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The cover photographs are structured to indicate the composition of this document in the series. The main picture is of an upland landscape, which is a representative of the four landscapes used in the analysis – the others being arable, pastural and marginal upland. The top photograph shows a monoculture of barley to represent the importance of crop management in determining the composition of fields. The middle shows a roadside with uncut false oatgrass (*Arrhenatheraum elatius*) and hogweed (*Heracleum sphondylium*) in the background and mown ryegrass (*Lolium perenne*) in the foreground, representing the importance of cutting regimes on roadside vegetation. The third photograph shows a Sitka spruce (*Picea sitchensis*) plantation with virtually no ground cover, to represent the importance of heavy shade on the composition of vegetation under commercial forestry.

# EXECUTIVE SUMMARY

## Introduction

Concerns about the declines of biodiversity in Great Britain (GB) have been addressed within the Biodiversity Action Plan and the UK Strategy for Sustainable Development. In order to ensure that these policies are effective, we need to quantify the stock and change of biodiversity on the one hand, and the relationships with the major driving forces of biodiversity change on the other. Only then is it possible to test whether the policies are likely to prove appropriate and effective.

Botanical data from the Countryside Surveys of 1978 and 1990 can be used to show how the vegetation of GB has changed, and also indicate the potential importance of these changes for particular animal groups. Other data are available to show how the major driving forces, such as agriculture or air pollution, also changed during this time. It is therefore possible to relate cause and effect for a range of biodiversity changes in the wider countryside, and thus give real insights into both what happened and why. These findings can then be updated once the results from Countryside Survey 2000 (CS2000) become available, the fieldwork for which took place in 1998–99.

## The driving forces

A wide range of human and environmental driving forces affects the diversity of vegetation. Not all of these can be assessed by looking at recent changes in vegetation at the national scale. Some are too localised, such as the effects of trampling or mineral extraction. Others are such long-term processes that we cannot yet detect their effects using the Countryside Survey data – climate change comes into this category. Some are best studied in other ways – thus the effects of urban expansion are best considered by looking at data on land use and cover, rather than vegetation composition.

The most important drivers of vegetation change during 1978–90 considered in this study were:

- changes in agriculture;
- changes in the management of road verges and hedgerows;
- conifer planting;
- inputs of nitrogen and other nutrients, both from the air and from agriculture.

Agriculture became increasingly intensive. Inputs of pesticides increased, and there were switches from hay to silage, to more sheep and fewer cattle, and from spring-sown to winter-sown crops. Extensification measures such as agri-environment schemes and set-aside were only just starting in 1990. Both broadleaved and coniferous woodland cover increased, and there was substantial turnover as land was clear-felled and replanted. Hedgerows were lost, more by neglect than by deliberate destruction. The period also witnessed reductions in the frequency of cutting road verges, and the continued drainage of agricultural land.

The deposition of nitrogen and potash increased markedly during this period, partly because of more intensive agriculture (especially in fields in the lowlands and marginal uplands), and partly because of increased pollution from cars. The deposition of acid pollutants declined, although by 1990 critical loads were still being exceeded – especially in the uplands and marginal uplands.

## Recording and analysing changes in vegetation

The programme of Countryside Surveys provides us with a highly sophisticated, national system for detecting changes in vegetation and land cover in the British countryside. A sample of 1 km squares were selected at random, stratified by climate, topography and other relatively stable attributes, and then mapped, and the vegetation recorded in fixed plots. These plot locations included fields, open land, and alongside linear features such as roads and hedgerows. Our data from these locations visited in both 1978 and 1990 gives us an accurate measure of overall vegetation change, and also change by locations within the landscape and by regions across GB.

Different kinds of vegetation change can be associated with different causes of change. For example, some categories of vegetation are typical of wet, or of dry conditions. Individual species may be favoured by increased or decreased nutrients, light or grazing levels. However, these relationships are not always straightforward: sometimes vegetation changes are forced over some form of threshold, from which a return to the original state is unlikely to occur without a deliberate restoration programme.

## Indicators of Botanical Diversity 1978–90

Vegetation data from Countryside Survey already contribute to the Indicators of Sustainable Development for biodiversity in the wider countryside. The data can also be presented using a variety of indicators that, together, help identify processes of vegetation change, and also changes in the conservation value of vegetation.

From 1978 to 1990, the major trends in vegetation as a whole were from less fertile to more fertile vegetation, and from more open to taller and wooded vegetation. Some areas of heath changed to moorland grass, some moorland grass was improved or forested, while grassland of road verges, streamsides and field boundaries became more overgrown. Species richness declined in many kinds of vegetation, while already common plants became more widespread, and vegetation in general became more homogeneous. There were declines in food plants for birds, bees and butterflies. Also, case studies indicated that scarce plant communities may have changed in their locations as well as their abundance. For example, an important grassland community was found in 1990 to be largely restricted to unproductive situations, notably road verges.

## The causes of change in British vegetation 1978–90

It is difficult to establish with certainty the causes for the botanical changes observed. This is partly because many different factors act in concert so that the individual effects of one driving force cannot be separated from another. Also, different factors may give the same pattern of change. Our approach was to consider the likely vegetation changes resulting from each major driver of vegetation change (in terms of the different indicators we have developed), and to consider the likely location of the change (whether in open land or by linear features, whether in the uplands or the lowlands, and so on). We hypothesised an expected pattern of vegetation change for each driving force based on independent published evidence, and looked for the extent of correspondence with detected changes in Countryside Survey vegetation data.

Matches between observed and expected changes were particularly strong for the effects of increased nutrients (eutrophication), especially from agriculture, leading to reduced species richness and increase of already widespread, tall, competitive plants at the expense of slower growing, more localised plant species. The expected effects of increasingly intensive management of crops were also seen, in particular the loss of diversity within the fields, especially of spring germinating plants that are important food resources for birds and invertebrates. Changes from upland heaths to grasslands are consistent with increased sheep grazing, but these effects were confounded with those of atmospheric deposition of nutrients. There were clear effects of canopy closure of upland conifer canopies on field-layer vegetation, but otherwise evidence of consistent vegetation changes in woodlands was limited. Evidence for road verge vegetation becoming taller and more nutrient-rich was consistent with reductions in cutting frequency and increasing inputs of nutrients. We found no sign of the effects of acidification (although these may have been masked by other driving forces, notably eutrophication), and little evidence of widespread and changes in land drainage.

## The main drivers of vegetation change in the wider countryside

Correspondence values, showing the match between observed and expected results, were ranked to give an idea of the relative importance of different driving forces, but they must be treated with caution. They reflected the different degree to which effects could be detected using this methodology: some patterns of effects were easier to detect than others, some drivers of change were easier to consider separately than others. Nevertheless, overall, the evidence for effects of agriculture, notably in terms of nutrient addition and crop management of crops, was striking for the period of this study.

## The policy implications of botanical change

The results of the Countryside Surveys of 1978 and 1990 showed clear declines in vegetation diversity which were strongly correlated with human-induced factors, notably agriculture, forestry and possibly air pollution. Developing the appropriate policy response requires an understanding of the processes of vegetation change. In some cases, the changes we have seen may be irreversible. In others, we may need to target new kinds of habitat that have received little attention so far, such as road verges. Conservation policies may need to distinguish between regeneration scenarios, that are favourable for biodiversity in which case a large number of small patches of diverse vegetation can act as sources for recolonisation of the countryside, and fragmentation scenarios, which may require areas large enough to sustain species within a hostile landscape. It is worth distinguishing the different mechanisms by which policies affect biodiversity; they may be targeted at particular species or habitats, they may be targeted at a particular driving force, or may have incidental effects on biodiversity.

## The ECOFACT case studies

These analyses were supported by a series of case studies, summarised here.

- Many of the vegetation changes observed across GB were also observed on a restricted sample of agricultural land of England and Wales only, although the reduction in sample sizes made the differences harder to demonstrate with statistical confidence.

- Species-rich vegetation was restricted to field edges in nutrient-rich situations, but species richness was greater in the field centre in nutrient-poor situations.

- The soil seed banks under typical grassland fields were species-poor, and would not provide suitable sources for the rapid restoration of species-rich grassland.

- The component species of at least one scarce plant community were restricted to locations that are sub-optimal but less likely to have been impacted by intensive agricultural practices. Road verges were an important refuge for some grassland communities, but these too are under threat as road verge cutting becomes less frequent later in the season, and the cuttings not removed.

- The effects of nutrient inputs from grazing and from the atmosphere can generate a positive feedback mechanism, making long-term conservation of low nutrient status difficult to maintain in some upland areas.

## Conclusions

Since the late 1980s, there have been a number of policy initiatives aimed at countering the impacts of these different driving forces. These include the reform of the Common Agricultural Policy (CAP), the development of the agri-environment schemes, the Strategy for Sustainable Development and the Biodiversity Action Plan following the Earth Summit in Rio. The results of 2000 will show whether the declines in botanical diversity have continued, or whether they have been halted or reversed. Also, analyses developed from the ones used here will be able to ascribe causes to the changes that are observed. Such information is essential for the delivery of sustainable development.

# INTRODUCTION

*Concerns about the declines of biodiversity in Great Britain (GB) have been addressed within the Biodiversity Action Plan and the UK Strategy for Sustainable Development. In order to ensure that these policies are effective, we need to quantify the stock and change of biodiversity on the one hand, and the relationships with the major driving forces of biodiversity change on the other. Only then is it possible to test whether the policies are likely to prove appropriate and effective.*

*Botanical data from the Countryside Surveys of 1978 and 1990 can be used to show how the vegetation of GB has changed, and also indicate the potential importance of these changes for particular animal groups. Other data are available to show how the major driving forces, such as agriculture or air pollution, also changed during this time. It is therefore possible to relate cause and effect for a range of biodiversity changes in the wider countryside, and thus give real insights into both what happened and why. These findings can then be updated once the results from Countryside Survey 2000 (CS2000) become available, the fieldwork for which took place in 1998–99.*

## Background

### *The problem of biodiversity decline*

Concerns have been expressed about the actual and potential loss of biodiversity in British vegetation over many decades, but until recently the scales and natures of such losses were not clear. This situation changed with the publication of the Main Report of the 1990 Countryside Survey, that showed losses of plant diversity in many elements of the British countryside, and also showed losses in landscape features important to people and wildlife alike (Barr *et al.* 1993). The policy impact of these and related results (eg Marchant *et al.* 1990) has been considerable, and is reflected in developments such as the Biodiversity Action Plan, Hedgerow Protection Regulations and Agri-environment schemes.

Losses in vegetation diversity have occurred – but why? These losses have taken place during a time of many simultaneous environmental changes in the wider countryside which are difficult to disaggregate. Results relating cause and effect can be difficult to interpret, as they are often based on correlations rather than experiments, and information about the relative importance of different environmental factors is either lacking or difficult to obtain on a consistent basis.

The policy framework for the conservation of biodiversity is given by the UK Biodiversity Action Plan (Anon 1994a) and the UK Strategy for Sustainable Development (DOE 1996, DETR 1999), both of which are in a process of development and refinement at the time of writing. If the problem of loss of biodiversity is to be solved, critical points of intervention in the underlying processes must be identified. Do opportunities exist, or are these processes intrinsically irreversible, making intervention futile? To what extent is the human side of the equation amenable to manipulation through policy, and to what extent is it due to social changes with their own dynamics and time lags? Can appropriate responses be delivered, given that there are other constraints in the management of the British countryside?

### *The ECOFACT research programme*

These are large and complex issues, and require major advances in environmental science if they are to be resolved. It was, therefore, most appropriate that Countryside Survey 1990 (CS1990), with its emphasis on the description of environmental stock and change, was followed by a research programme looking at "Ecological Factors Controlling Biodiversity in the British Countryside" (ECOFACT). The programme was constructed as a series of interlinked modules addressing a range of scientific and technical issues relevant to the study of change in botanical diversity. ECOFACT was led by the Institute of Terrestrial Ecology (ITE) team, at Merlewood, responsible for Countryside Survey, and involved collaboration with other stations at ITE and with outside academics and institutions. It was funded on a modular basis by ITE's parent body, the Natural Environment Research Council (NERC), and the Department of the Environment, Transport and the Regions (DETR), the Ministry of Agriculture, Fisheries and Food (MAFF), and the former Scottish Office, Agriculture, Environment and Fisheries Department (SOAEFD).

#### *The purpose of this report*

This document is the report for one of the modules of ECOFACT, called "Understanding the causes of change in Biodiversity". The objectives of this research programme were to:

- identify the causes of observed changes in botanical diversity;
- assess the relative importance of land management and other factors, such as pollution;
- recommend land management practices for the maintenance and enhancement of diversity;
- develop predictive techniques for determining ecological impacts.

Because of the complexity of the processes involved in shaping and reshaping the British countryside, and influencing its constituent plant and animal species, these objectives could only be addressed by a very ambitious programme of ecological research.

This report should be regarded as a first step in unravelling cause and effect in the changes in the biodiversity of vegetation at large scales. It does not attempt to provide all the answers to the problem of biodiversity conservation and management in the wider countryside, not least because its scope is largely limited to the diversity of widespread species of plants and plant assemblages.

The methods adopted in this report can be developed further for the interpretation of vegetation change recorded during Countryside Survey 2000, the fieldwork for which took place in 1998–99. These analyses are likely to be more sophisticated than those reported here. This is partly because of the greater sample size for detecting recent change, and partly because, for some surveyed areas, there will be data on biodiversity available for three points in time.

### Approach

#### *The driving force–state–response model*

Reports have already been published that present the evidence of changes in botanical diversity between 1978–90 as obtained from CS1990 (Bunce *et al.* 1999b) and that provide the full description of the new vegetation classification used to generate some of these analyses (Bunce *et al.* 1999a) (Box 1, page 51). In this report, these changes are interpreted in terms of their causes, illustrated and informed by a series of case studies which were designed to more fully explore specific patterns and processes of vegetation change characteristic of particular vegetation types, plot types and regions. A synthesis of these results is used to help highlight appropriate responses in terms of both policy and practice.

The driving force–state–response model is adopted (Holten-Andersen *et al.* 1995; DOE 1996). The 'driving forces' are those human-induced drivers of vegetation change, which operate in different areas of the landscape, and which arise from different sectors of human activity. The 'states' are those measures of botanical diversity, which include species number and vegetation character in different elements of the countryside. We hypothesise which changes in botanical diversity are consistent with the behaviour and recent history of the different driving forces. By comparing the expected with the observed changes, it is possible to identify which driving forces are consistent with having caused the observed changes in botanical diversity. In this model, the 'response' is the human response to the changes in state. In other words, the response is not the change in species number, or in vegetation character, it is the subsequent change in policy or land management practice designed to ameliorate or remedy the effects of a driving force. Thus if it is found that a driver such as air pollution is affecting a state such as species number in an unacceptable way, an appropriate response might be to reduce emissions of the relevant pollutant. The nature of the relationship between driving force and state is important in developing an appropriate response. For example, if the driving force causes changes in state that are irreversible, the response should be aimed at identifying and protecting sites in a state of high quality. If the changes in state are more easily reversed, then an appropriate response may include remediation and restoration.

The report is structured by identifying the driving forces themselves, and how they have changed during the period of study (1978–90). Of these, only some can be fully analysed using Countryside Survey data, either because their effects are localised, confounded with those of other driving forces, or because the driving force itself has not changed sufficiently during the period of study. Different indicators of botanical change are then considered in turn to try to show which driving forces are consistent with the changes observed in the field. Not all indicators turn out to shed light on the causes of botanical change. An assessment of the driving forces follows, in which their roles are characterised as far as possible. Finally, the policy responses to vegetation change are discussed in terms of the effects on the different driving forces.

### What is biodiversity?

The word biodiversity is remarkably new, apparently first used in 1985, and has already been given a number of definitions. Perhaps the most conventional is that given by Article 2 of the Biodiversity Convention, adopted by the UK Biodiversity Steering Group, which defines biodiversity as:

*"the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"* (Anon 1995a; see also Heywood & Watson 1995).

It should be clear from this definition that biodiversity can never be fully quantified, as that would involve the genetic characterisation of every living organism. Therefore, an operational definition is required for each biodiversity study. ECOFACT deals largely with higher plants characterised at the levels of species and local assemblages across habitats and landscapes, and it is the diversity in these vegetation units that is here termed "botanical diversity". These species and assemblages are associated with, and so act as indicators for, a range of animals and other species. However, while these associations have been explored for some groups (notably birds and the more prominent insect orders), they are far from completely defined or understood. In this report, the term "biodiversity" includes diversity at ecosystem, assemblage and species scales for higher plants and animals, and does not consider variability at the genetic level.

### How can botanical diversity be measured?

Diversity is here measured in terms of species and assemblages of higher plants. At its simplest, the greater the number of these, the greater the diversity. However, the actual situation is more complex, because diversity is a function of spatial and temporal scale. One of the results of CS1990 was that the species richness of heathlands had increased, and at the scale of the individual site (termed $\alpha$ diversity), this did indeed represent an increase in biodiversity. However, at the scale of assemblages, distinctive heathland communities represent an important biodiversity 'unit', and so an increase in species at the site level, (which was making these communities less distinctive from others), actually represented a loss in diversity at the within-region scale (termed $\varepsilon$ diversity) (see Whittaker 1977).

Diversity is more than the number of units present at a particular spatial scale and within a particular area (eg species in a field, or habitats in a region). It also needs to account for their relative proportions. This is because a grouping dominated by one particular unit is considered less diverse than one where the units are present in more equal proportions. There are standard tools for measuring diversity, which take both factors into account.

The identification of the units themselves is well understood at the species level for higher plants in GB (accepting the continual process of taxonomic updating). However, the identification of units of species assemblages is more complex. The existing classifications, in the Co-ordinated Information on the Environment (CORINE) biotopes database (Anon 1991) and the National Vegetation Classification (NVC) (Rodwell 1991), have a subjective element in that they deal largely with uniform stands of semi-natural vegetation. The selection of survey locations is thus not random, making the data unsuited to a statistical analysis of vegetation stock and change. Furthermore, for this project, it was considered important that changes in vegetation could be analysed at a range of levels of detail, and without reference to ideal vegetation types or standards.

A new approach was therefore developed to assess the diversity of British vegetation, based on a new, objective, hierarchical classification of vegetation plot data recorded in the Countryside Surveys of 1978 and 1990. This classification is called the Countryside Vegetation System (CVS) (Bunce *et al.* 1999a).

If one adopted a purely rational policy towards the management and conservation of botanical diversity, then species and assemblages can be assessed in terms of their relative proportion of diversity at different scales. Those species, assemblages or sites that somehow account for a high proportion of diversity, may be regarded as having special value or quality. However, this process inevitably throws up inconsistencies. For example, in GB, many of our rare species are rare because they are at the limits of their geographical range, and are much more common elsewhere in Europe. Furthermore, there are social and aesthetic elements to the evaluation of botanical diversity that reflect the long cultural history of British landscapes. There can be no single index of botanical diversity that reflects local needs and desires at all scales.

In this project, therefore, we propose a series of Indicators of Botanical Diversity (IBDs) which capture the present state of vegetation in the wider countryside of GB and how it has changed during the study period 1978–90. Such information is vital if appropriate policy responses to these changes are to be developed.

***How can change in biodiversity be interpreted?***

Driving forces, states and responses can all be measured by particular indicators. ‘Driving force’ indicators describe the processes that cause change in the ‘state’ variables of concern, in this case, as quantified using the IBDs. There are various lists of such human activities to draw from, for example, the Dobris Assessment of Europe’s Environment (Stanners & Bourdeau 1995). This includes a list of environmental problems including climate change, stratospheric ozone depletion and acidification. Such activities are frequently divided into the proximate causes of ecological change (referred to as ‘pressures’) and the ultimate causes (‘driving forces’) (eg OECD 1993). In this report we do not attempt this division explicitly, as the clarification of the chains of causality between different policy, social, technological and environmental processes is a major study in itself.

While there is often substantial research literature demonstrating relationships between individual driving forces and states of biodiversity at scales relevant to individual ecosystems and vegetation communities, the relative contributions of different driving forces on particular states is much less well understood at the larger scales of the wider countryside. This is not surprising, because the effects of different environmental driving forces are hard to separate in empirical studies, and difficult to assess experimentally at appropriate spatial and temporal scales. We suggest that one way of making the task more tractable is to develop ways of describing the changing state of biodiversity which can be used to indicate which forms of driving force may be responsible for the change. The development of a theoretical structure relating driving forces to states is essential to interpret the causes of change to biodiversity.

The approach we have adopted is to consider initially the range of possible driving forces, and the extent to which their effects can be detected using Countryside Survey vegetation data. If that extent is zero, the driving force is not considered further. In the other cases, the location of any effect is hypothesised, in terms of the landscape type (upland, marginal upland, arable lowland and pastural lowland, see Box 2, page 52) and of general location within the landscape, whether alongside particular kinds of linear features or areas of land. We then consider a range of indicators of vegetation diversity that can be calculated using Countryside Survey data, concentrating on vegetation changes between the surveys of 1978 and 1990. We consider to what extent these indicators shed light on the causes of vegetation change (ie to what extent there are unambiguous hypothetical relationships between the indicators and the driving forces). Those indicators that do not provide such information are identified. Using the remaining indicators, changes observed between the two surveys are compared with a pattern of responses expected if the driving force had indeed caused a change in state. Each set of expected responses was constructed by reference to published evidence. Given the timescale of the study, we emphasise the primary importance of land management practices on vegetation change, rather than slower processes such as climate change (eg Hodgson 1986). Furthermore, we recognise that much of the wider countryside is managed to prevent succession (especially farmland), and so signs of natural succession to scrub and woodland are interpreted here as changes in the intensity of management.

The final element of the driving force–state–response model is the 'response' of policy makers, land managers and others to the changes in states. There are theoretical reasons why particular responses are appropriate for particular driving force–state relationships. In particular, some ecological changes are very difficult to reverse simply by reducing the driving force (Box 3, page 53). Furthermore, not all ecological changes should be considered as being problems – many should be considered as being essentially neutral, while others are beneficial in terms of biodiversity conservation. We argue that indicators of the processes of vegetation change are not necessarily the best indicators of an appropriate response – we need indicators of vegetation quality, as well as indicators that help identify causes of change.

# THE DRIVING FORCES

*A wide range of human and environmental driving forces affect the diversity of vegetation. Not all of these can be assessed by looking at recent changes in vegetation at the national scale. Some are too localised, such as the effects of trampling or mineral extraction. Others are such long-term processes that we cannot yet detect their effects using the Countryside Survey data – climate change comes into this category. Some are best studied in other ways – thus the effects of urban expansion are best considered by looking at data on land use and cover, rather than vegetation composition.*

*The most important drivers of vegetation change during 1978–90 considered in this study were:*
- *changes in agriculture;*
- *changes in the management of road verges and hedgerows;*
- *conifer planting;*
- *inputs of nitrogen and other nutrients, both from the air and from agriculture.*

*Agriculture became increasingly intensive. Inputs of pesticides increased, and there were switches from hay to silage, to more sheep and fewer cattle, and from spring-sown to winter-sown crops. Extensification measures such as agri-environment schemes and set-aside were only just starting in 1990. Both broadleaved and coniferous woodland cover increased, and there was substantial turnover as land was clear-felled and replanted. Hedgerows were lost, more by neglect than by deliberate destruction. The period also witnessed reductions in the frequency of cutting road verges, and the continued drainage of agricultural land.*

*The deposition of nitrogen and potash increased markedly during this period, partly because of more intensive agriculture (especially in fields in the lowlands and marginal uplands), and partly because of increased pollution from cars. The deposition of acid pollutants declined, although by 1990 critical loads were still being exceeded – especially in the uplands and marginal uplands.*

## Introduction

Human activities impinge upon botanical diversity through different mechanisms, or driving forces. The same driving force may arise from different sectors of activity – thus eutrophication may result from atmospheric pollution or the application of fertiliser. There are many such driving forces, and they need to be categorised in order to undertake an integrated analysis of the causes of change in biodiversity (Box 4, page 54). Neither the Dobris Assessment (Stanners & Bourdeau 1995) nor the UK Indicators of Sustainable Development (DOE 1996) present an ideal classification for our purpose, because they do not clearly distinguish between driving forces and states with respect to botanical diversity. UK classifications of environmental driving forces, and indicators of sustainable development, are in revision at the time of writing. In this report, we follow Petit *et al.* (1998) in identifying ten major driving forces, which in some cases can be usefully broken down further (Table 1).

It is not possible to detect the impacts of all of these driving forces using Countryside Survey data, however. If the driving force is very localised (eg point source pollution, mineral extraction, footpath erosion in the uplands), its effects cannot be detected. Nor can effects of driving forces that did not change during the period of study. Our first task, is therefore, to assess each driving force in turn and consider whether firstly,

*Table 1.* Description of driving forces acting upon botanical diversity

| Driving Force | Description |
|---|---|
| **1. Eutrophication** | **The increased inputs of nitrogen and other nutrients** |
| Atmospheric deposition | Areal deposition, especially from power stations and road transport emissions |
| Agricultural fertilisers | Use of fertilisers on agricultural land, especially nitrogen |
| Waterside eutrophication | Increased trophic status of catchment waters and watersides |
| **2. Acidification** | **Deposition of sulphur dioxide and nitrous oxides** |
| **3. Urbanisation and transport** | **The loss and fragmentation of land parcels to urban and infrastructure land covers** |
| Road verge management | Impacts on transport routes; lack of management, increased disturbance, eutrophication |
| **4. Leisure** | **Trampling, disturbance, changes in land use associated with leisure** |
| Trampling, disturbance | Disturbance linked to walking and leisure activities largely in upland GB |
| Heather management | Moorland management for grouse shooting |
| **5. Agricultural intensification** | **The increase in the level of inputs per unit area** |
| Crop management & pesticide use | Cropping systems, cultivation practices and use of agrochemicals |
| Grassland cultivation | The conversion of grasslands and other semi-natural habitats to arable crops |
| Grassland management | Changes in fodder production, grazing regime and use of agrochemicals |
| Upland sheep grazing | Changes in stocking density |
| **6. Drainage** | **Ditches, tile drains / plastic drains in vegetation associated with wet soils** |
| Waterside management | Disturbance and dereliction of watersides, water abstraction |
| **7. Agricultural extensification** | **Transfers from intensive to less intensive agriculture** |
| Lack of cultivation | Including set-aside and former arable land managed for environmental benefit |
| Biodiversity enhancement | Use of practices designed to encourage wildlife, (eg habitat restoration, conservation headlands, managed productivity reductions) |
| **8. Land abandonment** | **Transfers from agricultural to scrub, excludes afforestation** |
| **9. Forest management** | **Changes in the cover of forest land and management of its canopy including hedgerows** |
| Broadleaved planting | Changes in land use and canopy closure |
| Broadleaved management | Thinning, clearfelling, coppicing, ride management, grazing, neglect |
| Conifer planting | Changes in land use and canopy closure |
| Conifer management | Thinning and clearfelling |
| Hedgerow management | Trimming, removal, lack of management leading to change of feature into line of trees/scrub |
| **10. Climate change** | **A modelled effect of increasing levels of certain gases due to human activity** |

the driving force has operated and, secondly, whether changes that may have resulted are detectable using Countryside Survey vegetation data for the period 1978–90.

## The major environmental driving forces

In this section, the ten major driving forces are discussed in turn (summarised in Table 1).

### *Eutrophication*

Eutrophication here refers to vegetation changes arising from inputs of nutrients. The major cause is the addition of nitrogen, but phosphorus and other nutrients can also be involved, either singly or in combination. In general, nitrogen additions to terrestrial ecosystems come from two major sources: atmospheric deposition, especially from the use of fossil fuels by power stations and motor vehicles; and direct application for agricultural production. The influences of other, more localised sources (such as emissions of ammonia from intensive animal units) cannot be discriminated individually given the sample design of Countryside Survey.

- **Atmospheric deposition**
  In 1982 motor vehicles overtook power stations as the largest source of nitrogen emission in GB (Brown 1992). Car numbers and distance travelled rose from 250 billion to 420 billion vehicle kilometres between 1978 and 1990, whilst the period 1986–88 experienced a typical deposition level of 0.5–1.0 kg N $ha^{-1}$ $year^{-1}$ across most of GB, with higher levels recorded in the uplands of northern England, mid-Wales and central Scotland. **We hypothesise that evidence of the effects of aerial deposition on terrestrial ecosystems could be found across the vegetation of the whole landscape.**

- **Agricultural fertilisers**
  Between 1978–90, the use of fertilisers increased substantially on crops and

grasslands in England and Wales (Wilkinson 1997). On arable crops, nitrogen applications increased 44% to a mean of 149 kg $ha^{-1}$ (not least due to the increase in winter cereals and oil seed rape (*Brassica napus* spp. *oleifera*)). Phosphate usage did not change, but potash usage increased 11%. On grassland, nitrogen applications increased by 7% to an average of around 130 kg $ha^{-1}$, and potash applications increased by 44% to around 25 kg $ha^{-1}$, due to the increase in silage making. **We hypothesise that evidence of agricultural fertlisers can be found particularly in fields, rather than in linear features, and in the lowlands and marginal uplands.**

- **Waterside eutrophication**
  Agricultural run-off can lead to eutrophication of water courses, in turn leading to eutrophication of the water edge vegetation (van Strien *et al.* 1989). Urban development also generates sewage effluent, contributing to increased phosphorus loads in river catchments, especially in the lowlands. Sewage effluent has been estimated to make up 53% of the annual phosphorus output to surface waters in the UK whilst an analysis of water quality data for 90 rivers of conservation importance in England showed a significant upward trend in orthophosphate between 1980 and 1990 (Garland 1991; Mainstone *et al.* 1994). **We suggest that the effects of this form of eutrophication will be most apparent in waterside vegetation within Countryside Survey data, and is likely to be less marked in the uplands.**

#### *Acidification*

Concerns over the effects of acid rain have led to a policy of reducing the emissions of sulphur dioxide and other causes of acidification during the period of study. In 1978 reductions had already been driven by the Clean Air Acts of the 1950s and 60s and were subsequently reinforced by the EC Large Combustion Plants Directive and the UNECE Convention on Long Range Transboundary Air Pollution (Brown 1992). Sulphur dioxide emissions from power stations fell from around 3 x $10^6$ tonnes in the late 1970s to 2.5 x $10^6$ tonnes in 1990, and the proportion of soils for which deposition exceeded the critical load declined during the late 1980s. $NO_x$ emissions from power stations also fell, but less dramatically or consistently, and not enough to counter the increased emissions from road traffic (Brown 1992).

There was a general trend to reduce the application of lime on agricultural soils, except perhaps on silage where lime may have been used to counteract acidifying effects of fertiliser (Wilkinson 1997).

The effects of acidification depend upon the patterns of deposition and the buffering capacity of the soil and vegetation. This capacity is termed the critical load (Hornung & Skeffington 1993). Critical load maps developed on the basis of data in 1986–88 show that sulphur exceedence was concentrated in upland areas, especially in England and Wales – maps for 1989–91 which include effects of reduced nitrogen show more widespread exceedence throughout the uplands and marginal uplands, reflecting the different characteristics of the soils and increased levels of rainfall resulting in increased deposition. Because the deposition is aerial, **we argue that all components of the vegetation may have been affected.**

#### *Urbanisation and transport (road verge management)*

It has been estimated that the cover of built up land in rural areas increased by 7% between 1984 and 1990 to around 1.76 million ha, about half gained from intensive grasslands (Haines-Young *et al.* 1996). These losses of land cover (and hence of vegetation) were concentrated in the lowlands and marginal uplands.

Other environmental pressures arise from urbanisation. They include habitat fragmentation from roads and building developments. Eutrophication and acidification also result from urbanisation, especially from industrial and transport-related sources. More specifically, road verge management also affects botanical diversity, as recognised by environmental management policies that have been introduced by some county councils. The two impacts most likely to have affected road verges since 1978 are the lack of full width cutting (only 1 m visibility splays require annual maintenance) and increased nitrogen deposition (Way 1977, 1978; Brown 1992). Changes in road management may have affected vegetation along roadsides in all landscape types. These effects can be broken down into those of lack of management, eutrophication and disturbance by motor vehicles and cable laying at the edge of the verge. Urbanisation can result in dereliction, notably the appearance of woodland and scrub corridors along disused railway lines (note that dereliction is not necessarily negative in terms of biodiversity; it depends upon the balance in terms of conservation value between those species that are lost and those that are gained). Such driving forces are inevitably highly concentrated and difficult to detect using the Countryside Survey sample design, while gardens and parks were not included in Countryside Survey. **Therefore, only road verge management is considered further.**

#### *Leisure*

Leisure and tourism have become increasingly important factors in rural policy. The popularity of enjoyment of the countryside is demonstrated by the fact that both the National Trust and the Royal Society for the Protection of Birds have over 1 million members; day visits to the countryside now exceed 1.1 billion in England alone (Anon 1995b). The idea that tourism needs to be environmentally sustainable is well accepted (eg Anon 1994b), but exactly what that means in practice is less well understood. In general, however, while leisure has the potential to harm ecosystems in particular locations, the popularity of the countryside as a recreational resource has had considerable influence on policies designed to conserve natural and landscape resources. This was particularly true in National Parks during the period of the study. The Environmentally Sensitive Areas (ESAs) scheme also supported the limited provision of recreation on farmland (Anon 1986). One major leisure-related driving force is the management of land for game shooting. In the lowlands, this has resulted in the planting and conservation of small woodlands for pheasant rearing (Firbank 1999). In the uplands, heather moorland may be managed for grouse shooting, but in this study the effects cannot be separated from those of sheep grazing. Site-specific leisure developments, and effects of disturbance on paths and bridleways, are too localised to be dealt with specifically within this analysis. Therefore, **the effects of leisure on botanical diversity are not considered further in this study.**

#### *Agricultural intensification*

The overall trends in British agriculture between 1978 and 1990 were of a slight reduction in land area used for highly productive agriculture, coupled with an increasingly intensive management of such land (ie both inputs and outputs increased per unit area). Several aspects of this intensification were reviewed by Little (1998) and by Wilkinson (1997). Arable rotations switched away from the use of spring cereals and leys towards winter cereals. There were also increases in the inputs of agrochemicals and fertilisers. Grassland management changed, with a switch from hay to silage production, and a tendency towards fewer cattle and more sheep. Linear features have been lost, and there have been effects of pesticide and fertiliser drift (see *Forest management (including hedgerows)*, page17). These drivers of ecological change are considered separately below. They should also be seen in the context of an increasing geographical polarisation of farming that has occurred since at least the 1950s. This resulted in a reduction in mixed farming and the concentration of intensive arable cropping in the east and southeast whilst in the early 1980s 70% of land along the western fringes of GB remained in permanent grass and ley (Donald 1997; Shrubb 1997).

- **Crop management and pesticide use**
  Arable agriculture changed substantially between the two survey years. There was an overall reduction of the area under

cereals (2.7%) between 1978 and 1990. Wheat and oil seed rape increased in area, while spring barley decreased by 73%. Grass leys in arable rotations also declined. The introduction of minimum tillage techniques encouraged continuous cereal rotations in some areas.

Pesticide usage on cereals increased greatly, by 142% between 1977 and 1990 (Wilkinson 1997). In 1982, 97% of pesticide use on grassland comprised herbicide applications (1.7 million spray hectares*) used largely against broadleaved weeds. This peaked at over 2 million spray ha in the early 1980s before falling back to 0.4 million spray ha in 1990.

- **Grassland cultivation**
  One sign of intensification is the conversion of grassland and other habitats into arable crop production. There was no evidence from MAFF statistics that this was the case. The proportion of agricultural area under temporary grass fell from 11.7% in 1978 to 9.0% in 1990, while areas of permanent grass and rough grazing remained fairly static at around 36% and 10% respectively. Analysis of land cover change between 1984–90 (Haines-Young *et al.* 1996) suggested minor, but not statistically significant, losses to arable rotations.

- **Grassland management**
  While the total area of grassland may have changed little, management regimes have changed greatly. Between 1978 and 1990 grassland became much more productive because of reseeding and the use of fertilisers, thus supporting increased stocking rates. Hay-making has been largely replaced by silage, which can be preserved without drying, has lower labour costs and is more nutritious by volume. Silage production increased from 23 million tonnes in 1978 to over 46 million tonnes in 1990; hay production fell from 8.1 million tonnes to 4.5 million tonnes over this period. Mixtures with very few species (typically rye-grass (*Lolium perenne*) and clover (*Trifolium repens*)) were sown more frequently, and herbicides were used more often against broadleaved species.

  The period witnessed a marked decline in cattle – numbers fell from over 10 million in 1975 to under 8.5 million in 1990, even though GB annual milk yields actually increased by 7.5%. The steepest reductions were seen in southern and eastern regions. The switch from bedding on straw to using slats as well as silage feeding did, however, cause an increase in the problem of slurry management, which tended to be applied to grasslands, increasing weed problems and hence the use of herbicides. It is clear that changes in grassland management may have been important for biodiversity in general, and for plants in particular. However, the effects of these changes would have been very highly confounded with those of agricultural nitrogen usage. We conclude that these two driving forces cannot be separated using Countryside Survey data on grasslands, and therefore, **grassland management is not considered further as a separate driving force in this analysis.**

- **Upland sheep grazing**
  At the time of the 1978 survey, sheep numbers were falling, but the introduction of the CAP regime in sheepmeat in 1980 led to an increase in sheep numbers of 24% between 1980 and 1990, reflecting increases of both mean flock size and total number of holdings. Increases occurred predominantly in upland Less Favoured Areas (LFA). The largest increases in flock size were seen in northern England (48%), in the southwest (67%) and in Wales (42%) (Wilkinson 1997).

### *Drainage and waterside management*

Drainage of agricultural land increased dramatically in the 1940s, and again in the 70s

* MAFF pesticide usage data are given as spray hectares. Thus, a field of 10 ha sprayed twice in a year would contribute 20 spray ha. Consequently the total spray hectarage in Britain would be twice the actual hectarage of sprayed land if two applications were made over the total area in one year.

and 80s, reaching a peak of 100 000 ha per year in the mid 1970s. Of the 750 000 ha drained in the 1970s, more than half was to upgrade grasslands, with just under 40% to allow arable cropping (Little 1998). It has been estimated that around half of British agricultural land is now dependent upon artificial drainage (Andrews & Rebane 1994). Wet habitats such as water meadows and ponds now make little contribution to agricultural production.

The loss of damp and wet habitats has been substantial. At present only around 20 000 ha of high conservation value wet grassland is thought to still exist (Little 1998). Water abstraction has been responsible for the drying out of wetland habitats particularly in lowland Britain (Fojt 1994; Mantle & Mantle 1992) whilst as many as 14% of Sites of Special Scientific Interest (SSSIs) may be affected by drainage at present (Anon 1998a). **We hypothesise that the effects of drainage on vegetation may be found in linear and area features.**

- **Waterside management**
  The management of the banks of ditches, rivers and other water-fringe habitats tended to become either over-engineered, removing waterside vegetation (Newbould *et al.* 1989), or more neglected. Fencing, and increased levels of nitrogen and phosphorus in drainage waters, favour unchecked accumulation of plant material. Changes to management prescriptions for agri-environment and related schemes (eg Firbank 1993) were introduced too late to have had much effect during the period of this study. **We suggest that the effects of waterside management may be expected in the Countryside Survey data in waterside vegetation in the lowland and marginal upland landscape types.**

#### *Agricultural extensification and environmentally sensitive farming*

During the 1970s and early 80s, agricultural policy acted to increase production. However, by the mid 1980s, increasing concerns about environmental effects of agriculture, coupled with the costs of managing substantial European food surpluses, raised the possibility of promoting more extensive, environmentally-friendly agriculture.

As a result, ESAs were introduced in 1986 to promote the conservation of particular regions. By 1990, they included 405 000 ha of eligible land. Each ESA had its own priorities and objectives, and provided for different intensities of positive management under a tiered system of compensatory payments, with an initial emphasis on preventing further habitat degradation and maintenance of landscape features. Because the ESA scheme was only introduced in 1986, we do not consider that its effects could have been detected using the Countryside Survey data.

A second element of extensification was the introduction of set-aside. The Five Year Set-aside Scheme (eg Ansell & Tranter 1992) was a voluntary scheme, introduced in 1988, whereby farmers could temporarily remove land from production. Land set-aside for more than a single season resulted in the conversion of crops to communities dominated by arable plants and volunteer crops, and eventually grassland (Critchley *et al.* 1994; Firbank 1998). It is likely that rotational set-aside accounts for part of the 230% increase in non-cropped arable between 1984 and 1990, although the area involved (1800 $km^2$) was small in terms of the detectability of change by plot samples (Haines-Young *et al.* 1996). The take up of set-aside remained relatively small until the reform of the CAP in the early 1990s. The results from the Farm Study survey of a sub-sample of Countryside Survey squares are also relevant here (Potter & Lobley 1996). This showed a substantial movement of land cover parcels toward less intensive cover types between 1984 and 1990, although in area terms these shifts were relatively small and equivalent in area to intensifying shifts. On farms in the arable landscape, 45% of extensifying changes were linked to set-aside. On the pastural and upland farms surveyed, movement to less intensive land cover involved a much smaller area than the arable farms, although there was some evidence that stocking rates and fertiliser applications had been reduced as a result of conservation management objectives (Potter & Lobley 1996). Interestingly though, species compositional changes still indicated movement toward more intensive vegetation types even within parcels considered to have had a less intensive land use (Potter & Lobley 1996).

A third aspect of extensification was a desire by some farmers to move away from continuous cereal systems towards more integrated or organic systems. Finally, there was increasing interest in the conservation value of farmland (Firbank *et al.* 1991), which gave rise to the development of measures intended to actively promote biodiversity, such as conservation headlands (eg Sotherton 1991). Here, too, few changes were expected during the period of study, and cannot be distinguished from a slower rate of intensification.

In general, we suggest that the specific effects of agri-environment schemes and extensification are hard to detect using Countryside Survey data between 1978 and 1990, and so **agricultural extensification is not considered further in this analysis.** Extensification became a much more important feature of policy in the early 1990s, following the 1992 McSharry reforms of the CAP (eg Floyd 1992), which was to lead to a variety of measures that may have effected vegetation change from 1990 onwards. They included:

- the revised set-aside scheme;
- aid for organic farming, and further ESAs;
- the declaration of nitrate vulnerable zones;
- the Countryside Stewardship Scheme and its Welsh counterpart Tir Cymen.

### *Land abandonment*

Agriculture becomes marginalised when it is no longer profitable given the existing production system and socio-economic structure. When no diversification is possible, land abandonment can follow. The process of land abandonment at the European scale is most pronounced in extensive livestock systems (Baldock *et al.* 1996).

MAFF statistics show a slight decrease in the total area of farmland (excluding common grazing) of 127 000 ha (–1%); some of this may have been due to abandonment, but a shift to other land uses is more likely. While GB has been affected relatively little, this may change in the future. However, such large-scale land use changes are not the only causes of abandonment; peri-urban areas such as allotments and transport corridors may well be neglected whilst land abandonment can also be a precursor to subsequent development (Barr *et al.* 1993). Parcels of land on intensively-managed farms can also become derelict. For example significantly more grassland SSSIs were likely to be in sub-optimal condition when located on exclusively arable rather than mixed or pastoral systems. This was linked to lack of management partly reflecting the unavailability of stock on enterprises geared up for tillage only (Sketch 1995). While abandonment is revealed as a succession through scrub and woodland within Countryside Survey data these changes can occur in other situations, such as habitat restoration.

Because of its low rate and localised occurrence between 1978 and 1990, **land abandonment is not considered further as a driving force in this analysis,** although we return to the issue of neglect of small parcels of land.

### *Forest management (including hedgerows)*

The pattern of afforestation between 1978 and 1990 was of a modest increase in broadleaved woodland from around 0.7 to 0.8 million ha. The cover of coniferous woodland continued to increase, from around 1.3 to 1.5 million ha, mostly on remote areas in the uplands. Thinning and felling of conifer plantations also increased against a backdrop of high turnover between planted and clear-felled land (DOE 1996; Haines-Young *et al.* 1996). Coppicing was re-introduced into some ancient woodlands to re-create the cycle of canopy opening and closure required by many woodland ground flora plants, and ride management was reinstated to create the habitats required by woodland butterflies, however, the extent of such practices may have been small. The survey period coincided with the loss of many elm trees through Dutch Elm disease of the 1970s as well as the Great Storm of October 1987 which affected a relatively narrow zone across south and southeast England (Kirby & Buckley 1995).

The status of hedgerows changed substantially during the survey period. An estimated 129 000 km of hedgerows were lost between 1984 and 1990 (Barr *et al.* 1993), with most losses due to lack of management so that hedgerows became lines of shrubs and trees.

We identified five driving forces to encompass these changes; broadleaved planting, broadleaved management (including felling), conifer planting, conifer management and hedgerow management (including removal). Because of the scarcity of hedgerow and broadleaved woodland in the uplands, we expected detectable effects only in the lowlands.

#### *Climate change*

Climate change is forecast to become an increasingly strong influence on British vegetation during the next century, with different scenarios suggesting a temperature increase (caused by increased levels of atmospheric $CO_2$ and other greenhouse gases) of around 2°C across Europe by 2050 (Alcamo & Kreilemann 1996; Viner & Hulme 1997; Hulme & Jenkins 1998). The precise vegetation trends will depend upon the behaviour of precipitation, and here the forecasts diverge. However, there is likely to be a tendency for the spread of species typical of more southerly and continental floras, with a decline of vegetation typical of montane and a possible drying of blanket bogs.

While the period 1978–90 experienced climatic variation, the period was too short, and local variation too great, for any unambiguous signal of directional change to be detected (Box 5, page 55). Effects on vegetation may have been influenced by the differences in weather conditions in the two sample periods; 1990 was hotter than 1978 but wetter in Scotland than England and Wales.

### Locating expected effects of driving forces in the wider countryside

The effects of different driving forces are not felt equally across the British countryside, and the likely spatial pattern of effects for each driving force allows one to discriminate between them. The Countryside Survey allows spatial discrimination in that the survey quadrats used in these analyses were either located in areas of land or along linear features (see *Countryside Survey methodology*, page 21), and secondly, the 1 km sample squares containing these quadrats were stratified by the ITE Land Classification.

#### *The ITE Land Classification*

Vegetation and land management are both intimately associated with land form, soil type and climate. For the ITE Land Classification, variables describing geology, topography, and climate were collected or estimated for each 1 km square in GB (Bunce *et al.* 1996). The TWINSPAN method of classification was used to identify 32 sets of squares with similar characteristics. These are the land classes, the level used for stratifying the survey squares used in Countryside Survey. These were then combined into four landscape types, namely the upland, marginal upland, arable and pastural (both lowland) landscapes (Box 2, page 52). These broad groupings were used as the basis for reporting the CS1990 results (Barr *et al.* 1993).

It is thus possible to hypothesise where each driving force would have had an effect, in terms of landscape type and area or linear features. Our suggested hypotheses are given in Table 2. Some of these hypotheses need little elaboration; for example, road verge and waterside management are assumed to be located alongside these particular linear

*Table 2.* Trends in driving forces and location of effects

| Driving force | Did the driving force change between 1978 and 1990? | Locations: Landscape type: Arable | Pastural | Marginal | Upland | Feature: Area | Linear |
|---|---|---|---|---|---|---|---|
| **1. Eutrophication** | | | | | | | |
| Atmospheric deposition | Yes – increased. | Y | Y | Y | Y | Y | Y |
| Agricultural fertilisers | Yes – increased. | Y | Y | Y | Y | Y | Y |
| Waterside eutrophication | Yes – increased. | Y | Y | Y | Y | Y | Y |
| **2. Acidification** | Yes – decreased. | Y | Y | Y | Y | Y | Y |
| **3. Urbanisation and transport** | | | | | | | |
| Loss of land cover to buildings | Yes. | Y | Y | Y | Y | Y | Y |
| Road verge management | Yes – less frequent full-width mowing. Cuttings left. Increased traffic volumes. | Y | Y | Y | Y | Y | Y |
| **4. Leisure** | | | | | | | |
| Trampling, disturbance | Yes – increase in mid-late 1980s but point impacts not widespread enough for detection in Countryside Survey data. | Driver not considered further | | | | | |
| Heather management | No – no major change in practice or extent. | Driver not considered further | | | | | |
| **5. Agricultural intensification** | | | | | | | |
| Crop management & pesticide use | Yes – move away from spring cereals, net increase in tilled land (1978–90) although reduction between 1984 and 90, large increase in use of pesticides. | Y | Y | | | Y | Y |
| Grassland cultivation | Some – mostly rotation from short-term leys, most large scale ploughing of old grassland happened earlier in century. | Y | Y | Y | | Y | |
| Grassland management | Yes – increased silage production. Effects impossible to separate from agric. N use and ley establishment. | Driver not considered further | | | | | |
| Upland sheep grazing | Yes – increased in LFAs links to HLCA. | | | Y | Y | Y | Y |
| **6. Drainage** | Yes – increased. | Y | Y | Y | Y | Y | Y |
| Waterside management | Yes – increased fencing along watersides. | Y | Y | Y | | | Y |
| **7. Agricultural extensification** | | | | | | | |
| Lack of cultivation | No – set-aside only started to have an impact in early nineties. | Driver not considered further | | | | | |
| Biodiversity enhancement | No – management under agri-environment schemes not sufficiently widespread even though they started in early to mid-80s. | Driver not considered further | | | | | |
| **8. Land abandonment** | No evidence of large-scale disuse of agric. land. | Driver not considered further | | | | | |
| **9. Forest management** | | | | | | | |
| Broadleaved planting | Yes – 3% increase between 1984 and 90. | Y | Y | Y | | Y | Y |
| Broadleaved management | Yes – overgrazing in uplands, neglect in lowlands. Other forms of management less widespread or marked in effect. | Y | Y | Y | Y | Y | |
| Conifer planting | Yes – 5% increase in plantation. | Y | Y | Y | Y | Y | Y |
| Conifer management | Yes – 150% increase in felled woodland. | Y | Y | Y | Y | Y | Y |
| Hedgerow management | Yes – sig. increases in relict hedge and relict hedge with fence. Hedgerow removal also ocurred between 1984 and 90. | Y | Y | Y | | | Y |
| **10. Climate change** | Insufficient difference in climate between 1978 and 90 (see Box 5, page 55) | Driver not considered further | | | | | |

features. Others make general simplifying assumptions about the distribution of particular driving forces. For example, we have assumed that atmospheric pollution is distributed across all landscape types and across both linear and area features. While this is true, it neglects the much more detailed information available about variation in deposition across the country (eg Hornung & Skeffington 1993). Our assumptions about the distribution of farming practices are similarly simplified. The advantage of these assumptions is that we can adopt a common suite of analyses (ie those presented in ECOFACT Volume 2 by Bunce *et al.* 1999b) in terms of all driving forces simultaneously.

***Driving forces not considered further***

Only those driving forces with an unambiguous pattern of effects across locations, and capable of being detected using the Countryside Survey vegetation data, are considered further (Table 2). Thus effects of leisure are not considered, as they are too localised, or too confounded with those of upland agriculture. Grassland management could not be distinguished from agricultural fertiliser usage in terms of expected locations of effects. Land abandonment and agricultural extensification took place on too small a scale during the study period, which was also too short to separate long-term directional climate change from year-on-year variability.

# RECORDING AND ANALYSING CHANGES IN VEGETATION

*The programme of Countryside Surveys provides us with a highly sophisticated, national system for detecting changes in vegetation and land cover in the British countryside. Sample 1 km squares were selected at random, stratified by climate, topography and other relatively stable attributes, and then mapped, and the vegetation recorded in fixed plots. These plot locations included fields, open land, and alongside linear features such as roads and hedgerows. Our data from these locations visited in both 1978 and 1990 gives us an accurate measure of overall vegetation change, and also change by locations within the landscape and by regions across GB.*

*Different kinds of vegetation change can be associated with different causes of change. For example, some categories of vegetation are typical of wet, or of dry conditions. Individual species may be favoured by increased or decreased nutrients, light or grazing levels. However, these relationships are not always straightforward: sometimes vegetation changes are forced over some form of threshold, from which a return to the original state is unlikely to occur without a deliberate restoration programme.*

## Countryside Survey methodology

### *The field survey component of Countryside Survey*

This report focuses on the changes in vegetation between 1978 and 1990 revealed by the analysis of botanical data from the Countryside Surveys of those years. The Countryside Survey was developed as a technique for the evaluation of stock and changes in vegetation and land cover, relying on a stratified sample of 1 km squares, within which the land cover is mapped and sample vegetation quadrats recorded. The use of the same sites allows for a very precise quantification of change between surveys. Vegetation surveys took place in 1978 and 1990, with an intermediate survey concentrating on land cover and linear features in 1984. A repeat survey, CS2000, was conducted in 1998–99 and will be reported in the year 2000 and onwards.

Countryside Surveys involve a census of land use and vegetation sampling within 1 km squares selected at random and stratified by the ITE Land Classification. The numbers of squares has increased with time, adding to the original sample of 256. Detailed land use surveys were undertaken in 1984, 1990 and 1998 (for CS2000), down to a minimum mappable unit of 20 m x 20 m. Land use, boundaries and features were mapped on the ground using a series of detailed mapping codes, for aggregation *post-hoc* according to the desired analysis. Vegetation surveys were undertaken in 1978, 1990 and 1998. Plots were located and permanently marked to allow the precise assessment of vegetation change between surveys. The plots come in various types according to their position in the landscape (Box 6, page 56). In all cases, species lists were recorded, along with estimates of cover for all species exceeding a cover of 5% (Barr *et al.* 1993).

In addition to the field survey, CS1990 involved the development of a national Land Cover Map using remotely sensed data, allowing census-based estimates of stock in 1990. The map was developed from Landsat TM imagery, and covers the whole of GB with a pixel size of 25 $m^2$ – valuable for estimation of features greater than 2 ha or so, but inappropriate for linear and other small or narrow features (Fuller *et al.* 1994). A new map is being produced as part of CS2000.

### *The analysis of Countryside Survey vegetation data*

There are two important sources of information to help interpret botanical changes. The first is the position of the Countryside Survey plots in the landscape: are they in the uplands or lowlands in field boundaries or in area features? The Countryside Survey analyses were stratified by landscape type and location of the plots, allowing direct comparison with the distribution of effects of particular driving forces hypothesised in Table 2 (page 19). The second is the nature of the vegetation change itself. Because individual plant species have their own profile of acceptable environmental conditions, changes in species composition can be used to infer changes in the local environment of the plot or plots. It is, therefore, possible to use the vegetation itself as an indicator of environmental change, helping to reveal which environmental driving force may have had the greatest effect.

## Relating changes in botanical diversity to driving forces

Different driving forces give rise to different effects on botanical diversity. However, these effects vary in their properties, with consequences for their detection and for the development of appropriate responses (Box 3, page 53).

***Non-linear dose-response relationships***

The relationships between the value of the driving force and the effects on biodiversity are often non-linear. Populations and communities are often buffered against a degree of change. For example, soils can buffer a degree of atmospheric acid deposition, and plant populations may be able to compensate for reductions in density by increases in seed production per plant. When these critical levels are exceeded, however, the loss of the species, or the change in the community, can be swift, even given a small change in the driving force.

***Reversible and irreversible change***

Some changes in biodiversity are more easily reversed than others. Once a species has been lost from an area of land, it can only re-appear by invasion from other sources, by germination from a propagule bank, or by deliberate re-introduction. It follows that effects of processes that lead to widespread, long-term reductions in species will be difficult to reverse without an active programme of re-introduction. Thus, botanical diversity of set-aside agricultural land tends to be highest near species-rich semi-natural habitats, that act as a source from which species can colonise (Firbank 1998). The relevant scales of recovery vary between species – those that disperse freely can respond to environmental change relatively quickly, while communities of species-rich woodland and grassland are virtually irreplaceable, because recolonisation is so slow and occurs over only very short distances.

***Local and regional changes in biodiversity***

Some turnover in vegetation classes is to be expected at a large enough scale, and so even where there is local change, it may not pose a threat to biodiversity at the regional or national scale if the net change is small. However, if there is a net change towards particular vegetation types, this is of greater concern, especially if these types are of less conservation interest in their own right. One of the more important issues raised by Countryside Survey is the extent to which there is a trend for increasing abundance of already common and widely-dispersed species and species assemblages.

***The importance of vegetation starting points***

The analysis of vegetation change needs to take into account the initial state of both the driving force and the vegetation (itself influenced by driving forces further in the past). A particular increase in a driving force may give rise to very little vegetation change if the starting level was very low (or very high), but at intermediate starting levels, a small increase in the driving force may be enough to exceed the buffering capacity of the soil and vegetation, causing a substantial change.

Vegetation starting point is also important, as different communities are affected by driving forces to different extents. For example a lowland road verge in which competitive ruderals and small annuals are present is likely to respond more rapidly to changes in fertility than an upland sward in which coexisting species share stress-tolerant attributes such as slow relative growth rate, limiting the capacity of the vegetation to respond rapidly to changing conditions (Hodgson *et al.* 1994). Similarly small fragmented patches of lowland heath have a high ratio of edge to area and are close to nearby seed sources. They may show rapid changes when conditions change. This contrasts with an extensive tract of upland heath even though the same driving force (eg atmospheric nitrogen deposition) may have operated with the same intensity and duration. Lastly if the species composition of a patch already reflects the past operation of a driving force (eg high nutrient inputs on improved grassland) there may be limited scope for further response even though a different driving force (eg atmospheric nitrogen deposition) may have operated to further increase nutrient status.

## Indicating the causes of change in vegetation

It is possible to describe all of these kinds of change within a single conceptual model. For any given indicator, there is a change in its value with increasing levels of the driving force. At low levels, the change is reversible, and may be difficult to distinguish from background variation due to other factors. As the level increases, the change becomes greater, until it becomes irreversible. At this point, reductions in the pressure will not result in restoration of the original state, although the new state may be of value in its own right (Box 3, page 53).

Different measures of botanical diversity are sensitive to particular stages in this process. For example, shifts between major land cover and vegetation units (such as Biodiversity Action Plan broad habitats (Anon 1998b)) indicate that an irreversible change may have taken place. On the other hand, an increase in nutrient status of vegetation may be indicated by apparently minor shifts in the relative proportions of species associated with nutrient-rich habitats. This example also shows how different measures of vegetation give important clues about the possible causes of change.

A whole suite of Indicators of Botanical Diversity (IBD) are needed to disaggregate the effects of the different causes of change. As part of the ECOFACT project, a series of 12 IBDs were proposed. Some were common to many existing studies, such as the mean number of species per sample unit. Some were related to the conservation value of the vegetation, either in terms of scarce species or plant communities, or in terms of potential value to animal groups. Others were used to imply processes responsible for change.

## The Countryside Vegetation System

In order to analyse change within quadrats representing similar vegetation and habitat, the range of floristic variation covered by Countryside Survey data needed to be classified. Among exisiting GB classifications, the NVC is the most widely used. It covers the range of British semi-natural and major artifical habitats. However, to achieve this level of coverage, it has relied upon a synthesis of datasets that varied greatly in age and sampling domain, whilst the majority of sample plots were located subjectively. These aspects of the NVC made it inappropriate as a system for stratifying the often internally heterogenous, and randomly located Countryside Survey plots where analysis of change rather than base-line description and evaulation was the objective. The CORINE Biotopes (Anon 1991) classification was not considered suitable, as again it is based on subjective assessment of vegetation and as a descriptor of the habitat as a whole – substantial shifts in vegetation can therefore take place within a CORINE category.

The CVS was constructed by using data from all Countryside Survey quadrats in 1978 and 1990, excluding plots considered to be salt marsh or bare ground. A total of 11 557 samples were grouped using the TWINSPAN classification technique with a pre-determined stopping rule, which generated 100 classes (Bunce *et al.* 1999a). The relationships between the classes were explored using the DECORANA ordination software, that brings together classes that are similar in composition, and spreads apart those which are different, in a multidimensional space. The first axis accounts for the greatest possible extent of variation among the classes, the next then accounts for the greatest possible amount of variation still remaining, and so on. Eight clusters of vegetation classes within this space were identified – these clusters are termed the aggregate vegetation classes, or in short, the aggregate classes (Box 7, page 57).

#### *The ecological interpretation of the CVS – relating vegetation change to the causal environmental driving forces*

Knowledge of the relationships between CVS classes and the ecological requirements of the constituent species can be used to infer what kind of environmental factors have induced changes in the vegetation as it has shifted from one class to another through time and space.

There are a variety of sources of information about the ecological requirements of vascular plants, but one of the more useful was devised by Ellenberg (1988; Ellenberg *et al.* 1991), for the central European flora. He selected seven scales of environmental variation of which five are considered here:

- light;
- moisture;
- pH;
- fertility;
- continentality.

Each species has a value, or a range of values, that estimate the position along each environmental gradient at which it is most abundant. The values were first derived using expert judgement for central Europe, but were re-calibrated for GB using CS1990 and NVC data (Hill *et al.* 1999).

Just as the Ellenberg indicators estimate the environmental optima of an individual species in the presence of other species, they can be used to assess the requirements of a vegetation class, or a species group, by looking at the mean indicator value of the constituent species (Hill & Carey 1997).

When mean Ellenberg scores of the vegetation classes were plotted against axis scores for the DECORANA analysis of the vegetation classes,

- Axis 1 scores were shown to be highly correlated with fertility score;
- Axis 2 scores were correlated with the light score;
- Axis 3 scores were highly correlated with wetness (Box 8, page 58).

In other words, the three major environmental gradients of British vegetation are fertility, then light, and finally wetness. Changes from one vegetation class to another involves shifts along one or more of these axes, which may have resulted from different combinations of human-induced driving forces changing the environment around the plants. Therefore, the mean Ellenberg score provides a valuable measure of the state of the vegetation at a given point in space and time. Such scores have been provided for each CVS class (Bunce *et al.* 1999a).

The Ellenberg scores use plant species as indicators of the environment, and some caution is needed in their interpretation. Firstly a score for one condition can change as an indirect result of a shift along a different environmental gradient. For example, if a species-poor community on acid soils receives inputs of nutrients, the new species may bring about an increase in the mean Ellenberg pH score, simply because they are more generalist species, associated with a wider range of soil types. Secondly, the summed nature of the scores can conceal different sorts of change – thus a decreased moisture score may reflect an increase in species suited to drier conditions with or without a decrease in wetland species.

***Species groups***

The vegetation from any plot within the Countryside Surveys can be assigned a CVS class. The CVS class is therefore a state variable, and changes in class between surveys demonstrate a change in state. It is possible to go further, and look at changes in botanical composition too small to result in a shift from one CVS class to another. Slight shifts in mean Ellenberg scores certainly provide valuable information. Another source of information is to group plant species in terms of their co-occurrence. To this end, the plant species data from CS1990 were ordinated and clustered to generate 37 species groups. These are groups of species that tend to be found together within Countryside Survey plots, reflecting their common preference for particular environmental conditions (Box 9, page 59). Some groups contain species which are widespread across the countryside, others contain species with more exacting requirements. In general, however, shifts in relative abundance of different species groups within a CVS class can provide a sensitive measure of the kinds of changes that may eventually lead to shifts between CVS classes. The CVS classification provides data on the characteristic species group(s) for each class (Bunce *et al.* 1999a).

***The CVS and the functional ecology of species***

Species groups bring together those species that tend to be found together, regardless of cause and effect, while the Ellenberg system summarises the relationships between plant and biophysical environment, but says little about the relationships with other plant species (other than whether it can grow in the shade of others). Therefore, neither tool can be used to analyse fully those trends in vegetation which are not due to changes in biophysical conditions – for this, plant strategy theory is useful.

Using this approach, each species of plant can be described using a series of traits that describe not only the environment in which it may be found, but its likely relationships with other species (Grime 1977). These traits include growth rate, plant size, seed bank dynamics and many others, all of which can be measured under standardised conditions. Plants with similar traits have a similar function in the community, thus some species are 'competitive' towards others, 'ruderals' are good at exploiting new or disturbed areas of land, while 'stress-tolerator' species can persist in conditions too extreme for their potential competitors in more favourable conditions. Each species can be located within the gradients between these three extreme positions (Grime *et al.* 1988) (Box 10, page 60). The balance between these strategies varies between habitats and management systems, thus ruderals would predominate in arable systems, competitors in rank grassland and stress-tolerators on mountains or bogs. The typical profile of these functional types has already been ascertained for each CVS class (Bunce *et al.* 1999a). Therefore, as the species composition changes, there may be shifts in the representation of different strategies that give valuable clues about the causes of vegetation change.

# INDICATORS OF BOTANICAL DIVERSITY 1978–90

*Vegetation data from Countryside Survey already contribute to the Indicators of Sustainable Development for biodiversity in the wider countryside. The data can also be presented using a variety of indicators that, together, help identify processes of vegetation change, and also changes in the conservation quality of vegetation.*

*From 1978 to 1990, the major trends in vegetation as a whole were from less fertile to more fertile vegetation, and from more open to taller and wooded vegetation. Some areas of heath changed to moorland grass, some moorland grass was improved or forested, while grassland of road verges, streamsides and field boundaries became more overgrown. Species richness declined in many kinds of vegetation, while already common plants became more widespread, and vegetation in general became more homogeneous. There were declines in food plants for birds, bees and butterflies. Also, case studies indicated that scarce plant communities may have changed in their locations as well as their abundance. For example, an important grassland community was found in 1990 to be largely restricted to unproductive situations, notably road verges.*

The classes of the Countryside Vegetation System (CVS) address only some of the variety of ways of expressing vegetation information. For other purposes, it is important to consider species number, the conservation importance of the species, or other aspects of diversity.

We propose twelve such Indicators of Botanical Diversity (IBD) to express the vegetation data from Countryside Survey (Box 11, page 61). In principle, all of these indicators can be analysed with respect to locations within and between landscapes, by selecting only certain plot types or certain landscape types or land classes. In practice, sample size sometimes reduced the number of analyses that could be done; indeed, for some Indicators it has not been possible to estimate changes between 1978 and 1990, but they should prove valuable when data from CS2000 become available.

These indicators are described in turn, along with key changes that took place between 1978 and 1990. These changes are reported fully in the ECOFACT Volume 2 report (Bunce *et al.* 1999b) in the sections and annexes indicated. All change analyses were stratified by combinations of plot type, aggregate class and landscape type across GB. Additional analyses were also carried out on a separate classification of plots located on agricultural land in England and Wales. A comparison between these results is given in Box 12 (page 63).

## IBD1 – The frequency of CVS aggregate vegetation classes

***The nature of the Indicator***

The aggregate vegetation classes are the eight major groupings of British vegetation within the CVS. While there are some general correspondences with land cover definitions within Countryside Survey and elsewhere, there are important differences. The aggregate vegetation class is defined purely in terms of the vegetation, and not on perceived land use (eg Countryside Survey maps of land cover (Barr *et al.* 1993)), nor on an integrated measure, such as reflectance (eg the ITE Land Cover Map (Fuller *et al.* 1994)). Also, aggregate classes are estimated at a smaller scale of resolution than many maps of land cover, giving more sensitive estimates of between-patch diversity in mosaics of vegetation than may be recorded from land cover maps. Thus, for example, plots in woodland clearings may be allocated to a grassland aggregate class but to woodland land cover.

The proportion of plots found within each aggregate class gives a valuable summary of the diversity of vegetation within and between units of land such as landscape types, different types of linear features and so on. Changes in aggregate class through time may be associated with natural succession, from disturbed land through to woodland, and may well be associated with changes in land use. Such changes are sufficiently large that they may represent the loss of much of the diversity within the former aggregate class (for example, the loss of species-rich grassland to scrub, the loss of heathland to plantation), whilst newly-formed stands of a particular aggregate class are likely to be of lower diversity than older ones. Therefore, turnover rates are as important in assessing change as net movement between time intervals.

***Data available in ECOFACT Vol 2, Annex 15***

Results are available for frequencies of CVS aggregate classes in 1990 and their changes since 1978, as well as area estimates for 1990 per aggregate class. They are reported separately for the major landscape types.

***ECOFACT results***

In 1990, AC VIII (heath/bog) was the most widespread aggregate class, followed by AC I (crops/weeds) and AC III (fertile grassland). There were net changes between the number of plots in the different aggregate classes between 1978 and 1990. There were net losses in AC I (crops/weeds), AC III (fertile grasslands), AC IV (infertile grasslands), AC VII (moorland grass/mosaic) and AC VIII (heath/bog), with net gains in AC II (tall grassland/herb), AC VI (upland wooded) and AC V (lowland wooded) (Figure 1). These shifts were not uniform across Britain. In the arable lowland landscapes, the major trend was from AC III (fertile grassland) to AC II (tall grassland herb), in the pastural lowland landscapes it was from AC IV (infertile grassland) to AC II (tall grassland/herb). Woodland classes increased in the arable and marginal upland landscape types.

## IBD2 – The frequency of individual CVS classes

***The nature of the indicator***

The 100 vegetation classes are the most detailed units of plant communities within the CVS; they are described in detail in Bunce *et al.* (1999a). All changes of a plot between aggregate class must involve changes at the level of the vegetation class. However, the vegetation class gives further detail that is useful in interpreting vegetation change. Some classes are of higher conservation value than others, for example, class 1 (almost weed-free wheat/other crops), has a very low conservation value, while class 100 (inundated bog/wetland), includes sundews and other restricted species. Some transitions between classes may indicate vegetation changes that

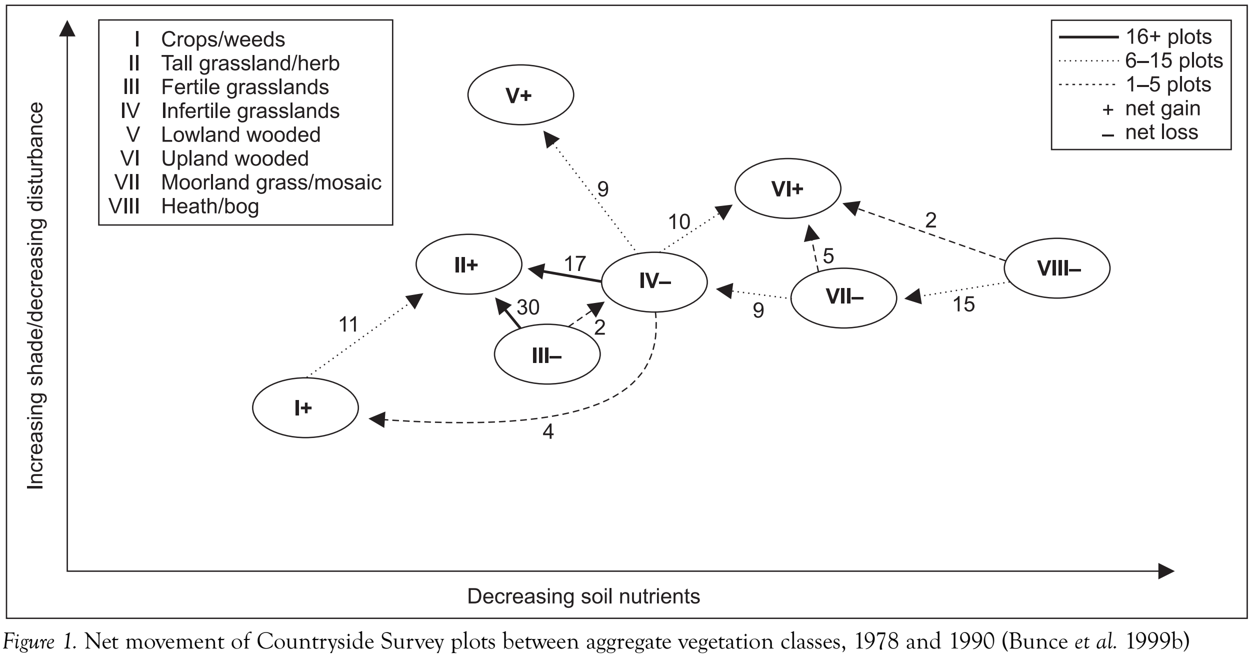



*Figure 1.* Net movement of Countryside Survey plots between aggregate vegetation classes, 1978 and 1990 (Bunce *et al.* 1999b)

are likely to be reversible. For example the grazing driven shifts between CVS class 80 (moorland grass/heath on podzolic soils, NVC U5) and CVS class 89 (dry heath on podzolic soils, NVC H12).

***Data available in ECOFACT Vol 2, Annex 16***

Results are available for frequencies of the individual CVS vegetation classes in 1990 and their changes since 1978, as well as area estimates for 1990 per class.

***Results from ECOFACT***

The areas occupied by individual CVS classes in 1990 varied greatly, from over 14 500 $km^2$ of fertile mixed grassland (class 30) to an estimated 10 $km^2$ of streamside and flushes on peats (class 85). An overall assessment of the diversity of vegetation types can be obtained by estimating diversity indices for 1978 and 1990 for those plots recorded in both years. Both the Simpson's and the Shannon diversity indices show an *increase* in diversity of vegetation types (Simpson's D = 40.3 in 1978, 47.8 in 1990; Shannon H = 4.08 and 4.20 respectively).

There were shifts of CVS classes within and between aggregate classes. Turnover in the crops/weeds aggregate class (AC I) was to be expected, but even so there was a trend towards less diverse classes, in particular to almost weed-free wheat/other crops (class 1). Within infertile grassland (AC IV) there was a shift towards fertile mixed grassland (class 30) from rye-grass/Yorkshire-fog (class 40) and rye-grass/clover grasslands (class 31). Lowland roadside vegetation classes increased in frequency by 25%. There was an increase in the upland conifer classes at the expense of other classes within moorland grass/mosaic (AC VII) and heath/bog (AC VIII), especially peaty moorland classes.

No marked shifts were apparent between drier and wetter lowland CVS classes. In the uplands however, there were net losses from wetter to drier classes (eg from saturated bog (class 99) to heath/moorland grass (class 91)). Some movement also occurred from the drier wet heath/bog (class 82) to saturated bog (class 99).

## IBD3 – The functional attributes of vegetation

***The nature of the indicator***

Grime and colleagues have developed a classification of plants by their strategies of growth, competition and reproduction. Plants are arranged between three extreme strategies of competitors, stress-tolerators and ruderals (C-S-R), and many plants in the British flora have been classified in this way (Grime *et al.* 1988) (Box 10, page 60). Stressful environments are unproductive, usually in GB because of nutrient limitations, sometimes because of drought. More productive situations tend to be dominated by competitive species if there is little disturbance, whereas frequent disturbance favours ruderal species. In the context of the other indicators, this is a particularly useful indicator of disturbance, not least because the analyses can be focused sharply on components of these strategies, such as the presence of a seed bank or plant growth rates.

***Data available in ECOFACT Vol 2, page 55***

Data are available for changes in the representation of a large number of functional traits in 1978 and 1990. Change analyses were stratified by aggregate class, landscape type and plot type. Analyses are given for all plots in the same aggregate class in 1978 or 1990, and for all plots in the same aggregate classes in both years. Changes in groups of traits were interpreted in terms of the process most likely to be correlated with vegetation change.

***Results from ECOFACT***

Drawing from the analysis of plots that stayed in the same aggregate vegetation class between 1978–90, there were tendencies for the vegetation in AC I (crops/weeds) to lose small-seeded, less competitive species with increased representation of larger, autumn germinating competitors. In both AC II (tall grassland/herb) and AC III (fertile grassland), there was a trend towards larger, more competitive species, while stress-tolerant species decreased in the AC II (tall grassland/herb) plots in the marginal uplands. In AC IV (infertile grassland) changes differed between landscapes types and locations. In the arable landscape, main plots and streamside plots appeared to gain ruderal species indicative of disturbance, whilst in the marginal uplands streamside and roadside plots seemed to have undergone eutrophication. On the same plot types in the pastural landscape both eutrophication and lack of management were inferred. Eutrophication appeared to have gone on in AC V (lowland wooded) plots. Upland vegetation showed little change apart from an increase in species of nutrient-rich habitats in new upland woods.

## IBD4 – Occurrence of CVS classes unique to particular plot types within 1 km squares

***The nature of the indicator***

This is an indicator of the degree of specialism of vegetation within particular landscape elements, such as road verges or hedgerows. If all vegetation types are found only in one such element, the value of this indicator is high. If vegetation types are generally dispersed among plot types, it is low.

***Data available in ECOFACT Vol 2, page 28***

Results are available for 1990 only, expressed by landscape type and also by plot type. No analysis of change is possible until CS2000 data become available.

## IBD5 – Species richness per plot

***The nature of the indicator***

Species richness per plot is a very robust indicator of botanical diversity within individual habitat patches and landscape elements. A reduction in species richness represents a loss of diversity, and an increase in species richness represents an increase in diversity. This is not necessarily true for larger-scale diversity if an increase in species is due to invasion that leads to the loss of distinctiveness of particular communities – this effect is largely restricted to low nutrient, species-poor situations, such as upland heaths. Changes in species number do not necessarily imply irreversible vegetation change, as ‘missing’ species may have become scarce, and hence more likely to be missed by the sampling procedure, rather than having become locally extinct.

***Data available in ECOFACT Vol 2, Annex 10***

Results of species number (using only taxonomically reliable native species) per plot are reported for 1978 and 1990. Change analyses were conducted using paired t-tests, and presented by aggregate class (taking the aggregate class of 1978 as the basis for the grouping, and including those plots that had shifted aggregate class in 1990), for landscape types and plot types.

***Results from ECOFACT***

As has already been reported in the CS1990 Main Report (Barr *et al.* 1993), one of the most important changes in vegetation between 1978 and 1990 has been a net loss of species richness per plot, except for a small number of exceptions such as heathlands. The same trends are evident in the ECOFACT re-analyses. At the national level, the losses were particularly marked for infertile grassland (AC IV) (a mean loss of 2.6 species per plot) and upland wooded vegetation (AC VI)(a mean loss of 4.2 species per plot), with a significant gain of species in heath/bog (AC VIII). Analysis by landscape type revealed other declines of species diversity, notably in crops/weeds (AC I) and fertile grasslands (AC III) in arable lowlands. Moorland grass/mosaic (AC VII) gained species in the marginal uplands, but lost them in the uplands.

There were also differences between plot types. Roadside plots, for example, actually gained species in the grassland aggregate classes AC II and AC III (tall grassland/herb and fertile grassland), while streamside and hedgerow plots lost species in most situations.

## IBD6 – Ellenberg scores per plot

***The nature of the indicator***

The Ellenberg scores are measures of the environments in which plant species are typically found. Changes in a mean Ellenberg score for a groups of plots can be assumed to reflect changes in the underlying environmental variable but, as described above, there may be other factors involved. The great value of this indicator over many of the others is that by focusing on individual environmental factors, it facilitates the interpretation of cause and effect of botanical change. Furthermore, Ellenberg scores deal with factors that are important in managing vegetation for conservation (light, water, nutrient levels) and so are valuable indicators of progress towards or away from particular ecological targets (Box 7, page 57). The problem with the indicator is that scores for species and assemblages for different indicators are intercorrelated, and so changes in one environmental factor may be interpreted falsely as changes in another.

***Data available in ECOFACT Vol 2, Annex 20***

Results of mean Ellenberg scores per plot are reported for 1990, along with changes since 1978. Results are presented by aggregate classes (taking the aggregate class of 1978 as the basis for the grouping, and including those plots that had shifted aggregate class in 1990), for landscape types and plot types.

***Results from Countryside Survey***

- **Fertility**
  Almost all shifts in mean fertility were positive, (ie the trophic status of the vegetation had increased). In the main plots, this was especially true for crop/weed communities (AC I) in arable lowlands, infertile grassland (AC IV) and heath/bog (AC VIII). On streamsides, there was weak evidence for a decline in fertility in tall grassland/herb (AC II) communities, and an increase in heath/bogs (AC III). There were also small increases in fertility in roadside grassland of heath/bog (AC III) and infertile grassland (AC IV) and for hedgerow plots with tall grassland/herb (AC II) and infertile grassland (AC IV).

- **pH**
  There were fewer significant changes, but most of them were positive, implying shifts towards vegetation suited to an increased pH (ie less acidic). The strongest evidence was for crops/weeds (AC I) and heath/bog (AC VIII) in main plots and in streamside plots, in fertile grasslands (AC III) on roadsides, and in tall grassland/herb (AC II) alongside hedges.

- **Light**
  Few changes in the Ellenberg light score were detected and results varied between strata. An increase in shaded conditions was detected in heath/bog (AC VIII) main plots and streamside plots and also in fertile grasslands (AC III) in hedgerow, roadside and main plots. Hedgerow plots in tall grassland/herb (AC II) became more shaded or less disturbed. The only evidence of increased light requirement was in lowland wooded (AC V) hedgerow and streamside plots, and in upland wooded (AC VI) streamsides.

- **Moisture**
  Evidence for changes in moisture requirement was limited, but suggested a segregation by plot type. For the main plots, the moisture index fell (for crops/weeds AC I and for the fertile grassland AC III and moorland grass/mosaic AC VII) or showed no significant change; while the index for streamside plots tended to increase (fertile grassland AC III, lowland and upland wooded AC V and AC VII), with a decline for heath/bog AC VIII. The moisture score for the infertile grassland AC IV increased in road verges and by hedges.

- **Continentality**
  There was quite strong evidence for increases in continentality, notably in the crop and grassland main plots and lowland woodland vegetation, especially in hedges. There were slight decreases in continentality in grassland classes AC II and AC III along streamsides.

## IBD7 – The frequency and cover of species groups

***The nature of the indicator***

Species groups are collections of species that are found together in the Countryside Survey database, as identified by ordinating all the vegetation data collected during Countryside Survey 1990 and performing a cluster analysis on the DECORANA species axes score. Each of the 37 resulting groups of plants may be considered to have similar ecological requirements, and therefore they are distributed non-randomly between plots (Box 9, page 59). Changes in frequency of these groups may indicate changes in the local environment of the plot that can be interpreted by reference to the environments in which these species groups are typically found. Thus a decline in species groups associated with damp habitats may indicate a reduced wetness.

***Data available in ECOFACT Vol 2, Annex 14***

Changes in median cover of the species groups between 1978 and 1990 were reported on the basis of the aggregate class in 1978, excluding data from plots where cover was less than 5% in both years.

Change in mean number of species in each species group per plot were also analysed based on aggregate class membership of plots in 1978.

***Results from ECOFACT***

The changes in species groups were complex, but several key themes emerge. In the crops/weeds (AC I), there were declines in plants associated with crops and increases in grassland plants, while the opposite occurred in fertile grassland (AC III). Grasslands in general, lost species groups. Woodland aggregate classes tended to lose cover in woodland species groups, especially in the lowlands where there were also increases in plants associated with crops on fertile soils. In the uplands, there appeared to be a tendency towards greater uniformity, in that heath/bog (AC VIII) tended to lose ericaceous species and gain grasses, with the opposite happening in moorland grass/mosaic (AC VII). There was evidence of decreases of scrub vegetation in the main plots, and of declines of species groups associated with damp habitats, especially in streamside plots.

## IBD8 – Change in frequency of aggregate class preferential species

***The nature of the indicator***

Different species were associated to a greater or lesser extent with particular aggregate classes. Those species that showed the strongest affinity with each class are termed aggregate class preferential species. They were selected on the basis of rejecting the null hypothesis that they were not positively associated with any particular aggregate class, using chi-square at $P < 0.05$. They may be abundant, intermediate or rare in each aggregate class. These species are characteristic of these broad vegetation classes, and so changes in their frequency may indicate very broad changes in the environment of these aggregate classes.

***Data available in ECOFACT Vol 2, Annex 19***

Data are available on the mean number of aggregate class preferential species per plot for each aggregate class, grouped by abundance, and analysed by landscape type and plot type, with changes between 1978 and 1990. While significance levels are given, it should be remembered that it is harder for scarce species to show statistically significant changes, and so consistency of directions of change becomes an important issue.

***Results from ECOFACT***

At the national level, 24 analyses are possible; eight aggregate classes with three categories of abundance for each. All but two of these analyses have shown declines (regardless of statistical significance). For analyses within individual landscape types, all but six out of a total of 55 analyses showed declines.

## IBD9 – Frequency of grassland indicator species

***The nature of the indicator***

While the CVS classifies vegetation statistically, it is not the only approach to analysing botanical change. Another is to consider the presence of species explicitly selected because they are associated with high value conservation habitats. To date, the data have been analysed as a case study that explores the techniques of analysing the distribution of scarce species and communities. For this purpose tests of change in frequency between 1978 and 1990 were carried out using lists of unimproved grassland indicator species compiled for acid, calcareous and neutral grasslands in England by English Nature (EN). Tests of difference in frequency of indicator species were also carried out between plot types for 1990 only.

***Data available in ECOFACT Vol 2, page 43***

Only one of the analyses has considered change since 1978, and so is relevant here. This is the analysis of change in the number of plots containing at least one of the EN grassland indicator species.

***Results from ECOFACT***

For lime-loving plants (calcicoles), the only significant change was in coastal areas, where the number of plots containing at least one indicator species increased by over 50%. There was a significant decrease of plots with acid grassland indicators at the GB level, consistent over all landscape types and strongest in the uplands. There was also a significant decrease in plots with mesotrophic indicators at the British level, strongest in the pastural landscape.

## IBD10 – Food plants for animal groups

***The nature of the indicator***

The ECOFACT research programme concentrates on botanical diversity. Yet there are ways of using vegetation data to investigate the diversity of animal groups, albeit indirectly. This indicator is a case in point. Data on animal/plant associations are particularly well established for butterflies and farmland birds, and so it is possible to estimate changes in the plants associated with these groups and relate them to observed changes in the animal populations themselves.

***Data available in ECOFACT Vol 2, pages 48–54***

Plant species have been identified that are associated with particular animal groups. The changes in frequency and cover of these species have been quantified between 1978 and 1990 by landscape type, aggregate class and plot type.

***Results from ECOFACT***

Plants associated with birds, bumblebees and butterflies have declined in adundance. Associations between changes in food plants and associated animals were particularly strong for butterflies and their larval host plants. Results for birds were less consistent, thus while thrushes have declined, their main food plants, notably bramble and ivy, have increased. Seed-eating birds have declined alongside their main food plants. These results point to the importance of other factors, not least animal food sources during the breeding season. In general, those species identified as food plants that have increased were associated with either scrub or nutrient-rich grasslands.

## IBD11 – Frequency of scarce species and NVC categories

***The nature of the indicator***

Inevitably, results for scarce plants and communities are less robust from Countryside Survey data than for more widespread species. Nevertheless, there are ways of using Countryside Survey data to elucidate some of the changes in these groups of conservation importance. First of all, one can combine records of rare species with similar habitat or other characteristics. In general, however, more targeted surveys such as Stewart *et al.* (1994) are to be preferred for this approach (see Bunce *et al.* 1999b, page 41). Another approach is to use the more widespread species characteristic of communities and habitats, using classifications such as the National

Vegetation Classification (NVC) (Rodwell 1991).

***Data available in ECOFACT Vol 2, pages 41–44***

A case study analysis was conducted on the joint occurrence of species typical of the neutral managed grassland NVC community MG5 *Centaurea nigra – Cynosurus cristatus* mesotrophic grassland (Rodwell 1992). Plots were located with different numbers of these species.

***Results from ECOFACT***

Seventeen plots had four of the most characteristic species of MG5 in 1978, and all of these increased in the number of MG5 species by 1990. Each plot was located using the original record sheets, and all seemed to share common constraints on productivity (eg steep slopes, road verges, western situations on poor soils) (Box 13, page 66).

## IBD12 – The mean number of CVS vegetation classes per 1 km squares

***The nature of the indicator***

This indicator assesses the $\beta$ diversity (Whittaker 1977) of vegetation assemblages at the 1 km scale. It is thus sensitive to factors such as the homogenisation of landscapes at the local level.

***Data available in ECOFACT Vol 2, page 27***

Results are currently available for 1990 only, expressed by landscape type and also by plot type. No analysis of change is possible until CS2000 data become available.

## Discarding redundant IBDs

Not all of the twelve IBDs are available for considering vegetation change between 1978 and 1990 and so cannot be used in this study.

*Table 3.* Summary of hypothesised links between driving forces and selected Indicators of Botanical Diversity. (y = indicator expected to convey effect of driving force, n = indicator unable to convey effect)

| Driving Force | IBD1 Shifts between AC | IBD2 Shifts at CVS class level | IBD3 Analysis of change in functional attributes | IBD5 Species richness changes | IBD6 Ellenberg score changes | IBD7 Change in freq. and cover of spp groups |
|---|---|---|---|---|---|---|
| **Eutrophication** | | | | | | |
| Atmospheric deposition | y | y | y | n | y | y |
| Agricultural fertilisers | y | y | y | n | y | y |
| Waterside eutrophication | y | y | y | n | y | y |
| **Acidification** | y | y | y | n | y | y |
| **Urbanisation and transport** | | | | | | |
| Loss of land cover to built | n | n | n | n | n | n |
| Road verge management | y | y | y | n | y | y |
| **Agricultural intensification** | | | | | | |
| Crop management & pesticide use | y | y | y | y | y | y |
| Grassland cultivation | y | y | y | n | y | y |
| Upland sheep grazing | y | y | y | n | y | y |
| **Drainage** | n | y | n | n | y | y |
| Waterside management | y | y | y | n | y | y |
| **Forest management** | | | | | | |
| Broadleaved planting | n | n | n | n | n | n |
| Broadleaved management | y | y | y | n | y | y |
| Conifer planting | y | y | n | y | n | y |
| Conifer management | y | y | y | n | y | y |
| Hedgerow management | y | y | y | n | y | y |
| *Corresponding annex/page in Bunce* et al. *1999b* | *annex 15* | *annex 16* | *page 55* | *annex 10* | *annex 20* | *annex 14* |

These are, IBD4 (CVS classes unique to 1 plot type per km square), IBD10 (food plants for animal groups), IBD11 (frequency of scarce species and NVC categories) and IBD12 (CVS classes per 1 km square). They will potentially be available for analyses with CS2000 data, however.

The hypothetical relationships between driving forces and IBDs are summarised in Table 3. It transpired that IBD8 (changes in the frequency of aggregate class preferential species) and IBD9 (changes in frequency of EN indicator species) shed no light on individual driving forces, and so these are not considered further in this process, although they are important in assessing the conservation significance of vegetation changes. Furthermore, two driving forces can also be excluded at this point. The change of land cover to built land cannot be analysed using the IBDs, and in any case, changes in land cover are more appropriate. Also, the effects of broadleaved planting are considered undetectable using the available information, as its effects cannot be confidently separated from those of other driving forces, such as scrub development resulting from extensification or abandonment.

## The IBDs and the Indicators of Sustainable Development

The IBDs also feed into other higher level statistics on the state of the environment. Three such indicators were used in the 1996 list of Indicators of Sustainable Development (DOE 1996), namely species number per plot (ie IBD5) for semi-improved grassland, hedgerow plots and streamside plots. Species number is a core indicator of trends in plant biodiversity under the revised Strategy (DETR 1999).

# THE CAUSES OF CHANGE IN BRITISH VEGETATION 1978–90

*It is difficult to establish with certainty the causes for the botanical changes observed. This is partly because many different factors act in concert so that the individual effects of one driving force cannot be separated from another. Also, different factors may give the same pattern of change. Our approach was to consider the likely vegetation changes resulting from each major driver of vegetation change (in terms of the different indicators we have developed), and to consider the likely location of the change (whether in open land or by linear features, whether in the uplands or the lowlands, and so on). We hypothesised an expected pattern of vegetation change for each driving force based on independent published evidence, and looked for the extent of correspondence with detected changes in Countryside Survey vegetation data.*

*Matches between observed and expected changes were particularly strong for the effects of increased nutrients (eutrophication), especially from agriculture, leading to reduced species richness and increase of already widespread, tall, competitive plants at the expense of slower growing, more localised plant species. The expected effects of increasingly intensive management of crops were also seen, in particular the loss of diversity within the fields, especially of spring germinating plants that are important food resources for birds and invertebrates. Changes from upland heaths to grasslands are consistent with increased sheep grazing, but these effects were confounded with those of atmospheric deposition of nutrients. There were clear effects of canopy closure of upland conifer canopies on field-layer vegetation, but otherwise evidence of consistent vegetation changes in woodlands was limited. Evidence for road verge vegetation becoming taller and more nutrient-rich was consistent with reductions in cutting frequency and increasing inputs of nutrients. We found no sign of the effects of acidification (although these may have been masked by other driving forces, notably eutrophication), and little evidence of widespread changes in land drainage.*

## Introduction

Different indicators are sensitive to different driving forces, and to different sections of the indicator/driving force relationship. Thus small shifts in mean Ellenberg scores may represent transient changes in the relative abundance of particular species, while changes in aggregate classes are more likely to reflect more profound changes that are difficult or impossible to reverse. Because of the stratified structure of the analyses, changes in different IBDs can be located within different landscape types, linear features and habitat types. It is therefore possible to discriminate between the effects of different driving forces in terms of location in the countryside. It is also possible to hypothesise the pattern of change in each IBD anticipated in response to each driving force. Provided that pattern is unique to that driving force, it is possible to estimate how important the driving force has been on the basis of the ECOFACT analyses.

The principles of the approach are given in Box 14 (page 67). The first steps have already been described, the list of driving forces has been selected, and the appropriateness of Countryside Survey botanical data as a means of detecting resulting changes between 1978 and 1990 has been considered for each. Then, the expected locations of effects in the landscape were hypothesised for each driving force in turn.

In this section, we consider the botanical changes expected from each driving force, in terms of which IBDs are likely to have been affected and how. These expected effects, and their locations, are compared with observed botanical changes. Additional information from the case studies within ECOFACT is used to help interpret data (Boxes 17 and 18). A close correspondence between observed and expected changes suggests that the driving force has indeed been a cause of botanical change (Box 14, page 67).

The information supporting this section is found in the Annexes of this report. Each Annex considers one of the driving forces and sets out expected and observed IBD responses and the degree of correspondence between the two. The agreement between observed and expected is indicated as good, moderate, poor or no match. Worked examples of the approach are given in Box 15 (page 68).

## Eutrophication

(see Annex 1, page 83)

There are many sources of evidence of eutrophication from the Countryside Survey data. Shifts in aggregate vegetation classes and Ellenberg scores are consistent with eutrophication.

### *Atmospheric deposition*

The expected changes were of uniform increases in nutrient status across plot types and landscape types. While there were increases in nutrient status, they were not uniform. In general, agreement between observed and expected results were moderate reflecting the lack of a ubiquitous effect across less-fertile vegetation in plot types.

### *Agricultural fertilisers*

The expected pattern of agricultural nitrogen usage was that effects would be seen in the main plots on arable and especially grassland aggregate classes. The matches between observed and expected patterns were almost all good.

### *Waterside eutrophication*

For this driving force to have been important, there should have been increases in nutrient status in the streamside plots. While this was true to some extent, there were exceptions. In particular, there was no evidence of expected shifts in CVS classes (IBD2).

### *Conclusion*

**The results from ECOFACT suggest strongly that eutrophication may well have been a major cause of vegetation change between 1978 and 1990.** The agreement between observed and expected patterns of change is particularly close for increased nutrient inputs on agricultural land.

However, it is an oversimplification to assume that the different forms of nutrient inputs act independently. An ECOFACT case study of nutrient inputs into upland vegetation suggests a positive feedback between the effects of atmospheric deposition and grazing. Sites in areas with a high atmospheric deposition of nutrients develop a more productive vegetation, which is in turn likely to be grazed more heavily by sheep, which in turn, causes more gaps for grass to colonise and more dung is input into the system (Box 16, page 72). The two driving forces could thus combine to increase the patchiness of upland vegetation.

## Acidification

(see Annex 2, page 84)

Even hypothesising the expected response to changes in acid deposition is far from straight forward. The driving force itself reduced in intensity over the study period, but the degree to which the effects of the driving force are subject to timelags and cumulative effects is not clear across the range of British vegetation since much of the research has been concentrated on freshwater bodies and forest crown condition.

We have assumed that an increased effect of acidification was expected, but it was not observed. In particular, Ellenberg pH scores increased rather than decreased. There were no observed decreases in the calcareous grassland or base-rich woodland classes.

### *Conclusion*

**There is no evidence that acidification has had a widespread national effect during the study period,** although this does not invalidate other evidence of more local effects (eg Kirby *et al.* 1996). However, nor is there evidence that the reduction in acidification has been responsible for vegetation change. It is possible that the increase in Ellenberg pH score reflects increases in more generalist species that have increased because of eutrophication.

## Road verge management (urbanisation and transport)

(see Annex 3, page 85)

As already discussed, Countryside Survey vegetation data do not, in general, provide a suitable means of analysing the effects of urbanisation. However, the analysis of the roadside plots can be used to assess the causes of vegetation change on road verges.

#### *Lack of management*

Reduced cutting frequency would favour shifts in the vegetation towards taller, more competitive species of grassland and scrub along roadsides. This is indeed what was observed.

#### *Eutrophication*

The shifts towards more competitive species can also be a symptom of eutrophication, and, indeed, Ellenberg fertility scores did tend to increase along roadsides. However, a dramatic increase in nutrient inputs would have been expected to have caused a general shift in grassland aggregate classes towards more fertile types of grassland; this did not happen.

#### *Increased disturbance*

Increased disturbance would have been expected to favour weedier vegetation. However, this was only observed in that species-rich CVS classes became scarcer, and weedier CVS classes became more frequent.

#### *Conclusion*

**There does seem to have been a decline in the intensity of road verge management that has allowed the vegetation to become taller and dominated by more competitive species.** A case study of road verges in Cumbria (Box 17, page 74) supports this conclusion. Detected increases in more competitive species and a loss of typical hay-meadow species were thought to reflect a continuing response to very infrequent full width cutting in preceding decades.

Increasing trophic status was likely to have been favoured by atmospheric deposition of nutrients associated with increased traffic volumes and the fact that cuttings are typically left on verges rather than being removed.

## Agricultural intensification

(see Annex 4, page 86)

The hypothesised location of vegetation change due to agriculture was in fields (ie the main plots). Eutrophication resulting from agricultural inputs has already been discussed above.

#### *Crop management and pesticide use*

More intensive crop management practices were expected to have resulted in increased rotation between crop and grassland categories, reductions in species-richness of crops, and shifts to autumn-germinating weed species. All of these were observed.

#### *Grassland cultivation*

The analysis of vegetation data showed no signs of cultivation of grasslands, consistent with the low level of this particular driving force. There was an increase in crop and weed groups in grassland plots, but this may well have resulted from increased disturbance due to grazing regimes, maturing leys and rotation from arable to leys, rather than from cultivation of permanent grass. Marked shifts from AC IV (infertile grassland) to AC III (fertile grassland) and AC I (crops/weeds) would have provided evidence for net losses of older and more species-rich grasslands and tillage. Such shifts were not detected.

#### *Upland sheep grazing*

Expected vegetation change in response to increased sheep grazing consisted of an increase in more fertile grassy vegetation in main plots in the uplands and marginal uplands, especially at the expense of heaths and bogs. These changes were indeed observed, and the agreements between observed and expected were typically moderate or good. Furthermore, the effects of sheep grazing were probably confounded with effects of eutrophication (Box 16, page 72) and possibly drainage.

#### *Conclusions*

**The results show a wide range of effects of agricultural intensification in both arable and grassland systems, with moderate correspondence between observed and expected effects of increased grazing pressure in the uplands.**

## Drainage and waterside management

(see Annex 5, page 87)

Results must be interpreted with caution, because of the different weather conditions in the months before the two surveys (Box 5, page 55) – it was hotter and (in England and Wales, but not in Scotland) drier in 1990 than in 1978.

#### *Drainage*

The expected pattern of drainage was for changes towards drier CVS classes, species groups and Ellenberg scores. There was moderate rather than total agreement with the observations, and in some cases wetter vegetation was more frequent.

#### *Waterside management*

The driving force is considered to have either been towards over-management, which would have resulted in the loss of much waterside vegetation, with taller communities reverting to shorter, grassland or ruderal communities, or alternatively neglect. In fact, the results agree well with those expected from dereliction, with increases in competitive, tall herb plant communities in waterside plots.

#### *Conclusion*

**The effects of drainage were not clearly detected from these analyses. Waterside vegetation became ranker, consistent with reduced management and neglect.**

## Forest and hedgerow management

(see Annex 7, page 88)

#### *Forest management*

A variety of driving forces operated in woodland during the period of study, including clearfelling, neglect, overgrazing and planting. The driving force most consistent with the evidence of vegetation change has been the planting of conifers in the uplands, with increases in the conifer vegetation classes and declines in speciesrichness in the uplands. Evidence for the effects of other driving forces was inconsistent, especially in the lowlands.

#### *Hedgerow dereliction*

Hypothesising the pattern of vegetation change that would result from hedgerow dereliction is complex, as hedges become both overgrown and gappy, resulting in a divergence of vegetation change that is much more difficult to identify than a uniform trend. Thus, in some cases, Ellenberg light scores increased, in others, they decreased. There was evidence of eutrophication in hedgerows. In general, the level of agreement between observed changes and results expected on the basis of hedgerows becoming overgrown was moderate.

#### *Conclusion*

**The planting of upland conifers, in particular Sitka spruce (*Picea sitchensis*), has had a clear effect on botanical diversity.** The effects of the management of lowland woods and even hedgerows are, however, difficult to identify because of the tendency of reduced management to lead to a greater diversity of gross vegetation structure, from dense shrub to open areas.

# THE MAIN DRIVERS OF VEGETATION CHANGE IN THE WIDER COUNTRYSIDE

*Correspondence values, showing the match between observed and expected results, were ranked to give an idea of the relative importance of different driving forces, but they must be treated with caution. They reflected the different degree to which effects could be detected using this methodology: some patterns of effects were easier to detect than others, some drivers of change were easier to consider separately than others. Nevertheless, overall, the evidence for effects of agriculture, notably in terms of nutrient addition and crop management of crops, was striking for the period of this study.*

## The results – the comparative effects of the driving forces

The degree of correspondence between observed and expected change was expressed by giving a high score for a good match and a zero score for no match, and correcting for the number of IBD values used for each driver. The results are shown in Table 4, ranked in order of correspondence.
The highest correspondences were given by road verge neglect, conifer planting, and the effects of agricultural fertiliser. Matches were poorest for acidification and broadleaved woodland management.

## The interpretation of the results

Table 4 represents the results of this particular research exercise. But what do they mean? The table provides a ranking of the ease with which the effects of the different driving forces were detected using the Countryside Survey vegetation data. A simple interpretation would be, the higher the correspondence, the greater the importance of the driving force during the period of study. However, this interpretation is not necessarily correct, for several reasons.

***Not all driving forces have been considered***

Several major driving forces have been excluded from these analyses, for a variety of reasons, not least because their effects cannot be distinguished easily from those of other driving forces. This does not mean that they have not had an important effect. It should be noted that the effects of different but

*Table 4.* Ranking the main driving forces of botanical change

The correspondence indices are *only a guide* to the potential importance of each driving force in terms of detected effects in Countryside Survey data. A detailed account of the possible location, confounding factors and importance of each driving force is given in the text and annexes in this report.

The correspondence index is calculated by:

1. Allocating a score to each category of match between expected and observed;
   0 = NO MATCH, 1 = POOR, 2 = MODERATE, 3 = GOOD.
2. Summing these scores and dividing by the total sum of scores that is possible. If there are five hypotheses then an overall GOOD match between expected and observed will give a maximum score of 15. If only two matches were GOOD, and the remaining three were MODERATE, then the actual score is 12. The index is then 12/15 = 0.8.

The number of available IBD states shows how many indicator variables were used to make the comparison between each driving force and its expected effects. Fewer variables mean that an assessment of the importance of the driving force was based upon less information.

| Driving Force | Correspondence index | Number of available IBD states |
|---|---|---|
| Road verge management – neglect | 1.0 | 5 |
| Conifer planting | 1.0 | 3 |
| Agricultural nitrogen usage | 1.0 | 5 |
| Crop management & pesticide use | 0.8 | 5 |
| Upland sheep grazing | 0.8 | 5 |
| Waterside management – neglect | 0.8 | 5 |
| Atmospheric deposition of nutrients | 0.7 | 5 |
| Catchment eutrophication | 0.7 | 5 |
| Road verge management – eutrophication | 0.7 | 5 |
| Drainage | 0.7 | 3 |
| Hedgerow neglect | 0.6 | 5 |
| Grassland cultivation | 0.4 | 5 |
| Conifer clearfelling | 0.4 | 4 |
| Road verge management – disturbance | 0.3 | 4 |
| Broadleaved – overgrazing | 0.2 | 2 |
| Acidification from atmospheric deposition | 0.1 | 4 |
| Broadleaved – dereliction | 0.1 | 4 |
| Broadleaved – clearfelling | 0.0 | 4 |

closely-related driving forces were sought from national surveillance data that, by definition, lacked designed interspersion of controls and treatments.

***Relationships between driving forces and vegetation may be non-independent, non-linear and non-equilibrium***

The procedure used here assumes that relationships between vegetation and driving forces show at least a reasonable rank correlation and are in reasonable equilibrium. Yet as we have already discussed, this is not always true. Many driving forces are likely to have cumulative effects on vegetation. Also, again as already discussed, separate driving forces are not independent of each other.

***Some patterns of responses are easier to detect than others***

It is perhaps no coincidence that the highest scores were given by drivers that operate in a manner that is concentrated among the strata of the Countryside Survey analyses. Their effects are easier to detect compared with drivers that operate in a wider range of strata, where they are easily confounded with other factors. On the other hand, those drivers of change with poor correspondence between predicted and observed findings include woodland management, acidification and hedgerow neglect, for which the expectations are less certain than for some other drivers, either because of divergent expected outcomes or because of limited understanding and limited evidence of the effects to be expected. Furthermore the models used to generate expected responses were preliminary, with much scope for further refinement, for example, in the use of critical loads and calibrating IBD responses with experimental data. The results of Table 4 should be regarded as indicating the effects of the different drivers, as opposed to providing a definitive statement.

***Effects of agriculture are clear***

Even taking all of these factors into account, the high degrees of correspondence between observed and expected findings for agricultural practice are striking. They are highest for nitrogen usage and crop management – drivers in a rapid state of flux during the study period compared with drainage and grassland cultivation.

The fact that correspondence levels for the effects of nitrogen deposition from the atmosphere were less than for agriculture can be explained by agricultural inputs being additional to atmospheric inputs. This does not necessarily make one source of nitrogen more important than the other, especially as they can act synergistically.

# THE POLICY IMPLICATIONS OF BOTANICAL CHANGE

*The results of the Countryside Surveys of 1978 and 1990 showed clear declines in vegetation diversity which were strongly correlated with human-induced factors, notably agriculture, forestry and possibly air pollution. Developing the appropriate policy response requires an understanding of the processes of vegetation change. In some cases, the changes we have seen may be irreversible. In others, we may need to target new kinds of habitat that have received little attention so far, such as road verges. Conservation policies may need to distinguish between regeneration scenarios that are favourable for biodiversity, in which case a large number of small patches of diverse vegetation can act as sources for recolonisation of the countryside, and fragmentation scenarios, which may require areas large enough to sustain species. It is worth distinguishing the different mechanisms by which policies affect biodiversity; they may be targeted at particular species or habitats, they may be targeted at a particular driving force, or may have incidental effects on biodiversity.*

## Assessing the importance of botanical change

The changes in British vegetation between 1978 and 1990 are consistent with the effects of the reduced management of road verges, conifer planting, intensive agriculture and aerial deposition of pollutants. However, this information does not, in itself, imply that the changes need be of conservation or policy concern. Such concern is only required if *biodiversity quality* is falling to an unacceptable level, or is declining at an unacceptable rate. Therefore, in order to develop appropriate responses to vegetation change, the effects of driving forces on quality need to be established.

Quality involves both subjective and objective elements. The subjective element is the perception of what the preferred state system should be like, the objective element is the extent to which the observed matches the ideal. To do this, the preferred state needs to be described in measurable terms around which there is some degree of consensus. There has been considerable effort in the United Kingdom to establish such consensus, and now there are a variety of statements that define (to a greater or lesser degree of completeness) what is high quality in terms of biodiversity. In general, these statements (including the NVC (Rodwell 1991) and, especially, the Biodiversity Action Plan (Anon 1995a; 1998b) attempt to deal with diversity as a key element of quality, particularly diversity at global, national and regional scales. Thus the presence of a single, globally rare, species is considered of greater importance than the presence of numerous, but common and widespread species. There is also a growing literature on including taxonomic distinctiveness to qualify measures of diversity (eg Clarke & Warwick 1998). Apparancy to humans is a factor – species with public resonance, such as the otter or the skylark, will tend to have a higher significance than those without such resonance, such as soil invertebrates. The organisms required by such a rare species (eg for food, or habitat structure) also take on an added ecological quality of their own. As the ECOFACT Volume 2 report puts it, "The quality of vegetation depends upon an anthropocentric assessment of its value according to its abundance, its contribution to the perception of high environmental character, or its importance to other elements of biodiversity which are regarded as of value in their own right." (Bunce *et al.* 1999b). These attributes are enshrined in the criteria for SSSIs; they should "comprehensively cover the major conservation interests .. in terms of the best examples of the full range of natural and semi-natural ecosystems...; include sites necessary to support viable populations of vulnerable, endangered or nationally scarce species" (DETR 1998).

Let us reconsider the model of vegetation change developed in Box 3 (page 53). The effects of driving forces on vegetation have been explored by selecting indicators of botanical diversity that respond to changes in the driving force along the *x* axis, such as Ellenberg scores. However, the assessment of quality is best expressed in changes along the *y* axis, that address the extent of change in overall vegetation state, and the capacity for returning to an original state (Figure 2). Thus it is not surprising that not all IBDs were used in the analysis of causes of change, for some of them are good indicators *only* of these quality changes, and do not help to distinguish between different driving forces. These include especially IBD9 (the frequency of species indicating high quality grassland), IBD10 (the frequency of species that are important in animal diets) and IBD11 (the frequency of scarce species and communities). All of these may change in response to a variety of driving forces, from eutrophication to land management changes, but the appropriate conservation responses to the changes in these indicators may be different depending upon the driving force and its location. Thus indicators of quality are required to evaluate whether change is good or bad, and indicators of process are needed to assess cause and suggest options for remediation.

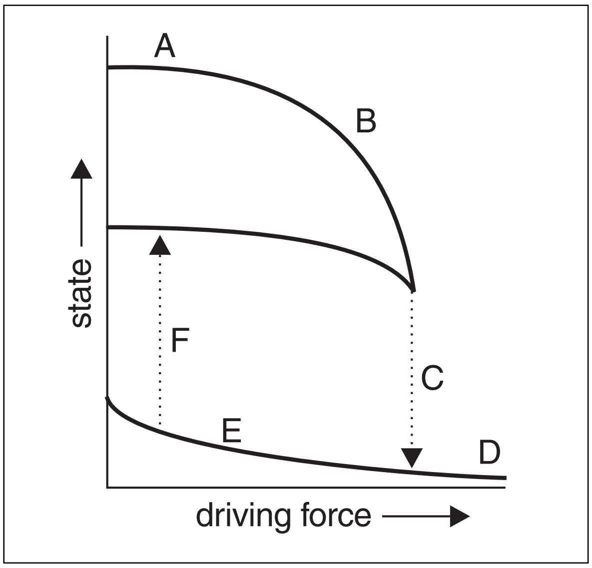



Figure 2. Relationships between an hypothetical biodiversity state and a driving force (see Box 3, page 53 for details).

## Driving force – botanical quality relationships and the implications to policy

The ECOFACT project explored the relationships between driving forces and botanical quality in a series of case studies that illustrate some of the issues concerning the use of vegetation data to develop appropriate policy responses.

#### *The effects of non-catastrophic vegetation change on vegetation quality*

In Figure 2, it is suggested that even before there is a catastrophic decline in the state of vegetation as a driving force increases, there are shifts in character. These can be described using indicators that are responsive to the particular driving force, as we have seen. However, they can also be described using quality indicators. One of the case studies considered the effects of the intensity of agricultural management, as measured by grassland productivity, on a measure of quality, in this case species-richness, IBD5.

As expected, the higher the productivity, the less the species richness. However, the species richness was greatest in the field centres on unproductive fields, but in the field edges on highly productive fields. The field edges act as refuges for high quality vegetation in more intensive grasslands (Box 18, page 75). This information guides the appropriate response: efforts should be concentrated on those situations where quality has not degraded to a near-irreversible state. Thus, where the effects of agricultural intensification have been low, and can be kept low (eg by an agri-environment scheme, or by SSSI status), the whole field should be maintained. However, where the driving force is, or recently has been high, it is appropriate to concentrate the policy response onto field margins where patches of higher quality vegetation are more likely to have persisted, making successful restoration more probable. This could be achieved, for example, by encouraging reduced fertiliser inputs around field edges.

### *Locating high quality patches of vegetation*

For any given combination of vegetation and driving force, there is spatial heterogeneity, in that there will be patches strongly subject to the driving force, and other patches that have been much less exposed. If such patches can be located, and common factors identified, then it becomes easier to target policy and land management to help ensure that they are not lost.

This issue was addressed in a case study analysing species that together define the NVC community MG5 (Rodwell 1992), associated with lowland unimproved hay meadows (ie using IBD11). The plots richest in such species were not found in fields, as might have been expected, but were found on road verges, steep slopes, and other small patches of land that have escaped intensification (Box 13, page 66). The concentration of conservation efforts in agri-environment schemes on whole fields and field margins may thus allow many of these small patches outside the farm management system to be lost.

### *The restorability of vegetation*

The point at which vegetation change becomes catastrophic is when it can no longer be reversed simply by reducing the driving force. Identifying this point precisely is very difficult, as it depends upon the buffering capacity of the vegetation, which in turn depends upon the proximity of high quality vegetation patches and, in some cases, upon the condition of the seed bank.

One of the ECOFACT case studies addressed this issue by revisiting some of the grassland plots recorded in 1978 and 1990, and assessing both the vegetation and the seed bank. The species-richness of these plots (IBD5) had declined over time. It turned out that the composition of the seed bank was most similar to the contemporary vegetation, and so it cannot be relied upon as a resource for the restoration of vegetation quality (Box 19, page 77).

## The mechanisms of policy responses

A number of policy initiatives have been introduced in recent years that may have influenced the driving forces acting on botanical diversity in the countryside, during or since the period of this study. Some of these are noted in Table 5, along

*Table 5.* Relevance of some UK policy initiatives to drivers of botanical change in the wider countryside. (– = no effect, S = small impact may slow driver locally, C = may check its action, M = likely to have major impact of driver

| | Drivers of botanical change | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Policy initiative | Road verge management | Conifer planting | Agricultural fertilisers | Crop management and pesticide use | Upland sheep grazing | Waterside management | Atmospheric deposition of nutrients | Catchment eutrophication | Road verge management – eutrophication | Drainage | Hedgerow management | Grassland cultivation | Conifer clearfelling | Road verge management – disturbance | Broadleaved – overgrazing | Acidification | Broadleaved – neglect | Broadleaved – clearfelling |
| Biodiversity Action Plan | S | S | S | S | S | S | – | S | S | S | S | S | S | S | S | – | S | S |
| SSSIs and associated designations | – | S | – | – | S | S | – | S | – | – | – | – | – | – | S | – | S | S |
| Clean Air legislation | – | – | – | – | – | – | M | C | C | – | – | – | – | – | – | M | – | – |
| 1992 CAP Reforms | – | – | C | C | C | – | – | S | – | C | – | S | – | – | – | – | – | – |
| Arable Area Payment Scheme | – | – | C | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Beef Premium Scheme | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Sheep Annual Premium Scheme | – | – | – | – | C | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Further ESA designations | – | – | S | S | S | – | – | – | – | – | S | S | – | – | – | – | – | – |
| Habitat Scheme | – | – | S | S | – | – | – | – | – | – | – | S | – | – | – | – | – | – |
| Nitrate Sensitive Areas | – | – | M | – | – | – | – | S | – | – | – | – | – | – | – | – | – | – |
| Countryside Stewardship Scheme | – | – | – | – | S | S | – | – | – | S | C | S | – | – | – | – | – | – |
| Farm Woodland Premium Scheme | – | S | – | – | – | – | – | – | – | – | – | – | – | – | – | – | S | S |
| UK Rural White Paper 1995 | – | M | – | – | – | – | – | – | – | – | – | – | M | – | – | – | M | M |
| Hedgerow protection legislation | – | – | – | – | – | – | – | – | – | – | M | – | – | – | – | – | – | – |
| Less Favoured Areas | – | – | – | – | S | – | – | – | – | – | – | – | – | – | – | – | – | – |
| National Parks/AONBs | S | S | – | – | S | – | – | – | S | – | S | – | – | – | – | – | – | – |
| Local Authority Management Guidelines | S | – | – | – | – | – | – | – | S | – | – | – | – | – | – | – | – | – |

with the driving forces they may have affected. The relationships between policies and driving forces are, not surprisingly, highly variable. Some policies, such as the UK Biodiversity Action Plan, cut across a wide range of driving forces, but may affect each of them only to a small and localised degree. Other policies, such as the Clean Air legislation act in a much more substantial way on particular driving forces.

One can consider different policies as having different modes of action (Box 20, page 78). Some policies are aimed at maintaining, or creating, specified species or habitats. Such biodiversity target-led policies are intended to alter the balance between positive and negative driving forces acting on high quality habitats and species. The objective of these target-led mechanisms is to enhance, and/or to remove or manage threats to, a specific biodiversity resource (perhaps a range of species, or a set of habitats). The threats may come from a wide range of driving forces, and so local circumstances must be taken into account.

Any target-led policy needs to be very explicit, considering both scientific and social issues. For example, whether it is better to concentrate resources on a small number of high quality sites, or on a much larger number of medium quality sites, is a policy issue, not a scientific one (although science can be used to evaluate the implications of these two approaches). The expected environmental trends should be taken into account. If high quality sites are expected to remain situated in a hostile landscape matrix over many years, they need to support minimum viable populations, and conserving large areas, concentrated together, may be the most appropriate strategy. If the surrounding landscape is expected to become more favourable in the future, it may be more important to have a network of small, but well distributed habitat patches, from which species can recolonise other areas. While these issues sound complex, they are not intractable – indeed, for a given species or habitat, there is often enough knowledge available to produce an action plan for effective conservation. This is the approach of the UK Biodiversity Action Plan, which addresses priority species and habitats, from perspectives ranging from global to local (Anon 1994a; 1995a; 1998b).

The majority of agri-environment schemes can also be seen as target-led, in that they require the identification, protection and management of a tightly defined resource, although the resource includes goods other than biodiversity, such as landscape quality, access and the conservation of historical sites. Such issues were also addressed as part of the 1998 review of hedgerow legislation (Anon 1998c). Of all such policy initiatives and schemes introduced since 1990 the ones perhaps most likely to have had an influence on vegetation changes detectable by Countryside Survey 2000 are ESAs and Countryside Stewardship. Even these, however, are localised in their impact, and have relatively low levels of funding compared with the sums involved in subsidies and support through the CAP.

Some policies operate by manipulating a particular driving force. Of these, some are designed with biodiversity in mind, they include hedgerow protection legislation, as well as laws against hunting and egg removal. They operate by reducing the driving forces acting on biodiversity, regardless of the state of the biodiversity resource. There is a risk that some of the damage has already gone past the point of likely recovery, and also there is a risk that even though the driving force has been reduced, its effects may continue because of time lags.

More frequent are policies that are 'other sector driver-led', where the main purpose of modifying the driving force is other than specifically to benefit biodiversity. Such policies may have positive, negative or neutral effects on biodiversity. Examples include clean air legislation (aimed primarily at human health) and the set-aside scheme (aimed primarily at controlling surplus production). All driving forces considered in our analyses have been influenced by such policies (Table 5, page 45).

Finally, it should be remembered that the driving forces themselves are not independent from each other, nor do they operate in a vacuum. They must be interpreted in social, economic, political and technological contexts if they are to be understood and, ideally, policy should address their inter-relationships. Such an approach is being developed within the Sustainable Development Strategy for the UK (Anon 1995b; 1998d; DETR 1999). The Strategy has four main aims:

- social progress which recognises the needs of everyone;
- effective protection of the environment;
- prudent use of natural resources;
- maintenance of high and stable levels of economic growth and employment.

The challenges for managing the environment and resources include driver-led approaches, such as achieving major long-term cuts in greenhouse gas emissions, and target-led approaches, such as reversing trends of damage to our landscape and wildlife. Of the latter, key actions include stronger hedgerow protection and strengthening the protection of SSSIs, and indicators include trends in plant diversity. Biodiversity is of course affected by policies in other areas. Some of these relationships are explicit, such as the continued emphasis on agri-environment measures in agriculture, while others are not; thus challenges and targets for transport do not address impacts on road verges. Nevertheless, the strategy for sustainable development strives for “joined up thinking” (DETR 1999); an appropriate policy response to our increasing understanding of the complexities of driving force–pressure–state relationships.

# CONCLUSIONS

*Since the 1980s, there has been a number of policy initiatives aimed at countering the impacts of these different driving forces. These include the reform of the CAP, the development of the agri-environment schemes, the Strategy for Sustainable Development and the Biodiversity Action Plan following the Earth Summit in Rio. The results of Countryside Survey 2000 will show whether declines in botanical diversity have continued, or whether they have been halted or reversed. Also, analyses developed from the ones used here will be able to ascribe causes to the changes that are observed. Such information is essential for the delivery of sustainable development.*

## The objectives of the research

The original objectives of this research were:

- **To identify the causes of observed changes in botanical diversity**
  This has been achieved, as far as is possible given the nature of the data available. Effects of agricultural intensification, road verge management, conifer planting in the uplands and (to a lesser extent) atmospheric nitrogen deposition have all been identified at the national scale. However, not all possible causes of change have been included in our analyses, also the interaction between the effects of different causes of change have not been addressed fully.

- **To assess the relative importance of land management and other factors, such as pollution**
  The results have indicated that land management has certainly been highly influential on changing botanical diversity. The effects of acidification have been small in comparison. The effects of fertiliser inputs and grazing pressures are apparent at the national scale, but these are hard to fully separate from those of aerial deposition, as they are not entirely independent.

- **To recommend land management practices for the maintenance and enhancement of diversity**
  Our analyses suggest how policies can be assessed in terms of their relationships to driving forces, implying that more quantitative models of policy impacts on biodiversity can be developed.

- **To develop predictive techniques for determining ecological impacts**
  The driving force–state–response model does provide a basis for predicting ecological impacts from changes in policy and land management, especially when the non-linear nature of the relationships are quantified. However, we need to know more about the dynamics of these systems before we can claim to have a genuinely predictive science for assessments of impacts on biodiversity.

## Looking ahead to CS2000

We are starting to clarify the relationships between ecological theory, field survey, experimentation and policy development that must be invoked if we are to reverse trends of damage to our landscape and wildlife (*cf.* DETR 1999). However, there is still some way to go.

The next field survey in the Countryside Survey series, CS2000, is due to report initially in 2000. The interpretation of these data can go beyond what we have attempted in this report for several reasons:

- **The science of driving force–pressure–state relationships is evolving rapidly**
  This is a rapidly developing area of research, and the availability of data on driving forces is far greater now than in 1990. For example,

MAFF will have published 'Indicators of Sustainable Agriculture' by the time CS2000 data will become available.

- **There is a longer time series available**
  CS2000 will allow results to be compared over a 20 year period, with a midpoint in time. This allows an improved estimate of longer-term changes. The dynamics of certain pressures can also be assessed to some degree.

- **Sample sizes are larger**
  The sample size has increased from 256 1 km squares in 1978 to 569 in 1998–99, allowing larger samples within the cells of the stratification when considering changes from 1990–98.

- **There have been substantial changes in driving forces**
  The period 1990–98 has seen great changes in environmental policy, particularly with agri-environmental schemes, new pollution controls and national and regional biodiversity action plans. In general, these changes would be expected to have enhanced biodiversity, but much depends upon the dynamics of other pressures, and upon the cumulative and delayed effects of driving forces in the past. The careful targeting of biodiversity action plans and some agri-environment schemes may bring important but localised benefits with less effect on the countryside and a whole.

- **It will be possible to generate better models of expected vegetation change**
  This report has mapped out a framework for analysis, within which other information can be placed. Thus, research into critical loads can be used to provide expected spatial distributions of effects. Data from controlled experiments can be re-analysed using the CVS to help formalise expected dose-response relationships on particular soil type and climate conditions and to confer greater precision on expected botanical changes. Data from agri-environment monitoring schemes can also be re-analysed to model expected rates of biodiversity change according to different starting points and driving forces.

## Conclusion

The Countryside Survey approach has shown evidence of biodiversity declines, and has been used to indicate the likely driving forces behind these declines. Since the 1980s, there has been a number of policy initiatives aimed at countering the impacts of these different driving forces. These include the reform of the CAP, and the development of the agri-environment schemes, the UK Strategy for Sustainable Development and the Biodiversity Action Plan following the Earth Summit in Rio.

The fieldwork for CS2000 has now been completed, and, using the methods developed in the ECOFACT project, the results will show whether the negative trends observed thus far have been halted or reversed. We will also be able to link causes to any effects we observe with greater sensitivity than is possible at present. This work will be of great value in delivering sustainable development in the future.

# BOX 1 – THE ECOFACT PROJECT

The main results of CS1990 were published in the Main Report in 1993 (Barr *et al.* 1993). However, this work is only one element of a much larger body of work, published as the Countryside 1990 series, with the following volumes published by the Department of the Environment (now DETR).

- Ecological Consequences of Land Use Change.
- Countryside Survey 1990 Main Report.
- Comparison of Land Cover Definitions.
- Development of the Countryside Information System.
- CORINE Land Cover Map: Pilot Study.
- Countryside Survey 1990: Inland Water Bodies.
- Processes of Countryside Change in Britain.
- Environmental Accounts for Land Cover.
- Countryside Survey 1990: Policy Review.

In 1995, ITE prepared a research project to look at Ecological Factors Controlling Biodiversity in the British Countryside (ECOFACT). This was designed as a modular project, aimed at developing the science of interpreting countryside change, while preparing the ground for CS2000. ECOFACT was sponsored by the Department of the Environment, Transport and the Regions (DETR), Ministry of Agriculture, Fisheries and Food (MAFF), the Scottish Executive (SE) and the Natural Environment Research Council (NERC).

The major results of ECOFACT are being reported as three volumes:

***Volume 1 – Vegetation of the British Countryside***

One of the key outcomes of ECOFACT was a new system of classifying British vegetation. This volume gives full details of the classification, and descriptions of the 100 classes and eight Aggregate Classes (Bunce *et al.* 1999a).

***Volume 2 – Measuring change in British vegetation***

This volume describes the vegetation of GB in 1990, and how it has changed since 1978 using a variety of established and novel measures. The changes are presented in terms of a range of Indicators of Botanical Diversity. It includes technical annexes which give details of the statistics of vegetation stock and change (Bunce *et al.* 1999b).

***Volume 2: Technical annex – Ellenberg's indicator values for British plants***

Contains Ellenberg's values for each plant species. These scores provide estimates of the range of ecological conditions at which species, on average, reach peak abundance. The values were calibrated for the British flora and terrestrial vegetation using the original scores, Countryside Survey and NVC data.

***Volume 3 – Causes of change in British vegetation***

The present Volume, which interprets the statistics presented Volume 2 in terms of a series of driving forces known to have operated between 1978 and 1990.

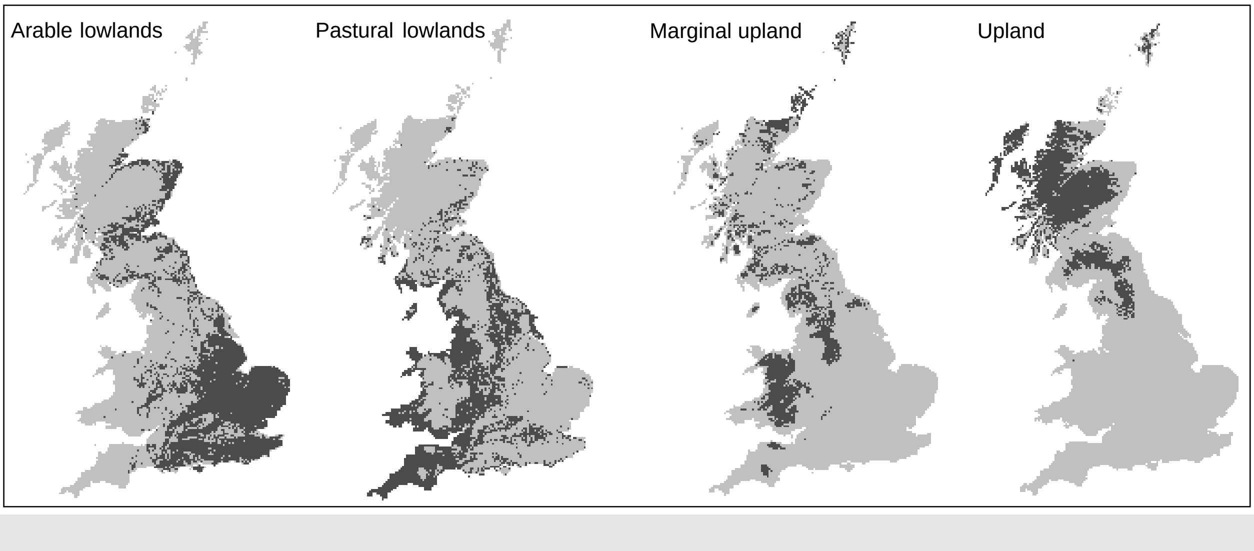
# BOX 2 – THE ITE LAND CLASSIFICATION AND THE FOUR LANDSCAPE TYPES

It is possible to pool information about national changes in land cover, land use and biodiversity. However, such data cannot be readily interpreted in terms of cause and effect because of the huge variation within and between different parts of the landscape of GB. The chances of detecting meaningful change are greater if analyses can be stratified by large-scale units that divide up variation, grouping like with like. The ITE Land Classification was designed to group together areas of GB with similar environmental characteristics, which therefore tend to have similar land uses and similar habitats.

The classification involved the analysis of a series of environmental attributes for every 1 km square in GB. These attributes included climate, geology, topography and elements of human geography. They excluded land use and vegetation, as the classification was intended as a basis of showing how these dependent factors change through time. The 1 km squares were then aggregated based upon similarity in environmental attributes, generating four major landscape types which could be used as a robust and meaningful way of partitioning Countryside Survey data for analyses of change (Bunce *et al.* 1996).

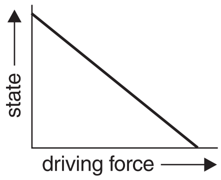
Different human and environmental processes take place between the four types. The arable lowlands is dominated by arable agriculture, and contains the intensively farmed region in south and southeastern England areas, which also have a relatively high population density. The pastural lowlands has a higher rainfall, and so has more grassland, as well as more hedgerows and woodlands. The marginal uplands are characterised by grassland, open moorland and forestry which are often heavily influenced by grazing and contain areas with high inputs of aerial pollutants compared with their critical loads. The uplands are typically remote and mountainous. Here, vegetation consists of montane grasslands, and is dominated by dwarf shrub heath and bog with large areas grazed by sheep.

Several important changes in land cover and vegetation have been reported separately for each landscape type, facilitating the analysis of causes of change. In CS1990 (Barr *et al.* 1993) and in ECOFACT Volume 2 (Bunce *et al.* 1999b) these four landscape types were used to partition change in land cover (eg increases in oil-seed rape), landscape features (eg changes in hedgerow characteristics), as well as changes in botanical diversity. Such changes are detected sensitively because the landscape types coincide with broad differences in land use. The stratification, therefore, offers a useful framework for exploring causes of change.

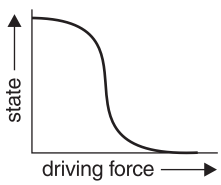


# BOX 3 – THE DYNAMICS OF ECOLOGICAL CHANGE

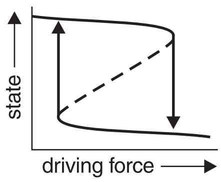
At first sight, the driving force–state–response model may give an impression that changes in one factor are proportional to changes in the others, and that if the 'state' is deteriorating, then the appropriate 'response' is to reduce the 'driving force'. This assumes that the relationships are linear and at equilibrium. However, ecological systems are rarely so well behaved, and show non-linear behaviour which makes interpreting and responding to ecological change far more difficult.




***Linear***
A linear response is where the biodiversity state is proportional to the driving force. The driving force is here assumed to be negative – the greater the force, the lower the quality of biodiversity.

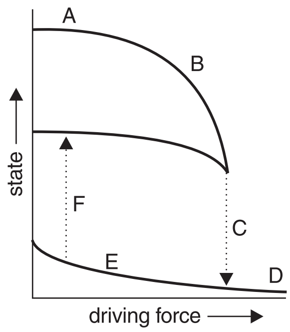



***Threshold***
A degree of driving force can be absorbed with little or no effects. Once that threshold, or 'critical load' has been exceeded, harm occurs, but it is reversible.




***Catastrophe***
If the change is catastrophic then once the critical load has been passed, the biodiversity crashes to a much lower level, which cannot be reversed without major reductions in pressure. Often other actions are required, such as re-introduction of species.

**We suggest that vegetation change is essentially catastrophic in nature, albeit with some scope for recovery at limited levels of damage, and some scope for restoration with greater inputs of effort. It is clearly more efficient to concentrate efforts to conserve biodiversity on those vegetation stands that have not already shifted to a state of lower diversity.**




## Modelling vegetation change

The results of this project allow us to build a general model of vegetation change in response to a wide range of driving forces. Starting from high-quality vegetation, a negative driving force will cause a slight decline at first, probably within the range of natural fluctuations (A). Then it becomes steeper – proportions of functional groups and individual species shift, along with mean Ellenberg scores (B) give warning of irreversible change. At this point, the vegetation can be restored by a reduction in the pressure, as the species are still present in or adjacent to the stand, or in the seedbank. Eventually a point is reached (C) where the vegetation shifts to a new state, a new CVS class or even a new aggregate class. While continued increases in the pressure will cause continued degradation (D), the species composition has altered to the extent that a reduction in the pressure is no longer sufficient to restore the original state of the vegetation (E). The spatial scale of the pressure affects point C, as a localised change is more reversible than a widespread one. Even the deliberate re-introduction of species (F) can only recreate a facsimile of the original community, as many members of the complex interacting assemblages of micro-organisms, animals and mycorrhizae may have been lost.

# BOX 4 – ENVIRONMENTAL INDICATORS

It is simply not possible to completely define and measure every aspect of environmental change, and even if it were, the amount of information would be so enormous that it could not be comprehended. Given that the amount of information that we can record and interpret is only a tiny subset of all that could be measured, it is important that this subset gives added value by providing insights about what the rest of the information would show, were it available. We need good 'environmental indicators'.

An ideal indicator is representative, scientifically valid, easy to interpret, sensitive to changes in the system it is intended to indicate, can be readily updated to known quality standards, and shows trends – especially early signs of irreversible change. In practice, there are few ideal environmental indicators, and so it is better to combine them into groups that cover the system to the required levels of completeness and detail.

The recent increase in data availability, and the increasing level of obligations concerning environmental quality assessment, have resulted in substantial effort to develop indicators for evaluation of the effects of environmental policies. The British Government, the European Union and the OECD are all active in this area, drawing data collected from a wide range of organisations (the list of UK Indicators for Sustainable Development is in revision at the time of writing).

At these highly aggregated levels, it is tempting to imagine that there might be a single best indicator for changes in biodiversity – this is not the case. Different processes of biodiversity change require different indicators for their detection and monitoring. These processes can be characterised by the driving force–state–response model, of which there are several variants. The most important is the DPSIR model (driving force–pressure–state–impact–response model), which splits the proximate cause of change, the pressure (eg a herbicide treatment) from the distal cause (eg intensification) (OECD 1993). We have rejected this split in this report, as the chains of causation we consider are frequently long and complex, and it is hard not to be arbitrary in dividing driving forces and pressures.

Different driving forces impact upon different biodiversity states, which need to be measured using different indicators. Furthermore, some indicators respond in similar ways to more than one driving force, and so a degree of apparent redundancy may be needed to characterise the causes of change in the state of biodiversity.

# BOX 5 – WEATHER IN THE SURVEY YEARS

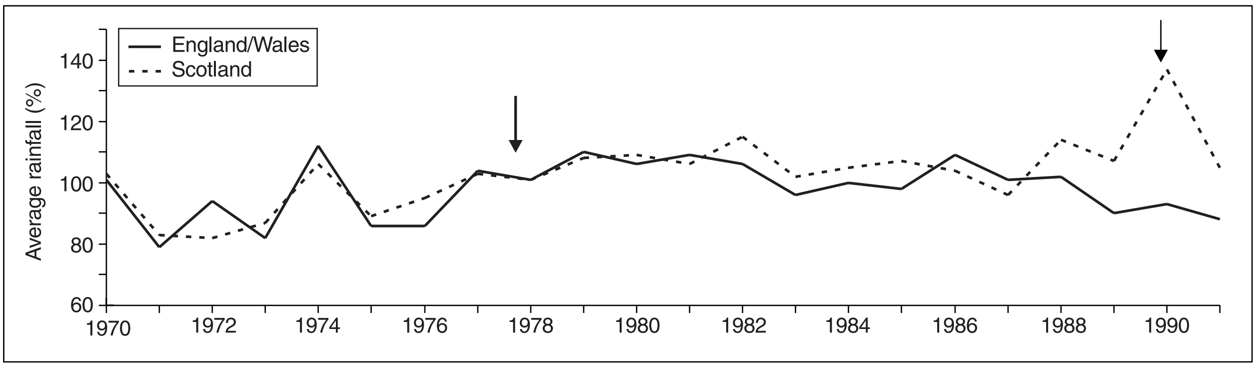
Overall, temperatures in England have risen about 0.5°C during this century. Thirty year variation patterns show that winter precipitation in Scotland is increasing, whereas summers in England are getting drier (Hulme & Jenkins 1998). In contrast with this steady but slow climatic change, weather in 1989 and 1990 was part of a 'freak' event, with two exceptionally warm winters and a warm summer in 1989. Temperatures and rainfall in the summer of 1990 were not exceptionally high, but as a direct consequence of the previous seasons' elevated evapotranspiration rates, there were year round soil moisture deficits. This meant that both winter and summer in 1990 were characterised by droughts (Cannell & Pitcairn 1993). These effects were especially noticeable in the southeast of England.

These exceptional climatic circumstances over a few successive seasons affected vegetation. The warm winter meant that individual species flowered earlier than normal, whereas germination of others was prevented due to lack of winter chilling. The drought led to a decline of various species, such as heather (*Calluna vulgaris*) and musk orchid (*Herminium monochis*) – and surveyors noted the effect on the appearance of the vegetation, especially in the southeast. However, species for which England is the northerly limit of their distribution range might have benefited from the 'Mediterranean' climate in those years.

The effects of such climatic 'freak years' on species communities is complex due to the spatial variability of weather and the differential effects on individual species (Cannell & Pitcairn 1993). Therefore, there is unlikely to have been a strong directional effect on vegetation assemblages at the national scale.

### Conclusion

Although the extreme weather in 1990 would almost certainly have influenced growing conditions in various parts of GB, it is difficult to establish a clear directional influence on vegetation as analysed in this report, especially when analysis is in terms of CVS classes (Box 7, page 57).




Rainfall in GB from 1970 to 1991, expressed as percentage of the average rainfall of the previous 30 years. Arrows indicate survey years. Although Scotland may show a similar deviation from the average as England and Wales, average rainfall in Scotland is higher. For instance in England and Wales in 1941–70 average rainfall was 912 mm per year, whereas in Scotland that period had an average of 1431 mm of rain per year.

# BOX 6 – COLLECTION OF FIELD DATA FROM COUNTRYSIDE SURVEY

The sample unit for Countryside Survey is the 1 km square, selected at random from within the Land Classes. A total of 256 squares were visited in 1977–78, and they were re-visited in 1990, giving the basis for the analysis of change in vegetation.

Vegetation data were collected from quadrats, or plots, sampling different landscape features. Each plot was marked with a metal plate for later relocation, allowing the magnitude of subsequent changes to be estimated with a high degree of precision.

Plot types recorded in the three Countryside Surveys

| Plot type | | 1978 | 1990 | 1998 |
|---|---|---|---|---|
| X | field and unenclosed land | • | • | • |
| B | field boundaries | | • | • |
| H | hedgerows | • | • | • |
| R | road verges | • | • | • |
| V | additional road verges | | • | • |
| S | stream/river sides | • | • | • |
| W | additional stream/river sides | | • | • |
| Y | targeted on atypical vegetation often fragments of semi-natural habitat | | • | • |
| U | ‘unenclosed’ Broad Habitats | | | • |
| A | arable field margins | | | • |
| D | hedgerow woody species | | | • |

***Main plots***

Main plots (200 m$^2$) were located at random within each of five equal-sized sectors of the square. They were relocated if they fell on a linear feature.

***Linear plots***

Linear plots were 10 m x 1 m and placed along linear features in the square. ‘Boundary’ plots were placed alongside field boundaries nearest to the main plots – these were recorded first in 1990. Two ‘hedgerow’ plots per square were placed at random alongside hedgerows. Similarly, two ‘streamside’ plots were positioned at random with a further three to represent different types of watercourses. Finally, two ‘verge’ plots were placed at random adjacent to roadsides, again with a further three to record different types of roads. The three additional road verge and streamside plots were first recorded in 1990.

***Habitat plots***

The ‘Y’ plots, or habitat plots (4 m$^2$) were placed in vegetation types not covered by the random plot series in each square. These were first recorded in the 1990 survey. Other plots types were introduced in 1998 – these are not discussed further within this report.

***Total number of plots***

All species found in each plot were listed, along with estimates of cover (where it was estimated to equal or exceed 5%). A total of 1871 plots were sampled in the same locations both in 1977/78 and 1990 – they provide the basis for the analysis of vegetation change described in ECOFACT Volume 2 (Bunce *et al.* 1999b) and for the analyses of causes of change presented in this report. The larger number of plots recorded in 1990 means that analyses of the sample data gathered during CS2000 will take advantage of a much larger dataset with which to explore recent changes. This replicate dataset is likely to be some six times larger than the 1978–90 replicate sample.

# BOX 7 – THE COUNTRYSIDE VEGETATION SYSTEM (CVS)

The CVS was developed especially to provide an appropriate tool for the description and quantification of change throughout the landscape. Since it was based upon stratified, random samples, rare and highly localised communities are not well represented and do not form separate classes; their description was the remit of the National Vegetation Classification. The unique contribution of the CVS is its ability to locate and estimate the magnitude of change in aspects of botanical diversity at the broader landscape scale.

The CVS resulted from a classification of almost all of the plot data from 1978 and 1990. Bringing together those plots with species in common, 100 vegetation classes were identified, each with its complement of typical species, distribution within and between landscapes and associations with soils. Each class has also been assigned mean Ellenberg values for light, moisture, pH, fertility and continentality. Full details of these CVS classes are given in Volume 1 of the ECOFACT series, *Vegetation of the British Countryside* (Bunce *et al.* 1999a).

The CVS classes were positioned along axes accounting for the maximum variation between them using detrended correspondence analysis, and then grouped statistically into eight aggregate classes using Wards minimum variance method:

| | |
|---|---|
| AC I | crops/weeds |
| AC II | tall grass/herb |
| AC III | fertile grassland |
| AC IV | infertile grassland |
| AC V | lowland wooded |
| AC VI | upland wooded |
| AC VII | moorland grass/mosaic |
| AC VIII | heath/bog |

These aggregate classes form floristically well defined vegetation types where differences in species composition between plots are maximised. On this basis they constitute powerful strata for analyses of plot data, which increase the chances of detecting meaningful change. Shifts of individual plots within aggregate classes imply subtle changes due to management, environmental change or successional processes. Shifts between aggregate classes imply major changes in land use and major changes in land management. They can also arise because of natural succession, but usually only when such succession has been allowed by changes in management.

# BOX 8 – ELLENBERG SCORES AND THE ECOLOGICAL INTERPRETATION OF AGGREGATE CLASSES

Ellenberg *et al.* (1991) published estimates of the position along a range of environmental gradients at which species would achieve peak abundance. A large proportion of the European flora was thus given scores indicating the kind of environment where each plant species was most likely to be found. In an ECOFACT case study, Hill and Carey (1997) found that the annual yields of the Park Grass experimental treatments were highly correlated to their Ellenberg N values, showing that the Ellenberg approach was basically sound.

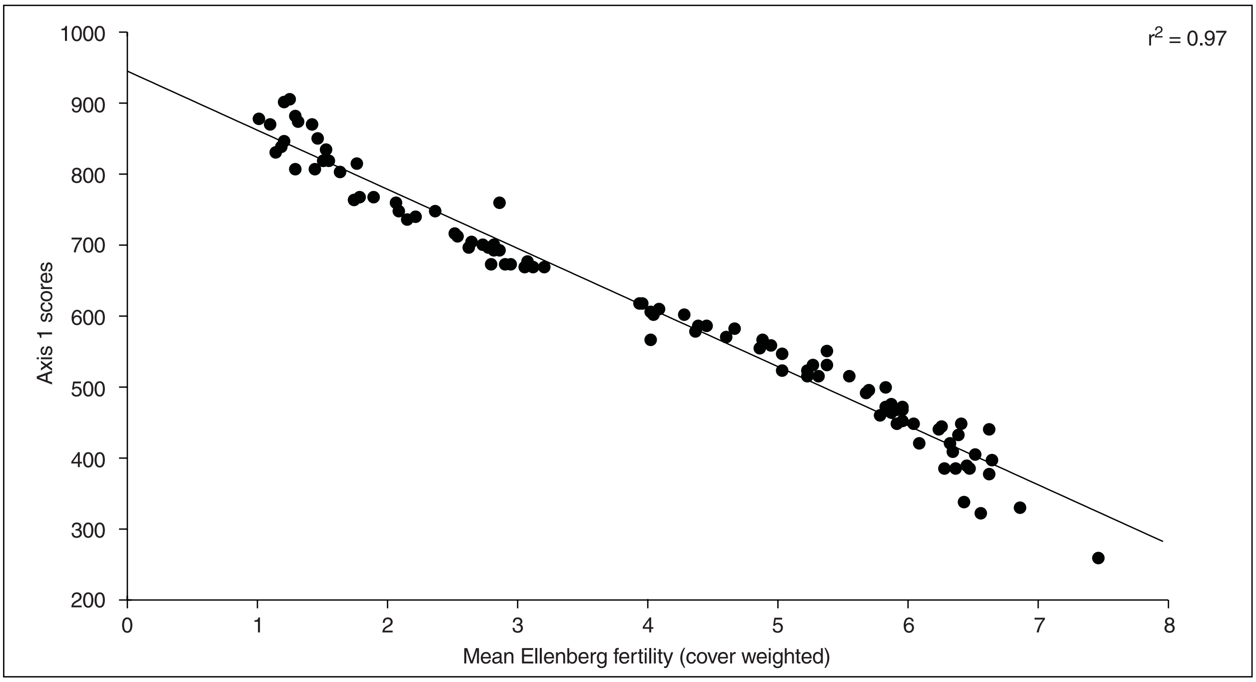
Ellenberg's values were recalibrated for GB, and the mean values were calculated for the different CVS classes. These are reported in ECOFACT Volume 2: Technical Annex (Hill *et al.* 1999).

***Findings***

The results showed very clear differences between vegetation classes – which was to be expected. What was not expected was how closely different mean Ellenberg scores were related to different DECORANA axes. The first axis was highly correlated with the Ellenberg fertility score ($r^2$ = 0.97, see Figure 1, page 28), the second with the shade score ($r^2$ = 0.61), and the third with the moisture score ($r^2$ = 0.82).

***Conclusions***

The major environmental variables controlling British vegetation are fertility, available light and wetness, in that order. Shifts in vegetation between CVS and aggregate classes imply shifts in one or more of these factors, providing a basis for exploring cause and effect in terms of changing vegetation and its changing physical environment.




Mean Ellenberg scores plotted against mean Decorana axis scores for each of the one hundred CVS classes.

# BOX 9 – SPECIES GROUPS

The identity of the 100 CVS classes is based upon similarities in species composition within groups of plots and differences in species composition between groups of plots. Any group of plots within a CVS class will therefore be characterised by a number of different species. For example a base-rich woodland class will consist of plots that have woody species as well as calcicoles (species associated with base-rich situations). The calcicoles may break down into those that are especially restricted to woods, whilst others may occur just as frequently in woods as in calcareous grassland. Within this base-rich woodland class there may also be plant species that help to distinguish between a wetter or drier base-rich wood. Both grassland and wetland calcicoles may also help to define another CVS class in combination with a range of other species groups. This highlights the important point that species groups can cut across CVS classes – it is the joint preference of members of different species groups that define the group of quadrats classified in each class.

The different species groups that together define a CVS class pinpoint different aspects of the environmental preferences of plots within the class and together give an overall ecological profile of the class. By analysing change in terms of these diagnostic groups of species we can indirectly investigate shifts in environmental conditions that may have been too small to cause plots to change CVS class. This approach augments analyses of change in individual species and can suggest links to various driving forces. For example, an individually significant increase in abundance of a competitive species could imply increased nutrient levels. If a significant increase in mean frequency or cover is then detected over a species group that is clearly indicative of eutrophic conditions, this would further support the hypothesis that nutrient status had increased.

The sensitivity of the approach rests on the common affinities of the species in each group with a particular range of conditions. The robustness of the approach comes about because a larger number of species over which to sum abundance in plots increases sample sizes compared to tests on individual taxa.

Ten plots typical of a base-rich woodland CVS class. The class is 'jointly' defined by a range of species (A–G) that together give the class its ecological distinctiveness and floristic definition. These can be grouped according to their common environmental affinities (ie woodland, calcicole wet or calcicole dry species groups). Changes in abundance of each of these groups within plots over time, can be used to say something about changes in wetness, base status and shade both within the class and across other CVS classes.

| Plant species by species group | Plots: wetter plots 1 | 2 | 3 | 4 | 5 | drier plots 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Woodland A | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Woodland B | ✔ | ✔ | | ✔ | | ✔ | ✔ | | ✔ | ✔ |
| Woodland C | ✔ | ✔ | ✔ | ✔ | | | | ✔ | | |
| Calcicole wet D | ✔ | ✔ | ✔ | ✔ | ✔ | | | | | |
| Calcicole wet E | ✔ | ✔ | ✔ | | ✔ | ✔ | | | | |
| Calcicole dry F | | | ✔ | | | ✔ | ✔ | ✔ | ✔ | ✔ |
| Calcicole dry G | | | | | | ✔ | ✔ | ✔ | ✔ | ✔ |

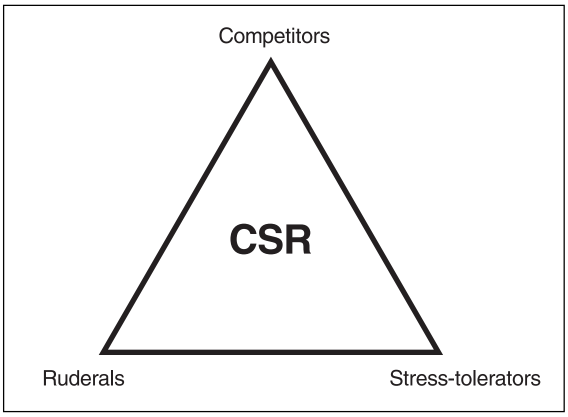
# BOX 10 – PLANT STRATEGIES AND VEGETATION CHANGE

Ecological strategy theory concerns itself with the role that different species can play within a community – the proportion of species with each strategy is a response to external driving forces, environmental conditions and the dynamics of community change and succession. The CSR model (Grime 1979) considers three main strategies:

- Competitors are plants that suppress other plants and tend to dominate communities (eg sycamore);
- Stress-tolerators are plants that can persist on conditions too harsh for the majority of others (eg saltmarsh plants);
- Ruderals are plants that occupy disturbed ground, reproducing and dispersing before the competitors take over (eg arable weeds).

These three strategies can be represented by the vertices of a triangle, and the position of a species within the triangle can be estimated using data from standard measurements of a range of plant traits (Grime *et al.* 1988)

Shifting balances between plants of different strategies show early warning of longer term trends. In particular, shifts towards competitors from ruderals can indicate natural succession (perhaps a sign of reduced management or disuse), while shifts to competitors from stress-tolerators implies that the stressing factor is being relieved (perhaps water or nutrients are becoming more available). Different positions within the CSR triangle are associated with different functional traits possessed by each plant species. These vary from 'hard' traits such as leaf nutrient concentration to 'soft' traits such as habitat preference (Hendry & Grime 1993). Each trait has an established correlation to aspects of plant performance in semi-natural vegetation. Analyses of vegetation change in terms of the increased or decreased representation of individual traits can therefore be used to infer processes such as disturbance and eutrophication.




The CSR triangle after Grime (1979).

# BOX 11 – INDICATORS OF BOTANICAL DIVERSITY

Changes in the vegetation of GB are complex and subtle, and need a range of indicators if they are to be interpreted with any degree of success. Using Countryside Survey data, we have identified ten types of analyses of botanical change that can be regarded as indicators. The choice of a type of analysis and its stratification determine the interpretation of the results. Analysing change by:

- landscape type is used to assess broad geographic differences,
- plot type is used to focus on features within landscapes, (eg fields, field boundaries, road verges, hedgerows and streamsides);
- aggregate class is used to look at differences within broad types of vegetation (eg separating forest from tilled land or grassland from heath).

Not all indicators or analyses are available to this project, usually because there were insufficient data from the 1978 survey. They differ in their state of scientific development.

### IBD 1 – Aggregate classes

Net changes and turnover in aggregate classes of the CVS reveal gross changes in vegetation due to land use change or major changes in land management.

### IBD 2 – CVS classes

Net changes and turnover in CVS classes within aggregate classes are sensitive to more subtle changes in land management. The diversity of CVS classes in the whole of the countryside gives a measure of the diversity of habitats, but says nothing about their conservation value.

### IBD 3 – Change in representation of functional attributes

Changes in representation of different plant traits as vegetation changes in composition can be used to infer processes such as dereliction, increased disturbance and eutrophication. The robustness of the inference is based upon experimentally validated correlations between trait and plant species performance under field conditions. Changes could give early warning of trends in vegetation that may eventually lead to changes in CVS and even aggregate classes.

### IBD 4 – CVS classes unique to 1 plot type per 1 km square

This indicator describes the diversity of different landscape units within local landscapes – the extent to which particular vegetation types are only found in, for example, streamsides or road verges. An increasing value of this index can arise from the creation of new habitats, but it can also arise from habitat loss, as particular classes of vegetation become restricted to isolated patches.

### IBD 5 – Species richness per plot

The more species, the greater the local botanical diversity. In general, this indicator gives a clear guide to vegetation quality at the national level, but even here care is needed in interpretation. Increases in species richness resulting from the invasion of generalist or alien species may result in an increase at this measure of alpha diversity, even though they also infer a decrease in the diversity of vegetation types.

### IBD 6 – Ellenberg scores by plot

Each species in the Countryside Survey database has associated index values for fertility, soil moisture, light, pH, and continentality, as

continued...

# BOX 11 ...continued

recalibrated for GB. It is thus possible to estimate mean Ellenberg scores for each index for a given plot. Changes in these mean Ellenberg scores give an indirect indication of changes in these conditions, which are themselves the direct or indirect results of environmental driving forces. Ellenberg scores thus have the potential to give very clear insights into the nature and causes of botanical change.

### IBD 7 – Frequency of species groups

Species groups comprise taxa species which tend to be found together, and thus reflect the influence of management as well as abiotic factors.

### IBD 8 – Frequency of aggregate class preferential species

Certain species are associated with particular aggregate classes. Changes in the frequency of these species within their aggregate classes therefore provide a measure of the species diversity within these vegetation types that is independent from changes in levels of generalist and alien species.

### IBD 9 – Frequency of English Nature grassland indicator species

Detailed floristic survey work carried out by the England Field Unit (then part of the Nature Conservancy Council) resulted in lists of plant species that appeared to be restricted to unimproved grasslands throughout England (R Jefferson pers. comm). These were divided up into indicators of neutral, calcareous and acid grasslands. Within each habitat group, species were also coded to reflect the strength of their preference. These plant species were used to evaluate the conservation value of grassland sites and so have an acknowledged link to botanical quality.

### IBD 10 – Frequency of food plants for animal groups

Vegetation can be used as an index of the suitability of habitats and landscape for animal groups. The nature of such indicators, and the mechanisms underlying them, is not clear as yet, but one approach is to consider changes in status of food plants for animal groups. Here, we analyse food plants for lowland farmland birds and butterflies as a case study. Work on this IBD is essentially exploratory at this stage.

### IBD 11 – Frequency of scare species and NVC categories

While Countryside Survey was not designed to detect scarce plants with a high degree of precision, there are nevertheless ways of using the Countryside Survey data to monitor changes in species and NVC communities considered to be of conservation importance. Work on this IBD is essentially exploratory at this stage but shows great potential for exploring the distribution and abundance of plant species that together characterise semi-natural plant communities some of which are the focus of conservation effort at the nature reserve scale.

### IBD 12 – CVS classes per 1 km square

The number of CVS classes per survey square provides information on the typical level of local diversity of vegetation in the wider countryside – the greater the number, the greater the diversity.

# BOX 12 – SIMILARITY AND DIFFERENCE BETWEEN BOTANICAL CHANGE IN GB AND ON AGRICULTURAL LAND IN ENGLAND AND WALES

## Introduction

Using an analogous approach to the analyses reported in ECOFACT Volume 2 (Bunce *et al.* 1999b), vegetation change was measured across only those plots recorded on agricultural land in England and Wales. For this purpose, an independent classification was undertaken of relevant plots sampled in the 1978 and 1990 surveys. The plots used for this classification of vegetation form a subset of the plots used for the GB classification. The classification resulted in eight aggregate classes describing vegetation on agricultural land in England and Wales, which are independent and distinct from the eight aggregate classes in the GB classification. Changes in species richness and Ellenberg scores per plot were analysed for these aggregate classes and are fully reported in the technical annexes of ECOFACT Volume 2 (Bunce *et al.* 1999b).

Direct comparison of the results of botanical change analysis for GB and for agricultural land in England and Wales is impossible because there is no real equivalence of the aggregate classes. Although there is a certain amount of correspondence between individual classes in each classification, they are not based on the same plots, and there are differences in the number of plots in each class. For example, three percent of all plots on agricultural land in England and Wales are in the heath/bog class (28 plots in AC H), whereas in GB 14 % of all plots are in heath/bog (270 plots in AC VIII).

## Findings

***Change analysis: species richness***
(Annex 10.10 and 10.11, ECOFACT Volume 2, Bunce *et al.* 1999b)

- Over all plots on agricultural land in England and Wales, there was a general loss of species, which corresponded to similar losses in GB.

- There was no increase of species richness in the heath/bog class in England and Wales (AC H) to correspond with the increase in this class in GB (AC VIII). This was not so surprising given the

Correspondence of the aggregate classes for agricultural land in England and Wales and in GB. A cross-tabulation can be found in Annex 11 of ECOFACT Volume 2 (Bunce *et al.* 1999b).

| Agricultural land in England and Wales | | | Agricultural land in GB | | |
|---|---|---|---|---|---|
| A | Sparse weeds/crops | 26 *plots* | I | Crops/weeds | 202 *plots* |
| B | Mixed weeds/crops | 202 | | | |
| C | Open wooded | 158 | V | Lowland wooded | 150 |
| D | Dense wooded | 32 | | | |
| E | Mixed grassland herb | 303 | II | Tall grassland/herb | 227 |
| | | | III | Fertile grassland | 319 |
| | | | IV | Infertile grassland | 369 |
| F | Wet grassland | 17 | IV | Infertile grassland | 369 |
| G | Acid grassland/moorland | 51 | VII | Moorland grass/mosaic | 210 |
| H | Heath/bog | 28 | VIII | Heath/bog | 270 |
| *No. replicate plots for analysis of change between 1978 and 1990* | | *817* | | | *1871* |

continued...

smaller sample size available in the absence of Scottish samples. There was a decline in species richness in streamsides on agricultural land in England and Wales, which was associated with woody vegetation types in the lowlands (AC C and D). In GB, the decline of species richness in streamsides was associated with several aggregate classes.

- There was a significant decline in species richness on agricultural land in England and Wales on plots in mixed grassland herb (AC E) on both main plots and hedge plots. In GB, however, the decline appeared to be mostly restricted to infertile grassland (AC IV) (main plots) and tall grassland/herb (AC II) (hedge plots).

- Road verges in the arable landscape increased in species numbers both on agricultural land in England and Wales and in GB.

***Ellenberg values***
(Annexes 21, 22 ECOFACT Volume 2, Bunce *et al.* 1999b)

- Trends of change in Ellenberg values per plot were similar for vegetation on agricultural land in England and Wales and in GB.

- There was a trend towards an increase in fertility scores and a increase in pH scores over the whole landscape.

- Species associated with shading increased in the wooded vegetation types, whereas there was a trend towards more open vegetation in the grassland classes. Although there were not many significant shifts in light scores for vegetation in plots on agricultural land in England and Wales, the evidence fits in with trends that showed up more widely throughout the GB landscape.

- Changes in wetness scores that were significant for various plot types in GB were only in a few cases significant for plots on agricultural land in England and Wales.

The results showed similar trends in change of botanical diversity occurring on agricultural land in England and Wales as were found for GB. This suggests that the driving forces responsible were operating across the whole landscape.

The main difference between the results from both datasets is that there were fewer significant changes in biodiversity indicators on agricultural land in England and Wales than in GB. A few points have to be borne in mind when interpreting these differences.

1. Changes that were only significant in GB could point to driving forces that acted mainly outside the range of agricultural land in England and Wales. Conifer planting and management were more likely to occur on a large scale in Scotland than in England and Wales. This may explain why both changes in species numbers and in Ellenberg values indicated more change in upland vegetation classes in GB than on agricultural land in England and Wales.

2. Potential change figures depended on the state of the vegetation in the baseline year 1978. For example, the decline in species richness was far less significant and widespread in streamsides on agricultural land in England and Wales than in GB. However, there was a lower species richness in 1978 on streamsides on agricultural land in England and Wales than there was in

continued...

1990 all over GB. This could suggest that processes of species loss had already advanced further on agricultural streamsides in England and Wales and the same driving force was likely to have had a smaller impact than in Scotland.

3. Reporting fewer significant changes on agricultural land in England and Wales could be a result of the focused nature of this study. By studying smaller sample sizes degrees of freedom were lost. Analyses were therefore less powerful and the chances of missed change were increased compared to overall analysis of GB.

### Conclusions

This study aimed to assess whether trends detected at the GB scale were also detectable on agricultural land in England and Wales. Results show that similar changes did occur. Only a limited number of results that were different between England and Wales and GB can be explained by driving forces having a differential effect on this part of the landscape. However, the independence of the classifications make it impossible to compare results directly whilst smaller sample sizes reduce the power of tests for detecting change on agricultural land in England and Wales.

# BOX 13 – LOCATING THE BUILDING BLOCKS OF SCARCE AND DECLINING PLANT COMMUNITIES

The decline of species-rich grasslands has been well documented (Fuller 1987; Hopkins & Hopkins 1994). What has been less well appreciated is whereabouts in the landscape these changes have taken place and to what extent characteristic plant species assemblages persist in situations not thought typical of the community type or overlooked by surveys searching for large, continuous stands.

A case study investigated the location of plots containing species characteristic of the valued NVC community, MG5 *Centaurea nigra – Cynosurus cristatus* mesotrophic grassland, in 1990. This community is considered to be typical of lowland unimproved hay meadows treated in a traditional manner (Rodwell 1992).

## Findings

While many plots had one or two of the 21 species characteristic of MG5, very few plots had more than 6 preferential species. The richest plots were located in lowland fields but were very rare. The largest number of plots containing the largest number of preferentials were located on road verges in the marginal uplands.

The landscape locations of a subset of 17 of the plots richest in MG5 species were examined as a case study by focussing on survey information gathered in each 1 km square. Factors responsible for maintaining species richness and the survival of patches appeared to include:

- succession on dune grassland;
- grazing;
- absence of agricultural improvement;
- western oceanic situations over poor soils.

The location of plots in the landscape was rarely consistent with the classic lowland hay meadow and included:

- ungrazed road verges;
- atypical patches in upland landscapes;
- steep slopes;
- small patches with a high ratio of edge to area;
- association with atypical species including marram grass (*Ammophila arenaria*), nettles (*Uritca dioica*) and mat-grass (*Nardus stricta*).

Information recorded by surveyors suggested that threats included cessation of low-intensity farming, ownership change, dereliction and building development.

## Conclusion

This important grassland community was once common in lowland grassland fields but is now restricted to less than 5 000 ha (Jefferson & Robertson 1996). The processes of changing land management have progressed to the point that the species that together characterise the community are restricted to road verges and small, easily overlooked, often agriculturally marginal patches in the wider countryside. Continued eutrophication, neglect and inappropriate verge management regimes threaten even these remnants. However, they also have the potential to act as sources of plants and other organisms for local restoration projects.

# BOX 14 – A LOGICAL FRAMEWORK FOR IDENTIFYING THE CAUSES OF CHANGE IN BIODIVERSITY BY LINKING ENVIRONMENTAL DRIVING FORCES TO IBD STATE VARIABLES

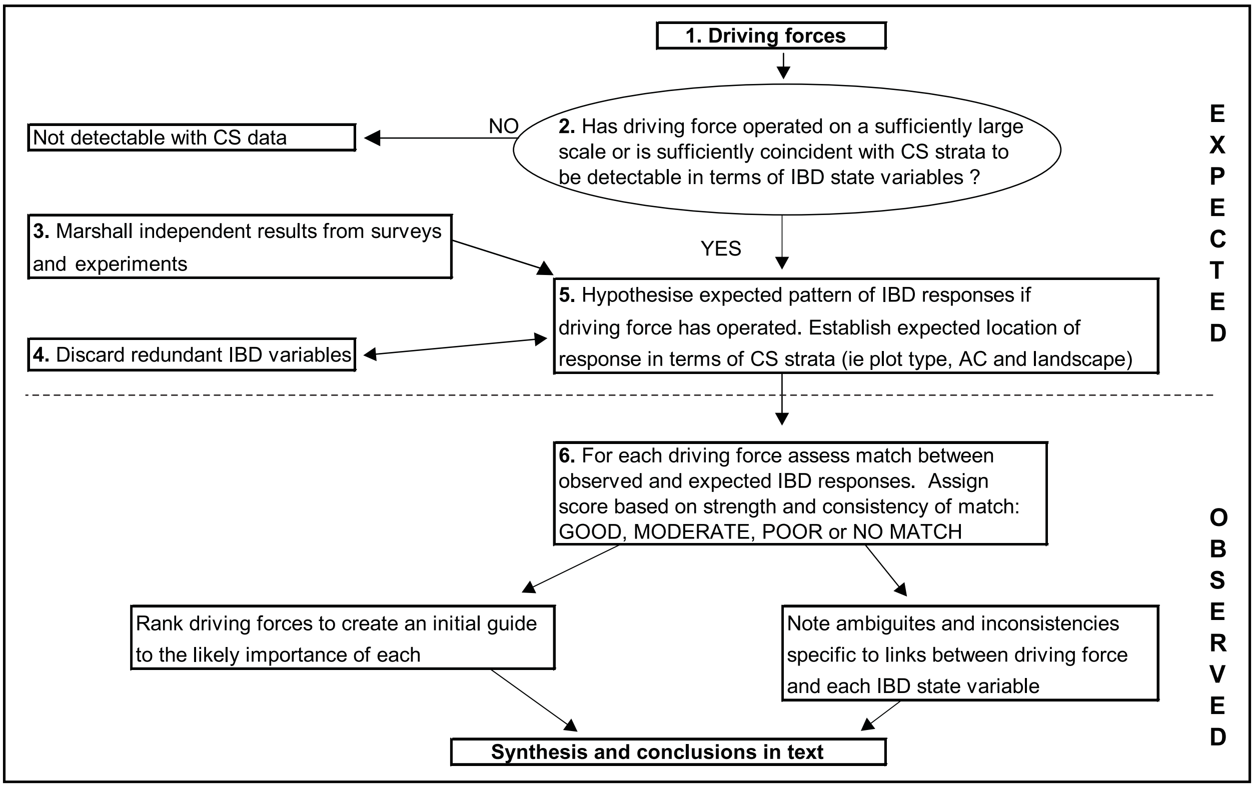
## Principles

We start from a list of potential driving forces. The assumption is that drivers known to have operated on a large scale and with the greatest intensity are more likely to be detected in terms of their effect than weak or localised pressures. Even if these less intense pressures have operated, unless they are highly coincident with specific Countryside Survey strata their effects are likely to be undetectable using Countryside Survey vegetation data.

The driving forces are used to build a framework of hypotheses that postulate a correlative link between each driving force and change in IBD variables. Identification of the probable effects of a driving force is then possible if the link to IBD variables is distinctive in terms of the pattern of responses expected.

By having a hypothetical framework of IBD responses expected to result from each driving force, we can quickly establish ambiguous results (eg where the same signals could indicate one driving force as well as another, whilst also identifying series of observed responses that do not appear to be linked to a driver). The clearest demonstration of a link between driving force and vegetation change is possible where a series of expected IBD responses as well as the expected location constitute a unique hypothetical signature of the effect of the driving force.

Convincing links between driving force and response can be quickly detected if expected patterns match those observed in the data. Two worked examples are given in Box 15 (page 68) to illustrate the way causes of change in biodiversity have been identified. Each numbered section in that box corresponds to a part of the flow diagram below.



# BOX 15 – TWO WORKED EXAMPLES ASSESSING THE IMPACTS OF ENVIRONMENTAL DRIVING FORCES: HEDGEROW MANAGEMENT AND AGRICULTURAL FERTILISER USAGE

Numbered sections refer to parts of the logical framework diagram shown in Box 14 (page 67).

## Example 1

***1. Driving force***

Hedgerow management.

***2. Has driving force operated on a large enough scale to be detected in Countryside Survey data?***

Land cover change results for the period 1984 to 1990 indicated a 55% increase in relict hedges across GB (Barr *et al.* 1993). Since Countryside Survey data comprise plots that specifically sampled hedgerows, the effects of lack of management on vegetation can be investigated. This driver is therefore retained.

***3. Gather independent results from surveys and reviews of experiments***

Conclusions from experiments and descriptive studies were used to help establish expected patterns of IBD responses. These were then matched with the responses that actually occurred.

Little is actually known about the effects of hedgerow neglect. In the review by Barr *et al.* (1995) no work was cited that explicitly described the effects of hedgerow neglect on plant biodiversity under different adjacent land use regimes. However the importance of interactions between hedgerow neglect and land use were highlighted by references to the general deterioration in quality of herbaceous vegetation in English arable field hedgerows (Boatman & Theaker 1993; Deane 1989). The importance of floristic starting point on subsequent changes in plant species composition has also been noted (Forman & Baudry 1984).

Since there are few pointers from other studies as to expected changes – a degree of uncertainty attaches to our hypotheses stating expected IBD responses. This must guide interpretation of the match with observed links.

***4. Discard redundant IBDs***

After considering all potential driving forces a number of IBD state variables were discarded.

***5. Erect hypothetical links between driving force and the responses of IBD state variables***

- **Location of the effect**
  Replicate hedgerow (H) plots throughout GB.

- **IBD 1 – Shifts in aggregate class**
  Expected net movement from unwooded classes (II, III, IV and VII) to lowland wooded (V).

- **IBD 2 – Shifts in CVS classes**
  Shifts to weedier and more competitor dominated wooded classes were expected even though such shifts could be confounded with disturbance in adjacent habitat. Shifts to more wooded classes were expected but these may also be confounded with lack of management on road verges.

  Taller, more gappy hedges may favour increased herbaceous biomass at the hedge base and consequently in hedgerow plots. The composition of the field layer is, however, likely to be influenced by adjacent land use and could range from an open assemblage of weeds or even bare ground to swards dominated by competitive ruderals favoured by low disturbance and fertile conditions but relatively quick to disperse from local sources.

continued...

- **IBD 3 – Change in plant functional attributes**
  This analysis was carried out on three subsets of Countryside Survey data one of which comprised only those plots that remained in the same aggregate class in 1978 and 1990. By concentrating on this 'stay-same' analysis we can focus specifically on hedgerows that remained shrub dominated in both years. The expectation was for attribute changes to indicate dereliction reflected by increases in representation of traits linked to competitive, tall growing species.

- **IBD 6 – Change in Ellenberg scores**
  Increased shading should result in decreased light scores particularly in H plots that, in 1978, were in aggregate classes II, III, IV and VII. Again increased gappiness and disturbance at the hedgerow base could potentially favour increased light scores in some plots.

- **IBD 7 – Change in mean frequency and mean cover of species groups**
  Woody species groups were expected to increase in frequency in non-wooded H plots. Woody group cover was expected to increase in wooded H plots (aggregate classes V and VI).

***6. Assess match between expected and observed IBD responses.***

- **IBD 1 – Shifts in aggregate class**
  Net shifts from II and IV to V were observed. However this was accompanied by marked turnover between aggregate classes so that many H plots moved from more wooded to less wooded classes even though the overall shift was for an increase in lowland wooded. The match was scored as MODERATE given the possibility of confounding land use effects.

- **IBD 2 – Shifts in CVS classes**
  Net shifts occurred within wooded CVS classes from those characterised by species of less fertile, less disturbed and shaded hedgerows to classes with a greater abundance of competitive ruderal species (ie from 25 and 16 to 7). The match was scored as MODERATE.

- **IBD 3 – Change in plant functional attributes**
  Changes in functional attributes in the 'stay-same' analysis indicated eutrophication only. Consequently the correspondence was scored as NO MATCH.

- **IBD 4 – Change in Ellenberg scores**
  Mean light scores indeed decreased significantly within H plots in aggregate classes II and V suggesting a reduction in shade intolerant species or an increase in shade tolerant species. Because of uncertainty surrounding the expected effect the match was again scored as MODERATE.

- **IBD 7 – Change in mean frequency and mean cover of species groups**
  Significant increases in mean cover of species group eight (dominated by hawthorn and blackthorn) were detected in aggregate class V H plots across GB and, separately, in the pastural lowlands. An increase in frequency of group 17 (dominated by greater stitchwort and hazel) occurred in aggregate class IV H plots across GB. Both changes matched expectation. Since the expected response, particularly the group cover change, was postulated as a good discriminator between unchecked hedgerow growth and other potential driving forces, the match was scored as GOOD.

***7. Generate correspondence index***

| IBD | Match (exp v obs) | Score |
|---|---|---|
| 1 | moderate | 2 |
| 2 | moderate | 2 |
| 3 | no match | 0 |
| 6 | moderate | 2 |
| 7 | good | 3 |

Index = Actual score/ Maximum score possible for complete match = 9/15 = 0.6

continued...

# BOX 15 ...continued

### Example 2

***1. Driving force***

Agricultural fertilisers.

***2. Has driving force operated on a large enough scale to be detected in Countryside Survey data?***

There is much evidence that farm management practices intensified between 1978 and 1990. Increases in nitrogen applications on tilled land and grassland increased substantially during this period (Hopkins 1988; Little 1998). A sample survey of landowners in Countryside Survey 1 km squares also confirmed that application of fertilisers along with stocking density had increased between 1978 and 1990 (Potter & Lobley 1996).

***3. Gather independent results from surveys and reviews of experiments***

A large number of experiments have been carried out which quantify and describe vegetation responses to nutrient inputs. These are reviewed in Green *et al.* (1998). Not surprisingly the results point to a shift towards vegetation typical of more fertile conditions. Species typical of less fertile conditions lose out to more vigorous forbs and grasses.

***4. Discard redundant IBDs***

As in Example 1, IBDs 8, 9 and 10 were discarded.

***5. Erect hypothetical links between driving force and the responses of IBDs***

- **Location of the effect**
  Main (X) plots should be affected in all landscapes but to a lesser extent in the upland landscape type. Managed grasslands and crops would be affected (ie aggregate classes I, III, IV and VII).

- **IBD 1 – Shifts in aggregate class**
  Net shifts were expected to more fertile aggregate classes (eg IV to III, VII to IV).

- **IBD 2 – Shifts in CVS classes**
  Net shifts expected from less to more fertile, grassland CVS classes.

- **IBD 3 – Change in plant functional attributes**
  Plant traits associated with eutrophication should be observed to increase in less fertile grassland aggregate classes.

- **IBD 6 – Change in Ellenberg scores**
  Fertility scores expected to increase in less fertile grasslands.

- **IBD 7 – Change in mean frequency and mean cover of species groups**
  Increase in fertile/improved grassland species groups in less fertile aggregate classes. Decrease in unimproved grassland groups.

***6. Assess match between expected and observed IBD responses.***

- **IBD 1 – Shifts in aggregate class**
  Net movements occurred from IV to III, from VII to IV and from VIII to VII all in main (X) plots. This fits well with expected patterns and the link was scored as GOOD.

- **IBD 2 – Shifts in CVS classes**
  A large shift of 11 main plots occurred from CVS class 43, a less improved grassland type with a high proportion of CSR species, to class 30 comprising much more improved and rye-grass dominated plots. The same trend towards more intensively managed grasslands was represented by shifts from classes 40 and 31 to 6. The link was scored as GOOD on the basis of these consistent results.

- **IBD 3 – Change in plant functional attributes**
  Eutrophication was inferred in main plots in aggregate classes III and IV. This was

continued...

scored as a GOOD match between expected and observed.

- **IBD 6 – Change in Ellenberg scores**
  Mean Fertility scores increased significantly in main plots in aggregate classes III and IV. This was scored as a GOOD match between expected and observed patterns of IBD response.

- **IBD 7 – Change in mean frequency and mean cover of species groups**
  Significant increases were detected in a number of more eutrophic species groups. For example, group 12 (dominated by cocksfoot and rye-grass) increased in aggregate class VII main plots across GB and in aggregate class IV main plots in the pastural lowland landscape. The unimproved acid grassland group 29 (dominated by sweet vernal grass, heath bedstraw and sheep's fescue) decreased in aggregate class IV main plots across GB and in the arable lowlands. The less improved neutral grassland group 18 also declined in aggregate class IV main plots across GB and in the marginal uplands. These changes were expected if agricultural fertiliser usage had increased, so the link was scored as GOOD.

### *7. Generate correspondence index*

| IBD | Match (exp v obs) | Score |
|---|---|---|
| 1 | good | 3 |
| 2 | good | 3 |
| 3 | good | 3 |
| 6 | good | 3 |
| 7 | good | 3 |

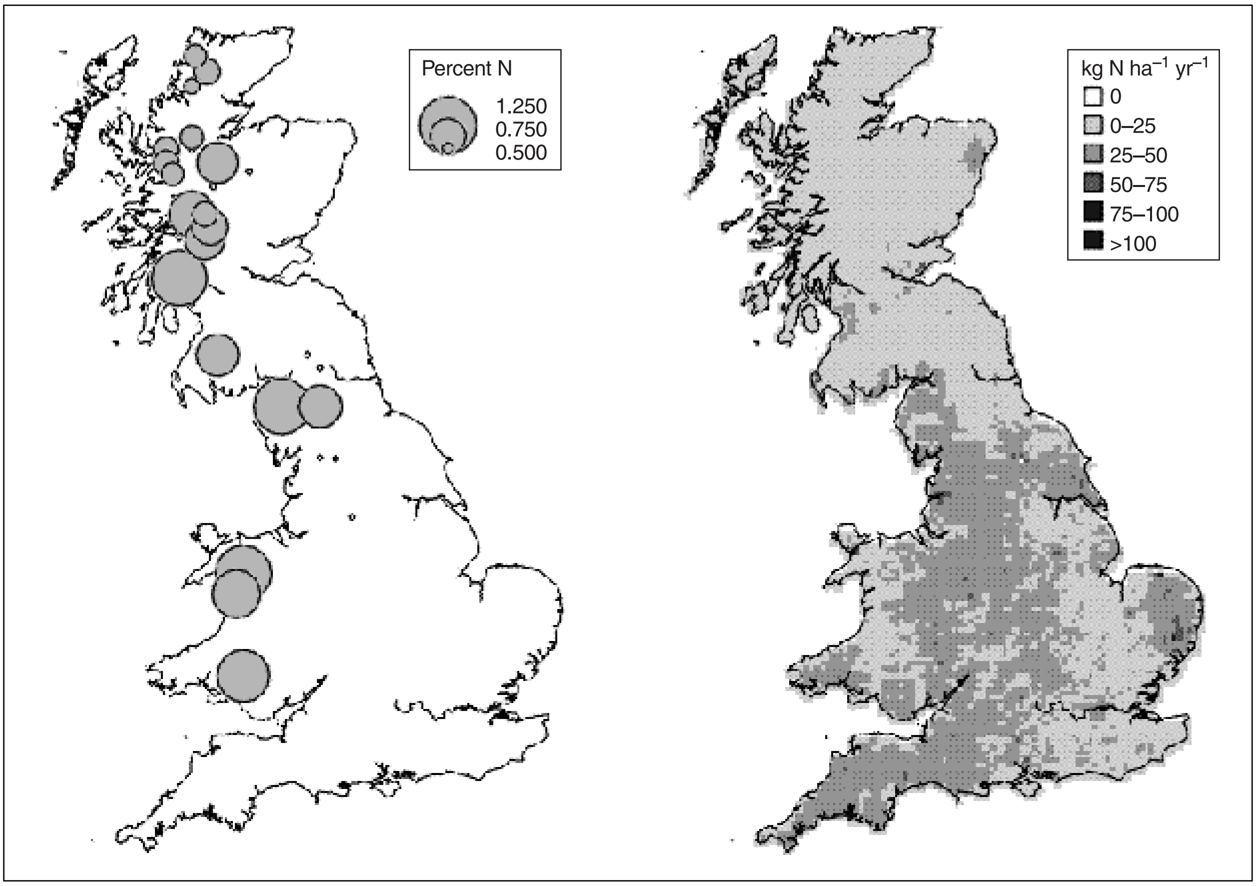
Index = Actual score/ Maximum score possible for complete match = 15/15 = 1.0

# BOX 16 – EUTROPHICATION OF UPLAND VEGETATION: GRAZING OR ATMOSPHERIC POLLUTION

The ECOFACT analyses provide evidence that eutrophication has affected vegetation in the uplands. The effects of grazing and of various pollutants have been studied in small-scale experimental systems. However, it remains unclear what the impact of these driving forces is on the landscape scale vegetation across GB. The aim of this study was, therefore, to assess the presence and combined impact of grazing and nitrogen deposition on British upland vegetation.

### Experiment

A total of 31 upland sites were visited in 1996, which included 17 established Countryside Survey squares. From these sites, soils and plant material from three species (two mosses and heather) were collected. The species sampled are known to show differing levels of tolerance to nitrogen pollution. Nitrogen content was determined for the plant material of these species, and compared to atmospheric deposition levels. These atmospheric pollution data were calculated from deposition maps, which are based on point measurements of atmospheric pollution concentration that are smoothed and corrected for altitude. From each of the study sites, data were also collected describing grazing intensity and vegetation composition. Multivariate techniques were then used to assess the relative impact of grazing and pollution on the vegetation of the study sites.




Maps show (left) the nitrogen content (% dry wt) in *Racomitrium lanuginosum* collected at the sample sites, and (right) figures for nitrogen deposition (kg $ha^{-1}$ $year^{-1}$) in GB (Sutton *et al.* 1992).

continued...

# BOX 16 ...continued

## Results

The major gradients in British upland vegetation related to geographical position. The vegetation types, furthermore, ranged along a gradient associated with nutritional status. The northern sites were characterised by mainly acidic heath/bog vegetation (AC VIII), whereas the southern upland sites were dominated by more eutrophic grass mosaic moorlands (AC VII). There was a positive correlation between nitrogen levels within the plant material and atmospheric deposition levels, and a weaker correlation with grazing intensity at a site. Furthermore, results showed that levels of atmospheric deposition and grazing were inter-correlated. Thus 'typical' upland vegetation types occur mainly in the far north of GB, where both deposition levels and grazing pressure are low.

## Conclusion

The range of vegetation types occurring in the uplands is determined by abiotic conditions which vary at all scales. Variation from south to north was correlated with both atmospheric deposition and grazing. There is likely to be a positive feedback mechanism, where elevated levels of nitrogen increase the proportion of grasses, making the vegetation more palatable for grazing animals. Grazing animals in turn increase the levels of nitrogen in the vegetation through input from dung and urine. Simultaneously, grazing animals open up dwarf shrub vegetation, thus giving grasses opportunity to establish. This can happen at quite local scales, increasing the patchiness of the vegetation and changing its suitability for upland birds such as red grouse, hen harrier and golden plover. Such feedbacks need to be taken into account when designating and managing areas for conservation.

# BOX 17 – VEGETATION CHANGE ON CUMBRIAN ROAD VERGES (1992–97)

Results reported in ECOFACT Volume 2 (Bunce *et al.* 1999b) highlighted a number of changes that were occurring on road verge plots between 1978 and 1990. These changes strongly suggested lack of disturbance and, to a lesser extent, eutrophication. They may be important, given that road verges can act as refugia for species of unimproved grassland. One possible explanation was that the management of road verges had changed.

In an effort to test this hypothesis, 32 fixed plots that had been established on Cumbrian road verges in 1992 were re-visited in 1997. Changes in the vegetation data recorded in both years were then analysed and interpreted in relation to shifts in disturbance and fertility and the occurrence of uncommon plant community types.

## Findings

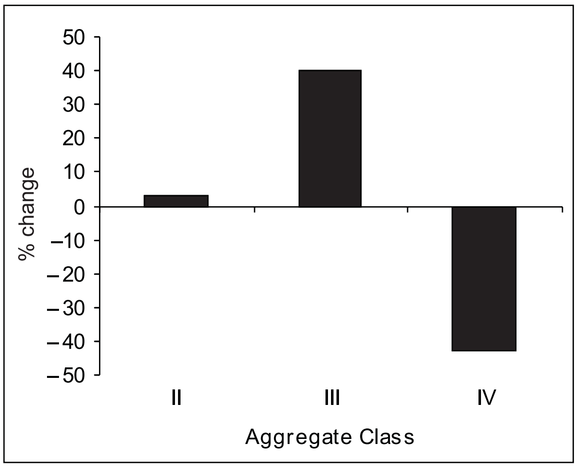
Two trends of vegetation change were detected.

Firstly, there was a loss of 43% of plots from the infertile grassland (AC IV), 3% shifting to the tall grassland/herb (AC II), the others all shifting to the fertile grassland, (AC III). These changes indicated a decline in the conservation quality of the plots, with reductions in unimproved grassland species and an increase in the proportion of competitive species present. The cause can be related to the continuing effects of management in the ten years up to 1995 when most of the verge width was mown infrequently, if at all, and cuttings left, whilst a safety swathe was mown at irregular intervals throughout the year.

Secondly, an increase in small annuals such as pineappleweed *(Matricaria matricarioides)* and knot-grass *(Polygonum aviculare)*, was also detected. This effect is most likely to have been located at the road edge, probably encouraged by disturbance from increased traffic volume and the recent cessation of edge trimming which allows a highly disturbed strip of open soil to persist between the metalled road surface and the verge proper.

## Conclusions

Road verges can act as refugia for plant species typical of declining grassland communities, but they require appropriate management if unimproved grassland communities are to persist. Experimental work has shown that late summer cutting regimes are most appropriate for the conservation of herb-rich communities (Smith & Rushton 1994; Parr & Way 1988), but it is important that they are not exposed to a build up of nutrients. Therefore cuttings should be removed. The threat posed by effects of longer-term build up of salts and deposition of nitrogen needs more research.




Net change in aggregate class membership of Cumbrian road verge plots between 1992 and 1997 (n = 32).

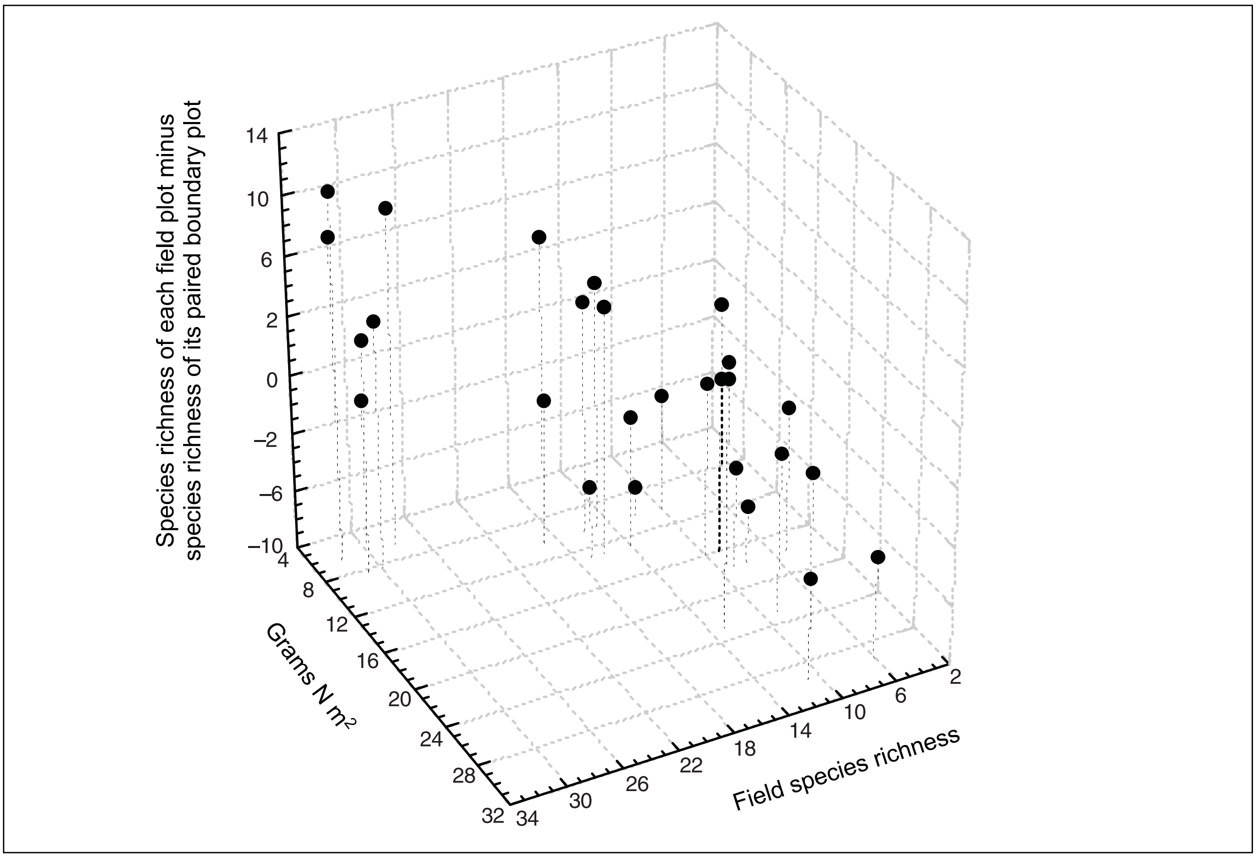
# BOX 18 – GRASSLAND PRODUCTIVITY AND SPECIES RICHNESS

A range of experimental and observational studies have shown that grassland plant species richness declines as productivity increases (Mountford *et al.* 1993; Keddy *et al.* 1997). One of the ECOFACT case studies was designed to explore this effect, to help interpret the declines in species number found in Countryside Survey data.

Plant species richness and composition were measured over the 1996 growing season at ten managed grassland sites across England representing a gradient of agricultural improvement. Productivity was measured as grams N m$^2$, averaged across the field. Recording took place from paired random plots placed separately within field edges and interiors.

## Findings

- Species richness in unimproved grasslands was greatest in the field interior.
- Species richness of both field and boundary declined with increasing productivity.
- Species richness declined less rapidly in the boundary, thus in improved fields, richness was greater in the boundary than in the interior.
- It seems that field boundaries provide a degree of refuge from the effects of increasing productivity.
- This refuge effect can be seen in species composition, as well as species number.
- CS1990 data exhibit similar effects, although with much variation due to other factors.




The relationship between field species richness, field productivity and the difference between field and boundary species richness. Data based on paired field and boundary plots (3 per field) taken from ten fields at five locations on a latitude gradient from southwest England to Cumbria. At each location two fields were sampled – improved and less improved. Positive difference values indicate that field plots were richer in species than boundary.

continued...

# BOX 18 ...continued

## Discussion

Except in the most unimproved sites, field edges tended to be richer in species than field interiors. Although productivity in boundary plots was significantly positively correlated with field interiors across all sites, productivity was often at lower levels in boundary plots. Overall, boundary species richness was less affected by differences in the level of improvement between sites than field interiors. It seems likely that field boundaries are less prone to the full effects of agricultural management partly because of less efficient application of fertiliser and cutting but also because of differences in the range of conditions associated with field edges including shade, slope, differences in soil depth and seasonal wetness. Because of these factors, boundary species assemblages in unimproved situations include species that would not normally occur in the field interior as well as plant species that are typical of the open field. Analysis of compositional similarity in the same data indeed showed the same boundary 'refuge' effect but with much more variation not accounted for.

## Conclusions

Field boundaries can harbour species no longer present in the improved interior of a field but this higher boundary species richness is also partly due to the presence of species suited to conditions found in boundaries and not typical of unimproved fields.

Opportunities for exploiting remnant components of richer field floras in boundaries are likely to be concentrated in a narrow range of the continuum from improved to unimproved fields. In improved fields, although boundaries may still be more species-rich than the field, the plant species are less likely to be characteristic of species-rich unimproved grasslands.

# BOX 19 – SEED BANKS: THEIR CAPACITY TO PROVIDE A BASIS FOR THE RECOVERY OF VEGETATION

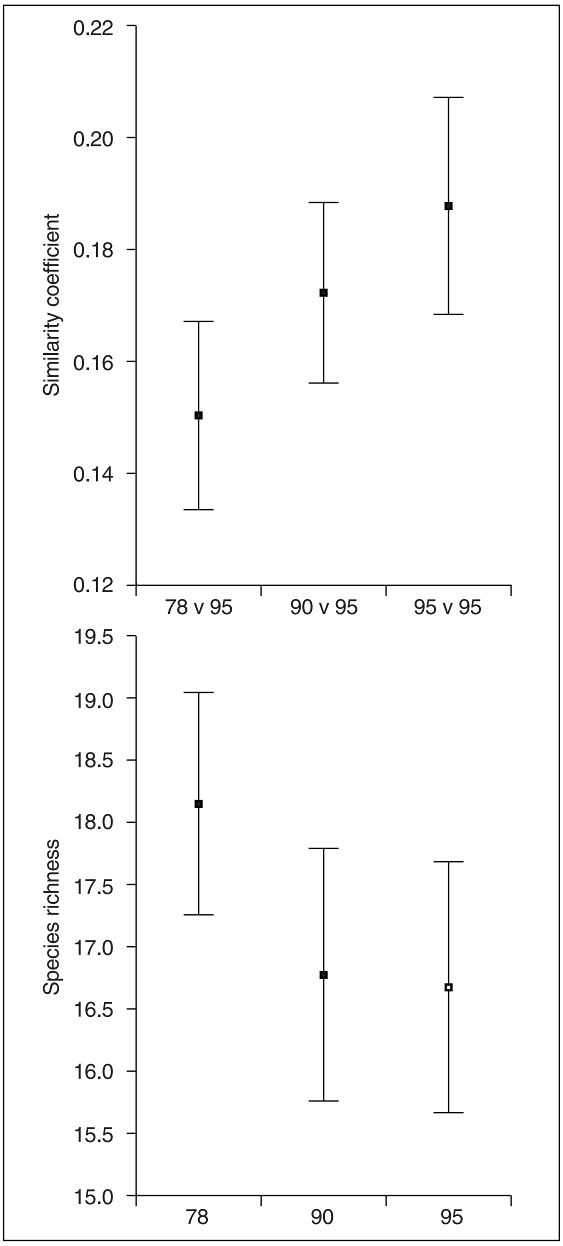
When vegetation changes the plant species present alter in terms of their proportional contribution to the stand. If, as a result of a driving force, plant species become locally extinct above ground, restoration may depend upon dispersal from nearby sources. This may be from nearby vegetation, such as a remnant patch of vegetation in a field boundary or road verge, but dispersal is often so limited that this source cannot be relied upon to restore extensive areas of degraded vegetation. The presence of a soil seed bank gives the potential for much more rapid colonisation. However, if the seed bank has been degraded over many years, it will no longer contain all species required to allow the vegetation to restore itself.

## Grassland seedbank study

In 1995, 40 Countryside Survey main (X) plots were revisited. All plots had been mapped as grassland in 1978 and 1990 and were still grassland in 1995. The vegetation was re-recorded and the composition of the seedbank estimated from soil samples. Vegetation species richness decreased significantly between 1978 and 1995 whilst similarity to the 1995 seedbank increased significantly over time. Ruderal species and grasses largely dominated the seedbank. Species typical of unimproved grasslands were absent from most samples.

## Conclusions

This work suggests that for grassland systems, soil seedbanks are typically not rich in species associated with less-improved and more species-rich vegetation but are dominated by propagules of species associated with eutrophic plant communities. The implication is that in many cases vegetation change will prove difficult to reverse without high inputs of effort, involving the deliberate re-introduction of plant species. Such re-introductions are costly, and the results far from assured even for the higher plants, while other groups of organisms are rarely considered.




Top: Changing species compositional similarity between the seedbank in 1995 and the vegetation in 1978, 90 and 95. Mean, untransformed, Jaccard similarity coefficients are plotted +/– 1 standard error. Similarity between seedbank in 1995 and vegetation in 1978, 90 and 95 increased significantly over time. Bottom: Vegetation species richness in seedbank sample plots declined significantly through time.

# BOX 20 – POLICY RESPONSES: THEIR MODES OF ACTION

Different policies impinge upon biodiversity in different ways. Some policies address biodiversity directly (often in conjunction with landscape conservation). Essentially, there are two modes of action. Target-led policies consider the threats to particular habitats, species or areas – this is the mode of action of the UK Biodiversity Action Plan, in which different driving forces of biodiversity change are addressed as appropriate for each target. Driver-led policies are those that attempt to manage the driving force itself. There are many such policies that impact on biodiversity, but in most cases, these effects are not the primary purpose of the policy. Finally, there are policies that attempt to address the inter-relationships between many drivers and targets simultaneously.

| Instigation | Characteristics | Examples |
|---|---|---|
| Biodiversity Target-led | Deal with threats to highly valued habitats or species. The objective of target-led policies has varied from straightforward protection but not necessarily accompanied by positive management (SSSI series) to direct positive management of the resource with amelioration of negative drivers (Wildlife Enhancement Schemes, ESA, Action Plans). Driving forces are likely to be recognised but this is not a requirement of the approach. | Priority Habitat and Species Action Plans, SSSIs (and associated designations), Wildlife Enhancement Schemes, Tir Cymen and Countryside Stewardship, ESA Tier II&III |
| Biodiversity Driver-led | These policy measures are introduced to counteract particular driving forces acting to the detriment of biodiversity. These might be large-scale factors such as atmospheric deposition or acidification. | Hedgerow Protection Legislation, Water Level Management Plans, ESA Tier I, Moorland Scheme, Proposed agricultural cross-compliance |
| Other Sector Driver-led | Policy mechanisms designed outside of the biodiversity sector with other aspects of the rural economy in mind might still impact on biodiversity. Many of these are designed to act on economic driving forces. | CAP Reforms, Headage Payments, Set-aside, Less Favoured Areas, Alternative Energy Incentives, Clean Air Legislation, EU Water Quality Standards |
| Integrating policies | The 1990s have seen an increased emphasis on integrated policy formulation. These mechanisms aim to take an holistic view across sectors. | Sustainable Development Strategy, Environment Agency Catchment Management Plans |

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# INTERPRETING THE ANNEXES

## Notation and coding

The following annexes present details of the observed and expected responses between the selected IBD states and different driving forces (see Boxes 13 and 14). Within the tables, the various Countryside Survey strata and IBD are referred to in abbreviated form or by code letters and numbers. Notation is explained below along with full names of aggregate classes, species groups and CVS classes.

***Aggregate classes***
These are referred to by Roman numerals.

**I** **Crops/weeds –** communities of cultivated and disturbed ground.

**II** **Tall grassland/herb** – typical of road verges and infrequently disturbed patches of herbaceous vegetation.

**III** **Fertile grassland** – improved often intensively managed agricultural swards.

**IV** **Infertile grassland** – unimproved wet or dry and basic to acidic graminaceous vegetation.

**V** **Lowland wooded** – hedges, woodland and scrub in lowland Britain.

**VI** **Upland wooded** – upland semi-natural broadleaved woodland and scrub plus forestry plantation.

**VII** **Moorland grass/mosaic** – extensive graminaceous upland vegetation, usually grazed.

**VIII** **Heath/bog** – ericaceous vegetation of wet or dry ground largely in uplands.

***Countryside Survey plots***
These are recorded in fixed locations in 1978 and again in 1990.

Plot types are listed below:

X Fields and unenclosed land (14 x 14 m)
H Hedgerow (1 x 10 m)
R Roadside verge (1 x 10 m)
S Streamside (1 x 10 m)

***Landscape types***
These are referred to as AR = Arable lowlands, PA = Pastural lowlands, MU = Marginal uplands, UP = Uplands (see Box 2 for maps).

- **Arable lowlands (AR)**
  Largely S and SE England; intensive agriculture, high proportion of arable.

- **Pastural lowlands (PA)**
  Western British lowlands; less arable, mainly grassland management for sheep, dairy and beef production.

- **Marginal upland (MU)**
  Much of Wales, the Pennines, Lake District and Scotland; extensive sheep grazing, grouse moor and forestry.

- **Upland (UP)**
  High montane, blanket bog and Scottish islands; Scotland and northern England.

continued...

***Species groups***

These are referred to in brackets. Full names and the three most frequent species in each group are given below.

| Species group | Species group name | Characteristic species |
|---|---|---|
| 1 | Crop or crop edge plants on fertile soils | *Bromus sterilis, Convolvulus arvensis, Lamium album* |
| 2 | Crops, crop edge or grassland on eutrophic soils | *Elymus repens, Rumex crispus, Sonchus oleraceus* |
| 3 | Woods, tall grasslands or wood edge plants on brown earth soils | *Heracleum sphondylium, Anthriscus sylvestris, Hedera helix* |
| 4 | Tall grassland plants on calcareous brown earths | *Tragopogon pratensis, Silene latifolia, Carduus nutans* |
| 5 | Wood edge, tall grassland or grassland plants on brown earths, often humus rich | *Urtica dioica, Arrhenatherum elatius, Galium aparine* |
| 6 | Water edge plants on wet alluvial soils | *Epilobium hirsutum, Polygonum persicaria, Phalaris arundinacea* |
| 7 | Crops or crop edge plants on brown earth soils | *Stellaria media, Polygonum aviculare, Veronica arvensis* |
| 8 | Woodland edge or scrub plants on brown earth soils | *Crataegus monogyna, Prunus spinosa, Tamus communis* |
| 9 | Grassland, tall grassland plants on wood edges on variable soils | *Cirsium arvense, Poa trivialis, Rumex obtusifolius* |
| 10 | Maritime saline or fresh water edge plants on gleyed brown earths | *Oenanthe crocata, Phragmites australis, Hordeum secalinum* |
| 11 | Water edge plants on saturated gleyed alluvial soils | *Sparganium erectum, Glyceria maxima, Lemna minor* |
| 12 | Grassland or tall grassland plants on brown earth soils | *Dactylis glomerata, Lolium perenne, Poa annua* |
| 13 | Grassland plants on brown earths, often skeletal and calcareous | *Medicago lupulina, Daucus carota, Leucanthemum vulgare* |
| 14 | Wood or wood edge plants on calcareous or neutral brown earths | *Rubus fruticosus, Fraxinus excelsior, Geranium robertianum* |
| 15 | Tall grassland plants on damp gleyed brown earths | *Potentilla anserina, Carex hirta, Juncus inflexus* |
| 16 | River edge or aquatic plants on wet alluvial soils | *Apium nodiflorum, Nasturtium officinale, Polygonum amphibium* |
| 17 | Woodland or wood edge plants on brown earth soils | *Stellaria holostea, Corylus avellana, Hyacinthoides non-scripta* |
| 18 | Grassland plants on semi-fertile, sometimes rocky, brown earths | *Taraxacum agg., Poa pratensis, Achillea millefolium* |
| 19 | Grassland plants on calcareous brown earths | *Campanula rotundifolia, Galium verum, Heiracium pilosella* |
| 20 | Wood or wood edge plants on damp fertile brown earths | *Filipendula ulmaria, Angelica sylvestris, Epilobium montanum* |
| 21 | Water edge or aquatic plants on hydromorphic soils | *Glyceria fluitans, Veronic beccabunga, Alopecurus geniculatus* |
| 22 | Grassland wood edge or scrub plants on brown earths | *Holcus lanatus, Agrostis stolonifera, Ranunculus repens* |
| 23 | Marsh, wood edge or woodland plants on wet gleyed brown earths | *Cardamine pratensis, Stellaria alsine, Lotus uliginosus* |
| 24 | Marsh or water edge plants on soil water gleys | *Galium palustre, Juncus bufonius, Caltha palustris* |
| 25 | Woodland or woodland edge plants on acid brown earths | *Primula vulgaris, Digitalis purpurea, Oxalis acetosella* |
| 26 | Plants of maritime habitats on variable soils | *Plantago maritima, Plantago coronopus, Armeria maritima* |
| 27 | Wood, wood edge, scrub, grassland or heath plants on acid or neutral brown earths | *Agrostis capillaris, Pteridium aquilinum, Lotus corniculatus* |
| 28 | Grassland marsh or water edge plants on moist brown earth or gleyed soils | *Juncus effusus, Ranunculus acris, Deschampsia cespitosa* |
| 29 | Grassland or wood edge plants on acid or brown podzolic soils | *Anthoxanthum odoratum, Galium saxatile, Festuca ovina* |
| 30 | Water edge or aquatic plants on wet humic soils | *Potamogeton polygonifolius, Carex rostrata, Potentilla palustris* |
| 31 | Flush, moorland or water edge plants on soil water gleys | *Juncus articulatus/ acutiflorus, J.bulbosus, Ranunculus flammula* |
| 32 | Moorland plants on peaty gley soils | *Carex nigra, C.echinata, Viola palustris* |
| 33 | Moorland or grassland plants on gley or peaty podzolic soils | *Potentilla erecta, Nardus stricta, Deschampsia flexuosa* |
| 34 | Moorland plants on wet peaty gley soils | *Molinia caerulea, Carex panicea, Dactylorhiza maculata agg.* |
| 35 | Heath or moorland plants on podzols or brown podzolic soils | *Calluna vulgaris, Juncus squarrosus, Vaccinium myrtillus* |
| 36 | Bog, water edge or aquatic plant on peaty soils | *Pedicularis sylvatica, Pinguicula vulgaris, Myrica gale* |
| 37 | Bog or heath plants on deep, raw peat soils | *Erica tetralix, Eriophorum angustifolium, Trichophorum cespitosum* |

***Countryside Vegetation System (CVS) classes***

Numbered 1 to 100. Full descriptions are given in Bunce *et al.* (1999a). The names of each class are listed below.

| | |
|---|---|
| 1 | Almost weed free wheat/other crops |
| 2 | Scattered weeds in various crops |
| 3 | Grassy weeds in cereal crops |
| 4 | Broadleaved weeds in mixed crops |
| 5 | Mixed weeds in cereal groups |
| 6 | Weedy leys/undersown cereal crops |
| 7 | Crop hedges/boundaries |
| 8 | Eutrophic hedges/boundaries |
| 9 | Boundaries/open crop hedges |
| 10 | Tall grass boundaries |
| 11 | Streamside banks within crops |
| 12 | Lowland eutrophic roadsides |
| 13 | Lowland mesotrophic roadsides |
| 14 | Lowland roadsides/crop boundaries |
| 15 | Lowland river banks |
| 16 | Shady eutrophic streamsides |
| 17 | Lowland wetlands/water edges |
| 18 | Eutrophic shaded ditches |
| 19 | Eutrophic riverside/wetland tall herb |
| 20 | Grassy roadside verges |
| 21 | Diverse lowland hedgerows |
| 22 | Nutrient-rich riverbanks |
| 23 | Eutrophic mixed grassland |
| 24 | Dry base-rich woodland |
| 25 | Shaded grassland/hedges |
| 26 | Tall grassland/scrub |
| 27 | Rye-grass roadsides |
| 28 | Eutrophic tall herb/grassland |
| 29 | Rye-grass swards |
| 30 | Mixed eutrophic grassland |
| 31 | Rye-grass/clover grassland |
| 32 | Gravel reedbeds |
| 33 | Marshy grassland |
| 34 | Mixed grassland scrub |
| 35 | Diverse base-rich woodland/hedgerows |
| 36 | Shaded moist stream banks |
| 37 | Diverse mesotrophic grassland/scrub |
| 38 | Enriched mesotrophic grassland |
| 39 | Eutrophic streamsides/woodlands |
| 40 | Rye-grass/Yorkshire fog grassland |
| 41 | Riverside silts/wetlands |
| 42 | Woodland on heavy soils |
| 43 | Rye-grass/bent grass swards |
| 44 | Calcareous grassland |
| 45 | Shaded grassy streamsides |
| 46 | Shaded nutrient-rich streamsides |
| 47 | Diverse mesotrophic pasture |
| 48 | Marshy riversides |
| 49 | Acidic woodland fragments |
| 50 | Acidic woodlands |
| 51 | Wet rushy grasslands |
| 52 | Mesotrophic grasslands |
| 53 | Diverse mesotrophic/acid grasslands |
| 54 | Marshes/wet tall herb |
| 55 | Rushy mesotrophic/acid grasslands |
| 56 | Mesotrophic diverse moist grasslands |
| 57 | Enriched moorland flushes |
| 58 | Rushy diverse streamside/flushes |
| 59 | Upland semi-shaded acidic streamsides |
| 60 | Streamsides/flushes within acidic grasslands |
| 61 | Herb-rich upland grassland |
| 62 | Acidic lowland woodland |
| 63 | Diverse upland streamsides/grasslands |
| 64 | Agrostis/Fescue/Bracken |
| 65 | Acidic herb-rich grass/heath |
| 66 | Streamsides/flushes in moorland vegetation |
| 67 | Moorland grass |
| 68 | Acidic oak/birch woodland |
| 69 | Open acidic heathy birch woodland |
| 70 | Shady acidic streamside |
| 71 | Herb-rich moorland grass/heath |
| 72 | Acid peaty streamsides/flushes |
| 73 | Moorland grass on wet peat |
| 74 | Streamsides/flushes in wet moorland grass |
| 75 | Upland coniferous plantations on moorland/upland grassland |
| 76 | Diverse streamsides/flushes in moorland vegetation |
| 77 | Dense Sitka spruce |
| 78 | Complex montane/moorland grass |
| 79 | Mountain streamsides and slightly enriched moorland grass |
| 80 | Moorland grass/heath on peaty gleys |
| 81 | Heath/montane acidic grasslands |
| 82 | Wet moorland heath vegetation |
| 83 | Heather moorland on peats |
| 84 | Heather moorland |
| 85 | Streamsides/flushes on peats |
| 86 | Moorland/streamside on peaty gleys |
| 87 | Moorland/bog on peats |
| 88 | Montane moorland/heath |
| 89 | Montane heather moorland |
| 90 | Wet heathland |
| 91 | Upland heather moor |
| 92 | Ombotrophic bog |
| 93 | Montane heath vegetation class |
| 94 | Sphagnum bogs |
| 95 | Species poor blanket bog |
| 96 | Wet bogs |
| 97 | Northern blanket bog vegetation class |
| 98 | Cotton grass bog |
| 99 | Saturated bog vegetation class |
| 100 | Inundated bog/wetland peat |

## Tracing observed and expected responses back to the source data

The source data used to establish observed patterns of IBD state are included as comprehensive annexes in ECOFACT Volume 2 (Bunce *et al.* 1999b). Readers who wish to follow the observed responses back to this source can do so by looking up the annex that corresponds to each IBD. See table below and the following text for an example comprising part of the links table for atmospheric nitrogen deposition.

***Examine Table 3***

To establish the annex number in Bunce *et al* (1999b) containing change analysis results for each IBD.

**IBD 1:** Annex 10.15
**IBD 2:** Annex 10.16
**IBD 3:** Section IV, page 55

***Match results***

For each IBD with annex information, as follows.

- **IBD 1** – refers to shifts in aggregate class plot membership between 1978 and 1990. The expected scenario is for plots to have shifted from less fertile to more fertile vegetation types. For example from IV to III, from VII to IV and from VIII to VII. This shift is consistent with movement from higher to lower numbered classes reflecting their dispersion along the dominant fertility gradient expressed across Countryside Survey vegetation data (See Box 8). The matrices in Annex 15 (Bunce *et al.* 1999b) give counts of plots in each aggregate class in each year by plot type. Examination shows that only X plots showed a consistent net shift of plots from VIII to VII (13 plots) from VII to IV (4 plots) and from IV to III (8 plots).

- **IBD 2 –** refers to shifts in CVS class membership. The matrix of flows between aggregate classes is in Annex 10.16. The daunting amount of information contained within the matrix gives some indication of the value of the approach adopted in the links matrices. By starting with a specific hypothesis to test, it is possible to search directly for the expected pattern rather than have to consider a large number of separate CVS class shifts unguided by any particular expectation of change. Even the task of searching for the expected shifts requires inspection of the largest net shifts in the matrix. These are then cross-referred to the CVS class descriptions in ECOFACT Volume 1 (Bunce *et al.* 1999a) to establish whether there were indeed shifts from less to more fertile classes.

- **IBD 3** – comprises analysis of change in plant species composition in terms of the changing representation of plant attributes (see Box 10). These results are summarised in the text of ECOFACT Volume 2 (Bunce *et al.* 1999b). Using these results, expected patterns are either verified or rejected.

Specimen Annex table (see text)

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shift to more fertile classes over ALL plot types. | Shifts not consistent across plots taking into account less fertile starting points. | MODERATE |
| IBD2 | Losses from heath to more eutrophic grassland classes throughout. | Shift from heath to classes with more *Nardus* eg. 82 to 86 and 99 to 91. Divergent trends between plot types, aggregate classes and landscapes (see agricultural nitrogen usage and drainage). | MODERATE |
| IBD3 | Eutrophication across less fertile aggregate classes and all plots. | Eutrophication certainly inferrred but only in particular strata eg. III X, IV X and S, II AR, V AR, VI UP and VIII throughout. | MODERATE |

# ANNEX 1 – EUTROPHICATION

## Atmospheric deposition

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shift to more fertile classes over ALL plot types. | Shifts not consistent across plots taking into account less fertile starting points. | MODERATE |
| IBD2 | Losses from heath to more eutrophic grassland classes throughout. | Shift from heath to classes with more *Nardus* eg. 82 to 86 and 99 to 91. Divergent trends between plot types, aggregate classes and landscapes (see agricultural nitrogen usage and drainage). | MODERATE |
| IBD3 | Eutrophication across less fertile aggregate classes and all plots. | Eutrophication certainly inferred but only in particular strata eg. III X, IV X and S, II AR, V AR, VI UP and VIII throughout. | MODERATE |
| IBD5 | – | – | – |
| IBD6 | Fertility increase in less fertile agg classes over all plot types. Light decrease in heath/bog as *Calluna* increases but in absence of grazing only. | Fertility increases ocurred in particular plot types eg.IV X,R and H; VIII X and S. Whilst light score did decrease in VIII. | MODERATE |
| IBD7 | Increased eutrophic grassland groups in VIII. Increase in fertile groups in less fertile aggregate classes in all plots. Decrease in unimproved grassland groups. | Decrease in (33) in UP VII X. Increase in (33) and (5) in GB VIII X. Decrease in (34) in GB VIII X. Increase in fertile groups in non-wooded lowland S and R plots. Increases in (12) ocurred in GB VII X and PA IV X but see Agric nitrogen usage. | MODERATE |

## Agricultural fertilisers

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shifts to more fertile classes (IV to III, VII to IV, VIII to VII) in X plots. | Movement from IV to III in X plots, VII to IV in X and S, VIII to VII in X. | GOOD |
| IBD2 | Shift to more fertile classes in all except uplands affecting mainly X plots. | Substantial shift from 43 to 30 and 40 to 6 all involving X plots. | GOOD |
| IBD3 | Eutrophication of less fertile classes outside uplands in X plots. | Eutrophication ocurred in IV X and III X. | MODERATE |
| IBD5 | – | – | – |
| IBD6 | Fertility score increases in all less fertile classes outside uplands especially in X plots. | Fertility increases detected in III X and IV X. | GOOD |
| IBD7 | Increase in fertile/improved grass groups in less-fertile aggregate classes in X plots. Decrease in unimproved grassland groups in less fertile X plots. | Increase in (12) in GB VII X and PA IV X. Decrease in (29) in GB and AR IV X. Decrease in (18) in GB and MU IV X. | GOOD |

## Waterside eutrophication

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shifts from IV to III and VII to IV in S plots largely in lowlands. | Net shift from VII to IV. | GOOD |
| IBD2 | Shift to more eutrophic CR dominated groups. | None observed. | NO MATCH |
| IBD3 | Eutrophication detected. | Eutrophication observed in IV S and II S in PA. | GOOD |
| IBD5 | – | – | – |
| IBD6 | Increased fertility scores. | Only increase in VIII S. | POOR |
| IBD7 | Increase in eutrophic groups, decrease in mesotrophic wetland groups. | Increases in (5) in GB and AR IV S. | GOOD |

# ANNEX 2 – ACIDIFICATION

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shifts from IV to VII in MU and UP in all plots. | Net shifts from VII to IV in S and X plots. | NO MATCH |
| IBD2 | Loss from base-rich classes to more acid. | No net loss from calc grassland class 44 or base-rich woodland class 24. | NO MATCH |
| IBD3 | – | – | |
| IBD5 | – | – | |
| IBD6 | pH scores decrease throughout. | pH scores increased in I, II, III, IV and VIII with reduction only in III S. | NO MATCH |
| IBD7 | Decrease in base-rich groups. | Decrease in (19) in GB VIII X. Decrease in (36) in GB 7 S. Increase in (36) GB 7 X. | POOR |

# ANNEX 3 – URBANISATION AND TRANSPORT

## Road verges (reduction of) management

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Net shifts in R plots from non-wooded classes to II, and II to V and VI. | Net shift from IV to II, smaller shift from III to II. | GOOD |
| IBD2 | Increase in CR dominated, tall grassland classes. | Net shifts from CSR dominated, more species-rich verge classes - 27 to 31 - to weedier more CR and R dominated classes 12, 13 and 14. | GOOD |
| IBD3 | Dereliction observed. | Dereliction detected on II R in AR, III R and IV R. | GOOD |
| IBD5 | – | – | – |
| IBD6 | Light scores decrease in R plots. | Light scores decreased in IV R and III R. | GOOD |
| IBD7 | Increase in scrub/ tall grassland groups | Increase in (14) in PA II R. Increase in (5) in GB III R. Increase in (3) in GB III R. Increase in (20) in GB IV R. | GOOD |

## Road verges – eutrophication

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shifts from less-improved grasslands to more fertile ie. VII to IV, IV to III. | Net shifts to II. | NO MATCH |
| IBD2 | Eutrophic classes gain from less fertile classes. | Shifts from more species-rich classes to weedier CR dominated classes are consistent with heightened trophic status but confounded with disturbance effects. | MODERATE |
| IBD3 | Eutrophication in R plots. | Eutrophication observed in IV R. | GOOD |
| IBD5 | – | – | – |
| IBD6 | Increase in fertility scores | Increases detected in III R and IV R. | GOOD |
| IBD7 | Increase in eutrophic groups. | Increase in (5) in GB III R. Increase in (2) in GB II R. Increase in (12) in GB II R. Decrease in (18) in GB 4 R. Decrease in (12) in GB III R. | MODERATE |

## Road verges – increased disturbance

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Net shifts in R plots to I. | None observed | NO MATCH |
| IBD2 | Net shifts to weedier classes. | Net shifts from CSR dominated, more species rich verge classes (27 to 31) to weedier more CR and R dominated classes 12, 13 and 14. | GOOD |
| IBD3 | Increased disturbance | None observed | NO MATCH |
| IBD5 | – | – | – |
| IBD6 | – | – | – |
| IBD7 | Increases in weedier groups | Increase in (1) in PA II R | POOR |

# ANNEX 4 – AGRICULTURAL INTENSIFICATION

## Crop management and pesticide use

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Increase in III, rotation through I and III; X plots only. | Net shift from I to III in X plots. Large amount of turnover between I and III. | GOOD |
| IBD2 | Loss of Spring cereal classes. Reduction in weedy crop classes; I plots only. | Net movement from 5 to 1 and 3 represents loss to Barley and gains to species poor Wheat. Large turnover through *Lolium* leys and crops represented by shifts in and out of 6, 29, 1, 30 and 31. | GOOD |
| IBD3 | Loss of ruderal species in plots that stayed in I; X plots only. | Shift to autumn germinating ruderals but only in AR and only in 'stay-same' and 'simple' analyses. | GOOD |
| IBD5 | Reductions in species richness | Reduction in AR I X plots only. | GOOD |
| IBD6 | Fertility scores increase in I. | NS | NO MATCH |
| IBD7 | – | – | – |

## Grassland cultivation

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Grassland classes move to I. | Net shift from I to III. | NO MATCH |
| IBD2 | Older grassland classes lose to new leys and crops gain. | Net shift from more established leys and semi-improved older grassland - 43 & 40 - to new leys - 30 & 6. | MODERATE |
| IBD3 | Increased disturbance in III, IV and VII in '78-based' analysis. | None detected | NO MATCH |
| IBD5 | – | – | – |
| IBD6 | Fertility and light score increases in III and IV X plots. | Increases in fertility score detected in III X and IV X. Light scores decreased. | POOR |
| IBD7 | Increased crop/ weed groups in grassland X plots. | Increase in (1) in GB III X and (7) in GB IV X. | GOOD |

## Upland sheep grazing

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Net shifts from IV to VII and VIII to VII in MU and UP. Concentrated in X and S plots. | Net shift from VIII to VII and VII to IV in X plots and from VIII to VII in uplands. | MODERATE |
| IBD2 | Net shift to more fertile, grassy groups with high *Nardus* at expense of heath/ bog. | Net shifts from heath/ bog to *Nardus* rich groups eg. 91 to 73, 99 to 91 and 82 to 86. | GOOD |
| IBD3 | Eutrophication and disturbance in UP and MU grasslands and heath/ bog. | Eutrophication and disturbance detected only in heath/ bog in '78-based' analysis. | MODERATE |
| IBD5 | – | – | – |
| IBD6 | Fertility light and pH score increases in UP and MU grasslands and heath/ bog. | pH and fertility scores increased in heath/ bog but light score decreased. No sig results were detected for VII and IV in MU and UP. | MODERATE |
| IBD7 | Increase in *Nardus* dominated groups and loss of heath/ moorland groups in IV, VII and VIII in X and S plots in MU and UP. | Increase in (33) in GB VIII X. Decrease in (35) and (37) in GB and MU VIII X. | GOOD |

# ANNEX 5 – DRAINAGE

## Drainage

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | – | – | – |
| IBD2 | Loss of wetter classes to drier in X and S plots in VII, VIII, III, IV and V. | Net shifts from upland wet heath/bog to drier classes eg. 82 to 86 and 99 to 91. Also shift from drier 82 to wetter 99. All in X plots. | MODERATE |
| IBD3 | – | – | – |
| IBD5 | – | – | – |
| IBD6 | Wetness scores decreased. | Decrease in III X and VIII S and X but other increases in VII, VI, V and IV. | MODERATE |
| IBD7 | Wetter groups decrease. | Decrease in (37) in GB VIII X. Increase in (37) in GB VII X. Decrease in (21) in GB and AG III X and in GB III R. | MODERATE |

## Waterside (reduction of) management

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Non-wooded agg classes shift to V, VI or II in S plots. | Large net shift from IV to II, smaller shift from III to II in S plots. | GOOD |
| IBD2 | Gains to taller, grass/scrub classes. | None observed. | NO MATCH |
| IBD3 | Dereliction in S plots. | Dereliction in III S in AR and II S in PA. Also in IV throughout. | GOOD |
| IBD5 | – | – | – |
| IBD6 | Light scores decrease. | Decrease in IV S. | GOOD |
| IBD7 | Increase in tall herb, C and CR dominated groups. | Increases in (5) in GB and AR IV S. Increase in (14) in GB IV S. | GOOD |

# ANNEX 6 – FORESTRY

## Broadleaved (reduction of) management

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | – | – | – |
| IBD2 | Spp poor wood/ scrub classes increase at expense of more species-rich woodland groups. | Only gain was from more open woodland classes to 50, a more Bracken dominated woodland class. This involved shifts on S, X and R plots. | POOR |
| IBD3 | Increased dereliction in V X and S. | None observed. | NO MATCH |
| IBD5 | – | – | – |
| IBD6 | Light scores decrease in V X and S. | Light score increased in V S only. | NO MATCH |
| IBD7 | Increase in groups dominated by woody species in V X and S plots. | No changes detected | NO MATCH |

## Broadleaved management – overgrazing

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | – | – | – |
| IBD2 | Net shift to grassier woodland classes in X and S plots. | None observed. | NO MATCH |
| IBD3 | Eutrophication and disturbance in 'stay-same' analyses for V and VI X and S plots. | Increased disturbance in VI S plots. Eutrophication in all VI plots but no sig results for 'stay-same' analyses. | POOR |
| IBD5 | – | – | – |
| IBD6 | – | – | – |
| IBD7 | – | – | – |

## Broadleaved management – clearfelling

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shifts from V X and S plots. | None observed. | NO MATCH |
| IBD2 | Decline in woody classes in X and S plots to grassy and weedier classes. | None observed. | NO MATCH |
| IBD3 | Increased disturbance in V X and S plots in '78-based' analysis. | None observed for separate plot types. | NO MATCH |
| IBD5 | – | – | – |
| IBD6 | – | – | – |
| IBD7 | Loss of woodland groups in V X and S plots. Reduction in frequency plus very large decrease in cover. | No changes detected | NO MATCH |

## Conifer planting

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Net shifts in upland X and S plots to VI. | High turnover between VII and VI but net shift to VI. | GOOD |
| IBD2 | Increase in conifer classes. | Net shifts to 77 from a range of starting points and from 73 to 75. | GOOD |
| IBD3 | – | – | – |
| IBD5 | Species richness reduced. | Reductions in MU and PA in VI X plots but not in upland where net shift was from VI to VII. | GOOD |
| IBD6 | – | – | – |
| IBD7 | – | – | – |

## Conifer management – clearfelling

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | Shift from VI to other. | Net shift across GB from IV and VII to VI but in UP only there was high turnover and a net shift from VI to VII. | GOOD |
| IBD2 | Conifer classes decrease. | None observed. | NO MATCH |
| IBD3 | Increased disturbance in VI X and S. | Increased disturbance in VI S plots only. Eutrophication in VI plots. | POOR |
| IBD5 | – | – | – |
| IBD6 | Light scores increase in VI X and S. | Scores only increase in VI S plots. | POOR |
| IBD7 | – | – | – |

# ANNEX 6 ...continued

## Hedgerow (reduction of) management

| | Expected | Observed | Correspondence |
|---|---|---|---|
| IBD1 | II, III, IV and VII to V. H plots only. | Net shifts from II and IV to V but very high turnover. Effects are also confounded with road verge neglect. | MODERATE |
| IBD2 | Shifts to weedier wooded classes, but confounded with disturbance in adjacent habitat. Shifts to more wooded classes but also likely to be confounded with lack of management on road verges.. | Shifts did ocurr from eutrophic classes to even more eutrophic classes more dominated by competitive ruderal species eg. 16 and 25 to 7, 9 to 12; all H plot shifts. | MODERATE |
| IBD3 | Dereliction in 'stay-same' analysis. | Eutrophication only. | NO MATCH |
| IBD5 | – | – | – |
| IBD6 | Light scores decrease in non-wooded H plots ie. II, III, IV and VII. | Light scores decreased in II H. Light scores increased in V H, could suggest increasing gaps. | MODERATE |
| IBD7 | Woody groups increase in non-wooded H plots. Increase in woody group cover in wooded H plots (V and VI). | Increase in (8, COVER) in PA and GB V H. Increase in (17, COUNT) in GB 4 H. | GOOD |

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# GLOSSARY

**Aggregate class (AC) I–VIII** The eight aggregate classes derived from the 100 CVS vegetation classes by cluster analysis and used to stratify data for analyses of change (see Bunce *et al.* 1999a,b).

**AONB** Area of Outstanding Natural Beauty.

**Biodiversity** In this report, the term "biodiversity" includes diversity at ecosystem, assemblage and species scales for higher plants and animals, and does not consider variability at the genetic level.

**CAP** Common Agricultural Policy.

**CS1990** The Countryside Survey which took place in 1990, but also repeating those carried out in 1978 & 1984. Results were reported in Barr *et al.* (1993).

**CS2000** The Countryside Survey which took place in 1989/99 and which will report on stock changes in land-care and vegetation in November 2000.

**Countryside Vegetation System (CVS)** The integrated system developed during ECOFACT for classifying vegetation of the wider countryside. Built from all Countryside Survey plot data recorded in 1978 and 1990 (see Bunce *et al.* 1999a,b).

**CSR** Refers to the model developed by Grime (1979) which recognises three primary strategies of plant species; Competitors, Stress-tolerators and Ruderals. Plant species can be assigned to one of these functional groups or an intermediate category depending upon the value of a series of attributes (eg canopy height and relative growth rate).

**CVS Classes** The 100 classes produced from the classification of all CS1990 vegetation data (Bunce *et al.* 1999a,b).

**DECORANA (ordination)** A procedure used to derive the principal gradients within multi-variate vegetation data (Hill & Gauch 1980).

**Driving force–state–response model** A framework used in this report for understanding causes of change in vegetation biodiversity. The 'driving forces' are those human-induced drivers of vegetation change, which operate in different areas of the landscape, and which arise from different sectors of human activity. The 'states' are those measures of botanical diversity, which include species number and vegetation character in different locations of the landscape. The 'response' is the human response to the changes in state, for example appropriate changes in policy or land management practices. The model is also used as a basis for reporting UK Indicators for Sustainable Development.

**ECOFACT** Ecological Factors Controlling Biodiversity in the British Countryside. The title of a research programme of which this report forms part.

**Ellenberg Scores** Scores attributed to species, which define their ecological range in terms of fertility, pH, light, and moisture (Ellenberg 1991). These were re-calibrated for the British situation and subsequently used in the ECOFACT program to interpret the CVS and to explore causes of change.

**ESA** Environmentally Sensitive Areas.

**HLCA** Hill Livestock Compensatory Allowance.

**IBD** Indicators of Botanical Diversity. The indicators identified as appropriate for measuring changes in vegetation of the wider countryside. Some are more appropriate for measuring botanical quality. Others can be used to infer processes of change.

**Indicators of Sustainable Development** Measures of environmental, social and economic trend and condition.

**Land Classification** A multivariate classification of all 1 kilometre squares in GB based on geology, climate and topography and thus independent of the biota of the land surface (Bunce *et al.* 1996).

**Landscape type** The 32 ITE Land Classes generated by the land classification were aggregated at a higher level into four landscape types (arable lowlands, pastural lowlands, marginal upland and upland) based on joint similarity in shared geological, climatic and topographic attributes (Barr *et al.* 1993). For many of the analyses in this report Countryside Survey data was stratified by these four landscape types.

**LFA** Less Favoured Area.

**National Vegetation Classification (NVC)** The classification system developed at Lancaster University for describing British vegetation (Rodwell 1991).

**OECD** Organisation for Economic Co-operation and Development.

**Ordination Axis** The gradient along which vegetation samples are ordered, according to their ecological affinities.

**Plot Types** The 6 types of sample vegetation plots placed in different landscape elements in the Countryside Survey (main, streamside, roadside, hedge, boundary and habitat) (Barr *et al.* 1993, Bunce *et al.* 1999b).

**Species Groups** Groups of species with relatively similar environmental affinities generated by minimum variance cluster analysis of ordination scores for each species (Bunce *et al.* 1999b).

**SAC** Special Area of Conservation. These will be designated under the EC Habitats Directive and will contribute to the Natura 2000 series of pan-European sites along with Special Protection Areas.

**SSSI** Site of Special Scientific Interest.

**WES** Wildlife Enhancement Scheme.