4

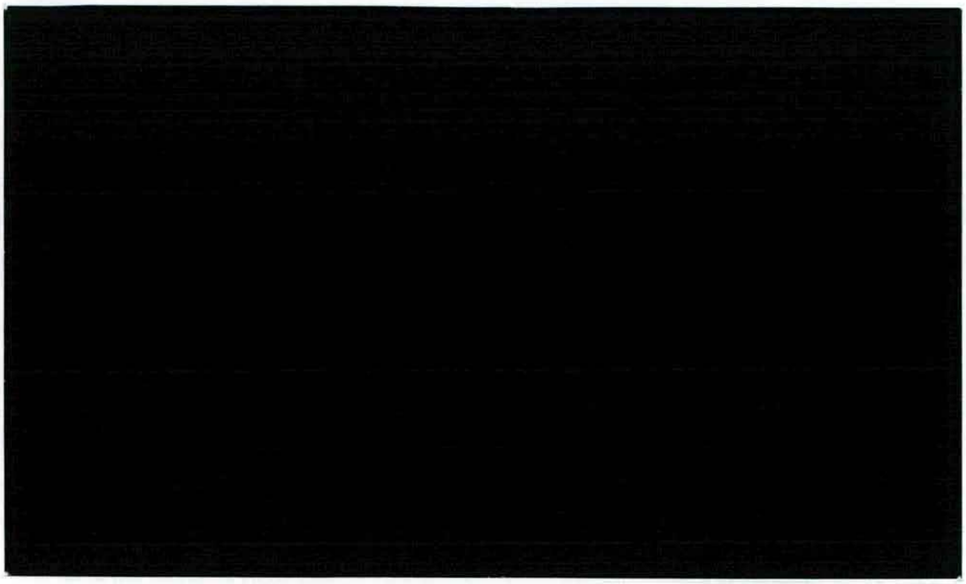
Institute of Terrestrial Ecology

[redacted]

Centre for Ecology & Hydrology

Natural Environment Research Council

The **Institute of Terrestrial Ecology** is a component Institute of the Natural Environment Research Council. It was established in 1973, and now forms part of the NERC Centre for Ecology and Hydrology.



The ITE mission

OL13
Unicorn entries
to be checked

~~Deposited~~

The Institute of Terrestrial Ecology will [illegible] multidisciplinary research and exploit new technology to advance the science of terrestrial ecology, leading to a better understanding and quantification of the physical, [illegible] of the land.

Priority is placed on developing and exploiting knowledge in the following areas:

- the factors which determine [illegible] processes of terrestrial ecosystems, and the characteristics of individual plant and animal species
- the dynamics of interactions between atmospheric processes, terrestrial ecosystems, soil properties and surface water quality
- the development of a sound scientific basis for monitoring, modelling and predicting environmental trends to assess past, present and future effects of natural and man-made change
- the securing, expansion and dissemination of ecological data to further scientific research and provide the basis for impartial advice on environmental protection, conservation, and the sustainable use of natural resources to governments and industry.

The Institute will provide training of the highest quality, attract commissioned projects, and contribute to international programmes.

ITE will promote the use of research facilities and data to enhance national prosperity and quality of life.

INTERIM REPORT

ECOLOGICAL FACTORS CONTROLLING BIODIVERSITY IN THE BRITISH COUNTRYSIDE (ECOFACT)

MODULE 6

Edited by: RGH Bunce

[1996]

CONTENTS

1. Introduction

The ECOFACT project is a research programme which has been approved under NERC's Peer Review system. It involves further analysis of the CS 1990 datasets, either by developing existing analyses further, or by using data which were collected as part of the Survey but which have not been analysed to date. The data will be supplemented where necessary by other available datasets, eg from the Agricultural and Food Research Council (AFRC) experiments.

The Work Programme will be co-ordinated with projects specified and supported by the Department of the Environment (DOE) the Ministry of Agriculture. Fisheries and Food (MAFF) and the Scottish Office Agriculture Fisheries and Environment Department (SOAEFD). A fully integrated approach has been developed so that common databases will be used wherever possible thus avoiding conflicts within the work timetable. In addition, ITE will also be carrying out underpinning scientific research, eg on pollution impacts and landscape ecology, which will contribute to the Work Programme.

In policy terms, it is worth noting that both the Government White Paper on the Environment, 'Our Common Inheritance' and the UK Action Plan on Biodiversity state that sound science should underpin all environmental policy. Rigorous scientific analyses of CS1990 data can make important contributions to many of the Action Plan objectives. Indeed, one stated objective is to improve the databases of the Countryside Surveys of Great Britain and Northern Ireland - these can best be achieved once a thorough analysis and understanding of existing data has been achieved.

In organisation terms within NERC, the full research programme which has been developed from the Peer Review project will comprise a series of interlinked Modules and sub-projects (Table 1). The present interim report covers work that has been done under Modules 6a and 6b although there has been some input from 6c. The comments of the Technical sub group for Module 6 held on the 25 March 1996 have been incorporated where possible, but further modifications may be necessary in due course.

Table 1 - List of Modules and interlinked sub-projects within the ECOFACT project

	SUB PROJECT TITLE	SOURCE OF FUNDS
MODULE 1	BOTANICAL ANALYSIS	
Module 1A	Measuring botanical diversity in the wider countryside.	DOE
Module 1B	Botanical diversity within woodlands	NERC
Module 1C	The relative importance of species and vegetation on agricultural land in England and Wales	MAFF
MODULE 2	INTEGRATION	
Module 2A	Development of links to other surveys and classifications	DOE
Module 2B	Land Cover Map development for Wales	NERC
MODULE 3	THE ROLE OF SEED BANKS IN THE RESTORATION OF BIODIVERSITY	MAFF
MODULE 4	Review of farm management practices that affect botanical diversity in England and Wales	MAFF
MODULE 5	HISTORICAL REVIEW OF COUNTRYSIDE AND AGRICULTURAL POLICY	NERC
MODULE 6	CAUSES OF CHANGE	
Module 6A	Understanding the causes of changes in biodiversity associated with linear features and upland vegetation in GB	DOE/NERC
Module 6B	Impact of pollution on biodiversity in the British landscape	NERC
Module 6C	The causes of change in biodiversity on agricultural land in England and Wales	MAFF
Module 6D	Biodiversity of agricultural land in Scotland	SOAFD
MODULE 7	PATTERN ANALYSIS	
Module 7A	Patterns of biodiversity in the landscape	DOE/NERC
Module 7B	The interrelations between landscape features and their ecological function	NERC
MODULE 8	REVIEW OF TECHNIQUES FOR BOTANICAL SURVEY AND MONITORING	NERC/DOE
MODULE 9	SEMINARS	DOE
MODULE 10	GIS DEVELOPMENT FOR CS2000	NERC
MODULE 11	CS2000 PLANNING GROUP	NERC

2. Summary Programme for Modules

2.1 Project Module 6a - Understanding the Causes of Changes in Biodiversity (DOE)

Project Leader: RGH Bunce (ITE Merlewood)

2.1.2 Introduction

Although the initial analysis of CS1990 identified the principal changes that were taking place in botanical diversity it was not designed to assess the underlying causes. This module is designed to go much further towards identifying these causes and will complement other modules funded by MAFF and SOAFD which are also concerned with the analysis of change. The main work of this Module will therefore necessarily be in the second year. Project Module 1 will provide more detailed information on change, especially concerning individual species, which will provide an input into this module.

Table 2 - Areas of work programme funded by each organisation :

	FUNDING ORGANISATIONS			
	6A: DOE (80%) NERC (20%)	6B: NERC	6C: MAFF	6D: SOAFD
COVERAGE	GB	GB	England & Wales	Scotland
FEATURES	Linear features and upland vegetation.	Woodland (not currently costed)	Agriculturally managed land: arable and lowland grassland.	Agricultural land in four intensity strata.
DATA PROVISION	Wye College - farm level data (part funded)	Pollution	AFRC data + Wye College farm level data (part funded).	Wye College farm level data

2.1.3 Policy context

Many of the objectives in the UK Action Plan on Biodiversity (eg: development of control; greening of the CAP; environmentally sensitive forms of agriculture; the use of environmentally damaging chemicals; enhancing wildlife habitats on farmland), require a thorough understanding of the causes of change in botanical diversity. Specifically:

- The causes of changes in biodiversity need to be understood in order to define appropriate policies for maintenance.

- The relative importance of management as compared with external factors is important in the development of policy.

- It is necessary to understand the influence of grazing on upland ecosystems in order to determine the necessary measures for heather regeneration.

2.1.4 Objectives

- To examine the causes of observed changes in botanical diversity.

- To assess the relative importance of land management and other factors, such as pollution.

- To recommend land management practices for the maintenance and enhancement of diversity.

- To develop predictive techniques for determining ecological impacts.

2.1.5 Work Programme

The main items of work will be as follows:

- Identification of sources of information relating to effects of land management on biodiversity. Relevant sources of information include work connecting botanical diversity with nutrient levels, eg the Park Grass experiment at Rothamsted Experimental Station, work on water and nitrogen levels carried out by ITE on the Somerset Levels and work on pollution loadings from the ITE Critical Loads Programme. The MAFF project on Review Land Management Practices ECOFACT (Module 4) will provide further information on the changes in farm practice which have taken place and their effect on botanical diversity. Where possible, botanical data from the CS1990 database will be analysed in conjunction with other databases, in order to link the principal gradients within botanical diversity with associated environmental factors.

- Examination of the relative importance of management compared with external factors. Where there is sufficient quantitative data, the logistic regression procedure, developed in NERC's TIGER IV Programme, will be used to partition variation between land management and other factors. For other variables, it will only be possible to consider the relative strengths of impacts on diversity using a procedure similar to that developed in the DOE project on

Countryside Impact Tables. This analysis will be carried out by developing a matrix, the columns of which represent relative impacts and their force, and the rows of which represent the extent or occurrence of species, and their susceptibility. The data from the Wye College project on the Processes of Change will be incorporated within these analyses in order to provide the necessary inputs from the socio-economic standpoint. This will require conversion of the whole farm data from Wye College to the field level. Some problems may be encountered in identifying the detailed management of individual fields, but the use of the Impacts Table approach will enable the principal changes and causes to be determined.

- A review will be undertaken of the variety of descriptive and quantitative models linking grazing pressure and vegetation characteristics, eg. models being developed at the MLURI. An assessment will be made of the value of these models and the most relevant will be linked to the vegetation categories defined by CS1990. For example, when grazing pressure is reduced on mat grass moorland, heather and bilberry can re-establish provided they are present in small quantities in the original vegetation.

- Hypotheses will be developed from these analyses, which will be tested subsequently by selected case studies, carried out during the second year of the project. Field data from these case studies will provide information on areas of vegetation that have changed between 1978 and 1990 and will be linked to the field survey being carried out as part of the MAFF Module on Seed Banks (Module 3).

- Consultations will be held with land managers and advisors, eg. County Councils, ADAS and the Farm Wildlife Advisory Group (FWAG), in order to identify practical management procedures and to produce recommendations based on an understanding of the causes of change. The information on management collected in the case studies will be used as the basis for determining the appropriate management practices for the maintenance of species and vegetation, eg. the suggested case study on roadside verges in Cumbria will enable recommendations to be made concerning the best management practices for maintaining diverse verges.

2.2 Project Module 6b - Impact of Pollution on Biodiversity in The British Countryside (NERC)

Project Leader: DC Howard (ITE Merlewood)

2.2.1 Introduction and methods

The possible contribution of pollutant inputs of nitrogen, sulphur and acidity to changes in biodiversity and species distributions will be explored through the application of the critical load concept and ecological response surfaces, both separately and in combination. the critical load approach will be applied at the GB scale and to individual 1 km survey squares. The latter will be used to explore the potential impacts of pollutants on species distribution and pattern at the landscape scale. Empirical critical loads of nitrogen will be assigned to vegetation groupings, as defined in the vegetation analysis carried out both as part of CS1990 and the ECOFACT project, based on published data and using approaches defined at workshops held at Lokeberg, Sweden and Grange-over-Sands. Critical loads of acidity and nitrogen will also be calculated for species group-soil combinations using mass balance models.

Ecological response surfaces will be derived for a range of plant species using a combination of species occurrence data and soil data from the CS 1978 and Ellenberg indices. These response surfaces will be used in combination with Biological Records Centre (BRC) data to define potential occurrence. The data on potential distribution of species can be combined with actual species occurrence data from CS1990 and exceedence maps, produced by combining the above derived data sets with the best available data on current deposition levels, to interpret the possible impacts of pollutant N and acidity inputs.

2.3.1 Project Module 6c - the Causes of Change in Biodiversity On Agricultural Land in England and Wales (MAFF)

Sub Project Leader: RGH Bunce (ITE Merlewood)

2.3.2 Introduction and methods

The stimulus for this module comes from the requirement of MAFF to determine the causes of change of species composition in agriculturally managed land in England and Wales. As such this Module will supplement Module 6A and will be concerned with the changes that have taken place in agriculturally-managed land. Although some of the procedures and data bases will be in common with module 6A they will be applied solely to agricultural land. This information on the actual fields will be utilised whereas in 6A indirect influences will be covered. The causes of changes identified will be linked to the categories developed in project 1C. The project will link the data from CS 1990 with results from earlier or current experimental work plus limited, additional field data. In particular there have been many experiments starting with Park Grass at Rothamsted in the 1850s that link grassland species composition to nitrogen level. More recently relevant research is also being carried out at AFRC centres at North Wyke and Aberystwyth that could be usefully linked to the vegetation data recorded in CS 1990. Work by ITE on the Somerset levels and by ADAS in ESA may also be useful.

On the farm management side, Dr Clive Potter from Wye College has undertaken a survey of farms within the samples squares of CS 1990. These data will therefore relate directly to the fields surveyed. Whilst data may only be available at the farm level the analyses of these data will give strong indications of the changes that have taken place between 1978 and 1990 in farm practice. This will be supported by Modules 4 and 5. The methods will be the same as in Module 6A.

2.3.3 Objectives:

- To assess the available experimental information and negotiate for its extraction.

- To analyse the botanical data from CS1990 in conjunction with available experimental botanical data from which detailed information on nutrient levels is available. Logistic regression will then be applied to link nutrient levels with different degrees of biodiversity.

- To discuss with Dr Clive Potter the structure and composition of the farm management data and then to proceed with appropriate analysis.

- To structure the botanical data from 1978 and 1990 into an appropriate format for co-ordinated analyses with management and pollution data.

- To carry out a scoping exercise to determine the relative importance of the major causes of change

- To set up appropriate hypotheses linking the observed changes with causal factors.

- To determine relevant field recording procedures, sites and sampling regime with Module 6A.

- To carry out the field survey of detailed case studies on samples stratified by different farm and field types.

- To analyse botanical data from management and soil nutrient data in order to confirm the hypotheses set up in the first year.

- To synthesise the results and summarise the available information.

- To produce a final report.

2.4 Project Module 6d - Biodiversity of Agricultural Land in Scotland (SOAFD)
Project Leader: RGH Bunce (ITE Merlewood)

2.4.1 Introduction and methods:

Agriculture is the dominant land use in Scotland but its use varies in its intensity from rich, farming straths in the east to moorland and mountain summits in the north and west. To reflect this variation, the study will be carried out using a broad agricultural stratification (based on enterprise types) :

a. Intensive arable land (mostly cereals and grass leys);
b. In-bye land (mostly permanent grass);
c. Sheep-dominated open moorland;
d. Mountain plateaux with only some sheep present; (areas that are managed exclusively for game will be excluded).

These enterprise types will be defined using three main data sources :

a. the Land Cover of Scotland map (produced from AP interpretation by MLURI for SOAFD);
b. the GB Land Cover map (produced from satellite imagery by ITE);
c. the ITE Countryside Survey 1990 field survey.

These agricultural enterprises will provide the framework for the subsequent collection of data and analysis. Additionally, results will be expressed in terms of broad regional distribution patterns (based on landscape types used in the Countryside Survey).

2.4.2 Analysis of extant data :

The main sources of information include :

a. Countryside Survey 1990 : vegetation quadrats from open vegetation and linear features;
b. Biological Records Centre : individual species (plants and butterflies) distribution maps;
c. BTO Atlas : individual bird species distribution maps.

These will be supplemented by regional and thematic data sets where available (eg. the ITE raptor database, SNH/ITE reptile database).

For each of the enterprise types, the relative frequency of species community will be determined using both quantitative methods and the National Vegetation Classification. Records of rare species and habitats will be available from the BRC and the 'habitat plots' of the CS1990 survey. During this work, indicator and critical species will also be identified.

This work will be based on the records that exist for Scotland (not predicted from GB estimates) and will involve de novo classifications and analyses. Biogeographic zones recently published by SNH/ITE will be investigated for stratifying the sample.

3. Draft Field Programme for 1996

An integrated programme is presented in which data will be collected for all three modules, 6a (DOE/NERC), 6b (NERC), 6c (MAFF) and 6d (SOAEFD) within the same field visits.

This field programme will be supported by interpretative analysis relating to the composition of vegetation and its associated management regimes e.g. vegetation by road sides is managed by cutting. Another example is the comparison of the vegetation composition of boundary plots and their association with management in the field.

The analysis of vegetation for all quadrats from all landscapes shows a strong relationship between the main plot classes and their associated management, in turn linked to major competitive species such as *Lolium perenne, Arrhenatherum elatius* and *Dactylis glomerata.*

Following the discussion held during the Technical Sub-group Meeting it is necessary to emphasise the following distinction between the hypotheses that will be tested:

i. The interpretative analyses described above are based on current data available within the CS 1990 database in conjunction with other available information and will generate hypothesis which can be checked by model validation or by subsequent further field work which can only be determined when the hypotheses are identified. For example if plants requiring high moisture levels had been found to have decline significantly then it may be necessary to check in the field that the dry summer of 1990 was not influencing the observed changes.

ii. The hypotheses to be tested during the field programme below have been identified from the previous analyses of 1990 data in conjunction with literature review and with work carried out under Module 6. They have been designed to cover the range of habitats in different management practices within the landscape to ensure that the influence of the causal factors being investigated is appropriate to the most important changes identified.

3.1 Upland Vegetation

The primary hypothesis to be investigated is that many pollutants potentially have an impact on upland vegetation since there is a concordance between the levels and the ability of the soil to accept such impacts.

The second hypothesis to be investigated is that high levels of pollutants are synergistic with grazing pressure in their impact on the growth of *Racomitrium.*

3.1.2 Background

The results reported to date indicate that within upland landscapes species have increased in moorland vegetation in general, but decreased along stream sides. The review work carried out on the project suggest that grazing pressure and pollution are the most likely causes of these changes and moreover that there are likely to be synergistic in their action (Baddeley *et al.* 1994).

The critical loads exceedence maps for sulphur and acidity show that the principal areas are in central and north Wales, the Pennines and the southern uplands of Scotland. Baddeley *et al.* (1994) have shown that *Racomitrium lanuginosum* (a moss that is a dominant species in montane heaths and bogs in Britain and in the in Arctic) is sensitive to a combination of pollution and grazing and can be used as a measure of pollution loadings by sampling the previous two years growth and subjecting these to chemical analysis. In some areas, especially in the Pennines, this species has largely disappeared. Examination of the CS 1990 database shows a coincidence between the distribution of *Racomitrium* and the high levels of pollution shown by Baddeley and the exceedence maps mentioned above. Many sites that would be expected from regression analysis of occurrence of the species and environmental factors to have the species present, do not.

Other work, notably by John Lee and colleagues, now at Sheffield University, have shown that *Sphagnum* species also accumulate pollutants. Whilst CS 1990 did not specify individual species of *Sphagnum,* one aggregate recorded is virtually entirely *S. recurvum,* a species more tolerant of pollution than *Racomitrium,* and which occurs in many quadrats where *Racomitrium* is absent. This species therefore can be used to record pollution levels where *Racomitrium* may have been eliminated. Data from the CS 1990 database can therefore be interrogated to extract an appropriate sampling framework.

The chemical section at ITE Merlewood have long-time series data for *Calluna* and it is proposed to analyse these to detect any long term changes in nutrient status of this species. For example Cressor has shown that calcium levels have declined in areas of high acid precipitation. Whilst these data will not be for the individual squares of CS 1990 they will provide background information about the general changes taking place in pollution loadings. A literature search will also be carried out to assess the changes in pollution levels between 1978 and 1990 - this coverage will include other pollutants e.g. ozone and ammonia that have not been covered in the analysis to date. There is also a CEH project which is acquiring vegetation samples primarily for caesium content, but which can also be used to check with data previously collected in 1986 for both soils and vegetation.

Grazing pressure on vegetation from sheep has increased in England, Wales and between 1978 and 1990, as reported in both the ADAS and CAS reviews recently completed, with numbers increasing by over 25% in the uplands. Grazing is critical in determining the relative balance between species in the uplands and grazing models will be applied to the data available between 1978 and 1990 in order to assess whether the observed changes are likely to be due to grazing pressure. The further data collection outlined below will provide site specific information that can be linked to these more general statistics, and will enable the pollution impacts to be compared directly with estimates of grazing pressure.

3.1.3 Proposed Data Collection and Analysis

It is proposed to select a stratified random series of quadrats recorded in 1978 and 1990 from the landclasses within which *Racomitrium* occurs, these will be paired with other samples where *Racomitrium* would be predicted to have occurred from the regression. The quadrats will be further screened by their occurrence in land cover categories recorded in CS 1990 since *Racomitrium* is only present in upland vegetation. Quadrats that occupy the same environmental position, but do not have *Sphagnum recurvum* will also be selected, so that information can be gained on the pollution loadings of sites where *Racomitrium* would be expected to grow. The following data will be collected in late August and September in order to incorporate the current years pollution loadings and a requirement for the analysis of grazing effects which requires the sampling not to be too late. There will be problems in obtaining access to grouse and deer estates which will need to be coordinated into the research schedule given at the end of this report.

i. A repeat of vegetation quadrats and collection of soil samples.

ii. Within vegetation immediately adjacent to the quadrat, samples of the current years growth of *Racomitrium, Sphagnum* and *Calluna* will be harvested according to the procedures laid down in the literature.

iii. Measurement of vegetation height and grazing pressure will be carried out using procedures developed by David Welch at ITE, Banchory.

iv. Supplementary information will be collected from the surrounding vegetation within which the quadrat occurs on topography, grazing pressure and land cover.

v. The two stream side vegetation plots within the kilometre square will be visited and the vegetation recorded using CS 1990 procedure.

The vegetation samples will be analysed for pollutants, especially nitrogen, which will then be correlated with critical load exceedancies. The predicted occurrence of *Racomitrium* will be compared with the estimates of grazing pressure using logistic regression and CANOCO to partition the variation between the causal factors. It is recognised that it will be difficult to obtain historical data on grazing and that the information will of necessity be restricted because a single visit only will be made. The approach described below in the section by Hill & Carey will potentially be able to identify groups of quadrats defined by particular combinations of environment and management factors that may overcome the limitations of the data described above.

3.2 Lowland Grasslands

3.2.1 Hypothesis

The hypothosis to be tested is that the species composition of lowland grasslands is dependant upon a combination of management practice and nutrient levels.

3.2.2 Background

The results from CS 1990 indicate that one of the most significant losses of species was in lowland grasslands, involving principally species from traditional meadows. Roger Smith at Newcastle University has carried out studies over many years in northern hay meadows and has demonstrated various links between management practices, e.g. application of fertiliser and cutting dates, and the species composition of the sward. The long term experiments at Park Grass and IGER are of limited use when modern intensive grassland management practices e.g. silage are involved. The programme below has been developed in discussion with Roger Smith and is designed to complement the studies which he has carried out and those available from other sources.

The long-term effects of grassland management has masked inherent differences in lowland pastures which were originally related to environmental differences and as a result differences in management practice largely determine the composition of the sward. The CS 1990 survey provides overall estimates of the composition of the pastures, but repeating a broad scale survey would not be able to enable separation the influence of management practices and detailed individual site monitoring is therefore required. The project below therefore is designed to examine management practices by intensive monitoring of relatively few sites throughout the season in order to determine the growth patterns and flow of nutrients through the system. Nitrogen is utilised almost immediately by the sward and therefore successive monitoring dates are required in order to establish its concentration within the vegetation.

3.2.3 Proposed Data Collection and Analysis

It is proposed to use the following sites:

- Fields on three farms in south Cumbria in Cartmel and Levens, representing a combination of fertilizer, silage, cutting date and slurry application.

- Fields on two farms in south Cumbria in Langdale and Borrowbeck with different types of traditional hay meadow.

- Fields from the long-term sites in Ravenstonedale and Colt Park used by Roger Smith in his long-term programme - sampling will be coordinated with the vegetation field sampling being carried out from Newcastle.

Fields will be selected in discussion with the farmers to represent different combinations of management procedures, although it may not be possible to develop a full factorial design because there may be no fields e.g. which have no fertiliser added, but which are used for silage. The following data will be collected from 2 x 1 m quadrat replicated 5 times in each field at 5 sampling dates through the year, monthly starting the third week in April. The actual dates will be modified slightly according to the cutting times determined by the farmers.

- Full species records will be made in each quadrat together with cover estimates.

- Quadrats will be clipped and weighed in the field for fresh weight. Sub samples will then be taken for obtaining conversion factors from fresh weight to dry weight, subsequently in the laboratory.

- Soil samples will be taken simultaneously.

Chemical analysis of the vegetation and soil samples will allow the nitrogen levels to be followed through the season and related to the overall yield. The results will be coordinated with the long-term monitoring programme carried out by Roger Smith who will advise on the practical field details.

3.3 Roadside Verges

3.3.1 Hypothesis

The hyphothesis to be tested is that different verge cutting procedures are a primary determinant of species composition of road side verges, providing that there are no overriding inherent ecological differences between them.

3.3.2 Background

Cutting regimes are critical in determining the composition of road side verge vegetation, but it is difficult to obtain consistent information about the details of management practices. However, ITE Merlewood provided advice on the joint programme between English Nature and the Cumbria Highways Department to carry out a broad survey of verges in Cumbria in 1992 to set a base line for the evaluation of sites of high floristic diversity. Data were collected using the standard CS 1990 procedure for 100 x $1km^2$ stratified according to the Cumbria land classification. Analyses of these data enabled a classification to be produced that was specific to Cumbria and which was subsequently used to map all road side verges in Cumbria and to identify "special verges" which were subsequently assigned different management regimes appropriate to their vegetation composition. These regimes were subsequently used as the basis for letting contracts to firms who would undertake the necessary management. The Highways Department are interested in assessing the success or otherwise of these contracts, and providing access to all their data in order to provide a basis for a comparison of the different management procedures involved.

3.3.3 Proposed Data Collection and Analysis

Two complimentary approaches will be used, the first to provide direct links between management and species composition and the second to provide an overview of management procedures used by highway departments in Britain.

The location of the 1992 Cumbria quadrats is accurately known and the detailed species information is available. In conjunction with the management information the sampling will be designed in order to enable comparisons between the management procedures currently in place. The following data will be collected over three week periods in May, June and August in order to monitor the changes through the season.

- Repetition of the 1992 quadrat within the designated verge.

- Two further quadrats within the management unit.

- Three further quadrats directly adjacent to the designated length, which are under standard management regimes.

- As in CS1990 additional species will be recorded behind the 1m sample along the edge of the road in order to obtain further information on management, as this band is cut less often since the statutory requirement for cutting is 1.2m.

In order to reduce travelling time, firstly two samples will be taken within the km^2 originally sampled and secondly an adjacent km^2 will be sampled on the same day, since the objective is to identify differences in management rather than obtain population estimates.

Work previously carried out by Terry Parr in ITE used a questionnaire approach to determine the range of procedures used by different countries. A new questionnaire will be produced and circulated to highway departments to determine the current status of roadside verge management in Britain.

3.4 Whole Farm and High Change Sample Plots

3.4.1 Hypothesis

That there is a relationship between the status of individual plots and the overall management regime of whole farms.

3.4.2 Background

Within the ECOFACT proposal it was intended to analyse the changes in the species composition of the individual plots to the changes observed in socio-economic characteristics of the farms as identified within the Wye College study. However, in practice, the sample numbers proved to be too small for meaningful analysis. It was therefore determined in discussion with Wye College to identify farms which had shown either the greatest degree of intensification or had shown very little change and which also contained sample plots, to compare the management status of the vegetation units within these farms. The report recently produced by Wye College provides information on the overall relationship between farm characteristics and the position on vegetation intensity gradients and will be used to interpret these links.

To compliment these farm studies it is proposed to visit representative sample plots that have shown the biggest botanical change and to record detailed data on management within them in order to link with the more generalised analyses of change being carried out at the landscape level.

3.4.3 Proposed Data Collection and Analysis

Whole farm

- Vegetation data will be collected from the random and targetted plots, to confirm their current status, and these will be related to the overall pattern of management within the farm in order to provide information to link the detailed management at the farm level with the characteristics of the vegetation. Management data will include type of grazing, grazing regimes, silage, fertiliser application and cutting dates.

- The boundary and linear plots will also be repeated and with the same objectives and similar data on management. Particular emphasis will be placed on the management of linear features which can then be coordinated with the project on verges described above, the River Habitats Survey described below and further analysis of the status of hedgerow and wall vegetation.

Plots from the different plot types will be selected according to the largest loss or gain in species and also according to vegetation categories e.g. improved grassland or woodland. Similar management data will be collected as in 1. above. Whilst these inevitably will be individual case studies they should enable the influence of extreme events to be assessed e.g. major disturbance patterns along road side verges or virtual destruction of a hedgerow.

Results from these case studies will be used to aid interpretation of the overall changes observed throughout the landscape and can be linked via CANOCO into direct causal relationships using small sub-sets of the vegetation data.

3.5 Riversides

3.5.1 Hypothesis

That the management of riversides has an important effect on the species composition and could have caused some of the observed changes.

3.5.2 Background

A literature search revealed very little information on the mangement of riverside vegetation except for information available from IFE. Currently IFE are carrying out the River Habitat Survey for the National Rivers Authority which provides a great deal of information on riverside vegeation at the broad level. In discussion with Hugh Dawson of IFE it was agreed that inadequate information on actual management of vegetation was available within the current survey procedure. It was therefore agreed that some further limited data records would be added to the survey procedure to be carried out this summer, this will have three advantages, firstly the saving of field time, secondly the acquisition of an extensive database and thirdly the benefits of cooperation with the expert knowledge of IFE.

3.5.3 Proposed Data Collection and Analysis

Details of the additional data will be decided following a meeting with Hugh Dawson in April and will include management information on the 1m band recorded in CS 1990 and will specifically include factors such as grazing, cutting and absence of management. These types of management are likely to be related to the size of the water course, surrounding land cover and local factors.

The complete River Habitat Survey database will be available in November and can be coordinated by the land classification with the available information on vegetation characteristics from CS 1990. Whilst this will not provide direct correspondence it will enable the broad characteristics of management to be associated with the observed changes in vegetation. These analyses will be supported by the determination of the environmental factors controlling individual species carried out elsewhere in ECOFACT.

Discussions will also be held with Hugh Dawson about historical change since 1978 and various other authorities e.g. Nigel Holmes will be consulted in order to provide the general background to changes in river bank management over the survey period.

3.6 Hedgerows

3.6.1 Background

The analysis of change in hedgerow species composition between 1978 and 1990 suggested that different processes of change were at work in the centre of the hedgerow, where lack of mangement had encouraged shade tolerant species, as opposed to the vegetation growing on the field edge which had shown an expansion of coarse growing species.

3.6.2 Proposed Data Collection and Analysis

A limited set of data will be collected from transects across different size hedgerows in order to provide data to determine whether such an approach could be usefully extended in the following year.

3.7 Supplementary Data 1997

Seed bank germination in lowland grasslands. The literature on this subject differs widely in the conclusions drawn as to the potential for the seedbank to contribute to re-establish plants in intensively managed grasslands. Following the results of the MAFF Project on seedbanks due to report next year it may be useful to monitor seedling establishment in intensively managed lowland grasslands.

Weed populations. It may be necessary to carry out a supplementary survey of weed establishment to support the broad information available on herbicides from the ADAS report. Consultation will be held subsequently with appropriate authorities in IACR in order to establish whether such data collection is required or if sufficient information is already available.

4. Biodiversity on Farm Lands in England and Wales

C Potter and M Lobley, Wye College, Ashford, Kent

4.1 According to **table 1**, 41% of plots in England and Wales exhibited an increase in intensity over the study period. This compares to 37% of plots for the Wye College GB sample as a whole. As in GB as a whole, the proportion of plots that have experienced a reduction in intensity as measured in botanical terms is 16%. A more revealing picture emerges when comparisons are made by landscape type. Plots in arable landscapes are most likely to have experienced an increase in intensity, those in upland landscapes most likely to have remained stable in botanical terms (see **table 2**). Interestingly, plots in pastural landscapes are least likely to have had a constant species composition, being more likely to have experienced either intensification or extensification. This is broadly similar to the picture for GB as a whole (see **table 3**).

4.2 It is important to identify more precisely the farming situations in which intensification and extensification have occurred. According to **table 4**, arable and mixed farms are most likely to have plots which have seen a move up the intensity gradient in botanical terms. Dairy farms are surprisingly stable according to the plot data, 57% of plots on these farms maintaining a stable position on the intensity gradient between the two survey dates. Livestock farms are most likely to have experienced a decline in intensity. **Table 5** gives a more detailed breakdown by landscape type. In arable landscapes, as might be expected, it is arable farms that are most likely to have plots exhibiting signs of intensification, with 81% of all intensifying plots being found on such farms. This is not true, however, of pastural landscapes where 26 % of all plots exhibiting signs of intensification are found on arable farms compared to 37% on livestock farms. Dairy farms account for 37% of all plots in this landscape subject to intensification. Further analysis is required to test the hypothesis that plot class change is a function of the management regime of different types of farm.

4.3 The cross-tabulation by farm size reveals a rather more complicated pattern of results (see **table 6**). According to this table, intensification and extensification is most likely to have taken place on small farms, with a higher proportion of medium and large farms having stable plots. This could be a reflection of the heterogeneous nature of the small farming community, with farms on both the intensive and extensive margins. It would be interesting to compare in more detail the intensifying and extensifying small farms in the sample. **Table 7**, which compares full and part time farms suggests that a high proportion of the intensifying small farms may be farmed on a part-time basis, 52% of farms in this category having intensifying plots. Controlling for landscape type (**table 8**) shows that it is medium sized farms in arable landscapes that are experiencing most change, with significantly more farms in this category being stable in pastural landscapes. Interestingly, there is no greater incidence of extensification on medium and large farms in pastural landscapes than in arable ones. Again, the full and part time split may be important, **table 9** showing that farms operated on a part-time basis have a higher proportion of intensifying plots.

4.4 Probing deeper, **tables 10 and 11** look at the relationship between changes in plot composition and farm business change over the study period. According to **table 10**, it is farmers with declining and stable income who are most likely to have plots subject to intensification, a counter intuitive result probably explained by the small absolute numbers involved. A more predictable result is that seen in **table 11**, which cross-tabulates plot data against farm business trajectory (a description of the direction of farm business development) This shows that a general expansion and intensification on farms is usually reflected in plot data. 42% of plots on "intensifying" farms have moved up the intensity gradient in botanical terms. The relationship is less clear in the opposite direction; 29% of plots belonging to 'extensifiers' have moved down the intensity gradient, but 33% have moved up. This relationship between intensification and extensification needs further exploration and a useful case study comparison could be made of the environmental profiles of farmers following different business trajectories.

We have made an initial selection of potential case study farms in England and Wales on this basis, **table 12** indicating the trajectory, number of plots and how long the current farmer has been in managerial control (an indication of how far our own data goes back).

Table 1. Change in ecological intensity (all plots in England and Wales)

	England and Wales		GB
	Number of plots	% of plots	% of plots
More intensive	105	40.5	37.2
Stable	112	43.2	45.6
Less intensive	42	16.2	17.2
Total	259	100.0	100.0

Table 2. Movement along ecological intensity gradient by landscape type (% of plots) - England and Wales

	More intensive	Stable	Less intensive	
Arable	48.0 (49)	41.2 (42)	10.8 (11)	100.0 (102)
Pastural	41.0 (48)	39.3 (46)	19.7 (23)	100.0 (117)
Upland	20.5 (8)	61.5 (24)	18.0 (7)	100.0 (39)

*Figures in brackets refer to number of plots

Table 3. **Movement along ecological intensity gradient by landscape type (% of plots) - GB**

Movement along ecological intensity gradient	Landscape types (% of plots) Arable	Pastoral	Marginal & Upland	All Plots
More intensive	48.1	37.9	23.2	37.2
Same intensity	39.7	37.9	64.0	45.6
Less intensive	12.2	24.1	12.8	17.2
Total	100.0	100.0	100.0	100

Table 4. Movement along ecological intensity gradient by farm type (% of plots)

	More intensive	Stable	Less intensive	
Dairy	31.4 (16)	56.9 (29)	11.8 (6)	100.0 (51)
Livestock	30.3 (23)	48.7 (37)	21.1 (16)	100.0 (76)
Arable	49.3 (34)	36.2 (25)	14.5 (10)	100.0 (69)
Mixed	51.0 (25)	36.7 (18)	12.2 (6)	100.0 (49)

*Figures in brackets refer to number of plots

Table 5. Change in ecological intensity by farm type controlling for landscape type (% of plots)

number col % row% total%	Arable landscapes Farm type			
chnage in plotsintensity	Dairy	Arable	Livestock	total No. of plots
increase	-	24 48.9 80.8	6 31.5 20.0	30
stable	-	20 40.8 66.7	10 52.6 33.3	30
reduction	-	5 10.2 62.5	3 15.7 37.5	8
total	-	49	19	68

number col % row% total%	Pastural landscapes Farm type			
chnage in plot intensity	Dairy	Arable	Livestock	total no. of plots
increase	13 30.2 37.1	9 52.9 25.7	13 43.3 37.1	35
stable	24 55.8 63.1	3 17.6 7.9	11 36.6 28.9	38
reduction	6 13.9 54.5	5 29.4 45.5	6 20.0 54.5	17
total	43	17	30	90

Table 6. Movement along ecological intensity gradient by farm size (% of plots) - England and Wales

Row % Total % Count	More intensive	Stable	Less intensive	
Very small	75.0 1.2 (3)	25.0 0.4 (1)	0.0 0.0 (0)	100.0 (4)
Small	35.3 4.7 (12)	41.2 5.4 (14)	23.5 3.1 (8)	100.0 (34)
Medium	40.7 18.6 (48)	46.6 21.3 (55)	12.7 5.8 (15)	100.0 (118)
Large	41.2 16.3 (42)	41.2 16.3 (42)	17.7 6.9 (18)	100.0 (102)

Table 7. Movement along ecological intensity gradient by farmer status (% of plots)

	More intensive	Stable	Less intensive	
Full time	38.9 (63)	45.7 (74)	15.4 (25)	100.0 (162)
Class I	40.7 (24)	37.3 (22)	22.0 (13)	100.0 (59)
ClassII/hobby	51.5 (17)	36.4 (12)	12.1 (4)	100.0 (33)

*Figures in brackets refer to number of plots

Table 8. Change in ecological intensity by farm size controlling for landscape type

number col % row% total%	**Arable landscapes** **Farm size**			
chnage in plot intensity	small	medium	large	total no of plots
Increase	5 50.0 10.2	23 53.5 46.9	21 42.0 42.8	49
stable	5 50.0 11.9	15 34.8 35.7	22 44.0 52.3	42
reduction	0 0.0 0.0 0.0	5 11.6 41.6	7 14.0 58.3	12
total	10	43	50	103

number col % row% total%	**Pastural landscapes** **farm size**			
change in plot intensity	small	medium	large	total
Increase	8 34.8 16.7	21 36.2 43.7	19 52.8 39.6	48
stable	8 34.8 17.4	28 48.3 60.9	10 27.8 21.7	46
reduction	7 30.4 30.4	9 15.5 39.1	7 19.4 30.4	23
total	23	58	36	117

Table 9. Change in ecological intensity by farm status controlling for landscape type

number col % row %	**Arable landscapes**

chnage in plot intensity	Full time	Part time	total No of plots
increase	29 45.3 59.2	20 52.6 40.8	49
stable	27 42.2 65.9	14 36.8 34.1	41
reduction	8 12.5 66.7	4 10.5 33.3	12
total	64	38	102

Change in ecological intensity by farm status controlling for landscape type

number col % row %	**Pastural landscapes**		
change in plot intensity	Full time	Part time	total
increase	27 46.6 56.3	21 42.8 43.7	48
stable	30 44.1 65.2	16 32.7 34.7	46
reduction	11 16.2 47.8	12 24.5 52.2	23
total	68	49	

Table 10. Movement along ecological intensity gradient by change in income (% of plots)

	More intensive	Stable	Less intensive	
Increasing income	33.0 (35)	42.3 (45)	24.5 (26)	100.0 (106)
Stable income	51.5 (35)	39.7 (27)	8.8 (6)	100.0 (68)
Declining income	41.0 (34)	47.0 (39)	12.0 (10)	100.0 (83)

* Figures in brackets refer to number of plots

Table 11. Movement along ecological intensity gradient by farmers cluster (% of plots)

	More intensive	Stable	Less intensive	
Intensifiers	41.7 (53)	42.5 (54)	15.7 (20)	100.0 (127)
Extensifers	33.3 (7)	38.1 (8)	28.6 (6)	100.0 (26)
Stabilisers	41.5 (27)	46.2 (30)	12.3 (8)	100.0 65

* Figures in brackets refer to number of plots

Table 12. Initial case study selection

Intensifiers and improvers

Sq No.	Occupier No.	No. of Plots	Year currant farmer began management
22	2	2	1980
91	3	2	1989
195	7	1	1952
307	2	1	1976
364	1	5	1974
393	3	1	1958
421	4	2	1946
449	3	2	missing
518	8	1	1984
579	2	2	1947
704	4	1	1967
724	3	1	1952
777	3	1	1956

Stabilisers and extensifiers

Sq No.	Occupier No.	No. of Plots	Year current farmer began management
15	6	1	1973
179	6	2	1976
273	2	4	1949
301	1	1	1974
324	1	4	1976
324	1	4	1976
355	3	1	1967
657	1	2	1984
713	1	2	1980

Change in ecological intensity on above farms

	Number of plots	% of plots
More intensive	20	50
Stable	18	45
Less intensive	2	5
Total	40	100

5. CRITICAL LOADS - JANE HALL, ITE MONKSWOOD

5.1 BACKGROUND

5.1.2 Critical loads approach

The critical loads approach provides a quantitative estimate of the effects of acidification on soils, freshwaters and vegetation. The use of critical loads is an effects-based approach to developing emission control policies. It links pollutant emission reductions on both national and international scales to environmental benefits. It requires the definition of sensitive receptor ecosystems and an understanding of pollutants which may adversely affect them.

The critical loads approach has been adopted both nationally (HMSO, 1990) and internationally by the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution. A critical load has been defined as "a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on sensitive elements of the environment do not occur according to present knowledge".

Critical loads are usually presented as maps, allowing the areas of the country most susceptible to acidification to be readily identified, by both the scientist and the policy maker.

5.1.3 Empirical critical loads for soils

This project has utilised the empirical critical loads of acidity for soils which has been nationally agreed. These critical loads are set to prevent chemical change in the soil (Nilsson & Grennfelt, 1988) and more specifically, to prevent an increase in soil acidity or a decline in base saturation. It is thought that such chemical changes may be prevented if acid inputs do not exceed the production of base cations by mineral weathering within the soil. The main factor determining the rates of weathering in soils is the soil mineralogy.

A 1km map showing these critical loads was developed jointly between the ITE, Soil Survey and Land Research Centre, Macaulay Land Use Research Institute and Aberdeen University (Hornung *et al.*, 1995). It is based on 1:250000 soil maps, with each map unit allocated to one of five critical loads classes on the basis of the dominant soil series present. Peat soils were originally assigned to a separate class until methods were developed at Aberdeen University for estimating critical loads for dystrophic, eutrophic and basin peats (Hornung *et al.*, 1995, Critical Loads Advisory Group, 1994). Each 1km square of Great Britain was subsequently assigned to a critical loads class based on the dominant soil unit present. With the help of the Department of Agriculture for Northern Ireland, the map has since been extended to include Northern Ireland.

The critical loads map (Figure 1) shows that soils with low critical loads (ie most sensitive) are widespread in the north and west of Great Britain, in areas dominated by relatively shallow soils derived from acid, base-poor rocks. High critical loads are found in the south and east where soils tend to be formed in thick calcareous and/or clay rich glacial deposits or in materials derived from calcareous rocks. However, some parts of East Anglia, the New Forest and the Weald have low critical loads where soils are formed in sands containing few weatherable minerals (Hornung *et al.*, 1995).

5.1.4 Exceedance calculations

The critical load shows the amount of acid deposition different soils can "buffer" without adverse effects occurring. By comparing critical loads with current acid deposition loads, the areas where deposition is greater than the critical load can be identified. These are known as "exceeded areas" and are presented as "exceedance" maps.

Deposition data (eg sulphur, nitrogen, base cations) are generated from the national monitoring network run by AEA Technology (UK RGAR, 1990). Values are estimated for each 20km grid square of the UK and forwarded to ITE Bush (Edinburgh) where the dry deposition fraction and altitude enhancements are modelled and added in.

To calculate exceedance, critical loads values are subtracted from deposition values. As these two data sets are at different resolutions, two options are available:

i. to aggregate the 1km critical loads data to 20km using a mean, median, mode or percentile value;

ii to assume that the deposition values are uniform within a 20km grid square.

The exceedances calculated for this project use the latter approach, so that the results can be directly compared with the 1km ITE Land Classification classes.

Exceedances have been calculated using mean deposition data for 1989-92. Two maps of exceedance were created: the first using non-marine sulphur deposition; the second using total acid deposition ie non-marine sulphur plus oxidised and reduced nitrogen, less non-marine base cations (calcium and magnesium).

5.2 Relating Critical Loads and Exceedances to Ite Land Classes

The critical loads, deposition and ITE Land Classification data are all held on the ARC/INFO GIS as gridded (raster) maps. The exceedance calculations as described above were performed using GIS. Additional maps were created to show the ITE land classes occurring in each critical loads (eg Figure 2) and each exceedance class (eg Figures 3 and 4). For these maps, statistics on the area of each of the 32 land classes in each critical loads or exceedance class were derived and are presented in Tables 1-3.

5.3 RESULTS

Tables 1-3 show the area of each Land Class in each critical loads and each exceedance class. The percentage of 1km squares in each critical loads and exceedance class is also given.

[Results based on the following class assignments:
Arable: 2, 3, 4, 9, 11, 12, 14, 25, 26
Grassland: 1, 5, 6, 7, 8, 10, 13, 15, 16, 27
Marginal uplands: 17, 18, 19, 20, 28, 31
Uplands: 21, 22, 23, 24, 29, 30, 32]

5.3.1 Relating critical loads to the ITE Land Classification

The map of empirical critical loads of acidity for soils is shown in Figure 1 and described in section 1.2. above. The areas where the least sensitive critical loads classes occur (> 1.0 keq/ha/year) are dominated by Land Classes 2, 3, 4, 10 and 11, which mainly reflect arable landscapes, not sensitive to acidification. Whereas the areas with lower critical loads (<0.5 keq/ha/year) are mainly characterized by the marginal upland and upland Land Classes 17, 21, 22 and 23 (Table 1), more sensitive to acidification.

5.3.2 Relating exceedance of critical loads by non-marine sulphur deposition to the ITE Land Classification

Empirical critical loads of acidity for soils are exceeded by non-marine sulphur deposition in approximately 38% of the 1km grid squares (Table 2). These areas tend to lie in the north and west, usually where soil critical loads are low, altitude is moderate to high, and rainfall, and hence, deposition are also high.

The areas with higher exceedances (>0.5 keq/ha/year) coincide mainly with marginal upland and upland Land Classes 10, 17, 18, 19, 22 and 24 and occupy approximately 15% of the country.

5.3.3 Relating exceedance of critical loads by "total" acid deposition to the ITE Land Classification

Using total acid deposition rather than just sulphur increases the estimate of exceeded areas from 38% to 69% (Tables 2 and 3). The exceedance values are also greater, with larger areas having exceedances >1.0 keq/ha/year (31.8%). These regions are largely characterized by Land Classes 10, 17 and 22. Areas not exceeded are now primarily confined to the south east and easternmost regions of the country.

5.4 CONCLUSIONS

Comparing critical loads with the ITE Land Classification identifies arable and permanent grass Land Classes in areas with high critical loads. Areas with low critical loads are characterized by marginal upland and upland Land Classes. Similarly, the areas where critical loads are not exceeded coincide with arable and permanent grass, whilst an increase in the amount of exceedance is characterized by increasing percentages of marginal upland and upland Land Classes.

This preliminary study will be followed up by examining the quadrat species data related to Land Classes with classes of critical loads and exceedances. In addition, this exercise has focused on the effects of sulphur and total acid deposition. The next stage of the work will look at the relationship between Land Classes and their associated species with maps of critical loads and exceedances for nutrient nitrogen.

5.5 REFERENCES

Critical Loads Advisory Group. 1994. Critical loads of acidity in the United Kingdom. Summary Report - prepared at the request of the Department of the Environment.

HMSO (1990), This Common Inheritance, HMSO, London.

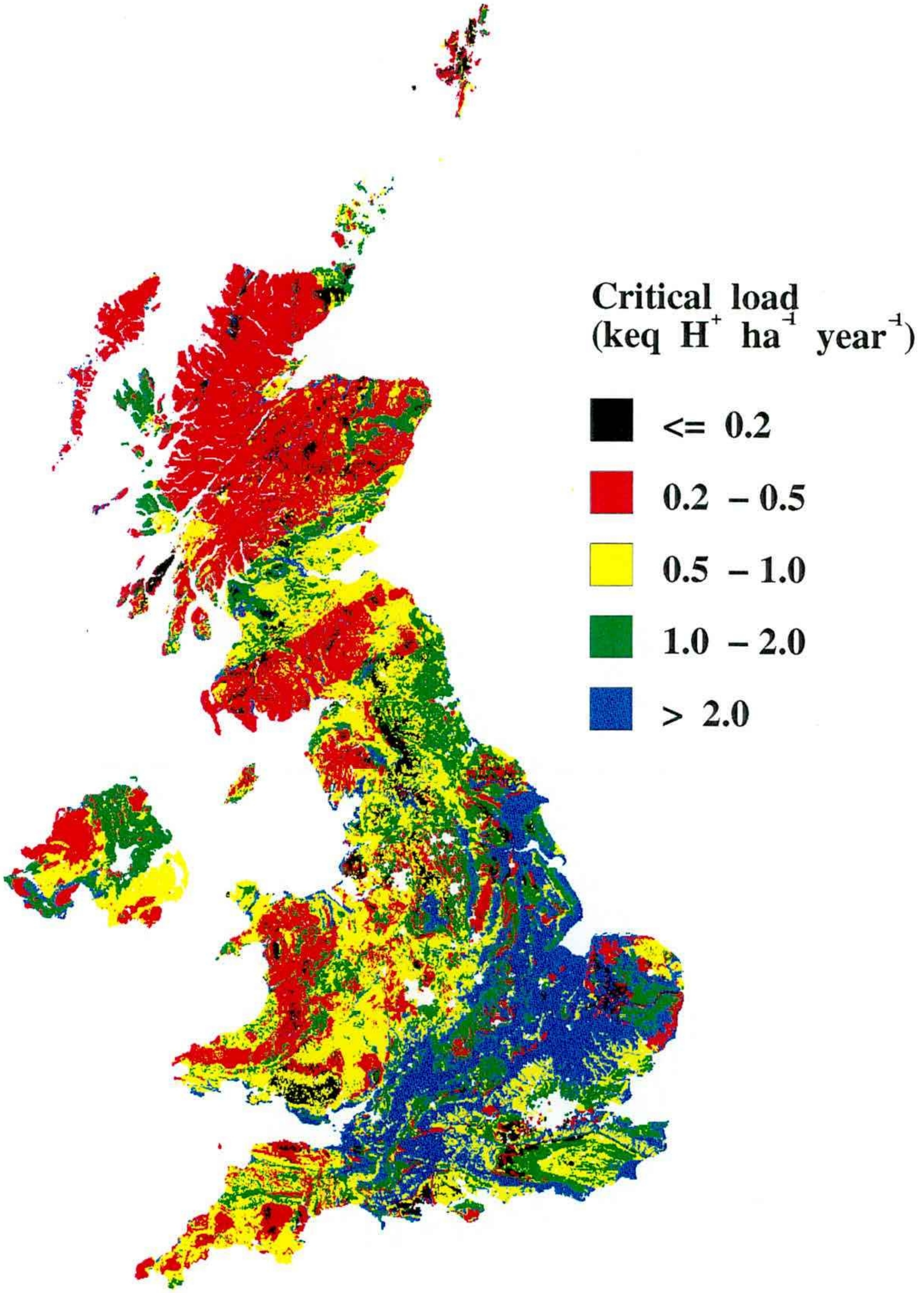
Hornung, M., Bull, K.R., Cresser, M., Hall, J.R., Langan, S.J., Loveland, P. & Smith, C. 1995. An empirical map of critical loads of acidity for soils in Great Britain. *Environmental Pollution* **90**, 301-310.

Nilsson, J. & Grennfelt, P. (eds.) 1988. Critical loads for sulphur and nitrogen. Report of a workshop held in Skokloster, Sweden 19-24 March 1988. (1988:11). Copenhagen: Nordic Council of Ministers.

UK RGAR. 1990. Acid deposition in the United Kingdom 1986-88. UK Review Group on Acid Rain. Third Report. Department of the Environment, London.

Figure 5.1

Empirical critical loads of acidity for soils



Critical Loads Mapping and Data Centre, ITE Monks Wood March 1996

Data acknowledgement: Critical Loads Advisory Group - soils sub-group (Institute of Terrestrial Ecology, Soil Survey and Land Research Centre, Macaulay Land Use Research Institute, Aberdeen University, Department of Agriculture for Northern Ireland)

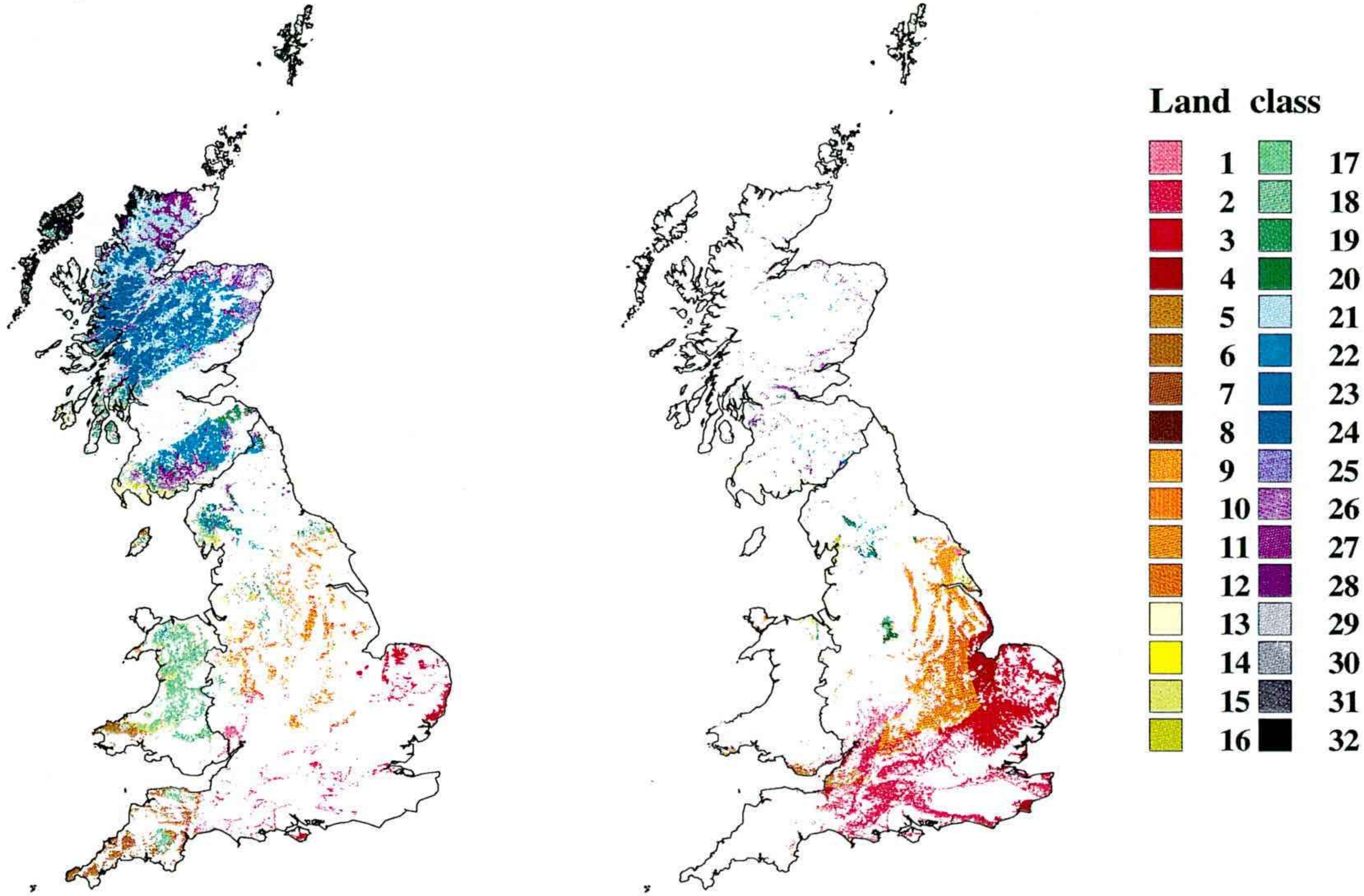
NB. GB and Irish data are mapped on their national grids, however, the location of Northern Ireland with respect to GB is only approximate.

Institute of Terrestrial Ecology

Figure 5.2

ITE Land Classes where the empirical critical loads of acidity for soils are

a) 0.2-0.5 keq H^+ ha^{-1} $year^{-1}$ **b) >2.0 keq H^+ ha^{-1} $year^{-1}$**

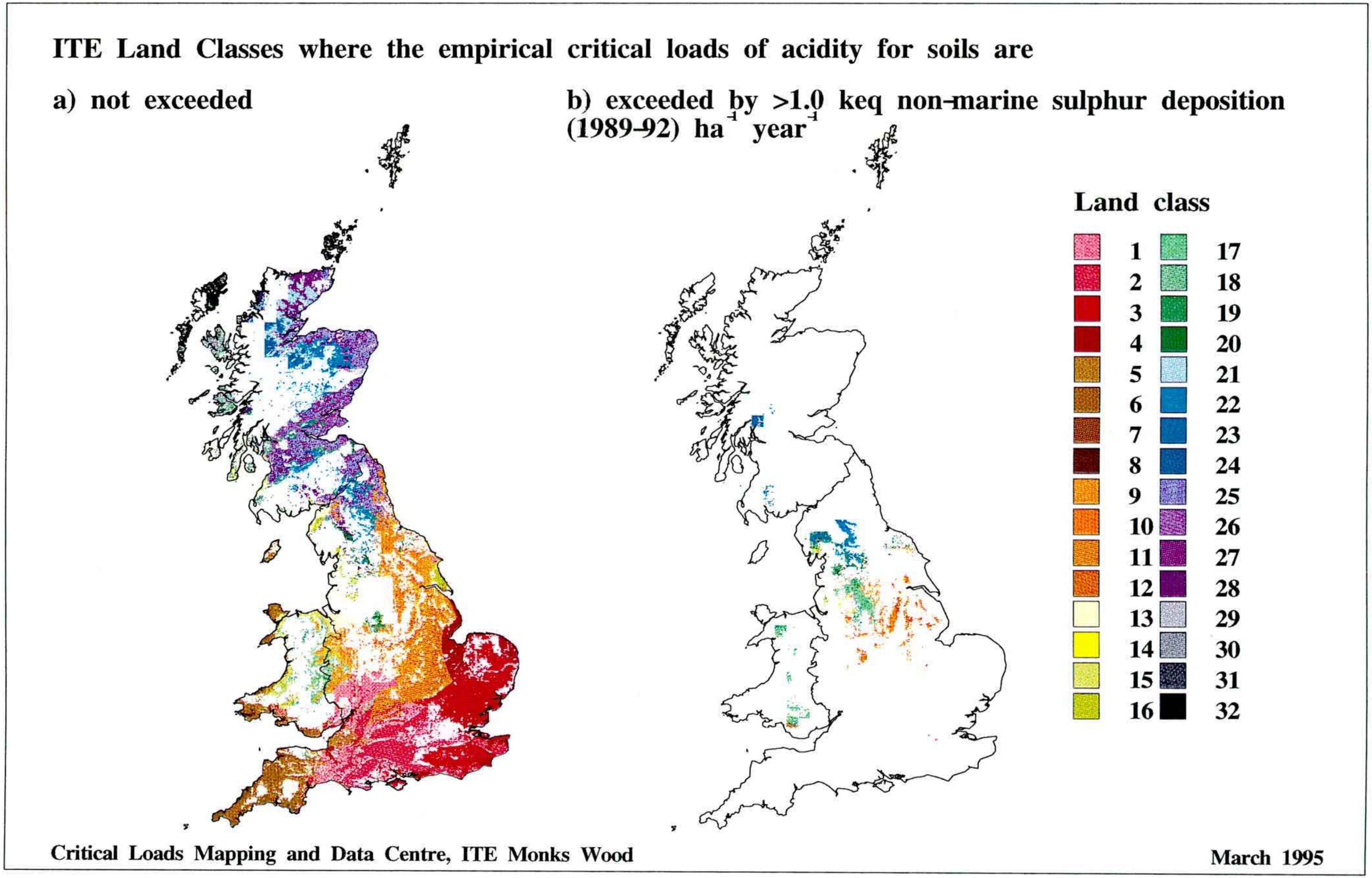


Critical Loads Mapping and Data Centre, ITE Monks Wood **March 1995**

Data acknowledgement: ITE Merlewood, Critical Loads Advisory Group – soils sub-group

Institute of Terrestrial Ecology

Figure 5.3



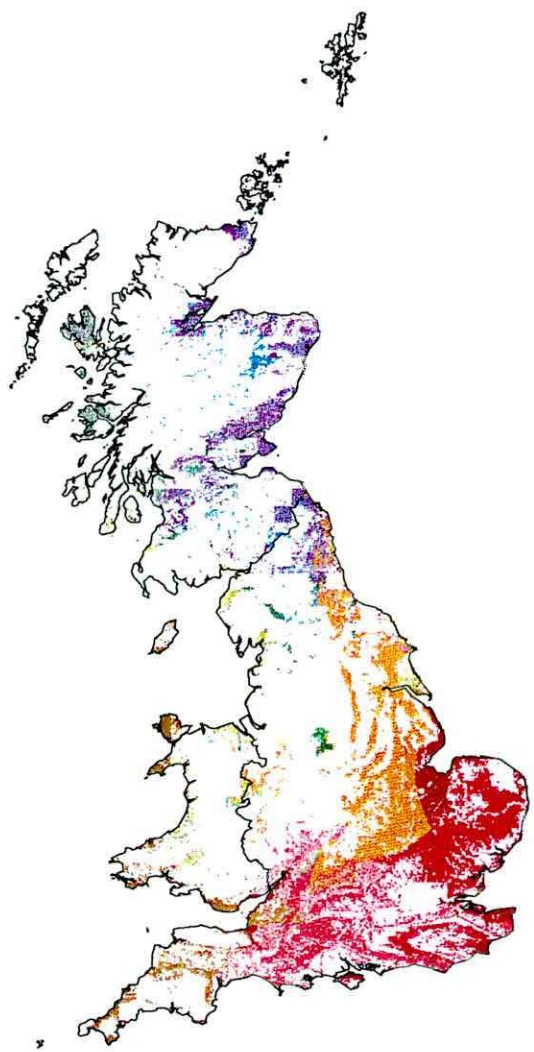
Data acknowledgement: ITE Merlewood, Critical Loads Advisory Group – soils sub-group, AEA Technology, ITE Bush.

Institute of Terrestrial Ecology

Figure 5.4

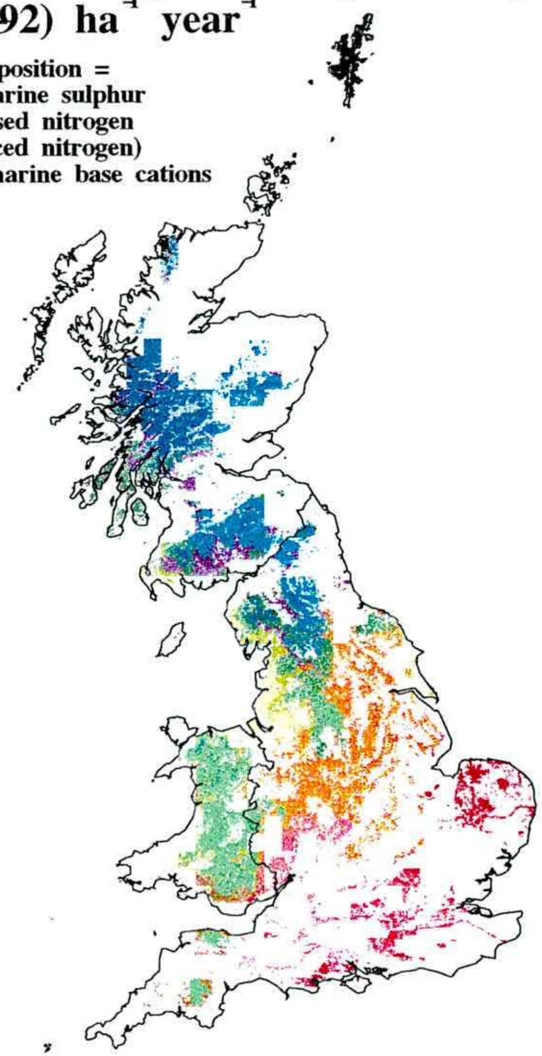
ITE Land Classes where the empirical critical loads of acidity for soils are

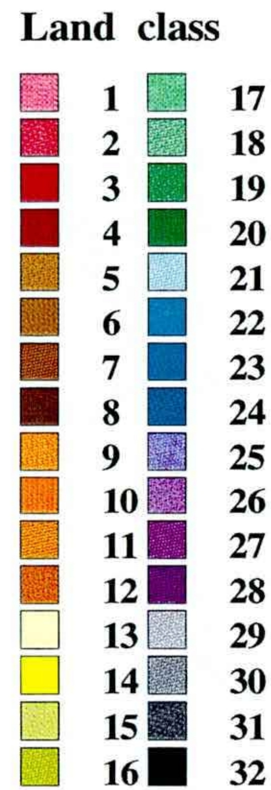
a) not exceeded



b) exceeded by >1.0 keq acid deposition* (1989-92) ha^{-1} $year^{-1}$

* acid deposition =
(non-marine sulphur
+ oxidised nitrogen
+ reduced nitrogen)
– non-marine base cations





Critical Loads Mapping and Data Centre, ITE Monks Wood

March 1995

Data acknowledgement: ITE Merlewood, Critical Loads Advisory Group – soils sub-group

Institute of Terrestrial Ecology

Table 1 Percentage area of the main ITE Land Classes (LC) in each critical loads class

Critical loads class (ranges in keq H^+ ha^{-1} $year^{-1}$)

	>2.0		1.0 - 2.0		0.5 - 1.0		0.2 - 0.5		<= 0.2	
	LC	%	LC	%	LC	%	LC	%	LC	%
	2	18.8	10	12.7	6	9.01	21	11.4	22	13.6
	3	16.0	3	10.1	1	8.04	24	9.23	17	12.7
	11	13.8	1	8.88	10	7.46	17	9.06	23	11.2
	4	10.2	25	8.14	25	7.07	22	9.05	18	5.65
	9	7.69	9	7.14	2	6.10	23	7.09	3	5.53
	1	7.36	27	4.57	9	5.85	28	6.11	2	5.05
	12	4.77	11	4.05	3	4.97	18	3.97	21	5.01
	8	3.43	17	3.48	17	4.94	6	3.83	1	3.75
Total % area in each critical load class		17.9		17.4		27.3		30.7		6.62

Table 2 Percentage area of the main ITE Land Classes in each class of exceedance of empirical critical loads of acidity for soils by non-marine sulphur deposition 1989-92

Exceedance class (ranges in keq H^+ ha^{-1} $year^{-1}$)

	<=0.0		0.0 - 0.2		0.2 - 0.5		0.5 - 1.0		> 1.0	
	LC	%	LC	%	LC	%	LC	%	LC	%
	3	9.54	21	10.7	17	10.8	17	16.1	17	19.3
	2	8.85	22	9.56	22	8.50	24	11.0	10	14.2
	1	7.74	23	8.88	24	6.87	22	10.2	18	11.4
	25	6.71	10	7.38	21	6.44	10	8.21	19	9.58
	6	5.66	6	5.98	23	6.38	18	5.54	9	7.31
	9	5.48	32	5.02	10	5.73	23	5.44	22	6.79
	11	5.23	24	4.49	13	5.51	19	5.17	23	6.54
	4	4.86	28	4.04	18	5.23	3	4.90	24	4.24
Total % area in each exceedance class		61.7		9.38		13.2		11.2		4.53

Table 3 Percentage area of the main ITE Land Classes (LC) in each class of exceedance of empirical critical loads of acidity for soils by "total" acid deposition 1989-92

Exceedance class (ranges in keq $H^+ ha^{-1} year^{-1}$)

	<=0.2	0.0 - 0.2		0.2 - 0.5		0.5 - 1.0	> 1.0
	LC	%	LC	%	LC	%	LC
%	LC	%					
	3	14.7	6	15.2	6	10.6	21
8.44	17	14.6					
	2	12.4	25	11.9	21	8.88	22
6.88	22	9.64					
	12	8.24	10	8.74	25	8.58	1
5.89	10	9.11					
	1	7.80	26	8.25	28	6.95	2
5.68	24	6.69					
	4	7.13	1	7.42	10	5.64	6
5.67	18	5.98					
	25	6.73	27	6.49	27	4.90	28
5.48	23	5.54					
	9	5.53	9	4.02	9	4.58	23
4.78	9	5.42					
	27	3.62	13	3.75	22	4.24	3
4.74	19	4.75					
Total % area in		31.1		5.41		10.6	
21.0		31.8					

each exceedance class

6. Impacts of pollution on biodiversity

Howard, D.C., Hall, J., Brown, M.J., Bull, K. and Bunce, R.G.H.

6.1 Introduction

6.1.1 The problem

While it is now widely accepted that changes in the British flora and fauna are occurring constantly, there is little agreement over the causes of change. The Countryside Surveys of 1978, 1984 and 1990 (Barr *et al.*, 1993) allow some quantification of the changes in biodiversity in different land cover types and using different biological units. Several factors driving change have been proposed usually described in generalised form with little or no supporting evidence; the factors are frequently spatially confounding. Among them are a number of atmospheric pollutants, which are recognised and monitored across Great Britain (GB) they have broad, wide-ranging effects, but the consequences of their presence and the mechanisms of distribution are not fully understood.

The following document describes one possible approach to partitioning changes in biodiversity to different factors. The results of some preliminary analysis give an indication of the potential of the technique and a series of proposals for further work, including field sampling are made.

6.1.2 Possible approaches

Correlative analysis of existing data cannot properly test a cause and effect relationship; the similarity in trends between datasets may be spurious. Targeted sampling of concomitant information offers a better test of a relationship, although ultimately experimental work to illuminate and test the mechanics of the process are needed. The relationships between datasets are still worth examining as a method of suggesting processes and improving the efficiency of future work.

National extrapolations of deposition and atmospheric concentrations for a number of pollutants (e.g. sulphur dioxide, total acidity, ozone, nitrous oxides, etc.) are known and published. They are presented at a course resolution which is appropriate for interpretation at a broad national scale and are usually averages over several months or years. There is limited knowledge of the spatial variability of some pollutants, but sample size of the information from which the national maps are extrapolated are too small to allow analysis and allocation of levels to different landscape units. It is essential to collect field estimates of pollutants at the same spatial precision as the floristic information used to describe biodiversity. Ideally, the pollutant data would describe both the history and extremes of concentration and extremes.

extremes.

The history of deposition of some pollutants (e.g. total acidity and sulphur dioxide) is reflected in the concentrations of some compounds found in soil. The interpretation of the information has to take into account the buffering of the soil to the chemical (i.e. the principle behind critical loads) and management or modification by man.

6.1.3 Selection of *Racomitrium lanuginosum*

The selection of a subject to analyse the effects of atmospheric at a national scale place a number of restrictions. The goal is to explain and minimise the variation due other factors so that the magnitude and direction of changes due to the main treatment can be estimated. The subject should potentially show a distribution across the full geographic range of GB, be easily recognised and recorded and have some sensitivity to the factor under study.

Expert knowledge and examination of the scientific literature produced a number of possible species to consider. One species is *R. lanuginosum* which will be used in the rest of this document to illustrate the possible approach. A study by Baddeley, *et al.* (1994) identified a relationship between nitrogen levels within *R. lanuginosum* and atmospheric deposition and the species is considered to be sensitive to nitrogen pollution (Hill, *et al.*, 1992).

6.1.4 Use of *Sphagnum recurvum* as a control

As *R. lanuginosum* is thought to be sensitive to atmospheric pollutants, its actual distribution is likely to be smaller than that expected in pristine conditions. To assess the levels of pollutants in areas where *R. lanuginosum* is absent, but the land cover and environmental conditions suggest it could exist, an alternative species less pollution sensitive should be studied. *Sphagnum recurvum* has a similar spatial distribution to *R. lanuginosum* although it may be slightly less arctic and the species do coexist, even being recorded in the same quadrats (see Table 6.1). The species appears to be much more pollutant tolerant

Table 6.1 Presence of *S. recurvum* and *R. lanuginosum* in 'X' plot quadrats recorded in Countryside Survey 1990.

	S. recurvum	*S. recurvum* and *R. lanuginosum*	*R. lanuginosum*
No. of quadrats	230	188	68

The two species would not be expected to occur in every 1 km square in GB. The potential location can be assessed by an examination of the land class and land cover type (as reported in the CS1990) in which the quadrats were found. *R. lanuginosum* was found in 14 of the 32 land classes (13, 17, 18, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31 and 32) while *S. recurvum* was also found in seven other land classes (2, 7, 15, 16, 19, 20 and 26) (Figure 6.1). *R. lanuginosum* was found in 15 of the 58 land cover reporting categories but wet heaths and saturated bogs was the dominant category with 47% of the quadrats. *S. recurvum* was found in the same categories and nine others (see Figure 6.2), but the dominant category remained wet heaths and saturated bogs with 31%; wet heaths and saturated bogs cover 7% of GB (Barr *et al.*, 1993).

6.1.5 Datasets

Quadrats 1978 and 1990

Plant species presence and cover were recorded using quadrats 1978 and 1990. Different styles of quadrat were used including stratified random nested quadrats ranging from 4 m^2 to 200 m^2 and linear quadrats of 10 m x 1 m. All vascular plants were identified and a selection of common mosses and lichens. The quadrats were recorded at the same location in the two years and the position mapped on the thematic land cover maps for the 1 km square. The species lists are all stored in an ORACLE database and the quadrat locations are held in digital map coverages in Arc/Info.

Surveyors also recorded a number of characteristics of the quadrat; land use, slope, aspect, shade and evidence of grazing (including species). Soil pits were dug adjacent to quadrats in 1978 and profiles recorded and soil samples removed for chemical analysis.

6.1.6 Field survey land cover and soil

The surveyed squares were mapped in five themes for land cover (agriculture & semi-natural vegetation, forestry, physical features, buildings & communications and boundaries). Each square was completely mapped, although features from different themes could overlap giving a theoretical total of more than 100 ha. Independently, SSLRC and MLURI mapped all squares by soil series. All the cartographic data is held in a GIS and analysis was performed to produce a summary land cover description for each square, reporting the proportion of each of 58 reporting categories in the square.

6.1.7 Land Cover Map

Countryside Survey 1990 also included the production of a complete Land Cover Map (LCM) for GB using multi-temporal satellite scenes from Landsat TM. The land cover is broken down into 25 categories and mapped at a resolution of 25 m pixels. The LCM bog category matches the wet heath and saturated bog category from the field survey, but the match is not perfect as bog is often found as a mosaic with heath and other moorland/upland categories.

6.1.8 National datasets (OS topology, climate, geology, position, etc.)

ITE have access to a variety of other datasets at a 1 km square resolution which can be used in combination with the field data. Datasets include descriptions of climate (average annual temperature, January minimum, hours of sunshine in July, days of snow-lay and soil moisture deficit), geology (solid and drift), topology (average altitude, slope, aspect and percentile coverages of altitude (10 and 90)). Care must be taken in combining datasets recorded and stored at different resolutions, since spurious correlations can easily arise.

6.1.9 Methods

Extrapolation using the ITE Land Classification

The distribution of *R. lanuginosum* can be mapped by shading the land classes in proportion to the probability of it being found within one of the random quadrats placed in that class (Figure 6.3). The map shows good agreement with the published distribution of records in Hill, Preston and Smith (1992). However, the map does not reflect any spatial structure within land classes (e.g. north/south or east/west gradients). The positions of squares where quadrats containing *R. lanuginosum* were recorded gives confirmation of the land class prediction (Figure 6.4)

6.1.10 Identification of potential sites containing R. lanuginosum

An important question is whether all habitat niches potentially available to *R. lanuginosum* are occupied. A point in polygon analysis of the quadrats and field mapped squares shows the land cover types the quadrats were found in (Figure 6.2), the dominant category (wet heaths and saturated bogs) is best matched by the LCM bogs category ; the national distribution is shown in Figure 6.5. Of all the quadrats located in wet heaths and saturated bogs only 66% include *R. lanuginosum.* A comparison of quadrats recorded in both 1978 and 1990 show little change in the proportion containing *R. lanuginosum.* It appears that factors are restricting the distribution of *R. lanuginosum* with suitable habitats.

6.1.11 DECORANA ordination of environmental factors for sites

Complex multi-variate datasets can be examined and described by a variety of forms of analysis. Ordination attempts dominant trends with the data which may indicate underlying structures and processes. DECORANA is the ordination technique which shares a common ordering algorithm with TWINSPAN and is widely used in phytosociology.

Different datasets from the Countryside Survey 1990 have already been analysed using DECORANA and summarised by land class. Ordinations of environmental variables (i.e. those that were used to produce the ITE Land Classification) and vegetation recorded in quadrats have been calculated for squares and quadrats and summarised as land class averages. Figure 6.6 shows the relationship between the presence and cover of *R. lanuginosum* in land classes and the position the land class occupies on the first axis of the environmental and vegetation ordinations.

DECORANA was applied to a dataset comprising of environmental characteristics describing the random ('X' plot) quadrats in those land classes where *R. lanuginosum* was present. Data included were:

Climate	Average annual temperature
	Minimum January temperature
	Days of snow-lay
	Soil moisture deficit
	Hours sunshine in July
Altitude	Mean altitude (square)
	10% ile (square)
	90% ile (square)
	Slope (square)
	Slope (quadrat)
	Aspect (quadrat)
Substrate	Geology
	Major soil group (square)
Land use/cover	Reporting category
	Grazing

Information was entered as category values; continuous variables were divided into 4 or 5 sections each of which became a category. Standard detrended correspondence analysis was carried out with rare categories being down-weighted.

6.1.12 Preliminary results

Distribution of *R lanuginosum*

The maps and graphs (Figures 6.1 to 6.6) suggest that *R. lanuginosum* is widely distributed across upland GB and that Countryside Survey 1990 mapped the distribution effectively. Combinations of datasets allow both potential and actual distributions to be predicted.

Environmental indicators

The first axis of the DECORANA reflected an altitude gradient ranging from saltmarsh, crops and low altitude through to hares, grouse, heath and high steep land. The second axis appears to divide the climatic features more with high snow lay and low temperatures at one end and high temp and sun at the other. The position of the quadrats on the scatterplot showing axis 1 and axis 2 is shown in Figure 6.7. *R. lanuginosum* shows more of a spread over the first axis and is more tightly restricted to the lower values in the second. The grouping of points is to the lower ends of both axes with two parts of the distribution not occupied by other quadrats, but the central area does show overlap.

6.1.13 Conclusions and future work

One element missing from the DECORANA analysis performed was atmospheric nitrogen deposition. Although datasets are available, these are at very course resolution and are likely to contain too much internal variation to produce interpretable results. The data can be collected by field sampling and chemical analysis can be performed on the vegetation to give some measure of the history of deposition. The same sites visited in 1978 and 1990 should be revisited and the plots to be sampled can be drawn by stratifying for different areas of interest. Two important areas would be to identify the variation in the broad scale deposition maps and to examine the differences between quadrats in environmental conditions apparently favouring *R. lanuginosum* and those where other species may also dominate the quadrat.

It would also be valuable to examine the nitrogen content of *S. recurvum* as it is more widely distributed and apparently more tolerant of pollutants. Samples where both species occur together, and where each is in isolation could offer some illumination on the strength of pollutants as determinants of floristic distributions.

The sample size needed to answer the questions will be dependant on the complexity and number of questions to be answered. At this stage, it is better to concentrate on a few well defined and simple questions.

References

Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B., Hallam, C.J., Hornung, M., Howard, D.C., Ness, M.J. (1993) *Countryside Survey 1990 Main Report.* Countryside 1990 Series, volume 2 Department of the Environment: London

Baddeley, J.A., Thompson, D.B.A. and Lee, J.A. (1994) *Regional and historical variation in the nitrogen content of Racomitrium lanuginosum in Britain in relation to atmospheric nitrogen deposition* Environmental Pollution **84** 189-196

Hill, M.O., Preston, C.D. and Smith, A.J.E. (eds) (1992) *Atlas of the bryophytes of Britain and Ireland* Vol 2 Harley Books, Colchester

Figure 6.1 Presence of bryophyte species in 'X' plot quadrats in ITE land classes

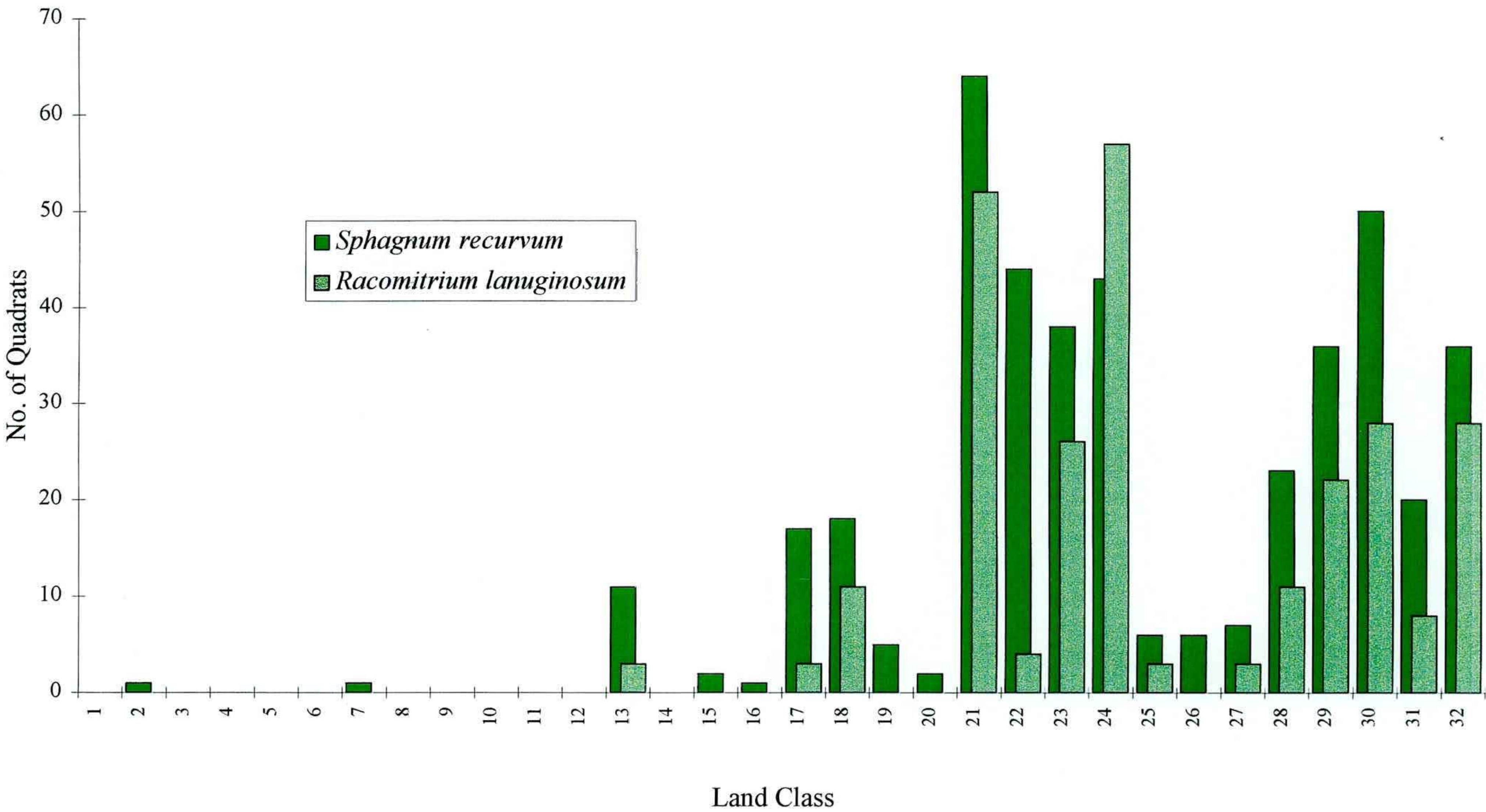


Figure 6.2 The occurance of quadrats containing *Racomitrium lanuginosum* and *Sphagnum recurvum* in different cover types

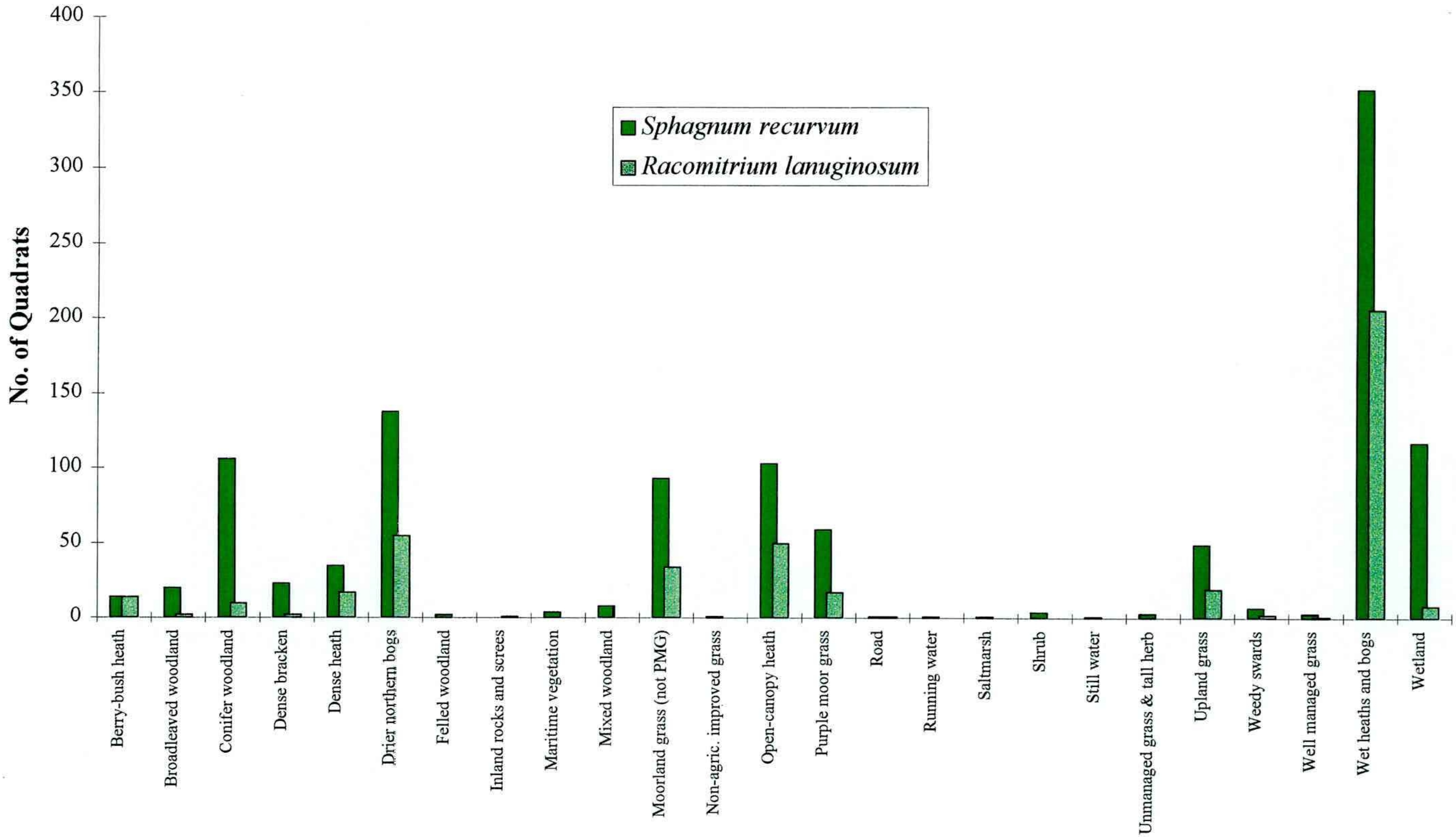


Figure 6.3 Predicted distribution of ***Racomitrium lanuginosum***

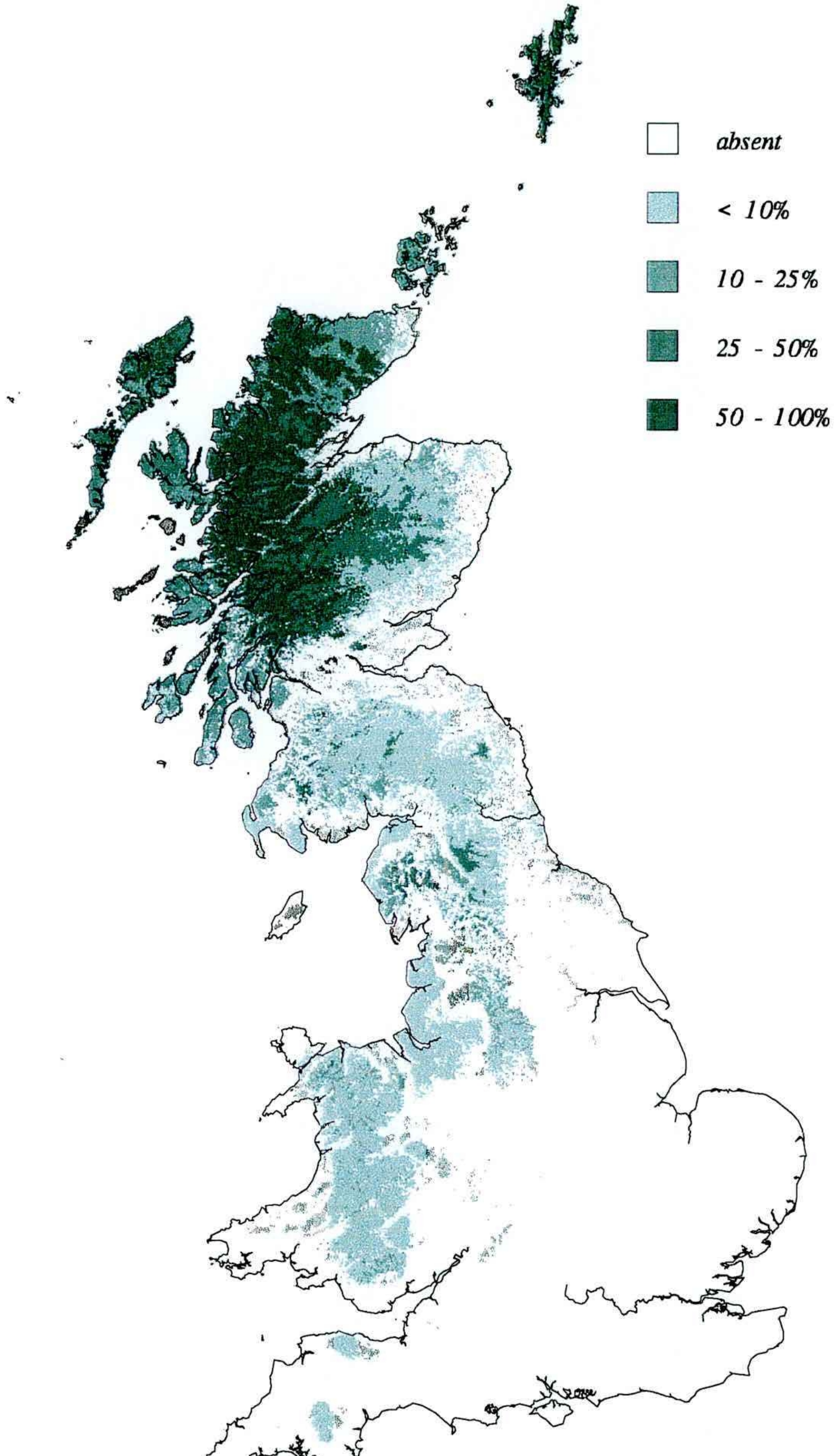


Figure 6.4 Countryside Survey 1990 squares with *Racomitrium lanuginosum*

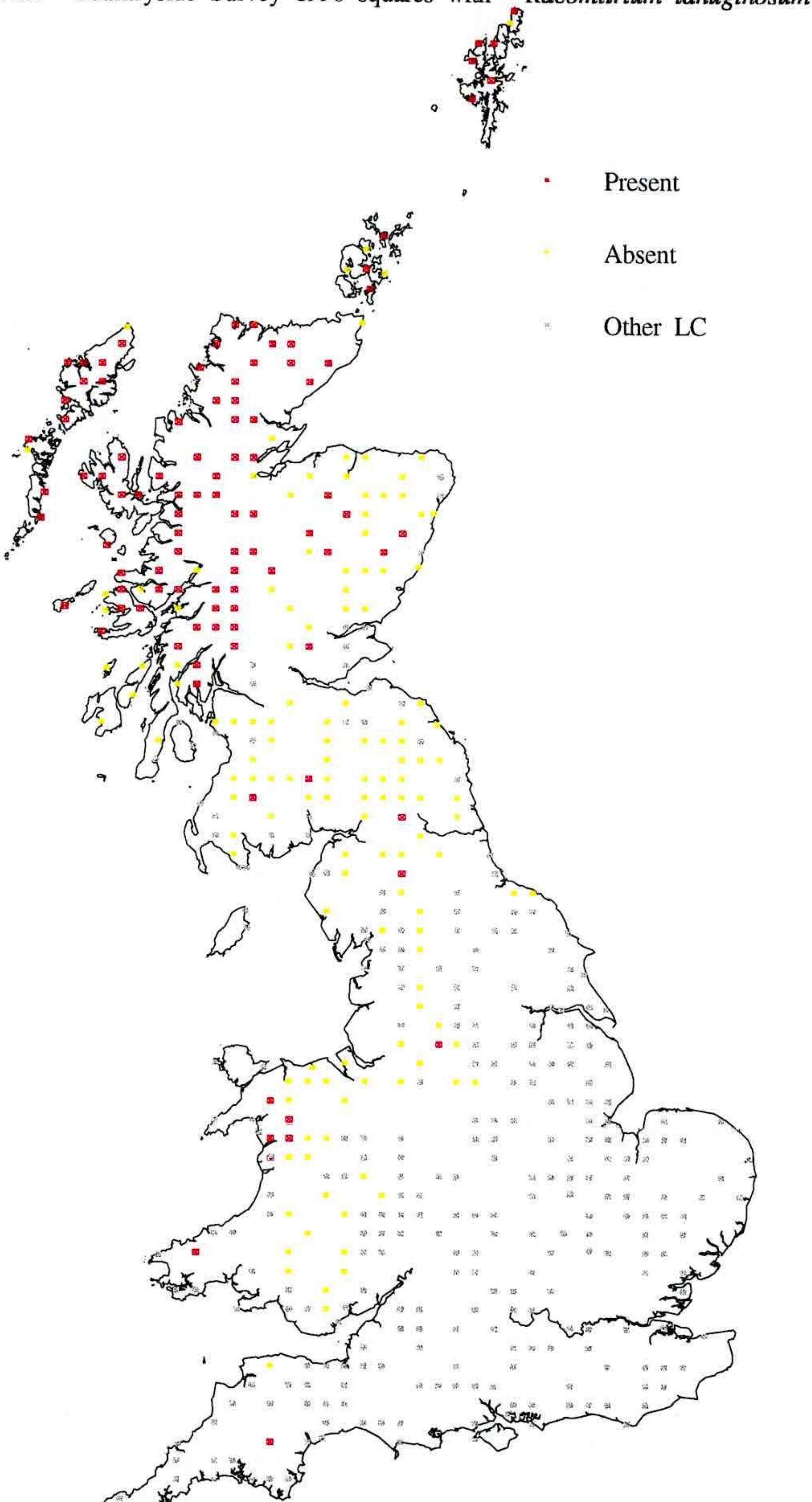


Figure 6.5 The distribution of bogs in the ITE Land Cover Map of Great Britain

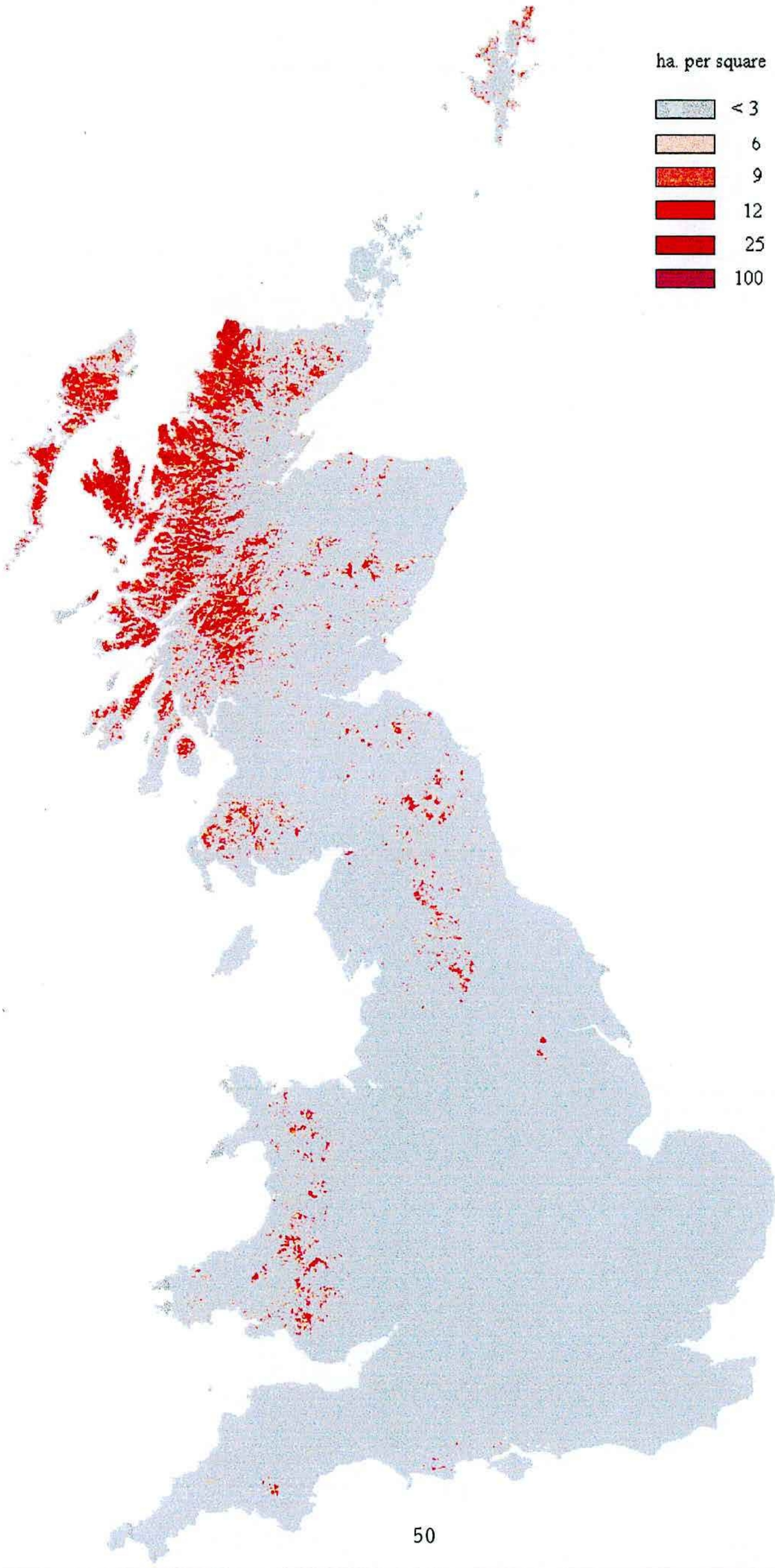


Figure 6.6 *Racomitrium lanuginosum* in X plots in CS 1990 in relation to DECORANA axis scores for land classes

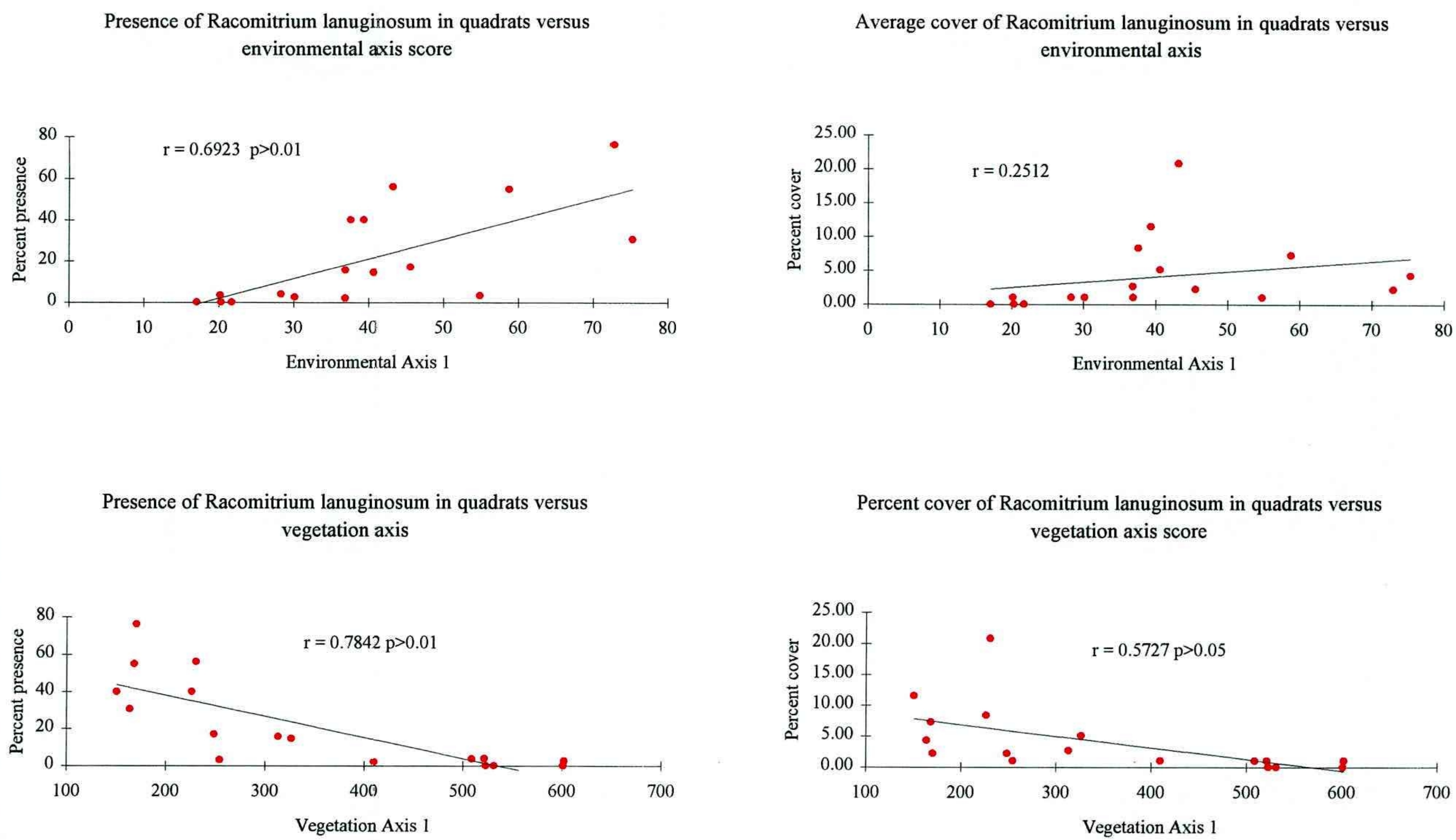
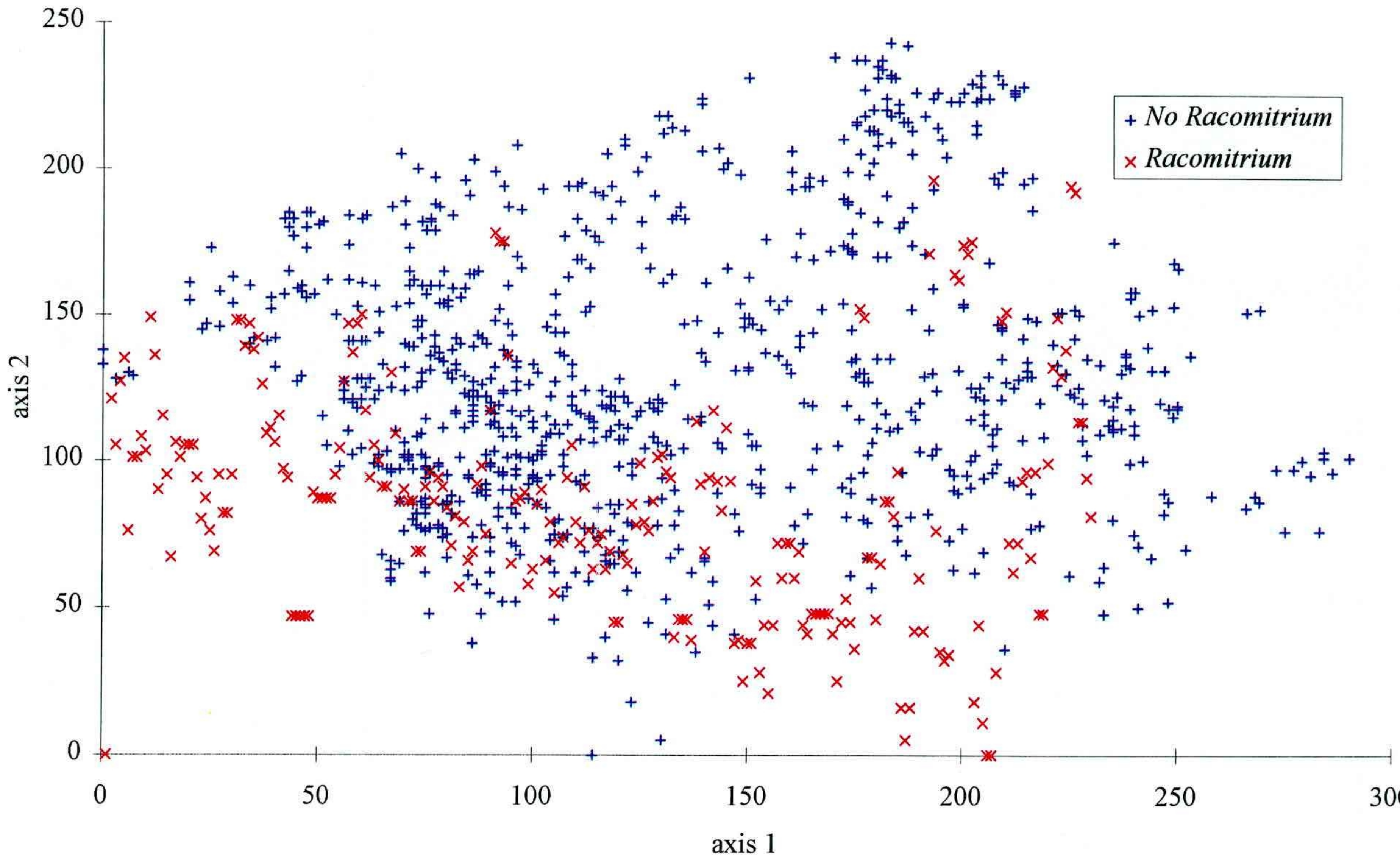


Figure 6.7 Scatterplot of DECORANA axis scores show the split between quadrats containing *Racomitrium lanuginosum* and those not



7. A comparison of the environmental requirements of the species surveyed in Countyside Survey plots in 1978 and 1990

P.D.Carey & M.O.Hill, ITE Monks Wood

7.1 Introduction

This study attempts to demonstrate how the nature of the quadrats used in the Countryside surveys in 1978 and 1990 had changed in terms of seven environmental variables; light, temperature, continentality, moisture, pH, Nitrogen and salt. The surveyed quadrats were categorised to one of seven groups by the assemblage of species that was found within it; arable, improved grassland, semi-improved grassland, upland grassland, moorland, saltmarsh and woodland. We also assessed if there had been any changes in the seven separate categories over the period 1978 -1990.

Ellenberg *et al.* (1991) assigned each of the vascular plant species of Central Europe values which represent the species requirement for the seven environmental attributes listed above. Although not all of the British flora are included in Ellenberg's list, and also the requirements of a particular species in Britain may also vary from the requirements of the same species in Central Europe, the values Ellenberg has given still provide an adequate tool for describing the requirements of species in Great Britain. We can produce an estimation of the environment for any given site by taking the mean Ellenberg values from a list of the species found growing there. If we have data from the same place on more than one sampling date it is possible to infer changes to the variables to which the Ellenberg scores refer by comparing the mean Ellenberg values from each sampling date.

7.2 Methods

The lists of species from the quadrats surveyed in both the 1978 contryside survey and also the 1990 countryside survey were supplied by ITE Merlewood. The species code used in the surveys was converted by a simple program to the Biological Record's Centre (BRC) code for the same species. A second program then added the Ellenberg values for all the species using a list comprising of BRC codes and the Ellenberg codes provided by Mark Hill. Any species which does not appear in Ellenberg's list was removed at this stage. Ellenberg values which denote a wide amplitude of response (x in the Ellenberg tables) and missing values in the Ellenberg tables were considered to be null data. A third program calculated the mean Ellenberg value for each of the seven variables available in each quadrat by adding the Ellenberg scores and dividing the total by the number of species which contributed a score.

The mean Ellenberg scores calculated for the 1978 and the 1990 quadrat data were compared by two sample t -tests. The means of the 1990 data were subtracted from the 1978 means to produce a pictorial representation of the data with a value above zero representing a decrease in the Ellenberg score over the period and a value below zero representing an increase in the Ellenberg score over the period. The same analysis was done for each of the seven groups of species; arable, improved grassland etc.

7.3 Results

34 species codes from the survey data could not be matched with Biological Record Centre codes giving a total of 1261 species that matched.

738 quadrats had data which could be compared between 1978 and 1990.

Very few significant changes in the quadrats between 1978 and 1990 are apparent from the changes in the mean Ellenberg values (Table 1). Although there has been a significant decrease in species which prefer warmth ($T = 2.41$, $p = 0.02$). The only significant changes in any of the groups was that species which show a preference for light increased in semi-improved grasslands ($T = -1.99$, $df = 328$, $p = 0.05$) and continental species became more common on moorland ($T = 1.95$, $df = 96$, $p = 0.05$).

Although not significant there has been a decrease in the species which are thought of as continental (Figure 1). Perhaps surprisingly there was a decrease in Nitrophiles (Figure 1). Figures 2-8 show the comparison in the mean Ellenberg values between 1978 and 1990 in the different groups. Only three squares designated as saltmarsh were identified as having identifiable Ellenberg species in both 1978 and 1990 and as a result this category has been omitted in the figures. Group 1 is the arable group, 2 is the improved grassland group, 3 is the semi-improved grassland group, 4 is the upland grassland group, 5 is the moorland group, and 7 is the woodland group. There has been a noticible increase in the Ellenberg moisture index in both improved grassland and semi-improved grassland and a decrease in the moisture index in the upland grassland, moorland and woodland groups (Figure 5). pH has increased in woodlands (Figure 6). The Nitrogen index shows very little change but an increase in woodland is indicated (Figure 7).

7.4 Discussion

There are two ways of interpreting the lack of significance in the results of this study. The first is to assume that there has been little change in the species composition of the British countryside between 1978 and 1990 and the second is that the methods used here are unable to detect the changes in the species composition. We have only considered presence/absence of species which means that any changes in the abundance of species will not be noticed, for example, the increase of competitive varieties of *Lolium perenne* at the expense of other grass species would be missed.

Study of the Figures 2-8 shows that the standard error bars are large which indicates that some quadrats have changed markedly. If we are to show changes in the countryside perhaps it is the quadrats that are found at the extremes of the data that should be studied and resurveyed later in this project as these are the ones that have changed most. It would be a straightforward exercise to determine which these quadrats were. It is possible that some quadrats may have changed considerably in all of the Ellenberg scores whereas others will only have changed markedly in one score.

Reference

Ellenberg, H., Weber, H.E., Düll, R., Wirth, V., Werner, W. & Paulissen, D. (1991). Zeigerwerte von Pflanzen in Mitteleuropa. *Scripta Geobotanica*, **18**, 1-248.

Table 1:

Group	Light T	Light P	Temperature T	Temperature P	Continentality T	Continentality P	Moisture T	Moisture P	pH T	pH P	Nitrogen T	Nitrogen P	Salt T	Salt P
All	-1.40	0.16	2.41	0.02 *	-0.64	0.52	0.33	0.74	1.91	0.06	0.29	0.77	-0.15	0.88
Arable	-0.32	0.75	0.60	0.55	-1.07	0.29	0.05	0.96	1.07	0.28	0.30	0.77	-0.23	0.82
Improved Grassland	-1.25	0.21	0.66	0.51	-0.47	0.64	-1.70	0.09	-0.43	0.67	1.04	0.30	1.02	0.31
Semi-imp Grassland	-1.99	0.05 *	1.63	0.10	-0.67	0.51	-0.94	0.35	1.29	0.20	0.26	0.80	-0.37	0.71
Upland Grassland	-0.68	0.50	1.19	0.24	1.95	0.05 *	0.47	0.64	1.68	0.10	0.58	0.56	0.23	0.82
Moorland	0.46	0.65	1.50	0.13	1.38	0.17	1.24	0.21	0.54	0.59	-0.62	0.53	-0.51	0.61
Saltmarsh	-3.56	0.07	-1.25	0.30	1.32	0.32	0.95	0.41	1.83	0.21	-2.52	0.13	-0.58	0.62
Woodland	-0.21	0.83	0.65	0.52	-1.13	0.26	0.52	0.60	1.68	0.10	0.82	0.42	0.69	0.49

Figure 7.1 The difference in mean Ellenberg scores between 1978 and 1990 in 738 quadrats surveyed on both occasions. The value zero represents no change. A negative value indicates an increase between 1978 and 1990 and a positive value a decrease.

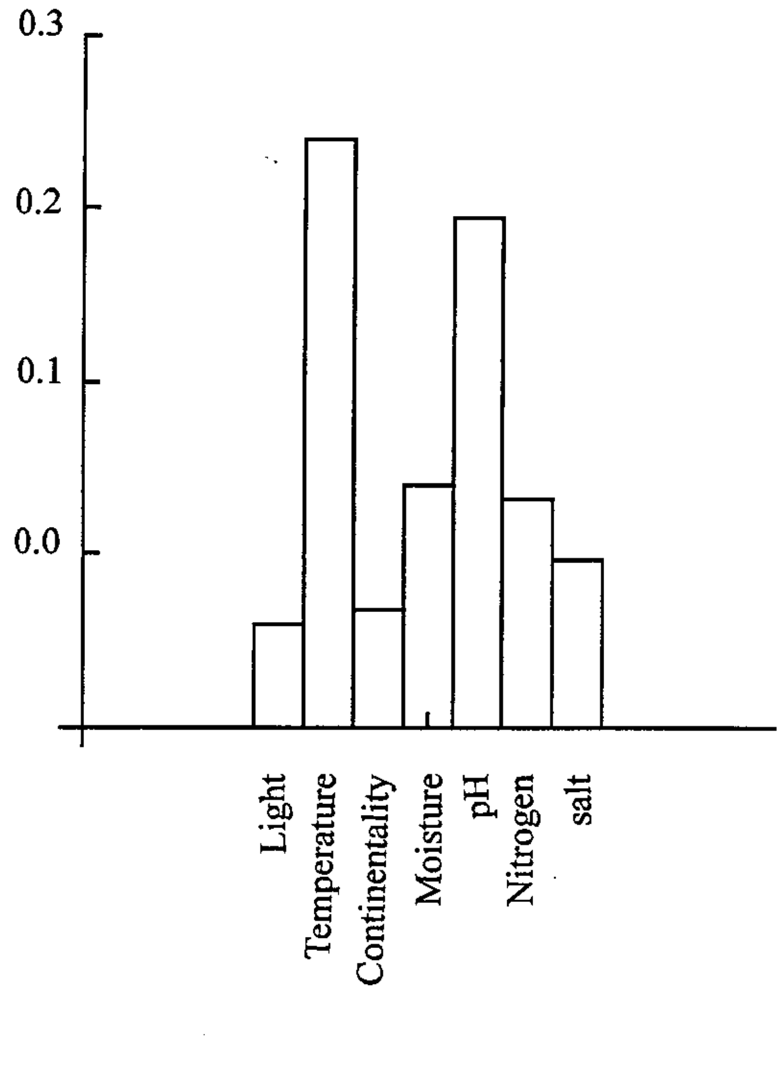


Figure 7.2 The change in mean Ellenberg scores for groups; 1 = arable, 2 = improved grassland, 3 = semi-improved, 4 = upland grassland, 5 = moorland, 7 = woodland

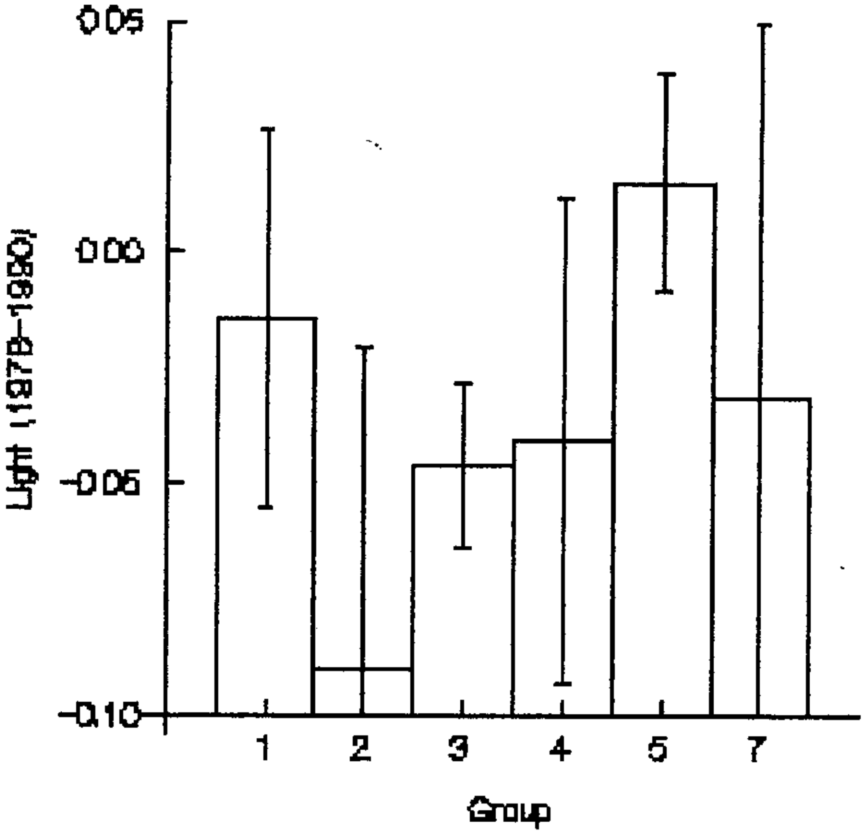


Figure 7.3 The change in mean Ellenberg score for temperature in groups; 1 = arable, 2 = improved grassland, 3 = semi-improved grassland, 4 = upland grassland, 5 = moorland, 7 = woodland

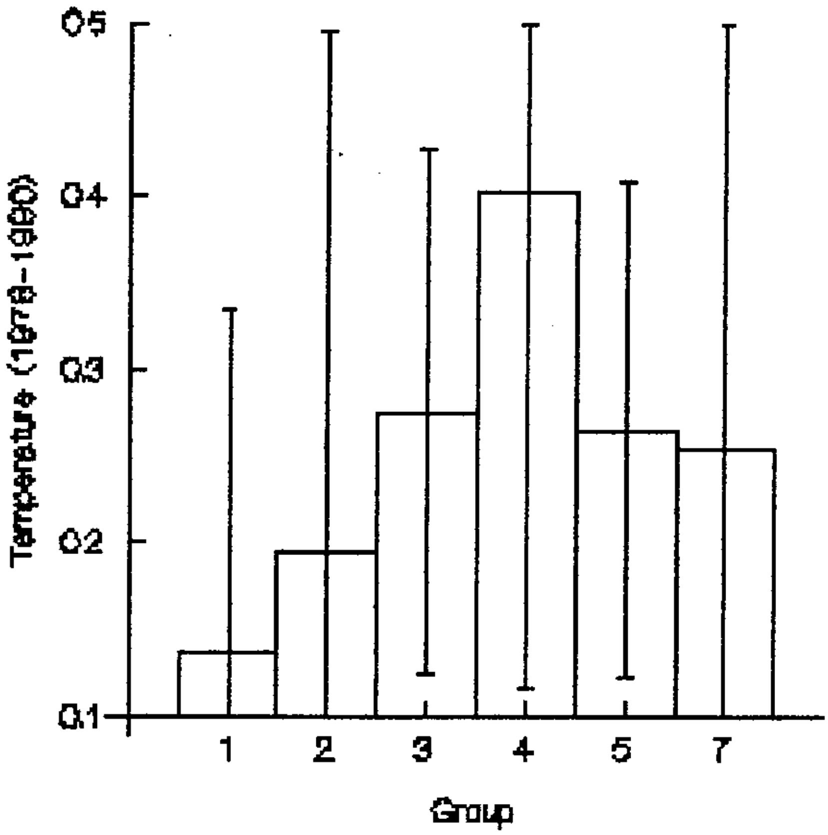


Figure 7.4 The change in mean Ellenberg score for continentality for groups; 1 = arable, 2 = improved grassland, 3 = semi-improved grassland, 4 = upland grassland, 5 = moorland, 7 = woodland

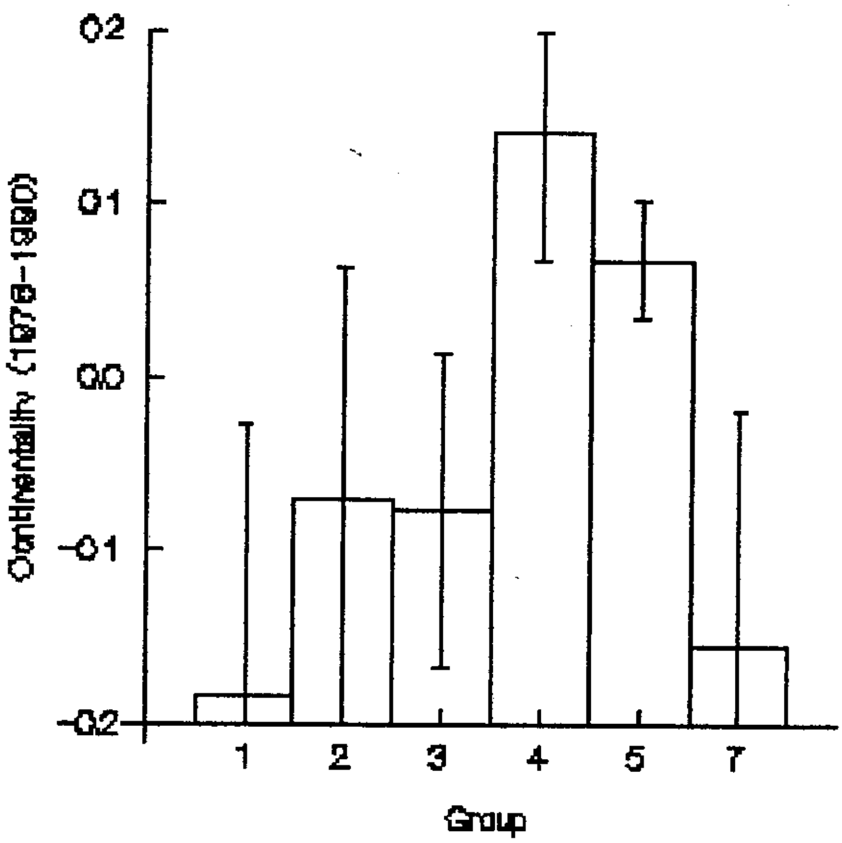


Figure 7.5 The change in mean Ellenberg score for Moisture in groups; 1 = arable, 2 = improved grassland, 3 = semi-improved, 4 = upland grassland, 5 = moorland, 7 = woodland

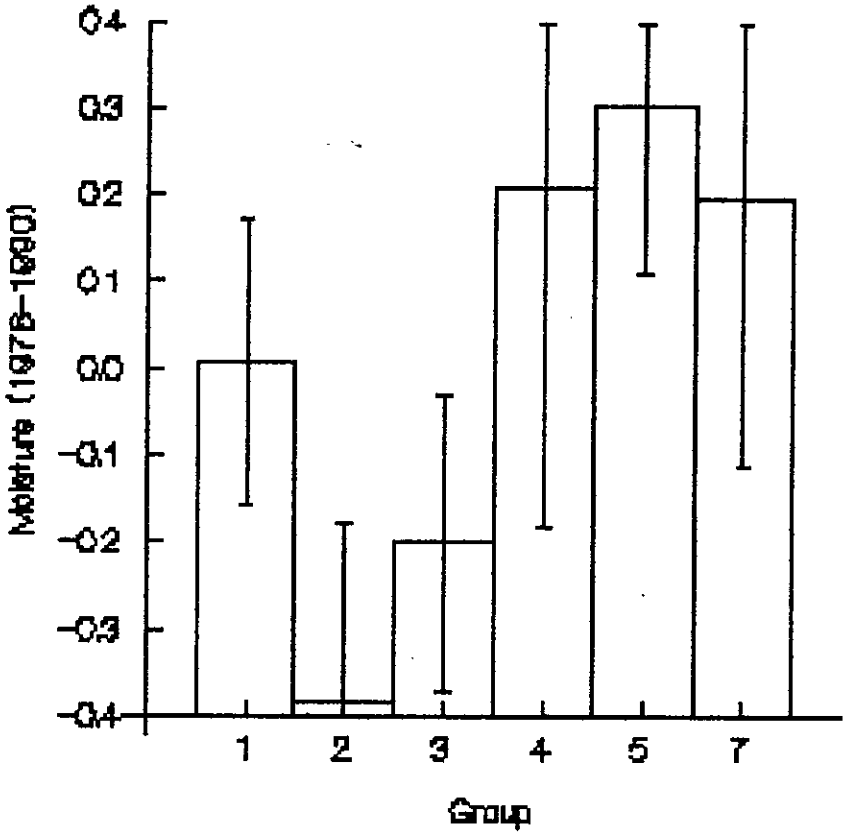


Figure 7.6 The change in mean Ellenberg scores for pH in groups; 1 = arable, 2 = improved grassland, 3 = semi-improved grassland, 4 = upland grassland, 5 = moorland, 7 = woodland

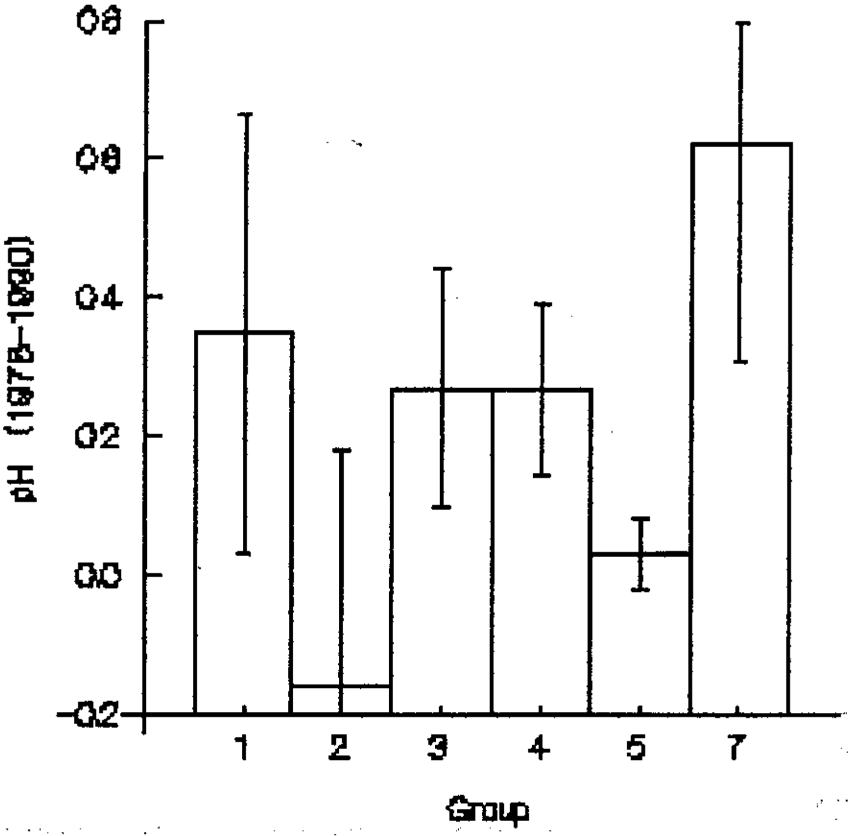


Figure 7.7 The change in mean Ellenberg score for Nitrogen in groups; 1 = arable, 2 = improved grassland, 3 = semi-improved grassland, 4 = upland grassland, 5 = moorland, 7 = woodland

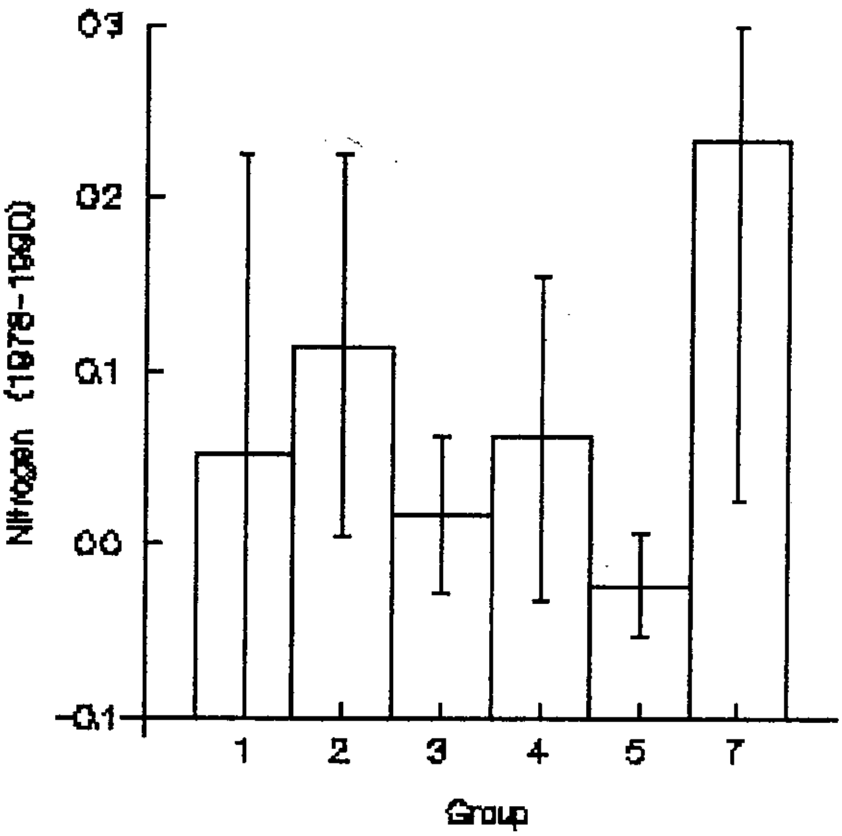
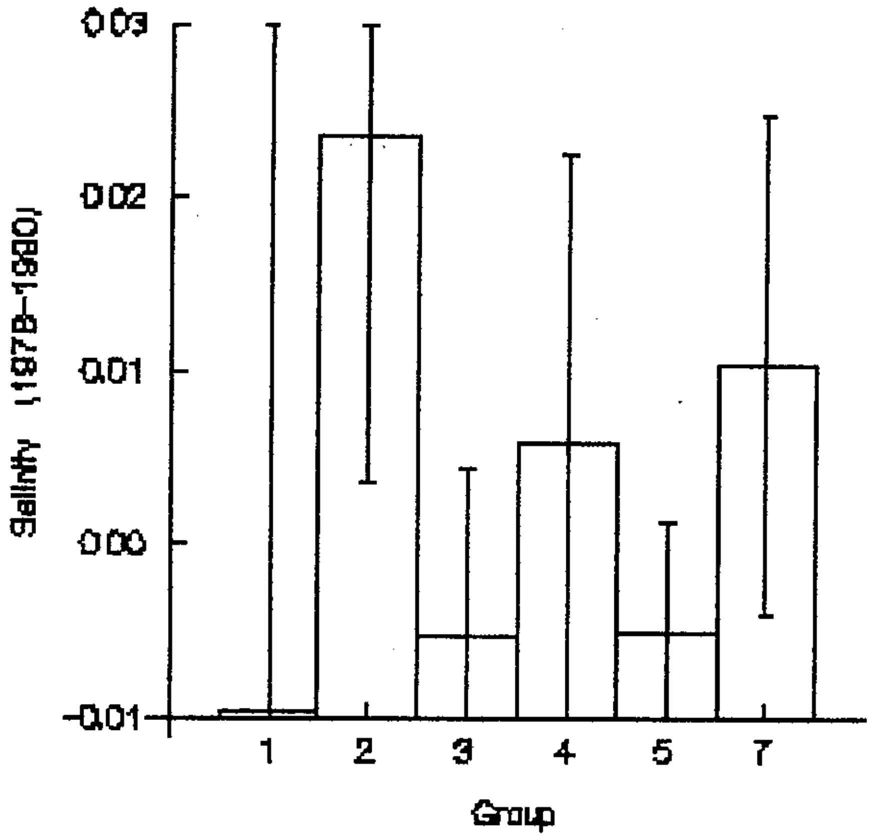


Figure 7.8 The change in mean Ellenberg score for salinity in groups; 1 - arable, 2 = improved grassland, 3 = semi-improved grassland, 4 = upland grassland, 5 = moorland, 7 = woodland



8. ELLENBERG INDICATOR VALUES APPLIED TO THE PARK GRASS EXPERIMENT

M O Hill & P D Carey - ITE Monks Wood

8.1 Introduction

It has been known for a long time that vegetation, especially long-established vegetation, provides a sensitive integrated measure of the environment. In the short term, historical factors determine which species are present, but in the longer run the species composition of the vegetation at any one place is determined more by environment conditions than by the initial condition. The timescale of adjustment may vary from decades to millenia according to the stability of the habitat, the lifespan of constituent species and their ability to disperse into the site.

One of the most remarkable demonstrations of the controlling influence of environment is provided by the Park Grass Experiment (PGE) at Rothamsted (Tilman *et al.* 1994). This experiment was started in 1856 and has continued to the present day, constituting a site of the Ecological Change Network (Parr, Scott & Lane 1995). The site is maintained as permanent grassland, from which two cuts of hay are taken each year. It is divided into plots, each of which has a particular fertilizer regime (Thurston, Williams & Johnston 1976). The experiment is not replicated, but the experimental effects are so large and so stable that, for many comparisons, they clearly exceed any stochastic fluctuations.

In a series of recent studies, it has been shown that there is a negative relation between species-richness and biomass (annual herbage yield) and between species-richness and acidity (Silvertown 1980). There is marked year-to-year variation in herbage yield, which can partly be explained by rainfall in the early part of the season (Jenkinson *et al.* 1994; Silvertown *et al.* 1994). Some of the less abundant constituent species increase and decrease over time, although the dominant grasses change relatively little (Dodd *et al.* 1994b; Tilman *et al.* 1994).

The plant communities resulting from the PGE treatments are not only stable but can be assigned to the phytosociological categories of the British National Vegetation Classification (NVC) (Dodd *et al.* 1994a). For example, plots acidified by high inputs of ammonium tended to the *Holcus lanatus-Deschampsia cespitosa* grassland (NVC type MG9), while plots 7,8 and 15, receiving phosphorus but no nitrogen, tended to the *Centaurea nigra* subcommunity of *Arrhenatherum elatius* grassland. Plots which received neither nitrogen nor phosphorus were classified as species-rich hay meadow, *Centaureo-Cynosuretum cristati*, either the *Lathyrus pratensis* subcommunity (MG5a) or the *Galium verum* subcommunity (MG5b). The grass *Lolium perenne*, so characteristic of many intensively-managed fields, was relatively scarce in PGE. Dodd *et al.* (loc. cit.) tentatively assigned the vegetation of one treatment (plot 10L, with high N and P but no K) to the *Lolium perenne-Cynosurus cristatus* grassland, but the abundance of *Lolium* was generally low.

Although the NVC categories successfully describe the major differences in the vegetation, they cannot be related in an obvious way to continuous variables such as herbage yield or soil pH. For this purpose, it is better to use methods of calibration in the sense of (ter Braak 1995; ter Braak & Prentice 1988), for example weighted averaging of species indicator values (ter Braak & Barendregt 1986).

The standard set of species indicator values for the Central European flora is that of Ellenberg (Ellenberg 1988; Ellenberg *et al.* 1991). Mean Ellenberg indicator values have been used, for example, to indicate the amount of light in woodland rides (Sparks *et al.* 1996) or the degree of eutrophication and desiccation in wetlands (Latour, Reiling & Slooff 1994). We therefore decided to apply Ellenberg values to the vegetation of the Park Grass experiment, to see how effectively they can indicate the ecological condition of the plots.

8.2 Data and methods

Data on the floristic composition of the vegetation were taken from Williams (1978); soil data and data on herbage yield were taken from Warren & Johnston (1964). There is a discrepancy between the dates for which these data were available, in that herbage composition (% dry mass of hay, sampled in June) data are available for almost all plots from either 1948 or 1949 and also from one of the three years 1973 to 1975. Comprehensive published soil data, however, are available only for 1959. Herbage yield data, including both first and second cuts of hay, are available as a mean for the period 1920-1959.

For calibration purposes, an average taken over long time-period is in some ways preferable to one based on results from a single year. We have therefore attempted to reconcile the disparity of dates by using an average proportional herbage composition, taking a mean of the latest value from 1948-9 and the earliest from 1973-75. The average date of herbage sampling was therefore 1962, which is fairly close to the 1959 data for soil samples.

Data on plot treatment, herbage yield and soils are given in Table 1.

The Ellenberg indicator scores (Table 2) were taken from Ellenberg *et al.* (1991). Mean Ellenberg indicator values were calculated for R (soil reaction) and N (nitrogen indication) in three ways: (1) a simple mean taken over all species, (2) a mean weighted by $\log(2+P_i)$ where P_i is the proportion of species i in the herbage, and (3) as a mean weighted by P_i. The logarithmic weighting is designed so that weights 1,2,3,4,...,k are assigned to the proportional abundance values $0,2,6,14,...,2^k-2$. It is intermediate between the other two methods of weighting.

8.3 Results and discussion

The correlation coefficients between variables clearly indicate the importance of nitrogen and potassium for high yield. The fact that the correlation between K inputs and yield is larger than that between N and yield is at least partly attributable to the fact that Plot 12 (P7L) has high yield through additions of P,K and lime; nitrogen fixation must supply much of its nitrogen.

Yield was, however, even more strongly correlated with total soil P ($r=-0.871$) and with the unweighted mean Ellenberg N value ($r=0.909$). The negative correlation with total soil P is clearly a result of removal of P in hay, although so large a negative value would not necessarily be expected given calculated mean annual removal rates up to 18 kg ha^{-1} (Warren & Johnston 1964) and inputs of 35 kg ha^{-1} in plots receiving P fertilizer. The extremely high correlation with Ellenberg N value is, however, remarkable and suggests that this could provide a good means of estimating annual productivity in other contexts.

In the rest of the correlation matrix, high correlations of N and K inputs with Ellenberg N reflect the high correlation of all these variates with yield. The large negative correlation of soil P with Ellenberg N is also to be expected, given its negative correlation with yield. Other large correlations are between topsoil N and C (the C/N ratio is not very variable) and subsoil N and C (for the same reason). It is perhaps surprising that there is so little relation between the topsoil and subsoil in this respect.

The pH of the topsoil shows only one large (>0.7) correlation, with the variable RQ, weighted Ellenberg R value.

The significance of these correlations can be further explored by inspecting Figures 1-4. From Figures 1 and 2, it is apparent unlimed that plots receiving no K have large negative residuals; i.e. that their yield was unexpectedly low in relation to their mean N values. Figures 3 and 4 show that soil pH was moderately well correlated with the weighted Ellenberg R, except for the acidified but limed plots 11.1L and 11.2L. These plots were dominated by *Alopecurus pratensis*, for which Ellenberg R=6. This value would not suggest that it would have high abundance on acid ground.

8.4 Conclusions

(1) Annual yield of hay was accurately predicted by unweighted mean Ellenberg N values of the component species.

(2) Large negative residuals from the relationship could be attributed to plots with a combination of low K and low pH.

(3) Soil pH was not at all well predicted by unweighted mean R values, but there was a potentially useful relation for weighted mean R values.

(4) Large negative residuals for soil pH could be attributed to two plots dominated by *Alopecurus pratensis*.

(5) These preliminary results are highly encouraging and suggest that Ellenberg values can be extended for use in other contexts.

Acknowledgements

We thank Jonathan Silvertown (Open University) and Paul Poulton (IACR Rothamsted) for supplying copies of papers and suggestions for reading, Caroline Ashton for help with data entry, and Tim Sparks for introducing us to useful computer packages.

References

Dodd, M.E., Silvertown, J., McConway, K., Potts, J., & Crawley, M. (1994a) Application of the British National Vegetation Classification to the communities of the Park Grass Experiment through time. *Folia Geobotanica et Phytotaxonomica*, **29**, 321-334.

Dodd, M.E., Silvertown, J., McConway, K., Potts, J., & Crawley, M. (1994b) Stability in the plant communities of the Park Grass Experiment: the relationships between species richness, soil pH and biomass variability. *Philosophical Transactions of the Royal Society of London*, **B 346**, 185-193.

Ellenberg, H. (1988) *Vegetation ecology of Central Europe* (4 edn). Cambridge University

Press, Cambridge.

Ellenberg, H., Weber, H.E., Düll, R., Wirth, V., Werner, W., & Paulissen, D. (1991) Zeigerwerte von Pflanzen in Mitteleuropa. *Scripta Geobotanica*, **18**, 1-248.

Jenkinson, D.S., Potts, J.M., Perry, J.N., Barnett, V., Coleman, K., & Johnston, A.E. (1994) Trends in herbage yields over the last century on the Rothamsted Long-term Continuous Hay Experiment. *Journal of Agricultural Science*, **122**, 365-374.

Latour, J.B., Reiling, R., & Slooff, W. (1994) Ecological standards for eutrophication and desiccation: perspectives for a risk assessment. *Water, Air and Soil Pollution*, **78**, 265-277.

Parr, T.W., Scott, W.A., & Lane, A.M.J. (1995) The UK Environmental Change Network. *Institute of Terrestrial Ecology Annual Report*, **1994-95**, 99-104.

Silvertown, J. (1980) The dynamics of a grassland ecosystem: botanical equilibrium in the Park Grass Experiment. *Journal of Applied Ecology*, **17**, 491-504.

Silvertown, J., Dodd, M.E., McConway, K., Potts, J., & Crawley, M. (1994) Rainfall, biomass variation, and community composition in the Park Grass Experiment. *Ecology*, **75**, 2430-2437.

Sparks, T.H., Greatorex-Davies, J.N., Mountford, J.O., Hall, M.L., & Marrs, R.H. (1996) The effects of shade on the plant communities of rides in plantation woodland and implications for butterfly conservation. *Forest Ecology and Management*, **80**, 197-207.

ter Braak, C.J.F. (1995) Non-linear methods for multivariate statistical calibration and their use in palaeoecology: a comparison of inverse (*k*-nearest neighbours, partial least squares and weighted averaging partial least squares) and classical approaches. *Chemometrics and Intelligent Laboratory Systems*, **28**, 165-180.

ter Braak, C.J.F., & Barendregt, L.G. (1986) Weighted averaging of species indicator values: its efficiency in environmental calibration. *Mathematical Biosciences*, **78**, 57-72.

ter Braak, C.J.F., & Prentice, I.C. (1988) A theory of gradient analysis. *Advances in Ecological Research*, **18**, 271-317.

Thurston, J.M., Williams, E.D., & Johnston, A.E. (1976) Modern developments in an experiment on permanent grassland started in 1856: effects of fertilisers and lime on botanical composition and crop and soil analyses. *Annales Agronomiques*, **27**, 1043-1082.

Tilman, D., Dodd, M.E., Silvertown, J., Poulton, P.R., Johnston, A.E., & Crawley, M.J. (1994) The Park Grass Experiment: insights from the most long-term ecological study. *Long-term experiments in agricultural and ecological sciences* (eds R.A. Leigh & A.E. Johnston), pp. 287-303. CAB International.

Warren, R.G., & Johnston, A.E. (1964) The Park Grass Experiment. *Report of Rothamsted*

Experimental Station for 1963, 240-262.

Williams, E.D. (1978) *Botanical composition of the Park Grass plots at Rothamsted 1856-1976*. Rothamsted Experimental Station, Harpenden.

Table 1 Treatmeant, herbage yield and soil attributes for Park Grass plots. The column labels are as follows:- No, serial number; plot number (U denotes unlimed, L limed); N annual nitrogen fertilizer addition, 1=48 kg ha^{-1}, 2=96 kg ha^{-1}, 3=144 kg ha^{-1}; P annual phosphorus fertilizer additon, 1=35 kg ha^{-1}; K annual potassium fertilizer addition, 1=225 kg ha^{-1}; Yld annual total dry matter yield (units of cwt/acre, 1=0.126 Mg ha^{-1}) of hay in two cuts, mean for 1920-59; Ctop organic carbon % in topsoil (0-23 cm); Csub organic carbon % in subsoil (23-46 cm); Nsub nitrogen % in subsoil; Ntop nitrogen % in topsoil; pHsub pH of subsoil; phtop pH of topsoil; P1 total phosporus (mg/100g) in topsoil; K1 exchangeable (1*N*-ammonium acetate) potassium in topsoil (mg/100g)

No	Plot	N P K	Yld	Ctop	Csub	Nsub	Ntop	pHsub	pHtop	P1	K1
1	P1U	1 0 0	13.6	3.0	1.1	.12	.24	5.2	4.0	52	6
2	P1L	1 0 0	18.9	3.5	1.6	.16	.30	6.6	7.2	59	6
3	P2U	0 0 0	13.6	3.5	1.6	.15	.28	5.3	5.2	51	8
4	P2L	0 0 0	14.8	4.2	1.6	.15	.35	6.8	7.3	60	8
5	P3U	0 0 0	11.8	3.3	1.6	.15	.27	5.3	5.2	49	8
6	P3L	0 0 0	13.0	4.0	1.3	.13	.33	6.8	7.2	57	7
7	P4.1U	0 1 0	17.1	3.7	1.7	.16	.29	5.3	5.2	43	7
8	P4.1L	0 1 0	15.9	4.1	1.6	.16	.34	6.6	7.1	59	6
9	P4.2U	2 1 0	16.4	4.1	1.2	.11	.30	4.2	3.7	56	5
10	P4.2L	2 1 0	29.4	3.6	1.2	.13	.29	5.6	5.7	28	6
11	P7U	0 1 1	29.2	2.8	1.4	.14	.23	5.0	4.9	32	67
12	P7L	0 1 1	35.3	3.4	1.5	.15	.30	6.3	7.0	34	61
13	P8U	0 1 0	21.5	3.0	1.3	.14	.24	5.3	5.2	34	8
14	P8L	0 1 0	17.2	3.7	1.4	.15	.31	6.6	7.0	53	8
15	P9U	2 1 1	37.2	4.1	1.4	.13	.30	4.3	3.8	36	22
16	P9L	2 1 1	44.9	4.0	1.5	.15	.31	5.2	5.3	23	39
17	P10U	2 1 0	24.2	4.2	1.1	.12	.34	4.4	3.8	48	6
18	P10L	2 1 0	35.5	3.5	1.1	.12	.28	5.6	5.6	22	8
19	P11.1U	3 1 1	44.2	4.5	1.5	.15	.34	4.1	3.7	27	22
20	P11.1L	3 1 1	53.6	4.1	1.7	.15	.30	4.4	4.2	17	24
21	P11.2U	3 1 1	50.8	4.7	1.9	.16	.35	4.3	3.7	27	22
22	P11.2L	3 1 1	58.9	3.7	1.7	.14	.29	4.7	4.6	12	25
23	P12U	0 0 0	15.0	3.4	1.4	.15	.28	5.4	5.2	56	8
24	P14U	2 1 1	49.5	2.9	1.2	.12	.21	6.1	6.0	10	49
25	P14L	2 1 1	45.2	3.7	1.1	.12	.32	6.9	7.3	35	47
26	P16U	1 1 1	34.8	3.6	1.4	.14	.28	5.6	5.4	40	67
27	P16L	1 1 1	35.4	3.8	1.4	.14	.32	6.9	7.1	50	61
28	P17U	1 0 0	21.1	2.9	1.2	.14	.26	5.5	5.7	50	7
29	P17L	1 0 0	23.0	3.5	1.4	.14	.30	6.9	7.5	56	6

Table 2 Ellenberg indicator values for R (soil reaction) and N (soil nitrogen) for species recorded in hay from the Park Grass Experiment; the value x signifies wide ecological amplitude and was treated by us as a missing value

Species	R N	Species	R N
Achillea millefolium	x 5	Lathyrus pratensis	7 6
Agrostis capillaris	4 4	Leontodon hispidus	7 6
Alopecurus pratensis	6 7	Linum catharticum	7 2
Anthoxanthum odoratum	5 x	Lolium perenne	7 7
Anthriscus sylvestris	x 8	Lotus corniculatus	7 3
Arrhenatherum elatius	7 7	Luzula campestris	3 3
Briza media	x 2	Ononis repens	7 2
Bromus hordeaceus	x 3	Pimpinella saxifraga	x 2
Carex caryophyllea	x 2	Plantago lanceolata	x x
Centaurea nigra	3 4	Poa pratensis sens.str.	x 6
Cerastium fontanum	x 5	Poa trivialis	x 7
Conopodium majus	4 4	Potentilla reptans	7 5
Dactylis glomerata	x 6	Sanguisorba officinalis	x 5
Chamerion angustifolium	5 8	Ranunculus acris	x x
Festuca pratensis	x 6	Rumex acetosa	x 6
Festuca rubra	6 x	Taraxacum officinale	x 8
Galium verum	7 3	Tragopogon pratensis	7 6
Helictotrichon pubescens	x 4	Trifolium pratense	x x
Heracleum sphondylium	x 8	Trifolium repens	6 6
Holcus lanatus	x 5	Trisetum flavescens	x 5
Knautia arvensis	x 4	Veronica chamaedrys	x x

Table 3 Correlation coefficients between variables listed in Table 1 and mean Ellenberg indicator values for plots. The notation for treatments, herbage yield and soil attributes is as in Table 1. Mean Ellenberg values are R(ell), unweighted R; RL2Q mean R weighted by logarithmic herbage proportions; mean R weighted by herbage proportions; N(ell), unweighted N; NL2Q mean N weighted by logarithmic herbage proportions; NQ mean N weighted by herbage proportions

	N	P	K	Yld	Ctop	Csub	Nsub	Ntop
P	0.450							
K	0.512	0.564						
Yld	0.790	0.619	0.855					
Ctop	0.444	0.275	0.182	0.245				
Csub	-0.013	-0.016	0.231	0.175	0.399			
Nsub	-0.299	-0.143	0.029	-0.067	0.198	0.852		
Ntop	0.196	0.093	0.024	0.056	0.898	0.336	0.285	
pHsub	-0.531	-0.309	-0.223	-0.300	-0.243	-0.135	0.101	0.096
pHtp	-0.513	-0.268	-0.194	-0.255	-0.201	-0.050	0.188	0.147
Ptot	-0.654	-0.625	-0.675	-0.871	0.016	-0.068	0.136	0.263
Ksol	0.098	0.463	0.832	0.555	-0.157	0.011	-0.042	-0.176
R(ell)	0.253	0.391	0.371	0.520	0.188	0.282	0.132	0.163
RL2Q	0.023	0.214	0.327	0.418	-0.017	0.250	0.220	0.087
RQ	-0.235	0.071	0.170	0.180	-0.138	0.166	0.260	0.041
N(ell)	0.851	0.640	0.765	0.909	0.368	0.055	-0.200	0.171
NL2Q	0.606	0.591	0.718	0.873	0.027	-0.016	-0.156	-0.048
NQ	0.333	0.438	0.583	0.705	-0.208	-0.018	-0.036	-0.206

	pHsub	pHtop	Ptot	Ksol	R(ell)	RL2Q	RQ	N(ell)
pHtp	0.979							
Ptot	0.417	0.373						
Ksol	0.098	0.102	-0.432					
R(ell)	0.212	0.264	-0.409	0.340				
RL2Q	0.509	0.566	-0.307	0.403	0.869			
RQ	0.662	0.727	-0.118	0.349	0.672	0.928		
N(ell)	-0.409	-0.365	-0.738	0.461	0.445	0.288	0.056	
NL2Q	-0.029	0.020	-0.769	0.618	0.687	0.671	0.482	0.835
NQ	0.192	0.249	-0.680	0.607	0.677	0.776	0.688	0.571

	NL2Q
NQ	0.911

Fig. 1 Yield (cwt/acre) in relation to Ellenberg score

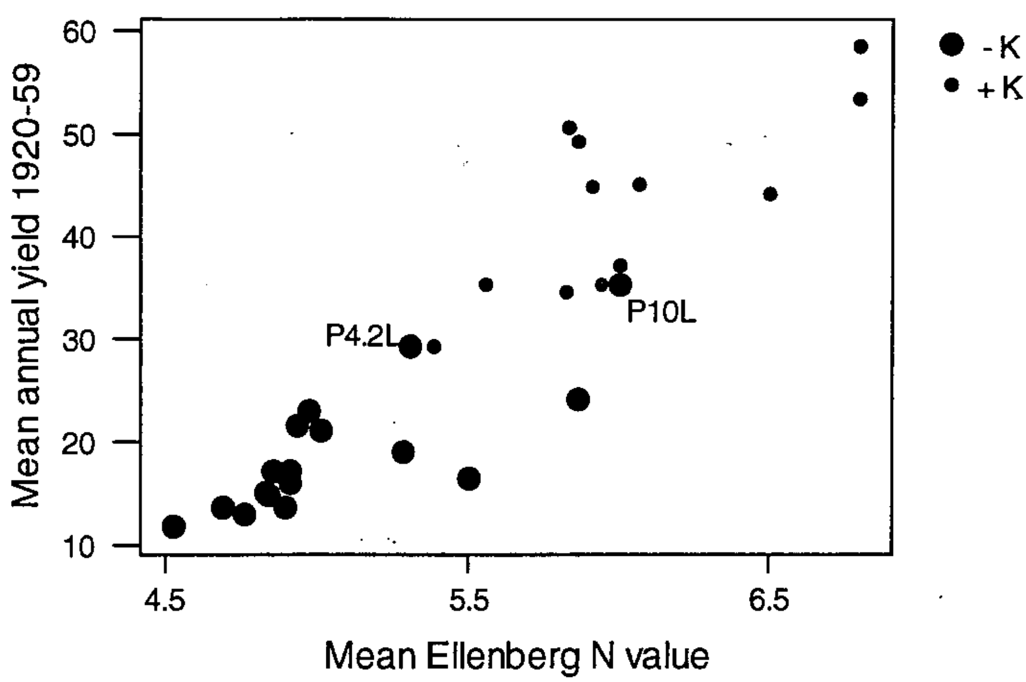


Fig. 2 Yield (cwt/acre) in relation to Ellenberg score

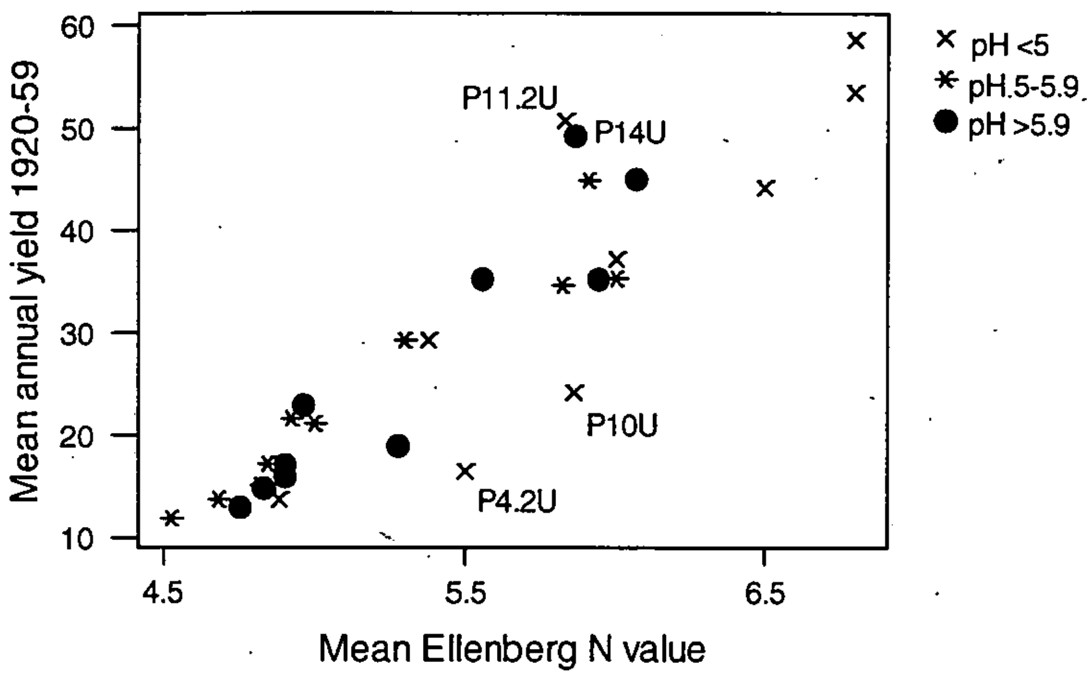


Fig.3 Soil pH in relation to Ellenberg R

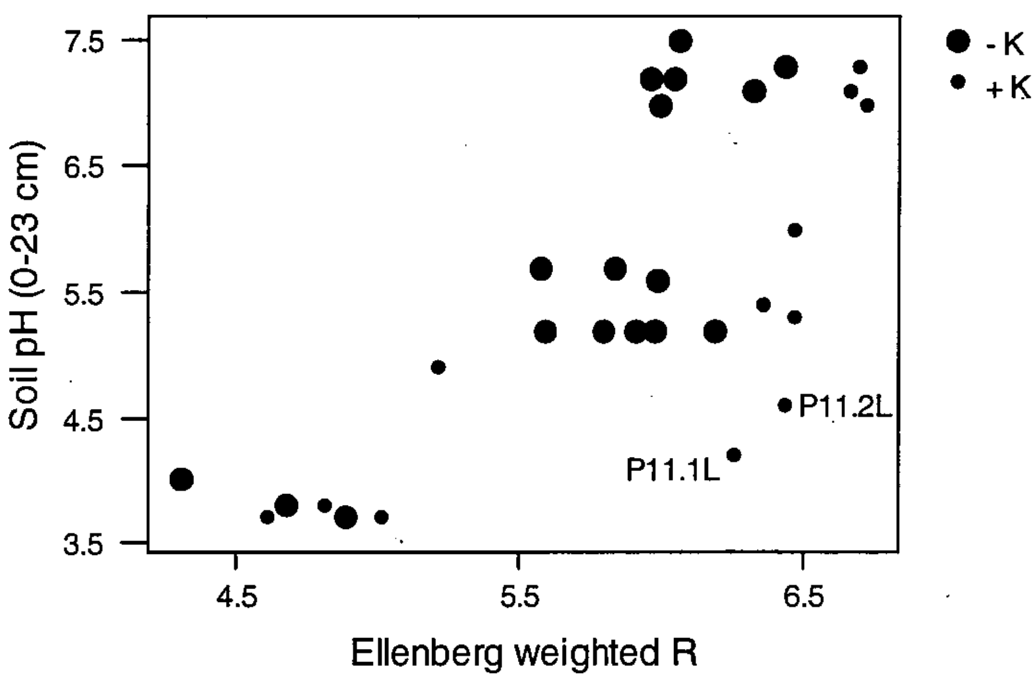
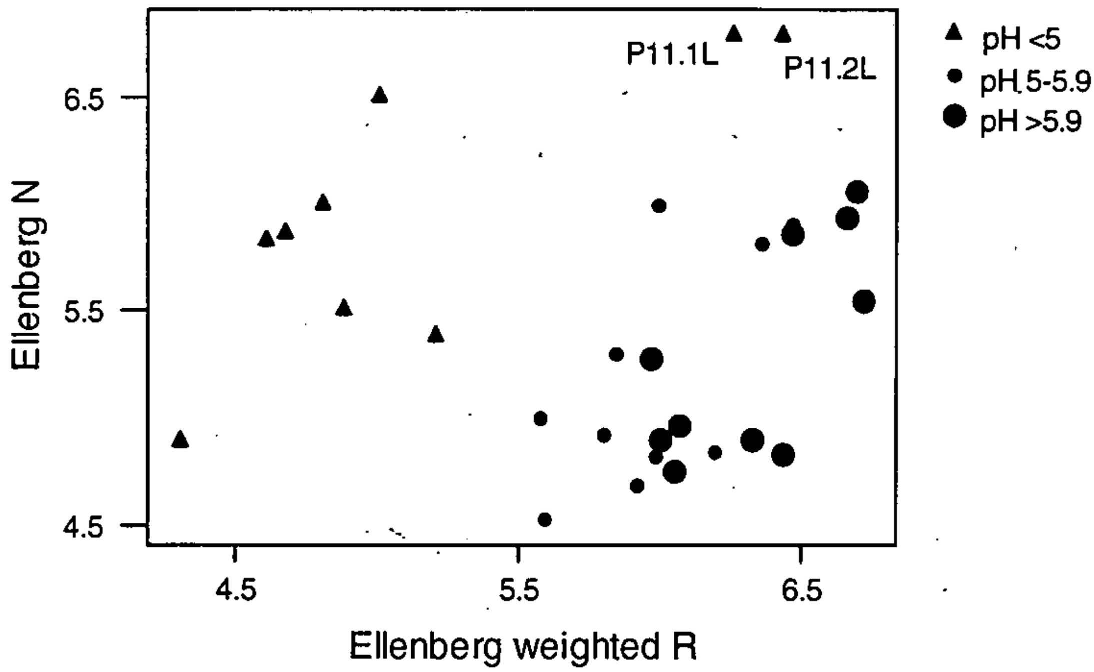


Fig. 4 Relation between Ellenberg N and R



9. Characteristic species of the European Climate Classes

DB Roy, BC Eversham & RGH Bunce ITE

9.1 Introduction

Species distribution data from the Biological Records Centre (BRC) were used to identify vascular plant species characteristic of each of the European climate classes described below.

9.2 The Biological Records Centre (BRC)

ITE's Biological Records Centre (BRC), set up in 1964, is the U.K. national biodiversity data centre. Its development and applications during the first 25 years are described by (Harding and Sheail 1992). BRC's computerised data sets include about 6 million individual records (minimum data = species, location, date) of some 10 000 taxa. These data have been used to prepare maps summarising the national distribution of species, which have been published in atlases, taxonomic treatises and studies of individual taxa. The data have been used in the preparation of Red Data Books and national reviews of threatened and uncommon species, including the UK Biodiversity Action Plan.

The BRC data sets now underpin a range of pure and applied research activities within ITE and in universities. Recent examples include studies of the ecological impacts of climate change, determining priorities to maximise the benefits of agricultural set-aside, and assessing the role of habitat corridors for wildlife. The range of research applications using BRC data has been reviewed by (Eversham 1993).

9.3 Reporting on characteristic species

The European Land classes are defined by 10km squares of the National Grid, and species records were extracted from the Biological Records Centre database as 10km square summaries. The distribution data for vascular plants are mainly based on those published in (Perring and Walters 1962), (Rich and Woodruff 1990), (Stewart, Pearman, and Preston 1994) and (Preston and Croft in press), but an extensive update is continuing for the forthcoming Atlas2000 project (Pearman 1996). Records dated post 1930 were used for analysis.

For each species and land class, the observed frequency in the class, o, was compared to its expected frequency e, i.e. its frequency in all classes. Then the preference index

$$P = \{(o-e) \times \mathrm{abs}(o-e)\}/e$$

after (Carey *et al.* 1995). The preference index, P, is a measure of the proportion of a species range which falls within a given land class.

The area of the land classes in Britain varies considerably; class 23 covers 635 10km squares, whereas class 21 only extends to 9 10km squares. This variation in area will affect the preference indices of species between land classes and the prevalence of rare and common species in the characteristic species lists. The P values should thus be used predominantly to rank species within classes and not to compare between classes.

The fifty species with the highest preference index have been chosen initially as the characteristic species for the land classes. The Biological Records Centre holds distribution data for a broad range of other plant and animal groups which could be analysed in the same way. The available data vary in comprehensiveness of geographic coverage, and in date of collection, between taxonomic groups. The taxa for which the most complete data are available are:

- Mosses and liverworts (bryophytes)
- Butterflies (Rhopalocera)
- Dragonflies (Odonata)
- Grasshoppers and allies (Orthopteroid orders)
- Snails, slugs and bivalves (Mollusca)

For each class the 50 species with the highest preference index were chosen, irrespective of their native/alien status. Alien species are represented as characteristic species in several classes, notably those in lowland England, but the proportion of aliens varies greatly between classes. Some alien plants are grossly under-recorded, or are mainly 'casuals' from gardens, whereas others are well established in seminatural vegetation. Therefore the validity of aliens as characteristic species varies between classes. For example, the characteristic species of class 21 which are alien, such as *Euonymus japonicus* and *Campanula poscharskyana*, are generally under-recorded garden-escape species which are seldom thoroughly naturalised but have a high proportion of their recorded range within the zone, but are known to be widespread elsewhere in the British Isles. Conversely, *Myrrhis odorata* and *Doronicum pardalianches*, which are two alien species with a high preference index for class 23, are genuinely characteristic and are typical members of the woodland flora of that region. Figures 9.1 and 9.2 give the distribution of the characteristic species in each class.

Species with low frequencies could have been omitted as there were in most cases other, commoner species with moderate or high preference for each class. The factors governing the distribution of the most rare species are often poorly understood and therefore such species do not make good characteristic species of large areas of the landscape. However, some of these species are confined to a single class and it would seem contradictory for all of them to be omitted from the list of characteristic species.

The balance in the GB land classification was obtained by using a wide range of parameters (climate, geographic position, geology, geomorphology and human geography). Data quality and availability constrained the selection of information, but 75 variables were used to produce the classification. The dominant elements which determined the broad structure of the classification were climatic, although other parameters were important for the finer divisions. At the European scale, however, data sets describing equivalent environmental features are more variable in quality or not available at the required level of detail. It was, therefore, decided that a comparable classification to achieve most of the objections required at the European scale could be developed using climatic and altitude data alone. It was subsequently suggested that some of the classes be combined or subdivided using non-climatic data, such as potential natural vegetation or geology.

9.4 Climate Classification

The classification (described below) was first produced at a 0.5 x 0.5 degree resolution, and the major groups correspond to recognizable divisions of European climate, such as Mediterranean or continental, as described by Kendrew (1953). These cells are of different size but are in most cases comparable within a country or region. Further resources and time could enable transfer to standard units or size, but the information content of the cells is likely to override size differences. The statistical procedures provide objective rules by which the classes are determined, as discussed by Jones & Bunce (1985). The classification has been applied successfully at a higher resolution to a 10 x 10 km data set for GB; subsequently, the classification will be extended to 1 x 1 km units, and the latter can then be nested into the ITE GB land classes.

Data derived from the Climate Research Unit (CRU) at the University of East Anglia (Hulme *et al.*, in press) were used as the basis of the classification. They contain the 1961-90 mean climate figures for a 'Greater European Window' region, extending from 32° West to 66° East and from 21° and 68° North. The data for air temperature, precipitation totals, sunshine hours, vapour pressure, wind speed, (ground) frost day and rain day frequencies are expressed at a resolution of 0.50° latitude/longitude as monthly minimum, maximum and mean values. The interpolation of meteorological station data to the National Grid used elevation as one of the predictor variables, and this enabled climate surfaces to be constructed for each variable. The full procedure is described by Hulme *et al.* (in press).

Only a subset of the data was used in the classification, chosen to represent dominant trends in variation in the variables concerned; otherwise, the classification may be weighted according to the most common variables. The mean climate data were processed using Principal Component Analysis (PCA) and those variables with the highest components were used to produce the classification. Further details are provided by Bunce *et al.* 1996 and Last & Bunce 1996.

Oceanity and northing (latitude) were added to make the final classification data set of 17 variables; these variables were then converted into attributes for TWINSPAN anlaysis (Hill, 1979a). The 68 attributes were classified by TWINSPAN to produce 64 classes for 5209 squares of the European window.

Having produced the broad-scale classification, it was necessary to convert the classification so that squares could be assigned to existing classes using different climatic scenarios. Discriminant function analysis was used to reallocate the 5209 squares in the European window to one of the existing 64 classes. Climate change across Europe could then be indicated by changes in the allocation of the squares to the classes, and hence the change in the geographic distribution of the classes. In successive scenario runs the sensitivity of different regions in Europe could be assessed.

The geographic distribution of the classes was smoothed using this procedure, with outliers being removed. The results from the discriminant function analysis have now been used as the final classification for the 5209 squares, rather than the TWINSPAN class, as described by Bunce *et al.* (in press). The discriminant function procedure has been applied at 10 km^2, and will subsequently be used at 1 km^2, to model climate perturbations.

As the European classification is based on climate data, any change in climate will produce movements in the geographic distribution of classes within the European window. However, the rules determining the classification do not change, neither do the climatic characteristics of each class, only their spatial distribution. Modifications to the original 68 attribute data set can thus be produced from any new climate scenario, and the distribution of the existing classes under those conditions determined using the discriminant functions.

The seven classes present in Britain at the 0.5 x 0.5 degree level of resolution are shown in Table

2 and in Figure 9.3. For example the Cairngorms come within class 23, a strongly oceanic type at this level, which is unique to Britain, but which is linked to the hyper-oceanic classes 15 and 16 at the next level of the hierarchy. The former is mainly British in its distribution, with two outliers in southern Norway, whereas the latter is evenly divided between western Norway and Scotland. These distributions contrast with the other western class 24, which is found in south Wales and western England, and the continental coastal ones from south-western Norway to north-west Spain. The affinity of these classes is, therefore, strongly Scandinavian, confirming many comments made in this volume about climatic, biogeographical and species distribution patterns. The comparison of the potential vegetation map from the CORINE data base, carried out as part of the TIGER IV project, showed the affinities with the vegetation, especially blanket bogs. Individual species distributions, e.g. *Vaccinium vitis-idea* and arctic-alpine species such as *Carex bigelowii*, also follow these classes, whereas in the other western class these plants are absent or occur only at high elevations.

Another approach was to apply the classification to the data derived by CRU at the increased resolution of 10 x 10 km as shown in Figure 9.4. At 0.5 x 0.5 degrees of resolution, the Cairngorms did not appear as a recognizable unit, whereas at 10 km^2, the main mountain areas in Britain are clearly recognizable. The main Cairngorm massif was classified as class 15 as opposed to 23, because the increased resolution enabled the main core to be separated from the surrounding lowlands, whereas previously these had been masked. The Cairngorm environment is, therefore, balanced between having purely British, as opposed to Scandinavian affinities. The scale of comparison obviously has an important bearing on the conclusions. Further analysis needs to be carried out to characterize these classes in order to examine the full implications of such increased resolution.

9.5 Scenarios of Climate Change

General circulation Models (GCMs) provide the most comprehensive method of investigating the response of the global climate system to various types of internal or external forcing. Results from three GCM experiments have been used in the TIGER Programme: two equilibrium and one transient (Hulme et al. 1994). For the present project the equilibrium experiment used was that performed in 1989 at the Hadley Centre (UKHI) as shown in Figure 9.5.

This scenario involves temperature increase of 1.38° C by 2050 and again by 2100.

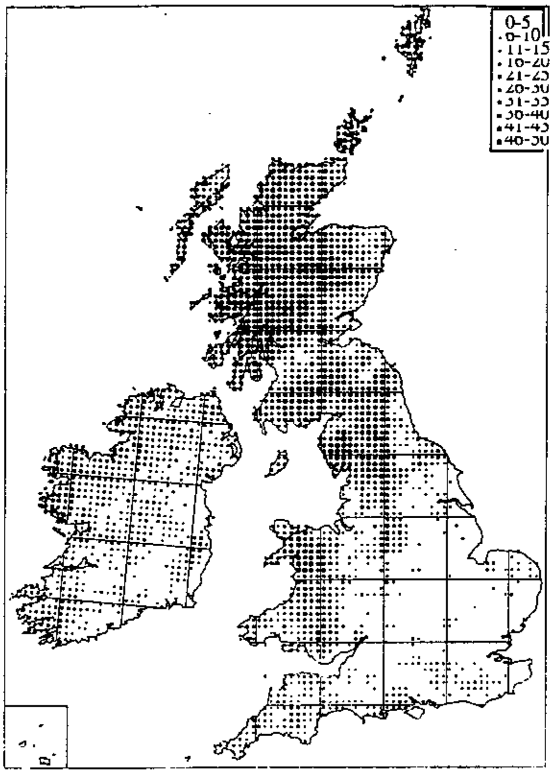
For the 2050 UKHI scenario, Europe stays relatively stable except for three regions, northern Russia, the Mediterranean and Britain, the last of which emphasises the sensitivity of the oceanic region ot the expansion of the continental influence. In Britain class 15 expands at the expense of class 23 beacuse of the warmer and moister conditions whereas the hyper-oceanic class 24 declines due to the expansion of the continental classes. The trend is more pronounced in the 2100 UKHI scenario in which the number of classes in Britain reduce from 7 to 4. This simplification has major implications for the scarcer types of semi-natural vegetation e.g., lusitanean and the dry subarctic vegetation of the Cairngorm plateau, both of which are likely to be under stress (Bunce et al., 1995a).

The shifts in classes cannot be attributed to changes in any one climate variable. As the classes are defined by PCA, the shifts will be produced by the statistical procedures calculating the relative weight of the changes introduced by the scenarios. These changes are in multi-variate space, so whilst it is possible to suggest the important controlling factors the change cannot be attributed directly to, say, temperature alone.

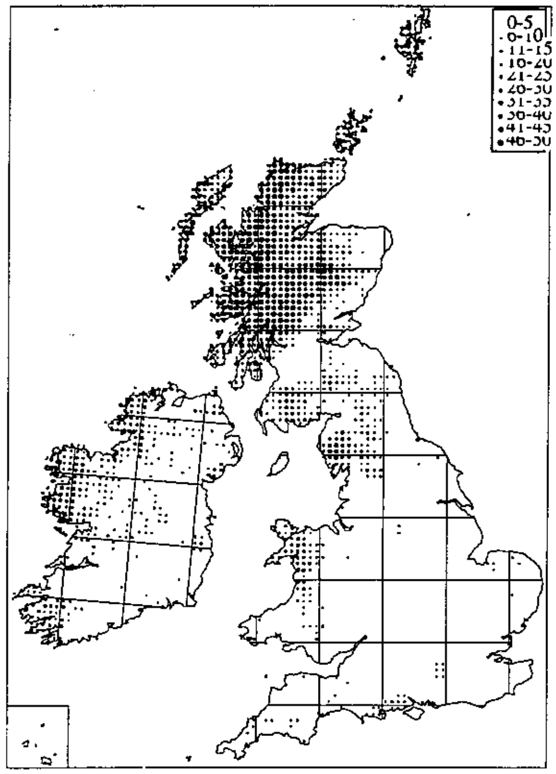
This demonstrates that the strategy of holding a characterised classification which is relocated by changes in climate is very important since it allows the identification of changes due to climate alone, rather than reclassification. It allows interpretation of the scenario results as each class is pre-defined. The underlying assumption of this method is that the current relationships between natural vegetation, land use and land class hold true. Therefore the impacts of scenarios on the characteristic species defined above can be determined. For example, the shift of the oceanic classes on the Cairngorm plateau as mentioned above will affect the high mountain species typical of climate class 16, whereas the continental expansion in southern England will favour the existing continental species. Further work will be carried out in order to expand these conclusions by examining the occurrence of the species identified by BRC within different categories of vegetation.

Figure 9.1

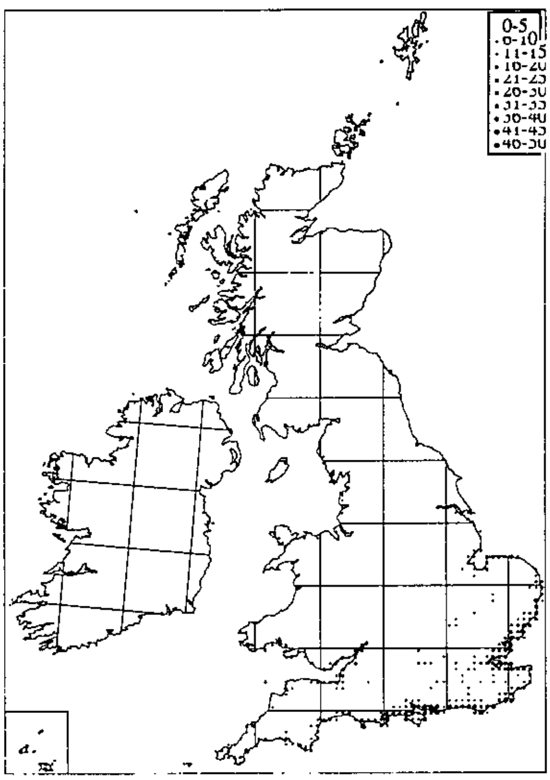
Class 15 - fifty most characteristic vascular plants



Class 16 - fifty most characteristic vascular plants



Class 21 - fifty most characteristic vascular plants



Class 22 - fifty most characteristic vascular plants

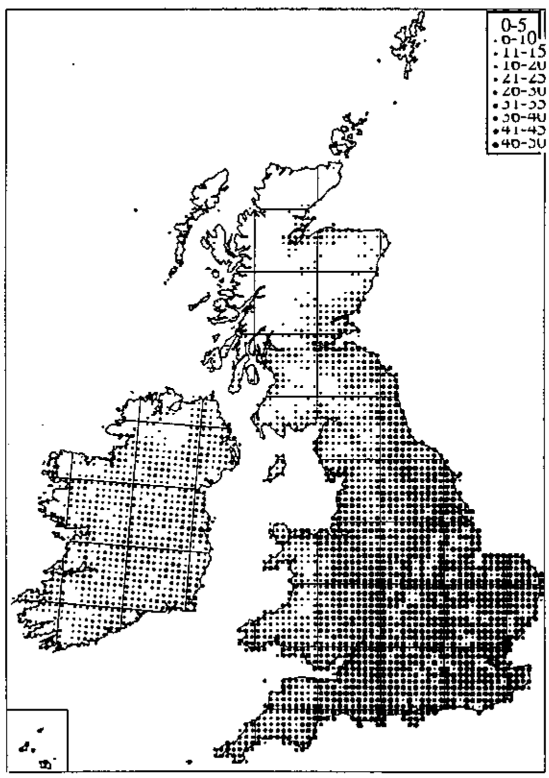
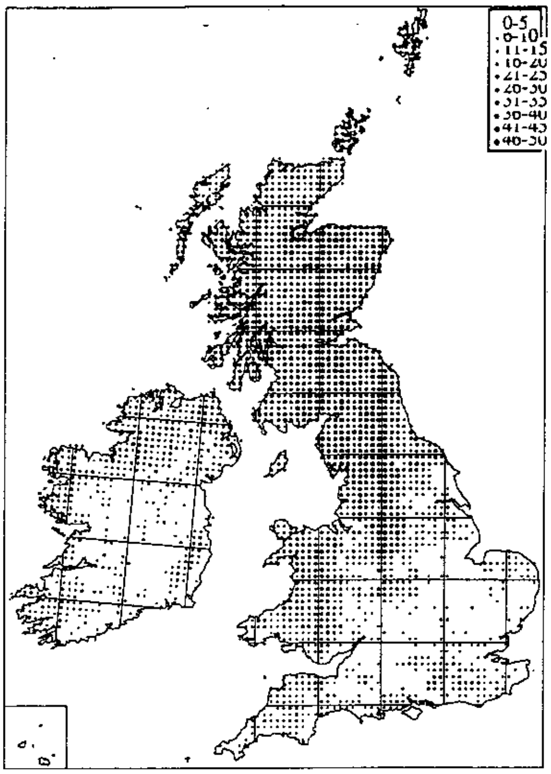
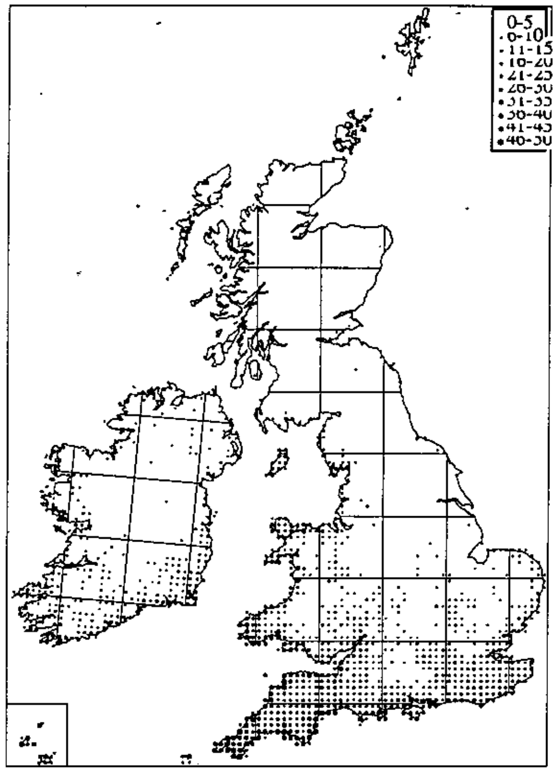


Figure 9.2

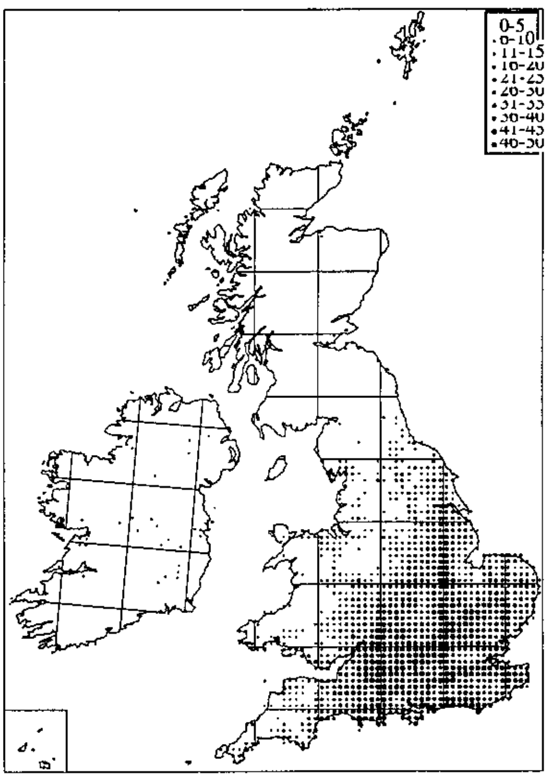
Class 23 - fifty most characteristic vascular plants



Class 24 - fifty most characteristic vascular plants



Class 25 - fifty most characteristic vascular plants



Class 29 - fifty most characteristic vascular plants

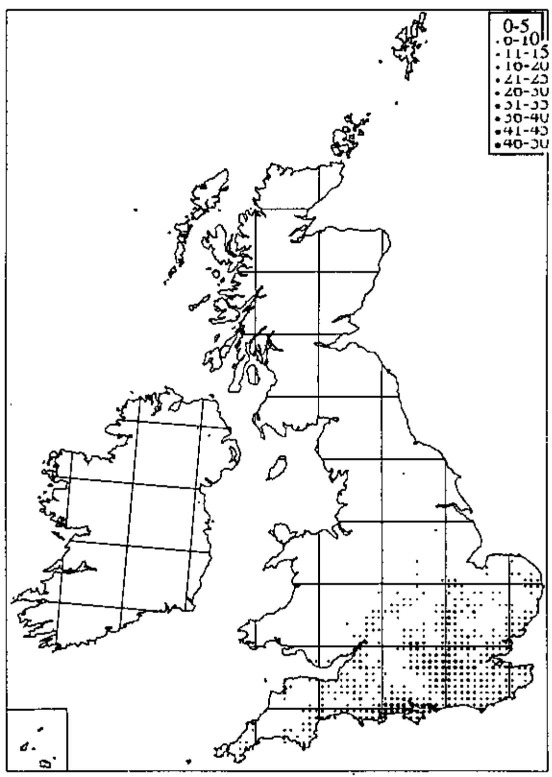


Figure 9.3 European baseline 64-class land classification, based on climate, altitude and oceanicity

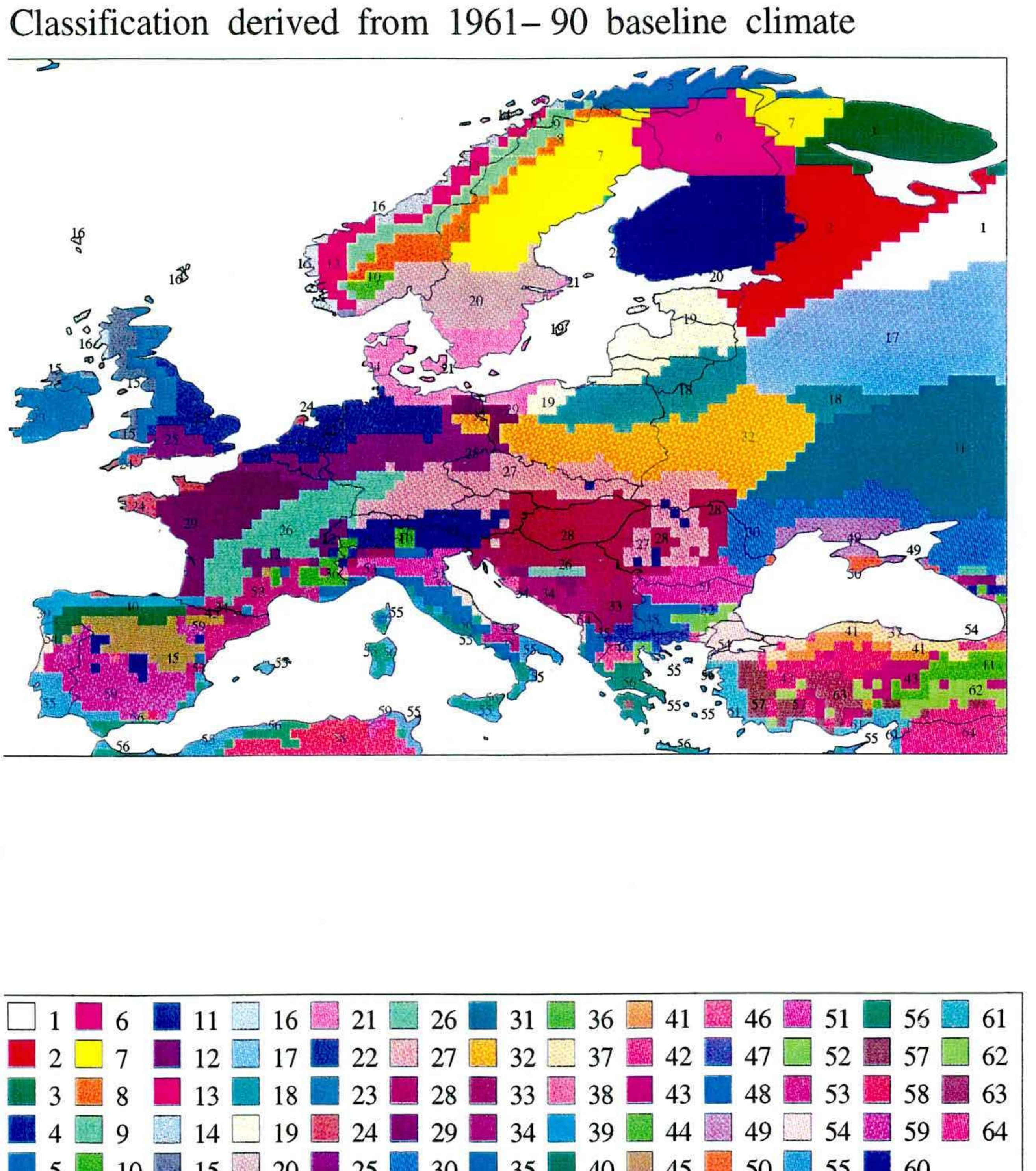


Figure 9.4 European baseline 64-class land classification, calculated at 10 km resolution in Great Britain

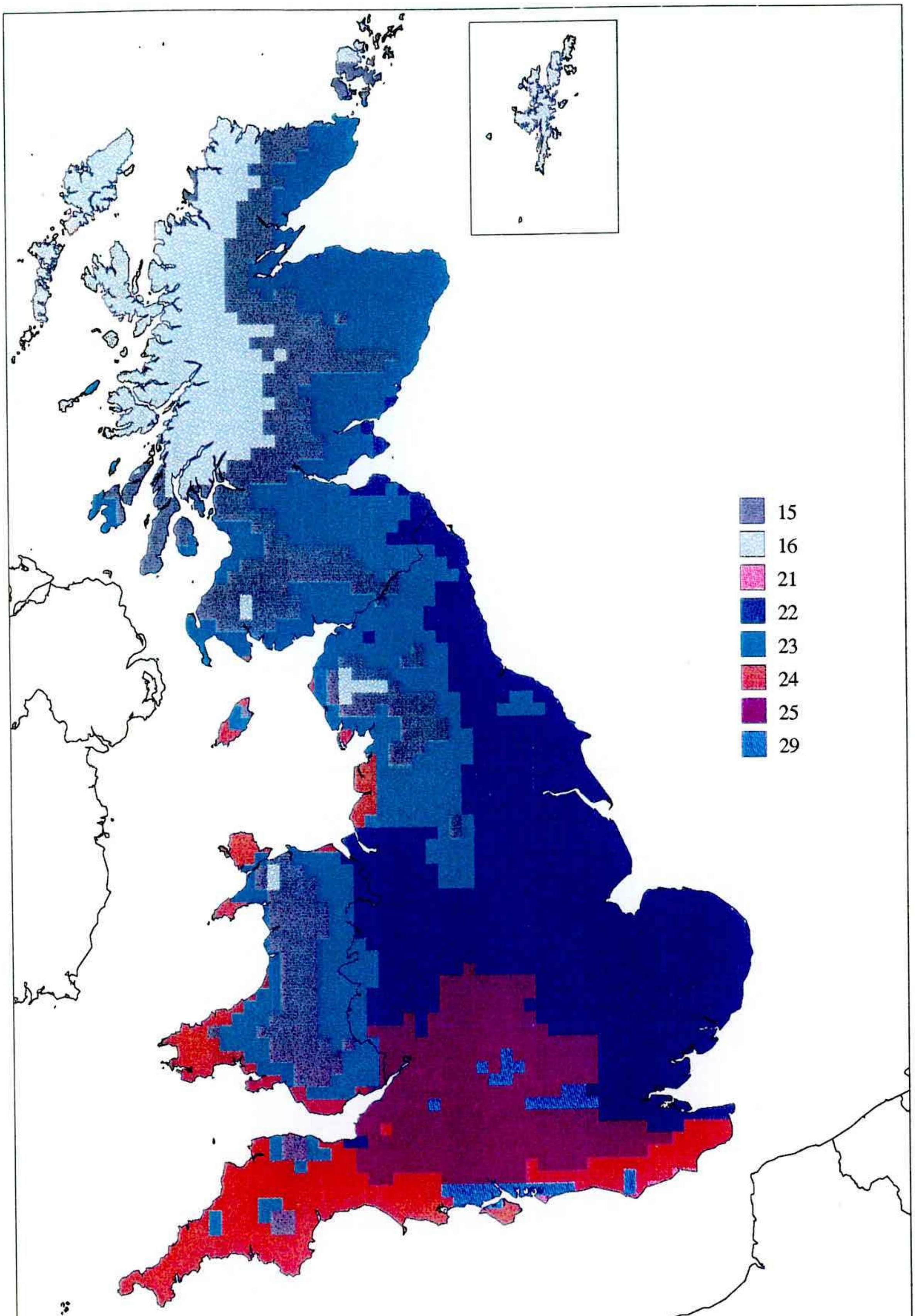
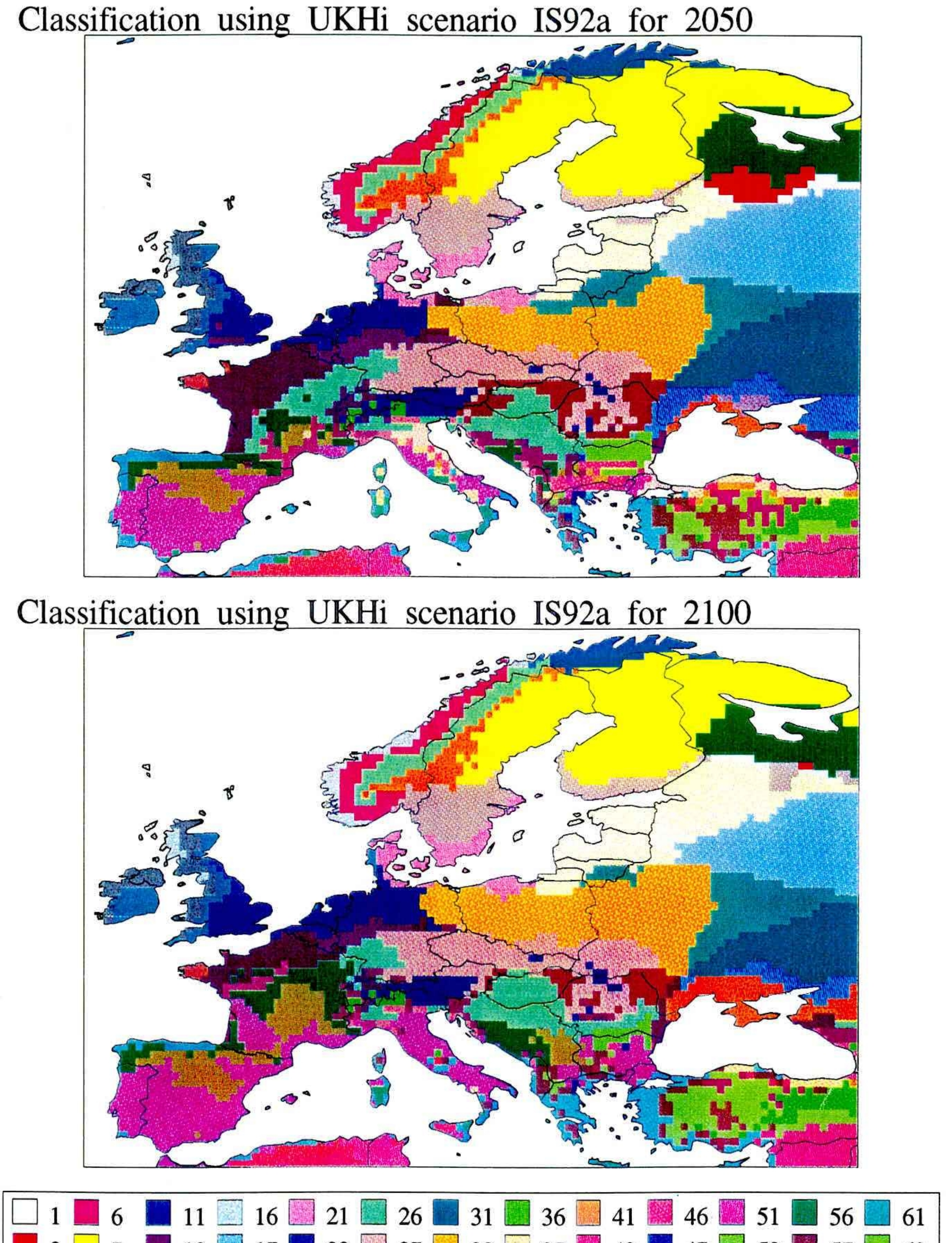


Figure 9.5 European land classification recalculated for 2050 and 2100 using climate scenarios



References

Bunce, R.G.H, Watkins, J.W., Gillespie, M.K. & Howard DC (1996). The Cairngorm environment and climate change in a European context. Bot. J. Scotl, 48 (1), 127-135.

Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. and Lane, A.M.J. (In press). The ITE Merlewood land classification *Journal of Biogeography.*

Carey, P.D., Preston, C.D., Hill, M.O., Usher, M.B., and Wright, S.M. 1995. An environmentally defined biogeographical zonation of Scotland designed to reflect species distributions. *Journal of Ecology* 83: 833-845.

Eversham, B.C. 1993. *Biogeographic research in the Biological Records Centre.* Annual Report 1992-3. 22-25. Swindon: NERC.

Harding, P.T. and Sheail, J. 1992. The Biological Records Centre: a pioneer in data gathering and retrieval. Edited by P.T. Harding. *Biological recording of changes in British wildlife (ITE symposium 23).* London: HMSO.

Hill, M.O. (1979a). TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered to-way table by classifying the individuals and atrributes. Ithaca, N.Y: Section of Ecology and Systematics, Cornell University.

Hulme, M., Conway, D., Jones, P.D., Jiang, T., Barrow, E.M. & Turney, C. (In Press). *A 1961-90 Climatology for Europe for Climate Change Modelling and Impact Applications.*

Jones, H.E. & Bunce, R.G.H. (1985). A prelimanary classification of the climate of Europe from temperature and precipitation records. *Journal of Environmental Management* 20, 17-29.

Kendrew, W.G. (1953). *The climate of the continents*, 4th edition. London: Oxford University Press.

Last. F & Bunce, RGH (1996). Greenhouse gases, climate change and plant performance. Caledonian Gardener 1996.

Pearman, D. 1996. Atlas 2000 starts now! *BSBI News* 71: 3.

Perring, F.H. and Walters, S.M. 1962. *Atlas of the British Flora.* London: Nelson.

Preston, C.D. and Croft, J.M. in press. *Aquatic plants in Britain and Ireland.* Colchester: Harley Books.

Rich, T.C.G. and Woodruff, E.R. 1990. *BSBI Monitoring Scheme 1987-1988.* Peterborough: Nature Conservancy Council.

Stewart, A., Pearman, D.A., and Preston, C.D. 1994. *Scarce Plants in Britain.* Peterborough: Joint Nature Conservancy Council.

Table 1. Characteristic vascular plant species of the eigth land classes in Britain The 50 most characteristic vascular plant species of each class are shown along with the preference index for each species and the frequency of the species in the 10-km squares of the class.

Class 15	Preference	Frequency
Phegopteris connectilis	0.55	61
Viola lutea	0.51	41
Crepis paludosa	0.49	70
Cryptogramma crispa	0.46	35
Pinguicula vulgaris	0.46	87
Huperzia selago	0.45	54
Empetrum nigrum	0.41	76
Eriophorum vaginatum	0.40	82
Oreopteris limbosperma	0.39	77
Trichophorum cespitosum	0.39	82
Trollius europaeus	0.38	48
Alchemilla glabra	0.38	74
Epilobium brunnescens	0.37	59
Narthecium ossifragum	0.37	88
Selaginella selaginoides	0.34	56
Gymnocarpium dryopteris	0.33	47
Rubus saxatilis	0.32	43
Rubus chamaemorus	0.32	31
Carex curta	0.32	62
Saxifraga hypnoides	0.32	30
Carex dioica	0.32	59
Cystopteris fragilis	0.32	54
Myosotis secunda	0.31	74
Drosera rotundifolia	0.31	86
Carex hostiana	0.31	76
Meum athamanticum	0.31	15
Asplenium trichomanes-ramosum	0.30	27
Saxifraga stellaris	0.28	33
Festuca vivipara	0.28	45
Geranium sylvaticum	0.27	43
Vaccinium vitis-idaea	0.27	48
Diphasiastrum alpinum	0.26	34
Euphrasia rostkoviana	0.26	19
Viola palustris	0.26	91
Lycopodium clavatum	0.25	36
Vaccinium oxycoccos	0.25	32
Galium sterneri	0.24	21
Carex pulicaris	0.24	89
Betula nana	0.23	14
Vaccinium myrtillus	0.23	95
Hymenophyllum wilsonii	0.23	35
Vicia orobus	0.23	17
Pedicularis palustris	0.23	73
Montia fontana	0.22	89
Galium boreale	0.22	32
Antennaria dioica	0.22	47
Parnassia palustris	0.22	50
Myrica gale	0.21	52
Saxifraga aizoides	0.21	29
Carex binervis	0.20	90

Class 16	Preference	Frequency
Festuca vivipara	1.65	79
Lobelia dortmanna	1.47	67
Thalictrum alpinum	1.39	49
Sedum rosea	1.37	60
Salix herbacea	1.36	48
Silene acaulis	1.28	36
Sparganium angustifolium	1.17	60
Isoetes lacustris	1.12	54
Oxyria digyna	1.11	41
Hymenophyllum wilsonii	1.10	58
Carex bigelowii	1.02	45
Drosera longifolia	1.01	54
Luzula spicata	1.01	29
Alchemilla alpina	1.00	46
Saussurea alpina	1.00	32
Saxifraga oppositifolia	0.99	36
Pinguicula lusitanica	0.96	48
Selaginella selaginoides	0.95	76
Saxifraga aizoides	0.95	48
Juncus trifidus	0.88	26
Antennaria dioica	0.87	70
Subularia aquatica	0.86	36
Huperzia selago	0.84	65
Saxifraga stellaris	0.83	46
Utricularia intermedia sens.lat.	0.81	39
Gnaphalium supinum	0.74	25
Vaccinium uliginosum	0.73	27
Juncus triglumis	0.73	24
Carex pauciflora	0.71	38
Schoenus nigricans	0.66	53
Rhynchospora alba	0.64	41
Listera cordata	0.64	52
Loiseleuria procumbens	0.63	22
Sibbaldia procumbens	0.63	21
Rubus saxatilis	0.62	53
Carex dioica	0.62	71
Diphasiastrum alpinum	0.61	44
Galium boreale	0.60	44
Cornus suecica	0.58	23
Littorella uniflora	0.57	76
Eleocharis quinqueflora	0.55	60
Persicaria vivipara	0.54	38
Epilobium anagallidifolium	0.54	26
Euphrasia scottica	0.53	21
Myrica gale	0.53	66
Gentianella campestris	0.53	47
Utricularia minor	0.53	40
Eleocharis multicaulis	0.51	55
Euphrasia foulaensis	0.51	18
Armeria maritima	0.51	73

Class 21	Preference	Frequency
Seseli libanotis	22.94	22
Frankenia laevis	17.97	56
Petrorhagia nanteuilii	17.32	11
Euonymus japonicus	17.32	11
Lathyrus japonicus	10.58	44
Crambe maritima	10.55	89
Crepis foetida	8.55	11
Oxalis latifolia	8.55	11
Parapholis incurva	7.78	56
Poa bulbosa	6.82	44
Carex divisa	5.68	56
Centaurium scilloides	5.63	11
Teucrium chamaedrys	5.63	11
Lactuca saligna	5.63	11
Oxalis exilis	4.79	11
Trifolium ornithopodioides	4.54	67
Vicia lutea	4.39	44
Mentha requienii	4.16	11
Trifolium suffocatum	4.00	33
Bupleurum tenuissimum	3.95	44
Hordeum marinum	3.87	44
Sarcocornia perennis	3.68	33
Polypogon viridis	3.68	11
Tamarix gallica	3.57	33
Wolffia arrhiza	3.47	22
Campanula poscharskyana	3.29	11
Vulpia ciliata	2.87	33
Trifolium squamosum	2.76	33
Disphyma crassifolium	2.70	11
Suaeda vera	2.69	22
Trifolium subterraneum	2.67	44
Lepidium ruderale	2.55	56
Glaucium flavum	2.49	44
Atriplex portulacoides	2.48	56
Senecio cineraria	2.48	11
Puccinellia rupestris	2.32	33
Silene otites	2.29	11
Carpobrotus edulis	2.22	22
Limonium vulgare	2.19	44
Parapholis strigosa	2.16	44
Althaea officinalis	1.96	33
Ranunculus sardous	1.96	44
Trifolium scabrum	1.92	44
Barbarea verna	1.81	33
Salicornia ramosissima	1.77	33
Petroselinum segetum	1.74	44
Limonium binervosum	1.73	11
Galeopsis angustifolia	1.65	56
Spiranthes spiralis	1.63	56
Lupinus arboreus	1.58	22

Class 22	Preference	Frequency
Ranunculus sceleratus	14.44	86
Hordeum murinum	14.40	84
Ballota nigra	13.73	80
Papaver rhoeas	13.30	90
Lemna trisulca	13.20	68
Tragopogon pratensis	12.76	91
Bryonia dioica	12.72	67
Juncus inflexus	12.64	91
Malva sylvestris	12.33	89
Anisantha sterilis	12.26	90
Aethusa cynapium	12.19	84
Armoracia rusticana	12.00	76
Lamium album	11.85	94
Scrophularia auriculata	11.76	81
Glyceria maxima	11.65	69
Convolvulus arvensis	11.19	90
Alisma plantago-aquatica	11.18	87
Acer campestre	11.07	78
Reseda luteola	11.06	73
Urtica urens	11.00	83
Epilobium hirsutum	10.98	95
Silene latifolia	10.98	92
Senecio squalidus	10.97	65
Salix alba	10.94	78
Senecio erucifolius	10.91	65
Salix fragilis	10.91	86
Carex otrubae	10.89	81
Potentilla reptans	10.77	94
Typha latifolia	10.74	83
Medicago lupulina	10.69	95
Avena fatua	10.65	60
Solanum dulcamara	10.60	91
Carex riparia	10.57	66
Euphorbia peplus	10.55	86
Medicago sativa	10.47	59
Agrimonia eupatoria	10.42	89
Apium nodiflorum	10.38	82
Carduus nutans	10.37	65
Pulicaria dysenterica	10.31	74
Tamus communis	10.30	76
Rumex conglomeratus	10.26	82
Chaerophyllum temulum	10.25	86
Matricaria recutita	10.25	66
Trisetum flavescens	10.23	80
Malva neglecta	10.22	55
Arum maculatum	10.15	86
Zannichellia palustris	10.14	60
Anagallis arvensis	10.06	88
Alliaria petiolata	10.04	90
Conium maculatum	10.02	80

Class 23	Preference	Frequency
Myrrhis odorata	0.42	62
Symphytum tuberosum	0.39	34
Alchemilla xanthochlora	0.33	53
Petasites albus	0.22	17
Stellaria nemorum	0.21	22
Alchemilla glabra	0.20	63
Rumex longifolius	0.19	21
Sambucus racemosa	0.19	16
Prunus padus	0.18	53
Claytonia sibirica	0.17	36
Viola lutea	0.16	30
Pyrola minor	0.15	20
Geranium sylvaticum	0.14	36
Campanula latifolia	0.14	42
Doronicum pardalianches	0.14	25
Trientalis europaea	0.14	27
Vaccinium myrtillus	0.13	86
Chrysosplenium alternifolium	0.13	26
Vaccinium oxycoccos	0.12	26
Carex curta	0.12	50
Goodyera repens	0.12	13
Corallorhiza trifida	0.12	8
Valeriana pyrenaica	0.11	10
Crepis paludosa	0.11	50
Ranunculus hederaceus	0.11	61
Meconopsis cambrica	0.11	46
Galeopsis speciosa	0.10	36
Equisetum sylvaticum	0.10	58
Eriophorum vaginatum	0.10	62
Dactylorhiza purpurella	0.10	38
Rosa mollis sens.str.	0.10	17
Rumex pseudoalpinus	0.10	8
Nardus stricta	0.10	85
Andromeda polifolia	0.10	13
Cardamine amara	0.10	44
Peucedanum ostruthium	0.10	6
Potentilla palustris	0.09	68
Empetrum nigrum	0.09	56
Persicaria bistorta	0.09	42
Callitriche hermaphroditica	0.09	20
Minuartia verna	0.08	10
Carex aquatilis	0.08	13
Geum rivale	0.08	69
Ribes alpinum	0.08	13
Salix pentandra	0.08	28
Sedum villosum	0.08	12
Juncus squarrosus	0.08	52
Montia fontana	0.08	75
Viola palustris	0.08	74
Luzula sylvatica	0.07	77

Class 24	Preference	Frequency
Lavatera arborea	1.61	47
Crithmum maritimum	1.56	39
Euphorbia portlandica	1.47	29
Rubia peregrina	1.46	35
Erodium maritimum	1.40	31
Agrostis curtisii	1.36	34
Spergularia rupicola	1.24	32
Linum bienne	1.04	34
Umbilicus rupestris	1.02	69
Viola lactea	1.02	27
Asplenium obovatum	1.00	24
Sibthorpia europaea	0.90	21
Beta vulgaris	0.90	48
Hypericum undulatum	0.89	16
Euphorbia paralias	0.89	27
Smyrnium olusatrum	0.89	53
Parentucellia viscosa	0.87	30
Melittis melissophyllum	0.86	21
Lotus subbiflorus	0.86	17
Chamaemelum nobile	0.85	34
Ranunculus parviflorus	0.84	42
Spiranthes spiralis	0.83	43
Orobanche hederae	0.83	26
Coronopus didymus	0.79	59
Catapodium marinum	0.76	34
Fumaria muralis	0.75	48
Epilobium lanceolatum	0.70	38
Arum italicum	0.70	29
Soleirolia soleirolii	0.67	31
Carpobrotus edulis	0.67	13
Centaurium pulchellum	0.66	35
Allium triquetrum	0.66	16
Polystichum setiferum	0.65	55
Iris foetidissima	0.63	43
Calystegia soldanella	0.63	27
Carduus tenuiflorus	0.62	36
Limonium procerum	0.62	12
Trifolium ornithopodioides	0.60	29
Geranium versicolor	0.59	16
Cuscuta epithymum	0.58	29
Isolepis cernua	0.57	19
Fumaria bastardii	0.56	33
Clinopodium ascendens	0.54	38
Centranthus ruber	0.53	65
Ulex gallii	0.53	56
Eryngium maritimum	0.52	24
Hypericum androsaemum	0.51	71
Ranunculus tripartitus	0.49	11
Erodium moschatum	0.49	22
Petasites fragrans	0.48	60

Class 25	Preference	Frequency
Viburnum lantana	2.45	84
Cirsium acaule	2.02	85
Bromopsis erecta	1.98	80
Polygala calcarea	1.94	39
Cephalanthera damasonium	1.84	39
Euphorbia amygdaloides	1.63	77
Rhamnus cathartica	1.61	81
Hippocrepis comosa	1.54	48
Onobrychis viciifolia	1.40	54
Cirsium eriophorum	1.39	44
Campanula trachelium	1.38	56
Galeopsis angustifolia	1.38	52
Sison amomum	1.34	72
Kickxia spuria	1.33	57
Asperula cynanchica	1.31	44
Crepis vesicaria	1.30	92
Pastinaca sativa	1.28	92
Euphorbia exigua	1.27	83
Impatiens capensis	1.27	37
Torilis arvensis	1.25	41
Orchis morio	1.23	82
Melilotus altissimus	1.23	69
Myosoton aquaticum	1.20	80
Campanula glomerata	1.18	46
Viola hirta	1.17	78
Alopecurus myosuroides	1.16	75
Clematis vitalba	1.16	94
Bryonia dioica	1.11	90
Thesium humifusum	1.07	25
Legousia hybrida	1.07	46
Euonymus europaeus	1.07	91
Carex strigosa	1.06	41
Chenopodium polyspermum	1.03	63
Buxus sempervirens	1.02	48
Valerianella dentata	1.02	51
Verbascum nigrum	1.00	46
Orobanche elatior	0.99	31
Orobanche minor	0.99	64
Cornus sanguinea	0.99	98
Viola reichenbachiana	0.98	79
Inula conyzae	0.98	64
Minuartia hybrida	0.97	34
Clinopodium acinos	0.97	46
Hordeum secalinum	0.97	73
Scandix pecten-veneris	0.96	65
Ranunculus arvensis	0.96	69
Lysimachia nummularia	0.95	93
Arctium lappa	0.95	65
Colchicum autumnale	0.95	28
Epipactis phyllanthes	0.94	23

Class 29	Preference	Frequency
Gladiolus illyricus	9.02	15
Galium constrictum	8.18	18
Leucojum aestivum	5.77	36
Myosurus minimus	5.38	67
Cyperus fuscus	4.98	12
Illecebrum verticillatum	4.74	24
Pulmonaria longifolia	4.44	24
Rhynchospora fusca	4.44	24
Ulex minor	4.38	64
Persicaria laxiflora	4.26	52
Elodea callitrichoides	4.05	15
Ludwigia palustris	3.94	12
Fallopia dumetorum	3.78	27
Crambe cordifolia	3.73	9
Cicendia filiformis	3.33	24
Mentha pulegium	3.26	36
Myriophyllum aquaticum	3.21	33
Chamaemelum nobile	3.15	58
Colutea arborescens	2.87	24
Impatiens capensis	2.83	52
Trifolium subterraneum	2.82	45
Robinia pseudoacacia	2.79	36
Euphorbia amygdaloides	2.71	94
Carex divisa	2.65	39
Misopates orontium	2.62	55
Oenanthe fluviatilis	2.60	45
Spiranthes aestivalis	2.55	3
Myrica cerifera	2.55	3
Cotoneaster congestus	2.55	3
Berberis buxifolia	2.55	3
Galega officinalis	2.52	36
Alisma lanceolatum	2.48	61
Helianthus decapetalus	2.43	9
Isatis tinctoria	2.43	9
Moenchia erecta	2.42	55
Quercus ilex	2.40	45
Chenopodium murale	2.39	36
Frankenia laevis	2.37	21
Tamarix gallica	2.30	27
Persicaria minor	2.28	45
Cuscuta europaea	2.19	24
Oenanthe pimpinelloides	2.15	45
Aster lanceolatus	2.12	15
Geranium purpureum	2.12	15
Carex montana	2.12	18
Geranium rotundifolium	2.11	39
Sison amomum	2.06	85
Lathyrus nissolia	2.04	61
Viola lactea	2.02	36
Ruscus aculeatus	2.02	64

Table 2 Presence of classes in countries, land form interpretation and potential natural vegetation

COUNTRIES

15	N-W GB, N-W Ireland, S Norway
16	N-W Scotland, Faroes, SW Norway
22	GB, Low Countries, NW Germany
23	SW Ireland and NE GB
24	S-W GB, N Holland, W Denmark, NW France, N-W Spain
25	S GB, Belgium, NE France, Central Germany, N/E Czech
29	W & Northern France, S GB, E Germany

LAND FORMS

15	Oceanic exposed, medium/low atlantic mountains
16	N Atlantic islands, medium /low altitude
22	North sea lowland margins
23	Atlantic coastal plains and low mountains
24	Lusitanean/oceanic coast/low hills
25	Plains & undulating low hills
29	Atlantic lowland plains

POTENTIAL VEGETATION

15	Blanket bog, heathlands, birch and acid oak
16	Blanket bog, willow/birch scrub, dwarf shrub heath
22	Acid oak, oak/conifer mesotrphic, coastal, polders
23	Acid oak, beech
24	Acid oak, beech, polders
25	Beech, oak and mesotrphic oak/conifers
29	Acid oak, oak/conifer thermophilic, boreal/conifer mesotrophic

10 Assessing Environmental Impacts in the ECOFACT Project

R Haines-Young, Department of Geography
University of Nottingham, Nottingham, NG7 2RD

10.1 Background

A methodology for environmental policy appraisal has been outlined in *Policy Appraisal and the Environment* (Department of the Environment, 1992). The approach uses a matrix concept, in which an 'impacts table' is constructed. The axes of the matrix are the 'actions' which characterise a proposal and a set of 'environmental receptors' which are potentially affected by the scheme. Entries in the cells of the matrix flag any environmental costs or benefits, or whether the effects are neutral or unknown.

This impacts methodology was used as the basis the Countryside Impacts Table project completed for DoE in 1993 (Haines-Young et al. 1993). The project constructed an impact matrix by access to a computerised database of information about the way in which activities associated with farming affects different components of the countryside. All of the information was derived from a review of the relevant scientific literature. The impacts matrix could be interrogated by the user to display the information about the mechanisms which link actions to environmental receptors. The axes of the matrices constructed by the system were the farm enterprise types and the different farming activities or practices associated with them (actions), in combination with the various landscape features and their attributes (receptors). When the system indicated an interaction between some action and a component of the landscape, the full bibliographic reference of the information used to support this conclusion could be accessed by the user. The structure of the system is shown in Figure 1.

The system allowed the impacts of different farming activities to be explored at different levels of detail. The 'primary' matrix provided the most general representation. Here, the axes were the major farm enterprises (e.g. arable, stock, etc.) and the different features which make up the countryside (improved land, semi-natural land, boundaries, etc.). The entries in the matrix were the number of database records contained in the database which described the relationship between the combination of factors.

A more detailed level of detailed level of information was provided to the user by selecting a particular cell in the primary matrix which showed a non-zero value. The system then produced a 'secondary' matrix in which the axes are the particular activities or practices associated with the farm enterprise selected and the attributes of the landscape feature for which information is sought (Figure 1). Once again the numbers shown in the body of the matrix were the number of records found for that combination of factors. For any cell in the secondary matrix which had a non-zero value, a detailed report describing the mechanisms underlying the effect of the particular activity on the attribute of the landscape feature could be generated by the user. The report provided the user with information about the nature of the impact, whether it was considered reversible, and the significasnce of the impact on the environmental receptor. For example, if the receptor was an organism, the user was informed if the plant or animal had been scheduled.

10.2 Future work within ECOFACT

The impacts table approach described above will be developed further to provide information about countryside impacts that result from the ECOFACT project. The original impacts table system was developed using the spreadsheet Excel 3.0. This software which has now been superseded by EXCEL 5.0, and the impacts table system needs to be upgraded to run with this new version. EXCEL provides more advanced reporting facilities than were originally available, and these can be exploited to report the key conclusions about the impact of farming on the countryside that are relevant to the ECOFACT project.

This work package within the ECOFACT project will therefore review and update the database describing the impact of farming enterprises and activities on the major elements of the countryside, and re-engineer the reporting system in EXCEL 5.0 to give output for the specific land cover categories used in CS90. The system will allow users to specify the broad landscape type of interest (e.g. arable lowlands, marginal uplands, etc.), and the type of target feature for which information is required (e.g. birds, mammals, plants). Where appropriate the system will display graphical or tabular information that would allow the used to better interpret and predict the effect of land cover change on the countryside. The system would be available as a windows utility which could be accessed via Microsoft Office (which includes EXCEL), alongside systems such as the countryside information system.

References

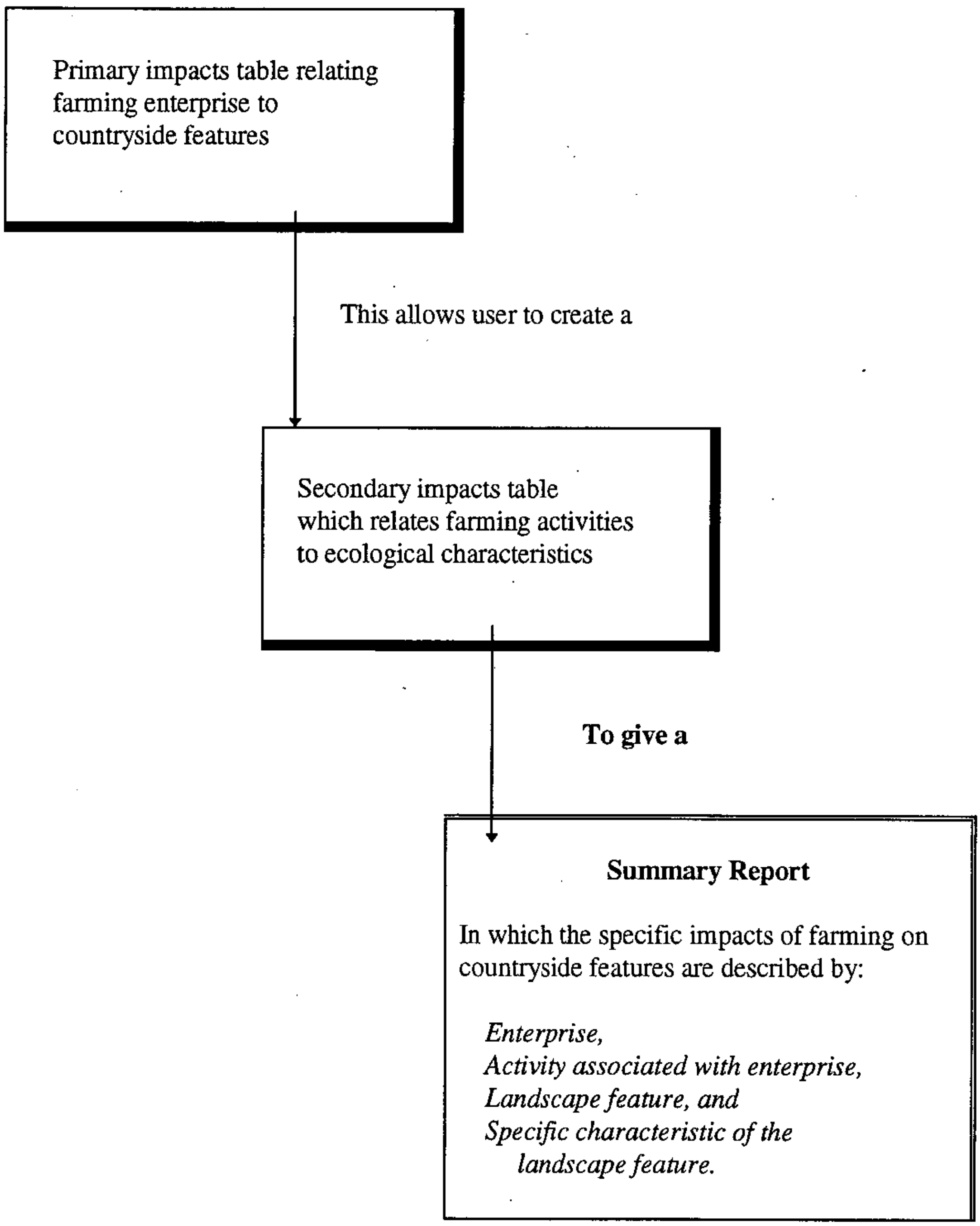
Department of the Environment (1992) *Policy Appraisal and the Environment.* HMSO, London

Haines-Young, R.H. Watkins, C, and Lavers, C.P (1993) *Countryside Impacts Table*, Final Report, Department of the Environment, June 1993.

Figure 1: A computer-based system for summarising the environmental effects of farming on the countryside

Example:

Given a question such as *'What is the effect of arable farming on the ecology of ditches?'* the system provides access to scientific literature via:



ITE has six Research Stations throughout Britain, which allows the efficient use of resources for regional studies and provides an understanding of local ecological and land use characteristics. The Institute's administrative headquarters is at Monks Wood.

ITE sites

Monks Wood
(Admin HQ)
Abbots Ripton
HUNTINGDON PE17 2LS
Telephone 01487 773381-8
Fax 01487 773467
Email MONKSWOOD@ITE.AC.UK

Merlewood Research Station
GRANGE-OVER-SANDS
Cumbria LA11 6JU
Telephone 015395 32264
Fax 015395 34705
Email MERLEWOOD@ITE.AC.UK

Edinburgh Research Station
Bush Estate
PENICUIK
Midlothian EH26 0QB
Telephone 0131 445 4343
Fax 0131 445 3943
Email BUSH@ITE.AC.UK

Furzebrook Research Station
WAREHAM
Dorset BH20 5AS
Telephone 01929 551518-9, 551491
Fax 01929 551087
Email FURZEBROOK@ITE.AC.UK

Banchory Research Station
Hill of Brathens
Glassel, BANCHORY
Kincardineshire AB31 4BY
Telephone 01330 823434
Fax 01330 823303
Email BANCHORY@ITE.AC.UK

Bangor Research Unit
University of Wales, Bangor
Deiniol Road
BANGOR, Gwynedd LL57 2UP
Telephone 01248 370045
Fax 01248 355365
Email BANGOR@ITE.AC.UK

Details about the Institute are available on the Internet via the World Wide Web (http:/www.nmw.ac.uk/ite)

Natural Environment Research Council