Agriculture, Ecosystems and Environment 166 (2013) 65–75

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Delivering multiple ecosystem services from Enclosed Farmland in the UK

Les Firbank[a,*], Richard B. Bradbury[b], David I. McCracken[c], Chris Stoate[d]

[a] School of Biology, University of Leeds, Leeds LS2 9JT, UK
[b] Conservation Science Department, RSPB, The Lodge, Sandy, Bedfordshire SG19 2DL, UK
[c] Scottish Agricultural College, Auchincruive, Ayr KA6 5HW UK
[d] Game & Wildlife Conservation Trust, The Allerton Project, Loddington, Leicester LE7 9XE, UK

ARTICLE INFO

Article history:
Received 3 December 2010
Received in revised form 8 November 2011
Accepted 17 November 2011
Available online 17 February 2012

Keywords:
UK National Ecosystem Assessment
Multifunctional
Land sparing
Trade-offs
External costs
Land use optimisation
Sustainable agriculture

ABSTRACT

Here, we review the delivery of ecosystem services from Enclosed Farmland in the UK, and explore how the expected demands for ecosystem services might be met in the future. Most Enclosed Farmland is managed for agriculture; the UK is 60% self-sufficient in foods. Pollinators are in serious decline, but little is known of trends of predators of crop pests. Effects of agriculture on water quality and climate regulation are negative but improving; GHG emissions fell by 20% between 1990 and 2008. Recent declines in numbers of some farmland birds and in plant species richness have been halted, though not reversed. Enclosed Farmland provides considerable leisure and cultural value. Effective delivery of multiple ecosystem services requires improved understanding of how ecosystem services are generated, and of their economics and governance. Food production can be integrated with the delivery of other ecosystem services by promoting a diversity of farming systems and allocating land to different ecosystem services according to its suitability. Approaches include, minimising negative environmental impacts of food production through technology; mitigating environmental harm by managing areas for environmental benefit, from patches within fields to much larger areas; and developing markets and regulations for environmental protection.

1. Introduction

The global demands on ecosystem services from farmland will increase in coming decades as the human population increases (Millennium Assessment, 2005; Tilman et al., 2002). Clearly, greater amounts of agricultural products will be required, including food, fuel and materials, even if waste is reduced; there is an expectation that global agricultural production will have to increase by at least 50% by 2050 (Royal Society, 2009). However, increased production may well compete with the delivery of other services from agricultural land, such as water regulation and better control of externalities, such as diffuse pollution. The challenge is to deliver multiple ecosystem services simultaneously, optimised in ways that reflect their values to the many stakeholders involved. This is unlikely to be easy, given the significant differences among people in the value given to different services, as well as differences in the distribution of benefit flows, mediated by different levels of access to services and power relations within society (Bateman et al., 2011).

Here we address the issue of ecosystem service delivery from agricultural land in the UK by reviewing recent output trends in the ecosystem services delivered by Enclosed Farmland and how they might be managed in the future. Enclosed Farmland includes agriculture and horticulture in lowlands and marginal uplands, and is defined here following the UK Countryside Survey (Howard et al., 2003) as comprising the two Broad Habitats 'Arable and Horticultural' and 'Improved Grassland'. It is therefore characterised by vegetation cover (i.e. crops, stubbles and grassland that is relatively poor in species and high in nutrient status) rather than land use. It is typically bounded by linear features such as hedgerows, ditches, grass strips and fences. Open farmland in the uplands is excluded, as are the more species-rich habitats of Acid, Neutral and Calcareous Grasslands. This analysis is part of the UK National Ecosystem Assessment (UKNEA), that sought to evaluate the benefits provided by every major habitat type in the UK in terms of the major provisioning, supporting, regulating and cultural services, their values and trends, the major drivers of change and options for the sustainable delivery of ecosystem services (UKNEA, 2011). It builds upon the Millennium Ecosystem Assessment (Millennium Assessment, 2005), and links the drivers of change (direct and indirect) to changes in biodiversity, ecosystem goods and services, and hence human wellbeing.

Enclosed Farmland is managed primarily for the provisioning of food. But it is important for many other ecosystem services, not least because it covers such large areas. It is the most widespread habitat in the UK, accounting for 39.3% of the land area in 2007, with

* Corresponding author. Tel.: +44 113 343 2859.
E-mail address: l.firbank@leeds.ac.uk (L. Firbank).

0167-8809/$ – see front matter © 2012 Published by Elsevier B.V.
doi:10.1016/j.agee.2011.11.014

Arable and Horticultural and Improved Grassland accounting for 18.8% and 20.5% of UK land cover respectively (Carey et al., 2008). While this paper addresses the UK, the issues are similar among many of the more intensive agro-ecosystems across Europe. The land areas involved are large: in 2007 over 41% of the land area of the European Union (EU27) was under agriculture; 61% of that 172 million ha of agricultural land was classified as arable and 6% was classified as permanent crops, while much of the remaining 33% classified as permanent grassland (Olsen, 2010) is likely to be improved grassland.

2. Ecosystem services derived from Enclosed Farmland

Here we summarise recent trends in delivery of provisioning, supporting, regulating and cultural ecosystem services within UK Enclosed Farmland, as defined within the UKNEA (UKNEA, 2011), following the Millennium Assessment (2005) (Table 1).

2.1. Provisioning services

2.1.1. Food production

The UK is currently 60% self-sufficient in all foods, and 73% self-sufficient in indigenous foods, a figure that has fallen slightly since the 1990s (Defra, 2010a). In 2009, the area of cereals planted in the UK was 3.1 million ha, producing just over 22 million tonnes of grain (Defra, 2010a), more than enough for the country's processing needs, with a decline in barley and increase in wheat, albeit with much annual variation (Fig. 1). Average wheat yields in the UK have risen from 2.5 tonnes $ha^{-1}\,yr^{-1}$ in 1940 to the present 7.9 tonnes $ha^{-1}\,yr^{-1}$. Over the past decade, there is little evidence of national yield increases in wheat, barley or oilseed rape (Defra, 2010a), in spite of the regular introduction of new varieties that provide higher yields in experimental plots.

Historically, most young grasslands were grass-clover mixes, in rotation with arable crops to restore fertility and provide hay. During the course of the 20th century, these have been replaced by regularly reseeded long-term leys, designed to maximise production of grazing or silage for feeding to stock over-winter, supplemented by concentrates and sometimes forage crops. Heterogeneity of sward structure has declined as a result (Wilson et al., 2005). The number of animals required to produce each tonne of meat has fallen by 5% from 3.23 in 1998 to 3.07 between 1998 and 2008 (EBLEX, 2009). Cattle numbers in the UK fell in the mid 20th century, but then livestock numbers rose until the 1990s, sustained by increasing inputs of inorganic fertilisers and feed; they have since fallen again to around 1.9 million dairy and 1.6 million beef cattle and 32 million sheep (Defra, 2010a).

In 1951, the 1 million agricultural workers represented 5% of the British workforce, while the present figure of 470,000 agricultural workers now constitutes fewer than 2% of the total, suggesting a redistribution of the economic benefits of food production. Globally, there was a halving of the prices of major food-stuffs in the 50 years up to 2006 (IMF, 2006). However, since then the FAO's index of global food prices has nearly doubled (FAO, 2011) and the global number of hungry people has increased (FAO, 2010).

In summary, the provisioning of food increased from UK Enclosed Farmland until the mid-1980s, after which it has largely stabilised, albeit with greater efficiency of production from fewer animals in the livestock sector.

2.1.2. Bioenergy production

The area of agricultural land under bioenergy crops is increasing in the UK, but from a very low base (Lovett et al., 2009). In terms of biomass crops, the area of *Miscanthus* spp. was 12,600 ha in 2007, and planting had been approved for over 3700 ha of short rotation coppice (Sherrington and Moran, 2010). Farm woodlands are rarely planted primarily for timber and fuel, but the recent widespread adoption of wood fuel boilers on farms has encouraged the production of wood chip and logs from a wide range of woodland types. The use of plant biomass for heating in the UK is thought to have been around 72,000 tonnes of oil equivalent from 1990 to 2004, rising to over 200 in 2009, while the generation of electricity from plant biomass has increased from 0 in 1997 to 364,000 tonnes of oil equivalent in 2009 (out of a total demand of 16,484), when the UK consumed 212 m tonnes of oil equivalent total primary energy (DECC, 2010). In summary, this service is now increasing from a very low base, and remains a very small component of the UK energy supply.

2.2. Supporting services

2.2.1. Pollination

Some farmland taxa have clear functional roles supporting agricultural production. Insects that contribute to pollination include bumblebees, honey bees, solitary bees, hoverflies, butterflies and moths. Pollinator-dependent crops covered 23% of UK cropped area in 2007, when the annual value of insect pollination was estimated to be £430 million (Defra, 2008, 2009; Basic Horticultural Statistics, 2008). Honeybee (*Apis mellifera*) colony numbers declined severely between 1985 and 2005 (Potts et al., 2010a). Similarly, wild bees and hoverflies are in serious decline, with more than half of UK landscapes studied showing a significant loss of bee diversity (Biesmeijer et al., 2006). Drivers of wild pollinator declines include the loss of flower-rich landscape elements in farmland (Winfree et al., 2009), the loss of grass/clover leys (Carvell et al., 2006), and improved weed control (Roy et al., 2003). Pesticides have been shown to have lethal and sub-lethal effects on bees (Morandin et al., 2005), and can result in local loss of bee diversity (Brittain et al., 2010). No data are available on trends in the actual levels of pollination, or on the impact of pollinator declines on UK food production. However, models developed and tested at a global level have indicated that crops with greater pollinator dependence have lower mean relative yield and yield growth, despite global yield increases for most crops, and that cultivation areas of pollinator-dependent crops have been increased. These results suggest that pollen limitation is hindering yield growth of pollinator-dependent crops, while promoting compensatory land conversion to agriculture (Garibaldi et al., 2011).

2.2.2. Biological pest control

Biological pest control is provided by a wide range of invertebrate predators and parasitoids, such as carabid beetles, spiders and ladybirds (e.g. Schmidt et al., 2003; Holland et al., 2005). Epigeal predators associated with grass margins have been shown to reduce cereal aphid numbers in adjacent fields by 40%, while more mobile flying predators reduced numbers by 90% (Holland et al., 2008). Little is known of trends in national populations of these invertebrates.

2.3. Regulating services

Soil organisms cycle nutrients and carbon, though our understanding of the mechanisms by which soil biodiversity influences ecosystem processes and the delivery of supporting services, and how it responds to land management, is limited (Bardgett and Wardle, 2010). For example, recent studies suggest that mycorrhizal soil fungi may have potential to influence phosphate availability to crop plants (Ehinger et al., 2009).

2.3.1. Climate regulation

Agriculture has a potential positive effect on climate regulation in that carbon sequestration is possible in soils and vegetation, and