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).

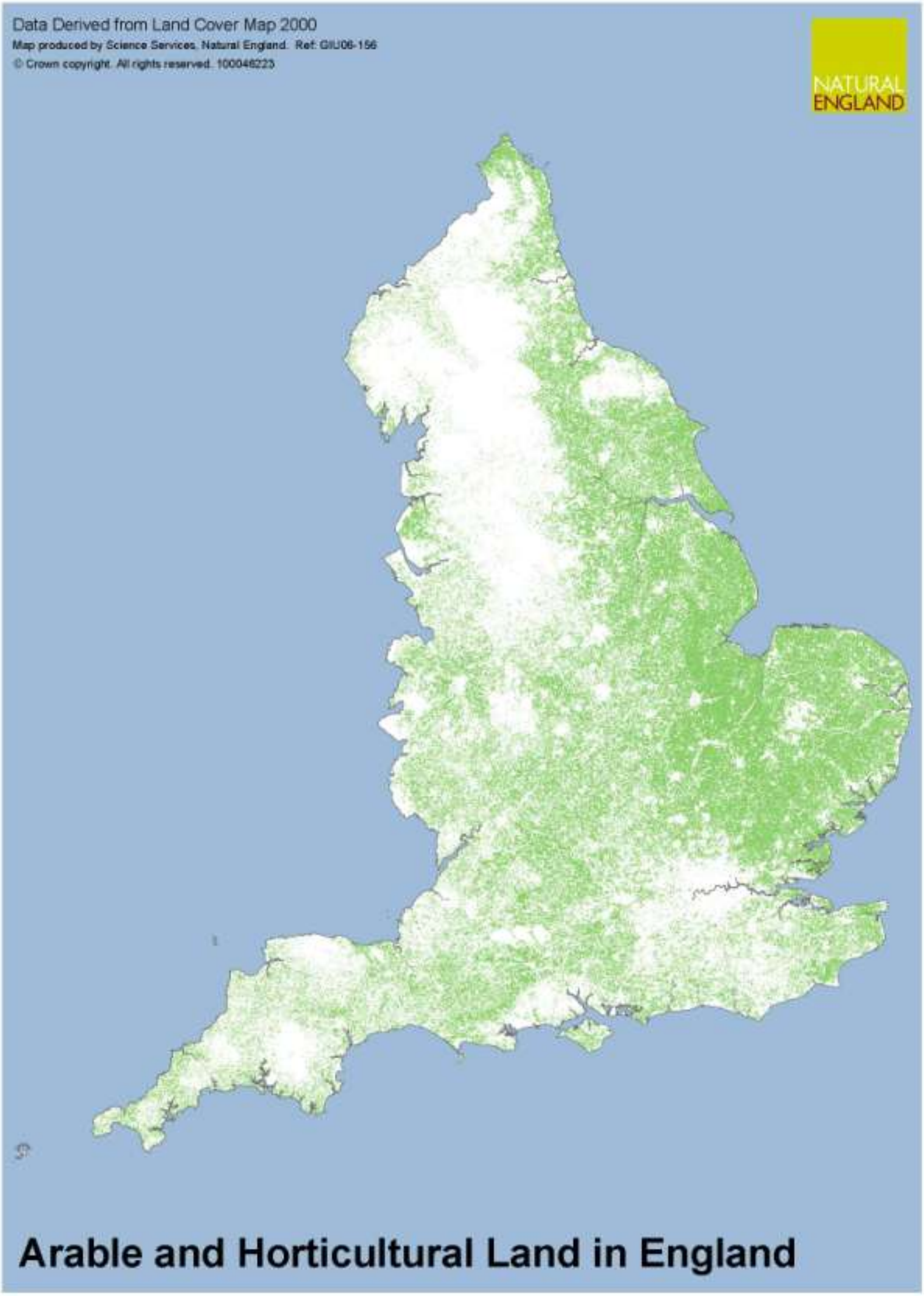

Figure 1 Land identified by Land Cover Map 2000[11] as arable or horticultural land in England

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.

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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.

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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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