Chapter 6: Semi-natural Grasslands

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Key Findings*

Semi-natural Grassland has greatly declined in area since the 1945, with losses of around 90% in the UK's lowlands. Currently, only 2% of the UK's grassland area comprises high diversity (Biodiversity Action Plans (BAP) Priority Habitat) Semi-natural Grassland. Two separate studies show a 97% loss of enclosed Semi-natural Grasslands in England and Wales between 1930 and 1984, and an 89% loss of lowland Semi-natural Grassland in Wales between the 1930s and 1990s[1]. Losses continued throughout the 1980s and 1990s[1], with regional English studies indicating declines in specific lowland grassland types ranging from 24% to 62% over various timescales within this period. There are few trend data for Scotland or Northern Ireland, but the scale of loss across the lowlands of these countries is similar to that reported for England and Wales[c]. Changes in upland Acid Grassland since 1945 are poorly documented.	[1] *well established* [c] *likely*
Since 1945, agricultural improvement was the major driver of the loss of Semi-natural Grassland. Technological advances and incentives drove the conversion of high diversity (BAP Priority Habitat) Semi-natural Grasslands to either 'improved grasslands' or arable land. Today, however, agricultural improvement has decreased in importance as a driver as much Semi-natural Grassland is now protected; for example, in England, 68% is within Sites of Special Scientific Interest (SSSIs) and, in Wales, 52% is within National Parks. There is now evidence for a number of other drivers which continue to cause habitat and species loss in Semi-natural Grassland, particularly nitrogen deposition, inadequate management and habitat fragmentation; although their relative effects are poorly quantified, they are widely recognised as the primary drivers[2]. In the uplands, forestry has been, and continues to be, a major cause of the loss of Acid Grassland, although the Scottish Forestry Strategy aims to plant woodland on 270,000 hectares (ha) of 'unimproved grassland'.	[2] *established but incomplete evidence*
The loss in area of Semi-natural Grassland has slowed substantially over the last decade. The Countryside Survey 2007 showed that there was generally no change in area of Acid, Neutral and Calcareous Grasslands in each of the UK countries between 1998 and 2007[1]. However, a few habitats did show some changes in certain countries over that time period; in particular, Acid Grassland increased in extent in the uplands of both Scotland (+9%) and Wales (+7%). The slowed decline is due to the improved protection, restoration and re-creation of grasslands through, for example, agri-environment schemes[c]. Conservation management is important to maintain the quality of Semi-natural Grasslands[1]; for example, only 21% of English non-SSSI Semi-natural Grasslands were found to be in favourable condition, whereas the management of Scottish SSSI lowland grasslands increased the amount of sites in favourable or recovering condition from 45% in the early 2000s to 71% in 2010. The cause of the increase in extent of Acid Grassland is less clear, but may be a continuing impact of overgrazing and degradation of upland heather moorland[d].	[1] *well established* [c] *likely* [d] *about as likely as not*
Semi-natural Grasslands are a vital part of the UK's cultural landscape and provide associated services. Most are remnants of traditional farming practices and are the product of thousands of years of human interaction with land and nature. Humans highly value Semi-natural Grassland species	[1] *well established*

and landscapes[1] as shown by the conservation designation afforded to many of these habitats in the UK. Semi-natural Grasslands provide habitat for important and rare species[1]. Of the 1,150 species of conservation concern named in the UK Biodiversity Action Plan (UK BAP), lowland Semi-natural Grasslands are home to 206 UK BAP priority species, while upland Semi-natural Grasslands are home to 41. The UK's National Parks are valued for their greenspace, health, recreation, education and cultural opportunities, and all contain significant areas of Semi-natural Grassland[1]. Calcareous Grassland is the major habitat of the new South Downs National Park. A 2003 study showed that there were about 39 million visitor days per annum to the South Downs and these visitors spent £333 million.	
Livestock production is low in Semi-natural Grasslands[1], leading to pressures on land use. The annual hay yield for a range of UK lowland Semi-natural Grasslands has been estimated as 2–8 tonnes per hectare (t/ha), which amounts to less than 30% of the dry matter usually obtained in silage over a year from agriculturally improved grassland. The addition of fertilisers increases yearly dry matter yields to about 10–12 t/ha. Upland Acid Grasslands have similarly low yields of about 1.5–5 t/ha, which compares unfavourably to the average of 8 t/ha for reseeded upland grasslands. Digestibility and nutrient content are also lower in forage from Semi-natural Grasslands compared to improved grasslands[1]. It has been suggested, however, that livestock grazing on species-rich pasture produce better quality meat than those on species-poor grassland, having, for example higher concentrations of nutritionally beneficial omega-3 fatty acids[4].	[1] *well established* [4] *speculative*
Biodiversity is positively related to many ecosystem services provided by Semi-natural Grasslands. Other than livestock production, many ecosystem services are higher in semi-natural than in agriculturally improved grasslands, and this can be linked partially with the higher plant richness[1]. The Countryside Survey 2007 showed that, within the top 15 cm of soil, Acid Grassland (82.3 t/ha) has the highest carbon stock of any UK NEA Broad Habitat. Although the stock for Neutral Grassland (62.4 t/ha) is lower, it is above that for Improved Grassland and Arable and Horticultural land. Acid and Neutral Grasslands contain 293 teragrams of the UK's carbon store in the top 15 cm of their soil. Semi-natural Grasslands have high invertebrate abundance and diversity, and may provide pollination and pest control services by the spread of insects to agricultural areas[c]. However, declines in bumblebees since the 1960s are linked to declines in key Semi-natural Grassland plants[1].	[1] *well established* [c] *likely*
Semi-natural Grasslands present opportunities for delivering multiple services while requiring relatively low energy inputs. In contrast to Improved Grassland and Arable and Horticultural land, low input Semi-natural Grasslands generally: store greater densities of carbon and produce less nitrous oxide; produce less methane due to their lower stocking densities; allow greater water infiltration rates and enhanced storage (which should aid flood prevention); and experience less pollution because of the low fertiliser input[2]. Nutrient cycling also seems to be more efficient in unimproved grasslands. Enhancement of plant richness within Semi-natural Grasslands can also increase production in the absence of fertilisers[a]; for instance, one experiment showed a 40% difference in hay yield between species-rich and species-poor plots. Therefore, low input, high service-providing Semi-natural Grasslands form an alternative land use to high input	[2] *established but incomplete evidence* [a] *virtually certain*

agriculture, albeit with lower overall animal production[a].	
Agri-environment schemes are critical to maintain and enhance the biodiversity and ecosystem services of Semi-natural Grassland. Maintenance of the biodiversity and cultural value of Semi-natural Grassland requires low intensity management related to traditional farming[1]. Restoration of Semi-natural Grassland from, for example, arable and improved grassland, is well-researched and will be critical to prevent further biodiversity loss through habitat fragmentation, and to improve certain services[1]. Maintenance, recreation and restoration are delivered mostly through the country-based agri-environment schemes. For instance, the Tir Gofal scheme in Wales currently has 35,258 ha of Semi-natural Grassland under maintenance options and 1,985 ha being restored. Such protected and restored Semi-natural Grasslands also have the potential to provide recreation and tourism services (particularly if rare livestock breeds are used), and pollinator and pest control services for adjacent intensive farmland[c].	[1] *well established* [c] *likely*

*Each Key Finding has been assigned a level of scientific certainty, based on a 4-box model and complimented, where possible, with a likelihood scale. Superscript numbers and letters indicate the uncertainty term assigned to each finding. Full details of each term and how they were assigned is presented in Appendix 6.1.

6.1 Introduction

The vegetation of Semi-natural Grasslands comprises a mixture of grasses and herbaceous plants, along with sedges, rushes, mosses and other low-growing species. In the UK, Semi-natural Grasslands are the remnants of habitats created by low-intensity, traditional farming, or, in some cases, the natural vegetation on poor soils or in exposed locations (Pigott & Walters 1954). Much grassland in the UK has undergone agricultural 'improvement' through the re-sowing of plants, high inputs of inorganic fertilisers and intensive cutting or grazing. These activities have created grasslands dominated by a few agricultural grasses and white clover (*Trifolium repens*). In contrast to the generic and species-poor composition of agriculturally improved grasslands, plant communities in Semi-natural Grasslands often have a rich variety of grasses and herbs, and fall into distinct types which have developed over many decades in response to the local climate, soil, geology and management methods.

From a broad ecological perspective, grasslands can be seen as intermediate stages in the development of vegetation over time. Open areas, such as cultivated soil, burned woodland, or silted-up ponds, will usually develop gradually into grasslands of various types. If undisturbed, such grassland will often eventually acquire tree cover. But the intermediate grassland stage may be maintained by grazing, light burning, cutting, flooding or other processes which prevent the establishment and growth of scrub or trees.

The wide extent of grassland in the UK (Improved and Semi-natural Grasslands make up 37% of the land area (Carey *et al.* 2008) is largely the result of human activity. The extensive coverage of the 'wildwood' following the glacial retreat after the last ice age (the early Holocene, about 10,000 years ago) meant that grassland was a rare habitat (Rackham 1986), although its extent is debated (Hodder *et al.* 2005). Natural disturbances to the woodland allowed grasslands to develop and persist until trees closed over again, while in floodplains or on poor soils, other grasslands may have persisted over longer time periods (Hodder *et al.* 2005). Some of the earliest activities of human settlers in the Holocene involved the clearance of woodland, resulting in the rapid expansion of grasslands which were used for grazing and fodder production (and fertiliser production as manure was applied to crops). Variations in social and economic conditions have caused the area of grassland in the UK to fluctuate over the centuries, especially through changes in the balance of arable and grassland areas. For example, the area of grassland increased at the expense of arable land following the Black Death in the early 14th Century and decreased during the Napoleonic Wars (Thirsk 1997).

Semi-natural Grassland is, therefore, a very fluid habitat, which is amenable for conversion to (and from) arable land and to improved grassland through cultivation, re-sowing and fertiliser application. The relaxation of human interventions also causes changes: the cessation of management techniques such as cutting, grazing or burning will lead to colonisation by shrubs and trees which over-top the grasses and herbs and develop into scrub and woodland – a process which, over the last few decades, has occurred on various abandoned Semi-natural Grasslands. These fluctuations, and the fact that grassland farming practices have evolved continually, mean the history of any particular location now classified as a Semi-natural Grassland is complex and reflects human history at both local and national scales.

Semi-natural Grasslands comprise the Acid, Neutral and Calcareous Grassland broad habitats of the Countryside Survey (Carey *et al.* 2008), along with Purple Moor-grass and Rush Pastures which fall within the Fen, Marsh and Swamp broad habitat (**Figure 6.1**, **Figure 6.2**). Within these broad categories, many specific types of Semi-natural Grassland habitat are of conservation concern, particularly the UK Biodiversity Action Plan (BAP) priority habitats, which are lowland meadows, upland hay meadows, lowland dry acid grassland, purple moor-grass and rush pastures, and lowland and upland calcareous grasslands. These are considered important habitats at the European level, with all those listed being afforded protection across the EU, for example, through the Natura 2000 network (Rodwell *et al.* 2007). Upland acid grassland is a major component of UK Semi-natural Grassland, but it is not considered a priority habitat in the UK Biodiversity Action Plan (UK BAP; www.ukbap.org.uk) because it is often the result of overgrazing of moorland.

[insert Figure 1 here]
[insert Figure 2 here]

Because of its fluid nature, its association with human activities and its characteristic as an intermediate stage in the development of vegetation from bare soil to woodland, Semi-natural Grassland also has a close association with many other UK NEA Broad Habitats:

- Semi-natural Grasslands are mostly still within farming systems, but are distinguished from the Improved Grasslands of Enclosed Farmland by their history (lack of recent cultivation, re-sowing or heavy fertilisation) and current low-intensity management: much is managed under agri-environment schemes or is within protected areas.
- Grasslands can closely interact with Freshwater systems; in particular, water meadows were traditionally managed so that they stored seasonal floodwaters, retaining silt that fertilised the grassland for farming. These and other types of wet grassland, such as purple moor-grass and rush pastures, have an important role to play in the flow of water from the land to waterways, for example, by slowing drainage.
- The coastal zone contains many specific types of Semi-natural Grasslands; Machair (Chapter 11), Sand Dunes and the maritime vegetation of Sea Cliffs all comprise Semi-natural Grassland, much of which has high nature conservation value.
- Woodland is the natural endpoint of vegetation development on grasslands, and many woodlands contain grass areas; the New Forest, for instance, is a mosaic of closed wood and grassland, as well as heath. Wood pastures – rare remnants of former parks and Royal Forests – are an intermediate between woodland and grassland, and are a UK BAP priority habitat.
- A variety of grassland types is found in Urban areas, from species-rich Semi-natural Grasslands to highly managed, species-poor amenity grasslands.

In this chapter, we consider all the Semi-natural Grasslands (as distinguished from improved or amenity grassland) associated with other UK NEA Broad Habitats insofar as they represent the general Semi-natural Grassland resource. Roles, goods and services specific to the associated UK NEA Broad Habitat (e.g. coastal defence for sand dunes or water flow in wetlands) are considered in those chapters. Semi-natural Grassland is often an important component of linear features, such as roadside verges and hedgerows. However, the contribution of these linear features to Semi-natural Grassland is poorly quantified and the figures given in this chapter regarding stock and service delivery do not include these small areas.

6.2 Trends and Changes in Semi-natural Grassland

6.2.1 The Current Extent of Semi-natural Grassland

6.2.1.1 Total extent

Priority habitat Semi-natural Grasslands (i.e. excluding upland acid grassland) comprise only 1% of the UK land area and only 2% of the total area of UK grassland (including rough grazing or 3% if rough grazing land is excluded). **Table 6.1** provides estimates of the total area of the UK BAP priority grassland types including estimates of upland acid grassland (UK BAP 2006). Upland acid grassland is not a UK BAP priority habitat as it is often the product of overgrazing of more highly valued upland dwarf shrub heaths and is considered to have low botanical value. However, it does form part of the habitat that supports important upland breeding bird assemblages.

[insert Table 6.1 here]

6.2.1.2 Designated sites

Data on designations differ among the countries, having been gathered in different ways and at different times. Therefore, we present each country separately.

Table 6.2 shows the area of Semi-natural Grassland covered by various designations in England. Designations overlap, for example, Special Areas of Conservation (SACs) will also be Sites of Special Scientific Interest (SSSIs), so the percentages sum to more than 100%. However, these figures demonstrate that a large proportion of England's Semi-Natural Grassland resource is protected to some degree.

[insert Table 6.2 here]

Table 6.3 shows the area of Semi-natural Grassland within SSSIs and National Parks in Wales. Designations overlap, so some SSSIs are in National Parks.

[insert Table 6.3 here]

There are no area measurements of grassland features within Scottish SSSIs, so we can present no figures for Scotland. To date, approximately 15% of the Semi-natural Grassland resource in Northern Ireland is within Areas of Special Scientific Interest (ASSI). This is likely to increase in the near future due to further notification of grassland sites (NIEA 2001).

6.2.1.3 Agri-environment schemes

Agri-environment schemes reward farmers and land managers for delivering environmental outcomes on registered agricultural land in the UK. Each of the four countries has its own individual scheme and, therefore, information is presented separately for each country.

England. In England, the Environmental Stewardship Higher Level Scheme (HLS) is the principal mechanism for maintaining existing UK BAP-condition Semi-natural Grassland, restoring grassland in poor condition and creating new Semi-natural Grassland. In England, there are 60,733 hectares (ha) of grassland entered into the maintenance and restoration of grassland options of either the classic schemes (Countryside Stewardship; Environmentally Sensitive Areas) or HLS. In HLS, 2,373 ha have been entered into the creation of species-rich grassland option (Natural England 2009a).

Wales. **Table 6.4** summarises data on the area of Semi-natural Grassland types entered into the Tir Gofal options in Wales. These options allow maintaining existing UK BAP-condition Semi-natural Grasslands, restoring grassland in poor condition and expanding the Semi-natural Grassland resource through habitat creation.

[insert table 6.4 here]

Northern Ireland. The Northern Ireland Countryside Management Scheme (NICMS) is the current agri-environment scheme. A total of 12,996 ha are currently under agri-environment management as species-rich grassland (dry/wet/calcareous and hay meadow). It should be noted that habitat definitions under the NICMS are generally broader than UK BAP priority habitat classifications and their application relates to the management of whole field parcels. These factors account for differences between **Table 6.5** and **Table 6.1**.

[insert Table 6.5 here]

***Scotland*.** The Scotland Rural Development Programme supports the management, creation and restoration of species-rich grasslands through Rural Development Contracts. Under this competitive funding mechanism, contracts are awarded for proposals which are best able to deliver the agreed regional priorities (**Table 6.6**).

[insert Table 6.6 here]

6.2.2 The Current Condition of Semi-natural Grassland

Data from various surveillance and monitoring studies have provided information on the current condition of Semi-natural Grasslands in three of the four countries of the UK (**Table 6.7**). Currently, there are no quantitative data for Wales on the condition of grassland features in SSSIs or non-statutory sites. There are some data for the condition of Annex 1 grassland types on SACs. Of 22 features assessed between 2002 and 2006, all were assessed as ‘unfavourable’, 18% of which were ‘unfavourable recovering’.

For English non-statutory Semi-natural Grassland sites, only 21% of the grassland sample was in 'favourable' condition in 2005. This contrasts with the situation for SSSIs where, in most cases, the percentage of sites which were favourable exceeds that for the non-statutory site sample. Common Standards monitoring data for Scottish SSSIs in 2010 show that recent measures to get features in unfavourable condition into appropriate management have improved the overall proportion of lowland grasslands in favourable or 'recovering' condition from 45% (1999 to 2005) to 71% (2010). The condition of Semi-natural Grassland features on ASSIs in Northern Ireland was assessed between 2002 and 2008. Despite small sample sizes, the data show that only 37.5% of all grassland features assessed were in favourable/unfavourable recovering condition.

[insert Table 6.7 here]

6.2.3 Historical Trends in the Semi-natural Grassland Habitat

6.2.3.1 Changes in area: historical survey data

The loss and degradation of Semi-natural Grassland, particularly in the lowlands of Great Britain during the second half of the 20th Century, has been well documented (Blackstock *et al.* 1999; Fuller 1987; Green 1990; Ratcliffe 1984). It is clear that there has been a profound and widespread transformation of grasslands across the lowland landscapes of the UK, so that, for the most part, only relatively small, remnant patches survive. Cooper *et al.* (1994) reported that improved and semi-improved grasslands comprised 95.5% of the grassland resource in the UK lowland landscape. In contrast, there are very few data concerning the fate of Semi-natural Grasslands in the unenclosed uplands. Here, the issue is probably less to do with loss, but more to do with degradation resulting from overgrazing or attempts at agricultural improvement, as well as losses to forestry.

Fuller (1987) reported a 97% loss of semi-natural enclosed grasslands in England and Wales between 1930 and 1984. These losses were largely attributable to the conversion of grassland to arable land or the intensification of farming in these areas through ploughing, drainage and reseeding, and improvement with fertilisers and herbicides. This scale of loss is likely to have been similar across the lowland areas of south and east Scotland as the agricultural systems are essentially similar to those in lowland England and Wales. Mackey *et al.* (1998) found that rough grassland declined by 10% between the 1940s and 1980s throughout Scotland, but there was much regional variation. The extent of rough grassland contracted from around 12,300,000 ha (16% of Scotland) to 11,100,000 ha (14% of Scotland). This work was based on the National Countryside Monitoring Scheme (NCMS) and used aerial photography and estimates of change based on visible sward structure, which is not necessarily related to species composition. Grassland was classified as 'rough', 'intermediate' or 'smooth'. The rough grassland category is the one most likely to correspond to Semi-natural Grassland and would probably include purple moor-grass and rush pastures and acid grassland.

During the late 1980s and 1990s, grassland surveys conducted by the statutory, country-based conservation agencies and other, non-governmental organisations, such as The Wildlife Trusts, showed that losses of Semi-natural Grassland continued during this period. For example, a survey of Berkshire's Neutral Grassland in 1995 (previously surveyed in 1984 and 1987), showed that 50% of sites (60% by area) had been damaged or destroyed (Redgrave 1995). In addition, Devon Wildlife Trust (1990) recorded a 62% loss of culm grassland sites (mostly comprising purple moor-grass and rush pasture) between 1984 and 1989/90. These examples of declining extent are also supported by local surveys undertaken by other county Wildlife Trusts during a similar timeframe (Plantlife 2002). More recently, a survey of about 500 non-SSSI Semi-natural Grassland sites in England (Hewins *et al.* 2005) revealed that 24% of these sites more closely resembled agriculturally improved grassland types than Semi-natural Grassland habitats, indicating further losses of Semi-natural Grassland between 1980 and 2003.

A comparison of lowland grassland cover in Wales between the 1930s and 1980/90s using data from Davies (1936) and the Habitat Survey of Wales (HSW) showed an estimated loss of semi-natural (unimproved) and semi-improved lowland dry grassland to improved grassland of 91% over the 50–60 years between the two surveys (Stevens *et al.* 2010).

Although there are no quantitative trend data for Northern Ireland, similar losses of Semi-natural Grassland have undoubtedly occurred during the second half of the last century. For Eire, Byrne (1996) reported losses of 38% of lowland meadow sites and 43% of acid bent/fescue grassland sites in Leinster over the period from 1979 to 1994. Improved grasslands now dominate the Northern Ireland landscape, with less than 5% of grasslands classified as being species-rich (Cooper et al. 2009; NIEA 2010).

6.2.3.2 Changes in area and condition: recent data from the Countryside Survey 2007

Using a standardised methodology, the Countryside Survey reports changes in broad habitats between 1990, 1998 and 2007. The methodology is less focused on Semi-natural Grassland than the data reported in Section 6.2.3.1, so we will report Countryside Survey trends and consider how they contrast with the data already presented.

England (Countryside Survey 2009):

- There was no significant change in the area of either Calcareous or Acid Grassland broad habitats between 1998 and 2007; but between 1990 and 1998, there was a significant decrease in the area of both habitats.
- There was a significant increase in the area of Neutral Grassland broad habitat between 1990 and 2007.
- There was a significant decrease in plant species richness in botanically rich Neutral and Acid Grasslands between 1998 and 2007.
- The decrease in plant species richness in Neutral Grasslands is also reflected by a significant reduction in the number of foodplants for butterfly larvae and farmland birds.
- There was a significant increase in more competitive, nutrient-demanding plant species in botanically rich Neutral Grassland.

Scotland (Norton *et al.* 2009):

- There was no significant change in the area of Neutral or Calcareous Grassland between 1998 and 2007.
- The area of Acid Grassland increased between 1998 and 2007.
- Plant species richness decreased in both Neutral and Acid Grasslands between 1998 and 2007. Competitive species increased at the expense of species of open ground.

- Some of the plant species lost included those which are important foodplants for particular birds and butterfly larvae.
- Plant species associated with wetter conditions increased in Acid and Neutral Grasslands between 1998 and 2007.

Wales (Smart *et al.* 2009)

- There was no significant change in the area of Neutral, Calcareous or Acid Grassland between 1998 and 2007. However, in the upland zone, Acid Grassland increased in area, while Neutral Grassland decreased.
- Species richness and bird and butterfly foodplants decreased in botanically rich Neutral and Acid Grasslands.

Northern Ireland (Cooper *et al.* 2009)

- There was a decrease (although not statistically significant) in species-rich dry grassland (which includes lowland meadow) from 6,257 ha to 4,345 ha (-31%).
- There was no change in the 1,802 ha of Calcareous Grassland.
- There was a statistically non-significant decrease in fen meadow which contains some of the most species-rich purple moor-grass and rush pasture, from 6,257 ha to 4,345 ha (-31%). However, there was only a small (2%) and non-significant) decline in species-rich wet grassland (13,186 ha) which contains the majority of the purple moor-grass and rush pasture resource.
- There was a statistically non-significant increase in Acid Grassland in lowland classes from 211 ha in 1998 to 549 ha in 2007. However, some of this habitat gain has occurred in marginal upland land-classes where there has also been a significant decrease in (-22%) Acid Grassland.

The above results generally accord with trends detected by other studies reported in 6.2.3.1. The decrease in plant species richness may be attributable to a combination of both a reduction in, and cessation of, grazing, as well as the continuing effects of atmospheric deposition of nitrogen. The data suggest, however, that the loss of grassland broad habitats has substantially slowed over the last ten years. This finding is in accordance with the UK BAP assessments for priority habitats (**Table 6.8**).Yet there have also been unquantified gains in grassland that conform broadly to the priority UK BAP types through creation, and restoration from arable, semi-improved or improved grassland, as a result of agri-environment incentive measures.

However, there are two surprising findings from the Countryside Survey (2007) results: the increase in the extent of Neutral Grassland (which includes less species-rich, semi-improved grasslands); and the increase in extent of Acid Grassland. The former might be due to the establishment of grasslands through agri-environment incentives or long-term set-aside. The cause of the increase in Acid Grassland is unclear, but could be due to the conversion of dwarf shrub heath to Acid Grassland by overgrazing, along with a reduction in bracken (*Pteridium aquilinum*) cover.

6.2.4 Conservation Status of Semi-natural Grassland

Table 6.8 shows recent assessments of the trend in the extent of UK BAP priority grassland habitats from the 2008 UK BAP reporting exercise, along with assessments of the overall conservation status of grassland Annex 1 habitats as required under Article 17 of the EU Habitats Directive. This reporting is largely based on expert opinion and anecdotal information. The findings illustrate the opinion that, across the UK, Semi-natural Grassland continues to decline in terms of extent, although probably at a slower rate than in the later decades of the 20th Century – a conclusion which largely matches the data presented in Section 6.2.3. The condition of these grasslands is generally considered poor but improving, although there are large differences between grassland types and countries. In England, and probably elsewhere, Semi-natural Grasslands in SSSIs are mostly in better condition compared to non-SSSIs.

[insert Table 6.8 here]

6.2.4.1 Trends in grassland species

Vascular plants. Many characteristic vascular plants of Semi-natural Grassland have declined markedly over the last 50 years. Preston *et al.* (2002, 2003) examined the *New Atlas of the British and Irish Flora* and compared recent (1987 to 1999) distributions and frequencies of native species and archaeophytes (ancient non-native species) with those recorded in the 1962 Atlas. By assigning each species to its Countryside Survey broad habitat, it was possible to calculate an ‘average’ change index for species within each broad habitat. They found that Calcareous Grassland and Acid Grassland both had a negative change index: many species associated with these habitats had declined substantially since the 1930s.

Butterflies**.** Fox *et al.* (2006) concluded that butterflies restricted to semi-natural habitats (including grassland specialists) have fared badly over recent decades. Farmland butterfly populations are considered good long-term biodiversity indicators because they respond to environmental change and agricultural management, occur in a wide range of habitats, and are representative of many other insects. A multi-species index of farmland butterfly abundance has been compiled by Butterfly Conservation and the Centre for Ecology and Hydrology, chiefly from data collated through the UK Butterfly Monitoring Scheme. The indicator includes 48 of the 51 native butterfly species resident in England and occurring on farmland for which sufficient data are available. The indicator includes a breakdown for 23 specialist (low-mobility species restricted to semi-natural habitats) and 25 generalist (mobile species that occur in a broad range of habitats in the wider countryside) species from data collected at 672 lowland farmland sites. Analysis of the underlying trend over the period 1990 to 2009, smoothed to factor out year-to-year fluctuations (structural time-series analysis, with confidence intervals applied by the Kalman filter), indicates a -42% change for all farmland butterflies, a -36% change in specialists and a -47% change in generalists (unpublished analysis supplied by Butterfly Conservation).

Birds**.** A number of conservation priority bird species are associated with Semi-natural Grassland, primarily during the breeding season. Waders are strongly associated with lowland wet grasslands, twite (*Carduelis flavirostris*) with northern hay meadows and stone curlews (*Burhinus oedicnemus*) with the Brecks and chalk downland (Green & Griffiths 1994). Salisbury Plain holds important populations of several declining passerines, including whinchat (*Saxicola rubetra*), grasshopper warbler (*Locustella naevia*) and skylark (*Alauda arvensis*) (Stanbury *et al.* 2000), along with the only re-established great bustard (*Otis tarda*) population in the UK. There were major declines in the numbers and distribution of breeding and wintering birds associated with grassland habitats in the UK over the second half of the last century (Vickery *et al.* 2001). This has been particularly well documented for breeding waders associated with lowland damp grassland. The first damp grassland breeding wader survey was conducted in 1982 (Smith 1983) and showed that numbers were already low and that large populations were confined to relatively few sites. Wilson *et al.* (2005) subsequently showed that lapwing (*Vanellus vanellus*), snipe (*Gallinago gallinago*), curlew (*Numenius arquata*) and redshank (*Tringa tetanus*) declined significantly on lowland wet grassland between 1982 and 2002. However, the picture is somewhat complicated because some wintering wildfowl species have increased over the last 30 years (Kershaw & Cranswick 2003). This is thought to be due to a number of factors including increases in nutritious, improved grasslands and winter-sown arable crops, refuge creation and climate change.

In upland grassland landscapes, populations of certain breeding birds (especially waders) declined during the last three decades of the 20th Century (Baines 1988; Fuller *et al.* 2002; Henderson *et al.* 2004; Taylor & Grant 2004). Recent surveys also indicate that since the early 1980s there has been a widespread decline in the breeding population, and a contraction in the breeding range, of yellow wagtails (*Motacilla flava*) in upland hay meadows; this decline accelerated during the 1990s (Nelson *et al.* 2003). Raine *et al.* (2009) showed that the range and numbers of breeding twite have declined considerably since the 1970s in the English uplands. This species nests on open moorlands but requires access to species-rich hay meadows and pastures for feeding during the breeding season (Brown & Grice 2005).

6.2.5 Drivers of Change in the Semi-natural Grassland Habitat

[insert Table 6.9 here]

The drivers of change in the Semi-natural Grassland habitat are well-rehearsed. There is qualitative information on the contribution of these drivers to change in Semi-natural Grassland since the war, and their potential role in the near future. However, exact figures – for example, of areas lost to certain land conversion activities – are rarely available. **Table 6.9** combines this qualitative information and our expert judgement to represent the role of each driver of change in Semi-natural Grassland in the past, present and future. It must be noted that degradation of an individual Semi-natural Grassland is often caused by multiple drivers. For example, a re-survey by Bennie *et al.* (2006) during 2001 to 2003 of 92 English Calcareous Grasslands first surveyed in 1952/53 showed declines in plant species richness and replacement of typical Calcareous Grassland plants with more competitive species. Bennie *et al.* (2006) suggested multiple drivers contributed to these losses, including habitat fragmentation, nutrient enrichment and reduced grazing.

Burnside *et al.* (2003) do provide quantitative information on the fate of Semi-natural Grasslands (which they call 'unimproved grassland') between 1971 and 1991, albeit only for the Western South Downs landscape in West Sussex. Analysis of aerial photos suggested a large amount of the 4,729 ha of Semi-natural Grassland present in 1971 was lost by 1991. The greatest losses were to arable land, while plantations and development of woodland and scrub also accounted for a large proportion of losses (**Table 6.10**).

[insert Table 6.10 here]

6.2.5.1 Agricultural improvement

A major process in the history of Semi-natural Grassland has been agricultural improvement to increase livestock production. Improvement has involved actions such as: substantial fertiliser addition (especially inorganic fertilisers); tillage followed by re-seeding with productive grass and legume varieties; drainage; lime addition; hay-cutting replaced by silage; and changes in the season and intensity of grazing and the grazing animal. Hodgson *et al.* (2005) show that, for a particular set of English grasslands, the recent economic climate has encouraged the improvement of pasture. Even taking into account the expenditure on fertilisers and other improvements, the economic yield from improved pasture (£600 ha/yr) was vastly greater than that of any unfertilised Semi-natural Grasslands they analysed (£100–300 ha/yr). Along with the loss of other aspects of traditional grassland management (e.g. shepherding and droving of livestock), intensification has caused declines in plant and animal biodiversity, decreased species richness and increased the domination of fast-growing, productive plants. For example, nitrogen additions over 25 kg/ha/yr have the potential to cause loss of botanical diversity, at least in Neutral Grassland (Mountford *et al.* 1993). This amount is small in comparison to the nitrogen rates routinely used on Improved Grasslands, which can be higher than 250 kg/ha/yr, with more moderate applications still in the range of 100-250 kg/ha/yr (Soffe 2003). As illustrated in **Figure 6.3**, improvement – driven by government incentives and grant aid – is considered to have been the main cause of the loss of upland and lowland Semi-natural Grassland priority habitats since the Second World War. Fuller (1987) calculated figures for the change in the area of permanent pasture in England and Wales that received nitrogen fertilisers from 1938 to 1984. In 1938, no fertiliser was applied to permanent pasture, but by 1944, fertiliser was applied to about 15% of permanent pasture; this figure rose to 28% in 1960, 60% in 1971 and 80% in 1984. Today, agricultural improvement is generally no longer a major cause of loss due to the small area of priority habitat Semi-natural Grassland that remains and the protection much of it is afforded (Section 6.2.1.2).

[insert Figure 6.3 here]

The classic Park Grass Experiment, which began in 1856, illustrates the impacts of agricultural improvement through fertiliser addition and liming (Silvertown *et al.* 2006). Fertilisers increased the availability of nitrogen, phosphorus and potassium in the soil, which, in turn, led to greatly increased hay yields in some plots (Hill & Carey 1997).

Increased fertility, along with greater soil acidity (an effect of the nitrogen fertiliser), led to declines in plant species richness. Compared to plots without the addition of nitrogen, fertilising with 50 kg/ha/yr was calculated to lead to a loss of 6.5 plant species per plot over the period of the experiment. Losses in plant diversity seem to have led directly to changes in the invertebrate fauna such as declines in the species richness of leafhoppers and springtails.

Declines in individual species have been linked to certain aspects of agricultural improvement. Grassland bird declines (Section 6.2.4.1) have been attributed to the intensification of agriculture which has substantially reduced the suitability of grassland as a feeding and breeding habitat (Vickery *et al.* 2001). The switch from hay-making to silage has had a strong impact on some species, with earlier cutting dates resulting in nest destruction before the chicks have fledged (e.g. yellow wagtail; Nelson *et al.* 2003) or the loss of important feeding sites during the breeding season (e.g. twite; Raine *et al.* 2009).

Although we state that agricultural intensification is currently a minor driver of Semi-natural Grassland loss across the UK, it is continuing in certain regions, for example, where traditional forms of management are still carried out. Crofting is a form of land tenure restricted to the north and west of Scotland. Typically, crofts provided a source of subsistence that had to be supplemented by employment away from the croft, and so, they are often clustered together to form townships. Traditionally, croft land was subject to rotational agriculture and hay production for winter feed. Cattle and sheep were kept on common grazing areas and then allowed to graze the croft land in the winter. The small scale of operations, coupled with low fertility, resulted in a low-intensity land use and often high biodiversity in the Neutral and Calcareous Grasslands associated with the croft land. Croft land is, however, subject to many threats. These have not been quantified and so much of the evidence is anecdotal. However, the following changes in agricultural management are ongoing:

- Abandonment of rotational agriculture and loss of fallow grasslands. Surveys of five areas on North and South Uist and Benbecula showed a 60% reduction in survey points under arable cultivation between 1976 and 2009 (Pakeman unpublished).
- A shift to increased cultivation of grass silage and reduction in the area of hay grown.
- A shift from traditional strip cultivation to management of land in large blocks.
- Fencing of individual holdings.
- Increased use of inorganic fertilisers and deep ploughing.
- Increase in the summer grazing of croft land. This appears to have led to a reduction in bumblebees as pollen and nectar sources are grazed away (Redpath *et al.* 2010).
- Complete abandonment of crofting agriculture due to other employment or absentee crofters.

Contributing to these changes is a diminishing and ageing crofting population opting for lower input agriculture. In contrast, drivers for increased intensity of management are also apparent as some individuals are farming full-time using sublet crofts to build a more efficiently sized management unit.

6.2.5.2 Land use change

The post-Second World War impetus to increase arable production and develop the UK's built infrastructure impacted on Semi-Natural Grassland. For priority habitat Semi-natural Grasslands the major process after improvement was conversion to arable (**Figure 6.3**; **Table 6.10**), which was kick-started by the compulsory 'Cultivation Orders' during the Second World War. Today, the Countryside Survey (2007) indicates that there are no major ongoing losses of Semi-natural Grassland to arable land. There were more moderate post-war losses through conversion to forestry, urbanisation and road building (**Table 6.10**), but these have largely ceased. In the uplands, forestry has been a major cause of losses of Acid Grassland (and associated moorland) (Thompson *et al.* 1995). These losses are likely to continue: the Scottish Forestry Strategy aims to increase Scotland's woodland cover from the current 17% to 25% by the second half of the 21st Century and the current indication is that 270,000 ha of the 650,000 ha planned will be planted on 'unimproved grassland/bracken' (Forestry Commission 2009)

6.2.5.3 Nutrient deposition and transfer

There is very clear evidence of the effects of atmospheric deposition of nitrogen on Semi-natural Grassland in the UK. Stevens *et al.* (2004) surveyed Great Britain's Acid Grasslands (*Agrostis-Festuca*) across a gradient of nitrogen deposition rates (5-35 kg/ha/yr). Plant species richness showed a negative relationship with nitrogen deposition rate such that the European average nitrogen deposition rate of 17 kg/ha/yr was related with a 23% reduction in species number compared to the lowest deposition rates (5 kg/ha/yr). Maskell *et al.* (2010) carried out a similar study using Countryside Survey 1998 data considering Acid, Neutral and Calcareous Grasslands. Across the whole dataset, plant species richness was negatively related to nitrogen deposition rates for Acid and Neutral Grasslands. The relationship was quite strong in Acid Grasslands and further analysis suggested that the driver was increased soil acidity caused by nitrogen deposition rather than increased fertility. The weaker relationship in Neutral Grasslands was related to the fact that many of these grasslands already have relatively high background soil nutrients. While Calcareous Grassland richness did not relate to nitrogen deposition, species composition did and there was increased representation by species typical of fertile habitats. Using temporal datasets for Acid Grasslands, Duprè *et al.* (2010) found similar nitrogen deposition effects in the UK, Germany and the Netherlands, and showed that these effects have been accumulating since at least the 1930s. It is difficult to predict the future course of changes in Semi-natural Grassland due to nitrogen deposition; it is likely that the major changes have happened already, but ongoing deposition will probably lead to some further change.

Semi-natural Grasslands may also be vulnerable to indirect sources of nutrient enrichment, including runoff from adjacent agricultural holdings, overflow from eutrophicated watercourses, movement of livestock between improved and unimproved pastures, or supplementary feeding (Kirkham 2006); however, these impacts have not been quantified.

6.2.5.4 Inadequate management

The abandonment of low or unproductive land is a major cause of habitat decline across Europe (Strijker 2005). Currently, lowland priority habitat Semi-natural Grasslands are under most threat from inadequate management – generally under-grazing. Only 21% of a sample of non-protected English priority habitat Semi-natural Grasslands was in favourable condition and this was attributed mostly to poor management of the remainder (Hewins *et* *al.* 2005). Similarly, the low percentages for favourable condition of lowland Semi-natural Grassland SSSIs given in **Table 6.7** are reportedly mostly due to under-grazing (Williams 2006). Under-grazing is a particular issue on Calcareous and Acid Grasslands and purple moor-grass and rush pastures, and results in rank vegetation (such as tor grass, *Brachypodium pinnatum*, on Calcareous Grasslands) and the exclusion of desirable species. Neglect reflects poor financial returns from grazing Semi-natural Grasslands with low productivity, and under-grazing of these habitats is likely to continue into the future because of a lack of funding for conservation grazing. The famous extinction of the large blue butterfly (*Maculinea arion*) in the post-war decades was directly attributable to loss of its niche through under-grazing (Thomas *et al.* 2009); many other warmth-loving invertebrates are also threatened by under-grazing (Thomas *et al.* 1994). The pasqueflower (*Pulsatilla vulgaris*), a perennial herb of Calcareous Grassland in England, declined dramatically during the 18th and 19th Centuries due to the ploughing of its habitat and is now a threatened species. By the 1960s, only 33 populations remained. Since 1968, it has become extinct on 16 sites and has declined on four others; these recent declines have been attributed to a reduction in grazing (Walker *et al.* in prep.).

6.2.5.5 Overgrazing

In contrast, upland acid grassland is under threat (only 23% is in favourable condition) from overgrazing (Williams 2006), particularly through overstocking with sheep. Anderson and Yalden (1981) showed that sheep numbers in an area of the northern Peak District trebled between 1930 and 1976. Of greater concern is the loss of heather moorland through overgrazing, which has caused an increase in the less biodiverse upland acid grassland (Anderson & Yalden 1981); this driver is discussed in more detail in Chapter 5 (Section 5.2.1.1). However, overgrazing has also damaged existing Acid Grassland through the loss of plant species and associated fauna, and the spread of unpalatable plant species such as mat grass (*Nardus stricta*). In addition, the unfavourable status of protected upland calcareous grasslands (again, only 23% are in favourable condition) is mostly due to overgrazing (Williams 2006). In extreme cases, very heavy grazing and trampling can lead to exposure of bare soil and erosion. The Common Agriculture Policy (CAP) reforms are leading to a reduction in livestock numbers in the uplands because payments are no longer linked to production (Chapter 5), thus reducing pressure on upland grasslands, although care will need to be taken that the problems of under-grazing do not now arise as a consequence.

6.2.5.6 Habitat fragmentation

Since the Second World War, Semi-natural Grassland sites have become increasingly fragmented and isolated among intensively managed agricultural land (Burnside *et al.* 2003). As a result, patch sizes of Semi-natural Grasslands, particularly in the lowlands, are now small. Stevens *et al.* (2010) found that mean grassland patch sizes recorded for different grassland NVC communities during the Lowland Grassland Survey of Wales ranged from 0.45 ha for Neutral Grassland MG5a to 0.08 ha for Acid Grassland U4c (**Figure 6.4**).

[insert Figure 6.4 here]

Table 6.11 provides data on site size of UK BAP priority lowland grassland types from the Natural England inventory. This shows that a high proportion of sites are less than 5 ha in extent. In England, of the sample of 483 non-statutory grassland sites surveyed by Hewins *et al.* (2005), the mean site area was 2.7 ha (range 0.1–10 ha). A study by Cooper *et al.* (1994) found that Semi-natural Grasslands in Northern Ireland were highly fragmented, especially in the lowlands. Mean size of a sample of Semi-natural Grassland field parcels (recorded between 1986 and 1991) ranged from 0.03 ± 0.02 ha (lowland calcareous grassland) to 1.6 ± 0.27 ha (upland species-rich wet grassland). Upland hill pasture, which probably equates to upland acid grassland, however, had a mean size of 2.40 ± 0.54 ha.

[insert table 6.11 here]

Such extreme fragmentation could compromise the long-term conservation of surviving populations of specialist taxa due an 'extinction debt' (Cousins *et al.* 2009). Small and isolated pockets of individuals may become locally extinct during unfavourable conditions and fail to recolonise because there are no populations within dispersal range (Bullock *et al.* 2002). Studies have shown these processes to be important for such iconic Semi-natural Grassland species as the marsh fritillary butterfly (*Euphydryas aurinia*) (Bulman *et al.* 2007) and devil's bit scabious (*Succisa pratensis*) (Soons and Heil 2002). Furthermore, management to reduce the fragmentation of Calcareous Grassland habitat has allowed the recovery of the silver-spotted skipper (*Hesperia comma*) in southern England (Davies *et al.* 2005).

6.2.5.7 Invasion by non-native plants

The spread of undesirable native plants on grassland (e.g. tor grass, mat grass, false oat grass, *Arrhenatherum elatius*, bracken) is a consequence of the drivers described in sections 6.2.5.1-6.2.5.6. Although Calcareous Grasslands can be locally infested by shrubs, such as *Cotoneaster* species, there is little evidence of widespread problems caused by the invasion of non-native plants into Semi-natural Grasslands. Using Countryside Survey 1990 and 1998 data, Maskell *et al.* (2006) found few non-native species in 'infertile grasslands', with 0.09 non-native species per 4 m^2 plot compared to 0.29 species in 'fertile grasslands'. In general, semi-natural habitats, such as Semi-natural Grassland, bog and moorland, were much less invaded than highly modified habitats, such as crops, Improved Grassland and plantation forestry. Maskell *et al.* (2006) suggest that non-native invasions *per se* will not be a driver of change in Semi-natural Grassland, although they may increase in response to other drivers such as climate change or nitrogen deposition.

6.2.5.8 Habitat protection

Post-Second World War conservation policies have had a huge impact on Semi-natural Grassland, with large areas now protected under a variety of designations (Section 6.2.1.2). While protection may prevent land use change in Semi-natural Grasslands, many are not in favourable condition (Section 6.2.2). However, it seems that the management of protected grasslands is improving, with the high percentages of grasslands recovering from unfavourable condition (Section 6.2.2). Thus, while protection should be maintained and even increased in the future, appropriate management (Section 6.5) is vital to making protection effective.

6.2.5.9 Agri-environment schemes

Agri-environment schemes began in the UK in 1987 and large areas of Semi-natural Grassland are now managed under these schemes (Section 6.2.1.3). Current prescriptions which impact Semi-natural Grassland include those targeted at maintaining or restoring the species-rich habitat, but also those focused on maintaining the historic environment, such as water meadows. Much is written about the effectiveness of agri-environment schemes, but the evidence for conservation of Semi-natural Grassland is generally positive. Hewins *et al.* (2005) assessed the condition of about 500 non-SSSI English priority habitat lowland Semi-natural Grasslands and found that those under an agri-environment agreements were twice as likely to be in favourable condition as those outside agreements (27% versus 14%). Considering only grassland under agri-environment schemes, Critchley *et al.* (2004) collated monitoring data for priority habitat lowland Semi-natural Grasslands across the UK. They found that existing high diversity Semi-natural Grasslands were generally maintained well under the schemes, and that there was evidence of some success in restoring diverse grassland on improved grassland. It is likely that improved targeting of agreements, and better management strategies and restoration methods will increase the effectiveness of agri-environment schemes in the near future (Anon 2008).

6.2.5.10 Climate change

As with other UK habitats, the direct impacts of climate change on Semi-natural Grassland are currently few, but are likely to become important in the future. For example, projections suggest an altered hydrology (lower rainfall and increased evapotranspiration) in wet grasslands which would negatively affect plant and bird species dependent on a high water table (Thompson *et al.* 2009). The MONARCH study combined analysis of the climate space currently occupied by selected plant and animal species with the climate projections of UKCIP98 for 2020 and 2050 to suggest threats to species of particular UK habitats (Harrison *et al.* 2001; Berry *et al.* 2003). This analysis indicated that the studied species of drought-prone acid grassland (certain acid grasslands found in south-east England), lowland hay meadows and lowland calcareous grassland would be little affected by climate change, while certain species of upland hay meadows, such as globeflower (*Trollius europaeus*) and wood crane's-bill (*Geranium sylvaticum*), may lose climate space. The authors emphasise the uncertainty in both climate projections and in understanding the role of climate in determining species' distributions. Furthermore, the statistical methods used in such 'climate envelope' analyses have been criticised (Beale *et al.* 2008).

It is important, therefore, that recent experimental studies have considered the responses of calcareous Semi-natural Grasslands to climatic manipulations in both the uplands (Buxton, near Sheffield) and the lowlands (Wytham, near Oxford) (Grime *et al.* 2000, 2008). The manipulations comprised elevated winter temperature, summer drought and summer watering. After five years, the lowland site showed increased productivity and large species changes in response to higher temperatures and water availability; the upland site changed very slowly. Monitoring continues at Buxton and, after 13 years, an analysis has shown that the treatments had little effect on productivity or species. When it was first assessed, the Wytham site had recently reverted from arable cultivation, so the large responses were probably a reflection of the immature state of the vegetation and the presence of fertiliser residues. The Buxton findings suggest that the stable dynamics of unproductive Semi-natural Grassland may mean that the response to climate change will be rather slow, at least in the medium-term (Grime *et al.* 2008).

6.3 Goods and Ecosystem Services from Semi-natural Grassland

The major services provided by Semi-natural Grassland relate to animal production and cultural heritage. These, and other services, are described in **Table 6.12** in categories which are related to the generic UK NEA final services and goods.

[insert Table 6.12 here]

6.3.1 Livestock Production

6.3.1.1 Quantity of production

The wide extent of grassland in the UK is the result of the human expansion of this habitat over the centuries to provide grazing and fodder for animal production – meat, dairy products, wool, etc. Modern farming methods were developed to boost production and the consequent improvement activities, such as re-sowing and heavy fertiliser application, have converted much of the Semi-natural Grassland resource to Improved Grassland (Chapter 7, Section 7.1.3). The remaining Semi-natural Grasslands are often still used for animal production, if only to achieve conservation management, but the production is much lower than that on Improved Grassland. Low production is related to the low soil nutrients – particularly phosphorus and nitrogen – compared to Improved Grassland (Janssens *et al.* 1998). For example, Tallowin *et al.* (2005) studied a range of English lowland grasslands, ranging from Semi-natural Grasslands receiving no fertilisers to Improved Grasslands receiving over 400 kg/ha/yr of nitrogen. The most intensive grasslands carried over three times the stocking rate of unfertilised Semi-natural Grasslands. Livestock production on Semi-natural Grasslands must, therefore, be tuned carefully to the specific conditions. For example, the Defra SUSGRAZ project on cattle-grazed, neutral Semi-natural Grassland demonstrated that individual animal growth rates equivalent to those on fertilised grassland (0.8 kg/day) could be achieved, albeit with stocking rates roughly half of those used on the fertilised grassland (Griffith & Tallowin 2007).

Tallowin and Jefferson (1999) carried out an important review of various studies of the agricultural productivity of UK lowland Semi-natural Grassland, which we draw upon here. The most straightforward measure of grassland production for agriculture is the dry matter yield of cut hay – Tallowin and Jefferson used this measure standardised for a cutting height of about 5 cm above ground level. Hay yield for the first cut in June or July varied greatly across Semi-natural Grasslands, but was between 1.5–6 t/ha. The total annual yield for one or more cuts during the growing season ranged from about 2–8 t/ha. Allowing for losses during haymaking and baling of about 20%, these yields are less than 30% of the dry matter usually obtained from two or more silage cuts on agriculturally improved grassland (ryegrass leys). The addition of inorganic fertilisers to Semi-natural Grassland increases yearly dry matter yields hugely, up to about 10–12 t/ha.

The Macaulay Institute Hill Grazing Management Model provides predictions of dry matter yield from various types of upland acid grassland (Armstrong *et al.* 1997a). Yield varies with vegetation type, management, location in the UK (based on temperature zone) and altitude (**Figure 6.5**). The baseline annual yields of 1.5–5 t/ha in the most favourable zones and altitudes are similar to those found by Tallowin and Jefferson (1999) for lowland grasslands. Such annual yields compare poorly with those for reseeded upland grassland, for which the model and empirical studies suggested an average of about 8 t/ha.

[insert Figure 6.5 here]

The quality of the herbage produced is also important for livestock production. Measured in the laboratory, the digestibility of the organic matter in the hay is a common measure of quality. High content of lignin and structural carbohydrates lowers digestibility and these constituents are generally higher in hay from Semi-natural Grasslands than from Improved Grasslands. Tallowin and Jefferson (1999) report digestibility percentages for lowland Semi-natural Grassland as about 70% for hay cut early in the season (April–May) to about 50% for hay cut later in the season (July–September); this means digestibility is about 20% below that of forage cut for silage from agriculturally improved grassland. Armstrong *et al.* (1997b) report similar values for upland acid grasslands: 48–67% for *Molinia* grassland and 64–72% for *Agrostis-Festuca* grassland, compared to 78% for re-seeded improved grassland. On poor diets, such as those of high fibre content, ruminant livestock become limited by the volume of their guts and the time they can spend feeding. Thus, along with intake and a host of other factors, digestibility has to be taken into account when determining the feed value of Semi-natural Grassland forage and, therefore, the provisioning service of animal production. Tallowin and Jefferson also showed that the mineral (particularly phosphorus and magnesium) and nitrogen content of hay from lowland Semi-natural Grasslands may often be lower than in Improved Grasslands and sub-optimal for the growth and body condition of livestock.

There has been speculation that the secondary metabolites (chemicals which are not essential to a plant's main functions, but are linked with defence against herbivores) of some grassland plants may be efficacious against the gut parasites of livestock (Rook *et al.* 2004). As secondary metabolites vary greatly among species, the greater diversity of plants in Semi-natural Grassland compared to Improved Grassland might enhance parasite control. Athanasiadou and Kyriazakis (2004) examined the evidence for such a process in relation to helminth nematode gut parasites. They concluded that secondary metabolites can have anti-helminthic properties, but that their effectiveness depends on their form and availability. High consumption of secondary metabolites can, however, be harmful to livestock as they have anti-nutritional properties. Indeed, there is considerable evidence that animals learn to avoid plants with high levels of secondary metabolites (Iason & Villalba 2006). Therefore, the balance of harmful and positive effects of plant secondary metabolites is critical and there is a lack of evidence as to how this balance is played out for livestock grazing on Semi-natural Grassland.

6.3.1.2 Quality of production

While the factors described in Section 6.3.1.1 generally lead to a lower quantity of livestock production on Semi-natural Grassland compared to Improved Grassland, the hypothesis that the *quality* of livestock production is higher on Semi-natural Grassland has been receiving attention recently. Quality refers to the nutritional value, taste, appearance and smell of meat and dairy products. A number of studies show that animals fed forage rather than concentrates produce meat which is more attractive to (better taste, appearance and smell), and healthier for (greater concentrations of omega-3 fatty acids), consumers (Wood *et al.* 2007). However, the evidence for such benefits from animals fed on biodiverse grasslands (i.e. Semi-natural Grassland) compared to agriculturally improved grasslands is less clear. Many studies are not well controlled, for example, so the conditions under which livestock develop vastly differ between 'biodiversity' treatments (Wood *et al.* 2007).

Some recent studies have been better designed. Whittington *et al.* (2006) compared lamb raised on semi-improved grasslands (control), saltmarsh, grass moor and heath. The meat from the control lambs was scored by a panel as having worse taste and odour compared to the semi-natural habitats. The moor and heath lambs had meat with higher amounts of polyunsaturated fatty acids than the other two groups, which may be linked to the improved flavour. A study by the University of Bristol (2008) analysed beef produced from cattle grazing on improved compared to neutral lowland Semi-natural Grassland. In one experiment, cattle produced fatter carcassess on the improved grassland, but the fatty acid composition and quality did not differ between the pasture types. In a second experiment, the cattle on improved pasture had a much higher fat concentration than those on Semi-natural Grassland. In this case, the low fat content of the latter allowed the nutritionally beneficial omega-3 fatty acids to reach higher concentrations. It should be noted that neither of these studies has been published in the peer-reviewed literature.

In a peer-reviewed publication, Fraser *et al.* (2009) reported a study in the Welsh uplands which compared cattle raised on improved pasture with cattle raised on *Molinia*-dominated rough pasture (i.e. upland acid grassland). In comparison to the rough pasture, the improved pasture carried more than twice the stocking rate, the rate of liveweight gain was about four times higher, and the final carcasses were about 15% heavier. The meat from the rough pasture animals contained less fat, reflecting the lower weight gain. However, the fatty acid composition differed only slightly between pasture types, with a marginally higher proportion of polyunsaturated fats in the animals from rough pasture. A taste panel found no effect of pasture type on meat quality. Therefore, Semi-natural Grasslands may produce better quality meat than Improved Grasslands, but the evidence remains inconsistent.

There is good evidence from France that the taste, aroma and texture of cheeses is affected by the botanical diversity of pasture or forage fed to livestock. This work is summarized in an excellent review by Coulon *et al.* (2004). Cheeses made by the same process, but using milk from animals grazed on different Semi-natural Grasslands, can differ strongly in taste, aroma and texture. When such comparisons have been made contrasting animals fed hay from Semi-natural Grassland with those fed from agriculturally improved grasslands, the Semi-natural Grassland-derived cheese were less bitter with less rancid odours. It is thought that grassland botanical composition directly affects the sensory characteristics of the resulting cheese through the transfer of plant species-specific chemicals, such as terpenes and carotenes, into the milk, but also indirectly affects it by influencing both the quality and quantity of milk proteins, fats and enzymes, and the diversity of microbes in the milk. These findings, especially the fact that the characteristics of the Semi-natural Grasslands on which animals graze influence the sensory characteristics of the resulting cheeses, provide support for the French terroir movement, which places value on the effects of regional variations in environment and culture on food, wine and other produce.

6.3.2 Cultural Services: Heritage, Recreation, Tourism, Education and Ecological Knowledge

Semi-natural Grasslands are part of the cultural landscape (environmental settings) of the UK. Most are remnants of traditional farming practices and are the product of thousands of years of human interaction with the landscape and wildlife. Semi-natural Grasslands are both ubiquitous and important throughout the UK, adding to the complexity and diversity of our landscapes. As well as the prominent, large fields of Semi-natural Grassland, there are numerous smaller patches, often found along streamsides and roadsides, which provide a refuge for many species that have been reduced elsewhere through intensification. The value placed by humans on Semi-natural Grassland species and landscapes can be seen in the conservation designations that are afforded to so much of the grasslands resource in the UK (Section 6.2.1.2).

6.3.2.1. Conservation and heritage

A measure of the cultural value of Semi-natural Grasslands is their provision of habitat for species of conservation interest, such as UK BAP priority species of which there are 1150 in total. Lowland grassland priority habitats (dry acid and calcareous grasslands, lowland meadows, purple moor-grass and rush pastures) are home to 206 UK BAP species, while upland grassland priority habitats (calcareous grasslands and upland hay meadows) are home to 41. For lowland and upland grasslands respectively, the UK BAP species comprise: 9 and 2 fungi, 24 and 0 lichens and bryophytes, 51 and 13 vascular plants, 86 and 13 invertebrates, 6 and 0 amphibians and reptiles, 23 and 11 birds and 7 and 2 mammals (Webb *et al.* 2009). Many of these species are restricted in their ranges (**Figure 6.6**), emphasising the importance of the grassland habitat. Important species of Semi-natural Grassland include the: date waxcap fungus (*Hygrocybe spadicea*); lady's slipper (*Cypripedium calceolus*), monkey (*Orchis simia*), green-winged (*O. morio*) and greater butterfly (*Platanthera chlorantha*) orchids; pasqueflower; adonis blue (*Lysandra bellargus*), large blue (*Maculinea arion*), marsh fritillary and silver-spotted skipper butterflies; brown-banded carder (*Bombus humilis*), great yellow (*B. distinguendus*) and large garden (*B. ruderatus*) bumblebees; stone curlew; skylark; chough (*Pyrrhocorax pyrrhocorax*); corn crake (*Crex crex*); and twite. The BAPs for these, and many other, species require the conservation of relevant Semi-natural Grasslands.

[insert figure 6.6 here]

As well as their importance in wider conservation planning, Semi-natural Grasslands are also the subject of more focused and local conservation activities. The Grasslands Trust promotes the maintenance and restoration of Semi-natural Grasslands, as well as their use as a local nature resource. The Parish Grasslands Project in the Wye Valley is a ‘grass-roots’ initiative started by a local group of friends. This project has promoted local interest in Semi-natural Grassland, provided valuable information on the location and status of local grasslands, and given advice to landowners on management and funding sources for the conservation of Semi-natural Grasslands. This initiative, and others like it (Peterken & Tyler 2006), allow a more proactive role for local people in appreciating and caring for natural resources.

6.3.2.2 Recreation and tourism

A Natural England report (Anon 2009) used social research to assess the cultural services derived by people from landscapes. The report is not of great use to this chapter as Improved Grasslands and Semi-natural Grasslands were not well differentiated. However, many of the reported positive attitudes towards particular areas of England (described in terms of 'Joint Character Areas') were related to grasslands or pastoral farming, and thus related to Semi-natural Grasslands. Comments include: "fields of different shapes and sizes" (the Devon Redlands); "chalk downland" (the North Downs); "valley between two sides" (the Eden Valley); "gently rolling hills" (the Yorkshire Wolds); "gently undulating plateau" (the Durham Magnesian Limestone Plateau); and "areas of wildlife importance within grasslands…" (the North Thames Basin).

More direct evidence of public use of Semi-natural Grassland comes from the UK National Parks, which are valued for recreation, greenspace, education, and other services, and which all contain significant areas of Semi-natural Grassland. For example, upland and lowland hay meadows contribute greatly to the wildlife, historical and landscape value of the Yorkshire Dales National Park, while species-rich neutral and calcareous grasslands and purple moor-grass and rush pastures are important in the Pembrokeshire Coast National Park. The Marble Arch Caves Global Geopark, which is the first international Geopark and covers the Fermanagh/Cavan border, includes important areas of calcareous grassland and purple moor-grass and rush pasture. There is also significant use by visitors of other Semi-natural Grassland conservation sites. A survey of all 222 English National Nature Reserves (Natural England unpublished) showed that the 41 sites that contained large areas of Semi-natural Grassland each had an average of about 21,000 visitors over a 12-month period during 2006/7.

Calcareous downland is the major habitat of the new South Downs National Park. An unpublished visitor survey of the South Downs took place in 2003 as part of the assessment of the proposal for National Park status (Tourism South East 2003). Of 7,342 people interviewed, more than 90% visited the area to indulge in relaxation or recreation within the South Downs landscape. Allowing for multiple responses, the landscape and scenery was the most cited (73%) aspect of the South Downs that was enjoyed by respondents, and 27% specifically mentioned wildlife as an attraction. Over a 12-month period, the study estimated there were about 35 million visitor days from outside the South Downs and over 4 million visitor days from residents. More than £177 million was spent in the South Downs by these visitors and about 5,200 jobs were supported in this area by visitor spend. If the total trip was considered (i.e. including activities on the way to and from the South Downs), then visitor spend was about £333 million and the jobs that it supported reached over 8,000. To such direct economic gains must be added others such as the physical and psychological benefits of visiting and exercising in the green spaces provided by these and other Semi-natural Grasslands (Barton & Pretty 2010).

6.3.2.3 Archaeological heritage

Scheduled Monuments represent our most valued archaeological sites and monuments, but a large number have been destroyed since the Second World War. English Heritage's Monuments at Risk Initiative (English Heritage 2011) showed that, of the 19,709 Scheduled Monuments in England, only 23% are in optimal condition, and 35% are in grassland habitats (Semi-natural Grassland and Improved Grassland). A survey undertaken in 2004/5 of 1,500 sites on the Northern Ireland Sites and Monuments Record (about 10% of the total number of sites catalogued) found that the 10% which were in Semi-natural Grasslands ('unimproved grassland') had survived well and were in generally good condition, while those in Improved Grassland and Arable had the poorest condition and survival rates (Gormley *et al.* 2009). In general, the lower the intensity of land use, the higher the chances of survival for archaeological features and the information they contain. Semi-natural Grassland is probably the most benign environment for the preservation of archaeology. Arable cultivation causes features to be degraded or effaced by the physical impact of tillage, chemical fertilisers (which affect metal artefacts), or drainage (which will cause desiccation of previously waterlogged remains). Direct physical impacts will be less in intensive grassland, but the latter two factors may still apply. Scrub growth on poorly managed grassland can also damage archaeological features. Obviously, once archaeology has been degraded or destroyed, it cannot be replaced. Many distinctive regional features have all but disappeared as a result of post-war intensification and improvement, including: Iron Age 'banjo enclosures' – a form of prehistoric stock corral – which were synonymous with the Wessex chalklands; and the ridge and furrow earthworks produced by medieval agriculture, which were once ubiquitous in the English East Midlands, but are now rare (Anderton & Went 2002).

The UK agri-environment schemes afford protection to monuments. Natural England (2009a) reports that 59% (by area) of English Scheduled Monuments on agricultural land are under agri-environment schemes, and provides evidence that a large proportion of sites under these schemes are showing improved condition. More than 90% of the archaeological sites in Northern Ireland which are specially protected, including by agri-environment schemes, have survived well (Gormley *et al.* 2009).

6.3.2.4 Ecological knowledge

Semi-natural Grasslands have also probably contributed more than any other ecosystem to the development of the UK's ecological knowledge. During the 20th Century, the UK's ecological pioneers (such as Alexander S. Watt, Sir Arthur G. Tansley) defined the science of ecology and its underpinning theory, often using grassland systems as a focus (Tansley & Adamson 1925; Watt 1947). Semi-natural Grassland in the UK have since been the testing ground for key ecological concepts, of which, the following is a small selection: ecological stability (Silvertown *et al.* 2006); the productivity-diversity relationship (Hector *et al.* 1999); the regeneration niche (Grubb 1977); plant strategy theory (Grime 1974); population biology (Sarukhan & Harper 1973); and interaction webs (Muller *et al.* 1999). This focus on Semi-natural Grasslands is related to their highly dynamic and fluid nature (Section 6.1), which makes them ideal for experimental work, and their extremely high local diversity of plants and animals. Thus, research on Semi-natural Grasslands has been critical to the UK's ecological research reputation, and is an area in which the UK punches above its weight internationally, as evidenced by international comparison of UK research papers in environmental and biological sciences (www.bis.gov.uk/assets/biscore/corporate/migratedd/publications/i/icpruk09v1_4.pdf).

6.3.2.5 Religious and spiritual benefits

Many churchyards and cemeteries comprise Semi-natural Grassland (although many others have been re-sown, or are recent or improved grassland) and provide a specific example of the role of these habitats in the religious and spiritual life of people. Many churchyard Semi-natural Grasslands have conservation value as remnants of old meadow and pasture. As such, churchyards can provide important areas for recreation and access to nature, especially in urban areas (Swanwick *et al.* 2003; Chapter 10). However, as part of the church estate, churchyards also have an important religious and spiritual role. In an unpublished sermon, Reverend Nigel Cooper of Anglia Ruskin University has developed this theme further. Cooper suggests a churchyard managed to benefit its wildlife, in contrast to those neglected or managed with fertilisers and frequent mowing, is a potent symbol of the Christian gospel: "neither hiding the reality of death, nor defeated by it". In other words, caring for the churchyard's wildlife and experiencing the natural processes of replacement and decay affords a continual reminder of the Christian belief in the resurrection. These spiritual aspects are also reflected in the widespread use of the churchyard as a motif in English literature. Some of these works link aesthetic and spiritual values with the mundane natural world; one of the most famous examples is Thomas Gray's 'Elegy Written in a Country Churchyard' – a meditation on human mortality in which the living wildlife of the churchyard forms an important metaphor.

There is much interest in managing churchyards for biodiversity (Cooper 1995, 1997). Indeed, the Church of England has more than 12,000 churchyards in which biodiversity projects are taking place (Hansard 2010), including the national Living Churchyards and Cemeteries Scheme which is delivered by various county Wildlife Trusts, among others, and the dedicated charity, Caring for God's Acre.

6.3.3 Greenhouse Gases

6.3.3.1 Carbon

The Countryside Survey (2007) reports estimated average carbon stocks for the top 15 cm of soil of Acid and Neutral Grassland broad habitats (**Table 6.13**). Insufficient samples were available to allow a figure to be estimated for Calcareous Grasslands.

[insert Table 6.13 here]

While grassland is often perceived as storing little carbon, it should be noted that Acid Grassland is on organo-mineral soils and has the highest carbon stock of any UK Broad Habitat. The stock for Neutral Grassland is only above that of Improved Grassland (61 t/ha) and Arable and Horticultural land (43 t/ha). The grassland figures can also be compared against other land uses to which Semi-natural Grasslands might be converted: deciduous (66.3 t/ha) or coniferous (73.0 t/ha) woodland, dwarf shrub heath (81.6 t/ha), or bracken (77.1 t/ha). Using the Countryside Survey (Carey *et al.* 2007) estimates, and accounting for their land cover, Acid and Neutral Grasslands contain 144 Tg and 149 Tg, respectively, of the UK carbon store in the top 15 cm soil layer (Chamberlain *et al.* 2010). These figures account for 21% of the soil carbon across the Countryside Survey broad habitats. Furthermore, Janssens *et al.* (2005) produced figures suggesting that UK grasslands (Semi-natural Grasslands and Improved Grasslands were not differentiated) sequester large amounts of carbon at a rate of 242 ± 1,990 kg/ha/yr, which is higher than that of more slowly growing forests (106 ± 40 kg/ha/yr) and contrasts with a net loss from arable land (-137 ± 103 kg/ha/yr).

It should be emphasises that the Countryside Survey (2007) figures are for the top 15 cm of soil only. The National Soil Resources Institute holds soil data taken to a depth of 1 m, which Bradley *et al.* (2005) used to estimate carbon content. Unfortunately, these estimates are less precise as to habitat and the general classes used include 'pasture' and 'seminatural' which include Semi-natural Grassland. Respectively, these habitats are estimated to have 16 kg/m^2 and 32 kg/m^2 of carbon in the 1 m depth of soil, and to hold UK-scale stocks of 1,345 Tg and 2,015 Tg. It is difficult to reconcile these data specifically for Semi-natural Grassland.

6.3.3.2 Other greenhouse gases

Most of the greenhouse gas emissions from grasslands will be linked to methane from animals and, therefore, are positively correlated with stocking rates (Soussana *et al.* 2004), which are lower on Semi-natural Grasslands than on Improved Grasslands (Section 6.3.1.1). Soil methane production is important only in waterlogged systems, and so, is only an issue for a minority of Semi-natural Grasslands such as purple moor-grass and rush pastures, and upland *Molinia* grassland. Few data exist for these wetter grasslands, as most methane work has been done on peatlands, so more research is needed. However, examination of patches of wet grassland within such peatlands has indicated high methane fluxes (McNamara *et al.* 2008) which suggests other wet grasslands may also produce appreciable quantities of methane. Nitrous oxide emissions are of greater concern and are higher on clay-rich soils and positively correlated with nitrogen fertilisation rates. In unimproved Semi-natural Grasslands, an assessment quantified production rates of nitrous oxide at 1–10% of total current day nitrogen deposition and equivalent to 1–2 kg nitrogen/ha/yr (Curtis *et al.* 2006).

6.3.3.3 Trends and drivers for greenhouse gases

The Countryside Survey provides information on carbon stocks in the top 15 cm of soils from 1978 to 2007; these data suggest no consistent change in carbon stocks in either Neutral or Acid Grassland broad habitats (Chamberlain *et al.* 2010). Over a similar period (1978 to 2003), Bellamy *et al.* (2005) report losses in grassland carbon from a large number of samples across England and Wales, also taken from a 15 cm soil depth. It is not possible to extract figures for Semi-natural Grassland carbon loss from the latter study. The cause of the differences between the studies is not clear, although there is some debate about the statistical analysis in the Bellamy study (Potts *et al.* 2009).

Increased soil nutrients in Semi-natural Grassland due to agricultural improvement or nitrogen deposition might be expected to affect soil carbon, but effects on soil chemical processes are complex. There are very few projects which study soil carbon in grasslands under simulated nitrogen deposition. Long-term nitrogen addition over a period of 12 years had no effect on soil carbon stocks in a mid-Wales Acid Grassland at Pwllpeiran (UKREATE 2009). Fertilising *per se* can increase carbon sequestration in grasslands through greater plant production (Conant *et al.* 2001; Jones *et al.* 2006), but the lower carbon storage reported in the Countryside Survey (2007) for Improved Grasslands compared to Semi-natural Grasslands (Section 6.3.1.3) indicates that other activities, such as re-sowing, more than counteract this effect. In the Park Grass experiment, the increasing acidity in some nitrogen-fertilised plots led to increases in soil carbon, but, in general, there were few effects of fertilising on carbon sequestration (Hopkins *et al.* 2009).

Considering other greenhouse gases, adding nitrogen stimulates nitrous oxide emissions (Conant *et al.* 2005). In addition, soils associated with semi-natural dry grassland have a relatively high fungal to bacterial biomass ratio compared to those of improved grasslands (Bardgett & McAlister 1999), which may be linked to other ecosystem properties; for example, fungal-rich soils appear to retain nitrogen more effectively (Gordon *et al.* 2008). However, studies are needed to assess the totality of grassland management impacts on greenhouse gases. A study on the Northern Great Plains in the USA calculated the 'Global Warming Potential' of grassland management practices by calculating carbon dioxide emissions associated with fertiliser production and use, methane production from grazing cattle, soil organic carbon changes, and fluxes of methane and nitrous oxide (Leibig *et al.* 2010). It found that native grassland with moderate stocking rates acted as a net sink of greenhouse gases, while heavily grazed, agriculturally improved grassland was a net source of greenhouse gases.

Liming has been widely used to increase productivity in acidic grasslands, with the greatest use (supported in some countries by agricultural subsidies) occurring during the middle of the 20th Century. Because decomposition rates in many upland soils are constrained by acidity, increases in pH due to liming consistently lead to accelerated carbon turnover, carbon dioxide production and carbon export (Andersson & Nilsson 2001; Rangel-Castro *et al.* 2004). Increased pH may also increase nitrous oxide losses (Yamulki *et al.* 1997). Although liming has become less prevalent since the mid-20th Century, historical liming is likely to have residual effects on soil acidity.

6.3.4 Pollination and Pest Control

Because they support more species and a greater abundance of animals than Improved Grassland or Arable and Horticultural land (Cole *et al.* 2002), and are often positioned within farmed areas, Semi-natural Grasslands have the potential to provide services for farming, in particular, pollination and pest control. It is suggested that both services should be delivered by the spread from Semi-natural Grassland to farmed land of species which pollinate crops or which attack pests – so-called 'spillover'.

Globally, there is some evidence of spillover of pollinators (Ricketts *et al.* 2008), and in mainland Europe the abundance and species-richness of bees, butterflies or hoverflies in arable fields has been shown to be related to the distance of the fields from Semi-natural Grasslands (Ockinger & Smith 2007; Jauker *et al.* 2009). Ricketts *et al.* (2008) report a UK study which showed that the proximity of field bean (*Vicia faba*) crops to 'natural habitat' influenced pollination within the crops by native bees. The distance that the crops needed to be from natural habitat in order for the measures of pollination to decline by 50% was about 1.4 km for pollinator species-richness and 900 m for visitation rate by pollinators to flowers.

Comparing data from before and after 1980, Biesmeijer *et al.* (2006) reported widespread declines in the species-richness of British bee faunas, but did not find the same pattern for hoverflies. Individual bumblebee species have also declined; Williams (1982) reported that, by the 1980s, only six of Britain's 19 native (true) bumblebee species remained throughout their pre-1960s ranges. Goulson *et al.* (2005) attributed bumblebee declines directly to the loss of Semi-natural Grassland over the 20th Century. Carvell *et al.* (2006) provided evidence for this link by detailing the diminution of the range and local-scale frequency of the principal forage plants of British bumblebees. The plants which showed notable declines were all from Semi-natural Grassland: knapweed (*Centaurea nigra*), meadow vetchling (*Lathyrus pratensis*), oxeye daisy (*Leucanthemum vulgare*), bird's-foot-trefoil (*Lotus corniculatus*), yellow rattle (*Rhinanthus minor*) and red clover (*Trifolium pratense*).

Spillover of natural enemies of pests has been little studied. While there is good evidence for positive effects on predators of habitat enhancement within crop fields, such as wildflower strips (Landis *et al.* 2000; Haenke *et al.* 2009), there is little evidence for the effect of nearby semi-natural habitats.

There is some evidence for declines in pest control services that have been caused by Semi-natural Grassland losses. The Carabid Recording Scheme (but note that not all carabids are predatory), summarised by the JNCC (1997), suggests that 134 of 251 species for which there are sufficient data declined in British range size between the 1960s and 1980s (only 20 species increased). Kotze and O'Hara (2003) show that the greatest declines, in terms of decreasing range sizes, of carabid beetles in northern Europe are of those species associated with open or grassland habitats.

6.3.5 Genetic Resources: Plant Wild Relatives and Rare Breeds

The plants sown to improve grasslands for agricultural production are derived from some of the species of traditional pastures and meadows. From an early date, native grassland species were subjected to selective breeding, which led to a trade in improved cultivars. For example, perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium perenne*) cultivars were available commercially from the 18th Century onwards, and were sown widely. There has been no bio-prospecting in UK Semi-natural Grasslands for new pasture plant species for a very long time. Current plant breeding tends to explore the genomic potential of these long-cultivated varieties, such as a project at Aberystwyth University to develop a physical map of the perennial ryegrass genome. 'Xenogenomics' examines the genomics of non-agricultural grassland species which are well adapted to certain environmental stressors, such as drought or salinity, thus exploring their potential contribution to further breeding of pasture plant varieties (John *et al.* 2005); but this idea is not being explored in the UK.

In the UK, many traditional garden plants have been sourced from Semi-natural Grassland, for example: bugle (*Ajuga reptans*), clustered bellflower (*Campanula glomerata*), greater knapweed (*Centaurea scabiosa*), viper's-bugloss (*Echium vulgare*) and ragged-Robin (*Lychnis flos-cuculi*). Domestic Semi-natural Grassland no longer benefits the horticulture trade as the UK's novel garden plants are now sourced from other countries (Dehnen-Schmutz *et al.* 2007). However, a significant amount of seed is sourced from Semi-natural Grasslands for use in creating species-rich grasslands under agri-environment schemes and other conservation initiatives. Natural England's GENESIS database indicates that, of the 2,486 current (April 2010) Higher Level Stewardship agreements (under the English agri-environment scheme) which involve the maintenance, restoration or creation of species-rich grassland, 421 receive a supplement for using native seed sourced from Semi-natural Grassland. There is also a significant trade in seed for such projects, sourced by seed merchants from Semi-natural Grasslands, although figures are not available.

Rare or traditional livestock breeds are often associated with Semi-natural Grassland. It is often suggested that these breeds, which date from times of less intensive farming, are more useful than modern breeds for managing this habitat (The Rare Breeds Survival Trust, www.rbst.org.uk) as they are better adapted to rough grazing and more able to utilise the poorer quality forage. There is little evidence to support this contention, prompting a call for more research (Anon 2006). The few studies that have been published have found little difference in performance between traditional and modern cattle breeds grazing on Semi-natural Grassland (Isselstein *et al.* 2007; Fraser *et al.* 2009). Recently, the Defra-funded BEFORBIO project found that commercial Simmental x Hereford Friesian and traditional North Devon cattle had similar grazing behaviours and effects on Semi-natural Grassland botanical composition. Indeed, rare breeds perform well on improved pasture and many Semi-natural Grasslands are grazed with modern breeds. It is probably more accurate to suggest that the use of rare breeds for grazing of Semi-natural Grassland can provide dual benefits for conservation of the breed and the habitat, but not that one is essential to the other. Rare breeds themselves are valued as providing aesthetic, cultural and historical benefits, as well as genetic resources for future breeding programmes (Anon 2006).

6.3.6 Water Quantity and Quality

Information about the impact of Semi-natural Grassland on water quantity and quality is generally in relation to alternative land uses. Water storage is less than under more woody vegetation, such as trees (Weatherhead & Howden 2009) or even bracken (Williams *et al.* 1987). Conversely, conversion to intensive grazing and the resulting compaction of the soil causes decreased infiltration and increased runoff, which both increases the risk of flooding and reduces the recharging of aquifers (Weatherhead & Howden 2009). Measures of streamwater quality in upland and lowland Britain across gradients from low-intensity grassland to arable and intensive livestock pastures show higher concentrations of polluting nutrients derived from agriculture, such as nitrogen and phosphorous, in the more intensive landscapes (Jarvie *et al.* 2008, 2010). Water pollution is a result of a number of processes including soil erosion, fertiliser inputs and contamination from manure and slurry. These studies suggest the lower intensity management of Semi-natural Grassland is critical in maintaining water quality and quantity. Phoenix *et al.* (2008) also showed that Semi-natural Grassland soils are able to store significant amounts of deposited nitrogen, which would reduce the pollution of groundwater. Within the Peak District, Calcareous Grasslands accumulated up to 89% of deposited nitrogen, while Acid Grasslands stored up to 38%. These results suggest the need for more research into the role of Semi-natural Grassland vegetation and soils in ameliorating water quality.

6.3.7 Soil Structure and Pollution

Soil compaction in grasslands is caused by high stocking rates, winter grazing and the use of heavy machinery. A recent review for Defra (Anon 2007) showed that compaction can decrease water infiltration and increase runoff, increase emissions of nitrous oxide and ammonia, decrease uptake of methane, reduce the abundance of soil fauna, decrease plant growth and yield, and limit food availability for some birds. Agricultural intensification is generally to blame for increased soil compaction – including increased wheel loads of farm machinery and higher stocking rates – and so will be less of a problem on Semi-natural Grassland than on Improved Grassland. However, where soil compaction does occur on Semi-natural Grassland, it can cause long-term changes in plant growth and composition (Hirst *et al.* 2003).

As in most UK ecosystems, heavy metal concentrations in Semi-natural Grassland soils are elevated above their pre-industrial levels. However, atmospheric heavy metal pollution has declined in recent years and the Countryside Survey (2007) assessed whether this was reflected in declines in soil concentrations between 1998 and 2007. It found that concentrations of heavy metals in Semi-natural Grassland (Neutral and Acid Grassland broad habitats) remained elevated and unchanged in Acid Grassland. In Neutral Grassland, there were significant declines in concentrations of chromium, zinc and nickel, while cadmium, copper and lead were unchanged.

6.3.8 Biomass Cropping

While plant biomass for fuels is generally considered in terms of planted crops, it has been suggested that hay from Semi-natural Grasslands might provide an alternative source of fuel which does not monopolise cropland. No studies relevant to Semi-natural Grassland have taken place in the UK and so figures for costs or potential production are not available; but Tilman *et al.* (2006) showed that a high diversity prairie grassland in the USA could produce reasonable biomass for fuel with low fertiliser inputs.

6.3.9 Military Use

Large areas of Semi-natural Grassland are owned, leased and used for training by the Ministry of Defence (MOD). A submission to the UK NEA by the Defence Estates reports that the Salisbury Plain Defence Training Estate is the largest (38,000 ha) and most important training area in the UK. Because of the nature of the terrain (resilient chalk soils), it is the only site in the UK where extensive armoured manoeuvre training can be undertaken. The majority of the Salisbury Plain Estate is Semi-natural Grassland (56%) and is used for the principal training activities including live firing and other training facilities for armoured vehicles, artillery, engineers, infantry and aircraft, and cross-country driver training. During the 2009/10 financial year, 740,560 personnel training days were spent on the estate; in 2008/9, this figure was 803,361, and in 2007/8, it was 858,347. It should also be pointed out that the Defence Estates carries out extensive conservation activities on this internationally important area of chalk grassland.

6.4 Trade-offs and Synergies Among Ecosystem Goods and Services

The fundamental trade-off in Semi-natural Grassland is the tension between production and many of the other services. Increased production from Semi-natural Grassland has been at the expense of biodiversity, cultural heritage, increased greenhouse gas production, water pollution, and many other negative effects. These impacts arise through decreased biodiversity and compromised soil and hydrological processes following agricultural improvement. However, the straightforward nature of the trade-offs suggests the potential for maintenance and restoration of Semi-natural Grasslands to provide a *range* of services which are not well provided by Improved Grasslands.

[insert Table 6.14 here]

In **Table 6.14** we list possible trade-offs and synergies in services from Semi-natural Grassland. Many of these are simply our judgement as there are few data to test the suggested relationships. In the following sections, we describe in more detail the relationships for which there are critical data. Biodiversity – generally plant species richness – is often the process through which relationships are formed, so **Table 6.14** also links biodiversity to these services. To avoid confusion we consider only *direct relationships* between services.

It should be noted that biomass cropping from Semi-natural Grassland may be a future use which could impact positively on many services and biodiversity if it is not accompanied by intensive management to increase production (Tilman *et al.* 2006). However, the outcomes would depend on the precise management used and its compatibility with the traditional management needed to maintain biodiverse grasslands (Ceotto 2008). Clearly, biomass cropping is incompatible with grazing. There are many unknowns concerning biomass cropping of Semi-natural Grassland, so we will not consider it further here.

6.4.1 The Effects of Livestock Production on Other Services

Grazing is important to maintain many Semi-natural Grasslands. Inadequate grazing can cause the loss of the Semi-natural Grassland habitat (Section 6.2.5.4). Here, we take the need for grazing as read and consider the impacts of actions to increase livestock production on grazed grasslands. Excess stocking impacts are considered in Section 6.2.5.5. As described earlier, agricultural improvement to increase production negatively impacts plant biodiversity (Section 6.2.5.1) and associated services, pollination, pest control (Section 6.3.4), and wild relative diversity. Rare breeds have become so as they are not perceived as suited to modern production livestock systems (Section 6.3.5). Linked to this is the possible higher fat content and so lower quality of intensively produced meat (Section 6.3.1). Section 6.3.2 suggested that landscapes of Improved Grassland have lower cultural value than those with Semi-natural Grassland, in terms of cultural heritage, recreation, archaeology, etc. As described in Section 6.3.3, despite the increased productivity, actions to increase livestock production overall have a negative or no effect on greenhouse gas storage. Chapter 7 describes the major role of intensive agriculture in diminishing air quality (e.g. ozone, ammonia; Chapter 7, Section 7.3.2.2) and water quality (leaching of nitrogen, phosphorus, etc; Chapter 7, Section 7.3.2.2). Finally, there is evidence that practices to intensify agriculture lead to soil compaction, increased runoff and flooding risk, poorer recharging of aquifers, and water pollution (Section 6.3.6; Section 6.3.7).

It should be said that all these trade-offs concern the agricultural improvement of Semi-natural Grassland. Increased production on grasslands maintained as Semi-natural Grassland is difficult to do without such improvement as the Semi-natural Grasslands are the outcome of traditional management optimised for production in a less technological world. Changing stocking densities, grazing season, livestock breed, cutting date, the degree of manuring and other management practices has complex effects on biodiversity depending on the grassland type (Crofts & Jefferson 1999). The impacts on services are neither well-studied nor straightforward.

6.4.2 The Effects of Biodiversity on Ecosystem Services

Higher plant species richness in grasslands, whether in Semi-natural Grassland compared to Improved Grassland, or among Semi-natural Grasslands, is linked to increased pollinator species richness (Carvell 2002; Potts *et al.* 2003). There may also be a reverse influence, such that declines in pollinators may cause plant losses (Biesmeijer *et al.* 2005). In contrast, invertebrate predators are more affected by the vegetation structure of grasslands than by plant diversity (Morris 2000). As discussed in Section 6.3.5, there is little evidence for a link between the use of rare livestock breeds and plant biodiversity. More complex plant community composition (functional diversity) and, to some extent, species richness, reduces leaching of inorganic nitrogen from grasslands (Scherer-Lorenzen *et al.* 2003; Phoenix *et al.* 2008).

There are many studies which show an effect of increased plant species richness on grassland productivity (Hector *et al.* 1999). This has caused some confusion because increased soil fertility leads to increased production and decreased plant diversity in grasslands (Thompson *et al.* 2005). However, if soil fertility is not altered, an increase in plant diversity can cause higher production (such as hay yield), and this effect can persist for many years (Bullock *et al.* 2007). This may arise because more species lead to a greater efficiency in using energy and other resources and/or because a species-rich community is more likely to contain species which are highly productive. The mechanisms are debated, but the outcome that increased species richness increases production is clear (Hooper *et al.* 2005). Recently, it has been shown that, in certain circumstances, experimental grasslands with low agricultural inputs and high plant diversity are as productive as high input, low diversity grasslands (Weigelt *et al.* 2009). In such circumstances, if higher plant diversity increases production, without a change in inputs, this leads to increased carbon sequestration rates (Tilman *et al.* 2006; Klumpp & Soussana 2009).

Positive effects of plant diversity for soil carbon sequestration have also been reported in USA and European grassland experiments (Fornara & Tilman 2008; Steinbeiss *et al.* 2008). The mechanisms involved are likely to be highly complex, involving a range of biotic interactions between plants, their symbionts (i.e. mycorrhizal fungi and nitrogen-fixing bacteria), and decomposer organisms whose activities determine the rate of decomposition and, hence, the loss of carbon from soil through respiration and leaching of dissolved organic carbon (Bardgett *et al.* 2008).

As described in Section 6.3.1, there is also some evidence of increased meat quality from animals grazing on Semi-natural Grassland compared to improved pasture. The evidence is not great and the mechanism seems to relate to slower growth rates in poorer quality pasture than a direct effect of plant richness. We retain this relationship in **Table 6.14**, but it is a poorly tested hypothesis. Section 6.3.1 also presents evidence for the role of Semi-natural Grasslands in determining cheese quality and local character in France; it would be interesting to explore this possibility in the UK.

Evidence is emerging that higher Semi-natural Grassland plant species richness not only increases individual ecosystem services, but is required to maximise a variety of services within a Semi-natural Grassland, such as soil carbon, herbage production, forage quality, and insect richness and abundance (Zavaleta *et al.* 2010). Thus, ecosystem services might be optimised by a high plant diversity within and among the Semi-natural Grasslands found in a landscape.

6.4.3 Impacts of Other Services and Biodiversity on Cultural Services

As described in Section 6.3.2, we ascribe the cultural heritage value of Semi-natural Grasslands directly to the richness of their flora and fauna, including pollinating bees and butterflies. Rare breeds are considered to provide aesthetic, cultural and historical benefits (Section 6.3.5).

In providing a greenspace for visitors, the wildflower species richness of Semi-natural Grassland may be directly related to the aesthetic appreciation and enjoyment of visitors. A study in Germany showed that non-expert visitors were able to recognise Semi-natural Grasslands with higher plant richness and that their stated aesthetic appreciation of the grasslands increased with plant diversity (Lindemann-Matthies *et al.* 2010). This important study counters suggestions that there is a lack of connection between people's aesthetic appreciation of landscapes and the ecological value of ecosystems. As described in Section 6.3.2.5, it is suggested that the maintenance of biodiversity in churchyards may enhance the resulting spiritual and religious experience of visitors.

6.5 Near-term Options for Sustainable Management

In this Section, we consider options for management to optimise individual ecosystem services. This is done partly to illustrate any conflicts among alternative objectives. However, we end with a consideration of how Semi-natural Grasslands might be managed for multiple services, that is, how they may be 'multifunctional'.

6.5.1 Maintenance of Semi-natural Grassland Biodiversity

Biodiversity of Semi-natural Grassland has effects on cultural values and a range of physical services such as pollination (Section 6.4.2). Maintenance of the Semi-natural Grassland habitat requires extensive (i.e. non-intensive) management such as no or light fertiliser additions (usually manure rather than inorganic fertilisers), traditional grazing or cutting regimes and appropriate seasonal water levels. These traditional farming methods were fine-tuned to the grassland type, the geographic region and the required products (e.g. wool, beef or dairy; hay for winter feed or an extended grazing season; etc.). Alternative extensive management regimes and their impacts on grassland biodiversity are well-researched and described (Crofts & Jefferson 1999, Jefferson 2005). The optimal management varies among different groups of species (Bullock *et al.* 2001). For example, bumblebees are more abundant in cattle-grazed than in sheep-grazed Calcareous Grassland on the Salisbury Plain, probably because the former activity encourages bumblebee forage plants (Carvell 2002). Indeed, an important aspect of traditional management was the variation in practices from one field or farm to the next and from one year to the next. This would lead to dynamic habitat characteristics which would maintain a high diversity of species. For example, Smith and Jones (1991) showed how historical variation in cutting dates among hay meadows in the Pennines had large effects on the plant species composition. Therefore, a critical aspect of the conservation of Semi-natural Grassland is to allow variation in management practices over space and time, and within a region.

6.5.2 Restoration of Semi-natural Grassland Habitat

Several issues require the Semi-natural Grassland habitat to be expanded in order to conserve its intrinsic biodiversity. Fragmentation of Semi-natural Grasslands into small, isolated sites is a major issue for the persistence of the grassland and the possible local extinction of plants and animals (Section 6.2.5.6). For example, persistence of the marsh fritillary butterfly on purple moor-grass and rush pastures is largely dependent on the connectivity and area size, as well as the quality of the grassland patches (Bulman *et al.* 2007). Climate change is likely to exacerbate these problems as species will need to migrate to track suitable habitat. Therefore, conservation planning requires the restoration of Semi-natural Grassland habitats and the creation of linked networks of Semi-natural Grasslands (e.g. the European Ecological Network and The Wildlife Trusts' 'Living Landscapes'. The UK BAP has ambitious restoration targets for Semi-natural Grassland (**Table 6.15**).

[insert table 6.15 here]

Restoration techniques are well-developed for all types of Semi-natural Grassland, for example, upland (Smith *et al.* 2008) and lowland (Pywell *et al.* 2002) hay meadows, calcareous grasslands (Pywell *et al.* 2002) and purple moor-grass and rush pastures (Tallowin & Smith 2001). Restoration is implemented through various conservation organisations, as well as the national agri-environment schemes. Agri-environment schemes provide detailed prescriptions for habitat restoration and, in some cases, are aiming to target such actions in the regions where environmental outcomes are likely to be greatest (www.naturalengland.org.uk/ourwork/farming/funding/es/hls/targeting/approach.aspx).

Semi-natural Grassland creation is most fruitfully carried out on ex-arable land or improved grassland (Walker *et al.* 2004). Problems to be overcome in such schemes include reducing soil fertility, introducing target species and establishing appropriate management. Residual soil fertility can be addressed through soil stripping (Walker *et al.* 2004), but appropriate grazing or cutting management can also ameliorate the effects (Pywell *et al.* 2002, 2007). However, restoration techniques require further research. Fagan *et al.* (2008) surveyed 40

English Calcareous Grassland restorations and found that even after 60 years restored grasslands were not identical to target ancient grasslands. Indeed, a meta-analysis by Pywell *et al.* (2003) showed that during restorations, generalist and competitive plant species tend to out-perform the Semi-natural Grassland specialists.

6.5.3 Increasing Livestock or Arable Production

Agricultural improvement methods used to optimise livestock production or to convert grassland to arable systems are described in Sections 6.3.1 and 6.4.1. Semi-natural Grasslands can be moderately 'improved' to increase livestock production, but even small increases in fertiliser and other intensive practices leads rapidly to biodiversity loss (Mountford *et al.* 1993; Hodgson *et al.* 2005; Isselstein *et al.* 2005). Issues of food security may increase the pressure to convert Semi-natural Grasslands to increase productivity. Opportunities for improvement on much of the remaining priority habitat Semi-natural Grasslands are probably limited by their topography which includes steep slopes, poor drainage and other such obstacles. However, the potential for improvement remains. A report on the land capability for agriculture in Scotland suggested that climate change may increase the potential for conversion of upland rough grazing to improved agricultural land (Brown *et al.* 2008).

6.5.4 Increasing Biomass Fuel Production

Similarly, requirements for increased biomass fuel might, hypothetically, lead to pressure to destroy Semi-natural Grasslands in order to plant biomass crops such as *Miscanthus* and short rotation willow. However, good quality agricultural land would be the prime focus of such planting (Haughton *et al.* 2009). The potential for harvesting biomass from Semi-natural Grassland (Section 6.3.8) is currently not being considered in the UK.

6.5.5 Enhancing Greenhouse Gas Sequestration and Storage

Increased carbon storage may be achieved simply by the conversion of Semi-natural Grassland to habitats with higher above- and/or below-ground storage potential. Conversion of grassland to forest is often suggested (Dawson & Smith 2007); for example, a desire to increase Scotland's carbon sink is a key driver of the Scottish Forestry Strategy aim to increase Scotland's woodland cover to 25% (Section 6.2.5.2). A less radical approach might involve limited tree planting. For example, the Pontbren Project in mid-Wales involves introducing tree shelterbelts into upland grassland (Marshall *et al.* 2009); here, carbon storage has been enhanced, as along with rainfall infiltration rates. However, tree planting on small, fragmented lowland Semi-natural Grasslands is likely to be less straightforward or desirable.

Several other ideas for the enhancement of carbon storage in temperate grasslands have been mooted, such as the introduction of legumes, irrigation and nitrogen addition to enhance production (Conant *et al.* 2001; Soussana *et al.* 2004). But these ideas are more relevant to Improved Grasslands. Indeed, conversion of Improved Grassland or Arable and Horticultural land to Semi-natural Grassland may be an effective approach to increasing carbon storage (Soussana *et al.* 2004; Ostle *et al.* 2009). A recent study provides support for this idea; restoration activities on an Improved Grassland, which involved sowing a variety of plant species and the cessation of fertiliser applications, increased the rates of soil nitrogen and carbon accumulation (de Deyn *et al.* in press). In the best treatment, carbon and nitrogen accumulated at 317 kg/ha/yr and 35 kg/ha/yr respectively, compared to net losses of 8 kg carbon/ha/yr and 1 kg nitrogen/ha/yr in the treatment with continued fertiliser addition and no seed-sowing.

A decrease in grazing intensity is also suggested to increase carbon storage, through both decreased carbon removal and lower methane production (Dawson & Smith 2007; Leibig *et al.* 2010). However, given the wide range of mechanisms by which herbivores can influence soil carbon dynamics, it is unsurprising that the effects of grazing on carbon stores and fluxes are highly variable, and depend on the physical properties of soil (e.g. texture and depth), the depth of soil sampling, and the responsiveness of the plant community to grazing (Bardgett & Wardle 2010). While carbon removal associated with animals is relatively minor in low-productivity Semi-natural Grasslands (Allard *et al.* 2007), modelling by Soussana *et al.* (2004) of an upland French grassland suggests that the carbon dioxide sink would be greatest, and methane production associated with the grazing cattle smallest, at low stocking densities. At an Acid Grassland on organic soils in Wales, experimental grazing intensification caused a loss of organic horizon carbon (Emmett unpublished); whereas at a nearby grassland on mineral soils, 12 years of experimental grazing removal did not change soil carbon stocks (Rowe unpublished).

6.5.6 Multiple Services from Semi-natural Grasslands

The agricultural origin of Semi-natural Grasslands presents opportunities for their management to provide multiple services and goods while requiring relatively low energy inputs. In contrast to Improved Grassland and Arable and Horticultural land, Semi-natural Grassland in general: a) stores greater densities of carbon and produces less nitrous oxide (Section 6.3.3); b) has lower stocking densities, resulting in lower methane production; c) allows greater water infiltration rates and enhanced storage, preventing flooding and resulting in less atmospheric (e.g. ammonia and ozone) and water (e.g. nitrogen, phosphorus) pollution (Section 6.3.6; Section 6.3.7). Nutrient cycling also seems to be more efficient in unimproved grasslands (Lovell *et al.* 1995). The current emphasis on production and the relatively low cost of agricultural inputs outweighs these benefits, but increasing energy costs may change the balance and encourage farming to address such issues as energy flows and nutrient cycling as a priority (Pretty 2008).

Conserved and restored Semi-natural Grasslands also have the potential to provide cultural services related to recreation and tourism (Section 6.3.2), especially if rare livestock breeds are used (Section 6.3.5), and pollinator and pest control services for surrounding intensive farmland (although the current evidence for these services from Semi-natural Grassland is extremely limited; Section 6.3.4). As suggested by Lawton *et al.* (2010), this combination of broad services would be best delivered by linked habitat networks (including large-scale restoration) which are better able to maintain Semi-natural Grassland species and which may enhance synergies in cultural benefits and the delivery of physical services (Wardle *et al.* 1997).

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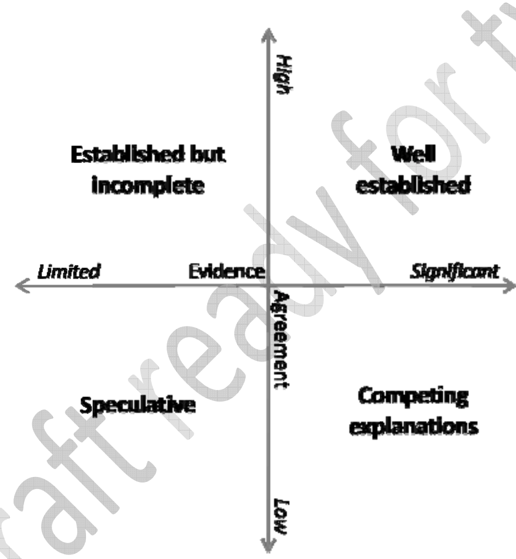
Appendix 6.1 Approach Used to Assign Certainty Terms to Chapter Key Findings

This chapter began with a set of Key Findings. Adopting the approach and terminology used by the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Assessment (MA), these Key Findings also include an indication of the level of scientific certainty. The 'uncertainty approach' of the UK NEA consists of a set of qualitative uncertainty terms derived from a 4-box model and complemented, where possible, with a likelihood scale (see below). Estimates of certainty are derived from the collective judgement of authors, observational evidence, modelling results and/or theory examined for this assessment.

Throughout the Key Findings presented at the start of this chapter, superscript numbers and letters indicate the estimated level of certainty for a particular key finding:

1. *Well established*: high agreement based on significant evidence
2. *Established but incomplete evidence*: high agreement based on limited evidence
3. *Competing explanations*: low agreement, albeit with significant evidence
4. *Speculative*: low agreement based on limited evidence



a. *Virtually certain*: >99% probability of occurrence
b. *Very likely*: >90% probability
c. *Likely*: >66% probability
d. *About as likely as not*: >33-66% probability
e. *Unlikely*: <33% probability
f. *Very unlikely*: <10% probability
g. *Exceptionally unlikely*: <1% probability

Certainty terms 1 to 4 constitute the 4 box model, while a to g constitute the likelihood scale.

GRAPHICS

FIGURES

Figure 6.1 Distribution of UK NEA Semi-natural Grasslands habitat in the UK by a) dominate (>51% area per 1 km cell) type and b) percent cover per 1 km cell.

a) **b)**

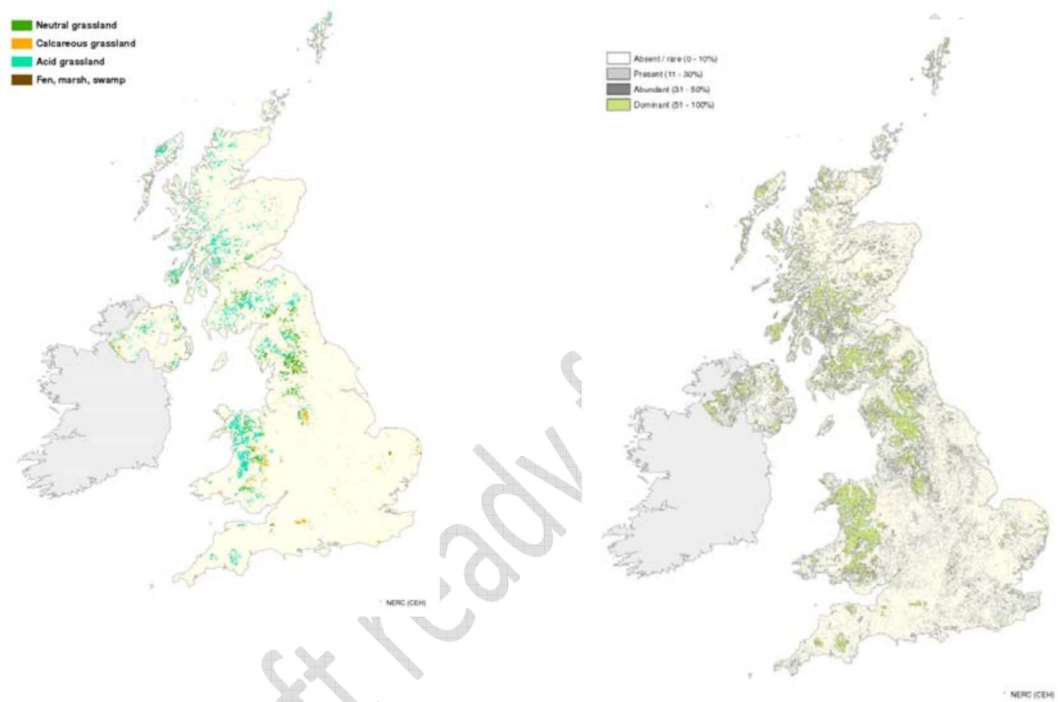


Figure 6.2 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Figure 6.3 The assessment of change in Semi-natural Grassland in England and Wales from 1932 to1984. Using various data sources, the change in Semi-natural Grassland (here, UPP: unimproved permanent pasture; and RG: rough grazing) is explained mostly by the increase in improved pasture (IPP). The loss not explained by improvement – i.e. the decrease in total grassland (TOT) – is mostly due to conversion to arable. Source: Fuller (1987). Copyright (1987), reproduced with permission from Elsevier.

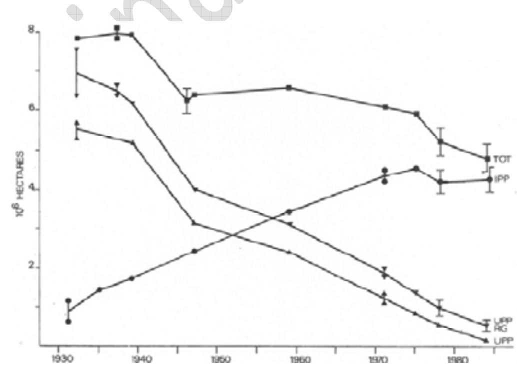


Figure 6.4 Mean (± standard error) patch size of semi-natural lowland grassland National Vegetation Classification communities (see Rodwell 1992) in Wales. Source: data from Stevens *et al.* (2010).

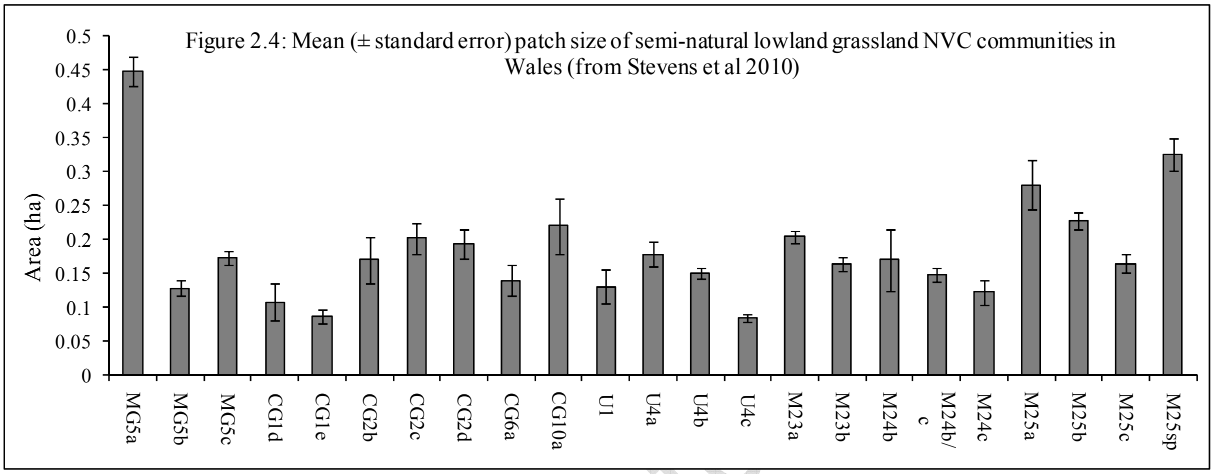
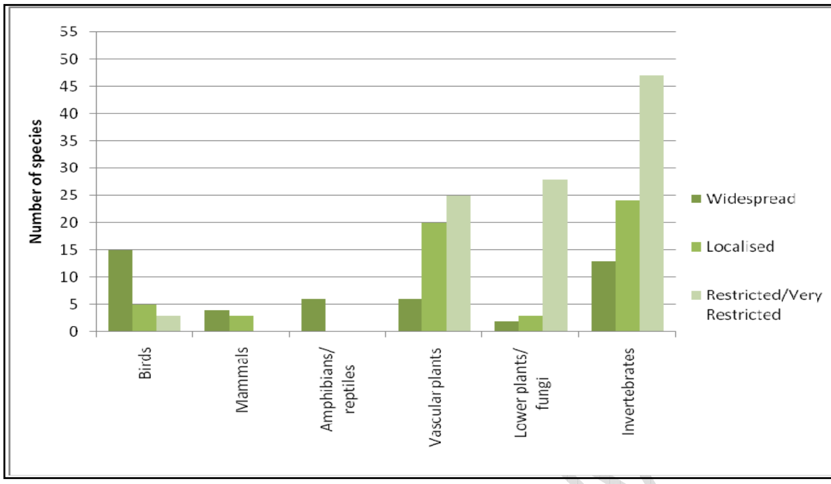


Figure 6.5 Projections of the Macaulay Institute Grazing Management Model for dry matter production of different upland acid grassland types as affected by temperature zone and altitude. The map shows the temperature zones. Source: reprinted from Armstrong *et al.* (1997a).

Figure 6.6 The taxonomic group and restriction class of UK BAP species associated with lowland grasslands. Source: reprinted from Webb *et al*. (2009).



TABLES

Table 6.1 Estimates of the extent of Semi-natural Grassland habitats in the UK. Sources: for priority habitats UK BAP (2006); Upland acid grassland: Countryside Survey – England (CS 2009) and Scotland (Norton *et al.* 2009), Blackstock *et al.* (2010) – Wales, Cooper *et al.* (2009)– Northern Ireland Countryside Survey (2007).

	Area (ha)				
	England	**Wales**	**Scotland**	**N. Ireland**	**Total**
UK BAP priority grasslands					
Lowland calcareous grassland	38,687	1,146	761	-	**40,594**
Lowland dry acid grassland	20,142	36, 473	4, 357	674	**61,646**
Lowland hay meadows	7,282	1,322	980	937	**10,521**
Upland hay meadows	870	-	27	-	**897**
Purple moor-grass & rush pasture	21,544	32,161	6,768	18,476	**79,392**
Upland calcareous grassland	16, 000	700	5,000	936	**22,636**
Totals for priority habitats	104,525	71,802	17,893	21,466	**215,686**
Other Semi-natural Grasslands					
Upland acid grassland	376,000	108,100	983,000	9,695	**1,476,795**
Upland marshy grassland	-	29,200	-	-	
Total Semi-natural Grassland Habitat	**480,525**	**209,102**	**1,000,893**	**31,161**	**1,692,481**

Table 6.2 Area of Semi-natural Grassland* under different designations in England. Source: Natural England (2008)

Designation	Total area (ha)	% of total area of SNG in England
Total resource	109,576†	100
Site of Special Scientific Interest (SSSI)	74,894	68
Special Area of Conservation (SAC)	43,790	40
Special Protection Area (SPA)	33,992	31
Ramsar site	3,134	3
National Nature Reserve (NNR)	6,328	6
Within National Park	10,166	9
Within Area of Outstanding Natural Beauty (AONB)	20,887	19

* Covers upland and lowland meadows, lowland calcareous grassland, upland calcareous grassland, lowland dry acid grassland and purple moor-grass and rush pastures.
† Differs from the estimate in Table 6.1 as the figure is taken from the Natural England habitat inventory data rather than the UK BAP targets review.

Table 6.3 Area of Semi-natural Grassland* under different designations in Wales (upland and lowland). Source: data from UK BAP (2006†); Blackstock *et al.* (1996)‡; Countryside Council for Wales Phase I habitat data¶

Designation	Total area (ha)	% of total area
Total resource	180,000†	100
SSSI	50,950‡	28
Within National Park	93,000¶	52

*Covers lowland meadows, lowland calcareous grassland, upland calcareous grassland, lowland dry acid grassland and purple moor-grass and rush pastures (UK BAP) and non-BAP upland acid grassland.

Table 6.4 Grassland under agri-environment schemes in Wales. Tir Gofal prescriptions based on active schedules – lowland grassland. Source: data for 2001 provided by the Wales Assembly Government.

<table>
<tr><th>Grassland Habitat Action Plan</th><th>Maintenance (ha)</th><th>Restoration (ha)</th><th>Expansion (ha)</th></tr>
<tr><td>Lowland meadow</td><td>1,778</td><td>1,461</td><td>5,596</td></tr>
<tr><td>Lowland calcareous grassland</td><td>181</td><td rowspan="2">388</td><td>0</td></tr>
<tr><td>Lowland dry acid grassland</td><td>13,952</td><td>0</td></tr>
<tr><td>Purple moor-grass and rush pasture</td><td>19,347</td><td>136</td><td>0</td></tr>
<tr><td>TOTAL</td><td>35,258</td><td>1,985</td><td>5,596</td></tr>
</table>

Table 6.5 Semi-natural Grassland under agri-environment management prescriptions for Environmentally Sensitive Areas and Northern Ireland Countryside Management Scheme. Source: data December 2007 provided by Department of Agriculture and Rural Development.

Management Prescription	**Area (ha)**
Species rich grassland (dry)	1,456
Species rich grassland (wet)	10,013
Species rich grassland (calcareous)	981
Species rich hay meadow	546
TOTAL	**12,996**

Table 6.6 Semi-natural Grassland agri-environment management options in Rural Priorities and legacy schemes Source: data for 2010 provided by Scottish Natural Heritage.

Management Option	**Area (ha)**
Management of species-rich grassland	272,500
Creation and management of species rich-grassland	50,500

Table 6.7 Condition of Semi-natural Grassland types from country surveys demonstrated by the percent of surveyed Semi-natural Grasslands which were in unfavourable recovering or favourable condition*. Note: This does not include sites that were notified as ASSIs between 2002 and 2008; these data are not available at present. Lowland dry acid grassland is not a notified feature on any ASSIs, although it does occur as small areas in a mosaic with upland calcareous grassland (NVC type CG10 *Festuca ovina-Agrostis capillaris-Thymus praecox* grassland [Rodwell 1992]). Sources: data from Natural England SSSI Information System (ENSIS)[‡]; Hewins *et al.* (2005)[¶]; data supplied for 2010 by Scottish Natural Heritage §; Northern Ireland Environment Agency (NIEA 2008)**.

a) UK BAP Priority Grassland	**English SSSIs in 2009†**	**English non-statutory Semi-natural Grasslands in 2005¶**	**Scottish SSSIs in 2010 §**	**Northern Irish ASSIs 2002 to 2008****
Lowland calcareous grassland	92.4	28	71	61
Upland calcareous grassland	92.4	No data	52	
Lowland dry acid grassland	84.5	21	53	No data
Lowland hay meadows	76.2	16	57	25
Upland hay meadows	91.3	7	100	No data
Purple moor-grass & rush pastures	78.1	35	90	39
b) Other				
Upland acid grassland	85.2‡	No data	No data	No data

* For definitions see English Nature (2003) and Williams (2006).

† This is the combined figure for unfavourable recovering + favourable and is an assessment for the upland breeding birds associated with upland acid grassland (total area = 27,587 ha).

Table 6.8 Overall trends and conservation status for UK Semi-natural Grasslands. Source: UK Biodiversity Action Plan reporting (BARS 2008)*; Favourable Conservation Status reporting (JNCC 2007).

<table>
<tr><th>Semi-natural Grassland type</th><th>Overall UK trend from 2008 UK BAP reporting*</th><th>2007 FCS assessment for grassland Annex 1 habitats†</th><th>Annex 1 habitat‡ assessed and relationship to column 1 grassland type</th></tr>
<tr><td>Lowland calcareous grassland</td><td rowspan="7">Declining (slowing)</td><td>Unfavourable (Bad) but improving</td><td>H6210/H6211 Semi-natural dry grasslands (Festuco-Brometalia). (Direct equivalence)</td></tr>
<tr><td>Lowland dry acid grassland¶</td><td>Unknown</td><td>H2330 Inland dunes with open Corynephorus and Agrostis grasslands (Subset: NVC types SD11 & SD12 only – Rodwell 2000)¶</td></tr>
<tr><td>Lowland hay meadows</td><td rowspan="2">Unfavourable (Bad) but improving</td><td>H6510 Lowland hay meadows (Subset -NVC type MG4 only – Rodwell 1992)</td></tr>
<tr><td>Upland hay meadows</td><td>H6520 Mountain hay meadows (direct equivalence)</td></tr>
<tr><td>Purple moor-grass & rush pastures</td><td>Unfavourable (Bad) and deteriorating</td><td>H6410 Molinia meadows (Subset - NVC types M24 and M26 only – Rodwell 1991)</td></tr>
<tr><td rowspan="2">Upland calcareous grassland</td><td>Unfavourable (Bad) but improving</td><td>H6210 Semi-natural‡ dry grasslands (Festuco-Brometalia)
H6230 Semi-natural dry grasslands
H6170 Alpine & sub-alpine calcareous grassland</td></tr>
<tr><td>Unfavourable (Bad)</td><td>H6230 Species-rich Nardus grassland</td></tr>
<tr><td>Upland acid grassland</td><td>No data – not a priority habitat</td><td>-</td><td>No Annex 1 habitat</td></tr>
</table>

† See www.jncc.gov.uk/PDF/FCS2007_ukapproach.pdf for an explanation of how the Favourable Conservation Status (FCS) assessment was derived. This assessment takes into account trends in range, area and condition of the habitat, as well as threats.
‡ See McLeod *et al.* (2005) for a description of Annex 1 habitats.
¶ Annex 1 habitat 2,330 inland dunes with open *Corynephorus* and *Agrostis* grasslands conforms to NVC types SD11 and SD12.The definition of the lowland dry acid grassland UK BAP priority habitat (UK Biodiversity Group 1999) includes inland types of two dune grassland communities SD10b and SD11b (Rodwell 2000). The main communities that make up the priority habitat (NVC types U1, U2, U3 and U4 (Rodwell 1992)) are not covered by the UK interpretation of Annex 1 types (Rodwell *et al.* 2007).

Table 6.9 A summary of drivers of change in Semi-natural Grassland and their impacts at different periods. The role of the driver of change is categorised as major (■), moderate (▣) or minor (□).

Driver of change	Semi-natural Grassland affected	Impact of driver on Semi-natural Grassland	Role since 1940s	Present role	Future role‡
Agricultural grassland improvement	Priority habitats	Domination by fast-growing plants; loss of plant and animal diversity; soil processes compromised	■	□	□
Conversion to arable	Priority habitats	Cultivation and total loss of habitat	■	□	□
Conversion to forestry	All*	Cultivation, planting and total loss of habitat	■	□/▣	▣ (uplands)
Other conversion: roads, building, quarries, etc.	All	Habitat destruction	▣	□	□
Nitrogen deposition and transfer	All	Increased soil fertility leading to domination by fast-growing plants and loss of plant diversity	■	■/▣	▣
Inadequate management	Priority habitats	Insufficient grazing leading to rank vegetation, scrub and trees	▣	■	■
Overgrazing	Upland acid	Overgrazing (sheep) of moorland causing loss of heather and increase in upland grassland	■	▣	□
Habitat fragmentation	Priority habitats	Remaining Semi-natural Grassland are small and isolated leading to local species losses and invasions	▣	▣	▣
Invasion by non-native plants	All	Exclusion of desirable species; change in soil processes	□	□	□/▣
Agri-environment schemes	Priority habitats	Conservation management of existing Semi-natural Grassland and re-creation of Semi-natural Grassland on agricultural land	□	▣	▣
Agri-environment schemes	Upland acid	Conversion back to heather moorland	□	▣	▣
Protection	Priority habitats	Designation for conservation and so protected and managed against destruction and degradation	■	■	■
Climate change	All	Species losses; colonisation by novel species; increased openness	□	□	■

* 'All' refers to all Semi-natural Grassland habitats; i.e. Priority habitats and Upland acid.
‡ Future roles to 2050 are predicated on the continuation of current environmental and land use policies

Table 6.10 Average transitions of Semi-natural Grasslands to other land uses and ecosystems in the Western South Downs between 1971 and 1991. Source: based on Burnside *et al.* (2003). Copyright (2003), reproduced with permission from Elsevier.

Ecosystem or land use	% of Semi-natural Grasslands converted	
	1971–1981	1981–1991
Semi-natural Grassland (% remaining as Semi-natural Grassland)	48	36
Arable	40	39
Wooded and plantation	6	14
Scrub	5	7
Buildings and roads	<1	2
Other	<1	2

Table 6.11 Site size classes of BAP priority lowland grassland sites in England. The first figure in each column represents the total number of sites in the inventory. The figure in parentheses represents the sites for which there is greater certainty about the area of priority grassland. The full data will include sites where the area includes other habitats, which inflates the site sizes. For further explanation see Martin *et al.* (2008). Source: data from Natural England (2009b).

UK BAP priority grassland	<5 ha (%)	5–9.99 ha (%)	10–19.99 ha (%)	>20 ha (%)
Lowland calcareous	73 (77)	13 (12)	7 (6)	7 (5)
Lowland meadows	80 (84)	11 (9)	5 (4)	4 (3)
Lowland dry acid grassland	71 (82)	9 (9)	6 (4)	14 (5)
Purple moor-grass and rush pastures	80 (87)	9 (7)	5 (3)	6 (3)
Upland hay meadows	86 (93)	8 (5)	5 (2)	1 (0)

Table 6.12 The final services and goods provided by Semi-natural Grasslands.

Service Group	Final ecosystem service	Goods and benefits
Provisioning	Livestock: forage for cattle, sheep, etc.	Food (meat, milk), fibre (wool), possibly enhanced quality of meat and milk
	Standing vegetation: biomass crops	Possibly fuel
	Crops: pollination and pest control spillover	Food (crops)
Cultural	Environmental settings: valued species and habitats, agricultural heritage, archaeological heritage, grazing for rare livestock breeds, ecological knowledge, training areas	Physical and psychological health, social cohesion, recreation and tourism, UK research base, UK military training
Regulating	Climate regulation: sequestration and storage of carbon and other greenhouse gases	Avoidance of climate stress
Provisioning / Regulating	Water quantity: storage of water and recharging of aquifers	Potable water, water for food production, flood protection
	Purification: reduced pollution and storage of pollutants	Clean air, clean water, clean soils
	Wild species diversity: plant genetic diversity, seed for restoration projects	Genetic resources, bioprospecting, recreation and tourism, ecological knowledge

Table 6.13 UK Semi-natural Grassland carbon stocks estimated in the Countryside Survey 2007 Source: Carey *et al.* (2007). Countryside Survey data owned by NERC – Centre for Ecology & Hydrology.

Grassland broad habitat	Soil carbon concentration (0–15 cm depth)	Soil carbon stock (0–15 cm depth)
Neutral	61.9 g/kg	62.4 t/ha
Acid	208.2 g/kg	82.3 t/ha

Table 6.14 Suggested direct relationships between major ecosystem services of Semi-natural Grassland. + positive, — negative, 0 no relationship. Biodiversity (plant species richness) is included to illustrate its important role in many services. In each case, the relationship is one of cause and effect (hence the focus on a direct relationship); the cause is the column title and the affected service is in the row. Unfilled cells indicate that no direct relationship is expected.

Cause / Effect	Rare breeds	Plant wild relatives	Pollination	Pest control	Livestock production quantity	Livestock production quality	Greenhouse gas storage	Water quality	Water flow	Soil structure	Biodiversity
Cultural services	+	+	+		—	+					+
Rare breeds					—						0
Plant wild relatives					—						+
Pollination					—						+
Pest control					—						0
Livestock production quantity	0					—				+	+
Livestock production quality	0				—						+
Greenhouse gas storage, etc.					—/0					+	+
Water quality					—					+	+
Water flow					—					+	
Soil structure					—						
Biodiversity	0		+		—					+	

Table 6.15 UK BAP targets for restoration of Semi-natural Grassland priority habitats from the Biodiversity Action Reporting System. Source: data from www.ukbap-reporting.org.uk/outcomes/targets.asp **.** Estimated achieved restorations are given under 2005.

Habitat	**UK restoration target (ha)**			
	2005	**2010**	**2015**	**2020**
Lowland acid grassland	31	313	597	879
Upland calcareous grassland	0	250	362	0
Lowland calcareous grassland	10	399	789	1176
Purple moor-grass and rush pasture	260	642	926	1408
Lowland meadows	1259	1736	2210	2687
Upland hay meadows	0	25	51	75