Journal of Applied Ecology

*Journal of Applied Ecology* 2009, **46**, 334–343 doi: 10.1111/j.1365-2664.2009.01619.x

# 100 years of change: examining agricultural trends, habitat change and stakeholder perceptions through the 20th century

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## Summary

**1.** The 20th century has witnessed substantial increases in the intensity of agricultural land management, much of which has been driven by policies to enhance food security and production. The knock-on effects in agriculturally dominated landscapes include habitat degradation and biodiversity loss. We examine long-term patterns of agricultural and habitat change at a regional scale, using the Peak District of northern England as a case study. As stakeholders are central to the implementation of successful land-use policy, we also assess their perceptions of historical changes.

**2.** In the period 1900 to 2000, there was a fivefold rise in sheep density, along with higher cattle density. We found a reduction in the number of farms, evidence of a shift in land ownership patterns, and increased agricultural specialization, including the virtual disappearance of upland arable production.

**3.** Despite previous studies showing a substantial loss in heather cover, we found that there had been no overall change in the proportion of land covered by dwarf shrub moor. Nonetheless, turnover rates were high, with only 55% of sampled sites maintaining dwarf shrub moor coverage between 1913 and 2000.

**4.** Stakeholders identified many of the changes revealed by the historical data, such as increased sheep numbers, fewer farms and greater specialization. However, other land-use changes were not properly described. For instance, although there had been no overall change in the proportion of dwarf shrub moor and the size of the rural labour force had not fallen, stakeholders reported a decline in both. Spatial heterogeneity of the changes, shifting baselines and problems with historical data sources might account for some of these discrepancies.

**5.** *Synthesis and applications*. A marked increase in sheep numbers, combined with general agricultural intensification, have been the dominant land-use processes in the Peak District during the 20th century. Stakeholders only correctly perceived some land-use changes. Policy and management objectives should therefore be based primarily on actual historical evidence. However, understanding stakeholder perceptions and how they differ from, or agree with, the available evidence will contribute to the successful uptake of land management policies and partly determine the costs of policy implementation.

**Key-words:** agricultural intensification, historical land-use, June Agricultural Census, Peak District, shifting baseline, stakeholder workshops, upland

## Introduction

Land-use change and agricultural intensification are two of the major drivers of global biodiversity loss and habitat degradation (Benton, Vickery & Wilson 2003; Millennium Ecosystem Assessment 2005; Donald *et al.* 2006). These changes often result in the conversion of natural habitat to agricultural uses (e.g. Sodhi *et al.* 2004). However, in areas where agriculture is already well established, major processes also include the encroachment of production into previously marginal areas and the steady intensification of land-use,

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leading to an incremental decline in habitat quality and biodiversity (e.g. Schmitt & Rákozy 2007).

In the UK, as elsewhere in Europe, the 20th century witnessed dramatic changes in the intensity of agricultural production, with a fourfold increase in yield from 1945 to the end of the century, associated with mechanization and increased chemical application (Robinson & Sutherland 2002). As the majority of the land surface of the UK is dominated by agricultural systems, the knock-on effects have been profound. At a national scale, there has been an overall reduction in low-input grasslands, moors, heaths and hedgerows, together with a loss of landscape heterogeneity (Fuller 1986; Rose *et al.* 1996; Robinson & Sutherland 2002; Swetnam 2007). Some land-use change has had a strongly regional focus (e.g. Rose *et al.* 1996), and more recent processes have not been uniform. For instance, in upland areas, intensification has continued to a greater extent than in lowland regions (Haines-Young *et al.* 2003), but patterns for the uplands remain much less well-described (e.g. Sinclair 1983). Given these heterogeneities, regional studies of change become increasingly important.

Agricultural practice in the last century has largely been driven by policy changes directed at improving food security and maximizing production (Robinson & Sutherland 2002). Recent policies have put a greater emphasis on environmental benefits. How successful these have been in ameliorating biodiversity losses remains unclear (Kleijn & Sutherland 2003; Kleijn *et al.* 2006). Although efforts have been made to link these policies directly to improvements in ecological conditions (Hanley *et al.* 1998), little work has placed biodiversity changes in the context of the evolution of agricultural land-use over the long term (but see Hanley *et al.* 2008). Two complementary methods for uncovering such processes are, firstly, to use longitudinal ecological data and, secondly, participatory approaches that reveal stakeholders' views. Ecological data can be used by policy makers and environmental managers to set targets, inform the choice of relevant baselines and to assess the level of natural variability (Froyd & Willis 2008). Stakeholder perceptions of agricultural and ecological change are important for understanding the likely acceptability of targets, to improve policy design and enhance ease of implementation, not least because stakeholder impressions of baseline conditions may diverge from what is objectively measurable.

Policy analysis traditionally uses an expert-based approach to decision-making, which takes little account of the diversity of stakeholder perceptions. However, as the effectiveness of policy depends on the attitudes and actions of many individuals, this may not always be appropriate. For example, in Western Australia the collapse of regional forestry policy was partly due to its rejection by stakeholders (Bruekner 2007). Therefore, disagreements on the most important drivers of change can also be important in predicting policy success. Moreover, stakeholders' views on appropriate objectives for land management can be based, in part, on their perceptions of past landscape development, strengthening the case for incorporating a historical dimension in developing policy.

In this study, we examine the evidence base for habitat and agricultural change, using a substantial temporal data set for the English uplands. Secondly, we compare the historical data with how stakeholders perceive those changes and discuss the reasons for, and policy implications of, differences between the two.

## Methods

### SURVEY AREA

We focus on an upland landscape with long agricultural and habitat change records. High-quality maps document the semi-natural habitat for the Peak District of northern England (Fig. 1a) as far back as 1913 (Moss 1913). In addition, the Peak District has been an important focus for rural policy in the UK. It was designated as the country's first National Park in 1951, and, in 1987, part of the region was the site of an early agri-environment scheme (the North Peak Environmentally Sensitive Area; ESA). Livestocking, predominantly sheep farming, is the main agricultural enterprise. In addition, large areas of heather *Calluna vulgaris* (L.) dominated moorland are managed for game bird shooting. The region is highly valued for recreation and contains important water catchments for major cities.

### AGRICULTURAL CHANGE

Changes in agricultural practice were derived from the June Agricultural Census (JAC), which is an annual survey of farm holdings in England (Defra 2008). Each year farms are required to provide details of their agricultural activity, which are aggregated and made available at the level of local government administrative regions ('parish' pre-1988 and 'ward' from 1989 to 2004). For our purposes, data were collected every 10 years from 1900 to 2000 and for the years 1914, 1932, 1966 (broadly relating to when habitat and land-use maps were available; see below) and 1988 (to ensure that the full time span of parish data were used). All data were converted to hectares, although prior to 1970, variables were reported in acres.

Data from 32 parishes that covered the mapped area (for 1900 to 1988, and 22 wards for 2000; see Supporting Information, Appendix S1) were aggregated. To identify the presence of any patterns in agricultural change across the study area through the last century, a linear regression was conducted for each of the agricultural variables through time, with response variables transformed appropriately. The area of agricultural land ascribed to each parish changed between years, as JAC data include all agricultural activity registered to properties within a particular parish. Parish boundaries themselves also altered. To overcome the effect of shifting agricultural area, all variables are presented on a per-hectare basis, or as a proportion of the overall land area (Table 1).

### HABITAT CHANGE

Habitat maps were available from 1913 (Moss 1913), 1940 (Ordnance Survey 1952), 1978/1979 (Anderson & Yalden 1981; Anderson 1983), 1990 (Barr *et al.* 1993), and 2000 (Haines-Young *et al.* 2000). The complete area featured in all maps was 891 $km^2$ and covered the northern portion of the national park (Fig. 1b). Each habitat map used a different set of vegetation types and definitions. However, these were assigned to new common categories that were consistent across the set of surveys (Dwarf Shrub Moor, Acid Grassland, Scrub, Urban, Inland Water and Woodland; Table 1). All other land types,


**Fig. 1.** A map of the Peak District, northern England (a) showing the extent of habitat maps used in the study (b).

**Table 1.** Agricultural variables collected from the June Agricultural Census

| Agricultural variable | Definition | Unit | Years available |
|---|---|---|---|
| Agricultural land area | Total agricultural area, including all land-use categories | Total ha | 1900–2000 |
| Rough grazing | Mountain and heathland from 1900 to 1950, Rough grazing from 1960 | Proportion of agricultural area | 1900–2000 |
| Temporary grassland | Temporary grassland for mowing and grazing | Proportion of agricultural area | 1900–2000 |
| Permanent grassland | Permanent grassland for mowing, grazing and pasture | Proportion of agricultural area | 1900–2000 |
| Arable | Corn crops, green crops, other crops and fallow land | Proportion of agricultural area | 1900–2000 |
| Woodland | Woodland, orchards and other land | Proportion of agricultural area | 1900–2000 |
| Sheep | Total number of sheep, including ewes, lambs and other sheep of all ages | Nos/ha of agricultural land | 1900–2000 |
| Cattle | Total number of cattle including cows, heifers, calves and other cattle of all ages | Nos/ha of agricultural land | 1900–2000 |
| Horses | Total number of horses of all ages | Nos/ha of agricultural land | 1900–1950 |
| Labour | Total number of farm labourers including full and part-time workers | Total, Nos/ha of agricultural land, Nos/Livestock Unit | 1930 – 2000 |
| Number of holdings | Total number of holdings | Nos/ha of agricultural land | 1900–2000 |
| Holding size | Number of holdings within given size categories | Proportion of total number of holdings in size categories | 1910–1988 |
| Owned land | Number of hectares owned | Proportion of agricultural area | 1910–1930 and 1970–2000 |

whether they were primarily agricultural or semi-natural, were not compatible across the habitat maps and were hence included in a single category 'All Other Land' (see Supporting Information, Appendix S2). Although cotton grass represents a major semi-natural habitat type, it was not consistently mapped through the study period, and therefore, we were not able to consider it in detail. To assess habitat change, a 50 × 50 m grid was placed over the survey area. A random sample of 1% of these grid squares (3452 in total) was selected and examined for every map. Each grid square was ascribed a habitat category, based on the predominant habitat type for that cell. For every available year, the number and proportion of squares that belong to each habitat type were recorded.

**Table 2.** Direction, strength and significance of linear trends through time for agricultural variables aggregated across 32 parishes in the Peak District National Park between 1900 and 2000

| Variable | Slope of relationship with year | *P* value |
|---|---|---|
| Rough grazing | 0·0010 | 0·004 |
| Permanent grassland | –0·0008 | 0·014 |
| Temporary grassland | 0·0010 | 0·009 |
| Arable | –0·0011 | 0·005 |
| Woodland | 0·0013 | 0·002 |
| Sheep density | 0·0201 | < 0·000 |
| Cattle density | 0·0035 | < 0·000 |
| Horse density | –0·0009 | 0·002 |
| Total labour use | 9·2050 | NS |
| Labour $ha^{-1}$ | 0·0002 | NS |
| Labour $sheep^{-1}$ | –0·0003 | 0·002 |
| Labour livestock $unit^{-1}$ | –0·0002 | 0·005 |
| Number of holdings | –0·0004 | < 0·000 |
| Owned land | 0·0047 | < 0·000 |

NS, Not significant.

### STAKEHOLDER PERCEPTIONS

We aimed to identify events, processes and institutions that stakeholders believed to have had historical importance in the development of the Peak District upland landscape. Workshops, based on the qualitative 'Grounded Theory Approach' (Glaser & Strauss 1967), were run in November 2006 with stakeholders from a range of backgrounds all of whom were involved in the design or implementation of policy (farmers, gamekeepers, land owners and managers, conservation workers from local and national NGOs, local government, academics, water utility employees and government conservation agency staff). This provided a variety of expertise, knowledge and experience.

Workshop participants were split into three groups, with each group being asked to consider the patterns and drivers of change in relation to either wildlife, agriculture or society. The participants in each group were from diverse backgrounds and were given a flexible structure in which to operate. The relative importance of a particular phenomenon was gauged by whether it was mentioned by all three groups (Downward, Finch & Ramsey 2002). Participants were asked to identify a time-line of impacts with a rough starting point of 1880 running through to the present. Outputs from this exercise were thus qualitative statements from participants regarding their perceptions on both the process and drivers of change.

## Results

### AGRICULTURAL CHANGE

Significant trends in agricultural data were observed for 12 out of 14 variables (Table 2). Both sheep and cattle numbers and density increased. Sheep density did so dramatically from an average of less than one sheep per hectare in 1900 to nearly five sheep per hectare in 2000 (Fig. 2). Horse density declined from 1900 until data were no longer recorded in 1950 (Fig. 3).

The JAC itself reports on land-use change, albeit somewhat coarsely. Although significant changes in the proportion of rough grazing, temporary grassland and permanent grassland were evident, it is difficult to draw many inferences as definitions of these grassland types changed during the study period. However, a significant decline in the proportion of arable land and an increase in the proportion of woodland cover were clear (Fig. 3).

There were significant changes in the structure of farm holdings. The number of holdings fell, from 2158 (0·067 $ha^{-1}$) in 1900 to just 727 (0·021 $ha^{-1}$) in 1988 and 0·022 $ha^{-1}$ for 2000.

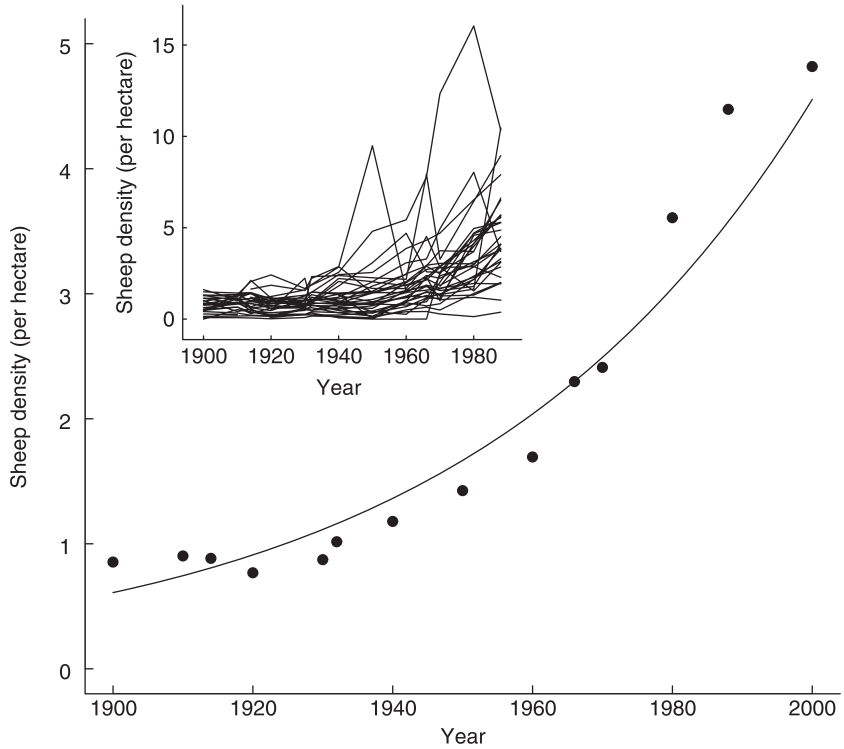


**Fig. 2.** Change in sheep numbers per hectare of agricultural land in the Peak District, northern England. The main figure shows aggregated sheep density across 32 parishes, together with the fitted trend line. Inset shows sheep density for individual parishes, with each line representing a different parish.

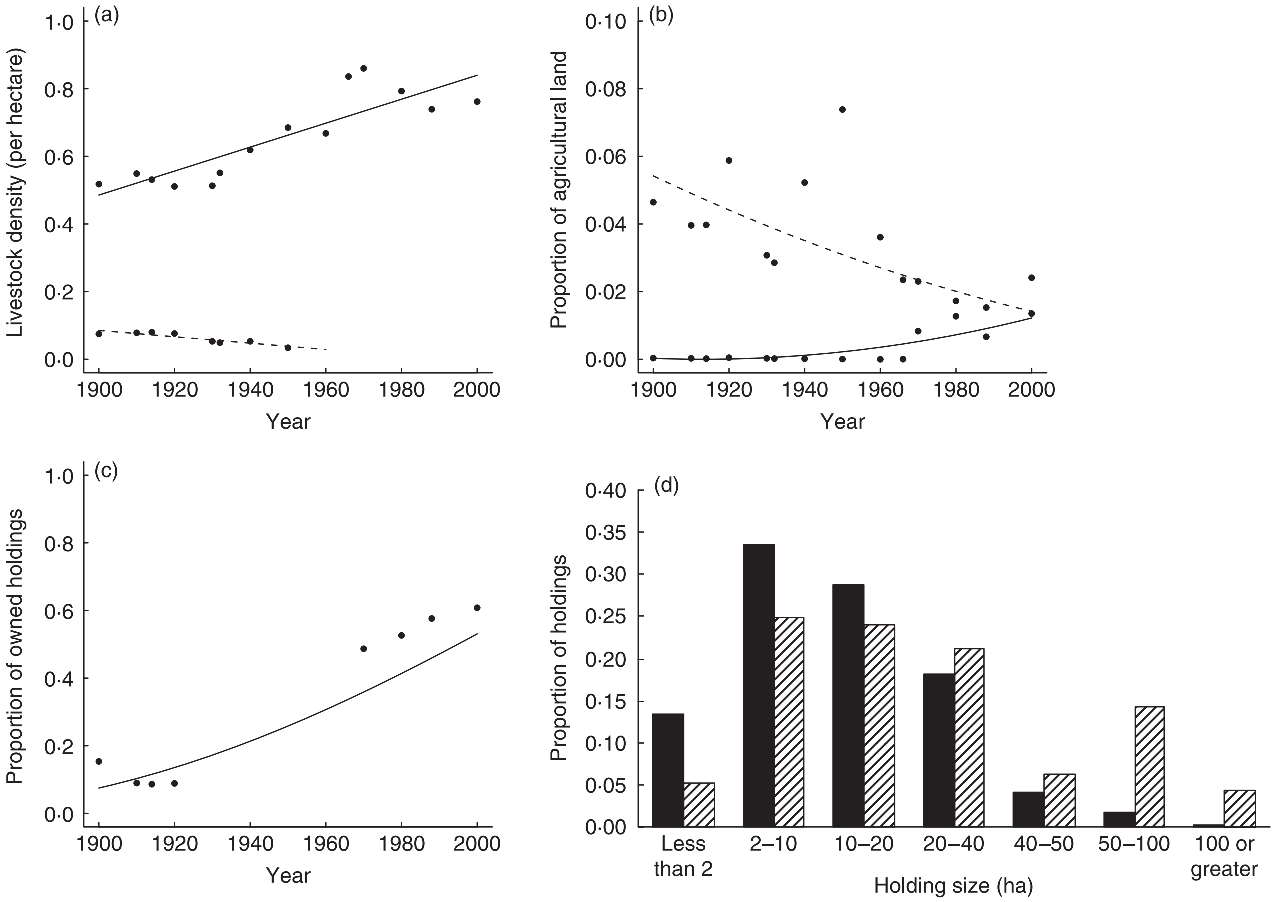


**Fig. 3.** Changes to agricultural variables from 1900 to 2000 aggregated across 32 parishes in the Peak District, northern England. (a) Livestock numbers: cattle (solid line), horses (dashed line). No data for horse numbers were recorded after 1950. (b) Proportion of agricultural land used for woodland (solid line) and arable (dotted line). (c) The proportion of land that is owned. (d) Proportion of farms reported in size categories for farms. Solid bars, holding size in 1910; dashed bars, holding size in 1988.

The proportion of holdings that were owned rose substantially, from between 8% and 15% prior to 1920 to over 60% in 2000. Holding size also altered, with the proportion of large holdings going up between 1910 and 1988 and a decrease in the proportion of holdings in the smallest category (less than 2 ha). There was a non-significant increase in the total number of labourers and labour use per hectare, which contrasted with a significant fall in the labour use per output unit (sheep or livestock unit). Labour productivity therefore rose over the period.

The pattern of agricultural change varied between parishes. As an illustrated example, the number of sheep per hectare for each parish was plotted against year (Fig. 2, inset). There was an increase in the variation of sheep density between parishes through the century. In 1988, sheep density ranged from 0·38 to 10·46 sheep $ha^{-1}$ for different parishes. Such variation is not apparent at the beginning of the century, where sheep density varied only threefold between 0·42 to 1·49 sheep ha.

### HABITAT CHANGE

The overall percentage of grid squares covered by dwarf shrub moor fluctuated between years, but was 21·7% in both 1913 and 2000. A larger percentage (24·9%) of squares was recorded as dwarf shrub moor in 1982 than in 1913. There was, however, a decline in the proportion of squares covered by acid grassland from 19·4 to 13·8%. Woodland cover was not recorded in 1940 and fluctuated, perhaps indicating inconsistent recording practices, but did increase slightly from 8·2% in 1913 to 8·8% in 2000 (Fig. 4), agreeing with the pattern derived from the JAC.

Despite a stable percentage of squares being occupied by dwarf shrub moor between 1913 and 2000, there was a shift in the particular squares that were classified as this habitat type (Fig. 4). Of the squares classified as dwarf shrub moor in 1913, only 55% retained this classification in 2000. This suggests that while the average level of dwarf shrub moor coverage remained relatively constant, the location of this habitat type shifted through time.

### STAKEHOLDER PERCEPTIONS

Within the workshops, certain events stood out as important perceived drivers of change. This was particularly true of the changes brought about through industrialization (see Supporting Information, Appendices S3 and S4; Tinch *et al.* 2009). Here we focus solely on those perceptions connected with agricultural and habitat change.

Stakeholders perceived that both World Wars had implications for increased agricultural production and reductions in

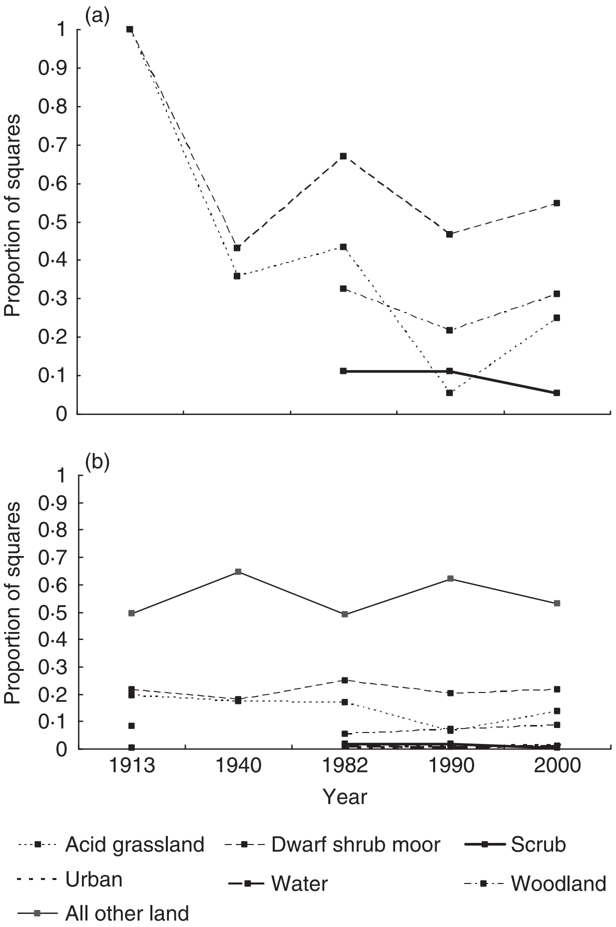


**Fig. 4.** Changes in habitat types between 1913, 1940, 1982, 1990 and 2000. (a) For four habitat types, the proportion of habitat classified in 1913 that remained in the same habitat class for each year. (b) The total number of sampled squares of the given habitat type for each year.

available labour. After the Second World War, many large estates were broken up. The first livestock production subsidies were introduced in 1947 and the National Park established in 1951. Management practices were noted to have changed through time, both in the grouse shooting industry and as a result of ownership shifts to agencies such as the National Trust, Forestry Commission and water utility companies. Afforestation was identified as being relatively unimportant in the Peak District, but having major impact in other upland areas of the UK. Stakeholders reported that there had been a loss of heather cover in the Peak District of approximately one-third between 1913 and 1980, reflecting results of an influential previous study (Anderson & Yalden 1981).

Prior to 1900, agricultural intensification was believed to have been restricted to draining lower lying land to allow cultivation. This process was thought to have continued in the 20th century, mainly through technological innovation and the introduction of subsidy supports. Opinions were that the mechanization of agriculture had led to the fall in the use of working horses and the subsequent total disappearance of small oat fields. After the 1930s, the perceived dominant process was an increase in sheep numbers. A general reduction in the diversity of agriculture was reported, with a perceived move towards ‘sheep ranches’. Increased agricultural productivity was made possible through higher chemical inputs, one result of which was described as the loss of biodiverse upland hay meadows. In the latter third of the century, stakeholders reported that European agricultural policy became the dominant driver, leading to further intensification of farming. Some of these pressures were reduced from 1987 with the introduction of the North Peak ESA. Participants indicated that ESA agreements had driven sheep numbers down. The same group stated that ESA agreements also led to an increase in heather burning for grouse shooting. Other participants felt that upland grazing intensity had continued to rise in the past 15 years and had led to further habitat loss. Finally, the reduced levels of air-borne pollution towards the end of the century were believed to have allowed the return of many mosses and lichens.

## Discussion

The 20th century in the Peak District was characterized by a fivefold increase in sheep numbers, and a dynamically changing pattern of vegetation cover against a background of constantly changing pressures from society and shifting policy aims. We discuss patterns of agricultural and habitat change in turn, both in terms of those that were revealed by the historical data sources, and those highlighted by stakeholder workshops.

### AGRICULTURAL CHANGE

Many of the agricultural changes that have been classically invoked as important determinants of adverse impacts on biodiversity in the UK are noted from the agricultural census returns analysed here. These include a considerable increase in sheep and cattle numbers, a concomitant rise in stocking density, an increase in specialization, a fall in the number of farms and a rise in farm size (cf. Robinson & Sutherland 2002).

The rise in sheep density started well before UK membership of the Common Market in the 1970s, although acceleration is apparent post-1960. UK entry into the Common Agricultural Policy in the 1970s coincided with a period of rising levels of support for agricultural commodities (Anderson & Josling 2007). Although the rapid increase in sheep density evident from the 1960s slowed from 1988 to 2000, and even fell for some parishes, the data do not indicate much impact of agri-environment schemes on overall grazing intensity in the study area. This is also in agreement with the findings of Anderson, Tallis & Yalden (1997) regarding the initial impact of these schemes.

In the workshops, stakeholders referred to a decline in the rural workforce. However, the evidence suggests that labour use itself has remained relatively constant, but, as expected with technological advances and management changes, labour per output unit has fallen (Fig. 5). Here, therefore, the perceptions of stakeholders do not match the overall headline figures available from the JAC.

The JAC reports that during the 20th century, there has been a shift in the patterns of land ownership away from most holdings being rented to most being owned. This has been

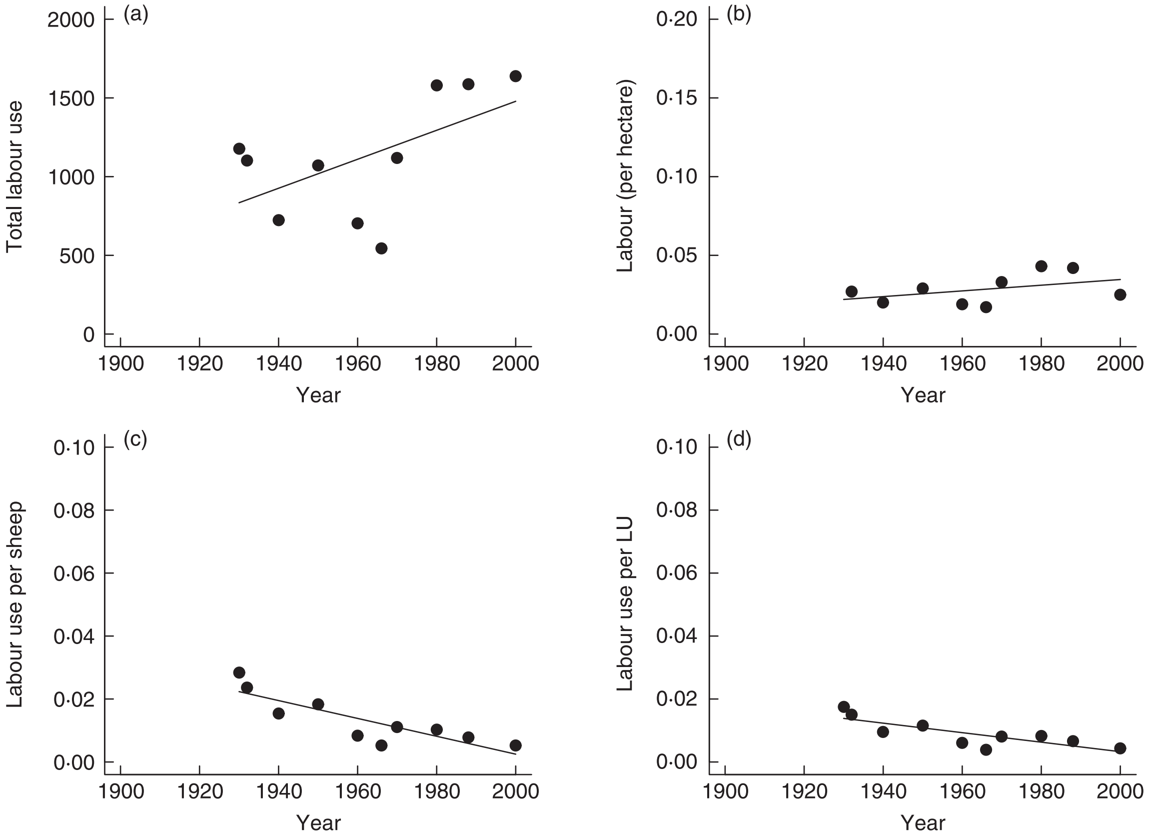


**Fig. 5.** Labour use aggregated across 32 parishes in the Peak District. (a) Total labour use; (b) labour use per hectare; (c) labour use per sheep; (d) labour use per livestock unit (LU).

accompanied by an increase in the size of holdings. Both trends were recognized to a certain degree by workshop participants, with the emergence of 'sheep ranches' as an acknowledgement of the changes in property size, while changes in land ownership patterns were discussed, although in a different context to the general patterns discernable from the historical data.

Stakeholders commented on the loss of a diverse agricultural base in the Peaks, which is reflected by a significant decline in the proportion of land used for arable crops as reported in the JAC, and a loss of low-intensity upland hay meadows, which, although viewed as locally important for biodiversity conservation (PDNPA 2007), were not reliably recorded in any of the historical habitat maps. Although afforestation was not considered a major driver in the Peak District, woodland cover increased significantly, with most increases happening in the second half of the century and mainly limited to areas that were previously grassland.

### HABITAT CHANGE

The northern portion of the Peak District that was surveyed in 1913 (Moss 1913) was resurveyed in the late 1970s (Anderson & Yalden 1981) and a 36% loss of heather cover described. As overgrazing is recognized as one driver of conversion of heather moor into grassland (Simpson *et al.* 1998), the reduction in heather cover was ascribed in part to the threefold increase in sheep numbers between 1930 and 1976. This headline figure of heather loss has had an enormous impact on conservationists and policy makers both at a national (e.g. English Nature 2001; Natural England 2008) and local scale (PDNPA 2001), where it plays a prominent role in defining targets for habitat restoration.

In contrast with these earlier results, when including more recent survey data, we find a steady state in the proportion of sample squares that were covered by dwarf shrub moor. This is despite a continuing rise in stocking densities. Specifically, almost 22% of the sampled area was classified as dwarf shrub moor both in 1913 and 2000. This percentage is roughly equivalent to the amount of this type of moorland present in the national park as a whole (PDNPA 2007).

One possible explanation for the disparity in the two contrasting findings lies in the taxonomic resolution available from the different sets of survey data. Anderson & Yalden (1981) were able to distinguish between different types of dwarf shrub moor [such as that dominated by *Vaccinium myrtillus* (L.) or *Empetrum nigrum* (L.), which have different levels of palatability and resistance to grazing compared to heather]. We relied on national rather than local habitat survey data that did not allow us to resolve these finer categories. We were further limited in our taxonomic resolution in part because the vegetation classifications that were used in the national habitat surveys changed between 1990 and 2000. The conflicting results indicate the importance both of the taxonomic resolution at which habitat surveys are designed and also the consistency with which repeat surveying is conducted.

By looking across multiple time periods, we reveal a very dynamic picture of habitat change. For example, although the number of squares classified as dwarf shrub moor was relatively stable, only two-thirds of squares categorized as moor in 1913 were still classified as such in 1978/1979, which roughly equates to the average 36% loss in heather cover. This picture of ongoing habitat change is reflected spatially in the landscape with some areas experiencing an increase in heather cover and others a decrease. This pattern, that was operated across the multiple time periods of our study, was initially observed in the 1913–1978/1979 comparison of Anderson & Yalden (1981).The turnover of upland vegetation communities is even discussed in Moss (1913). More generally, high turnover of land-use types through the 20th century has been documented for England and Wales as a whole, where less than half of surveyed sites remained in the same land-use category between 1930 and 2000 (Swetnam 2007). For moorland in particular, shifts in vegetation types, including the rapid dominance of heather, have been observed in other upland areas (Atherden 2004; Chambers *et al.* 2007). A combination of changing management practices, such as burning, grazing intensity and type of grazer were considered to be driving these changes. Equally, recent management efforts have focussed on moorland restoration with successful re-establishment of dwarf shrub moorland reported (Holland 2002; Smith & Bird 2005; PDNPA 2007). Finally, spatial heterogeneity in how land managers have responded to changes in technology, financial incentives and opportunities to manage the uplands for competing land-uses, may partly explain why a shift is observed in where dwarf shrub cover was recorded over this period.

### OTHER DRIVERS OF CHANGE

The impacts of changes in moorland management were frequently described by workshop participants, with an increase in controlled burning following the introduction of the North Peak ESA noted. Indeed, the ESA was partly established in order to redress the perceived reduction in burning activity in the area. In the first nine years after designation, burning increased fourfold. This trend, both in regularity and area burnt, has continued through to the present and is a widespread phenomenon across the English uplands, with so far unknown consequences for moorland vegetation communities (Yallop *et al.* 2006).

Since the industrial revolution, the Peak District has been subject to high amounts of airborne pollution, such as nitrogen and sulphur dioxide (NEGTAP 2001). Levels of sulphur dioxide peaked in the 1970s, but nitrogen deposition continued to rise into the 1980s before tailing off (Fowler *et al.* 2004). Workshop participants identified recent reductions in aerial pollutants as one factor involved in the improvements of moorland vegetation observed in the latter portions of the century, but there was no explicit mention of the historical damage that pollutants would have caused to vegetation, such as the almost complete loss of sphagnum and moss communities on moorland and bogs (Lee 1998). In addition, increased nitrification has been implicated in losses of heather moorland. However, the outcome of nitrogen deposition on moorland vegetation communities can depend on climatic and management variation and is not straightforward to predict (Britton *et al.* 2001). For example, on experimental plots raised nitrogen level results in an increased growth response from both grasses and heather (Carrol *et al.* 1999; Leith *et al.* 1999).

Climate is viewed as a major driver of change in all global ecosystems (Millennium Ecosystem Assessment 2005), yet was only mentioned in the context of 'different seasons' in the wildlife-focussed workshop, despite the likely past and continuing impacts on the agricultural practices and vegetation communities of the English uplands. The Peak District lies at the southern and eastern margins of climatic suitability for upland bog formation and is therefore likely to be severely impacted by climate change. The precise effects on the vegetation community are unknown, although current heather distribution in the Peaks does favour warmer, drier areas (D. Chapman, unpublished data) and Anderson & Yalden (1981) noted that heather occurred at higher altitudes in 1978/1979 compared to 1913. Visual inspection of our complete set of historical habitat maps suggests an upward shift in dwarf shrub moor distribution through the century which would be consistent with both rising temperatures and changes to management practices over the period.

Workshop participants also made no mention of agricultural prices or land rents as direct drivers of change. Nonetheless, prices are key economic determinants of management in upland areas (Hanley *et al.* 2008). If prices are low, the least economic land-uses should cease and land managers should shift their enterprise mix. However, EU agricultural policies have (until recently) effectively disassociated market prices from farm returns through production subsidy, which may be part of the reason that prices were not seen as a major driver of change by stakeholders.

### ALIGNMENT OF STAKEHOLDER PERCEPTIONS WITH HISTORICAL DATA

When interpreting stakeholder perceptions of historical change, insights can be gained from where there is both agreement with, and divergence from, the patterns of change identified from actual data sources. Our results show that some stakeholder perceptions accorded well with the available historical evidence, such as the major intensification of sheep farming. Other perceived trends were harder to reconcile, such as the dynamic nature of vegetation changes and the patterns in agricultural labour. We discuss these differences under three headings: spatial scale, consistency of historical data sources, and problems with stakeholder approaches.

#### *Spatial scale*

There is a notable impact of spatial scale on stakeholder perceptions, which operates in two different directions. In one case, policy and individuals can focus on headline figures, such as those of heather loss, but ignore local patterns, which can be varied and dynamic. By way of contrast, local factors can outweigh the overall picture. The rapid increase in sheep numbers through the century was a feature of the JAC and also stakeholder perceptions of change. However, since the introduction of agri-environment policies, stakeholder perceptions diverged. Some reported a reduction in sheep numbers and others an increase, which matches the varied pattern in the parish-level data (Fig. 2). Parish returns aggregate agricultural data from both moorland and non-moorland areas, as well as across land that both falls within and outside ESA areas. Even within a parish, moorland sheep numbers could have fallen in some areas with those animals not removed entirely from the system but simply moved elsewhere (e.g. Russel & Froud 1991), maintaining an overall increase in sheep density. Local characteristics observable in particular circumstances have, therefore, created a spatially shifting baseline. Local perceptions may be correct, but when scaled up to a region or a specific area, perceptions may not directly agree with the evidence. Equally, the significance of broad scale economic and ecological changes, such as climate and prices, may not be fully appreciated by stakeholders focussing on a particular issue or specific location.

### *Consistency of historical data sources*

Historical records always have associated difficulties as data are rarely collected and documented in a consistent manner through time. Within the JAC itself, definitions of land types altered through the century (Table 1), and local government areas (parishes and wards) did not remain consistent, meaning that the data were reported for different areas of land for each year. From the historical vegetation maps, it was impossible to report change figures for many semi-natural grasslands or cotton grass moorland as these habitats were not recorded consistently. In this study, we also attempted to incorporate land-use maps from the 1930s and 1960s (Stamp 1947; MAFF 1961). However, neither map had sufficient land-use categories in common to provide useful additional data.

### *Problems with uncovering historical patterns using stakeholder approaches*

Stakeholders had a tendency to think and talk in very holistic terms, which can result in complex patterns of inter-relationships as they may not separate different drivers, causes and effects (see Supporting Information, Appendix S4). However, in general their perceptions are likely to reflect the multi-faceted ways in which landscapes are actually managed. In addition, a 'recency bias' in collective memory, which is inherent in any participatory approach examining historical drivers of change, could account for some of the differences in actual and perceived events (Tinch *et al.* 2009).

## MANAGEMENT AND POLICY IMPLICATIONS

We have demonstrated that, throughout the last century, there has been a dynamic pattern of habitat change taking place in the Peak District. This has occurred against a backdrop of stark changes to agricultural and land management practices. Indeed, agricultural intensification was identified by stakeholders as the dominant process underpinning changes to land-use. Despite the implementation of agri-environment policies in the latter portion of the 20th century, sheep numbers have continued to climb. However, the perspectives of a diverse array of stakeholders have not necessarily agreed with the patterns of agricultural and ecological change that have occurred, raising questions as to the value of stakeholder opinion and workshops in revealing actual events and processes. Determining patterns of historical changes through the use of long-term ecological data should remain of central importance when setting targets, establishing baselines and ranges of natural variability for policy and land management.

As stakeholder impressions do not adequately reflect the documented historical changes, we could argue that consulting them should not form a central part of developing land-use policy. However, if policy does not address those drivers that stakeholders see as important for underpinning trends in land-use, land cover or rural jobs and incomes, then it will be harder to achieve a high level of acceptability of a particular policy. This can lead to low levels of uptake and higher implementation costs (e.g. legal fees and monitoring). From a more positive perspective, stakeholders may draw attention to changes that are hard to detect in the data (for example the loss of upland hay meadows in our system), thus enabling the design of more comprehensive policy responses to ecological problems.

## Acknowledgements

Our thanks go to: Moors for the Future for hosting the workshop and providing a digitized version of the 1913 Moss map; The Peak District National Park Authority for access to original hand-coloured habitat maps prepared by Penny Anderson and Derek Yalden; CEH provided data for the CS1990 and CS2000 maps; Jill Edmondson, Mark Parnell and other members of BIOME for useful discussions. Paul Carter of the University of Portsmouth digitized a version of the Dudley Stamp maps. Zoe Davies commented upon, and much improved, earlier versions of this manuscript. Funding was provided by the RELU programme of the UK Research Councils. KJG holds a Royal Society-Wolfson Research Merit Award.

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*Received 30 June 2008; accepted 7 January 2009*
*Handling Editor: Simon Thirgood*

## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Appendix S1.** Habitat categories from the historical land use maps covering the Peak District National Park

**Appendix S2.** Parish and ward names in the Peak District, northern England

**Appendix S3.** Timeline of key impacts identified by stakeholder workshops

**Appendix S4.** Key events in the development of the landscapes of the UK uplands, as identified by stakeholder workshops

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