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Landscape and Urban Planning 75 (2006) 244–264
LANDSCAPE AND URBAN PLANNING
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Modelling natural capital: The case of landscape restoration on the South Downs, England

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Available online 23 June 2005

Abstract

Habitat suitability modelling has shown itself to be an important decision support tool for those concerned with the problem of where to target habitat and landscape restoration efforts. However, present approaches generally focus upon the biophysical characteristics of habitats and sites, and tend to ignore the social values associated with landscapes and habitat features. As a result current approaches only partially resolve the problems we face when dealing with a multifunctional landscape. In this paper, we examine how these limitations of current approaches may be overcome.

The paper shows that present approaches to suitability modelling can be broadened by linking them to ideas about natural capital and landscape function. The approach is illustrated by means of a case study from the South Downs of England. It is suggested that by using the approach to model the spatial aspects of the natural capital associated with a given landscape, we may provide the user community with a framework that more fully addresses management issues that arise in the context of a sustainable, multifunctional landscape. In the case of the South Downs we show that restoration strategies that seek to take account of the multiple functions of downland differ from those which focus exclusively on enhancing or restoring the biodiversity of these areas.

Keywords: Natural capital; Ecosystem function; Multifunctional landscapes; Habitat restoration; Habitat suitability modelling

1. Introduction

The restoration of ‘ecological’ and ‘landscape function’ has become an important theme of recent scientific and policy work in Britain and elsewhere. Along with acceptance of the wider goals of Sustainable Development, which include the need to maintain the integrity of ecological systems, has come the recognition that efforts are also required to replace habitats that have been lost. Thus, the UK Biodiversity Action Plan (Department of the Environment, 1994) sets out targets for re-establishing key species to former levels of abundance and patterns of distribution. It also includes objectives for the restoration of habitats that are considered to be important for conservation and landscape purposes. These goals were confirmed in a

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doi:10.1016/j.landurbplan.2005.02.012

report of the Biodiversity Challenge Group (see Avery et al., 2001) which identified 10 key actions to promote biodiversity in the UK, of which one is to 'deliver a real increase in the extent of priority habitats, including heathland, downland and woodland, in a way that improves public access, human health and biodiversity'. In the wider international arena similar themes and concerns are evident in the European Union Habitat Directive (92/43/EEC, May 1992).

When faced with the problem of where to target resources for habitat restoration, habitat suitability modelling has proved itself to be a valuable decision support tool (Jankowski and Richard, 1994). The application of such techniques is not without their limitations, however, because the problem of what is being restored is generally treated as unproblematic. Habitats patches are, for example, generally treated as objects to be 'placed' in the most appropriate locations, given the factors that constrain them. The ecosystem functions associated with habitat patches are rarely considered. Thus, analyses tend to overlook the way in which the output of ecosystem goods and services vary across a collection of habitat patches in a given landscape. Moreover, the ways in which different people or groups value these functions in different places is generally not considered.

In this paper, we consider how ideas about natural capital and ecosystem function can inform questions of habitat and landscape restoration of chalk grasslands on the South Downs of England. The work was stimulated by calls for a broader approach to landscape restoration that were being made by agencies concerned with the management of these areas, such as the Sussex Downs Conservation Board and its partners (Sussex Downs Conservation Board, 2001). We consider restoration strategies in the context of national policies for biodiversity and the promotion of wider access to the countryside, in order to develop a more integrated view of downland restoration than has been achieved in previous studies that have mainly focused on its biophysical characteristics (e.g. Burnside et al., 2002).

2. The problem context

Calcareous grasslands are important for their plant diversity. In the UK, they are found on shallow, lime-rich soils generally derived from chalk and limestone, and are distinctive in terms of the number of rare plant species associated with them and the occurrence of more widespread grassland plants that are restricted to lime rich soils.

The *Habitat Action Plan for Calcareous Grassland* (UK Biodiversity Action Plan, 2004) estimates that there are currently about 40,000–50,000 ha of this habitat in the UK. In the past, however, they were more extensive. Although comprehensive data are lacking it has been estimated that between 1966 and 1980, about 902 ha of calcareous grassland were lost in Sussex alone, an area which at that time represented about 25% of the total stock in the county (Joint Nature Conservation Committee, 2005). Species-rich chalk grassland now covers less than 3% of the South Downs (Sussex Downs Conservation Board, 2001). The most recent Countryside Survey suggests that the general loss of calcareous grassland is continuing (Haines-Young et al., 2000).

A range of factors have been responsible for the loss of these grasslands (Joint Nature Conservation Committee, 2005). In lowland areas, such as the South Downs, these factors include: under-grazing or the complete cessation of management, resulting in reversion to rank grassland and eventually to closed scrub and woodland; agricultural intensification though fertiliser use, herbicide application, ploughing and re-seeding; and industrial and urban development.

Given the importance of calcareous grassland for their species diversity, it is not surprising that restoration is an important element in recent policies for the management of these areas. The *Rural White Paper for England* (Department for Environment, Food and Rural Affairs, 2000) has, for example, endorsed the initiatives already set in place by the Sussex Downs Conservation Board, the Countryside Agency and English Nature, 'to explore additional mechanisms for bringing about restoration of the South Downs to open downland'. Such initiatives build on those mechanisms already in place to encourage reversion through the Environmentally Sensitive Areas and Countryside Stewardship schemes. The more recently published England Rural Development Plan (Department for Environment, Food and Rural Affairs, 2003) also includes the objective of '. . .enhanced, restored and recreated open downland' in the section for South East England, and identifies the South Downs as a primary focus.

The restoration of downland is not simply a technical exercise, depending upon the identification of suitable sites and the application of appropriate mitigation and management techniques. Restoration strategies must also take account of wider social and economic issues. The motivations of individual landowners need to be understood, for example, because it will only be through their actions, and the way they might be triggered by incentive schemes, that restoration will be achieved. Moreover, since the restoration of downland will also have implications on patterns of recreation, the impacts of habitat creation on other aspects of the rural economy should also be taken into account. This study, therefore, builds on existing information about the biophysical factors that need to be considered if habitat recreation is to be successful (Burnside et al., 2002) and asks how this understanding needs to be revised given the wider socio-economic benefits associated with these habitats.

The conceptual framework adopted by this study is the 'natural capital paradigm' (Haines-Young, 2000). Using it, five key questions form the focus of the case study and this paper:

1. How is 'downland' conceptualised by the science and policy communities, and what is it that is being restored or created in the context of present policy objectives?
2. What is the current distribution of the 'downland' resource in relation to the main environmental gradients in the study area?
3. What is the potential for restoration or habitat creation given current biophysical characteristics?
4. What is the spatial distribution of the existing downland resource in relation to current patterns of countryside access, as defined by the rights of way and road networks within the study area?
5. To what extent should restoration strategies designed to promote the conservation of biodiversity be modified if policy objectives are widened to include the promotion of better access to the countryside?

The geographical extent of the study area is shown in Fig. 1. Our concern is with the landscapes within the two Areas of Outstanding Natural Beauty in Sussex and East Hampshire, which are likely to be the core of the

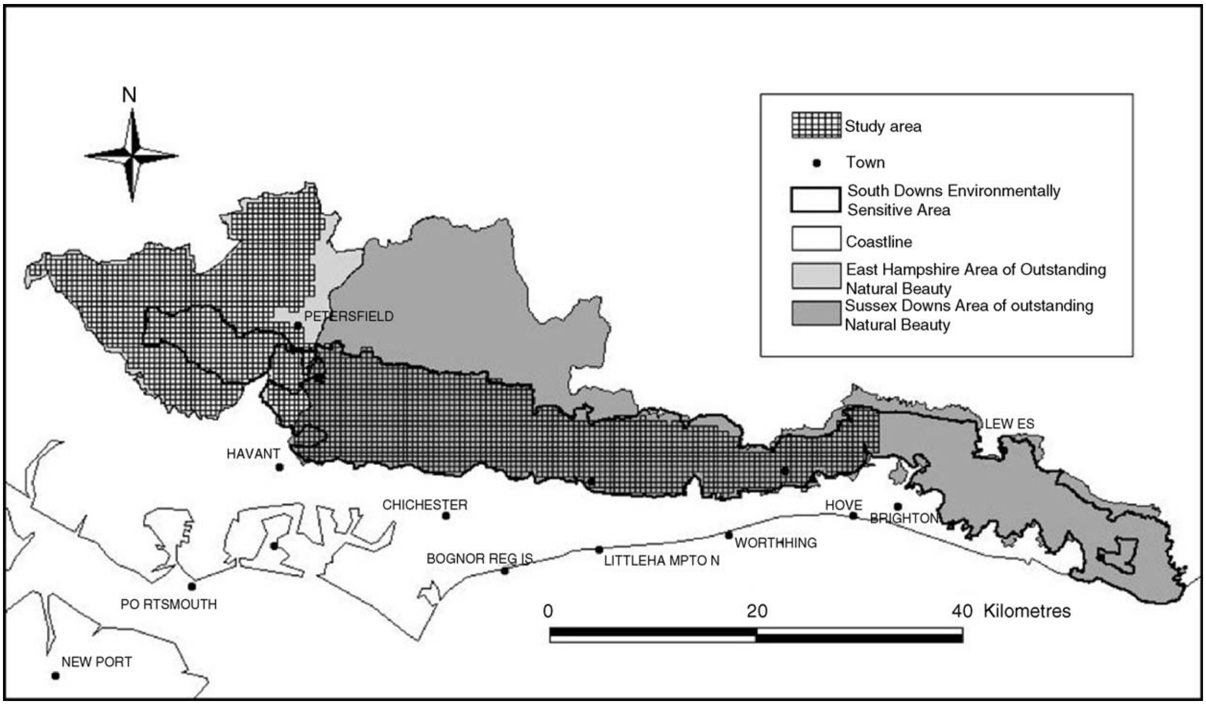


Fig. 1. Study area.

new National Park. The study area includes the South Downs Environmentally Sensitive Area. Due to data constraints the study was confined to the Hampshire and West Sussex sections of the area.

3. Downland as natural capital

3.1. Downland creation: what is being restored?

A feature of discussions about 'downland restoration' is that there are numerous terms used to denote the feature or features of concern. The labels 'downland', 'down', 'chalk downland', 'unimproved grassland on chalk', 'calcareous grassland' and 'chalk grassland', for example, are often used interchangeably, but just as frequently they are used to imply subtle ecological differences between grassland types that may or may not be significant in wider landscape terms. The meanings that these terms carry depend on context and reflect the different agendas and concerns of different interest groups.

Early writers, such as Tansley and Adamson (1926) used the term 'chalk grassland' to cover a variety of grasslands types found on 'moderate or steep slopes', with differences largely reflecting variations in grazing pressure. Using the framework of the National Vegetation Classification (Rodwell, 1991), modern commentators have given a more detailed and systematic account of this variation, identifying 4 of the 14 types of calcareous grassland found in the UK as being present on the South Downs (Burnside et al., 2002). When considering the grasslands of the area in terms of their botanical characteristics or their value for nature conservation, it is usually to these habitat types that the labels 'calcareous grassland' or 'chalk grassland' are applied, often with the prefix 'species-rich', to emphasise their special ecological qualities (e.g. Joint Nature Conservation Committee, 2005).

In other areas of policy, especially when land cover is considered from an agricultural perspective, the description of grassland types is quite different. Within the Environmentally Sensitive Area documentation, for example, the term 'chalk grassland' is used as a general label to refer to a variety of calcareous grassland types of different degrees of improvement (Agricultural Development Advisory Service, 1996). Labels, such as 'species-rich' and 'species-poor' are used to denote variations in botanical value, while 'grazed' and 'ungrazed' are used to denote management status. The important point to note here is that whatever chalk downland is conceived to be in this literature, it can clearly be both 'species rich' and 'species poor', with the implication that it is not just the diversity of plant species that is being restored by the various habitat creation measures.

Differences in use of the terms 'down' or 'downland' are also found in the literature, with sources varying in the degree of generality implied when referring to the various types of grassland on chalk. Thus, the recent 'right to roam' legislation, which has been introduced in England and Wales, aims to provide freer public access to mountain, moor, heath and down (Her Majesty Stationary Office, 2000), where "...mountain, moor, heath or down" does not include land which appears to the appropriate countryside body to consist of improved or semi-improved grassland (Her Majesty Stationary Office, 2000, part 1, Chapter 1, Section 2).

Although the phrase 'appears to the appropriate countryside body' allows certain flexibility, according to this formulation 'down' is fairly restrictive, being more or less equivalent to the 'unimproved chalk grassland category' used in the Environmentally Sensitive Area literature, which, as we have seen, may or may not be 'species rich'. The consultative document, identifying the potential extent of open access areas in South East England (Countryside Agency, 2001a) illustrates further the restrictive way in which the term has been interpreted, with only a limited number of grassland parcels being proposed as candidate sites for open access by virtue of their status as 'down'. The pattern of these sites is highly fragmented, with an average size of open access parcels of only 22 ha.

In contrast to the narrowness of the definition used in the Access legislation, elsewhere in the literature, we find the terms 'down' and 'downland' interpreted in a more general way. Thus, in its description of the South Downs Environmentally Sensitive Area, the Agricultural Development Advisory Service (1996, p. 7) describes the area as '...being characterised by rolling chalk downland and dry valleys'. A measure of the success of Environmentally Sensitive Area schemes to revert 'arable land to chalk grassland' is the development of '...vegetation with the potential to develop into chalk downland' (Agricultural Development Advisory Service, 1996, p. 78). Even more general usage is found amongst those who consider the grasslands on the chalk in a cultural context. Massingham (1936), for example, uses the term 'downland' to refer to the extensive grasslands of the area that were a key element of the cultural landscape. As we know from the work of contemporary ecologists, such as Tansley and Adamson (1926), such grasslands were not exclusively short, closely grazed species rich swards.

Given the variety of ways in which the terms down, downland and chalk grassland have been used, one might ask what it is that is being restored when people use the terms 'restoration' or 'creation' in the context of grasslands on chalk. Some commentators see the problem mainly as the restoration of a diminished resource that is of value for nature conservation; the creation of species-rich calcareous or chalk grassland (Burnside et al., 2002). Others, by contrast, mainly see the issue in terms of the ease or costs of transforming different types of agricultural land cover, with a view to restoring improved grassland or arable land to less intensively managed 'downland'. Finally, there may be some who have a more general desire to restore an important cultural resource, which includes extensive grassland cover (Sussex Downs Conservation Board, 2001).

In this paper, we will use the terms 'chalk grassland' or 'calcareous grassland' to refer to grasslands of high conservation status. 'Downland' will be used to denote unimproved or mesotrophic grassland on calcareous substrates more generally, which may or may not be species rich, but which have higher landscape or recreational value than more intensively managed grasslands or arable areas. By juxtaposing the two interpretations of 'downland', we seek to explore how a management strategy that aims primarily at the restoration of the botanical richness of these grasslands might need to be modified if the wider goals of landscape restoration and the enhancement of recreational opportunity were also of a focus of concern.

3.2. Ecological status and dynamics of chalk grasslands

Analyses of the dynamics of species-rich chalk grassland have long been a focus of ecological study in the UK. Early work by Tansley and others (Tansley and Adamson, 1925, 1926; Hope-Simpson, 1940, 1941), for example, established that these communities were a 'plagio-climax', stabilised largely by the grazing of sheep and rabbits. With the cessation of grazing management, or the reduction in rabbit numbers by disease, the turf was often rapidly invaded by tall grassland species and scrub, resulting in the loss of the species characteristic of chalk grassland (Gibson and Brown, 1991).

Following the work of Grime (1979, 1985) and Grime et al. (1988), the high species richness of calcareous grassland came to be explained both by the suppression of larger species by grazing and the effects of the poor nutrient status of calcareous soils. The latter served to prevent more competitive grassland species from achieving dominance in the community. According to Grime's 'C-S-R model', the species typical of calcareous grasslands are those able to tolerate or cope with the effects of nutrient stress and disturbance.

As a result of the early ecological work, initial efforts at restoring or maintaining species rich downland turf were focused on the removal of scrub and woodland (Dzwonko and Loster, 1998), or the elimination of competitive grassland species (Bobbink and Willems, 1993; Willems and vanNieuwstadt, 1996; Hurst and John, 1999). More recently, attention has shifted to the restoration of downland on intensively managed pasture or arable land using such techniques as ploughing and reseeding (Dutoit and Alard, 1996; Hutchings and Booth, 1996a,b; Davies and Waite, 1998; Partel et al., 1998).

Several broad conclusions emerge from the literature dealing with the restoration of calcareous grassland. First, the richness and composition of the restored grassland depends strongly on the community composition before scrub or woodland clearance (Gibson and Brown, 1991; Dzwonko and Loster, 1998) or before the cessation of intensive agricultural management (Willems and vanNieuwstadt, 1996; Muller et al., 1998). Second, the resulting species composition is also dependent on the presence of grassland species in the neighbourhood (Gibson and Brown, 1992; Bobbink and Willems, 1993; Muller et al., 1998). It is generally accepted that the persistence of species typical of diverse downland turf in the seed bank is low (e.g. Dutoit and Alard, 1995; Stevenson et al., 1995, 1997; Hutchings and Booth, 1996a,b; Davies and Waite, 1998; Partel et al., 1998). Finally, successful restoration generally requires continued management (Bobbink and Willems, 1993; Hutchings and Booth, 1996a,b; Huhta and Rautio, 1998; Willems and van-Nieuwstadt, 1996; Muller et al., 1998).

In short, when planning for the restoration of species rich calcareous grasslands, the major lesson that we should draw from the literature is that landscape context and initial conditions matter. It is also apparent that while restoration is possible, it may take some time to achieve. What evidence exists, for example, suggests that it may take many decades to establish high-quality grassland containing the range of rare plant and animal species associated with this habitat (Gibson et al., 1987; Gibson and Brown, 1991, 1992). However, it is possible to create a community that approximates to this 'ideal' end state within about 10–20 years. Such an 'approximation' lies within our definition of 'downland'. Although such grasslands, roughly equivalent to the 'mesotropic' on calcareous substrates grasslands identified by the National Vegetation Classification, may have lower conservation status than their species-rich counterparts, they may nevertheless have important landscape (aesthetic) or recreational functions.

3.3. Ecological restoration and agri-environmental schemes

The recent discussion and commitment to restore the calcareous grasslands of the South Downs must not obscure the fact that these areas have, for some time, been the targets of policy aimed at conserving and enhancing the landscapes of these areas. The Sussex Downs Environmentally Sensitive Areas Scheme was introduced in 1987, to encourage farmers to help safeguard areas of the countryside '. . .where landscape, wildlife and historical interest is of national importance and is dependent on the use of beneficial farming practices'. Within the designated Environmentally Sensitive Areas area (Fig. 1), entry into the scheme by farmers is voluntary, and involves making payments to establish 10-year management agreements. The levels of payment depend on the nature of the land cover change expected or the restrictions to management practice that are required. A key aim of the scheme is to maintain the stock and condition of the existing downland resource (i.e. unimproved, often species rich grassland on chalk), and to encourage the reversion of arable land and improved pasture to less intensively managed grasslands.

As Thompson et al. (1999) note, while Environmentally Sensitive Areas represent one of the largest and most successful environmental conservation schemes operating in the agricultural sector in the UK, they have been criticised. It has been argued, for example, that the schemes should have clearer biodiversity objectives, and that there is a need to set target take-up rates that will achieve these objectives (Thompson et al., 1999). There have also been calls for a clearer vision of how the success of schemes is to be judged (Bailey et al., 2005).

When the Environmentally Sensitive Areas scheme was first introduced by the Ministry of Agriculture, Fisheries and Food in 1987, it was recognised that there was a need to monitor the extent to which they delivered the required environmental benefits. A national monitoring programme was initiated, with each Environmentally Sensitive Areas reviewed on a 5-year cycle. The results of the first phase of monitoring in the South Downs Environmentally Sensitive Areas was published in 1996 (Ministry of Agriculture, Fisheries and Food, 1996). It is interesting to compare the conclusions of the Report with more recent assessments of the scheme.

The report for first phase the Environmentally Sensitive Areas Scheme for the South Downs found that take-up 'has been good' and that there had 'been some progress towards realising the objectives set for the scheme'. However, in the context of the overall aim of the Environmentally Sensitive Areas, the report noted that while the landscape, wildlife and historical values have been maintained, and there had been important examples of enhancement over the monitoring period, these were 'limited' (Ministry of Agriculture, Fisheries and Food, 1996). Clearly, although the goal of maintaining the stock of existing environmental resources is relatively easy to establish by monitoring, it is not so easy to determine whether or not there has been 'enhancement'. To make such a judgement we have to be clear about what the eventual outcomes of the scheme should be (Thompson et al., 1999). A subsequent position paper published by the Sussex Downs Conservation Board (see Sussex Downs Conservation Board, 2001) provided a very different assessment of the success of the Environmentally Sensitive Areas.

As part of the background to their argument for restoring the landscapes of the South Downs, the

Sussex Downs Conservation Board departed from the assessment of the Environmentally Sensitive Areas monitoring report (Ministry of Agriculture, Fisheries and Food, 1996), and concluded that '. . .there has been a relatively low take-up of the South Downs Environmentally Sensitive Areas scheme' (Sussex Downs Conservation Board, 2001). They note that while the scheme covers most of the chalk grassland within the two Areas of Outstanding Natural Beauty, only 30% of the eligible land had been entered. They add that schemes '. . .may have reversed, but have not stemmed the declines in traditional habitats' (Sussex Downs Conservation Board, 2001, p. 4).

In the context of the Chilterns Area of Outstanding Natural Beauty, Thompson et al. (1999) have argued that there is a need to adjust the current Environmentally Sensitive Areas mechanism to maximise the protection and restoration of chalk grassland in such areas. They compared the existing Environmentally Sensitive Areas mechanism and a 'model Environmentally Sensitive Areas', and concluded that a selective targeting approach embodied in their model could avoid unnecessary cost and allow extra funds to be channelled into threatened habitat conservation. In their model selectivity was achieved by adjusting the payment rates set by the scheme. Payments increase progressively, with maintenance of existing grassland being better remunerated than recreation, and recreation in locations where chalk grassland is most easily restored (e.g. on steeper slopes) receiving higher payments than elsewhere.

This is the approach recently explored for the South Downs by Burnside et al. (2002), who analysed the present distribution of calcareous grasslands in the area, and applied GIS habitat suitability mapping to identify locations most suitable for the re-establishment and expansion of these habitats. The approach adopted used information about the relationships between specific grassland communities and topographic variables to predict the nature of grassland communities likely to result from restoration efforts at specific sites. The analysis suggests that on the basis of site suitability criteria, a doubling of the area of higher conservation status calcareous grassland could be achieved, with such habitats coming to occupy about 10% of the chalk downland landscape.

Work, such as that by Thompson et al. (1999), Burnside et al. (2002) and Bailey et al. (2005) is valuable in helping us think through the design of the 'second generation' of Environmentally Sensitive Areas, or what other schemes might augment or replace them. Undoubtedly adjustment to payments may be successful at targeting conservation resources more effectively, and go some way to preventing the fragmented take-up of schemes (National Audit Office, 1997). However, the models developed by these authors mainly focus on the biodiversity gains that might be associated with such schemes, and do not take account of the fact that conservation goals have to be achieved through appropriate social and economic development (Department of Environment, Transport and the Regions, 1999). We have, as argued in the Rural White Paper for England (Department for Environment, Food and Rural Affairs, 2000), '. . . to move environmental and social goals closer to the heart of agricultural policy alongside its economic objectives'. In this paper, we therefore seek to broaden the modelling approach developed elsewhere, by taking account of the other 'ecosystem services' (cf. de Groot, 1992, 2005; Daily, 1997; de Groot et al., 2000, 2002) that downland might deliver. In addition to biodiversity, we focus here on recreational and scenic benefits, and thus, consider restoration of downland more generally. We seek, in other words, to consider the issues of habitat restoration in the context of the downs as a 'multifunctional landscape', and ask how might modelled outcomes differ from those based solely on biodiversity issues.

3.4. Characterising natural capital

The idea of 'natural capital' has been used to help explore the inter-relationships between environmental, economic and social issues. Natural capital has been defined as '. . .any stock of natural resources or environmental assets which provide a flow of useful goods and services, now and in the future' (Pearce and Turner, 1990; de Groot, 1992; Van Dieren, 1995; de Groot et al., 2000, 2002). As MacDonald et al. (1999) note, although some commentators have expressed reservations about the concept (Hinterberger et al., 1997), it continues to be widely used to refer to features of natural systems that we have traditionally regarded as 'resources', such as soil, water and biomass, together with properties of ecological systems that include their assimilative and life support capacities, as well as their aesthetic and recreational properties (CSIRO, 2001).

The idea of natural capital is a useful one, because it helps us focus on the ways in which people use or depend upon the properties of ecological systems (Countryside Agency, 2001a,b). Indeed, it has been suggested that ecosystems can be characterised in terms of their various functions, or capacities to provide goods and services that directly or indirectly satisfy human needs (de Groot, 1992). It should be noted that use of the term 'ecosystem function' by de Groot (1992) differs from that found in the ecological literature, where, following Odum (1973), the functional properties of ecosystems are simply those which have a 'time dimension', such as the various nutrient and energy fluxes associated with ecosystems. The distinction can be characterised in terms of the difference between the functions "of" natural systems and the functions "for" people (see de Groot et al., 2000). Four broad functional groups are distinguished, namely regulation, habitat, production and information functions (Table 1).

While normally applied at the ecosystem level, the idea of natural capital can also be used as a framework in which one can consider the outputs of goods and services associated with whole landscapes, where the latter are viewed as a mosaic of different land cover elements (Haines-Young, 2000). The concept is useful at the landscape level because it is clear that many of the goods and services people derive from nature depend on the juxtaposition of different ecosystems in space. In this paper, we use the concept to explore how one might target the restoration of 'multifunctional' downland to maintain and enhance not only its 'biodiversity outputs', but also its capacity to provide recreational opportunities and by implication wider economic and social benefits.

Although we may identify a range of functions associated with natural systems, in a spatial or landscape context it is clear that not all patches of a given ecosystem will have the same 'natural capital profile'. Some might be considered to be of 'higher quality' as a

Table 1
Functions, goods and services of natural capital (after de Groot et al., 2002)

Regulation functions: maintenance of essential ecological processes and life support systems
1. Gas regulation (e.g. UVB-protection by O_3, breathable air)
2. Climate regulation (maintenance of a favourable climate for human habitation/health, cultivation)
3. Disturbance prevention (e.g. storm protection, flood prevention)
4. Water regulation (e.g. drainage and natural irrigation, medium for transport)
5. Water supply (Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
6. Soil retention (e.g. maintenance of arable land, prevention of damage from erosion/siltation)
7. Soil formation (maintenance of productivity on arable land, maintenance of natural productive soils)
8. Nutrient regulation (maintenance of healthy soils and productive ecosystems)
9. Waste treatment (pollution control/detoxification; filtering of dust particles, abatement of noise pollution)
10. Pollination (maintenance of wild plant species and population, pollination of crops)
11. Biological control (e.g. control of pest and diseases, reduction of herbivory—crop damage)
Habitat functions: providing habitat (suitable living space) for wild plant and animal species
12. Refugium function (maintenance of biological and genetic diversity)
Production functions: Provision of natural resources
13. Food (hunting, gathering of fish, game, fruits, etc. nursery function for (locally) harvested species)
14. Raw materials (buildings and manufacturing, fuel and energy, fodder and fertilizer)
15. Genetic resources (to improve crop resistance to pathogens and pests and other commercial applications)
16. Medical resources (drugs and pharmaceuticals, chemical models and tools, test- and essay organisms)
17. Ornamental resources (for fashion, handicraft, jewellery, decoration and souvenirs)
Information functions: providing opportunities for cognitive development
18. Aesthetic information (enjoyment of scenery, e.g. scenic roads, housing, etc.)
19. Recreation (travel to natural ecosystems for eco-tourism, outdoors sports, etc.)
20. Cultural and artistic information (use of nature as a motive in books, film, painting, folklore, national symbol, architect, etc.)
21. Spiritual and historic information (use of nature for religious or historic purpose, i.e. heritage value)
22. Science and education (e.g. school excursions, etc. scientific field laboratories, etc.)

result of their history or management; where quality is defined in terms of the ability of a patch to deliver particular benefits or services, such as biodiversity or other outputs. Other ecosystem patches may be more 'valuable assets' in a particular economic or social context, by virtue of their location. Thus, when we come to apply the concept of natural capital to the restoration of downland landscapes, the problem becomes one of modelling the existing or potential functional properties of the different land cover elements across the area (Bailey et al., 2005). Using such a model one may then assess the likely net, ecological, economic and social benefits that might result from any change in these functional properties through restoration. The natural capital concept, therefore, allows the South Downs to be conceptualised as a multifunctional landscape (Tress et al., 2001; Brandt and Vejre, 2004). The framework for this assessment is provided by criteria such as those set for the Sussex Downs Conservation Board, which include the promotion of the "quiet enjoyment of the Sussex Downs . . .by the general public" so far as it is consistent with the protection, conservation and enhancement of the natural beauty of the area (Sussex Downs Conservation Board, 1996).

The representation of downland as an element of natural capital, capable of delivering a range of ecosystem functions or services, is one that captures the different ways in which these habitats have been viewed by the science and policy communities. Downland is clearly a multifunctional resource, and the restoration of such habitats has a number of objectives, beyond that of enhancing or conserving biodiversity. In the remaining parts of this paper, we therefore consider how one might approach the problem of developing a management strategy that takes account of these multiple functions. We ask whether a restoration strategy that accommodates both the biodiversity and recreation functions of these grasslands, would be different from one that focused on biodiversity alone.

4. The restoration potential for downland

4.1. Data resources

The data used for this study were derived from the South Downs GIS, which was developed in partnership with the Sussex Downs Conservation Board though an European Union fourth Framework project. The aim of the work was to develop information-handling tools for those concerned with protected areas management across Europe.

A key data set available from the South Downs GIS that could be used to characterise the current distribution of chalk grassland and potential sites for restoration was the Phase I Habitat Map of the area, where Phase I is a classification of terrestrial and freshwater habitats for large scale surveys, used for environmental audit. The map describes, on a parcel-by-parcel basis, the distribution of habitats using the classification system set down by Joint Nature Conservation Committee (1993). Although the classification is an ecological one, it uses terms describing intensity of agricultural management to distinguish between grassland types on chalk. Within the Phase I classification, the code 'B3' refers to calcareous grassland generally, with the sub-categories 'B31' denoting unimproved grassland and 'B32' semi-improved calcareous grassland. The definitions on the Phase I map are also supported by reference to the various National Vegetation Classification types that occur in each of the units (Rodwell, 1991), but does not distinguish between 'improved' and 'poor semi-improved' grasslands, which are mapped as a single unit (Classes B6/B4), alongside cultivated or disturbed arable land (J11). Areas of dense and scattered scrub (A21 and A22) are also distinguished from more mature woodland types.

A second key data source was the land cover classification for the Environmentally Sensitive Area. These data are particularly important because they define the types of land eligible for entry into the different tiers within the Environmentally Sensitive Area scheme. The least intensively managed grasslands on the chalk are described as 'unimproved grassland'. Other cover categories distinguished are 'semi-improved' and 'improved' grasslands, and arable. A comparison with the Phase I map suggests that the distinction between grassland types made in the Environmentally Sensitive Area data is more sensitive to the different management treatments than the Phase I map. Table 2 shows the correspondence between the classes used in the classifications across the study area. While there is consistency between the improved grassland and arable cover types, it is clear that the Phase I chalk grassland class includes grassland denoted as 'unimproved', 'semi-improved'

Table 2
Correspondence between Environmentally Sensitive Area and Phase I habitat mapping categories (Phase I: a classification of terrestrial and freshwater habitats for large scale surveys, used for environmental audit)

Phase I mapping code	Phase I mapping classification	Environmentally Sensitive Area classification
B3	Calcareous grassland	
B3.1	Unimproved	Unimproved grassland
B3.2	Semi-improved	Semi-improved grassland
B4/B6	Improved grassland	Improved grassland
B4	Improved grassland	
B6	Poor semi-improved grassland	
J11	Cultivated/disturbed land, arable	Arable

and 'improved' in the Environmentally Sensitive Area data.

Unfortunately, only Phase I data are available for the whole study area, and so only these could be used to examine the extent of the 'downland resource'. Given our discussion of what constitutes 'downland' it is clear that the mapping unit 'chalk grassland' is a general category that only approximates to the more ecologically valuable types of sward. In what follows it is assumed that these grasslands are, nevertheless, worth conserving for their botanical characteristics and are more easily restored to 'species-rich chalk grassland'. It is further assumed that the improved grasslands and arable areas mapped in the Phase I study are also restorable to 'downland' in a more general sense, providing they are on the chalk outcrop. In these cases the establishment of grassland that is both appropriate in landscape terms and ecologically rich may, however, involve higher costs and longer time scales.

In order to constrain the use of the various Phase I grassland and scrub categories to the appropriate geographical area, the map was intersected with a 'chalk mask'. This was constructed for the purposes of the project by assigning each 500 m × 500 m grid square within the study area to a category according to the landscape types recorded in the landscape character assessments for the study. These assessments divide the two 'Areas of Outstanding Natural Beauty' into different landscape character areas using a number of different parameters, such as soils, natural processes, land use, etc. but with geology as a key factor. It is, therefore, possible to differentiate between, for example, Chalk and Wealden landscapes in the area.

4.2. Current distribution of downland

Analysis of the distribution of the downland (i.e. the Phase I chalk grassland class) within the study area shows that existing parcels are located preferentially on steeper slopes (greater than 10°) of northern and easterly aspects (Fig. 2). These results largely confirm the more detailed statistical analysis of Burnside et al. (2002), based on the 'Principal Components Analysis'. The current highly fragmented distribution appears to result from two key factors. First, the underlying relationships between this habitat type and the biophysical conditions that allows them to develop under specific management practices; that is the grasslands are confined to shallow soils on the chalk outcrop. Second, the processes of land use change, which have tended to remove downland from specific parts of the landscape, thereby leading to the remnant pattern we see today. For example, historical sources, such as the 1942 Land Utilisation Survey prepared by Dudley Stamp (Briault, 1942), shows 'downland' (note: the term used to describe the extensive grasslands of the area on the Land Utilisation map is 'downland pasture'.) to be much more extensive in the East and West Chalk Upland landscape zones of the Sussex Downs Area of Outstanding Natural Beauty than they are at present.

4.3. Restoration potential

Given the current distribution of downland, several potential ecological restoration scenarios could be envisaged. One aim could be to buffer, protect and extend the existing distribution, as suggested for the Chilterns by Thompson et al. (1999) and Burnside et al. (2002). Under this scenario steeper slopes would

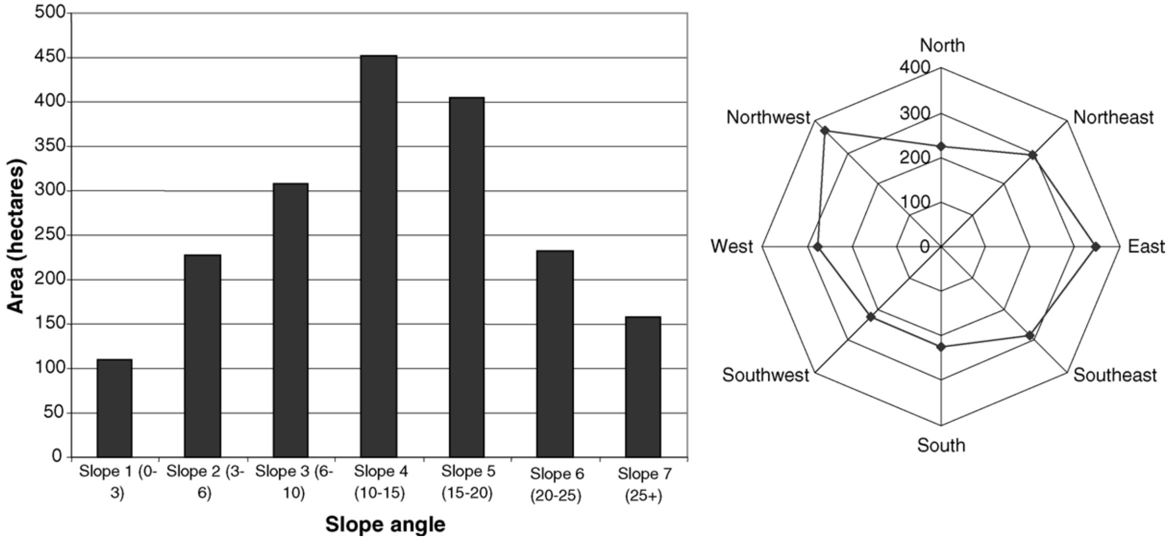


Fig. 2. Distribution of downland within the South Downs Environmentally Sensitive Area in relation to slope and aspect.

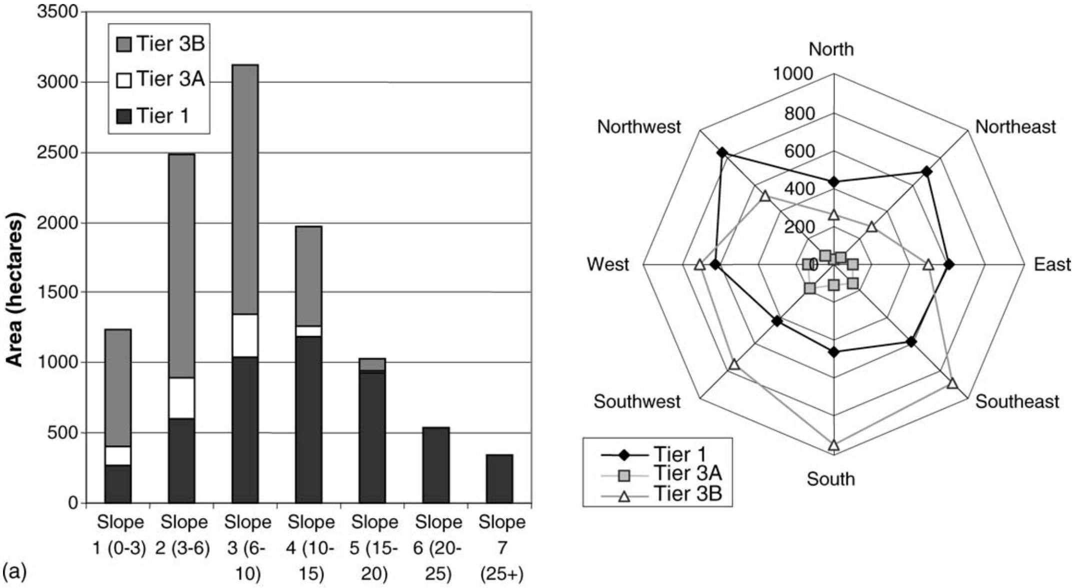
be targeted because relative costs under Environmentally Sensitive Area payments would be lower because land is considered more marginal for farming. By targeting schemes close to existing patches of downland, the quality of the restored patches may increase more rapidly though colonisation processes. However, as the analysis of Burnside et al. (2002) illustrates, such restoration scenarios essentially reproduce and extend the existing biogeographical distribution of these grasslands.

An alternative restoration strategy might be to increase the area of downland on lower angle slopes and on slopes of more southerly and westerly aspects, so as to extend and restore the biophysical range of this habitat across the study area. Perring (1958, 1959) has analysed the distribution of chalk grassland species across slopes of different aspect and slope. He showed that the habitat could occur on all slope angles and aspects, but that the different microclimates favoured different floristic elements of the plant community. This restoration strategy would, therefore, have the advantage of extending and restoring the former range of the habitat in the area, and establish downland on terrain that is better for walkers than steep slopes.

In order to explore these scenarios and their relationship to the recent restoration efforts achieved through the Sussex Downs Environmentally Sensitive Area Scheme, the biophysical characteristics of land parcels that entered the various options or ‘Tiers’ under the programme were determined (Fig. 3a and b). The ‘Environmentally Sensitive Areas Uptake’ data that were used for the analysis were those for the period 1987–1995.

Land in Tier ‘1’ (4909 ha) covers what is termed ‘unimproved pasture’ under the Environmentally Sensitive Area classification, and includes the existing fragments of chalk grassland for which agreements have been made. In the analysis, these areas have been separated from land in Tiers ‘3A’ and ‘3B’, which represent areas of arable (i.e. crop and ley grassland in arable rotation) reverting to ‘chalk downland’ and permanent pasture, respectively. Together these areas constitute extent of the restored resource within the Environmentally Sensitive Area up to 1997. Several features are apparent from the data shown in Fig. 3a and b.

The land taken into the scheme (especially in Tiers 3A and B) is distributed in blocks across the Environmentally Sensitive Areas, reflecting the fact that uptake occurred at the holding level, rather than on a field-by-field basis. The area entering Tier 3A, which represented restoration of downland proper, was small (817 ha) but nevertheless increased the area of downland by about 17% within the Environmentally Sensitive Areas. Such land was similar in terms of its slope and aspect characteristics to the existing stock of down-



(a)

(b)

Fig. 3. (a) Distribution of Environmentally Sensitive Area agreement land within the South Downs in relation to slope and aspect. (b) Map showing the distribution of Environmentally Sensitive Area Tier agreement land within the South Downs.

land (Tier 1). The area of land entering into Tier 3B is larger than Tier 3A (4998 ha). The parcels were located on more southerly aspects than the existing downland stock, and on slopes of lower angle. Their location appears to have linked and consolidated many of the existing downland patches.

As noted above, it is estimated that in between 1987 and 1998 only about 30% of the eligible land within the South Downs Environmentally Sensitive Area had entered the Scheme. Thus, it is useful to extend the analysis undertaken above by considering the character and extent of the 'untapped resource' both within the Environmentally Sensitive Area and across the entire study area.

The area of unimproved and semi-improved grassland within the South Downs Environmentally Sensitive Area that was not covered by the scheme up to 1997 is small (680 ha). Thus, while its inclusion would have been beneficial in terms of linking existing downland fragments, uptake would have done little to extend

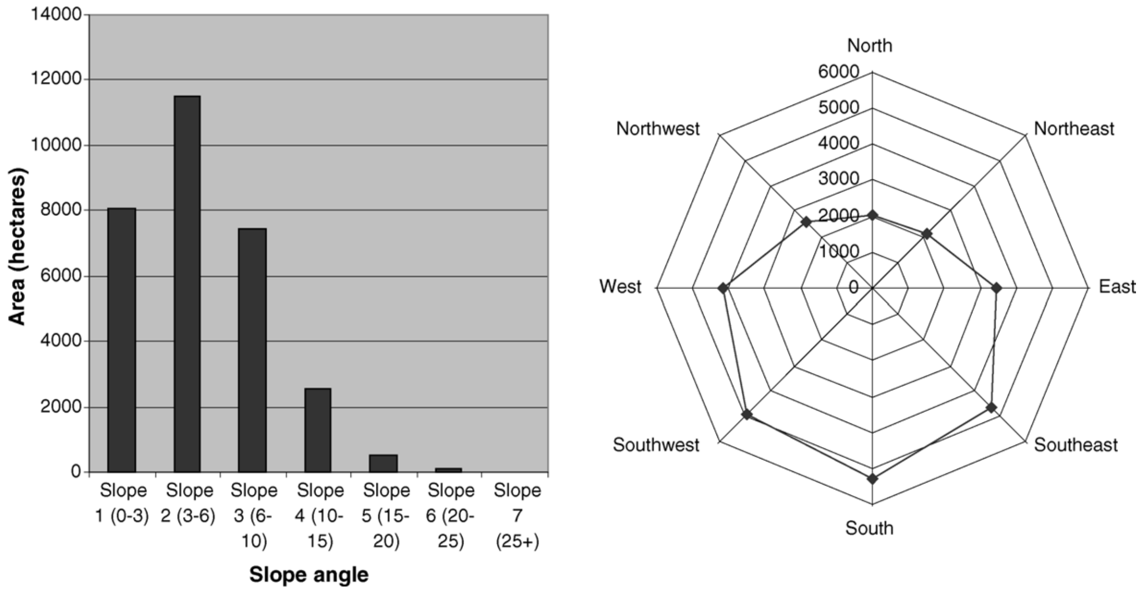


Fig. 4. Distribution of potentially restorable land within the South Downs Environmentally Sensitive Area in relation to slope and aspect.

the biophysical range of the habitat. Fig. 4 shows the characteristics of land classified as either ‘improved grassland’ or ‘arable’ in 1998, which together represented the area of ‘restorable land’. These data show that the distribution of such land within the Environmentally Sensitive Area is different to that of the existing habitat, in that it occurs on much gentler slopes of a more southerly aspect. Only by extending habitat restoration efforts to these areas would there have been any prospect of fundamentally changing the initial distribution of the downland habitat within the Environmentally Sensitive Area.

Fig. 5 shows the distribution of existing downland within and outside the Environmentally Sensitive Area, together with the extent of potentially restorable land. For this analysis the Phase I data were used because they covered the entire study area. Several features are evident. First, the area of existing downland outside the Environmentally Sensitive Area is small (478 ha), suggesting that little would be gained by extending the scheme beyond the existing boundaries only to this habitat type. Second, that although the potentially restorable land outside the Environmentally Sensitive Area is similar in its biophysical characteristics to that found inside the Environmentally Sensitive Area, inclusion of these areas within future restoration schemes would significantly increase the area available, by about 64%.

Taken together Figs. 3–5, therefore, allow us to answer the second and third questions posed in the introduction to this paper. For the study area during the period considered, chalk grassland has been preserved in areas that have been marginal for agriculture, and that current conservation and restoration schemes tend only to reproduce this relict distribution. Only by directing restoration efforts to areas of improved grassland and arable would there have been any prospect of extending the biophysical range of the habitat over the period concerned. The analysis showed that in 1997 the area of improved grassland and arable within the study area was substantial, and that the characteristics of the potentially restorable land were similar on either side of the Environmentally Sensitive Area boundary.

4.4. Downland as a multifunctional resource

If the extent of potentially restorable downland in the study area is large, then it is likely that future schemes may target locations where benefits can be maximised. The analysis presented above has considered the issue mainly from the ecological perspective. In this section we consider downland as

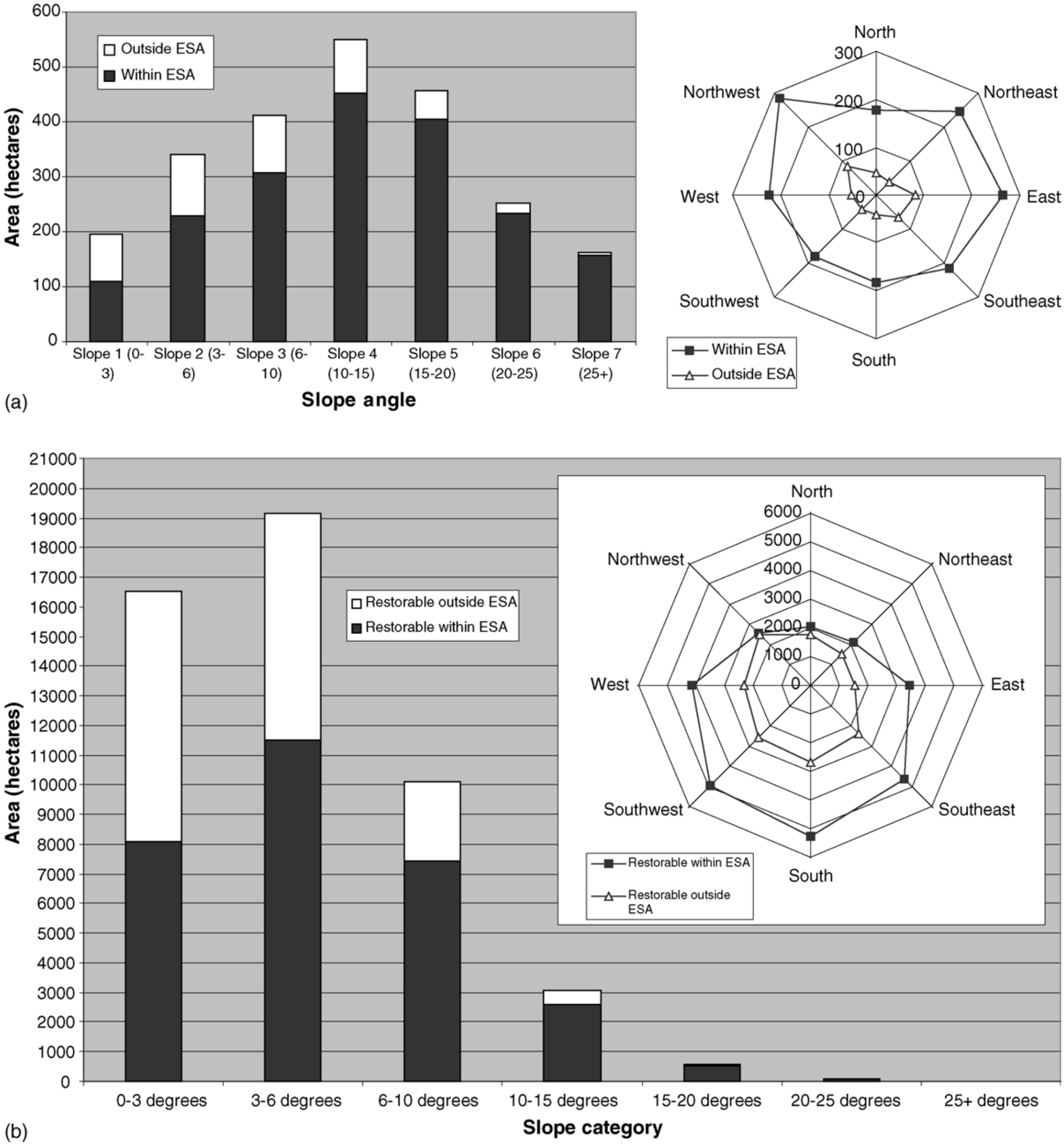


Fig. 5. (a) Area of downland within and outside the Environmentally Sensitive Area (ESA) by slope angle and aspect. (b) Area of restorable land within and outside the Environmentally Sensitive Area (ESA) by slope angle and aspect.

an element of 'natural capital' with multiple functions, and examine how the outcomes of restoration strategies might differ if recreation is considered alongside that of biodiversity. The analysis assumes that downland restoration will enhance recreation in the area by facilitating, amongst other things, more or better recreational opportunities, mainly for walkers. The extent of the potential benefit, it is assumed, will depend on the location of restoration in relation to existing, likely, or 'future desired' patterns of

Fig. 6. Recreational asset map for the study area.

Table 3
Scoring system for natural capital analysis

Score based on	Calculation method/scoring system
Length of footpath network in each 500 m grid square	Scored on a scale from 1 to 5, five being high length of footpaths: 5 = 3600–4500 m 4 = 2700–3600 m 3 = 1800–2700 m 2 = 900–1800 m 1 = 0–900 m
Tranquillity rating of grid square	Scored by populating each grid square with the results of a tranquil area study of the Sussex Downs and East Hampshire Area of Outstanding Natural Beauty. Scores are on a scale from 1 to 5, with five being remote and 1 being disturbed: 5 = Remote 4 = Very tranquil 3 = Tranquil 2 = Semi-tranquil 1 = Disturbed
Distance from a long distance footpath (South Downs Way)	Scores based on the distance of a grid square from the South Downs Way. 5 = 0–25 m from the South Downs Way 4 = 25–50 m from the South Downs Way 3 = 50–75 m from the South Downs Way 2 = 75–100 m from the South Downs Way 1 = Over 100 m from the South Downs Way
Distance from an Urban Area	Scores based on the distance of a grid square from an urban area (gateway): 5 = 0–0.25 miles from an urban area 4 = 0.25–0.5 miles from an urban area 3 = 0.5–0.75 miles from an urban area 2 = 0.75–1 mile from an urban area 1 = Over 1 mile from an urban area
Distance from a village (with shops, pubic houses, etc.)	Score based on the distance of a grid square from a village 5 = 0–250 m from a village 4 = 250–500 m from a village 3 = 500–750 m from a village 2 = 750–1000 m from a village 1 = Over 1000 m from a village

access, and the factors affecting the 'quality' of that access.

The recreational function of the study area was modelled spatially by means of a 500 m × 500 m grid, that was used to score cells against a set of characteristics that are assumed to affect the quality of the recreational experience (Fig. 6, Table 3), namely: tranquillity, foot path density, location in relation to long distance footpaths, distance from an urban area, and distance from a village with a pubic house or shops, etc. The cell size was chosen to reflect the fine-grain nature of the landscape without unduly adding to the volume of data for processing.

The rationale for the selection of these parameters and the scoring system used to characterise them, was provided by reference to various local policy statements which have sought to create a pleasant walking environment and to promote the 'quiet enjoyment of the countryside' (Sussex Downs Conservation Board, 1996), and the conclusions of recent visitor surveys. The results of the *South Downs Way National Trail User Survey, 1996–1997* (Countryside Agency, 2000) suggested, for example, that both long and short distance walkers rank tranquillity highly. Although the different categories of walkers varied in their responses, ease of access to the countryside via the footpath network was also considered important, together with ease of access to the public transport and parking facilities. Proximity to villages and other urban centres was also considered significant, both because they serve as a place of residence for walkers, and because of the services they provide during a visit. Clearly other indicators of the state of the recreational resource could have been used. However, there are little systematic empirical data available to justify their use in the study area. The advantage of a limited set, such as the one used is that geographical patterns may more easily be interpreted, and limitations of the analysis clearly identified.

In Fig. 6, the darker areas are those with a higher recreational asset score, which are therefore considered to provide a 'better quality' walking environment than lighter squares. The darker areas are concentrated along the escarpment of the Downs, reflecting the higher tranquillity of these areas, the general density of the footpath network, and the presence of the South Downs Way, which is a major, national long-distance trail. Using these data we ask whether the current distribution of downland is coincident with those cells that score most highly and whether recent restoration efforts have contributed significantly to the enhancement of landscape and habitat in those places. Finally we can

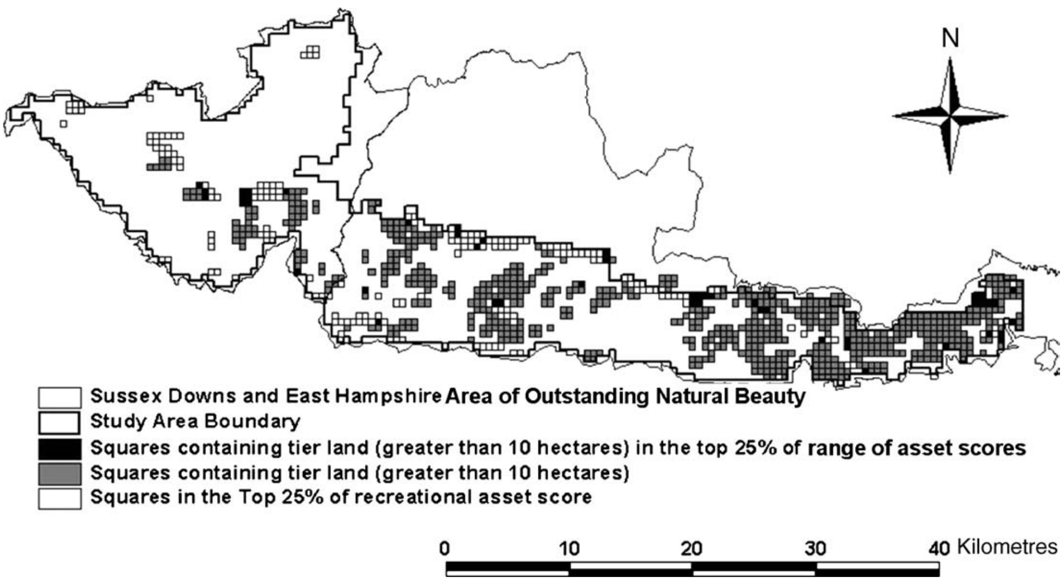


Fig. 7. Distribution of cells in the 25% range of recreational asset scores in relation to the existing Environmentally Sensitive Area Tier agreements.

Table 4
Area of each land cover (arable, improved, downland) in the top 25% category of squares on recreational asset map, with area of this land which is covered by an existing Environmentally Sensitive Area tier agreement

Land cover	Area in top 25% score category on recreational asset map (ha)	Area already covered by a Tier agreement in top 25% score category on recreational asset map (ha)	% of land without a Tier agreement
Arable	5109	215	96
Improved	456	25	95
Downland	493	121	75

explore how the distribution of potentially restorable land relates to the areas the areas of higher recreational value.

Fig. 7 and Table 4 present the results of the analysis of the extent of the downland based on the area of each Phase I habitat type in each cells on the map shown in Fig. 6. The analysis focuses on the cells which have recreational scores in the top 25% of the range.

Fig. 7 shows that only a small area of the land covered by the various types of agreement that were made to restore downland between 1987 and 1995 are found in cells that score most highly on the recreational asset map. The bulk of the agreement land is in the east of the study area, on the dip slope of the Downs. The divergence between the distribution of the agreement land and the areas of highest recreational potential is emphasised by Table 4, which shows that 75% of the existing downland in these cells is apparently not covered by any agreement. Moreover, less than 5% of the arable and improved grassland in these areas was included in the Environmentally Sensitive Area scheme up to 1997. The land cover and associated biophysical characteristics of the potentially restorable land in the cells that score highly are summarised in Fig. 8.

The analysis (Table 4) shows that there are significant areas of arable land (58%) in the 25% of cells with the highest recreational scores (Fig. 6) which could be converted to Down. Improved grassland is less significant in these areas as potentially restorable land (10%). Significantly only a small proportion of the top 25% is already downland (5%). Table 4 shows that, of this restorable resource, a high proportion lacked an Environmentally Sensitive Area agreement up to 1997 (95%), although between 65% of this resource is within the South Downs Environmentally Sensitive Area and therefore could have been eligible for an agreement.

Since a high proportion of land that is eligible for Environmentally Sensitive Area agreements had not been entered into the scheme up to 1997 it is clear that more effective methods of encouraging Environ-

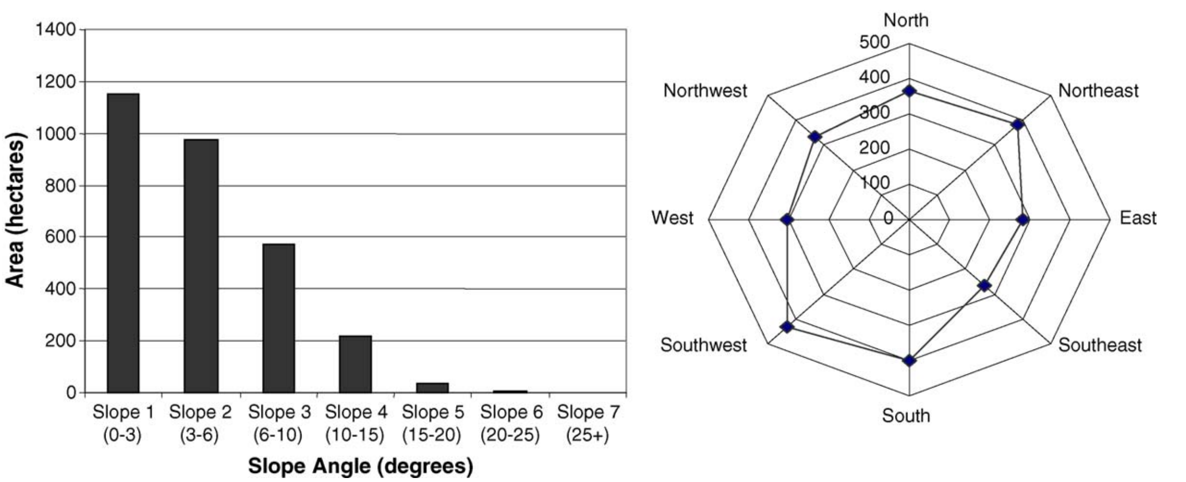


Fig. 8. Biophysical characteristics of restorable resource in top 25% without an existing Environmentally Sensitive Area Tier agreement (for comparison with Fig. 5b).

mentally Sensitive Area participation were needed over this period. As a result of their analysis, Burnside et al. (2002) has also argued that the existing scheme is unlikely to achieve the objective of restoring grasslands of higher conservation status, and that greater targeting may be necessary. Our conclusion is that in the context of a multi-functional landscape, the scheme is also unlikely to produce downland in areas of higher recreational value.

If the land already entered into existing Environmentally Sensitive Area agreements is removed from the 'restorable resource' in the cells which score most highly, then it is useful to examine the biophysical characteristics of the remaining land parcels. Fig. 8 demonstrates that, in comparison to the restorable land shown in Fig. 5b, this 'untapped' recreational resource, which is not covered by existing agreements, is concentrated on lower angle slopes most commonly on north and south facing aspects. The majority of the restorable land is also arable, rather than improved grassland. In terms of the final two questions posed in the introduction, the conclusion that may, therefore, be drawn is that the character and distribution of land that would be most beneficial to target for recreational purposes differs significantly from sites rated highly for their for biodiversity potential by Burnside et al. (2002) and Thompson et al. (1999), unless one also considers the need to extend the biophysical range of the habitat in the area.

5. Modelling natural capital—conclusions and implications

This paper set out to answer five specific research questions relating to the restoration of 'downland' in Southern England. We have shown that while habitat restoration often presents significant technical challenges, equally important questions arise about what is actually being restored. On the South Downs restoration is often discussed in the context of restoring sites which have high biodiversity value. However, wider social objectives may also require that we consider such initiatives in the context of the extent to which sites may also support recreational outputs. We have shown that in each case what is being restored is different conceptually, and that in landscape terms different spatial outcomes would result depending on objectives.

The targeting of sites for restoration of high biodiversity values would maintain the current biogeographical distribution of species rich chalk grasslands in the area, and reduce the fragmentation of the resource (Burnside et al., 2002). However, in terms of delivering downland in places where people go most frequently, such targeting of sites for their conservation potential alone would not achieve wider objectives of expanding public access to these traditional landscapes which also have high cultural value. Clearly one cannot restore high biodiversity in places where biophysical constraints would render the exercise most difficult or impossible. However, the establishment of mesotrophic grasslands under low intensity management regimes would nevertheless constitute 'downland' in its most general sense, that would have value in terms of its recreational or landscape functions.

Burnside et al. (2002) have argued that if restoration programmes are to succeed then 'a coherent and consistent methodology for site selection that considered the biological and physical characteristics of potential sites' is required. These conclusions relate specifically to the restoration of species rich grasslands on the South Downs, but clearly the message is an important one for those using habitat suitability techniques more generally. What our analysis has shown is that while these biophysical models may be scientifically robust and thus defendable, habitat suitability analysis has the danger of being 'one-dimensional'. Most landscapes exhibit aspects of multi-functionality. The South Downs are no exception. If modelling approaches are to be developed in the context of managing such landscapes, then the whole range of functions or outputs associated with them must be considered (Haines-Young, 2000).

In the context of this study we have shown that scenarios for enhancing the recreational function of a landscape may differ from those designed to deliver high biodiversity. Clearly the assumptions and weightings used in our recreational asset model could be varied to test the sensitivity of these scenarios, to reflect more firmly the values of 'stakeholders', but this is not a key issue here. Most significantly, in terms of drawing more general lessons from this study, the key conclusion is that as a scientific community we have to find more appropriate methods of modelling the natural capital of an area, in terms of understanding the range of functions land cover and landscape can deliver, and how these functions vary spatially. The study by Bailey et al. (2005), together with this paper shown has shown how conventional approaches to suitability mapping can be extended to include the social values of landscape as well as the biophysical. Most significantly for the future, these models must be extended to allow both the identification of the trade-offs that society has to confront, when considering the restoration of different types of landscape function. They must also help to identify the range of alternative landscape configurations that can sustain the delivery of the landscape outputs that people value. The task of modelling natural capital in terms of the range of functions supported by landscape provides, we suggest, a framework in which issues of multifunctionality can be explored and a better foundation on which questions of sustainability of ecosystem outputs can be resolved.

Acknowledgements

The data used for this study were derived from the South Downs GIS, which was developed in partnership with the Sussex Downs Conservation Board though an EU fourth Framework project (PRIMAVERA, contract no. ENV4-CT97-0758). We gratefully acknowledge Dr. Burnside for assisting with access to these and associated data.

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