likely to be on a larger scale than is maintained by agricultural activity. • Potential loss of traditional landscapes; the new patterns created might take time to become accepted, for example concerns about the spread of 'unsightly' scrub on open grasslands,[36] heathlands and moorlands.[37] This may impact on the short-term value to tourism of some traditional landscapes. • Reduction in the 'human' element of the landscape. The historic environment may be adversely affected: • Obscuring/deterioration of landscape scale patterns such as fields. • Physical disruption of features by tree and shrub growth.[38] • Potentially reduced access to features if scrubbed over. • Loss of historic meaning of the landscape (albeit a new meaning will start to develop).

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