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A Review of UK Agricultural Biofuels: Potential Effects on Birds and Knowledge Gaps for Bird Conservation in the UK

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A report carried out by the British Trust for Ornithology

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1. EXECUTIVE SUMMARY

1. On the subject of bioenergy, an enormous field of research is dedicated to questions of feedstock suitability, production economics and environmental efficiency. This report presents a research-focused and up-to-date account of the potential effects on birds of the developing biofuels industry in the UK, with specific reference to agricultural crops. The implications of biofuel crop production in the UK (primarily to produce liquid bioethanol or biodiesel from starch or oil) on critical resources for birds are identified along with priority areas for future research.

2. Calculations on the viability of crops to be produced as legitimate bioenergy crops are complex and require accurate assessments of inputs, emissions and energy costs throughout the complete cycle of a crop's production and processing time. Gallagher (2008) further emphasises a need to accurately assess the indirect costs of changes in land use, affecting working practice (energy costs) and the environment. These uncertainties mean that accurate predictions of future land-use are difficult to ascertain. The UK government predicts that bioenergy crops could occupy some 1·1 million ha by 2020 with increased demand for additional areas of land for cultivation.

3. Among current conventional agricultural crops, oilseed rape, wheat and, to a lesser extent, sugar beet appear to have the highest potential for large scale production of biofuels. Some sources predict that agronomic circumstances or effects of competition on the world market will limit any future expansion in the UK, of either oilseed rape or sugar beet. For wheat, expansion may be limited by demands on this crop to produce food.

4. Oilseed rape can provide nest sites and high densities of summer and winter food for birds. A number of studies report elevated densities of birds associated with oilseed rape, at least relative to winter wheat, which may thus provide the potential to raise the carrying capacity of some crop rotations for some bird species. These species include a number currently of high conservation concern in the UK, such as Linnet, Yellowhammer and Reed Bunting. There is a general lack of data on whether rape affects breeding productivity of farmland birds. In addition, the role of oilseed rape in mixed rotations warrants analyses to quantify optimal configurations of cropped habitats for birds, weed control and reduced chemical leaching.

5. Sugar beet has the potential to attract high densities of seed-eating birds in winter, but this resource is inconsistent as weed seed densities vary widely from crop to crop. For sugar beet, the main limitation is the short period during which stubbles become available to birds, mainly between early and mid winter. Beet stubbles are frequently ploughed in soon after harvest as beet tends to be followed by winter-sown cereals and so offer only a very narrow window for their use.

6. The value of most of the non-cereal, spring sown crops (rape, beet, beans) may be in the scope for manipulating the preceding over winter stubbles in such as way as to provide additional seed resources for birds in late winter. Exploring how cultivation techniques during the temporal transition between beet stubbles and the following crop affect seed availability would be an interesting and potentially beneficial area of research.

7. Cereals will probably remain one of the dominant commodities grown in the UK for the forseeable future. Its structure and management are generally considered hostile to most bird species and overall the crop is avoided in relation to its widespread availability.

8. The scale of biofuel expansion in the UK is difficult to predict but knowledge is lacking in several relevant areas concerning delivery of biodiversity targets for birds. These include: knowledge of the character and scale of land likely to be replaced by any potential biofuel crop expansion (both in the UK and more widely across Europe); whole-crop systems (e.g.

optimising crop rotations); effects of soil and crop management (fertilizers, pesticides and cultivation) on birds and their ability to access food and provision food to their young. The Gallagher Review underlines the need for improved data on the indirect consequences of biofuel demands on land-use issues. At both international and domestic levels the imperative is to identify and characterize land under threat of replacement by bioenergy crops. In the UK this means especially Grade 3 and 4 land. In the UK and abroad there is an urgent need to define the year-round character and scale of ‘idle’ and ‘marginal’ land. For biofuels derived from conventional crops, the net impacts on birds will depend on the way crop rotations will change in terms of their configuration, to allow spatial and temporal heterogeneity to exist. The potential to optimise crop rotations (including rested, fallow land) for agronomic and environmental benefit needs to be fully re-assessed.

2. INTRODUCTION

2.1 Aims

On the subject of biofuels and bioenergy, an enormous field of research is dedicated to questions of feedstock suitability, production economics and environmental efficiency. In the UK, detailed reviews have adequately analysed the complexity of the field, in an objective manner (Turley *et al*. 2002 and 2008). Meanwhile the '2nd generation' lignocellulose crops have also been the subjects of considerable recent research (e.g. Haughton *et al*. 2009). The present report assesses the current 'direction' that the biofuels industry appears to be moving in, specifically with respect to the potential for conventional arable crops to be grown as biofuel crops in future, primarily to produce liquid bio-ethanol or bio-diesel from starch or oil. The report identifies implications of agro-fuel crop production for availability of critical resources for birds in the UK and outlines potential priority areas for future research. Implications for birds of woody biomass or woodfuel harvested for energy / heat generation, such as short-rotation coppice and *Miscanthus*, are not discussed in this report, these forming a distinct set of questions.

2.2 Background

Across the world there is now huge interest in the growing of bioenergy crops for power / heating or fuel from either plant biomass or suitable plant derivatives (*e.g.* Turley *et al*. 2002, 2008). The perceived benefits are strategic and environmental as countries seek solutions to the long-term delivery of their energy needs, as well as economic, being worth the equivalent of around 33 million Euro worldwide in 2008 in a rapidly growing market (www.lifescience-online.com). In 2002 the European Union accepted ratification of the 1998 Kyoto Protocol of the United Nations Framework Convention on Climate Change and set targets for reduced greenhouse gas (GHG) emissions (UN 1998, UN 2007+). Targets were set in 2007 to achieve a minimum 20% reduction in GHG by 2020, relative to 1990 (Anonymous 2007). Within the debate, 'home grown' renewable fuels were seen as having the potential to contribute towards reduced atmospheric emissions of GHG that the burning of fossil fuels can exacerbate. Some calculations suggest that the 'lifecycle' production and use of biodiesel, for example, produces up to 80% less carbon dioxide and almost 100% less sulphur dioxide than for fossil fuels (Hill *et al*. 2006). As such, bioenergy crops may provide a source of energy that can be used in a carbon negative manner, especially where carbon released during combustion may be significantly less than the carbon absorbed by the plant material over the plant's lifecycle. For some perennial crops, approximately one third of the carbon absorbed by the plant during its life is sequestered within the intact root system, at least during the plant's harvestable lifetime (McLaughlin & Walsh 1999). In addition, there are further perceived benefits of home-grown sources of bioenergy potentially reducing the dependency on the source and stocks of current fossil fuel reserves.

2.3 Areas of Uncertainty

Arguments such as those above, lie at the foundation of policy decisions, at both national and international level, to drive forward the rapidly developing bioenergy industry abroad (*e.g.* Turley *et al*. 2002, Hill *et al*. 2006, Tilman *et al*. 2001, 2006) and in the UK (Biomass Strategy Defra 2007a, Natural England 2008). The European Commission has proposed that EU members should move towards indicative targets of 5.75% replacement of fossil fuels with biofuels by 2010. Yet despite this momentum, the agronomic and environmental benefits of bioenergy crops are far from certain (Gallagher 2008), and in fact frequently and strongly debated (*e.g.* Ulgiati 2001, Kim & Dale 2005, Crutzen *et al*. 2008, Milder *et al*. 2008, Koh & Ghazoul 2008, Searchinger *et al.* 2008). One key area of debate focuses on definitions of the true lifetime costs and benefits of bioenergy crops for reducing emissions. Hill *et al*. (2006) for example, concluded that compared with ethanol, biodiesel releases into the atmosphere just 1.0% and 8.3% nitrogen and phosphorus respectively, per net energy gain. Both Crutzen *et al*. (2008) and Searchinger *et al*. (2008) emphasise that far more nitrous oxide (N_2O) is produced in processing and burning bio-diesel compared to either bio-ethanol or fossil fuels. Nitrous oxide is considered to be close to 300 times more potent as a greenhouse gas than CO_2

(Turley *et al*. 2002). Such calculations require accurate assessments of inputs, emissions and energy costs throughout the complete cycle of a crop's production and processing time. Gallagher (2008) further emphasises a need to assess accurately the indirect costs of changes in land use for example, effecting working practice (energy costs) and the environment. By their nature, such calculations are highly complex, such that consistent conclusions are often difficult to finalise as regards a crop's absolute or relative potential to be a viable energy source. Importantly, this uncertainty undermines a second key area of debate, namely the predictive process for determining future demand for commodity crops (leading to competition for land and water resources) and associated changes to patterns of land-use (Berndes 2002). This impacts upon the third key area of debate, namely our inability to predict and quantify changes in land-use, let alone predict and quantify direct and indirect effects of land-use for bioenergy crops on biodiversity (*e.g.* Wilson *et al.* 2004, Green *et al.* 2005, Firbank 2008). Koh & Ghazoul (2008) venture that, in addition to the uncertain rationale that biofuels may substantially reduce carbon emissions, the environmental and societal costs of biofuel use will include threats to forests, biodiversity and food prices, as well as increased competition for water resources (see also Berndes 2002).

In conclusion, while the Gallagher Report (Gallagher 2008) recommends a 'slow down' in the production of liquid biofuels crops, and despite areas of uncertainty, the UK government predicts that bioenergy crops could occupy some 1·1 million ha by 2020 (Biomass Strategy Defra 2007a). Clearly this could have two effects: i) to increase demand for additional areas of land for cultivation (with costs incurred by natural and semi-natural populations of plants and animals) and, ii) it could alter the proportions of conventional crops grown, as required to serve the end-markets for both fuel and food provision, with knock-on effects in other countries, due to import demands.

3. BIOENERGY CROPS IN EUROPE

Theoretically, given sufficient processing, almost any crop could be used to generate energy, either as biomass and burned to generate heat or electricity or refined as biofuels (*e.g.* bio-diesel or bio-ethanol) for use in engines or generators. Biomass crops typically include perennial crops with permanent root-stocks that allow repeated harvesting over time. Examples include short-rotation coppice (SRC; willow *Salix* spp. or poplar *Populus* spp.) or perennial monocotyledons such as *Miscanthus* spp., reed canary grass *Phalaris arundinacea* or switchgrass *Panicum virgatum* in the US. For biofuels, Turley *et al*. (2002), identify three common ‘feedstocks’ for producing liquid and gaseous fuel from ‘agrofuels’: sugar, starch and cellulose. Crops high in sugar or starch may be grown for fermentation to produce ethyl alcohol; plants that contain high amounts of vegetable oil may be grown to produce diesel oil. In addition, cellulose (so called 2nd generation biofuels), from lignocellulose in wood or straw, from crops such as SRC, *Miscanthus* or cereals, may also be converted into biofuels, such as ethanol via the fermentation of plant carbohydrates, though the plant material may simply be burnt directly as a biomass crop.

The 2nd generation lignocellulose, biofuel crops or biomass crops, have been the subject of a considerable body of research effort (Howes *et al*. 2002, Tubby & Armstrong 2002, Defra 2004, Finch *et al*. 2004, Semere & Slater 2005, Sage *et al.* 2006, Defra 2007b), more recently via the *Rural Economy and Land Use* (RELU) programme (Haughton *et al*. 2009, Lovett *et al*. 2009). While the details of some of this research are still to emerge, the consensus for SRC at least is promising on several fronts (R. Sage, BOU 2009). For example, net benefits for CO_2 emissions may be much higher than for annual agrofuel crops and reduced leaching is considered more likely of perennial biomass crops due to the longevity of the root system (*e.g.* 7-25 years, Powlsen *et al*. 2005, Haughton *et al*. 2009). SRC willow, as a native species (unlike *Miscanthus*) is perhaps especially promising and ‘acceptable’ in providing net energy gains at apparently relatively low net costs in terms of resource protection and biodiversity (BOU 2009). In terms of land-use issues, Lovett *et al*. (2009), calculate that up to 3.1 million ha of Grade 3 and 4 land currently exists in the UK with suitable growing conditions for either SRC or *Miscanthus* (see also Natural England 2008). This implies minimum impact on current conventional crops grown for food use and normally grown on Grade 1 and 2 land. Neither Haughton *et al*. (2009) nor Lovett *et al*. (2009) compared the levels of biodiversity associated with SRC/*Miscanthus* with land typical of Grade 3 and 4 land (Appendix 1), but this comparison should be carried out as a matter of urgency, before any significant replacement of land takes place. Such an analysis would benefit from detailed studies of land character, distribution and scale. Anderson *et al*. (2004) point out that there may even be significant biodiversity benefits in adding certain types of bioenergy crops, such as cereals or rape, into areas dominated by either rotational or especially permanent grassland. This is because small areas of arable land inserted into a grassland-dominated landscape can have a relatively large positive effect on the abundance of some farmland bird species, especially seed-eating species (Robinson *et al.* 2001).

Tuck *et al*. (2006) derived maps of the potential distribution of 26 promising bioenergy crops in Europe, based on simple rules for suitable climatic conditions and elevation. The impact of climate change scenarios on the potential future distribution of these crops suggested that the potential distribution of temperate oilseeds, cereals, starch crops and solid biofuels was predicted to increase in northern Europe by the 2080s, due to increasing temperatures. Powlsen *et al*. (2005) considered that at least in the short-term, liquid biofuels from conventional annual crops were an easy option as they require ‘little change to either agriculture or transport infrastructure’. According to Tuck *et al*. (2006) potentially suitable crops include, for starch: wheat *Triticum* spp., barley and potatoes; for sugar: sugar beet *Beta vulgaris* (sugar cane in the tropics); for vegetable oil: oilseed rape *Brassica napus* and sunflowers; and for cellulose: cereal straw. Hemp *Cannabis sativa* also has potential as an ‘agrofuel’ (annual agricultural crop for biofuel end-use) being a crop requiring low inputs of herbicides or pesticides.

Biofuel crops of immediate interest are those with the greatest potential for large-scale commercial fuel production, which may result in significant changes in land-use or air and water resource quality.

For this reason, in the present report, oilseed rape, sugar beet and cereals (mainly wheat) are examined in more detail below. The economic and agronomic rationales for growing bioenergy crops in the UK are analysed and reported in detail by Turley *et al*. (2002, 2008), and only summary accounts are presented here.

3.1 Liquid Biofuel Crops in the UK

3.1.1 Oilseed rape

3.1.1.1 Bioenergy and agronomy (summarised in Table 1)

Oilseed rape has become a common crop across the UK over the last 30 years (Chamberlain *et al*. 2000). Oilseed rape is associated with a major trend in recent change in cropping patterns that have involved large increases in areas of wheat and rape at the expense of spring crops, barley, bare fallow and grass. The production of oilseed rape on a large scale in Britain began in 1973. The crop forms an integral part of a cereal rotation and covers on average more than 400,000 ha (9% of the cropped area). Rapeseed has traditionally been used to produce oil for food products, cosmetics or industrial end-use. Turley *et al*. (2008), illustrate that oilseed rape represents a high risk of nitrate leaching loss, compared to cereals or most other crops, except root crops such as potatoes.

According to Turley *et al*. (2002) oilseed rape is the crop most likely to provide large volumes of competitively priced biodiesel in the UK, given a favourable climate for high yields and seed quality. The UK is the third largest producer of rape in Western Europe and rape oil production is estimated at 450,000 tonnes per annum. Rapeseed oil is used in the manufacture of biodiesel, normally to combine with fossil-fuel diesel at varying ratios from 2% to 20% biofuel content. Since 2005, prices of rapeseed oil have been at high levels because of increased demand for biodiesel, making the manufacture of biodiesel from oilseed rape more viable. Apparently, rapeseed oil is the preferred oil stock for biodiesel production in most of Europe, partly because rapeseed produces more oil per unit of land area than other oil sources, such that biofuel production has grown rapidly, especially in France and Germany (Turley *et al*. 2002). A major concern over the use of rapeseed for use as biodiesel is N_2O production which, as a potent greenhouse gas with 296 times the global warming potential of CO_2, is a consequence of high nitrogen fertilizer inputs. Despite its potential as a biofuel crop, Turley *et al.* (2002) consider significant future expansion unlikely due to agronomic constraints, but demand and commodity prices can alter the balance. It is likely that any expansion in the oilseed area would occur in the areas currently dominated by rape, for reasons of economics and competitiveness, perhaps with shorter rotations between rape crops, at the expense of wheat or cash crops depending on soil type, or at the expense of fallows, existing former set-aside land or uncropped land that may be required for agri-environment schemes. Without biofuel cropping, oilseed rape is considered as one of the most profitable break crops for UK farmers.

3.1.1.2 Birds and biodiversity (summarised in Table 1)

There are many anecdotal accounts of the use of rape by many bird species both as feeding and nesting within the crop (also Bradbury *et al.* 1990). They include Grey Partridge *Perdix perdix*, Swallow *Hirundo rustica* (over the flowering crop), Dunnock *Prunella modularis*, Blackbird *Turdus merula*, Grasshopper Warbler *Locustella naevia*, Reed Warbler *Acrocephalus scirpaceus*, Sedge Warbler *A. schoenobaenus*, Whitethroat *Sylvia communis*, Willow Warbler *Phylloscopus trochilus*, House Sparrow *Passer domesticus*, Greenfinch *Carduelis chloris*, Linnet *C. cannabina*, Yellowhammer *Emberiza citrinella* and Reed Bunting *E. schoeniclus.* There has been limited study of the use of rape as a nesting habitat but species such as Marsh Harrier *Circus aeruginosus* and Montagu's Harrier *C. pygargus*, Skylark *Alauda arvensis*, Yellow Wagtail *Motacilla flava*, Sedge Warbler, Whitethroat, Yellowhammer, Reed Bunting and Corn Bunting *Miliaria calandra* have all been recorded in the crop (Snow & Perrins 1998). In terms of supporting higher densities of birds, relative to neighbouring crops, and in the context of a crop rotation, there is evidence that rape is associated with increased numbers of several species of conservation concern such as, for foraging only: Song Thrush *Turdus philomelos*, Tree Sparrow *Passer montanus* and Linnet, and for purposes of foraging and nesting: Reed Bunting, Corn Bunting and Yellowhammer (*e.g.* Stoate *et al*. 1998, Moorcroft *et al*. 2002, Brickle and Peach 2004, Gruar *et al*. 2006, Henderson *et al*. 2009). In winter, crops are widely exploited by Woodpigeons *Columba palumbus* and Skylarks (both of which graze on the crop), Song Thrushes, finches and buntings, and oilseed stubbles are strongly preferred by seed-eating species, in some cases to the virtual exclusion of other field types (Wilson *et al*. 1996). Moorcroft *et al*. (2002) and also found rape fields that were left fallow after harvest (*i.e.* stubble fields) supported high wintering densities of many species of granivorous birds, though these stubbles tend to be cultivated early in the winter and the benefits are short-lived. Higher seed abundance was associated with greater occupancy of stubbles by Linnet, Grey Partridge, Yellowhammer, Reed Bunting and Corn Bunting (Vickery *et al.* 2002). Vickery *et al.* (2002) found that weed seeds on the soil surface of crop stubbles were most abundant in sugar beet and oilseed rape. Indeed, one key factor in determining use of stubbles by birds is the density of weed seeds present (Wilson *et al*. 1996, Robinson & Sutherland 1999, Moorcroft *et al*. 2002), including rape seed from the preceding crop, as well as Polygonaceae and Chenopodiaceae seed (Vickery *et al*. 2002). Relative to winter wheat or sprayed set-aside fallows, Henderson *et al*. 2009 found that oilseed rape was associated with higher summer foraging densities of thrushes (Blackbird and Song Thrush), Whitethroat, Reed Bunting and Yellowhammer, as well as Linnet in following crop in winter (exploiting the rape seed: cf., Vickery *et al*. 2002).

Oilseed rape provides suitable habitat for Reed Buntings both to nest and to forage in and as such has probably buffered some of the long-term decline in population size and range associated with this species in the UK (Gruar *et al*. 2006). Gruar *et al*. (2006) identified oilseed rape as “one of the most important breeding season habitats for Reed Buntings in lowland Britain, providing a relatively rich source of seed and invertebrate food and possibly protection from nest predators”. Occupancy rates and densities of Reed Buntings were approximately four times greater in oilseed rape than in cereals or set-aside. Many Reed Bunting nests are lost to agricultural operations. While first broods in rape are relatively safe, up to 50% of second brood nests can be lost to harvest operations by swathing. Gruar *et al*. (2006) suggest harvesting by desiccant would avoid most of these losses, which could amount to as much as 25% of the species’ annual productivity (Burton *et al*. 1999, Crick *et al.* 1994).

Henderson *et al*. (2009) found that in mixed rotations, a higher proportion of non-cereal crops and oilseed rape in particular, can significantly increase the carrying capacity of a rotation at the farm-scale, to support higher densities and breeding populations of farmland bird species.

For one species, the Woodpigeon *Columba palumbus*, oilseed rape has been a major factor in population increase and its current status as a major pest of this crop. Following the introduction of oilseed rape into Britain in the early 1970s, over-winter mortality from starvation declined and the number of young produced each summer now has a more important effect upon woodpigeon population size (Inglis *et al.* 1997). The Woodpigeon population in Britain has undergone a rapid and sustained increase since the mid 1970s (Baillie *et al*. 2009). Oilseed rape is the preferred winter food of Woodpigeons and they forage more efficiently on oilseed rape fields than clover–rich pastures, their original, principal food source on farmland, and the main alternative source of food in winter (Inglis *et al*. 1997). Woodpigeons are also a serious economic pest of horticultural brassica crops. They cause damage that is very difficult to control (Macdonald 2005, Tayleur & Henderson 2007) and while the scale of this additional ‘cost’ is difficult to quantify, it is most serious for oilseed rape amongst the range of potential biofuel crops currently available.

Intensive monoculture management of oilseed rape is likely to reduce overall abundance and bird richness for a given area. Caveats are provided by Brickle and Peach (2004), and Siriwardena *et al*. (2000) who emphasise the importance of uncropped habitats for birds that may be threatened where extra demands are placed on farmers to produce higher yields. For example, Brickle and Peach (2004) suggested that rank and emergent vegetation provided Reed Buntings with greater nest concealment and a richer source of invertebrate prey than agricultural habitats such as set-aside, cereals or oilseed rape. They suggest that the crop (rape), though covering large areas of land, is nevertheless sub-optimal for Reed Buntings. In winter, Siriwardena *et al*. (2000) concluded that features of intensive arable farming, including large areas of sugar beet, wheat and oilseed rape, tended to be associated with low frequencies of occurrence for nine to 11 farmland species. So while association and occupancy have been widely reported, generally intensive areas of crops including rape are linked to high inputs for weed and pest control, potential loss of semi-natural habitats and relatively low densities of birds.

Some species, such as Yellow Wagtail, Skylark and Lapwing *Vanellus vanellus* are uncommon as breeding birds in winter sown rape crops (Wilson *et al.* 1997, Mason & Macdonald 2000) due to the height and density of the crop structure in spring. Instead these species utilise low growing spring, non-cereal crops such as peas, beans, potatoes and sugar beet or weedy set-aside (*e.g.* Wilson *et al.* 1997, Mason & Macdonald 2000, Henderson *et al*. 2009). Hence rape may be considered as complementary within a mosaic of crops and uncropped habitats. The contribution of rape for birds must therefore be measured relative to replacement crops or habitats and the crop not added at the expense of uncropped habitats. Ideally, an appropriate balance of cross-compliance measures and agri-environment prescriptions should provide buffered protection against further increases in intensification, to allow the crop to contribute in a net beneficial way. Unfortunately, the quality, quantity and configuration of environmental measures have yet to be fully calculated for truly effective deployment (G. Tucker, BOU 2009).

3.1.1.3 Conclusions, implications of expansion of oilseed rape and further research

Overall, oilseed rape can provide nest sites, high densities of summer food (insects (Holland *et al.* 2002) and unripe seed (Moorcroft & Wilson 2000) and winter food, both as seed and as the crop itself (*e.g.* Skylark: Gillings & Fuller 2001), for a selection of species, including several of serious conservation concern on farmland in the UK. Productivity data throughout the growing season, of birds nesting either in or near to rape, are generally lacking for most species and from most studies and warrant renewed attention. As such, the crop harvest poses the greatest threat to later nesting attempts (Burton *et al*. 1999). This is one of several factors specific to oilseed rape. Others include high invertebrate densities and a complex crop structure, where the benefits need to be weighed against costs to birds (*e.g.* a tall, winter-sown crop unsuitable for ground-nesting birds). Other than productivity, the proportionate role of oilseed rape (amongst other crop types) in mixed rotations warrants varying-scale-dependent analyses to quantify optimal configurations of cropped habitats for birds, for weed control and for the control of chemical leaching. Other subjects requiring more detailed study are minimal tillage and spring tillage. Energy inputs for oilseed rape may be reduced by both methods, potentially with associated benefits for the soil fauna and the food chain. Calculations are needed to establish relationships between energy savings, soil management and the food chain.

3.1.2 Sugar Beet

3.1.2.1 Bioenergy and agronomy (summarised in Table 1)

In an extensive study of the suitability of sugar beet, Tzilivakis *et al*. (2004) found energy input was dictated largely by the energy associated with crop nutrition (beet also receives high inputs of herbicides). The smallest energy inputs per hectare related to organic crops or conventional crops grown on fertile soils. The greatest energy inputs were required for crops grown on sandy soil due to additional needs for irrigation and fertiliser applications, relative to low yields. According to Turley *et al*. (2002) the processing and transport costs of sugar beet are very expensive (also JNCC 2007). The UK sugar beet area reached 205,000 ha, the area of optimal production for the UK (limited by factory locations and growing conditions). In 2009, complete liberalization of the sugar market is expected, increasing exposure to low cost competition from outside the EU. Thus, in the UK there is unlikely to be scope for significant expansion, due to soil limitations for beet production (above) and competition for space within the rotation with potentially higher earning cash crops such as potatoes or root vegetables. The future of sugar beet as a long-term UK biofuel feedstock is therefore uncertain. See Gillings *et al*. (2009) for a wider discussion of the sugar beet industry and issues surrounding its production.

3.1.2.2 Birds and biodiversity (summarised in Table 1)

As a spring-sown crop, sugar beet is associated with providing breeding habitat for birds such as Lapwing, Skylark and Yellow Wagtail. Further benefits are possible for the preceding and post-harvest stubbles (see below; Summarised in Table 1). In spring, Skylarks for example require structurally diverse crop mosaics in order to make multiple nesting attempts without territory enlargement or abandonment. Structural diversity of field vegetation can be enhanced by adopting mixed rotations of winter and spring cereals, root crops such as sugar beet and grass (Wilson *et al.* 1997).

Beet stubbles have the potential to provide important winter-feeding resources for some farmland birds due to the remains of leaves and tops or the invertebrates that feed on them (Gillings *et al*. 2009). Beet stubble may support high densities of broad-leaved weed seeds, such as fat-hen *Chenopodium album*, that are common in the diet of many granivorous passerines (Wilson *et al*. 1996). Upon harvesting, a large volume of organic matter (leaves, tops) is ploughed into the soil, increasing the organic matter content of the soil and providing a more favourable environment for invertebrates such as earthworms (Gillings *et al.* 2009). Furthermore, the addition of farmyard manure as part of the sugar beet rotation can benefit soil invertebrates (*e.g.* Edwards & Bohlen 1996) with potential benefits for invertebrate-feeding birds such as plovers and thrushes. At times beet stubbles can attract high relative densities of birds. Vickery *et al.* (2002) report that in some years, but not all, finches, sparrows, thrushes and starlings were recorded in the highest densities on sugar beet in early to mid winter (although the vast majority of all stubble fields of all crops supported no birds at all; see also Robinson and Sutherland 1999). Vickery *et al.* (2002) point out that compared with winter barley, where *Chenopodium* and *Polygonum* seeds at harvest were 68 and 0 seeds per m^2 respectively, sugar beet had some of the highest numbers of seeds at harvest (1400 *Chenopodium* and 150 *Polygonum* seeds per m^2 respectively). One key factor in determining birds' use of stubbles is the density of weed seeds present (Wilson *et al*. 1996, Robinson & Sutherland 1999, Moorcroft *et al*. 2002), especially, Polygonaceae and Chenopodiaceae seed (Vickery *et al*. 2002). Despite this, winter barley was more often associated with consistently high densities of seed-eating birds than beet, probably due to lower late inputs of herbicides and more consistent availability of weed seeds. So sugar beet stubbles have the potential to produce high but unpredictable volumes of seed, and in some crops the seed densities are very low. These resources would undoubtedly be utilised by seed eating birds in winter, especially if higher average seed loads could be encouraged and tolerated within the crop on a regular basis (the subject of recent research M May pers comm., also Henderson and Holt 2009).

3.1.2.3 Conclusions and further study

Gillings *et al*. (2009) identify the main limitation to beet stubbles as being the short period during which they become available to birds, mainly between early and mid winter. Beet stubbles are frequently ploughed in soon after harvest as beet tends to be followed by winter sown cereals and so offer only a very narrow window for their use. This management practice severely limits the availability of beet stubbles during the late winter period, or the so-called "hungry gap" for birds when other resources are also low (Siriwardena *et al*. 2008). Given the potential of the crop to support high densities of weed seeds in the stubbles (which incidentally are also exploited by resident and migrant winter thrushes; Gillings *et al*. 2009), then in the regions in which it is grown, sugar beet could offer a serious winter resource for birds, should the two limiting factors (inconsistent seed resource and late winter provision) be resolved. For example, potentially, the cultivation of beet stubbles (or better, the stubbles preceding the drilling of beet) could improve the weed seed foraging resource for birds by bringing new seed to the surface from the seed bank below. If this practice operated over the protracted period of harvest, from early to late winter, then the value of beet stubbles for birds might be extended into the late winter period (though the beet crop may need to followed by a spring cereal). Data are needed from the period beyond December, to assess potential seed resources at that time. Exploring how cultivation techniques during the temporal transition between beet stubbles and the following crop affect seed availability would be an interesting and potentially beneficial area of research.

3.1.3 Cereals

3.1.3.1 Bioenergy and agronomy (summarised in Table 1)

Around 70% of the cropped area in the UK is allocated to cereal production, albeit with many applications of herbicides, pesticides, fertilizers, fungicides, molluscicides and growth regulators. According to Turley *et al*. 2008, the main UK starch bearing crops, suitable for ethanol production are wheat and potatoes (wheat having a higher starch yield than barley). Cereals incur relatively low transport costs and are suitable for low cost, long-term storage, which extends the seasonal availability of the product (sugar beet and potatoes are more seasonally available). Tzilivakis *et al*. (2004) estimate the Global Warming Potential of wheat to be similar to sugar beet so that in this regard, its potential as a biofuel crop is at least comparable with potatoes (see below) and sugar beet, and possibly oilseed rape. In the UK about 1.4 million tonnes of wheat are grown annually, but because of its value as a commodity, Turley *et al*. (2002) consider that probably no more than around 5% of the UK cereal crop would be available for bio-ethanol production (*circa* 435 thousand tonnes of ethanol), with the potential for additional wheat limited by rotational agronomy.

The UK's temperate climate is suited to growing cereals in quality and with high yields. Turley *et al*. (2008) illustrate that nitrate leaching from wheat is relatively low compared with potatoes (the highest) or oilseed rape, thus improving its credentials as a viable bioenergy crop (low environmental impact on water quality). Wheat is very demanding of nitrates (like oilseed rape) but relatively efficient in utilizing them (unlike oilseed rape where there have been serious concerns for leaching). Despite declines in the application of nitrates and phosphates on crops, due to improved advice and development of more efficient application measures, this complex area involving soil type, rainfall, compaction and soil management remains open for detailed study and research as regards consequences for birds and other organisms using crops. Wheat receives high doses of pesticides, over twice that of rape but less than sugar beet and especially potatoes (potatoes receive 3.5 times that received by wheat) (Table 1). Turley *et al*. (2008) outline the changing pesticide demand for wheat according to perceived risk, efficacy and legislation. Products that are increasing currently are those used for midge control. Herbicides, such as glyphosate, are initially and widely applied to create a sterile seedbed in early winter with follow-up spraying later in spring. As with all such inputs there are continuing issues relating to their potential impact, directly or indirectly, on non-target animals and water resources. These effects require careful and continuous research and monitoring, including focus on the success of measures in controlling and reducing the environmental impact of pesticides (Turley *et al*. 2008). The latitude for abstaining from, reducing or manipulating these inputs in other ways may be critical for improving the weed or invertebrate resource in cereal crops or stubbles, with pressures now being applied from legislation (listed products), costs of application and emphasis on integrated farming methods (see section 4).

3.1.3.2 Birds and biodiversity (summarised in Table 1)

Winter cereals and winter wheat in particular, are highly intensively managed crops, grown in swards of high density, and receiving repeated treatments of fertilizer and herbicides or pesticides. Winter sown cereal fields are generally avoided by most farmland birds in winter (Wilson *et al.* 1996) and summer (*e.g.* Crocker *et al*. 2001) with species occurring at very low densities. Winter cereal stubbles tend to support lower weed-seed densities than oilseed rape or sugar beet (Vickery & Atkinson 2003) and thus attract lower densities of seed-eating passerines (Evans & Smith 1994, Donald & Evans 1994). They may be available for longer periods over winter than rape or beet stubbles, since leaching is less of a problem for cereals and spring crops are more likely to follow winter cereals. In summer, winter cereals in particular create dense summer cover that restricts accessibility for birds seeking to nest and forage within the crop (Morris *et al*. 2004). Creating gaps in the crop cover has been shown to be effective in increasing the densities of nesting Skylarks in winter wheat by approximately two-fold, with chick productivity increasing by 50% (Morris *et al*. 2004). Henderson *et al*. (2009) found that reducing the proportion of winter wheat cover in a crop rotation (in favour of non-cereals and weedy set-aside) increased the carrying capacity of a crop rotation for year-round bird densities and breeding populations. They also reported that unsprayed crop treatments in summer supported higher densities of foraging seed-eating species, especially in the following winter, implying effects of summer herbicide management of wheat on the value of the preceding crop for foraging birds.

Winter cereals probably provide a more positive role as an integrated part of a crop rotation scaled appropriately to benefit nutrient control and biodiversity. For example, Stoate *et al*. (1998) made observations of Yellowhammers provisioning chicks to assess the use of foraging habitats in relation to availability. Cereal crops were increasingly used as they ripened and unripe cereal grain formed a major component of nestling diet. Stoate *et al*. (1998) suggest that farming systems that increase habitat diversity and reduce pesticide applications will benefit Yellowhammers and other farmland buntings (c.f., Wilson *et al*. 1996). Appropriate scaling of rotations will depend on the landscape context and the taxa of interest, let alone agronomic demands. But this area of difficulty for sustainable farming presents an obstacle to progress and potentially delivery of mitigation measures, and would benefit from close observational scrutiny.

3.1.3.3 Conclusions and further study

Cereals and wheat in particular, will probably remain one of the dominant commodities grown in the UK for the forseeable future. Its structure and management are generally considered hostile to most bird species and overall the crop is avoided, certainly in relation to its widespread availability. Apart from improving the effectivness of agri-environment scheme (AES) prescriptions, once again, detailed studies of crop rotations may provide the evidence-base for improved and optimised management of mixed–cropping, including cereals, for agronomic and environmental benefit. This is likely to be the case whether or not there are additional burdens on growing cereals for biofuels use. AES measures most specific to biofuels would be those that seek to retain over-winter stubbles and integrated areas of fallow land in summer, as these are most likely to counteract the negative impacts of increased crop production (summarised in Table 1).

3.1.4 Other potential crops: potatoes, maize and hemp

3.1.4.1 Potatoes

As a potential bioenergy crop, there is less information available for potatoes than the above crops. Turley *et al*. (2002) state that "the rates of ethanol production per unit area of crop are very similar for wheat and potato crops". Current systems of potato growing use large amounts of pesticides and fertilizers (Turley *et al*. 2008) and strategies such as employing a suitable crop rotation (to absorb nutrients and control weeds), reducing fertilizer use and adopting mechanical weed control would reduce costs, improve product quality and may reduce environmental damage (Vereijken & van Loon 1991). Management, however, makes potatoes an expensive source of ethanol on the basis of both cost and practicality (storage, transport).

For biodiversity (summarised in Table 1), spring-sown sugar/starch crops (potatoes, sugar beet) may provide benefits for farmland birds, but potatoes are under-studied in this regard. Only breeding Yellow Wagtails seem to have a strong preference for nesting in potatoes, which appear to provide especially suitable nesting sites (Mason & Macdonald 2000, Gilroy *et al*. 2008). According to Holland *et al*. (2002) potatoes may be poor in terms of providing summer invertebrate food for birds, relative to cereals or oilseed rape. Like sugar beet, the over-winter stubbles that precede spring-sown crops in some regions may provide important winter food resources for birds (Siriwardena *et al.* 2008) and the best opportunity to manipulate conditions for their benefit, especially where the stubbles are allowed to become weedy following a cereal or oilseed crop (Gillings & Fuller 2001, Moorcroft *et al.* 2002).

3.1.4.2 Maize

Few relevant data are available for maize in Europe or the UK but one system-based case study of biofuel production from maize concluded that the biofuel option on a large scale was not a viable alternative, based on economic and energy grounds (Ulgiati 2001). This suggests that in regions such as the UK where maize is less often grown, it is unlikely to be considered as a viable energy crop in the near future (but see crop-climate predictions for Europe by Tuck *et al*. 2006). Maize is an important staple food and fodder crop widely grown in Europe, but it has a bad reputation for requiring high inputs of fertilizer and a lot of irrigation. The crop is associated with high glyphosate and glufosinate-ammonium use as well as higher fertilizer inputs which may leach into the groundwater, polluting surface and drinking water (www.cordis.europa.eu: Article "Micromaize: More maize less fertilizer"). Anecdotal accounts suggest that the crop may be poor for birds, as a stubble and as a growing crop, although as a late-sown crop this offers opportunities for management of the preceding cereal stubbles.

3.1.4.3 Hemp

As a lignocellulose crop, hemp has been proffered as having viable potential, being very easy to grow and requiring few chemicals as it is competitive and naturally out-competes weeds. There are by-products too, such as, paper, fibre-material for clothes, biodegradable plastics and food and bedding for livestock that may make the crop more viable as a commercial venture. Apparently hemp as a biofuel is not as economically competitive as other sources of biomass, possibly because the industry in the UK is not set up to deal with it on a large scale. This is despite the number of high-value end uses such as food, cosmetics and various industrial applications. However, as a fast growing crop, requiring relatively little attention when growing, its potential to be included as a viable alternative feedstock is real (www.biodieselmagazine.com 2009). All research and implementations of hemp for biofuel has centred on the US and little, if any, research in Europe has looked at hemp critically and objectively in terms of its environmental credentials. We are unaware of any information on its use by birds, but enough hemp is grown in the UK as a break/cash crop, to allow studies to take place.

3.1.4.4 Conclusions and future research

Depending on the prospects of these alternative crops either increasing in area or becoming established as viable commodities or biofuel feedstocks, studies may be especially valuable where they assess the crops with respect to potential complementary benefits within mixed rotations. Although currently, there is no legitimate financial incentive to grow large areas of hemp, this crop may carry a relatively low net environmental impact that would benefit from closer investigation.

4. PREDICTING FUTURE CHANGE AND AREAS FOR RESEARCH

4.1 A Broader Perspective Across Europe

Balmford *et al*. (2005) assessed the potential for 'land sparing' for conservation, due to improvements in yield efficiency. They used values for human population size, diet, yield, and trade to calculate the area needed to meet a demand for 23 food crops by 2050. For the developed world, they predicted a 4% decline in the area required to grow these crops, in contrast to a predicted approximate 23% increase for developing countries, plus an increase in average yield (crop productivity). Indeed, Ericsson & Nilsson (2006) further reported that there were no important resource limitations in meeting early biomass targets for 2010, as set by the European Commission in 1997, and countries such as France, Germany and Spain have responded (below). In the longer term however, from climate change models, that the potential distribution of temperate oilseeds, cereals, starch crops and solid biofuels would increase in northern Europe by the 2080s, increasing pressure on land availability and cropping practices at those latitudes.

Part of this predicted demand for biofuels (*e.g.* Rowe *et al.* 2008) may be absorbed by increased efficiencies in technology (Gallagher 2008). Rounsevell *et al*. (2004 and 2006) and Ewert *et al.* (2006) used modelled scenarios to demonstrate the importance of technological development for future agricultural land use, where under current levels of progress in technology (such as plant breeding), the area of agricultural land could decline substantially (though the costs in terms of intensification are not made clear and would need to be understood). Yet importantly, the predictions reported by Balmford *et al*. (2005) imply a differential effect across regions and countries. Hence the effects of intensified production, due to climate change, as predicted by Tuck *et al*. (2006), at least in terms of additional land use requirements, may be felt principally in northern latitudes (Scandinavia or Scotland) or by agriculturally less developed countries across the world (Wolf *et al* (2003). This may raise important implications for agriculture and habitat protection in Northern Europe or in Eastern European counties, for example (*e.g.* van Dam *et al*. 2007). Meanwhile in Western Europe, attention is more likely to be given, at multiple levels within the existing structure, to efficiencies in agronomics, energy expenditure, functioning ecosystems and conservation delivery.

In direct contrast to Ericsson & Nilsson (2006), in the UK, Turley *et al*. (2002) conclude that scope for significant expansion of the most promising liquid biofuel crops, such as oilseed rape and wheat, was unlikely given constraints on appropriate growing conditions and competition for land that was being used to grow other valued commodity crops in the rotation (for food and industrial end uses). They calculate that the UK will struggle to reach targets for liquid fuel and overall biofuels production from conventional crops alone (not including 2nd generation lignocellulose crops). To do so, production efficiency of oilseed rape may have to be improved, from say 3 tonnes/ha to 4 tonnes/ha, to make oilseed rape increasingly viable as a biofuel crop, potentially with further implications for crop inputs. Moreover, on the basis of inaccurate calculations and unknown factors relating to energy balances and indirect effects, Gallagher (2008) questions the whole rationale for attempting to develop the agrofuel industry at this point in time. Such obstacles have not prevented countries such as France, Germany and Spain increasing biofuel output to 344, 130 and 300 thousand tonnes per annum, respectively, in response to EU and government priorities. This illustrates how policy directives can alter the *status quo* by strongly and rapidly influencing market demands for commodities. Policy may encourage increased investment in technology efficiencies and create improvements in the commercial viability of products (Turley *et al*. 2002). Thus, both in mainland Europe and in the UK, policy decisions may still influence a shift in land-use and improvements in yields, with effects on proportional areas of crops grown within rotations and renewed pressure on uncropped land. Some of this land may be required for hard-pressed agri-environment measures to mitigate against the worst effects of arable and grassland intensification on existing populations of animals and plants. Other pressures will be directed towards existing, unprotected, dispersed semi-natural habitats within agricultural landscapes in northern latitudes, and not least in Eastern Europe. The environmental consequences of further intensification of production, or extra demands for land in the UK or on mainland Europe, are therefore consistent with those effects considered fundamental in driving the recent historical declines in farmland biodiversity across Europe to date (*e.g.* Chamberlain *et al*. 2000, Donald *et al*. 2001).

In the Gallagher Report (Gallagher 2008) it was concluded that:

> "there is a future for a sustainable biofuels industry but that feedstock production *must* avoid agricultural land that would otherwise be used for food production. This is because the displacement of existing agricultural production, due to biofuel demand, is accelerating land-use change and, if left unchecked, will reduce biodiversity and may even cause greenhouse gas emissions rather than savings. The introduction of biofuels should be significantly slowed until adequate controls to address displacement effects are implemented and are demonstrated to be effective. A slowdown will also reduce the impact of biofuels on food commodity prices, notably oil seeds, which have a detrimental effect upon the poorest people."

As an alternative to liquid biofuels, perennial biomass crops, with longer term root stocks, are less prone to leaching, receive less inputs of herbicides and pesticides, compete less with existing commodity crops for land and produce higher net energy yields. These crops would appear to be a far better prospect for long-term attainment of energy targets from home-grown feedstocks (Turley *et al*. 2008). Implications of the Gallagher Report (Gallagher 2008) may also indicate that bioenergy requirements are better met using 2nd generation lignocellulose feedstocks (Turley *et al*. 2002, van Dam *et al*. 2007) if grown on Grade 3 and 4 land (Haughton *et al*. 2009) as opposed to the best quality arable land. Just over 80% of approved agreements for these crops, under the Energy Crops Scheme from 2001 to 2007, were indeed grown on land in Grades 3 or 4 (Natural England 2008).

But Gallagher (2008) also draws the following conclusions (here given as summarised extracts):

> "Advanced technologies have significant potential, but may only produce biofuels with higher GHG savings if feedstock production avoids use of existing agricultural land that leads to indirect land-use change. This can be achieved using feedstock grown on marginal land."

> "… shifting production to idle and marginal land will reduce pressure for land-use change. Stronger policies are needed to slow rates of deforestation particularly in South America, Africa and parts of South-East Asia."

> "Mechanisms do not yet exist to accurately measure, or to avoid, the effects of indirect land-use change from biofuels."

> "Large areas of uncertainty remain in the overall impacts and benefits of biofuels. International action is needed to improve data, models and controls to understand and to manage effects."

> "The current biofuel industry sources much of its feedstock from crops grown on existing agricultural land through international commodity markets. In many cases this is likely to cause indirect land-use change and makes tracking … sustainability criteria … extremely difficult. This review has proposed to reduce the risk of indirect land-use change by [using] idle land that would not otherwise have been used for food production; or, land made available as a result of productivity improvements. Action to promote the shift to production on idle land is needed at an EU-level and eventually internationally. The UK should begin this process by amending the current carbon and sustainability requirements…to establish robust definitions. Requirements for sourcing feedstock from idle land should be made mandatory, through the EU Renewable Energy Directive. Shifting production onto idle land will require robust criteria to be developed that define appropriate idle land."

In conclusion, the Gallagher Review (Gallagher 2008) underlines the need for improved technologies and data on the indirect consequences of biofuel demands on land use issues, across international borders. At both international and domestic levels the imperative is to identify and characterize land under threat of replacement by bioenergy crops. In the UK this means especially Grade 3 and 4 land (Appendix 1), to identify what it represents for current and future biodiversity. In the UK and abroad there is an urgent need to define the year-round character and scale of 'idle' and 'marginal' land. Does this threaten areas of largely unprotected, dispersed, uncropped habitats or semi-natural habitats, including those connected by the migration and inter-seasonal locations of species? Could this result in a reduction of uncropped areas within productive farmland landscapes that have been seriously depleted since the 1950s and that support high levels of biodiversity within these landscapes (Fuller *et al*. 2004, Fuller & Ausden 2008). Data on birds may play a significant role in attempting to determine effects and process at multiple scales (*e.g.* Scharlemann 2008).

4.2 Biofuel Aspects of Particular Interest in the Context of UK Farmland Birds

Changes in agricultural land-use have been at least partly responsible for contractions in range of a number of bird species over the past three decades, such as Grey Partridge, Lapwing, Turtle Dove *Streptopelia turtur*, Yellow Wagtail, Tree Sparrow, Corn Bunting and Reed Bunting (Chamberlain *et al*. 2000). Four aspects of agricultural change have been the main drivers of bird population declines, each affecting a wide range of species, namely: (1) weed and pest control, especially through herbicide use; (2) the change from spring-sown to autumn-sown cereal varieties, and the associated earlier ploughing of stubbles and earlier crop growth; (3) land drainage in all sectors and the intensification of grassland management; and (4) increased stocking densities, mainly of cattle in the lowlands and sheep in the uplands (Chamberlain and Fuller 2000). These changes are considered to have reduced the amounts of habitat and/or food available to many bird species (Donald 2001a, Newton 2004).

Each of these issues remains relevant to biofuels, albeit with a change in approach for mitigation in recent years towards enhanced ecosystem function and landscape management. At the recent meeting of the British Ornithologists' Union on the subject of farmland birds (BOU 2009), against a background of continuing declines in farmland bird populations, the central issues of concern were identified as the scale, quality and effectiveness of mitigation policy to resist further declines in bird populations (*e.g.* Vickery *et al.* 2004). Thus, emissions aside, and regardless of end use, the generic issues of crop management and production are familiar in terms of agricultural land use practice. They include:

- i) Resource protection: especially regarding air, soil, water quality and water demands.
- ii) Proportionate and gross effects on land use: availability and diversity of land and impacts on uncropped land and semi-natural habitats.
- iii) Effects of monocultures: soil and crop management, loss of heterogeneity and spatial configuration as relevant to landscape and ecosystem needs.
- iv) Immediate effects on biodiversity of the management practices adopted in cropped and adjacent uncropped habitats.

Integrated farming
Integrated farming is not a very closely defined field but it involves a whole-farm and relatively holistic perspective of management. Farmland intensification will increase damage to all ecosystem services, such as declining soil fertility and declining water availability. Firbank (2008) argues that ecological impact assessments for all bioenergy projects must address changes to landscape diversity, potential impacts to primary and secondary habitats and potential impacts on climate change and biodiversity at a variety of scales, alongside an *evidence-base for good working practice*. Though the latter is well intended among practitioners (*e.g.* GAEC: Good Arable and Environmental Condition as part of the cross compliance measure attending especially to soil condition) the consequences as regards biodiversity are always difficult to assess and probably should be better monitored. One system, which attempts to do this, is the LEAF marque (www.leafuk.org), using advice and whole-

farm audits to gauge working practice, soil care, resource protection and environmental responsibility. Under this system, farmers are awarded accreditation for effective best practice. The relevance of integrated farming is that it may operate as a 'hub' for sustainable practices to formally rationalise agronomic and environmental conflicts demands (through improved auditing). This convergence is pertinent to biofuels due to the emphasis attached to life-time auditing of the production system (energy, agronomics and the environment). For biodiversity, efficiency savings can operate in two ways. For example, the extra effort that a farmer must give to managing agri-environment prescriptions may be viewed as an undesirable energy cost. Are there ways of devising environmental prescriptions that are both effective for core delivery and energy efficient? Elements may include: reduced traffic in crops; less frequently applied, more targeted and more efficient use of chemical inputs; reduced cultivation intensity (minimal tillage?). Possible outcomes may be improved soil condition (for efficient chemical transfer, less compaction and reduced pollution), with benefits to soil organisms and increased carrying capacity of cropped land for higher organisms, such as birds. These indirect, fundamental but poorly understood links deserve far greater attention (*e.g.* Gilroy *et al.* 2008). More direct impacts on birds at least are likely to occur as a result of immediate changes to cropping patterns, where more data are needed to accurately predict effects on birds in order to identify effective protection measures.

Soil management and biodiversity

An important subject that is still poorly researched is the ecosystem value of soil management (nutrients and cultivation techniques) for improving resource provision to higher trophic groups. The subject is biologically fundamental in terms of the health and viability of food chains. Moreover, evidence-based advocacy would have the huge potential to influence basic crop management practice on a large geographical scale in the UK.

An example is provided by Gilroy *et al.* (2008) who were able to demonstrate that soil penetrability was a significant influence on the abundance of territorial Yellow Wagtails. Yellow Wagtails may use soil penetrability as a predictive indicator of prey abundance during the chick-rearing period. Gilroy *et al*. (2008) make the point that soil degradation (exposure to erosion, declining soil organic content and increasing soil compaction) on birds has received little attention. This knowledge gap is especially relevant to the bioenergy crops industry due to their obligation to optimize delivery of energy, agronomic and environmental benefits. Turley *et al*. (2008) emphasise the need for enlightened management of fertilizer and pesticides (and specifically molluscicides) on crops such as oilseed rape for which soil management may play a fundamental role. Minimum tillage may also help reduce the energy costs of cultivation and soil compaction (to improve the efficiency of cultivation and nutrient uptake by plants), while potentially creating a favourable soil environment for invertebrates such as earthworms (*e.g.* Gillings *et al*. 2009).

Multi-taxa responses to soil management practices are poorly understood, yet accurate and representative data on functioning trophic links would provide a foundation for the improved implementation, effectiveness and delivery of conservation actions.

Agronomic and environmental benefits derived from crop rotations

Turley *et al*. (2002) propose that biofuel production from a broad mix of arable crop feedstocks (diverted from food use) could result in reduced agrochemical inputs where the <u>quality</u> of product was less important. They indicate, however, that for oilseed rape, crop yield may have to improve (from say 3 tonnes/ha to 4 tonnes/ha) for viable biofuel production and if yields were to be met using a reduced rotation, additional inputs would be required to ensure economic viability. The expansion of oilseed rape at the expense of second wheats might create a better balance for birds between cereal and non-cereal crops in the landscape (*e.g.* Henderson *et al*. 2009). On the other hand, the replacement of spring-sown break crops by an expanding area of winter oilseed rape may be undesirable for crop diversity and the conservation of some farmland birds (Wilson *et al*. 1996). Generally, higher crop diversity and integrated areas of uncropped habitats (*e.g.* set-aside or fallows) will provide more favourable conditions for farmland birds than monocultures. Powlsen *et al*. (2005), however, estimate that if 80% of recent set-aside land in the UK were used for production of biomass crops for electricity generation, about 3% of current UK electricity demand could be met from this source, with potential benefits for biodiversity too. The common consensus for set-aside (Gillings *et al*. in prep) is that set-aside provided important feeding and nesting resources for farmland birds (Evans *et al.* 1997, Donald *et al.* 2001), in the breeding season (Wilson *et al.* 1997, Henderson *et al.* 2000) and in winter (Wilson *et al*. 1996, Stoate & Parish 2001, Gillings *et al* 2005). Some set-aside still exists on farmland though much less than before 2007 (Gillings *et al*. in prep) and Turley *et al*. (2008) concur that "if the required additional crop production for biofuels was met on former set-aside land, the majority of remaining naturally regenerated set-aside would disappear with increased nitrogen and pesticide use and reduced habitat diversity and net losses of bird species". Of key importance is how agri-environment scheme prescriptions for target species, such as Lapwing and Skylark in the UK, will fit in with any increased demand for land to produce biofuel feedstock.

Kim & Dale (2005) proposed that unless measures, such as planting cover crops (*i.e.* post harvest crops such as mustard, designed to absorb nutrients and prevent leaching) were taken, the utilization of biofuel crops would also lead to increased acidification and eutrophication in rivers, primarily due to large nitrogen (and phosphorus) related environmental burdens being released from the soil during [post harvest] cultivation. The issue of water quality has had a major impact on policy and legislation, due to increased eutrophication and diffuse pollution of drinking water. Surprisingly, there have been few if any studies of birds in respect of water quality issues. This is despite the principles of effects on the food chain, on micro- flora, fauna, macrophytes, invertebrates and fish, being well researched and well established (*e.g.* Harper 1992).

In conclusion, the potential to optimise crop rotations (including rested, fallow land) for agronomic and environmental benefit needs to be fully re-assessed. Conflicting data and opinions demonstrate that, as far as the potential expansion of annual biofuels crops is concerned, further data are needed to identify how the configuration of crop rotations, in varying proportions and scale, can deliver benefits for biodiversity (*e.g.* Henderson *et al*. 2009), agronomic efficiency, energy savings, optimised inputs for weed and pest control and improved soil condition. Data are still needed on the scope for including uncropped areas into commercial rotations. Meanwhile, the biodiversity 'value' of nutrient-absorbing cover crops, at least for birds, has not been fully investigated.

5. CONCLUSIONS

This report presents a research-focussed and up-to-date account of the potential effects on birds of the developing biofuels industry in the UK, with specific reference to agricultural crops. Wider geographical context is provided mainly through reference to mainland Europe. Emphasis on the association between potential biofuel crops and birds is updated since the report of Anderson *et al.* (2004) and Anderson and Ferguson (2006). Effects of crop management, crop expansion and knowledge gaps are discussed that might be required to advance the delivery of biodiversity measures on farmland in the UK. Important sources of reference include, first, Turley *et al*. (2002 & 2008), who completed a thorough and in-depth appraisal of the agronomic, energy and emissions costs and benefits of various crops in the UK that might be considered genuine biofuel feedstock on large scale. Second, the Gallagher Report (Gallagher 2008) is cited as being a major influence on the policy-direction on biofuels in the UK (or at least England) in the short to mid-term future.

There is considerable difficulty in predicting how biofuel crops may affect birds, since the concept itself is still widely debated. Conflicting scenarios, and scenarios that are difficult to validate mean there is a lack of reliable data available on which to judge impact of future biofuel development on land use change and related areas affecting biodiversity.

On the basis of energy conservation and emissions, the second-generation lignocellulose/biomass crops appear to be emerging as a better prospect for bioenergy feedstock in comparison to annual agricultural crops. Crops such as short-rotation coppice may even provide net gains in biodiversity, although on this subject there is **an urgent need** for verification with respect to the types of land being threatened with replacement ('idle' land, 'marginal' land, and Grade 3 and 4 land), and what net change there may be among bird assemblages. *Immediate in-roads could be made by interrogating existing data sets and ongoing monitoring studies (e.g. BTO/JNCC/RSPB Breeding Bird Survey and current BTO Atlas data; the Waterways Breeding Bird Survey (Environment Agency/BTO) for river corridors), superimposed on Defra spatial data of the distribution of these land types at varying scales (national and regional). Crucially, the extent, character and configuration of these habitats within farms also require close attention through new dedicated and targeted survey work, since many 'patches' may be relatively small in area, but potentially valuable on farms as bird-habitats.*

For annual biofuel crops, oilseed rape may be the most viable, though there appears to be only modest scope for crop expansion in the UK. Oilseed rape could be beneficial in providing food supplies or nest sites for quite a large number of farmland birds. However, much depends on inputs and other management details. An effective and complementary crop rotation is needed to help control high leaching potential of oilseed rape and to provide habitats for groups of species, such as ground-nesting birds, that largely avoid the crop. Greater details and better representation is needed of the breeding demography and provisioning demands on birds (buntings, finches, warblers and thrushes) nesting in or near to oilseed rape, and using the crop as a source of food.

Improved knowledge of how 'whole-cropping' systems (including uncropped habitats) can optimise low energy/emissions, commercial output and deliver meaningful environmental benefits is crucial for future landscape and ecosystem management and effective AES deployment. There may be considerable scope for developing new rotations and crop management systems within biofuel crops that reduce their intensity in terms of inputs *etc.* However, this subject needs detailed research. Some of the potential crops, notably hemp, are hardly researched in terms of their environmental aspects. A whole landscape approach needs to be taken to assessing and planning the delivery of biofuels and to assessing potential environmental impacts. It is especially unclear how expansion of biofuels could impact on existing areas of high environmental value (*i.e.* on uncropped land in agricultural landscapes and marginal farmland both in lowlands and uplands). Again, *a thorough and urgent assessment of the character, distribution and wildlife potential of land targeted for all biofuel feedstock is needed.*

In summary, details are needed on how bird assemblages, movements, territory settlement and demographic parameters are affected by:

1. cropping patterns: area and configuration;
2. replacement of land-use types and requirements for uncropped land;
3. management (or over management) of uncropped land, linear features, fallows, crop edge, buffer strips, scrub and woodland edge;
4. in-crop management: controlled inputs of chemicals, soil management and cultivation techniques, water quality in ditches for example and other water ways.

Grade 3 land and land considered as ‘marginal’ and ‘idle’ appears to be in most urgent need of attention, both from a national and Europe-wide perspective.

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Table 1. A summary of a typical agronomic profile of selected crops grown in the UK (from Turley *et al*. (2002) and/or Turley *et al*. (2008) or Garthwaite *et al*. 2006)), with a summary of the crop-specific areas of potential benefits for birds and areas of future research.

	Oilseed rape	Sugar beet	Winter wheat	Potatoes
Total area x 1000 ha (2007)	601	125	1816	140
Fertilizer Approx. 1998-1996: kg /ha):				
N	200	90	190	150
Phosphate	40	40	40	140
Potassium	50	100	50	230
Pesticides: Active ingredient applied: kg /ha	2.59	6.43	4.72	16.02
Total energy input (M. Joules/ha)	11660	17809	16000	–
GHG emissions as CO_2 equivalents ($CO_2 + CH_4 + N_2O$)	1731	1438	2220	–
Birds	Used by a wide variety of spp. High densities but complementary fauna to summer fallows or cereals. Harvest threat to bird productivity. Short-lived winter stubbles attractive to seed-eating birds. Winter crop little used, but grazed by Skylarks and Woodpigeons.	Variable densities of birds on quite short-lived stubbles, though used by a wide variety of spp: granivores, insectivores, plovers etc. Lapwing and Skylark may breed successfully in the crop.	Typically, low densities of birds, year-round. Breeding species aided by better in-crop access. Helpful 'nutrient soak' within a rotation.	Understudied crop. Associated with relatively high densities of Yellow Wagtails. Pre-crop stubbles may have potential for late-winter birds.
Issues for birds	Effects on bird productivity. Spray/ molluscicide use: effects on birds either directly or indirectly? What importance has oilseed rape to bird assemblages and demography, relative to replacement crops or habitats?	Scope for management of pre-beet stubbles for late-winter bird food. Assess spring crop role within a whole-crop system.	Potential role within a whole-crop system, at least for nutrient control, but are benefits for birds better provided for by using fallows?	High inputs of chemicals need investigation, and harvest methods too (*e.g.* desiccation). Assess spring crop role within a whole-crop system; pre-beet stubbles for late-winter bird food.

Appendix 1. Agricultural Land Classification of England and Wales (MAFF 1988).

Grade 1 - excellent quality agricultural land
Land with no or very minor limitations to agricultural use. A very wide range of agricultural and horticultural crops can be grown and commonly includes top fruit, soft fruit, salad crops and winter harvested vegetables. Yields are high and less variable than on land of lower quality.

Grade 2 - very good quality agricultural land
Land with minor limitations which affect crop yield, cultivations or harvesting. A wide range of agricultural and horticultural crops can usually be grown but on some land in the grade there may be reduced flexibility due to difficulties with the production of the more demanding crops such as winter harvested vegetables and arable root crops. The level of yield is generally high but may be lower or more variable than Grade 1.

Grade 3 - good to moderate quality agricultural land
Land with moderate limitations which affect the choice of crops, timing and type of cultivation, harvesting or the level of yield. Where more demanding crops are grown yields are generally lower or more variable than on land in Grades 1 and 2.

> Subgrade 3a - good quality agricultural land
> Land capable of consistently producing moderate to high yields of a narrow range of arable crops, especially cereals, or moderate yields of a wide range of crops including cereals, grass, oilseed rape, potatoes, sugar beet and the less demanding horticultural crops.
>
> Subgrade 3b - moderate quality agricultural land
> Land capable of producing moderate yields of a narrow range of crops, principally cereals and grass or lower yields of a wider range of crops or high yields of grass which can be grazed or harvested over most of the year.

Grade 4 - poor quality agricultural land
Land with severe limitations which significantly restrict the range of crops and/or level of yields. It is mainly suited to grass with occasional arable crops (e.g. cereals and forage crops) the yields of which are variable. In moist climates, yields of grass may be moderate to high but there may be difficulties in utilisation. The grade also includes very droughty arable land.

Grade 5 - very poor quality agricultural land
Land with very severe limitations which restrict use to permanent pasture or rough grazing, except for occasional pioneer forage crops.