Ecology of Vegetation Change in Upland Landscapes

Part1: General Synthesis

PREFACE

The work reported in this Occasional Paper was carried out by the Institute of Terrestrial Ecology (Natural Environment Research Council) under contract to the Department of the Environment as DOE/NERC contract DGR/483/23. The Natural Environment Research Council is grateful to the Department of the Environment for their permission to publish the contract report in this format. Part I is a general synthesis of the work and its results, Part II gives individual accounts of each of the 12 study areas.

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Errata

p.v, 12, line 8, delete 'per', insert 'for'.
p.xi, 21, line 13 delete 'areas are discussed' insert 'main sites'.
p.75, 4.44, lines 9-10, insert between '1914 and 'then rose' ... 'rose slightly between 1915-20, fell again until 1940, ...'.
p.192, line 1, should read '5000 m^2'.

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SUMMARY AND CONCLUSIONS - PART I: GENERAL SYNTHESIS

Chapter 1: INTRODUCTION

Background

1 Changes in the landscapes of the uplands of England and Wales may result from either major alterations in land-use such as the introduction of forestry or comprehensive agricultural improvement, or more gradually from modification of traditional management methods. The vegetation that clothes the uplands, determining much of their visual character, is subject to the influence of such gradual changes. The Department of the Environment (DOE) commissioned an investigation of 12 study areas to determine their main classes of upland vegetation, the factors influencing gradual change, and their possible future pattern of vegetation. The work has been carried out at the same time as the Upland Landscapes Study (ULS). That study, by consultants under contract to the Countryside Commission, had the aim of determining past, present and future trends in agriculture in the same 12 areas. The chosen areas were parishes listed as meeting the European Economic Community (EEC) definition of 'less-favoured areas' of 'mountain and hill farming'. They cover 746 km2 and include about 3% of the land above 244 m in England and Wales.

Approach

2 Research was concentrated on widely distributed types of vegetation in the range from agricultural grasslands to heath and moorland. In addition, a limited assessment was made of woodland types in the study areas. Field recording was used as a basis for subsequent classification and description of the vegetation; map analysis provided data to define variation in the physical environment in the study areas and to classify land types; historical documents showed the nature and distribution of past land-use changes. Results from these approaches have been used to show the influence of environmental and land-use factors on vegetation in the study areas. Experimental evidence on the courses and rates of gradual vegetation change is available for a small number of locations outside the study areas at which management has been intentionally controlled. Visits to these gave some information on trends and

rates of change. Predictions of vegetation change in the pasture and heath vegetation of the study areas as a result of intensified or declining agriculture can only be generalised because of the lack of detailed environmental data and of knowledge of present and future management intentions for each individual site. Such standardised predictions based either on ecological principles of possible change at recorded sites, or alternatively on assumptions of the land-use potential of land types, give assessments of the types and maximum scale of change likely in different circumstances. A synthesis of results from all study areas as a group is presented in Part I of this report, while Part II considers the environment, history, vegetation and potential future vegetation of each area individually.

Chapter 2: STUDY AREAS IN THEIR GEOGRAPHICAL CONTEXT

3 The administrative parishes selected by ULS and the Countryside Commission for study were Alwinton in the Cheviot region, Lunedale in the Northern Pennines, Shap and Shap Rural in the Lake District, Bransdale in the North York Moors, Heptonstall in the Southern Pennines, Monyash and Hartington Middle Quarter* in the Peak District, Llanfachreth in Snowdonia, Ysbyty Ystwyth in the Cambrian Mountains, Glascwm in the Radnor-Clun Forests, Ystradgynlais Higher and Glyntawe in the Brecon Mountains, Lynton in Exmoor, and Widecombe in the Moor and Buckland in the Moor in the Dartmoor region.

4 The extent to which the study areas are a representative sample of the total upland in England and Wales has been investigated through their physiographic, climatic, geological and soil characteristics analysed from map data, and from their geographic relationship to previously identified national upland land classes. They are found to include the main range of national land classes in the uplands of England and Wales, although the limited sectors of extreme montane habitats are poorly represented and it is only in Widecombe and Buckland, and to a lesser extent in Lynton, that there is substantial representation of the relatively low altitude and gentle relief land of the 'marginal' half of the national upland classes. These limitations are not critical because the study areas sample extensively the upland and hill sectors in which the widest range of potential options for vegetation change are most likely to be found.

5 More detailed consideration of study area characteristics shows that most typical upland rock and soil types are strongly represented. The climatic conditions covered run from relatively cold and dry at Alwinton, and cold and wet in Lunedale and Shap, through to a relatively warm, dry climate at Glascwm and warm, wet

*ULS considered Monyash only. ITE added the Hartington parish.

conditions at Llanfachreth and Ystradgynlais. These environmental factors are primary features which substantially determine the patterns of vegetation and of land-use in the study areas, recognising that vegetation and land-use interact with each other, and that local land-use has been, and is, also strongly influenced by social and economic factors. The natural environmental characteristics of the study areas are reflected in the range of grades of land into which they are classified in the Agricultural Land Classification scheme of the Ministry of Agriculture. The lowest grade (5) dominates Lunedale, Alwinton, Ysbyty Ystwyth and Ystradgynlais, while there is a notable proportion of grades 4 and 3 in Monyash, Glascwm, Lynton and Widecombe. The current intensity of agricultural use in the study areas, shown by the extents of rough grazing, tillage and improved grassland, as determined by the Upland Landscapes Study, is closely correlated with mapped Agricultural Land Class. A wide range of typical upland land-uses is represented in the study areas.

6 The extent to which the study areas are statistically representative of the wider geographic regions in which they occur has not been investigated in detail. However, comparison shows that 7 of the areas have average values of environmental and land-use characteristics that are similar to the averages of these for their regions. Of the remaining 5, Alwinton, Lunedale and Ysbyty Ystwyth tend to have higher altitudes and steeper slopes with associated less intensive agricultural use than their respective regions as a whole, while Monyash and Widecombe have less high ground, gentler slopes and more intensive agricultural use than are general for their regions.

Chapter 3: VEGETATION

7 Work concentrated on the widely distributed grasslands and heaths, which are the more important vegetation categories in their impact on landscape. To provide the necessary detail of the composition of this vegetation, field recording was carried out at a series of sites, using data for 5 000 m2 quadrats. 70 or more 'main sites' were examined in each area in 1977 or 1978, giving a total of 938 moorland and grassland vegetation data sets, with additional but limited information on site and soil characteristics at each site. These data have provided the opportunity for a new classification of upland vegetation extending through from cultivated improved grasslands to little-modified moorland.

8 The main vegetation groups produced by a classification using the method of Indicator Species Analysis can be attributed to gradients of decreasing intensity of management and increasing environmental severity. The grassland groups are a 'farmland' element in the vegetation, the heath groups a 'moorland' element. IMPROVED PASTURES, present at 27% of the recorded sites, were particularly common in Monyash, Glascwm, Lynton and Widecombe, with herb-rich Lolium grassland the dominant class of the four in this group. ROUGH PASTURES (17% of the recorded sites) are present on more acid and often poorer drained soils than those of the improved pastures. The most widespread of the 4 classes (Festuca/Agrostis grassland) occurs in all study areas except Lynton. GRASSY HEATHS (23% of the recorded sites) are dominated by coarse grasses (Nardus, Deschampsia, Molinia) but have a prominent secondary shrubby heath element. Two of the classes were quite uniformly distributed, but the third, Festuca/Nardus/Vaccinium heath, showed a distinct northern emphasis among the recorded sites. SHRUBBY HEATHS, characteristic of the least fertile soils and lowest intensity of agricultural management, and comprising 5 classes, occupy 33% of the recorded sites. Eriophorum/Calluna heaths were widespread, whilst the drier Calluna heaths occurred mainly in the south-west.

9 The range of vegetation identified at the main sites reflected environmental and management variation in the study areas, with Monyash showing the lowest diversity in terms of number of vegetation classes present, while in Llanfachreth and Ystradgynlais all 16 vegetation classes were recorded. The moorland element of the vegetation, and in particular the shrubby heaths, was most strong in Lunedale, associated with land managed as grouse moors. It was also notably important in Ysbyty Ystwyth, in Bransdale which is influenced by landscape conservation and shooting interests, and in Heptonstall where agriculture is limited by water catchment requirements and management for grouse shooting again promotes shrubby heaths. Shap shows a contrast between grassy and shrubby heaths on the volcanic rocks in the west, and improved pastures on the eastern area of limestone. A high proportion of pasture vegetation occurs in Glascwm, Lynton and Widecombe, while Monyash is dominated by improved pastures only.

10 Deciduous woodlands were calculated by the Upland Landscapes Study to occupy between less than 1% (Alwinton) and almost 7% (Lynton) of each study area. The woodlands examined can be considered in 3 categories: lowland basic woodlands, common in Monyash; acid lowland woodlands, well represented in Heptonstall; and acid upland woodlands, prominent in Alwinton, Lunedale, Shap, Bransdale and Llanfachreth. The wide diversity of main site vegetation in Llanfachreth is also followed in its woodlands where 7 of 11 possible classes are present. Although concern is frequently expressed over the apparent lack of regeneration in small upland

deciduous woodlands, tree seedlings or saplings were recorded in woodland sites in 11 of the study areas. They were particularly frequent in Lynton and, to a lesser extent, in Llanfachreth and Widecombe, but no significant regeneration was observed in Shap. Brief recording of roadside verge vegetation, which beside being an important visual element in the immediate landscape along access roads can act as a reservoir of potential colonising plant species, showed that only those verges containing trees had a strong lowland element amongst their associated species.

Chapter 4: CONTROLS ON VEGETATION

Approach

11 The factors which control the distribution of vegetation, and which decide whether the balance of plant species is stable or is changing, are those of land character and of land-use and management. Three aspects were examined: i. variation in land character in the study areas was determined by analysis of existing maps; ii. historical changes in land-use and management were identified from documents, maps and air photographs; and iii. current management practices were reviewed. Land character sets limits on the potential range of vegetation; past land-use has created the general pattern of vegetation within these limits; and this pattern is maintained or modified by current management practices.

Land character

12 Data extracted from Ordnance Survey and climatic maps cover a range of physiographic (altitude, slope, aspect, water), topographic (settlements, roads and footpaths, field boundaries) and climatic (rainfall) features. This information was initially recorded quantitatively for 0.5 x 0.5 km grid squares covering the study areas. The distribution of individual characteristics can be displayed on diagramatic maps from computer-stored data, and average land statistics per study areas can be calculated. From an edited list of these quantitative data, Indicator Species Analysis was again used as a classification method in order to identify the main aspects of land variation and to simplify these into a classification of 7 land types in 3 land groups. The HILL land group covers mainly the altitude range between 428 and 610 m. Within this group, 3 land types with different combinations of slope and relief are distinguished. The UPLAND group is of moderate altitude, mainly between 245 and 335 m, and also contains 3 land types distinguished by slope and relief. UPLAND MARGIN consists of a single land type, with the lowest dominant altitude, mainly

122-244 m, of moderate relief and dominantly moderate slopes. The frequency of land types in the study areas shows Lunedale and Alwinton to contain most hill land, followed by Shap, Ysbyty Ystwyth and Ystradgynlais, with the remaining areas being dominated by upland or upland margin land groups.

Land-use history

13 Interaction of environmental and human factors has determined the character of present day vegetation. Early man exploited the natural resources of the uplands so intensively that he destroyed most natural woodland cover and accelerated its replacement by open communities of heath and moor. The structure and species composition of those communities reflected trends in both the numbers and types of grazing animal, and such practices as burning. In addition to these early and long-lasting gradual changes arising out of pastoral use of the uplands which have created what is now perceived as the traditional upland character, there have been phases of relatively dramatic local change in plant communities, particularly in the last 100 years or so. These have been caused by the direct and indirect effects of reservoir construction, quarrying and industrial development, and, more extensively, by afforestation and ploughing. Greater availability of documentary evidence, particularly in the form of land-use statistics and in maps, makes it possible to study these changes in some detail. Analysis of statistics available in the Annual Returns for agriculture since 1900 gives an overall impression of general stability in agricultural land-use in the areas as a group but there is marked variation between areas. In general, the area of tillage and the numbers of sheep and cattle are similar now to what they were in 1900. The numbers of farm holdings and of farm workers show general declines between 1925-1940 and 1950-1965, but there is again very considerable variation between areas, as there is also in the average size of the agricultural holdings.

14 In terms of past land-use and management, the uplands are of course far from being a homogeneous unit. Large scale Ordnance Survey maps in successive editions, and air photographs of the study areas, were used to distinguish sectors for which there is no evidence of previous disturbance (MOORLAND CORE) from those areas which have at different periods been both moorland and ploughed or otherwise 'improved' (MOORLAND FRINGE). For the study areas as a group, moorland fringe covers 11% of the total area, of which 30% represents land now reverted from cultivated grassland to moorland plant communities. Of the remainder about one quarter has been reclaimed for agriculture and three quarters converted to forestry. About a third of the reverted fringe is covered by communities that have been evolving since before 1850, and over a third has come out of more intensive agricultural use since about 1940.

Land management

15 A summary of contemporary management practices emphasises the general importance of burning and grazing as factors influencing vegetation in the study areas. Evidence of burning as a management tool was recorded on sites in all areas with heath vegetation except Ysbyty Ystwyth. 72 and 23% of all shrubby heath and grassy heath sites respectively showed evidence of burning. Sheep and cattle influence upland vegetation through trampling, selective grazing and nutrient cycling via dung and urine, and thus have complex effects on vegetation. Changes in stock type as well as species or numbers can alter the effects of grazing. For example, the decline in the numbers of older wether sheep on the hills this century because of a preference for lamb rather than mutton has probably resulted in reduced grazing of coarser, less palatable vegetation. Drainage, and the application of lime, fertilisers and herbicides not only modifies vegetation in the short term, but may have residual effects for at least decades through alteration of soil acidity and nutrient status.

Chapter 5: POTENTIAL FOR VEGETATION CHANGE

Approach

16 Having defined the main classes of vegetation in the study areas, and described the land characteristics, land-use history and management factors which influence the pattern of vegetation and its potential for change, the various pieces of information are combined to consider what are possible and likely gradual changes in vegetation between the recognised classes. Several strands of evidence are listed below, none of them definitive, but each providing insights into the rate and direction of vegetation change.

i. Associations between vegetation and land characteristics in the study areas indicate the classes of vegetation which are now found in particular environments, and thus suggest the potential for change from one vegetation class to another in such environments.

ii. General knowledge of the principles of the ecology of key plant species in upland vegetation classes permits a summary of how they are likely to respond to a particular management factors.

iii. Controlled management experiments are the only direct *method* of determining vegetation change. Results from the available limited number of long-term experiments, related to particular vegetation classes, can give some information on actual rates of change.

iv. Historical evidence allows sectors in the study areas to be identified on which management changed during a known period. Examination of sites within these dated sectors provides further evidence of rates and directions of vegetation change.

Vegetation and land

17 The associations between vegetation classes and land characteristics were examined in some detail because they show the range of conditions under which particular types of vegetation now occur, and by inference the range of potential vegetation with a high probability of occurrence under particular environmental conditions. The presence of different vegetation classes in the same land type, though partly related to other environmental factors such as geology, is in part attributable to the results of management practices. Such classes may often therefore be interchangeable through management. The frequency of vegetation classes in the land types showed that hill land types contained a restricted range of vegetation, mainly grassy and shrubby heaths with some rough pastures. Upland land types have a greater range of vegetation with fairly distinct patterns of distribution. Upland margin land contains the full spectrum of vegetation classes but has improved pastures dominant with only a limited extent of shrubby heaths. Variation between study areas in the classes of vegetation occurring in a land type results from the effects of different techniques and intensities of land management. Measurement, mainly from maps, of land characteristics at the recorded sites enables associations between these characteristics and vegetation classes to be investigated. The results support the relationships determined from the association between vegetation and the grid square classification of land types, and provide an alternative means of assessing vegetation options at a site. Additional limited observations of soil characteristics show the importance of soil acidity in controlling the occurrence of the vegetation groups and classes. The association tables presented can be used to indicate the range of vegetation which can occur with high probability at a particular site and interpret possible options at that site. This application is considered through a hypothetical example.

Vegetation and management

18 Within the study areas no detailed investigation was possible of soil characteristics or of the specific management, eg grazing intensities, applied now or recently to individual recorded sites. However, literature and experience have been used to tabulate the general response of individual species, and of the communities of species which comprise the vegetation classes, to the gradual changes in management outlined in Chapter 4, particularly burning and grazing (Tables 5-11, 5-12). It is especially important to determine the response of species within a plant community because it is often the response to change of a few individuals of a few species, present initially as minor components, which can determine its future composition. This is emphasised in the record of vegetation change resulting from controlled management trials in Snowdonia, where, after exclusion of sheep some Nardus grasslands changed to shrubby heaths in 10 years while others, because of the absence of dwarf shrub species in the original swards, remained as grasslands but dominated by Molinia. Experimental management sites visited outside the study areas, at Lephinmore and Redesdale Experimental Farms, and at Moor House and Snowdon National Nature Reserves, showed that increased grazing pressures can change Calluna-dominated shrubby heaths to grassy heaths, and Molinia-dominated grassy heaths to rough pastures (Agrostis/Juncus and Festuca/Juncus grasslands) in about 10 years, the latter change also typically involving some surface treatment. Exclusion of grazing from rough pastures and grassy heaths often produced a marked change in species composition in 10 years, but this was apparently followed then by only a slow succession towards the ultimate alternatives of shrubby heath or possibly woodland, depending on the location of the site and the nature of its surrounding vegetation.

19 Historical evidence has been used to identify sectors in the study areas in which intensive agriculture, probably at the time supporting improved pasture vegetation, was abandoned at various times in the past, allowing reversion to moorland vegetation. Analysis of vegetation data from 124 sites in such sectors indicated that within 40 years rough pastures were present on 40% of the sites, grassy heaths on 40% and shrubby heaths on 20%. These proportions appear to remain generally stable for about a further 40 years, after which, through the period 80 to 130 years after reversion, half of the rough pastures have developed into shrubby heaths. The trend in reversion is ultimately towards the local type of moorland vegetation. However, even more than a century after intensive agricultural use ceased, the proportions of vegetation groups on reverted sites do not match those of the moorland core which has not been modified at least during the past 200 years or so, and which may never have been improved. It is not certain that

the improved sites were initially like the present moorland, but assuming this to be so, their very slow rate of reversion can be explained by continued pressure on them of selective grazing by domestic stock even after intensive pasture management stopped. Heavy grazing favours the more rapidly growing finer grass species by sustaining pressure on coarser species that might otherwise spread, and maintains rapid nutrient cycling and a higher nutrient status in the surface soil, while the residual effects of applications of lime and fertilisers retard the naturally slow process of increasing soil acidity which is necessary for succession to grassy and shrubby heaths.

Predictions of change at main sites

20 Evidence collected during the study has been integrated into an assessment of possible trends and rates of change within and between the vegetation groups. If the pattern of vegetation change over the past 150 years is maintained, then transfers between moorland and farmland are likely to be concentrated in approximately 10% of the study areas which comprise the moorland fringe. However, future change may not be so confined, and broad assessments are therefore given of the degree of vegetation change that would ensue if the principles of gradual change were applied in conditions of agricultural intensification or decline to levels involving about a 50% increase or fall in stock numbers. There are clearly reservations about assessing the possible outcome of gradual change in an area by treating all sites in a uniform way, and others which arise from the uncertain importance of gradual as against major direct vegetation change in modifying upland vegetation. With these reservations appreciated, overall predictions of vegetation change through gradual response to management are summarised from the individual area accounts that form Part II of this report. The overall short- to medium-term (10-20 years) landscape impact of intensified agriculture would be greater than that of a declining agriculture. From the predictions based on general ecological principles, in an intensified agriculture situation there would be a 60% increase in the number of sites that are improved pastures, a 40% increase in the sites that are rough pastures, an almost stable proportion of grassy heaths, and a 65% fall in the proportion of shrubby heath sites. If agriculture were to go into a prolonged decline, then it is predicted that improved pasture sites would fall by 25%, rough pasture sites by 40% and grassy heath sites by 45%, while shrubby heath sites are predicted as increasing by 70%. In an intensified agriculture situation, absolute increases of improved pastures could be highest in Alwinton and Llanfachreth. Shrubby heaths would only remain prominent constituents of the vegetation in Alwinton, Lunedale, Heptonstall and Ysbyty Ystwyth, particularly Lunedale. In

a declining agriculture situation high relative falls in pasture vegetation could occur in Alwinton, Lunedale, Bransdale, Llanfachreth, Ysbyty Ystwyth and Ystradgynlais, while shrubby heaths would increase relatively sharply in all areas except Lunedale, Heptonstall and Widecombe.

Predictions of change from land types

21 Finally, in order to compare the predictions of potential gradual change based on uniform treatment of site data against the results suggested from major alterations of land-use in the study areas, the possible effects are discussed of assumed maximum expansions of agriculture or of forestry. These alternative predictions are calculated from the known extent of land types in the study areas, and assumptions of the frequency of vegetation groups in the land types in the agriculture expansion hypothesis, and of land-use proportions in the land types in the forestry expansion hypothesis. The agriculture expansion predictions result in vegetation group changes that are of a similar order to those determined from standard ecological principles of change applied to individual areas are discussed. In considering a forestry expansion option the extent of land suitable for agriculture, for forestry, and remaining as unplantable hill, is respectively calculated as potentially 33%, 37% and 30% of the 12 areas combined. Present farmland and woodland (including planted forest) is given from ULS data as comprising 21 and 10% respectively of these areas. The theoretical scope for change is obviously great, though such assessments omit local land factors and all social and economic considerations. Accepting these limitations, the prediction from this assessment is that Monyash, Glascwm and Lynton would remain primarily agricultural; Bransdale, Heptonstall, Llanfachreth and Widecombe would have approximately equal areas devoted to agriculture and forestry; Alwinton, Shap and Ystradgynlais would have forestry as their most prominent land-use, while only Lunedale and Ysbyty Ystwyth would remain with substantial areas of unplanted moorland hill.

Conclusion

22 These predictions of change remain untested speculations. The site data recorded in 1977, 1978 and 1979 at almost 1 100 sites in the study areas can be used as a baseline for monitoring future change. Monitoring observations need to be supplemented by experimental management of selected sites within and outside the study areas as appropriate. Only in these ways can a more confident understanding be given of whether the predictions made here are being met, or whether other factors, and non-gradual courses of change, become of

overriding importance in the modification of the present vegetation as an element in upland landscape change. It is particularly significant to upland landscapes as a recreational and wildlife amenity that shrubby heath moorland vegetation can be lost, even though 'gradual' change, in only a few years of altered management if this involves any degree of cultivation and fertiliser application, but may not be regained in its previous form in centuries when intensive use is abandoned, at least through natural trends and under the historic forms of grazing management.

1 INTRODUCTION

BACKGROUND AND OBJECTIVES

1.1 Change in the British countryside has become a subject of increasing discussion and concern. In New Agricultural Landscapes the Countryside Commission (CC 1974) considered the impact of contemporary agriculture on the visual character and wildlife of lowland England, and presented 'fresh and deeply disturbing facts about the nature and scale of change taking place in the appearance of much of the English countryside'. Recent changes in the intensively farmed lowlands of Britain, though conspicuous, affect mainly the detail of areas already dominated by modern agriculture. Changes in land-use are also altering landscapes and affecting wildlife in upland Britain. In upland areas where past agricultural use has been less intensive the effects of different methods of farming can be more widespread, transforming the complete character of the uplands, rather than simply amending the detail in an otherwise essentially unchanged picture.

1.2 Because upland character and history vary widely in Britain, the nature and scale of past and contemporary landscape changes are not uniform across the country. Most changes are immediate in their impact, as when they result from major agricultural reclamation or afforestation schemes. Additionally, changes that are more gradual, such as are brought about by limited modifications of traditional management and use, may be effective in altering landscape character over a longer term.

1.3 A desk study, Upland Land Use in England and Wales (ITE 1978), outlined the general character and main land uses of the uplands, indicating ways in which land-use is likely to change and the effects such changes may have on landscapes and vegetation. Following this work, the Department of the Environment (DOE) considered that more detailed information was required about the upland landscapes of England and Wales, the factors which control their character and use, and the possible courses and rates of gradual changes in their appearance, with particular reference to vegetation. In consultation with the Countryside Commission (CC) 2 projects were initiated, the Upland Landscapes Study and this work, Ecology of Vegetation Change in Upland Landscapes.

1.4 Consultants were engaged by CC to carry out the Upland Landscapes Study (ULS) in 12 areas chosen to sample the geographic range of the uplands of England and Wales, from Northumberland in the north-east to Devon in the south-west. The objectives of ULS were to assess the present landscape character of the study areas; to determine the attitudes of farming and land-holding interests to their future use; and to predict, from these attitudes and from wider trends, the likely nature and scale of land-use changes that could affect the visual character of the study areas.

1.5 Because semi-natural vegetation is a prominent element in upland landscapes and because the scale and types of gradual changes in vegetation were less obvious than those resulting from abrupt modifications of land-use, the nature and rates of such changes were considered by DOE to require particular study. The Institute of Terrestrial Ecology (ITE) was commissioned by DOE to carry out studies based on the areas chosen for ULS, with the objectives quoted below:

a. to identify and describe the main vegetation categories in the study areas;

b. to characterise the environmental factors affecting vegetation;

c. to define the regional and national context of the study areas;

d. to determine the historical changes in land use and their effects on the vegetation;

e. to relate vegetation and land use to environmental factors;

f. to define alternative management practices for the vegetation;

g. to identify likely future vegetation patterns and options.

It is the results of this work by ITE under contract to DOE that are reported here.

THE STUDY AREAS

1.6 For their study areas, ULS chose administrative parishes rather than the alternative of using statistically distributed areas of standard size to sample different regions, because agricultural and other statistics were available on a parish basis. The parishes were selected on 2 criteria. They were geographically spread to sample 12 upland blocks based on the 18 main upland geographic regions previously identified by ITE in reports to DOE (2.3). They also had to be among those listed by the European Economic Community (EEC) as falling wholly within 'less-favoured areas' with 'mountain and hill farming' (EEC 1975). In each upland block, ULS selected at random one parish or, in some cases, 2 adjacent parishes from the listed parishes in that block. The initial random selection was not always accepted because of such considerations as the number of farms in a parish, the location of the parish in relation to a National Park, or a previous history of parish use for questionnaire surveys. In such cases a further random selection was made of an alternative parish in the upland block.

1.7 The study areas chosen for ULS are, with one exception, those also used in the ITE study (Table 1-1). The exception is Monyash and Hartington Middle Quarter in the Peak District. ULS studied only Monyash, but this parish is too small on its own in relation to the others to have been suitable for the vegetation work, and an adjacent parish wholly within the EEC 'less-favoured areas' was combined with it in the ITE study. Figure 1-1 shows the location of the study areas listed in Table 1-1 in relation to the main upland geographic regions (see 2.3) of England and Wales, and Figure 1-2 their location in relation to the limits of the EEC 'less-favoured areas'.

1.8 To appreciate the size of sample of the uplands that the study areas represent, 330 hill and upland parishes within England and Wales fall wholly within the EEC 'less-favoured areas', of which the 15 in the sample are thus, in numerical terms, some 4.5%. In extent, the study areas cover 746 km^2, 640 km^2 of which are above 244 m and 227 km^2 above 427 m. Within the total area of England and Wales (151 141 km^2) the amounts of land above 244 m and 427 m have been determined as 19 900 km^2 and 4 700 km^2 respectively. The study areas therefore cover 3.2% of the land above 244 m and 4.8% of that above 427 m, so that the data to be discussed are drawn from about one twenty-fifth of the uplands of England and Wales.

STUDY PLAN AND REPORT PRESENTATION

1.9 The main lines of the ITE approach are now briefly described in relation to the objectives quoted in 1.5. The chapters which will discuss each aspect in more detail are indicated.

1.10 So that the study areas may be appreciated in context relative to each other and, so far as possible, to the uplands of England and Wales regionally and nationally, their land characteristics are compared in Chapter 2 (Objective c).

1.11 Vegetation data were collected from about one thousand sites mainly covering widely distributed vegetation types in the range between agricultural grassland and heathy moorland. These data have been used to produce a classification that forms a framework for discussion, interpretation and future use (Chapter 3; Objective a). Limited woodland vegetation data were also recorded.

TABLE 1-1 THE STUDY AREAS - LOCATION AND SIZE

Study Area[1]	Upland Geographic Region	County	National Park (N P)	Area (km^2)[2]	Ordnance Survey Maps covering Study Areas 1:50 000 scale	1:25 000 scale
ALWINTON (AL)	Cheviot	Northumberland	Northumberland N P (in part)	155	80	NT 70, 71, 80, 81, 90, 91
LUNEDALE (LU)	Northern Pennines	Durham		93	91	NY 72, 81, 82, 92
SHAP RURAL AND SHAP (SS)	Lake District	Cumbria	Lake District N P (in part)	113	90, 91	NY 40, 41, 50, 51
BRANSDALE (BR)	North York Moors	North Yorkshire	North York Moors N P	32	94	NZ 50, 59, 60, 69
HEPTONSTALL (HE)	Southern Pennines	West Yorkshire		23	103	SD 92, 93
MONYASH AND HARTINGTON MIDDLE QUARTER (MH)	Peak District	Derbyshire	Peak District N P	36	119	SK 06, 16
LLANFACHRETH (LL)	Snowdonia	Gwynedd	Snowdonia N P	72	124	SH 71, 72, 82
YSBYTY YSTWYTH (YY)	Cambrian Mountains	Dyfed		54	135	SN 76, 77, 86, 87
GLASCWM (GL)	Radnor-Clun Forests	Powys		37	148	SO 15, 16
YSTRADGYNLAIS HIGHER AND GLYNTAWE (YG)	Brecon Mountains	Powys	Brecon Beacons NP (in part)	48	160	SN 71, 81, 82
LYNTON (LY)	Exmoor-Brendon Hills	Devon	Exmoor N P	32	180	SS 64, 74
WIDECOMBE IN THE MOOR AND BUCKLAND IN THE MOOR (WB)	Dartmoor	Devon	Dartmoor N P	51	191, 202	SX 67, 77, 78

1 The study areas are arranged from northernmost to southernmost. Underlined abbreviations for combined parish study areas, or the initials given, are used as convenient in text and tables.

2 Area to nearest km^2 from the 0.25 km^2 grid squares falling entirely or dominantly in the study areas. This can differ by 1-2 km^2 from the area within administrative boundaries.

FIGURE 1.1

STUDY AREAS IN RELATION TO THE MAIN UPLAND GEOGRAPHIC REGIONS (BASED ON O S 10x10 KM GRID)

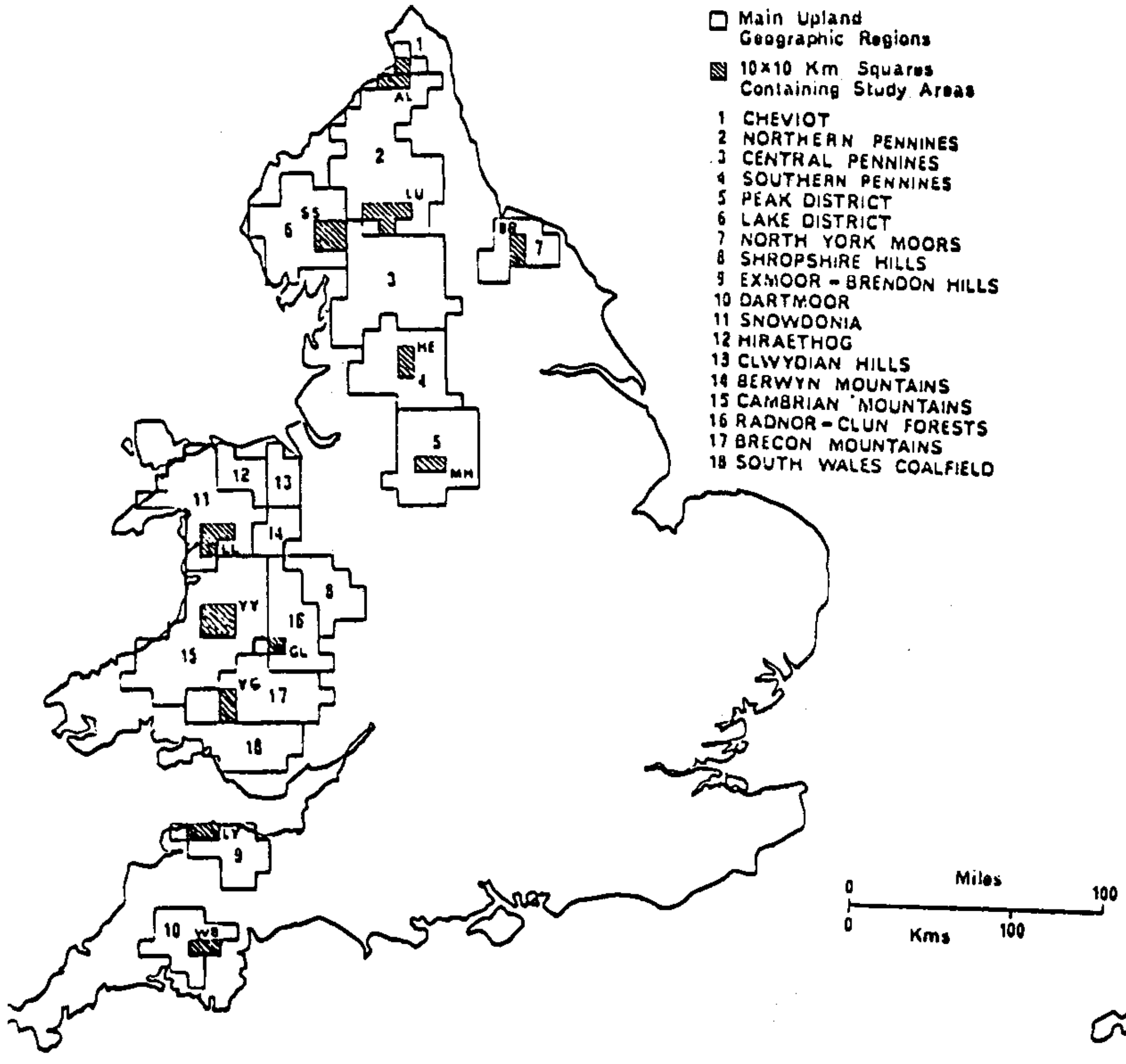
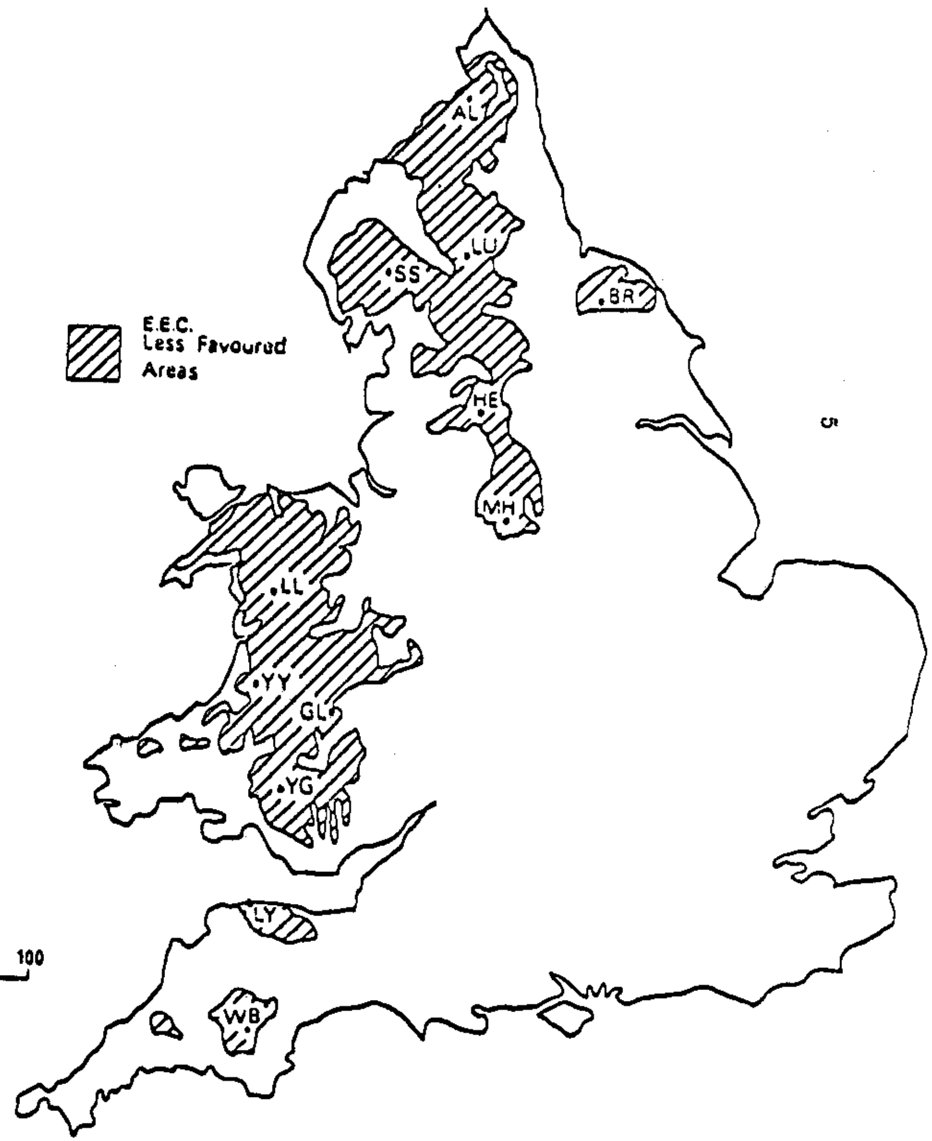


FIGURE 1.2

STUDY AREAS IN RELATION TO THE E E C LESS-FAVOURED AREAS



1.12 The physical environment of the study areas has been assessed from map-derived land data. A classification based on these data divides the study areas as a whole into 7 land types in 3 land groups. Land use factors that influence the past and present distribution of vegetation have been considered from documentary and map sources for historical aspects, and through a review of management methods that can induce gradual change in the balance of plant species (Chapter 4; Objectives b, d and f).

1.13 By comparing the vegetation class at a site with land characteristics at the site and with the land type in which the site occurs, associations are found which allow quantitative interpretation of the present relationships between vegetation class occurence and physical environment factors. Recent land-use history can be partially determined at some sites so that this history can be compared with the present vegetation. The reactions of key plant species in the vegetation to management factors that cause gradual change are also described from general ecological principles. These approaches, considered in Chapter 5, allow an assessment of the frequency of occurrence of particular vegetation in specified situations. From the frequencies with which each vegetation class actually occurs, the potential for it to occur at a site with particular characteristics, or to develop there through gradual change from the vegetation that is present, can be inferred. In order to strengthen, so far as presently possible, the interpretation of data from the study areas, additional locations outside them for which some experimental management evidence concerning gradual change was available were also examined. (Objective e).

1.14 The predictions of vegetation change made in this study have had to be drawn from examination of the present vegetation at a large number of sites, and from the application of general ecological principles and broad land-use assumptions. Chapter 5 includes a summary of the scale of change predicted from ecological principles for individual study areas, and alternative approaches to possible change if agriculture or forestry were to be expanded to their assumed maximum potential. (Objective g).

1.15 The report is in 2 parts. Part I (Chapters 1 to 5 as summarised above) is a general consideration of the ecology of gradual vegetation change in upland England and Wales, based on combined data from the study areas. Part II briefly considers each study area individually, summarising its land and settlement characteristics and history and its vegetation as recorded in this study. The individual accounts conclude with assessments of the scale of vegetation change that can be predicted for each area, applying the general principles discussed in Part I. These predictions are made by uniform application of the expected trends of change to all sites of the same vegetation class, regardless of individual site characteristics of environment, actual or potential management, and history. More specific consideration of the potential for change at each site is not possible with the information available.

2 STUDY AREAS IN THEIR GEOGRAPHIC CONTEXT

INTRODUCTION

2.1 In order to consider the relationship of the study areas to the regions in which they occur and to the uplands as a whole, this chapter describes the main land characteristics and land-uses of the 12 areas. The approach used first compares their average characteristics with those of the regions in which they occur (2.4); next compares the study areas with each other, summarising the position of each within the ranges of upland character they cover as a group (2.5-2.35); and then considers them in relation to a provisional national land classification of the uplands of England and Wales (2.36-2.37).

2.2 Emphasis is placed on natural environmental features of the study areas and regions - their climate, physiography, geology and soils - because these are important in determining the current pattern of vegetation. Definition of the environmental character of the study areas should also assist consideration of the results of this study in relation to other parts of the uplands, regionally and nationally. In this respect it should be emphasised that the selection of the study areas was not intended to ensure that they represent the average conditions of the regions in which they are situated, but, as shown later in this chapter, they as a group do cover most of the national variation in upland conditions.

2.3 Before relating land characteristics of the study areas to those of their geographic regions, it is necessary to describe briefly how these regions have been defined. In the desk study previously referred to (condensed for publication in ITE 1978) 'upland' was defined as those 10 x 10 km grid squares of the national grid which contained 4% or more land above 244 m (800 ft) OD, and 'core upland' as squares with more than 50% land above 244 m OD. The 'upland' squares were grouped into regions which were given names based on widespread usage. Figure 1-1 showed the position of the study areas in relation to these upland regions, and Figure 2-1 shows that the study areas fall mainly with 10 x 10 km grid squares classified on simple altitudinal grounds as 'core upland'. Three study areas lie in part in what can be described as marginal upland squares, ie with less than 50% of their land above 800 ft, but only Widecombe does so to a substantial degree. The concentration of study areas in the core upland is because the parishes are in the EEC 'less-favoured areas' and these cover the more positively upland sectors of Britain (see 2.37). It is reasonable in relation to this study for the study areas to be concentrated in this way because more probabilities for gradual vegetation change are likely to remain in this upland sector than in the already generally intensively used 'marginal' upland.

STUDY AREAS AND GEOGRAPHIC UPLAND REGIONS

2.4 Some average land characteristics of the study areas (see 4.12 for the source of these data) are compared in Table 2-1 with those of the core regions in which they are situated. There are broad similarities and some contrasts to be seen between equivalent statistics obtained for core regions and for study areas. Particular points for each area are:

Alwinton includes relatively more high ground than the Cheviot core region does as a unit, and has much less cultivated ground.

Lunedale has higher ground, steeper slopes and poorer average Agricultural Land Class than the Northern Pennines core region, with much less cultivated and improved ground.

Shap Rural and Shap include relatively rather more high ground than the Lake District core does, but are similar to the average for the region in Agricultural Land Class and land-use.

Bransdale has closely comparable ranges in the listed characteristics to those of the North York Moors core region, except for a much lower area of tillage..

Heptonstall is similar in its average statistics to the Southern Pennines core region, though it has rather more steep slopes and grade 5 agricultural land.

Monyash and Hartington Middle Quarter have rather less high ground, less steep slopes, more grade 3 and 4 agricultural land, and less rough pasture than has the Peak District.

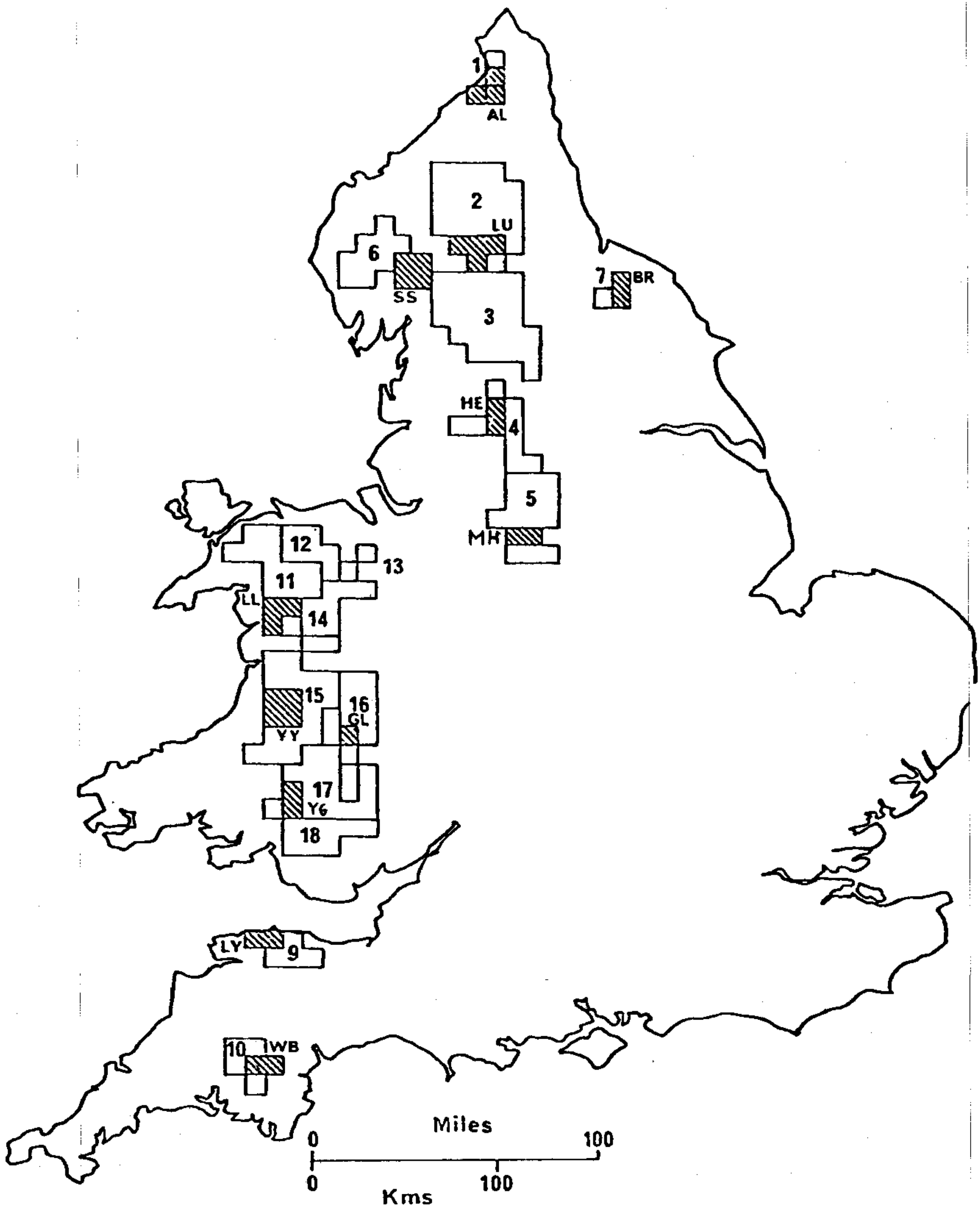
Llanfachreth is closely comparable to the Snowdonia core region as a whole.

Ysbyty Ystywth has more high ground and less grade 4 agricultural land, tillage, and improved grassland, than does the Cambrian Mountains region.

Glascwm is generally comparable to the Radnor-Clun Forest region.

Ystradgynlais Higher and Glyntawe have less land which is of better than agricultural grade 5 quality, and also much less tillage and improved grass, than the Brecon Mountains core region.

FIGURE 2.1 STUDY AREAS IN RELATION TO UPLAND GEOGRAPHIC 'CORE' REGIONS



Study Area symbols (Al, Lu, etc.) as given in Table 1.1

Geographic regions numbered as in Figure 1.1

TABLE 2-1 GENERAL CHARACTERISTICS OF THE STUDY AREAS AND THEIR REGIONS

Study area[1] and region[2]	Land above 244 m	Land above 427 m	Land with slope more than 5^{o}	Agricultural Land Grade 3	Agricultural Land Grade 4	Agricultural Land Grade 5	Agricultural Land Grade Other use	Agricultural Land Use[3] Tillage	Agricultural Land Use[3] Improved grass
Alwinton, Cheviot	91 (81)	65 (21)	83 (76)	0 (1)	0 (7)	85 (84)	15 (8)	0.4 (32)	5 (21)
Lunedale, North Pennines	100 (87)	74 (40)	58 (34)	0 (3)	5 (20)	95 (70)	0 (6)	0 (11)	8 (31)
Shap, Lake District	93 (76)	54 (32)	61 (72)	0 (2)	20 (19)	75 (71)	5 (9)	1 (10)	25 (39)
Bransdale, North York Moors	69 (57)	3 (0)	57 (43)	0 (4)	15 (17)	75 (72)	10 (6)	2 (46)	20 (25)
Heptonstall, South Pennines	92 (75)	9 (9)	62 (41)	0 (6)	20 (36)	70 (43)	10 (15)	0 (3)	20 (59)
Monyash, Peak District	98 (78)	1 (11)	42 (68)	15 (6)	70 (42)	15 (40)	0 (12)	4 (8)	89 (58)
Llanfachreth, Snowdonia	65 (77)	28 (28)	89 (84)	0 (1)	20 (17)	65 (64)	15 (19)	1 (5)	16 (25)
Ysbyty Ystwyth, Cambrian Mountains	90 (79)	51 (24)	69 (82)	0 (0)	0 (23)	90 (58)	10 (19)	1 (9)	12 (45)
Glascwm, Radnor Clun Forests	85 (80)	23 (13)	75 (83)	0 (6)	50 (56)	45 (29)	5 (0)	5 (14)	55 (55)
Ystradgynlais, Brecon Mountains	84 (77)	32 (23)	61 (62)	0 (3)	10 (29)	85 (49)	5 (19)	1 (11)	16 (55)
Lynton, Exmoor - Brendon Hills	75 (65)	0 (10)	74 (52)	0 (6)	50 (47)	50 (38)	0 (8)	3 (16)	54 (60)
Widecombe, Dartmoor	84 (67)	6 (35)	76 (28)	5 (8)	30 (13)	55 (74)	10 (5)	3 (14)	39 (26)

Data as percentages of the total area of study areas and core regions, with regions in parenthesis

1 Study area averages from the 0.5 x 0.5 km squares comprising the study area

2 Core region averages from the characteristics of 10 x 10 km squares comprising the core region (Figure 2-1)

3 Land use proportions for the regions are as % total agricultural land; *for the study areas as % total area*

Lynton is generally closely similar to the Exmoor core region in the characteristics tabulated.

Widecombe and Buckland have less high ground and more moderate to steep slopes, with less grade 5 agricultural land than the Dartmoor core region.

COMPARISONS BETWEEN STUDY AREAS

Study area summaries

2.5 Turning to the land characteristics of the study areas in relation to each other, a brief relative summary is given here for each, drawing from the quantitative, physiographic and topographic data recorded on Ordnance Survey (OS) maps (4.12) and from published national map sources covering rainfall (Meteorological Office 1977); temperature (Meteorological Office 1975b); soils (Soil Survey 1974); and Agricultural Land Class (ALC) (MAFF 1976). Plates 1-18 are aerial photographs which illustrate important facets of the terrain and landscape character of the study areas.

2.6 Alwinton - has generally high altitudes with strong relief and mainly moderate to steep slopes, and a low settlement density and road frequency. It is (with Bransdale) one of the areas of lowest rainfall but is also relatively cold and therefore has one of the shortest growing seasons among the study areas. Soils are dominantly peaty and hence in such a climate are of low agricultural potential. This is reflected by Alwinton having no land graded above ALC 5. (Plate 1)

2.7 Lunedale - also is of generally high altitude but has relatively low average relief and mainly gentle to moderate slopes, and has low settlement density and road frequency. With Alwinton and Shap it is one of the coldest of the study areas, and, like Shap, it has high rainfall. It contains a very high proportion of peaty soils and has only 5% of its area graded higher than ALC 5. (Plates 2, 3)

2.8 Shap Rural and Shap - as a whole have relatively high altitude, strong relief, and mainly gentle to moderate slopes with some steep slopes in the west. This area has overall a low average settlement density and road frequency. It is relatively cold with high rainfall. There is a sharp contrast between the north eastern corner of the study area which has relatively high settlement density on moderate altitude land of ALC 4 with mainly mineral soils over limestone, and the bulk of the area which has mainly peaty-surfaced upland soils of ALC 5. (Plates 4, 5)

2.9 Bransdale - is characterised by relatively low altitude and relief with mainly gentle to moderate slopes. It has a moderate road frequency but low settlement density. Climatically it is the area of lowest average rainfall and it has moderate winter temperatures. It is of moderate to low ALC (15% class 4) in conformity with a dominance of poorly drained soils. (Plates 6, 7)

2.10 Heptonstall - is of relatively low altitude and relief and gentle to moderate slopes. This area has a high settlement density and moderate road and field boundary frequencies. Settlement and access here are related more to past industrial history than to exploitation of a high agricultural potential. It is of moderate rainfall and moderately cold winters. With its dominant very poorly drained peaty-surfaced and peat soils it is of low average ALC. (Plates 8, 9)

2.11 Monyash and Hartington Middle Quarter - are also of relatively low altitude and relief with gentle slopes and a high settlement density, road and field boundary frequency. This area has the highest proportion of ALC 4 land among the study areas and includes 15% land in ALC 3. Although climatically relatively cold, rainfall is relatively low. The area dominantly has freely drained mineral soils overlying limestone. These have given a higher agricultural quality than is found in other study areas under similar climatic situations. (Plate 10)

2.12 Llanfachreth - is overall of relatively moderate altitude but this average masks a substantial range. This area has the strongest average relief, and a high proportion of moderate and steep slopes. Settlement density and road and field boundary frequency are relatively high. Llanfachreth is of high rainfall but relatively warm temperatures. It is moderate in its soil conditions and ALC. (Plates 11, 12)

2.13 Ysbyty Ystwyth - has high average altitudes but moderate relief and mainly gentle and moderate slopes. It is also of moderate settlement density but has low road and field boundary frequencies. The mining history of the area caused increased settlement beyond what would have been likely to have happened on purely agricultural grounds, since it has relatively high rainfall, and moderately cold temperatures, a moderate to poor soil quality and no land graded higher than ALC 5. (Plate 13)

2.14 Glascwm - is moderately high in altitude, with strong relief and a wide slope range, but dominantly moderate slopes. Settlement density and road freqency are moderate and field boundary density high. A relatively dry climate with moderately warm winter temperatures and dominantly better quality soils gives relatively high ALC, with 50% of the area in class 4. (Plate 14)

2.15 Ystradgynlais Higher and Glyntawe - are of relatively high altitude but of low average relief and gentle to moderate slopes, with a moderate settlement density but low road and field boundary frequencies. This is another area where settlement has followed industrial influences rather than having an entirely agricultural basis. Climatically, this area is of high rainfall with moderately warm winters. Soils are not generally of good potential for agriculture and only 10% is graded ALC 4. (Plate 15)

2.16 Lynton - is of relatively low altitude but moderate average relief and slopes. Settlement density, road and field boundary frequency are all relatively high, reflecting a relatively warm and moderately wet climate with relatively good soils present, half the area being of ALC 4. (Plate 16)

2.17 Widecombe in the Moor and Buckland in the Moor - are also of relatively low altitude but moderate average relief and slopes, with high average settlement density and road and field boundary frequency. Again this study area is moderately wet but relatively warm in winter temperatures. Also as with Lynton, there is a relatively high proportion of better soils for agriculture, giving 30% of the area in ALC 4. (Plates 17, 18)

2.18 Figure 2-2 summarises how the study areas stand in relation to each other for a number of characteristics of land and land-use. Soils and climatic factors, which are covered shortly, (2.24 and 2.29) are included in this figure.

2.19 The interaction of physiography, geology, climate and soil in general determines the land-uses which can economically be maintained in an area, although the extent to which natural land use potential is realised (or expanded) depends on additional social and economic factors. The physical environment thus provides the foundation for contrasts between the land-use of upland areas. Physiographic and topographic characteristics (4.2) are used as the basis for a classification of land types in the study areas (4.9-4.20), but here we summarise geology (2.20-2.23), soil (2.24-2.28), and climate (2.29-2.34) of the study areas and list their principal land-uses (2.35).

Geology

2.20 A simple grouping of rock types of the uplands of England and Wales, with their relative prominence in the study areas, is given in Table 2-2. Information for this was drawn from published (IGS 1957, 1977) and other maps of the Institute of Geological Sciences. Sandstones, slates and shales are the most widespread rock types in the study areas, as they are in the uplands of

Plate 1 Alwinton - Rounded hills with summit plateaux and steep-sided valleys in the north of the study area. Drainage channels for forestry on plateau in foreground and eroding peat on higher plateau in mid-distance.
(Photo by Dr. St. Joseph, Cambridge, No. BAJ 29, 5.1.1970)

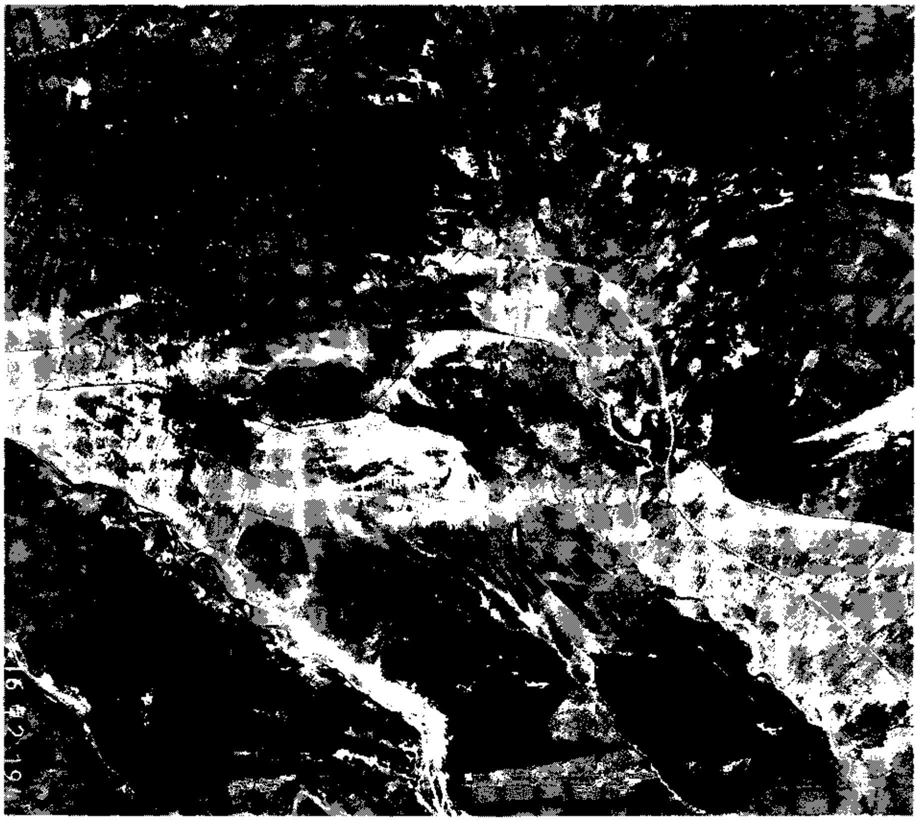


Plate 2 Lunedale - Hill and high plateau land in the west-central part of the study area around Closehouse Mine. The localised effects of extractive industry are seen and more broadly, the chequer pattern of cyclic heather burning used in grouse-moor management on Blindgill Moss and Lune Head Moss.
(Photo, with the permission of Durham County Council, by Meridian Airmaps Ltd., No. 16.72.194, 21.3.1972)

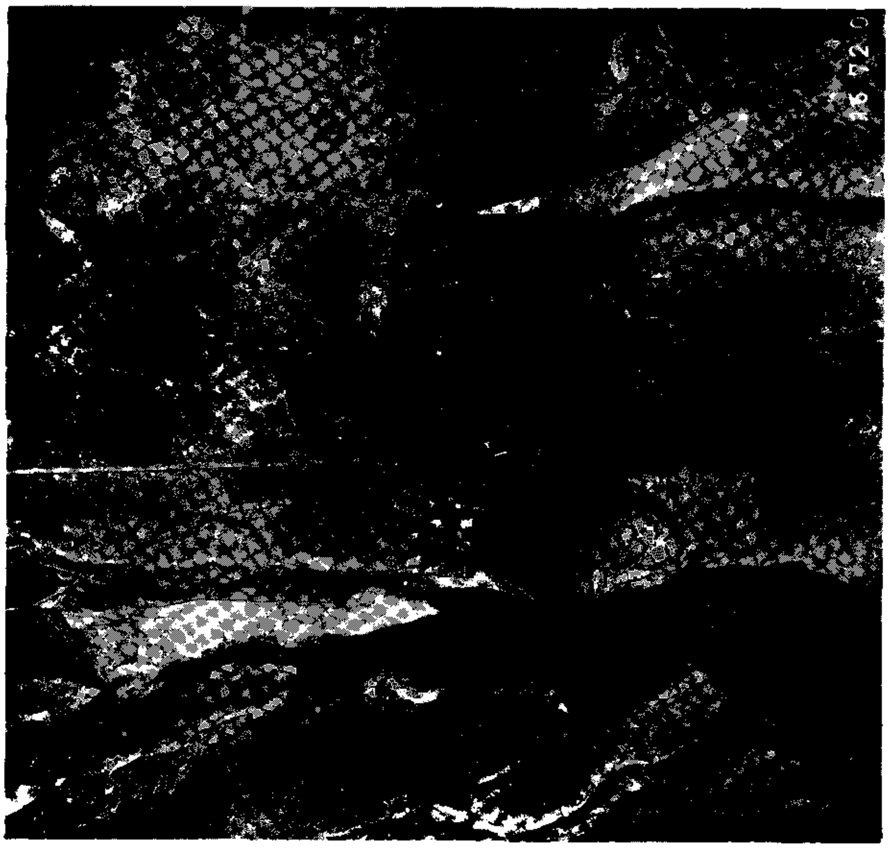


Plate 3 Lunedale - Upland and upland margin land of the Lune Valley around Selset Reservoir. The woods of Wemmergill Hall are on the north shore of the reservoir. Contrasting patterns in the large enclosure fields of the valley, partly flooded by the reservoir, result from poor soil drainage.
(Photo, with the permission of Durham County Council, by Meridian Airmaps Ltd., No. 16.72.046, 21.3.1972)

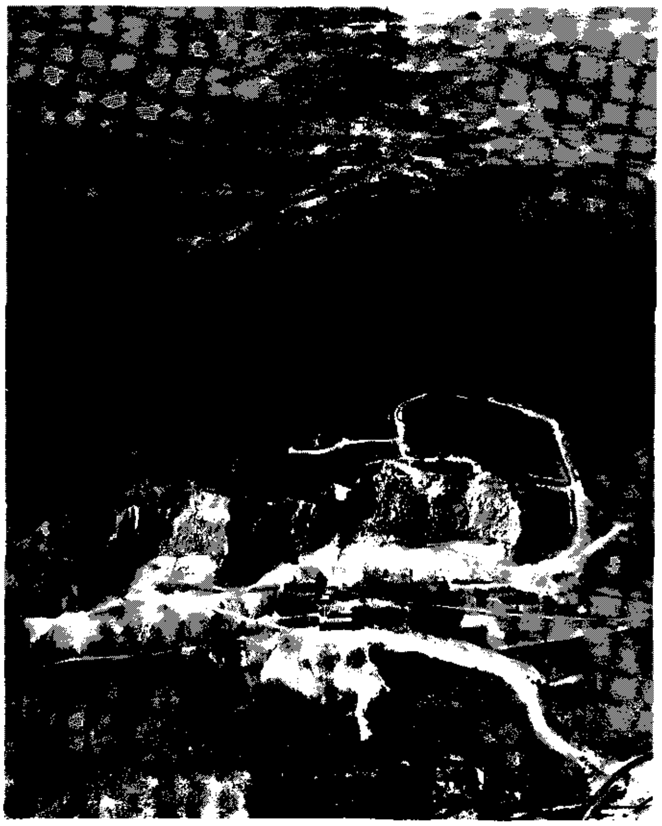


Plate 4 Shap Rural and Shap - Fell country in the southeast of the study area, with the mineral industry of the Shap granite quarries prominent in the foreground. Wet Sleddale reservoir is just visible in the extreme background.
(Photo by Dr. St. Joseph, Cambridge, No. AOD91, 30.5.1966)

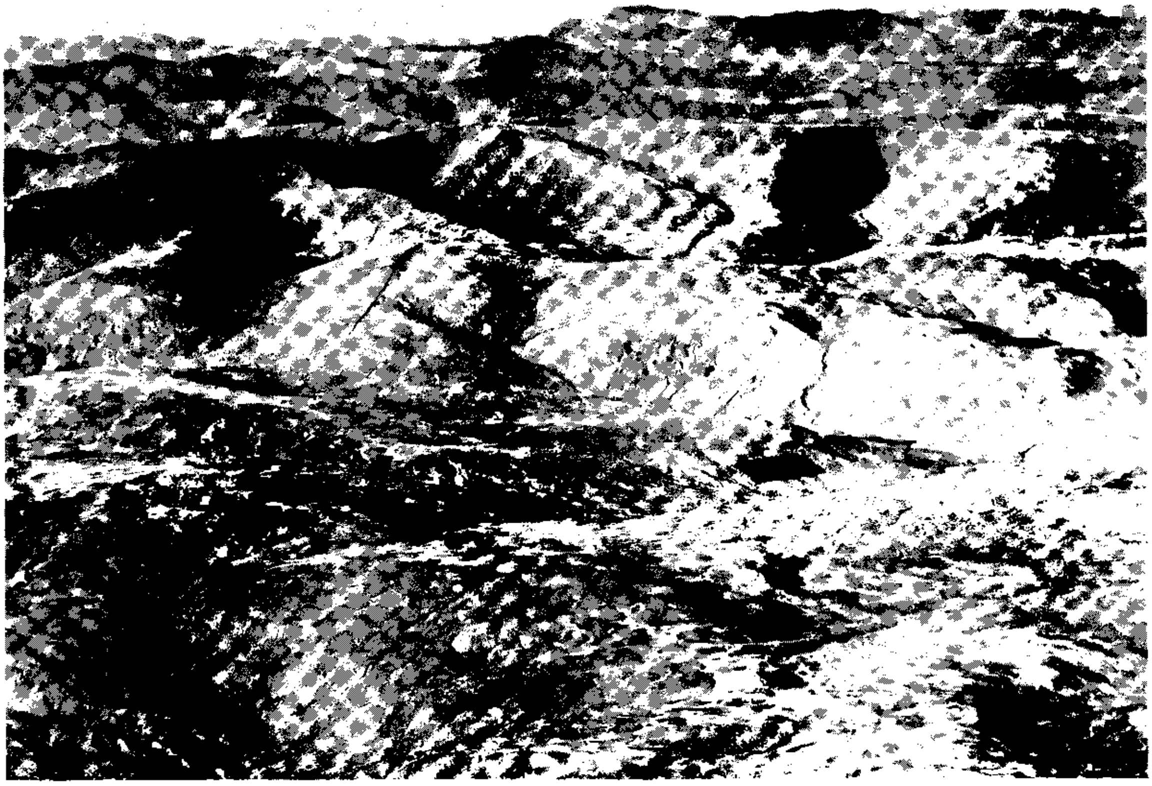


Plate 5 Shap Rural and Shap - Montane terrain of steep hill land in the southwestern corner of the study area, with the head of Mosedale in the right foreground and mid-distance. Background hills lie outside the study area.
(Photo by Dr. St. Joseph, Cambridge, No. BPA 7, 20.11.1973)

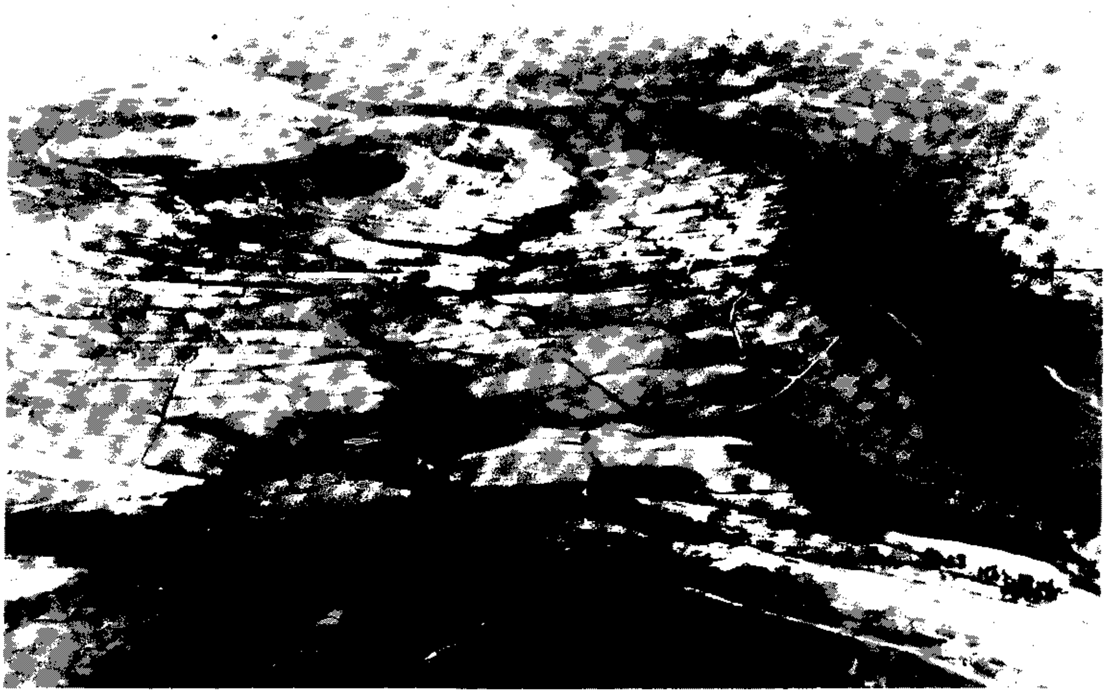


Plate 6 Bransdale - View southward that includes most of the study area. The farmland of the dale floor is flanked by moorland ridges. Field boundaries have few trees but narrow woodland picks out the stream courses.
(Photo by Dr. St. Joseph, Cambridge No. ARL140, 8.6.1967)

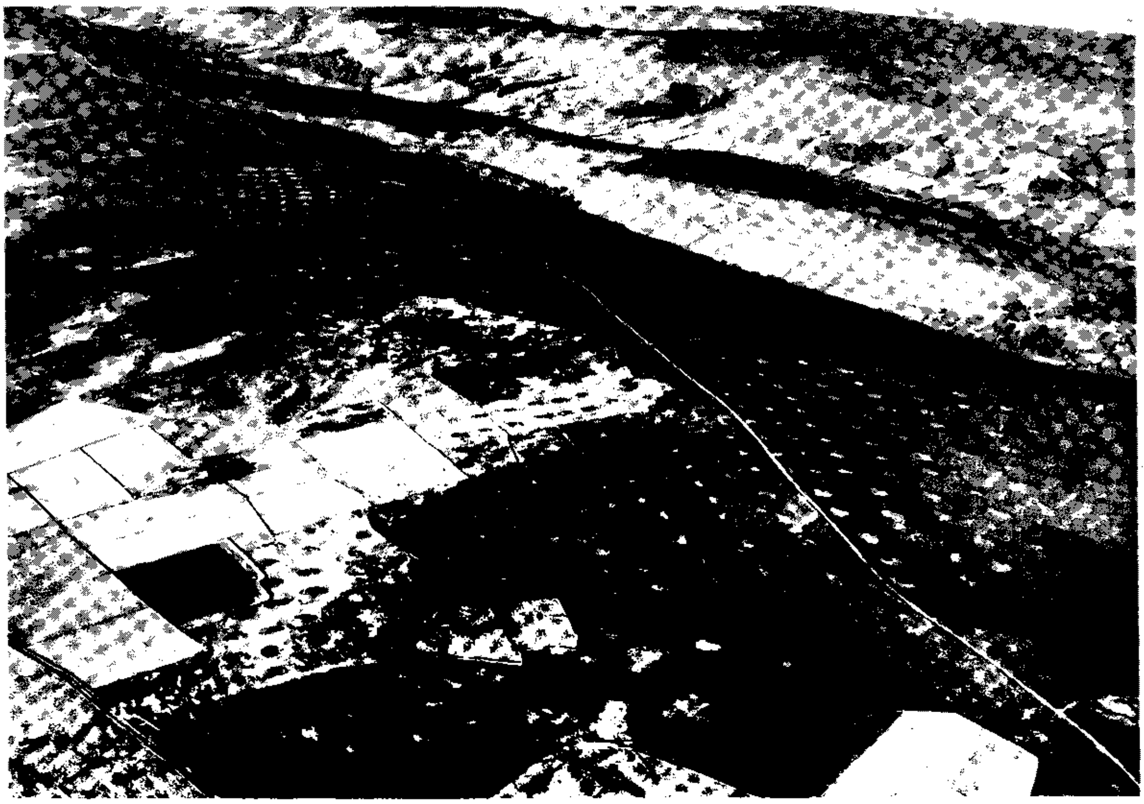


Plate 7 Bransdale - Rectangular enclosure fields penetrate the moorland of Rudland Moor in the southeast of Bransdale, the parish boundary of which follows the old track along the moorland ridge. The cratered effect is from shallow workings for low-quality coal.
(Photo by Dr. St. Joseph, Cambridge, No. A 22 69, 13.11.1969)

Plate 8 Heptonstall - View over the east of the area, with the edge of Heptonstall village and the settlements of Slack and Colden. Deeply incised wooded valleys of the Hebden and Colden Waters bound the study area. Farmed land adjoins the road access westwards towards the moorland.
(Photo, with the permission of West Yorkshire Metropolitan County Council, by Meridian Airmaps Ltd., No. 44.68.077, 13.6.1968)

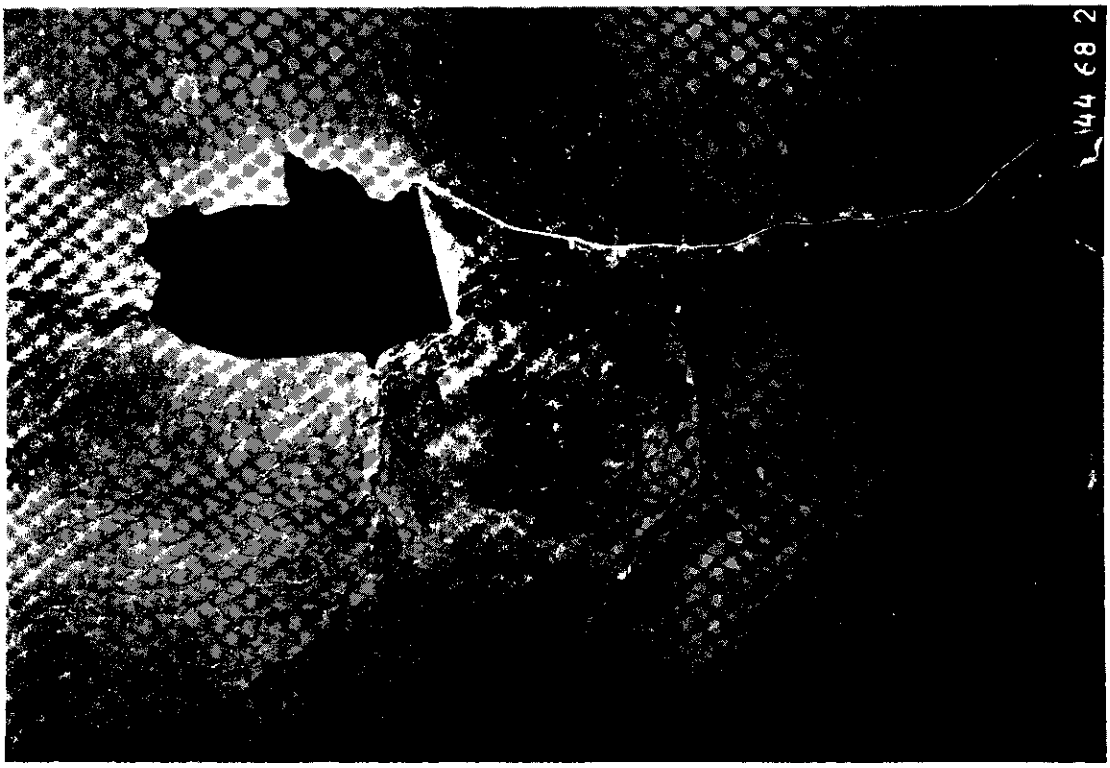


Plate 9 Heptonstall - Western end of the study area on the plateau of Heptonstall Moor around the Gorple Reservoirs.
(Photo, with the permission of West Yorkshire Metropolitan County Council, by Meridian Airmaps Ltd., No. 44.68.212, 13.6.1968)

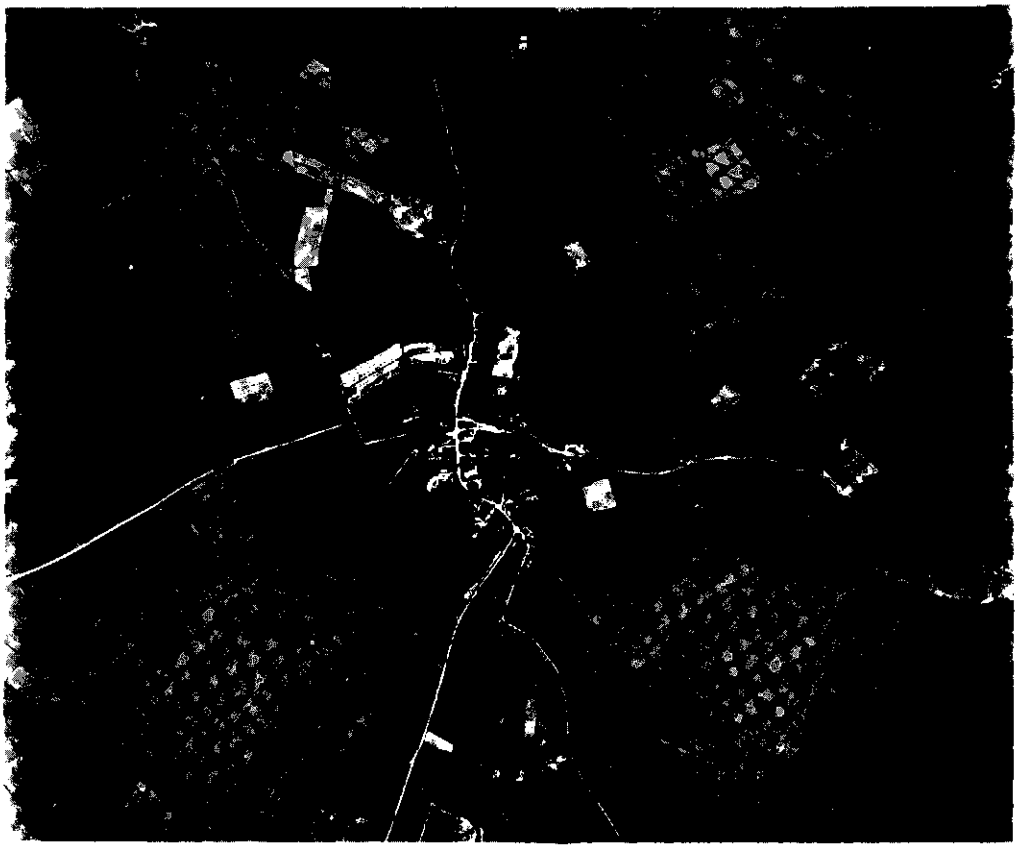


Plate 10 Monyash and Hartington Middle Quarter - Monyash village in a completely agricultural landscape of fields with stone wall boundaries on an upland plateau of Carboniferous Limestone. The head of Lathkill Dale-Fern Dale is seen just cutting into the plateau in the lower right corner.
(Photo, with permission of Derbyshire County Council, by Clyde Surveys Ltd., No. 7145-15 009, 6.8.1972)

Plate 11 Llanfachreth - Small, irregular fields of the farmland around Llanfachreth village in the south; Forestry Commission Plantations of Coed-y-Brenin in the west and north-west; hill ground of Cerniau and the footslopes of Rhobell Fawr in the centre and east (Photo, with the permission of the University College of Wales, Aberystwyth, by Clyde Surveys Ltd., No. 7178.2.228, September 1971)

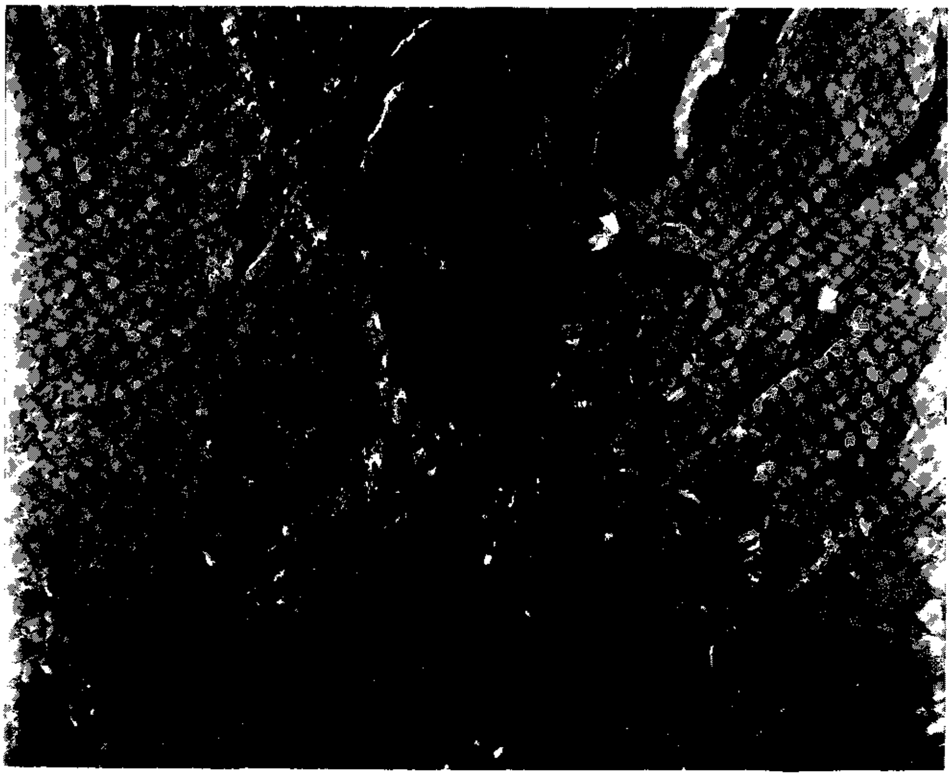


Plate 12 Llanfachreth - Slopes of Rhobell Fawr in the north west; valley of the Wnion in the southeast with wooded subsidiary valleys, and a landscape dominated by tree and hedgerow - bounded irregular fields around Rhydymain. This plate overlaps on the west with the eastern margin of plate 11.
(Photo, with permission of the University College of Wales, Aberystwyth, by Clyde Surveys Ltd., No. 7178.2.259, September 1971)

Plate 13 Ysbyty Ystwyth - Hill sector in the southeast of the area, under snow. High plateau terrain cut by deep valleys with a forestry plantation conspicuous in the left foreground.
(Photo by Dr. St. Joseph, Cambridge, No. BAN7, 7.1.1970)

Plate 14 Glascwm - View in the north of the study area showing its dominantly agricultural character with hedgerow - bounded fields. Isolated remnants of unimproved land with scrub woodland and heath vegetation remain, as around Craig Fawr, the hill in the foreground and middle distance.
(Photo by Dr. St. Joseph, Cambridge, No. AZW85, 5.11.1967)

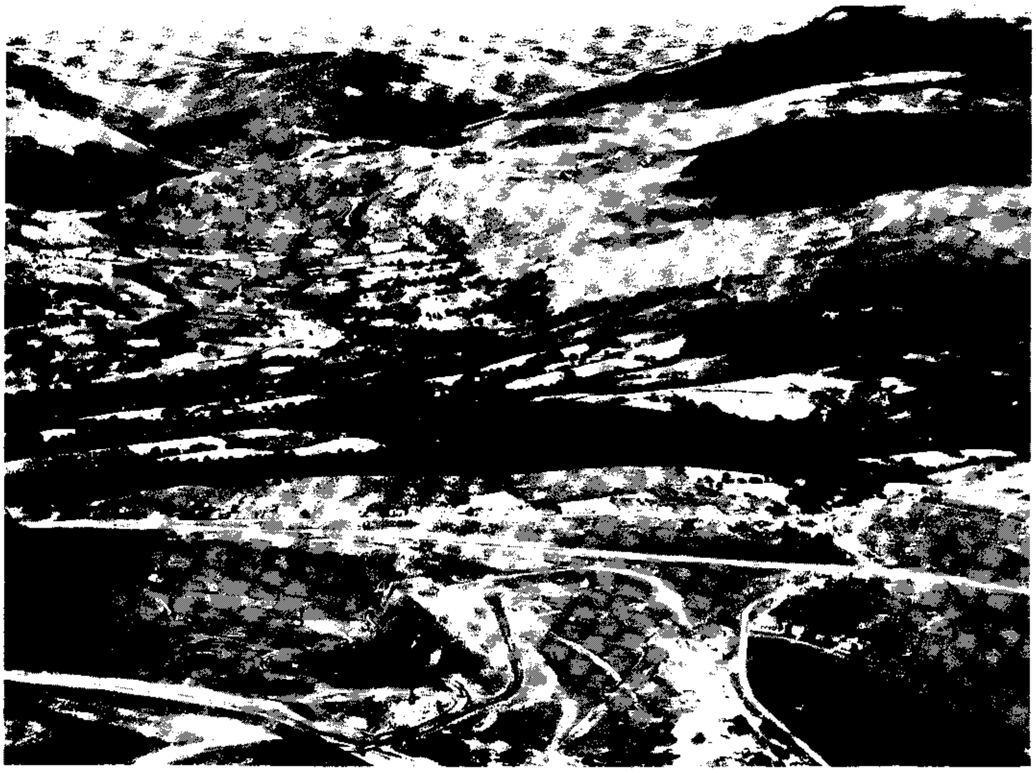


Plate 15 Ystradgynlais Higher and Glyntawe - View north along the well-wooded farmland of the Tawe Valley, flanked by open hill with mining activities; open-cast coal workings in the foreground; and stone quarries in the central mid-distance. (Photo by Dr. St. Joseph, Cambridge, No. CA 718, 4.8.1976)

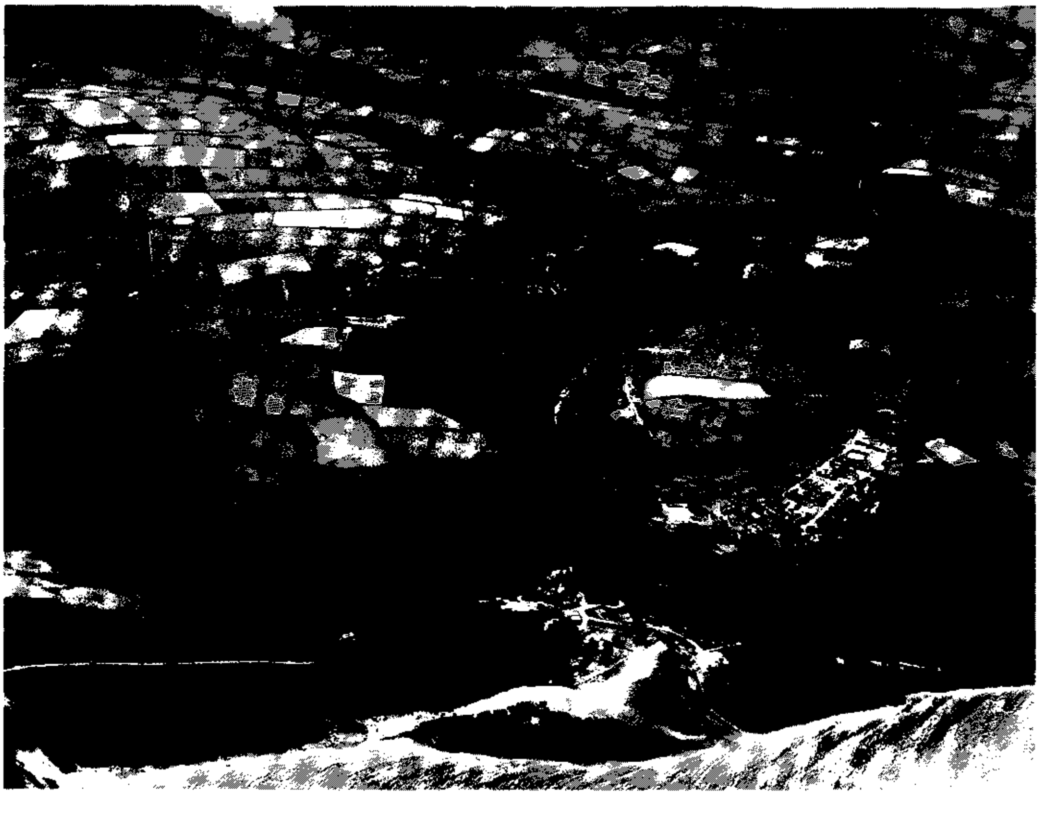


Plate 16 Lynton - A complete view of the study area, looking approximately southward. Steep coastal cliffs and the twin settlements of Lynton and Lynmouth in the foreground. Wooded valleys penetrate between agricultural ridges in the mid-distance. In the background, tongues of moorland run northward from the high core of Exmoor south of the study area.
(Photo by Dr. St. Joseph, Cambridge, No. BCU 71, 3.7.1970)

Plate 17 Widecombe in the Moor and Buckland in the Moor - In the foreground, common land of heath vegetation is conspicuous. Deciduous woodland, or cleared woodland areas, follow the river courses. The farmed land has a contrast in field boundaries. Generally smaller, older fields have frequent trees picking out their hedgerows. Younger enclosures of larger fields are generally without hedgerow trees. (Photo by Dr. St. Joseph, Cambridge, No. 70H-F64, 27.7.1973)

Plate 18 Widecombe in the Moor and Buckland in the Moor - Boundaries of an archaeological site, "Foales Arrishes", c. 2 km ESE of Widecombe village on Blackslade Down near the eastern border of the area, conspicuous on uncultivated moorland. (Photo by Dr. St. Joseph, Cambridge, No. AFG 92, 8.6.1962)

FIGURE 2.2 POSITION OF STUDY AREAS RELATIVE TO EACH OTHER FOR SOME LAND AND LAND USE CHARACTERISTICS

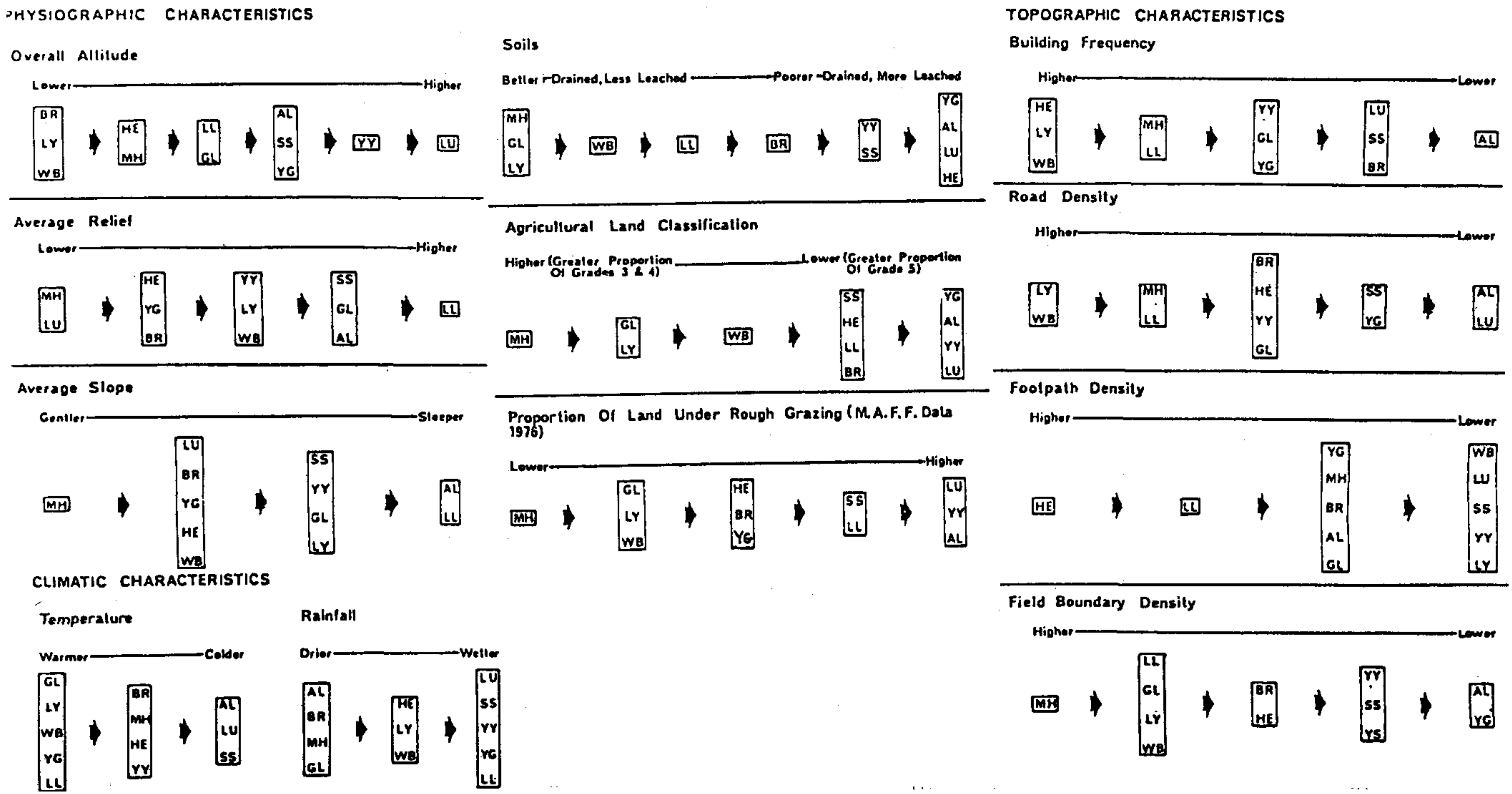


TABLE 2-2 ROCK TYPES IMPORTANT IN THE STUDY AREAS

	Solid Geology						Surface Geology	
Study Area	Sandstones	Shales and Slates	Limestone	Granite (Acidic Intrusive Igneous Rocks)	Dolerite (Basic Intrusive Igneous Rocks	Volcanic Rocks	Deep Glacial Drifts	Peat
Alwinton	*					*	*	*
Lunedale	*	*	*		*		*	*
Shap		*	*	*		*	*	*
Bransdale	*	*						*
Heptonstall	*	*						*
Monyash			*					
Llanfachreth		*				*	*	1
Ysbyty Ystwyth		*						1
Glascwm		*						
Ystradgynlais	*	*	*				*	
Lynton	*	*						
Widecombe	*	*		*				

1 Peat probably important in surface geology (2.27)

England and Wales as a whole. The sandstones are mainly of Carboniferous age, except for the Jurassic rocks of Bransdale, while the shales and slates include, as well as rocks of these systems, rocks of Ordovician and Silurian age. Limestone is only prominent in limited areas of the uplands, particularly in sectors of the Lake District, Northern Pennines, Peak District, Brecon Mountains and the South Wales Coalfield. In the study areas Monyash consists entirely of limestone, and this is also important in the north-eastern part of Shap. Granite outcrops are prominent features of the Cheviot, Lake District and Dartmoor regions, while volcanic rocks are most widespread in the Cheviot, Lake District and Snowdonia regions. The geology of the study areas is generally representative of the range of rock types in their regions, but the Peak District does not consist wholly of limestone, as Monyash and Hartington Middle Quarter do.

2.21 It would require more than the available space to deal comprehensively with the role of geology as one of the main soil-forming factors which, through soils, influence vegetation. In general, higher ground in the uplands is relatively free of glacial drift cover, so that rock exposures are frequent and shallow soils, directly related to underlying rock material, are typical. On gentle slopes where rainfall is heavy and temperatures low, deep peat may well have accumulated over rocks and glacial drifts of inherently low fertility. A surface cover of deep glacial drifts typically gives deeper soils than are derived from most solid rocks in the uplands. Drift soils may be freely-drained on moderate slopes in areas of relatively low rainfall, or may be poorly-drained and frequently have peaty surface horizons on gentler slopes in areas of higher rainfall. Glacial drifts are most often located on valley floors and lower slopes or in moderate-altitude plateau situations. Limestone, when pure, as it weathers leaves a negligible amount of insoluble residue to form soil and is typically found to be covered with thin drifts of non-limestone origin, but it in general maintains, under such thin cover, a high enough lime status in the soil to prevent heath plants establishing themselves or peaty material accumulating at the soil surface. Volcanic rocks are very variable in their chemistry, ranging between silica-rich types, comparable chemically to granite and sandstones, and iron/magnesium/calcium-rich types, comparable chemically to dolerite and slightly calcareous sedimentary rocks.

2.22 Purely in chemical terms, considering the 'quality' of rocks as soil parent materials capable of producing soils of inherently high fertility, the rock types listed in Table 2-2 can be roughly ranked from 'better' (>) to 'poorer' as limestone>shale/slate, intermediate volcanic rocks and dolerite>granite, sandstone and acidic volcanic rocks. The position is much more complex than this in reality. Parent rock type requires detailed assessment in terms of its chemistry, mineralogy and weathering rate; the nature of glacial, periglacial and alluvial breakdown and transport of rock is locally variable; rocks weather differently in response to different climates; and rock debris, which makes up the mineral part of soils, accumulates differently in response to local landform.

2.23 There is greater geological diversity in some regions than others. The Lake District and Snowdonia particularly include a wide range of rock types of very contrasting chemistry, mineralogy, and mode of formation, with resulting direct effects on soils and hence on vegetation (see for example a study of Snowdon soils by Ball et al 1969). Other regions, such as the Cambrian Mountains or the North York Moors, have a less varied range of rock types.

Soils

2.24 The natural character and land-use capabilities of any land are substantially affected by the properties and distribution of its soils. Geology, physiography and climate are main factors affecting soil development, and they, with the soils, all interact to provide an environment most appropriate for the growth of a particular range of natural and semi-natural vegetation or for a particular type of land use. A general consideration of the upland soils of Britain is given by Ball (1978). No detailed assessment of soil type and properties at the sites at which the vegetation was recorded was possible in the study, but a limited series of soil observations was made. (See 5.26-28) The general character of soils of the study areas can be outlined from the broad picture provided by the national soil map (Soil Survey 1974). Further information is available in district reports or unpublished maps for some study areas but no more detailed soil maps yet cover them all at a consistent level, a position due to change over the next few years through the current mapping programme of the Soil Survey of England and Wales.

2.25 The national soil map includes 12 mapping units that are complexes of 'soils of the uplands and humid lowlands'. Nine of these occur in the study areas. Of the 3 not represented, 2 are 'humid lowland' units. The only upland soil unit not represented in the study areas is one dominated by bare rock and skeletal soils, mapped in the most montane sectors of the uplands of England and Wales, in the Lake District and Snowdonia. This end of the upland range is not strongly represented in the study areas. The extent of the national soil map units in each study area is given in Table 2-3.

TABLE 2-3 SOIL UNITS IN THE STUDY AREAS

	Soil Mapping Unit								
	60	61	63	64	66	68	69	70	71
Study Area	Brown Earths + Rankers or Rendzinas and Bare Rock	Brown Earths + Rankers	Brown Earths + Stagnogleys and Brown Podzolic Soils	Brown Podzolic Soils + Brown Earths	Stagnopodzols + Stagnohumic and Humic Gleys, Brown Podzolic Soils, Rankers and Peat Soils	Stagnogleys + Brown Earths	Stagnogleys + Brown Earths, Brown Podzolic Soils, and Stagnohumic Gleys	Stagnohumic Gleys + Peat Soils, Humic Gleys, and Stagnopodzols	Raw Peat Soils + Stagnohumic or Humic Gleys, Earthy Peats and Stagnopodzols
Alwinton					75				25
Lunedale								25	75
Shap	10				85		5		
Bransdale						25		75	
Heptonstall					10			40	50
Monyash		100							
Llanfachreth			55						45
Ysbyty Ystwyth			15		50				35
Glascwm			95		5				
Ystradgynlais								100	
Lynton			100						
Widecombe			10	80	10				

Data as percentage of study areas occupied by map unit, from sketch maps drawn from the 1:1 000 000 National Soil Map (Soil Survey 1974)

2.26 The mineral soils of good drainage which dominate map units 60-64 have, in an upland context, higher agricultural potential than do the predominantly peaty-topped or peat soils (units 66, 70 and 71), or the poorly-drained mineral soils which dominate units 68 and 69. In terms of a rough balance of soil quality, assessing more highly those soil units with a wider potential for productive use, then Monyash, Glascwm and Lynton are better than Widecombe and Llanfachreth, which are better than Shap, Ysbyty Ystwyth and Bransdale, with the remaining areas being of lowest soil quality. The use of the already very simplified national map in this way must not be taken too far, as clearly the agricultural sectors of parishes such as Heptonstall and Ystradgynlais include some soils which are better than indicated by the dominant soil of the national mapping unit. With some deviations this ranking of the study areas in terms of general soil quality corresponds to that from the Agricultural Land Classification (Figure 2-2, Table 2-1). Soil of course is one criterion used in the assessment of Agricultural Land Class.

2.27 Comparing Tables 2-2 and 2-3 there are apparent discrepancies in the importance of peat in the study areas. 'Peat' as defined for the geological maps is of greater depth and purity than is required for the soil map to give 'peaty' soils. Llanfachreth and Ysbyty Ystwyth therefore should also be considered, from ecological and pedological standpoints as having sectors with significant surface peat.

2.28 The soil mapping units can be further simplified into four classes in terms of their dominant soils, grouped as: i. well-drained mineral soils; ii. poorly-drained mineral soils; iii. moderately-drained, peaty-surfaced soils; and iv. poorly- and very poorly-drained peaty-surfaced or peat soils. From data derived from the Soil Survey 1: 1 000 000 map, it has been estimated that the uplands of England and Wales as a whole have 45, 20, 14 and 21% of these four categories (Ball 1978). Equivalent percentages in the study areas are 27, 2, 33, and 38%, giving an apparent under-representation in these areas, relative to the uplands as a whole, of poorly-drained mineral soils, and an over-representation of the peaty-surfaced soils. Despite reservations on the over-simplified use of these data, there is probably a real contrast here which is due to under-sampling of marginal upland by the study areas, as marginal upland has a higher proportion of mineral soils than does core upland. The core upland, as defined on an altitudinal criterion (Figure 2-1), contains 33, 10, 23 and 34% of these soil categories, closer to the proportions found in the study areas. The study areas on the whole then contain a reasonable representation of most of the widespread upland soil associations.

Climate

2.29 Turning to upland climate in England and Wales there are general trends of falling temperature and rising precipation with increasing altitude in any district. Superimposed on these trends are gradients in rainfall from wetter in the west to drier in the east, and in temperature from warmer in the southern and coastal areas to colder in the north and inland. Although no compatible or comprehensive local climatological records are available for the twelve areas, these general trends, and an impression of the climatic contrasts between the study areas, are illustrated by the data of Table 2-4.

2.30 Rainfall averages in Table 2-4 have been calculated for the study areas from the extents in them of different rainfall bands sketched from the national rainfall map (Meteorological Office 1977). These averages can conceal substantial variation as will be noted in Part II for individual areas.

2.31 Temperatures have been determined from the approximate location of the study areas on small scale maps (Meteorological Office 1975b) which give temperatures reduced to mean sea level. There is a fall in temperature with altitude (the 'lapse rate'), that is assumed in calculations for the Meteorological Office maps to be 0.5°C per 100 m for minimum temperatures, 0.6°C per 100 m for mean temperatures, and 0.7°C per 100 m for maximum temperatures. Actual lapse rates vary according to location and season, and may be higher than the values used, having been shown to average around 0.8°C per 100 m in the Pennines (Harding 1978, 1979). Table 2-4 gives average temperatures for the study areas as at mean sea-level, and as adjusted from sea-level values to the average altitudes of each study area, using the Meteorological Office lapse rates.

2.32 In Figure 2-2 relative rankings of the study areas are included for rainfall and temperature. Combining these, the study area climates can be summarised as:

Cold and dry	Alwinton
Cold and wet	Lunedale, Shap
Moderately cold and dry	Bransdale, Monyash
Moderately cold and moderately wet	Heptonstall
Moderately cold and wet	Ysbyty Ystwyth
Warm and dry	Glascwm
Warm and moderately wet	Lynton, Widecombe
Warm and wet	Llanfachreth, Ystradgynlais

TABLE 2-4 CLIMATIC CHARACTER OF THE STUDY AREAS

Climatic Characteristic		Study Area: AL	LU	SS	BR	HE	MH	LL	YY	GL	YG	LY	WB
Average Annual Rainfall (mm)[1]		1040	1675	2030	990	1395	1195	2110	1830	1245	2030	1420	1475
Average Annual Number of Days with Snow Lying at 0900 hrs[2]		30	60	35	20	20	30	20	20	20	15	10	15
Temperatures (reduced to mean sea level)[3]	Mean Daily Temperature, January (°C)	2.7	2.7	3.0	3.2	3.5	3.5	4.5	4.2	4.2	4.5	5.5	5.0
	Mean Daily Temperature, July (°C)	14.7	15.2	15.2	15.5	16.0	16.0	15.5	15.7	16.2	16.0	16.0	16.0
	Mean Annual Minimum Temperature (°C)	-10	-10	-9	-6	-8	-9	-6	-8	-8	-8	-4	-6
Temperatures (adjusted to average altitude of study area)	Average Altitude of Study Area (m)	370	480	380	290	340	330	310	410	340	370	270	310
	Mean Daily Temperature, January (°C)	0.5	-0.2	0.7	1.5	1.5	1.5	2.6	1.7	2.2	2.3	3.9	3.1
	Mean Daily Temperature, July (°C)	12.5	12.3	12.9	13.8	14.0	14.0	13.6	13.2	14.2	13.8	14.4	14.1
	Mean Annual Minimum Temperature (°C)	-11.8	-12.4	-10.9	-7.4	-9.7	-10.6	-7.5	-10	-9.7	-9.8	-5.3	-7.5
Mean Annual Number of Days with Minimum Temperature less than 0°C[4]		90	110	80	70	70	70	60	70	60	60	60	60

1 Calculated from the frequency of rainfall bands and their class means, taken from Meteorological Office, 1977, data

2 From small-scale map, 1941-1970 averages, (Met. Office 1975a)

3 From small-scale maps, 1941-1970 averages, (Met. Office 1975b)

4 As 3, but 1956-1970 averages

2.33 Parry (1978) from data for accumulated temperatures above 4.4oC (taken as a starting point for cereal growth), gives a small-scale map of Great Britain showing 'climatically marginal' and 'climatically sub-marginal' agricultural zones. Locating the study areas approximately on this map suggests that Lunedale falls entirely in the climatically sub-marginal zone (defined as having temperatures below those required for cereal growth under almost any conditions). Alwinton and the Shap parishes are partly sub-marginal and partly marginal (defined as having temperatures only just suitable for cereal cropping, and hence particularly sensitive to climatic change). The other study areas are all climatically marginal, except for Lynton, which is in part non-marginal. It is necessary to appreciate in relation to such generalisations that, as Parry's work has discussed, climates have longer-term fluctuations, as well as considerable contrasts from year to year, and that climatic fluctuations have been an important influence on land-use changes in the uplands through historic time.

2.34 Gregory (1976) gave a comprehensive regional summary of climate in the British Isles. His map classes the neighbourhoods of Lunedale, Shap, Llanfachreth, Ysbty Ystwyth and Ystradgynlais as having 'mountainous climates'; that of Alwinton as being in part 'humid temperate with a cold season' (C) and in part transitional from (C) to a climate with 'cooler summers and colder winters'; and the remaining study areas as being transitional between (C) and 'mountainous climates'.

Land-uses

2.35 Table 2-5 gives the categories of upland land-use which are important in each study area. Agriculture and woodland, together with to a lesser extent conservation and recreation, are uses in all study areas, but are only listed in the table for areas in which they are particularly prominent.

STUDY AREAS AND NATIONAL UPLAND LAND CLASSES

2.36 In the third approach to setting the study areas in geographic context they have been considered in relation to the distribution of national upland land classes. The variation in land character in the uplands of England and Wales was simplified in ITE (1978) by an analysis of mapped physiographic, climatic and soil characteristics recorded for 10 x 10 km grid square units. This analysis determined the main environmental gradients present in the data for all the grid squares and defined, in a provisional national upland land classification, 8 classes, 4 of 'high upland' and 4 of 'marginal upland'. The initial division of the classification was comparable

TABLE 2-5 CONTEMPORARY LAND USES PROMINENT IN THE STUDY AREAS

Land Use Category	Study Area											
	AL	LU	SS	BR	HE	MH	LL	YY	GL	YG	LY	WB
Agriculture[1]			**	**	**	***	**		**	**	**	**
Sport		*	*	*	*						*	
Forestry	*			*			*	*	*	*		*
Woodlands					*		*			*	*	*
Water		*	*		*			*				
Recreation			*		*		*			*	*	*
Conservation	*	*	*	*				*		*	*	*
Defence	*	*										
Mineral Workings		*	*					*		*		

1 Agriculture is emphasised only where intensive use dominates substantial sectors (**) or all the study area (***)

to that mentioned earlier (2.3), as made on a simple altitudinal basis to give upland 'core' and 'marginal' categories. The class characteristics are summarised in Table 2-6, where they are listed in approximate order of decreasing environmental severity. The relationship of the study areas to these classes is given in Table 2-7. It is seen that the majority of land in the study areas falls into sectors classified in the 'high upland' national land classes. Only Widecombe, and to lesser extents Lynton and Alwinton, fall in part into 10 x 10 km squares classified nationally as marginal uplands.

2.37 Land composition of the study areas in respect of these national upland classes compared with the uplands as a whole (Table 2-8) shows that there is a reasonably balanced representation of 3 of the 4 high upland classes and an over representation of 'Western High Upland'. The under representation of the 'marginal upland' classes, which have a relatively high potential for agriculture, is not critical to the present study. It is probable that in the majority of such areas most options for gradual change in land-use and vegetation have been pre-empted by past land use adjustment, or remain available only in localities where the survival of semi-natural vegetation is for reasons other than limited land-use potential.

CONCLUSION

2.38 Analysis of the physiographic, climatic, geological and soil characteristics of the study areas shows the range of land character which they contain. The study areas represent the main range of conditions in the 'core' uplands of England and Wales, although it is only Widecombe and, less markedly, Lynton which include to a significant degree the relatively low altitude and gentle relief terrain of the 'marginal' national upland classes.

2.39 A wide spectrum of upland rocks and soils are strongly represented. Climate ranges from relatively cold, dry conditions in Alwinton, and also cold but wetter conditions in Lunedale and Shap, through to a relatively warm, dry climate in Glascwm, and relatively warm but wet conditions in Llanfachreth and Ystradgynlais. These environmental features are primary controls which affect the patterns of vegetation, present and future, and of land-use in the study areas, recognising that vegetation and land-use interact with each other, and that local land-use is influenced also by social and economic factors. The primary environmental characteristics of the study areas are reflected in the 'quality' of land they contain, as assessed by the Agricultural Land Classification. This range runs from a dominance of the lowest grade (Grade 5) in Lunedale, Alwinton, Ysbyty Ystwyth and Ystradgynlais, to a high

TABLE 2-6 LAND CLASSES IN A PROVISIONAL NATIONAL UPLAND CLASSIFICATION FOR ENGLAND AND WALES

National Land Class	General Characteristics	Major Regions in Which the Class is Most Prominent	Study Areas with High Proportion of Class
Montane Upland	Very high altitude, very strong relief, very steep slope, very high rainfall, low settlement density. ALC 5.	Lake District, Snowdonia	
Western High Upland	High altitude, strong relief, steep slopes, high rainfall, low settlement density. ALC 5.	Central Pennines, Lake District, Snowdonia, Cambrian Mountains, Brecon Mountains, Exmoor.	LU, LL, YY, YG, LY
Midland High Upland	Moderately high altitude, moderate relief, steep slopes, moderate rainfall, moderate settlement density. ALC 4 and 5.	Southern Pennines, Peak District, Cambrian Mountains, Radnor-Clun Forests, Brecon Mountains.	MH, GL
Northern High Upland	Moderately high altitude, moderate relief, gentle slopes, moderate rainfall, moderate settlement density. ALC 4 and 5.	Northern, Central, and Southern Pennines, North York Moors, Dartmoor.	AL, SS, BR, HE
Southwestern Marginal Upland	Low altitude, low relief, gentle slopes, moderate rainfall, high settlement density. ALC 3 and 4.	Cambrian Mountains, South Wales Coalfield, Exmoor, Dartmoor.	
Midland Marginal Upland	Low altitude, moderate relief, gentle slopes, low rainfall, high settlement density. ALC 3 and 4.	Radnor-Clun Forests, Shropshire Hills.	WB
Northeastern Marginal Upland	Low altitude, low relief, gentle slopes, low rainfall, high settlement density. ALC 3 and 4.	Cheviot, North York Moors, Central and Southern Pennines, Peak District.	
Southern Marginal Upland	Very low altitude, low relief, moderate slopes, low rainfall, high settlement density, ALC 2 and 3.	Shropshire Hills.	

TABLE 2-7 EXTENT OF STUDY AREAS IN NATIONAL UPLAND LAND CLASSES

National Land Class (see Table 2-6)		Study Area											
		AL[1]	LU	SS	BR	HE	MH	LL	YY	GL	YG	LY	WB
Montane Upland	(5)[2]	9		21				1			4		
Western High Upland	(6)		77	24				99	100		96	82	
Midland High Upland	(7)		14			43	100			100			
Northern High Upland	(8)	41	9	55	100	57							40
Southwestern Marginal Upland	(2)											18	
Midland Marginal Upland	(1)												60
Northeastern Marginal Upland	(4)	7											
Southern Marginal Upland	(3)												

1 Part of Alwinton lies in 10 x 10 km grid squares that fall mainly in Scotland, which were not classified in the provisional upland classification for England and Wales.

2 National land class reference numbers used in Table 2-8.

TABLE 2-8 REPRESENTATION IN THE UPLANDS OF ENGLAND AND WALES AND IN THE STUDY AREAS OF THE NATIONAL UPLAND LAND CLASSES

	National Upland Class[1]							
	5	6	7	8	2	1	4	3
Percentage Occurrence of Provisional National Upland Classes in the Uplands of England and Wales (on 10 x 10 km grid square basis)	7	16	16	22	13	8	15	9
Percentage Occurrence in Study Areas	6	44	14	30	1	4	1	0
Ratio $\frac{\text{Occurrence in Study Areas}}{\text{Overall Occurrence in Uplands}}$	0.9	2.8	0.9	1.4	0.1	0.5	0.1	0

1 Class numbers as given in Table 2-7

proportion of Grades 4 and 3 in Monyash, Glascwm, Lynton and Widecombe. The current intensity of agricultural use in the study areas, shown by the extent of tillage, improved grassland and rough grazing, is closely correlated with the grade and extent of the agricultural land classes. A wide range of upland land-uses as well as agriculture is represented in the study areas.

2.40 The extent to which the study areas are representative of the wider geographic regions in which they occur has not been investigated in detail. However, comparison of environmental and land-use features shows that 7 of the areas have characteristics similar to the average for their regions. Of the remaining 5; Alwinton, Lunedale and Ysbyty Ystwyth tend to have higher altitudes and steeper slopes with an associated less intensive agriculture than their respective regions as a whole, while Monyash and Widecombe have less high ground, but gentler slopes and more intensive agricultural use than is general for their regions.

2.41 With an acceptance that the study areas represent a reasonable general sample of the parts of the uplands of England and Wales in which vegetation change remains a prominent option, it is possible to turn to the heart of this study: the upland vegetation of the grassland-moorland sequence, and its relationship to land, land-use history and management.

3 VEGETATION

INTRODUCTION

3.1 Although small pieces of land with rare plant communities or species are often of critical interest from a conservation viewpoint it is in general the widespread more common vegetation which has the maximum landscape impact in the uplands. Woodlands which may be prominent in lower altitude marginal uplands, but only minor components of most higher upland vegetation, are considered briefly later (3.25-3.31). Gradual change between the common elements of the grassland-moorland upland vegetation spectrum is the main theme of this study. As a basis for considering such change it is not only necessary to have detailed records of vegetation composition in the sample of the uplands represented by the study areas, but to be able to identify classes within this vegetation range as a means of simplifying discussion.

3.2 ITE (1978) included description of broad categories of the vegetation of sub-montane grasslands, moors and bogs and the main ways in which these could change, but the categories used were not drawn from detailed data or a comprehensive classification of the vegetation range likely to be met between cultivated grassland and little-modified moorland. The system of identification of vegetation mapping units used by ULS* is based on an estimate of the percentage cover of key species, that is the proportion in which these key species are noted by eye as dominating the character of an assemblage. Change however can depend on the presence of species which are not conspicuous in cover estimates (see 5.58). This fact, and the greater reproducibility over a wider range of season that is possible in assessments of vegetation based on species presence, compared to the more subjective and seasonally variable estimates of cover, decided the use of species presence records in this report. It may seem surprising that no existing classification was available to pigeon-hole the vegetation of the recorded sites into a convenient number of categories. Parts of the spectrum of British upland vegetation have been described in detail by a number of authors (eg Mcvean & Ratcliffe 1962; Birks 1973), and an important National Vegetation Classification study is at present in progress at various centres under contract to the Nature Conservancy Council but the only available classification which might have been appropriate for use here was that of Evans, Hill and Ward (1977). The vegetation they covered (see also Hill & Evans 1978) extends beyond the range of habitats in our investigation to include more montane categories but, at the other end of the spectrum, it does

*Pårt II includes copies of the ULS vegetation maps of the study areas by G. Sinclair not include the cultivated grasslands. In order to cover the full range of grassland-moorland vegetation prominent in the landscapes of the study areas and hence, hopefully, most of the widespread vegetation classes in the uplands of England and Wales as a whole, a new classification has been produced based on plant species lists recorded at 938 sites in the study areas. The new classification, where it overlaps with that of Evans, Hill and Ward, gives broadly similar results to the latter with no substantial discrepancies (see Appendix 1).

Main Sites

3.3 The vegetation record which is at the centre of this study involved field observations at a minimum of 70 'main site' locations in each study area, to give adequate representation of the vegetation range. Main sites describe those locations at which vegetation was recorded to sample the farmland-moorland range, and they are so termed to identify them from a smaller number of woodland and roadside verge sites also recorded and from some supplemental grassland-moorland sites examined later (5.66). Because the study areas differed sharply in size (by a factor of almost 7 between Heptonstall and Alwinton, see Table 1-1) the density of main sites in each area varies considerably since their total number was kept comparable in each area. The basis for spacing and location of sites was the 1 km^2 grid. On 1:25 000 Ordnance Survey maps a rough division of each area was initially made into sectors quite uniformly dominated by farm fields or by open moor, and a complex intergrade zone between these. Where because of study area size it was necessary to spread recording sites relatively widely, a greater emphasis was placed on sampling the intergrade zone than the more uniform farmland and moor sectors. The number of main sites per km^2 or number of km^2 per site was adjusted to give the order of 70-80 main sites in each area (Table 3-1, and see maps in Part II for site locations), apart from larger numbers recorded in Bransdale and Shap, two of the first areas worked in. The locations of main sites to be recorded were marked on the 1:25 000 OS maps before field work took place, rather than being subjectively chosen on the ground.

Woodlands

3.4 Between 10 and 15 woodland sites were also examined in each area (Table 3-1). This number was often sufficient to sample all woodlands in a study area, but for the few more wooded areas it gave a selection of the possible woodlands.

TABLE 3-1 NUMBERS OF SITES AT WHICH VEGETATION WAS RECORDED

Study Area		Number of Sites at Which Vegetation was Recorded in: Farmland and Moorland 'Main Sites'	Woodland Sites
Alwinton	(2)	80	10
Lunedale	(2)	79	10
Shap	(1)	115	12
Bransdale	(1)	88	15
Heptonstall	(1)	70	14
Monyash	(2)	72	10
Llanfachreth	(2)	72	15
Ysbyty Ystwyth	(2)	75	10
Glascwm	(1)	71	11
Ystradgynlais	(1)	70	12
Lynton	(2)	71	12
Widecombe	(1)	75	13
Total Number of Sites		938	144

Year in which vegetation site data were recorded: (1) = 1977
(2) = 1978

DATA COLLECTION: SAMPLING IN THE FIELD

3.5 In the field, attention was paid to ensuring that each recording location was accurately identified from the point marked on the 1:25 000 map, so that the record would refer to a site that it should be possible to relocate with reasonable accuracy for future monitoring. In a few instances the original marked location straddled a major management boundary or was, for example, situated in a growing crop and not located in grassland or moorland vegetation. Such sites were relocated to the nearest suitable point. At each main site, plant species present were recorded from a series of 6 concentric quadrats running progressively in size up from 1 m^2 to 5 000 m^2. The analysis discussed here was based on the final plant list from the 5 000 m^2 quadrat at each site, since this size is more appropriate to vegetation pattern in the landscape than are the smaller quadrats, although in some cases it inevitably combined a mosaic of vegetation.

3.6 Reasonable efforts were made to identify all plant species in the field, particular care being taken to ensure that field surveyors were consistent in their identifications and had back-up field herbaria for the identification of difficult species. A standard list of 198 species (Appendix 2) was adopted for field use at main sites in order to avoid emphasis on rarities in the field and in analysis, while covering all expected widespread species. Species which present particular identification problems were amalgamated in this list. Appendix 3 shows the field sheets used, 3a being that for species at the main sites, coded as numbered in Appendix 2. The procedure was to record all species present in the m^2 quadrat, then move progressively through the larger quadrat sizes, noting additional species only. This standard programme ensured a thorough search for species in a convenient way. Cover data, noted in 3.2 as not having been used in this report, were also recorded on this part of the field sheet (see 3.8). Woodland data, covering all species present in quadrats up to 200 m^2, were recorded on a similar sheet (Appendix 3c) and a small number of roadside verge sites were also recorded (Appendix 3d) for strips 10 x 1 m in length, though little use has been made of these last data (3.32).

3.7 Site information (Appendix 3b) was also listed for the main sites, covering notes on the presence of such conspicuous ground surface features as boulders, ditches, tracks and evidence of burning. These notes are drawn on in the later summary descriptions of vegetation classes if a class is associated generally with particular ground features. A specialist record of soil type at each site was not possible but again limited notes, based on rapid assessments of soil texture, depth and drainage, were made. Four samples of the surface zone (0-10 cm depth) of the soil at each site were taken from the corners of the 200 m^2 vegetation recording quadrat to be used for laboratory determination of soil acidity, this being the most easily obtainable single quantitative soil chemical measure with which to correlate vegetation class occurrence.

VEGETATION CLASSIFICATION

3.8 Species presence and species cover data sets for the vegetation records from the 5 000 m^2 quadrats at 938 main sites were analysed separately by computer to give classifications using Indicator Species Analysis (ISA). Appendix 4 gives a summary of this method which is more fully considered by Hill, Bunce and Shaw (1975). Although the cover data undoubtedly include material that it would be interesting to study (it is hoped later to be able to compare species presence and cover data and classifications from these sites) the classification based on species presence data is used as the sole basis for discussion in this report. The vegetation groups and classes of this classification provide a simplified means of discussing associations between vegetation and the characteristics of land and management which control it, but the vegetation detail contained in a full species list from a site may also often require consideration in assessing that site's individual potential for change. The same vegetation class, which can occur with or without a particular minor species, may respond to the same management by a different direction, or at least rate, of vegetation change, as mentioned later (5.58-59) for a situation in Snowdonia. Thus, although the principles of gradual change in relation to environment and management are discussed in this report largely with emphasis on the changes between vegetation classes, a species list (Appendix 2) (or at least an abbreviated form of this, see 3.10) is an essential element to assess fully the potential changes possible on any particular site. A separate classification of the woodland sites was drawn from a wider national woodland scheme, and this is discussed later (3.24-31) after consideration of the main site classification of the grassland-moorland range based on species presence.

MAIN SITE VEGETATION CLASSIFICATION

3.9 Sixteen vegetation classes have been established from ISA of the species presence data from 938 main site vegetation records in the 12 study areas. The classes fall into 4 broad groups named as Improved pastures; Rough pastures; Grassy heaths; and Shrubby heaths. The first 2 of these are a farmland element in the vegetation range, the others a moorland element. Table 3-2 gives the classes in each of these groups, arranged in an order intended to emphasise the ecological relationships between the classes as they are outlined in paragraphs 3.11-3.17. The class numbers are those allocated by the classification analysis and are included here to allow them to be used for brevity in discussion later. The classes have been given descriptive names based on prominent species in them. Appendix 5 lists the species which characterise each class, ordered alphabetically in 'constancy groups'. Constancy

TABLE 3-2 VEGETATION CLASS COMPOSITION OF MAIN SITE VEGETATION GROUPS (BASED ON SPECIES PRESENCE CLASSIFICATION)

Group 1 Improved Pastures	Group 2 Rough Pastures	Group 3 Grassy Heaths	Group 4 Shrubby Heaths
Herb-rich *Lolium* grassland, Class 4	*Agrostis/Holcus* grassland, Class 7	*Festuca/Nardus/ Vaccinium* heath, Class 15	*Calluna* heath, Class 13
Lolium grassland, Class 2	*Agrostis/Juncus* grassland, Class 5	*Festuca/Nardus/ Molinia* heath, Class 16	*Calluna/Molinia Vaccinium* heath, Class 9
Lolium/Trifolium grassland, Class 3	*Festuca/Agrostis* grassland, Class 8	*Festuca/Vaccinium* heath, Class 14	*Vaccinium/Callun* heath, Class 10
Lolium/Holcus/ Pteridium grassland, Class 1	*Festuca/Juncus* grassland, Class 6		*Nardus/Sphagnum/ Calluna* heath, Class 11
			Eriophorum/Callur heath, Class 12

is the frequency of occurrence of a species in all sites falling in a class - ie if a species occurs at all sites in a class its constancy is 100% while if it occurs at half of them, its constancy is 50%. Constancy groups below 20% are not listed in Appendix 5. The details of the species composition of vegetation classes in Appendix 5 amplify their brief description in this chapter, allow a direct comparison of any additional site plant list with the average for a class; and enable the classes to be located in which key species that are considered in Chapter 5 (Table 5-11) in relation to management effects occur prominently. The total number of plant species recorded in each vegetation class is given also in Appendix 5. As a group, rough pastures contain the most species and shrubby heaths the fewest. The range of vegetation types through from improved pastures to shrubby heaths follows a sequence of diminishing management intensity. Management effects become less overriding, and site land characteristics more prominent in their impact, towards the shrubby heath end of the spectrum. There is a particular barrier between rough pastures and improved pastures along the trend of agricultural improvement because agricultural grass species have to be introduced in addition to the native species. Paragraphs 3.11 to 3.17 summarise the vegetation classes in each group.

3.10 A key to this classification that can identify the appropriate vegetation class at any upland grassland or moorland site for which a plant species list is available is given in Appendix 6. It will be seen that the key can be operated with a record of the 75 key species which emerge from ISA as those which lead to division through this clasification down to the 16-class level. This list provides an alternative to recording the full 198 species of Appendix 2 that were initially used to create the classification, though the full list of course provides more detail. It would be reasonable to consider the key as applicable to most upland grassland or moorland sites below say 900 m (that is omitting the most montane situations) within England and Wales and at least the southern uplands of Scotland, since these regions will be within the general range covered by the study area sites.

Improved pastures (Group 1, classes 1-4)

3.11 The 4 classes which comprise the improved pastures constitute 27% of the recorded sites. They are characterised by the presence of introduced species of high agricultural value, eg Lolium perenne (Rye-grass), Dactylis glomerata (Cock's-foot) and Trifolium repens (White Clover), together with a range of herbs. Agriculturally undesirable species may occasionally be present, such as Pteridium aquilinum (Bracken), Juncus spp. (Rushes), and Cirsium spp. (Thistles), depending partly on environmental factors such as soils, drainage and physiography, and partly on management. Class 4 is the most frequent improved pasture and has the strongest lowland relationship. This is reflected in its prominence in Monyash, Glascwm, Lynton and Widecombe. Vegetation classes 3 and 1, in which the lowland element is more dilute, are notably absent from Monyash. Group 1 as a whole is naturally weakest in those study areas (Alwinton, Lunedale, Llanfachreth and Ysbyty Ystwyth) which are more strongly moorland in character. The classes in this group can be considered as a sequence from class 4 which is the most productive pasture, through classes 2 and 3 which are progressively poorer in quality because of their increased 'weed' content, to class 1, the improved pasture class with fewest recorded species. Class 1 forms a link between 'improved' and 'rough' pastures. The sequence within the improved pastures group represents responses to the interaction of inherent site fertility, management intensity, and the time that has elapsed since the grasslands were last reseeded.

3.12 Class 4: Herb-rich Lolium grassland. This class, which is likely to include recently re-sown swards, is dominated by Lolium perenne and has a range of agricultural weeds present. Trifolium repens and Dactylis glomerata are other prominent species.

Class 2: Lolium grassland. Lolium perenne is also the dominant species in this class but Agrostis tenuis (Common Bent-grass) and Holcus lanatus (Yorkshire Fog) are present as the 2 major co-dominant species. The class includes some land utilised for hay meadows.

Class 3: Lolium/Trifolium grassland. Lolium perenne and Trifolium repens are co-dominant species characterising this class. There is a tendency towards drainage impedence which is reflected in the presence of thistle and rush species.

Class 1: Lolium/Holcus/Pteridium grassland. This class is generally to be found on shallower soils than other improved pastures. Rocks and boulders are typically present on the surface. Lolium perenne and Holcus lanatus are the co-dominant species with Pteridium aquilinum present as an invading species. Trees and scrub are present on many sites.

Plates 19-22 illustrate contrasting locations of improved pastures and a close-up of class 4.

Rough pastures (Group 2, classes 5-8)

3.13 The 4 'rough pasture' classes, covering 16% of the recorded sites, are found under less intensive management than the improved pastures. The group is characterised by the prominence of species such as Agrostis tenuis and A. canina (Brown Bent-grass), Festuca ovina (Sheep's Fescue), Juncus spp. and other coarser species. The content of introduced species is generally reduced compared to the improved pastures and these species, if still present, occur only at low constancies, ie less consistently. Lower soil fertility (assessed from soil acidity) is also characteristic, and poor drainage is frequent. Almost half the rough pasture sites are Festuca/Agrostis grassland (class 8), which occurs in all the study areas except Lynton. The classes in this group can be ordered ecologically to run from class 7, which occurs on well drained soils and contain some herbs typical of higher quality agricultural grassland, through classes 5 and 8 in which herbs become less frequent and there may also be some degree of drainage impedence. Class 6 is agriculturally the poorest end of this range, with a notable increase in coarser species and drainage impedence common. Juncus effusus and Juncus articulatus both have high constancy levels in this class, with other species associated with poor drainage also present.

3.14 Class 7: Agrostis/Holcus grassland. The dominant grasses are Agrostis spp. and Holcus lanatus. This class contains a variety of herbs and is confined to well drained soils mainly on moderate slopes (range 6-11°). The pH data show a higher proportion of less acid soils in this class than in the other rough pastures. Species diversity is high (188 species recorded). Trees are typically present, as are also some surface rocks and boulders.

Class 5: Agrostis/Juncus grassland. This class and class 6 are similar in many respects and the latter is probably a wetter phase of this vegetation class. Herb-rich flushes are a feature, while bracken, brambles and scattered trees are fairly frequent. Species diversity (189 species recorded) is again high.

Class 8: Festuca/Agrostis grassland. Festuca ovina and Agrostis tenuis are the co-dominant grass species of this class. Lolium perenne occurs at 20-40% constancy. Soils are fairly shallow and slopes mainly moderate. A higher proportion of soils with low pH (ie acid soils) were present in this than in other rough pasture classes. Some species of wet habitats often occur, eg Juncus effusus. There are generally rather fewer trees and surface rocks and boulders present on sites of this class than at those of other rough pasture classes.

Class 6: Festuca/Juncus grassland. The main feature which distinguishes this class from the Agrostis/Juncus grassland (class 5) is the frequent presence of more coarse grass species, including Deschampsia cespitosa (Tufted Hair-grass), Agrostis canina/stolonifera (Brown Bent-grass/Creeping Bent-grass) and Nardus stricta (Mat-grass). Slopes also tend to be slightly steeper and soil pH somewhat lower than for class 5, while peaty soils were noted more frequently than for the other rough pasture classes.

Plates 23-29 show typical sites and vegetation of rough pasture classes 5, 8 and 6. Plate 43 shows a management contrast between pasture classes.

Grassy heaths (Group 3, classes 14-16)

3.15 Grassy heaths, consisting of 3 classes, are characterised by the dominance of coarse grasses such as Nardus stricta, Deschampsia flexuosa (Wavy Hair-grass), Molinia caerulea (Purple Moor- grass), and the presence of a secondary shrubby element, consisting of mainly ericaceous species, that links the group with the shrubby heaths. Rushes and bracken may also be present. In the grassy heaths as a whole, Galium saxatile (Heath Bedstraw) shows a very high constancy, and Vaccinium myrtillus (Bilberry) is probably the most prominent of the shrubby species. Occupying 23% of the total sites recorded, this group is widespread through the study areas. Vegetation classes 14 and 16 have broadly similar distributions, but class 15, Festuca/Nardus/Vaccinium, shows a distinctly northern bias. The classes can be considered as running from class 15 in which the heath element is least in evidence, through 16 to class 14 in which it is the most prominent, this class forming a bridge to the shrubby heath group.

3.16 Class 15: Festuca/Nardus/Vaccinium heath. This class occurs typically on moderate to steep slopes, on sites that are drier than those of class 16 which it most closely resembles. As well as Festuca ovina and Nardus stricta, Deschampsia flexuosa is also a prominent grass, while Vaccinium myrtillus is a common associated species. The distribution of this class appears to be more northern than other shrubby heaths (88% of the sites classified in this class are in Bransdale or study areas north of Bransdale). Gullies and scree patches are landform features that are frequently present.

Class 16: Festuca/Nardus/Molinia heath. Wet upland grassy heath with relatively high species diversity (159 species recorded). Species characteristic of wet situations such as Carex nigra (Common Sedge), Eriophorum vaginatum (Cotton-grass), Juncus bulbosus (Bulbous Rush), Trichophorum cespitosum (Deer-grass), and Narthecium ossifragum (Bog Asphodel) are present. Surface water, as pools and streams, is frequent at sites of this class.

Class 14: Festuca/Vaccinium heath. This class is mainly found on gentle to moderate slopes with shallow soils and good drainage. Soil pH is relatively low for the group, the majority of sites being below 4.7. This is the typical dry grassy heath characterised by species such as Galium saxatile, Festuca ovina, Deschampsia flexuosa, Juncus squarrosus (Heath Rush) and Potentilla erecta (Common Tormentil).

Plates 31-34 show the appearance in close-up of vegetation classes 14, 15 and 16 and a typical site of class 16. The landscape contrast between moorland-grassland vegetation and planted conifers is illustrated in Plate 30.

Shrubby heaths (Group 4, classes 9-13)

3.17 Shrubby heaths consist of 5 classes occupying 34% of the recorded sites. They are characterised by the predominance of dwarf shrub species such as Calluna vulgaris (Heather or Ling), Vaccinium myrtillus, Erica cinerea and E. tetralix (Bell-heather and Cross-leaved Heath) and Empetrum nigrum (Crowberry), as well as Ulex spp. (Gorse), acidic grasses, sedges and rushes. The group is found on the poorer soils and at sites with the lowest intensity of management. Nardus/Sphagnum/Calluna heath (class 11) and Eriophorum/Calluna heath (class 12) are the most frequent and most widely distributed types of shrubby heath, whilst class 13, Calluna heath, shows a strong southern bias, with two thirds of its sites in Widecombe. The order in which the vegetation classes are set out here reflects both a trend of lower intensity of agricultural use and a reduction in the potential of the vegetation for easy modification through management.

3.18 Class 13: Calluna heath. Dry Calluna heath, with bracken present in some cases, was recorded mainly in the south-west, usually on rocky site with pockets of well drained soils. Ulex, present at a constancy of 80-100%, is conspicuous as large bushes in about a third of the samples in this group. Agrostis tenuis is the grass species of highest constancy but the other grasses of acidic soils are also prominent.

Class 9: Calluna/Molinia/Vaccinium heath. This rather species-poor (55 species recorded) type of heath is of limited occurrence and mainly located in Widecombe, Lynton and the South Wales areas, on relatively shallow soils. Calluna vulgaris is the dominant species but all the other common ericoids are also present. Five grass species occur in more than 60% of the sites in this class.

Class 10: Vaccinium/Calluna heath. Again a rather species-poor (65 species recorded) heath which mainly differs from class 9 in the presence of a less diluted shrubby heathland element. Only one grass species (Deschampsia flexuosa) occurs in more than 60% of the plots in class 10. Heathland surface attributes such as evidence of burning and eroding peat are conspicuous at sites in this class.

Class 11: Nardus/Sphagnum/Calluna heath. This mixed heath occurs on boggy moorland with coarse grasses (Nardus and D. flexuosa) present in most samples. Other species with moderately high constancy include Trichophorum cespitosum, Empetrum nigrum, Carex echinata (Star Sedge) and Narthecium ossifragum.

Class 12: Eriophorum/ Calluna heath. This class is a blanket bog community on deep peaty soils, most strongly represented in Lunedale among the study areas. Calluna vulgaris is dominant, with Eriophorum vaginatum and Deschampsia flexuosa co-dominant. Eriophorum angustifolium (Common Cotton-grass) and Sphagnum spp. (Bog Moss) are among the high constancy species.

Plates 35-42 illustrate the vegetation of classes 13, 10, 11 and 12 in close- up, with typical sites for these shrubby heaths. Plate 44 illustrates a management contrast between heath classes.

THE DIVERSITY OF VEGETATION IN THE STUDY AREAS

3.19 The identification of the vegetation groups and classes present at a known time at sites in each study area provides a baseline against which future re-recording at the same sites could give an overall view of the general scale of vegetation change that will have occurred in the upland study areas. The frequencies of the vegetation categories at sites in an area also can be used as a general guide to the vegetation range in that area and as a means of making comparisons between the areas. Table 3-3 gives the numbers of main sites in each vegetation class for each study area, while Figure 3-1 shows the percentage representation of the 16 vegetation classes, in their 4 groups, at the recorded sites in each study area. If vegetation diversity is simply assessed as the number of vegetation classes represented at main sites in each area, then the sequence of increasing vegetation diversity runs from the least diverse to the most diverse area as: Monyash less diverse than (<) Lunedale and Alwinton < Bransdale < Widecombe and Ysbyty Ystwyth < Glascwm, Lynton and Shap < Heptonstall < Llanfachreth and Ystradgynlais.

TABLE 3-3 DISTRIBUTION OF VEGETATION CLASSES AT MAIN SITES RECORDED IN EACH STUDY AREA

Study Area	Vegetation Group and Class																Total of sites in Study Area
	Group 1				Group 2				Group 3			Group 4					
	1	2	3	4	5	6	7	8	14	15	16	9	10	11	12	13	
Alwinton		4		1		4		18	13	11	4			11	14		80
Lunedale				1		2		7	1	13	2		1	6	46		79
Shap	2	9	1	10		6	3	7	6	5	28	2	2	30	4		115
Bransdale	1		4	5				10	16	1	13		31	5	2		88
Heptonstall	1	6	2	8	1	1	1	5	4		3	1	16	2	19		70
Monyash		29		32			8	3									72
Llanfachreth	3	1	1	2	3	2	9	7	5	1	16	1	1	11	3	6	72
Ysbyty Ystwyth	1	1	3				2	7	13		9	1	2	17	19		75
Glascwm	4	1	13	17	2	2	5	7	9	1	1		9				71
Ystradgynlais	1	1	3	8	7	1	2	2	15	1	11	1	5	8	1	3	70
Lynton	5	1	6	36	2	1	4		7	1	2	3		1		2	71
Widecombe	3	4	3	18	8	2	4	1	4			5				23	75
Total of Sites in Class	21	57	36	138	23	21	38	74	93	34	89	14	67	91	108	34	938

As number of main sites in each vegetation class in each study area

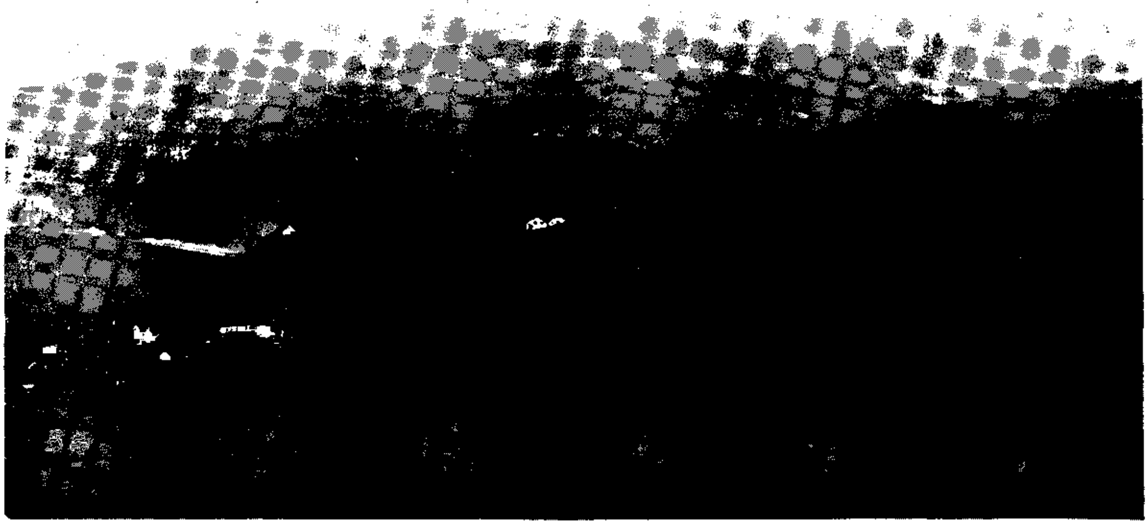


Plate 19 Lynton - Improved pastures of class 4 (Herb-rich Lolium grassland) on gentle slopes, in association with class 1 improved pastures (Lolium/Holcus/Pteridium grassland) on steeper slopes in the foreground. Steep-sided wooded valleys and coastal cliff sites with some grassy heaths are features of the Lynton landscape.
(Photo by P. Ainsworth).

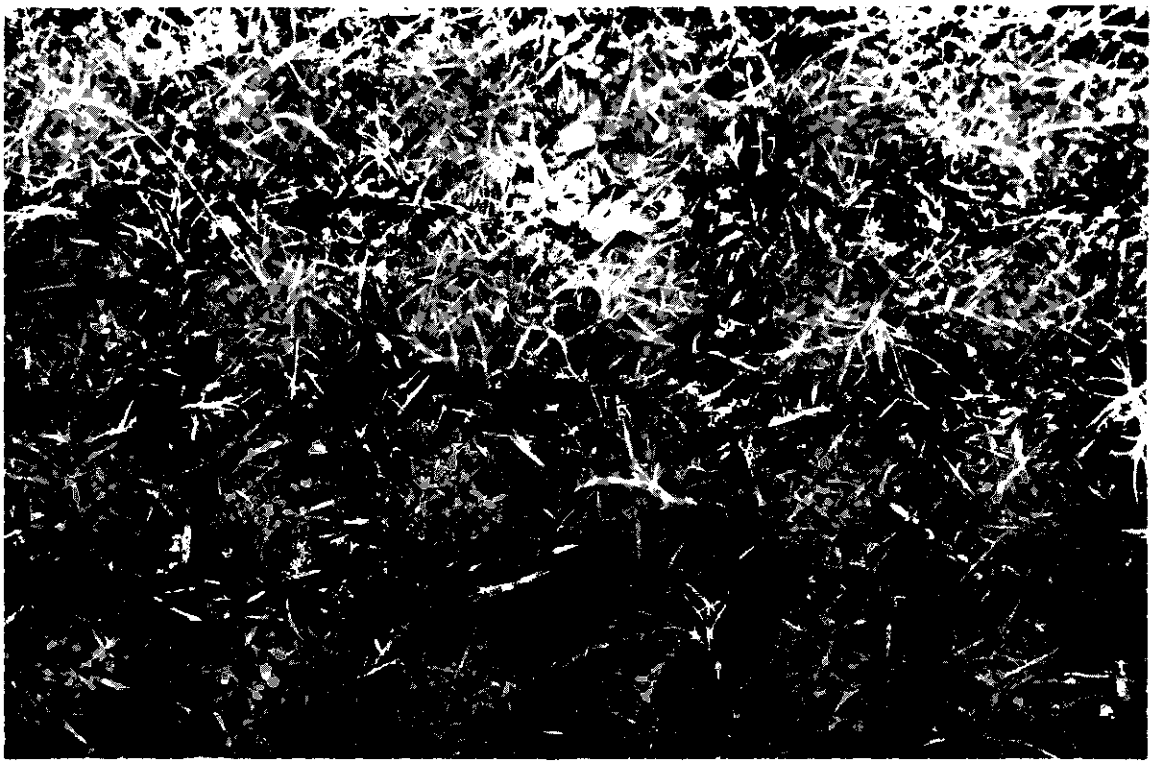


Plate 20 Close-up of improved pasture class 4 (Herb-rich Lolium grassland) at a Lynton site. Close grazing and a wide selection of herbs (e.g. Trifolium repens, Achillea millefolium and Plantago lanceolata) are characteristic.
(Photo by J. Dale).

Plate 21 Monyash - Improved pastures of similar character to those in Plate 19, (mainly class 4, Herb-rich Lolium grassland) in the contrasting landscape of Monyash, with its plateau landform, limestone outcrops and walls, and scattered trees, mainly ash.
(Photo by P. Ainsworth).

Plate 22 Widecombe - Improved pastures in a third area - the wooded landscape with hedge-bounded fields of the East Webburn valley near Widecombe village. In the left background there is moorland with heath vegetation above the fields.
(Photo by P. Ainsworth).

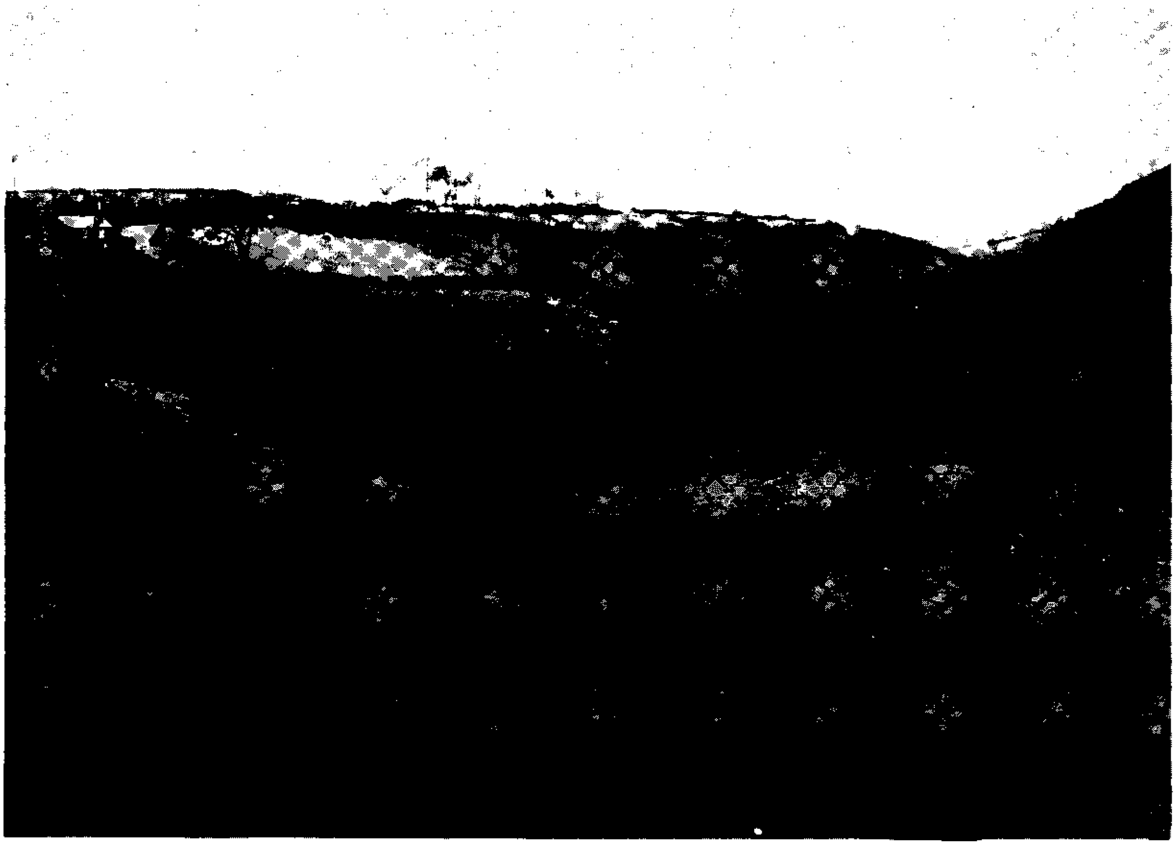


Plate 23 Lynton - Rough pastures of class 5 (Agrostis/Juncus grassland) in Ranscombe Combe in the west central sector of Lynton. Scrub woodland is developing on steeper ground.
(Photo by P. Ainsworth).

Plate 24 Close-up of rough pasture class 5 (Agrostis/Juncus grassland) at a Llanfachreth site. Characteristic species visible include Cirsium palustre, Potentilla erecta Rumex acetosa, Juncus spp. and Ranunculus spp.
(Photo by J. Dale).

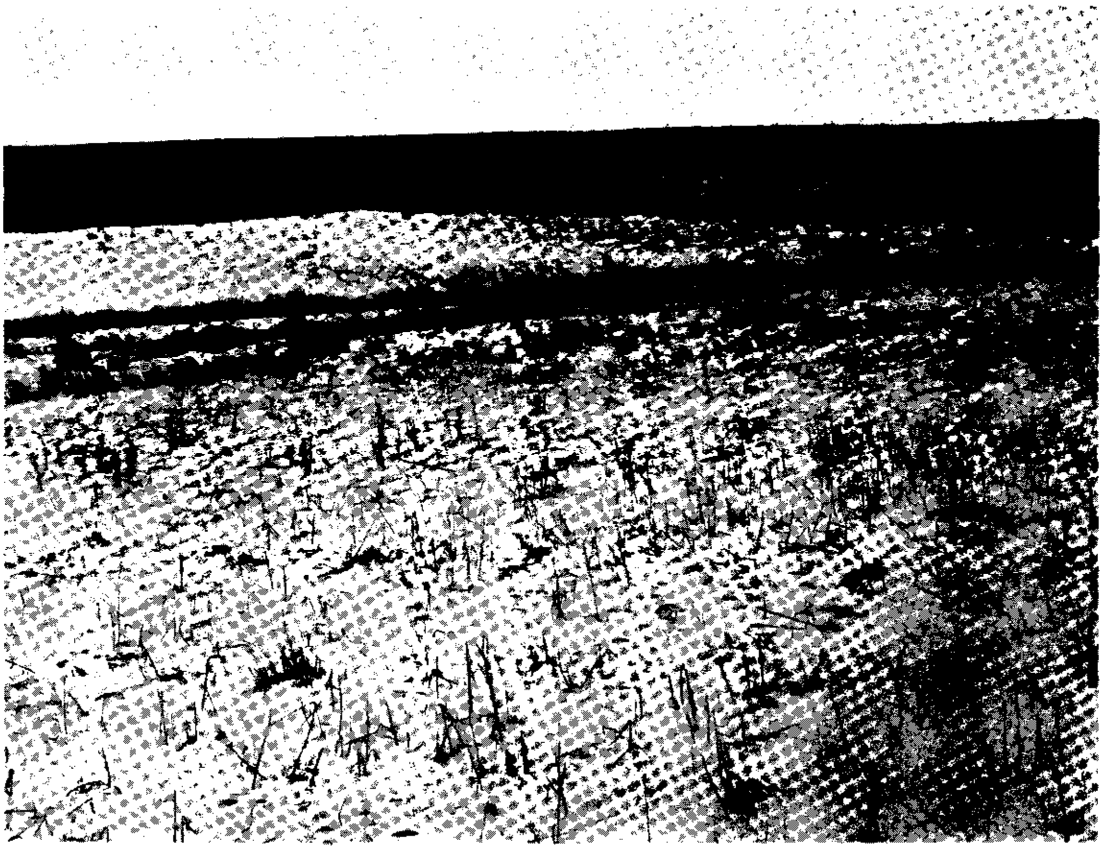


Plate 25 Bransdale - A winter view of rough pasture class 8 (Festuca/Agrostis grassland) with shrubby heath of class 10 (Vaccinium/Calluna heath) in the background. Snow enhances further what at other times is a strong contrast between yellow-green colours of the pasture and the darker hues of the heath. (Photo by P. Ainsworth).

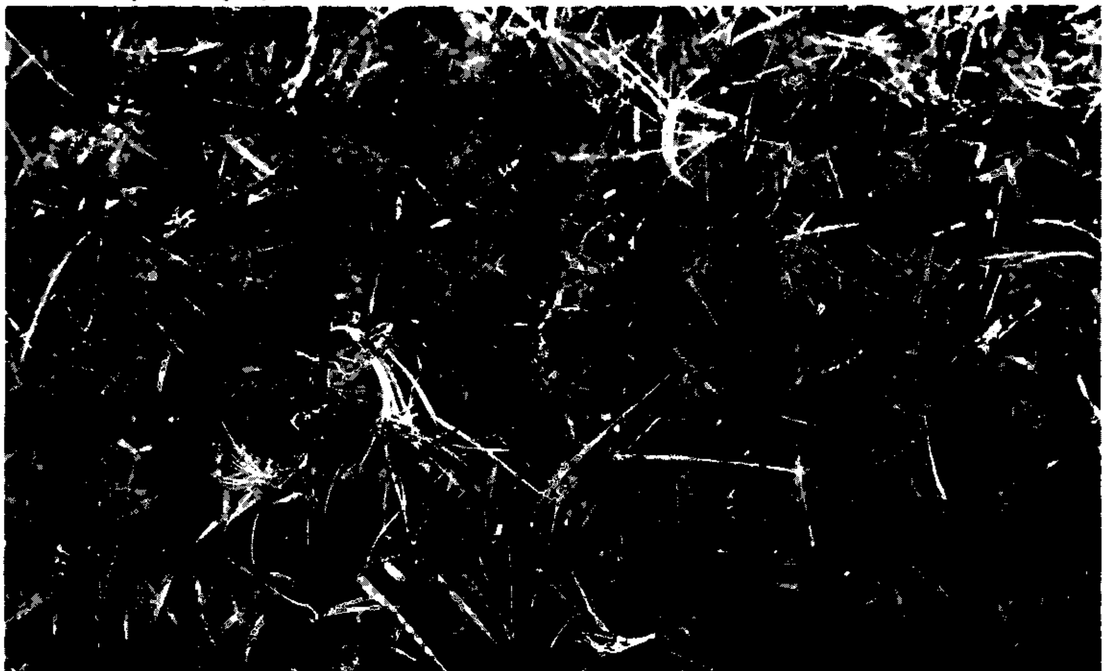


Plate 26 Close-up of rough pasture class 8 (Festuca/Agrostis grassland), the commonest rough pasture class, at a Bransdale site. A mixture of herb species is characteristic of one of the most widespread classes of upland vegetation. (Photo by J. Dale).

Plate 27 Heptonstall - Rough pastures of class 6 (Festuca/Juncus grassland) in the foreground. The conspicuous nettles (Urtica dioica) are not a general constituent of the class but are an invasive plant. The pattern of regular fields with stone walls, many supporting improved pastures, is typical of the Heptonstall farm landscape. (Photo by J. Dale).

Plate 28 Close-up of rough pasture class 6 (Festuca/Juncus grassland) at a Heptonstall site. The typical scattered clumps of rushes that characterise this and the similar class 5 (Agrostis/Juncus grassland) dot this grazed phase of the class (cf. Plate 41).
(Photo by J. Dale).

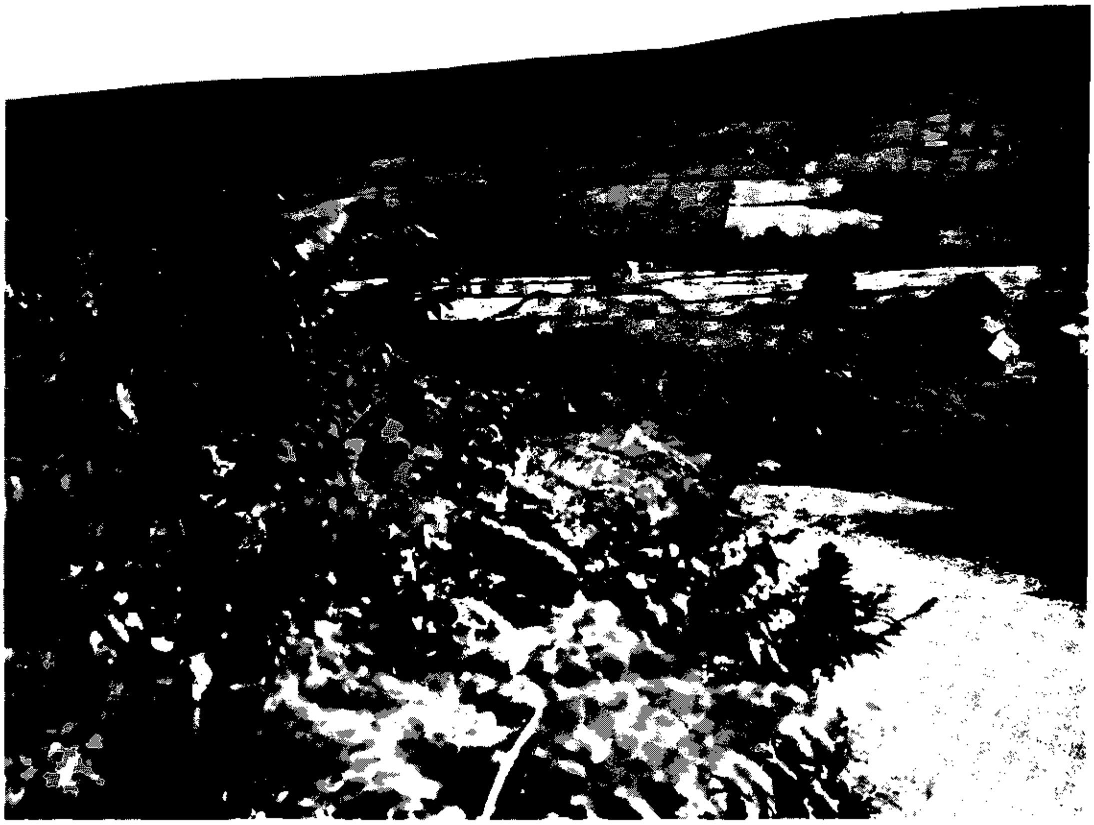


Plate 29 Bransdale - In the foreground, Festuca/Agrostis grassland (class 8) in its bracken-infested phase occurs along steep slopes adjoining the roadside. In the middle distance are farm fields with crops and improved pastures. On the upper slopes and ridge crest, shrubby heaths dominate the vegetation. (Photo by J. Dale).

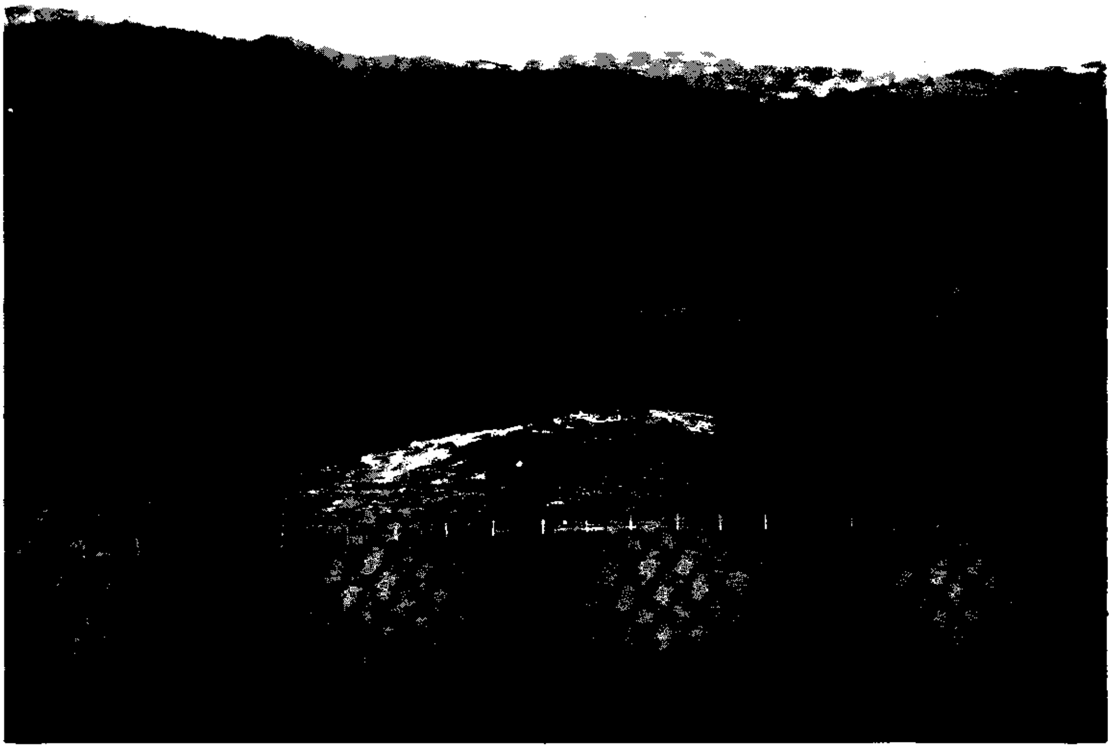


Plate 30 Ysbyty Ystwyth - A forestry plantation blankets the detail of relief and former vegetation contrasts that are still seen between the improved pastures of the foreground and the grassy heath beyond the fence. (Photo by P. Ainsworth).

Plate 31 Close-up of grassy heath class 14 (Festuca/Vaccinium heath) at a Glascwm site. Scattered bracken, as here, is present on some sites. Calluna vulgaris is a more conspicuous species in this class than in class 15. This is a widely distributed grassy heath.
(Photo by J. Dale).

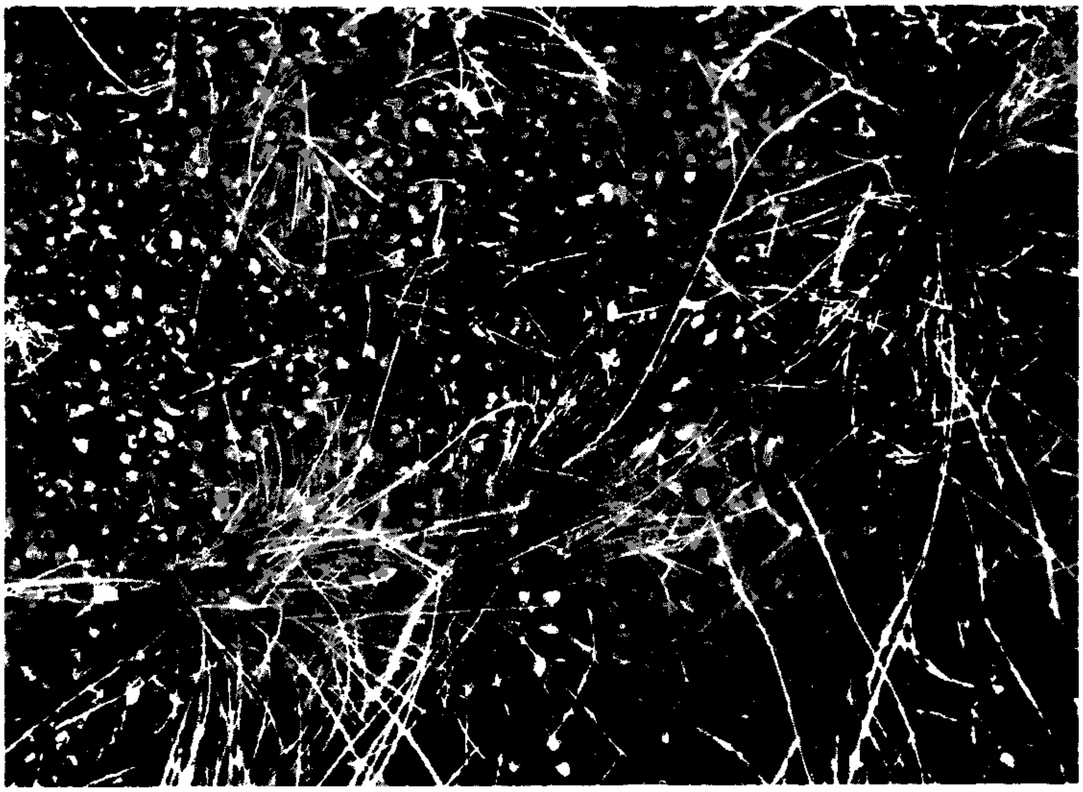


Plate 32 Close-up of grassy heath class 15 (Festuca/Nardus/Vaccinium heath) at a Lunedale site. Vaccinium myrtillus is prominent, as is Nardus stricta. This grassy heath class is more frequent in the northern study areas.
(Photo by J. Dale).

Plate 33 Ystradgynlais - The ground in the mid-distance and left background carries mainly grassy heath class 16 (Festuca/Nardus/Molinia heath). Rough pastures of class 5 (Agrostis/Juncus grassland) occur below the quarry, and there are improved pastures in the foreground fields.
(Photo by P. Ainsworth).

Plate 34 Close-up of grassy heath class 16 (Festuca/Nardus/Molinia heath) at an Ystradgynlais site. Dead leaves of Molinia caerulea are obvious, and the moss Polytrichum commune, a major constituent species of the class, is present in the left bottom corner.
(Photo by J. Dale).

Plate 35 Lynton - In the immediate foreground as well as to the left of the track and in the background, unimproved moor with shrubby heath class 13 (Calluna heath) is frequent. The enclosed improved fields of Shallowford Farm lie to the right of the road.
(Photo by J. Dale).

Plate 36 Close-up of shrubby heath class 13 (Calluna heath) at a Lynton site. Heather (Calluna vulgaris) is predominant, with gorse (Ulex spp.) a characteristic associate, and also heath (Erica) species.
(Photo by P. Ainsworth).

Plate 37 Bransdale - Shrubby heath class 10 (Vaccinium/Calluna heath) contrasts with the grazed and trampled verge which has Festuca/Agrostis grassland of rough pasture class 8.
(Photo by J. Dale).

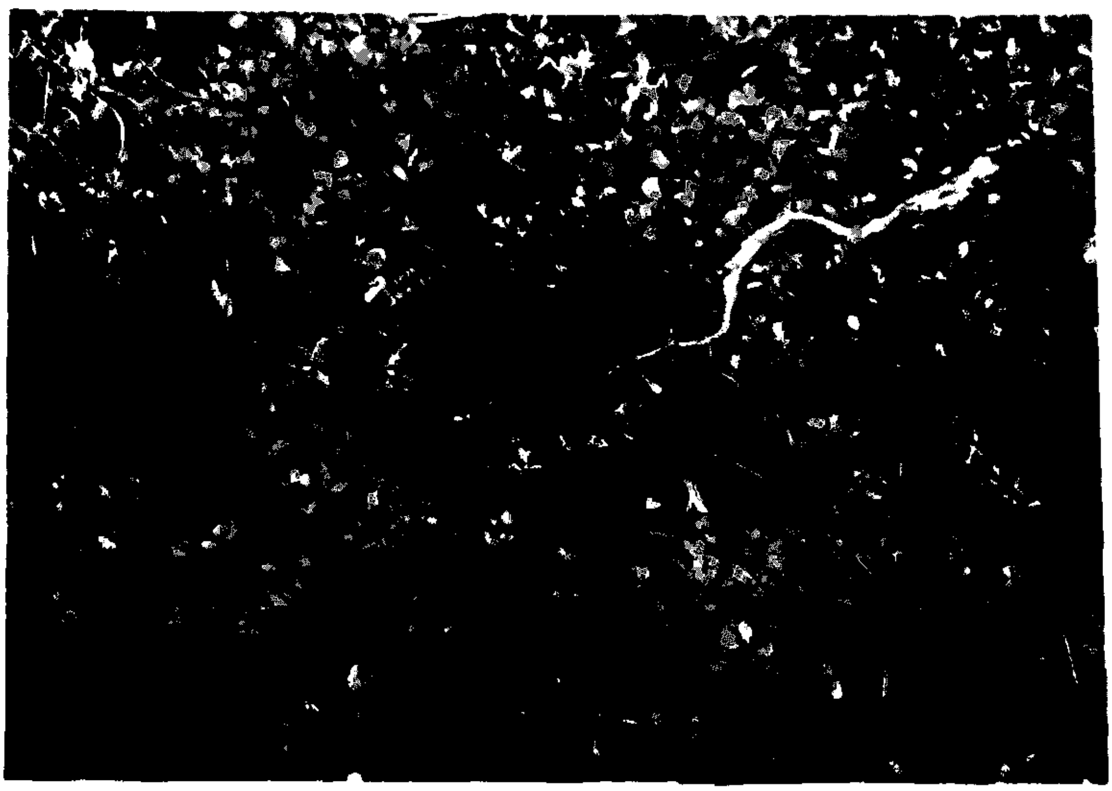


Plate 38 Close-up of shrubby heath class 10 (Vaccinium/Calluna heath) at a Bransdale site. This plate shows the V. myrtillus - dominant phase which can occur after burning (the dead stems are of former old heather).
(Photo by J. Dale).

Plate 39 Bransdale - Shrubby heath of class 11 (Nardus/Sphagnum/Calluna heath) on moorland at the southern end of Bransdale parish.
(Photo by P. Ainsworth).

Plate 40 Close-up of shrubby heath class 11 (Nardus/Sphagnum/Calluna heath) at a Lunedale site. This is the commonest shrubby heath class at the recorded sites typical of much wet moorland, as well as being most widely distributed.
(Photo by J. Dale).

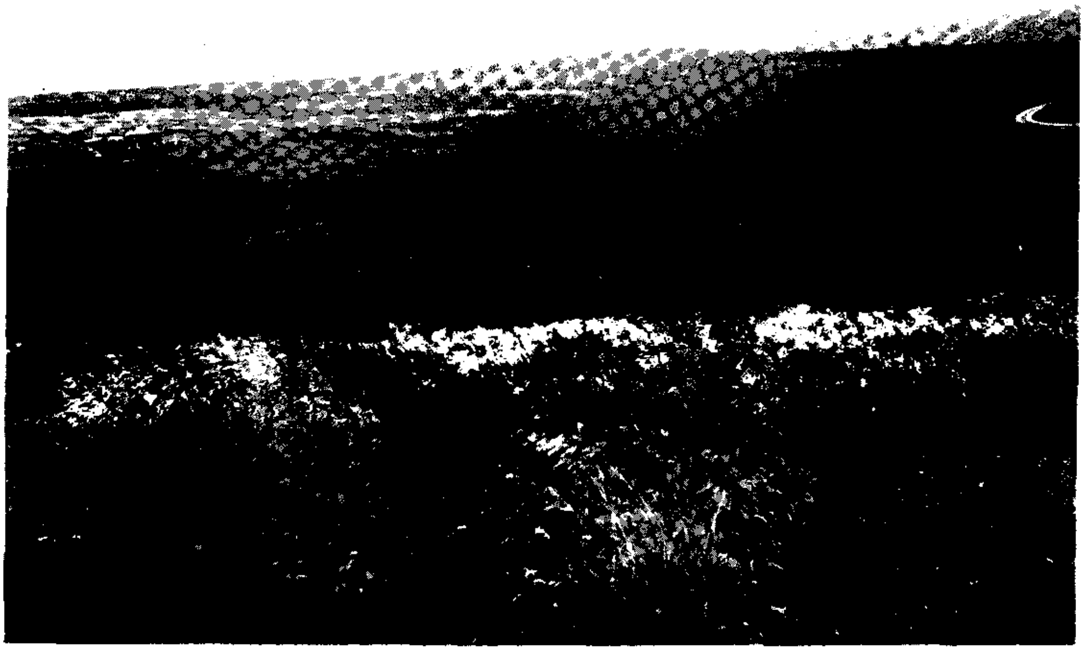


Plate 41 Heptonstall - In the foreground a lightly grazed phase of rough pasture class 6 (Festuca/Juncus grassland) (cf. Plates 27 and 28 for a heavily grazed phase of this class). Deshampsia cespitosa is conspicuous. Beyound the shallow ravine is an area of blanket bog with shrubby heath class 12 (Eriophorum/Calluna heath) (Photo by J. Dale).

Plate 42 Close-up of shrubby heath class 12 (Eriophorum/Calluna heath) at an Ysbyty Ystwyth site. This is a common and widespread heath class over the peaty moorland bogs.
(Photo by J. Dale).

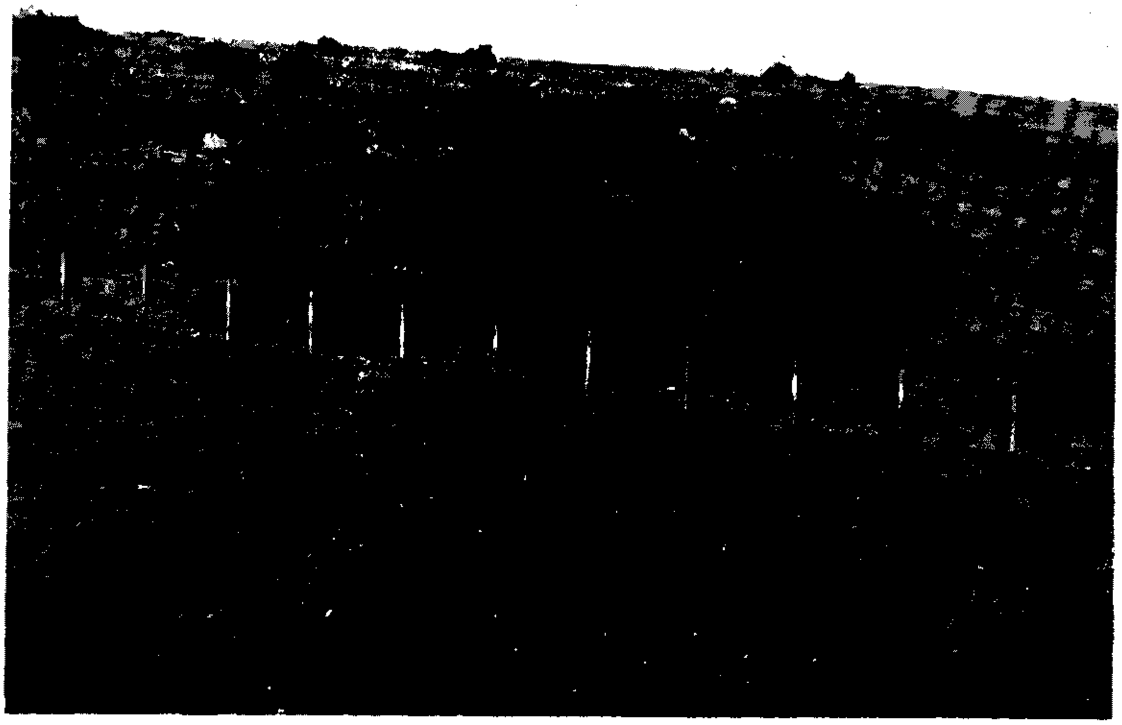


Plate 43 Shap - Management effects on grassland. Improved pastures produced by reseeding and cultivation and maintained by stocking are separated from rough pastures with much gorse (<u>Ulex</u> spp.). The rough pasture area may have shallower soils and boulders or outcrops but is potentially improvable agriculturally.
(Photo by P. Ainsworth).

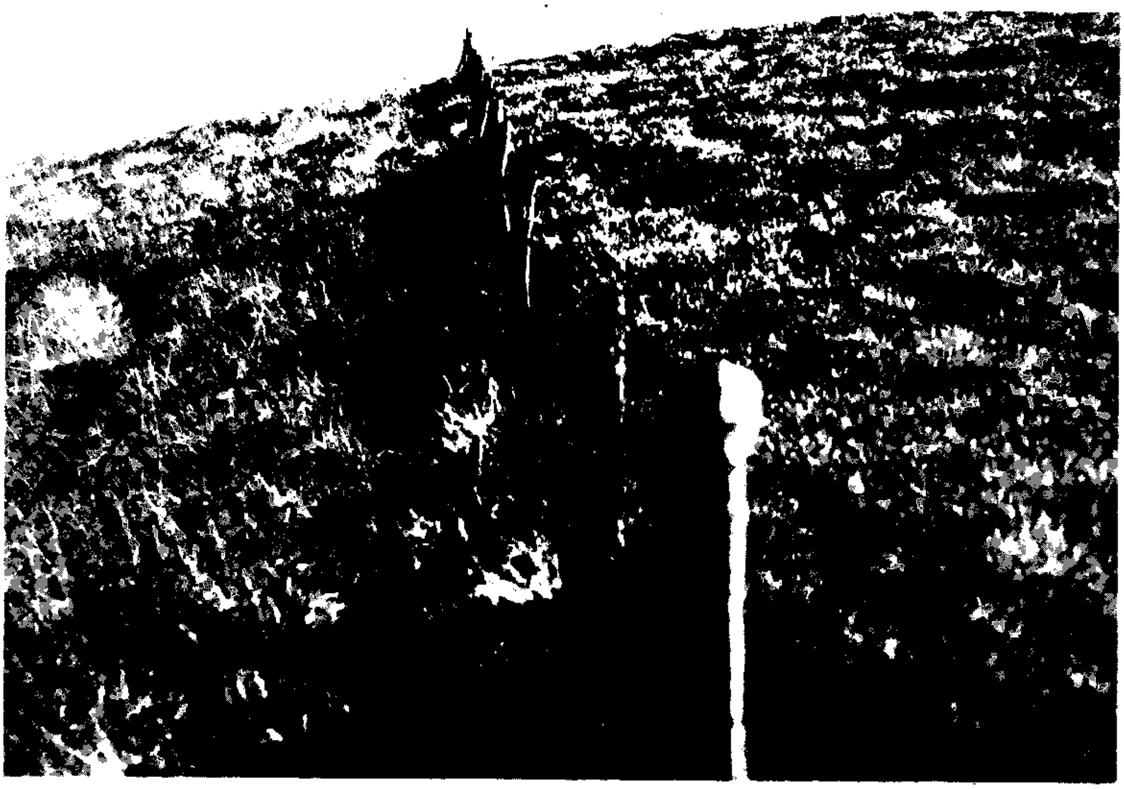


Plate 44 Glascwm - Management effects on heath. To the right of the fence class 10 shrubby heath (<u>Vaccinium/Calluna</u> heath) is maintained by rotational burning and light grazing. To the left heavier grazing and trampling impacts have produced a grassy heath.
(Photo by P. Ainsworth).

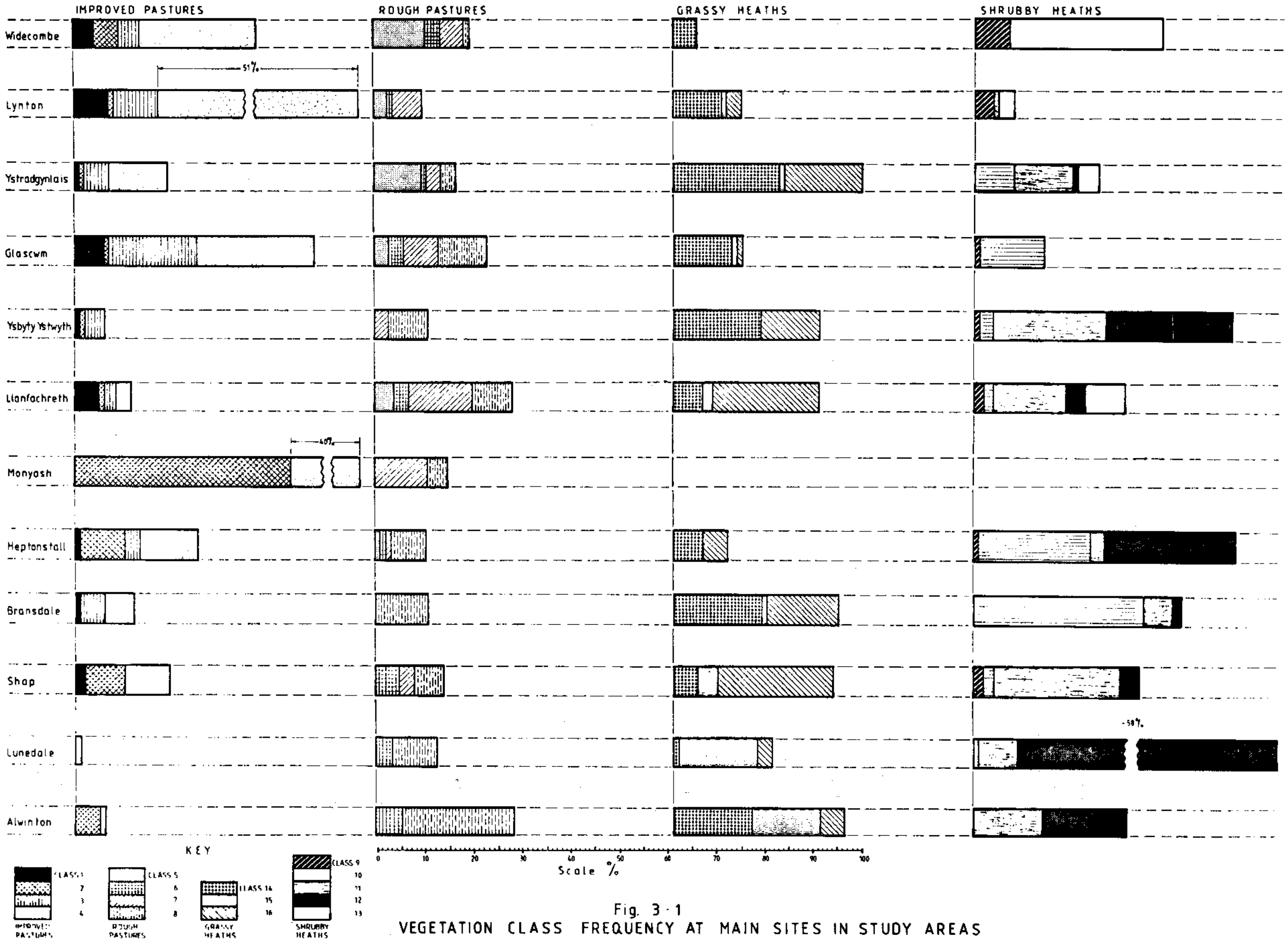


Fig. 3·1
VEGETATION CLASS FREQUENCY AT MAIN SITES IN STUDY AREAS

3.20 The frequencies of vegetation classes at main sites in the study areas do not, however, determine quantitatively with statistical precision the proportion in which each vegetation class is present in a study area, because the sampling programme adopted for the choice of recording sites was not appropriate for this purpose. The sampling was designed to ensure that all those widespread vegetation classes prominent in the transition zone from farmland to moorland were likely to be sampled by a fair number of sites, since this, rather than a quantitative overall assessment of the vegetation in each study area, was the main need in this study. Because main sites, in the case of the larger study areas, were sited more frequently in the marginal zone between dominant moorland and dominant farmland (3.3) than in the uniform moorland, the frequencies of vegetation groups and classes at main sites are likely to include rather more improved pastures and fewer heaths than would be found in a statistically quantitative uniform sampling of the study area. Calculations relating to the extent of different land types (Chapter 4) and the proportions in which they have been sampled by main sites suggest that the degree of bias is not great. It is likely to be of an order giving an over-representation of pastures and an under-representation of heaths by some 10% of the estimated frequencies in the larger study areas. There is no conflict in any discrepancies that may occur between assessments of the areas of vegetation mapping units based on cover estimates in the ULS reports and the data in Figure 3-1 for proportions of vegetation classes, since these two assessments are based on different criteria for vegetation categories and a different approach, the mapping of the whole area, against the vegetation of a set of sites in an area. Associations between the 2 sets of vegetation categories are considered for each area, and summarised for 11 areas, in Part II of this report.

3.21 A 'moorland' vegetation element is present to a greater or lesser degree in all study areas except Monyash. This element can be taken as the proportion of the recorded sites in each area in the grassy and shrubby heath vegetation groups, while improved pastures and rough pastures represent a 'farmland' element in the vegetation. Where the moorland element is strongest, it implies a moderate to low general level of management. Conversely, where the farmland element is more strong, management has been generally at a more intensive level with a great deal of grassland improvement. The study areas may be placed in order from the most 'moorland' (>) to the most 'farmland' in character as follows: Lunedale > Ysbyty Ystwyth > Bransdale > Shap > Alwinton > Ystradgynlais and Heptonstall > Llanfachreth > Widecombe > Glascwm > Lynton > Monyash. The 8 parishes Lunedale - Llanfachreth are at present distinctly moorland in overall character, with more than 50% of their recorded main sites occurring in the heath vegetation groups. Widecombe, Glascwm, Lynton and Monyash all have less than 50% heaths at their recorded main sites.

The moorland element

3.22 Lunedale and Ysbyty Ystwyth particularly contain very low proportions of improved pasture classes, with rough pastures also rather poorly represented. The very high occurrence of shrubby heaths in Lunedale gives it overall the most moorland character, reflecting its major land-use as a grouse moor. In Shap there is a contrast between a strong representation of improved pastures associated with limestone outcrops and the prominent moorland component to be found on the more extensive volcanic rocks on the western side of the study area. Bransdale is another area influenced by sporting interests, so that the management of its moorland sector for grouse leads to a relatively high frequency of shrubby heath classes. Alwinton is largely controlled by the Ministry of Defence which uses much of the area as a military range and training ground, a use mirrored in a low proportion of improved pastures, since the normal agricultural pressures do not operate freely in this parish and grassland improvement schemes have not been undertaken on the same scale as in other physically similar upland areas. Heptonstall is an important water catchment area, of which part again is also managed for grouse. The moderate representation of improved pastures in Heptonstall has in part resulted from the abandonment of farms in the vicinity of the reservoirs, and the relatively high presence of shrubby heaths results from the shooting interests. In Ystradgynlais open-cast coal mining has had some influence on the vegetation in that these operations have inevitably disturbed areas which have subsequently been encouraged to revegetate to a form of rough pasture or have been planted to coniferous forest. Moorland is still dominant in Llanfachreth, but with the farmland element occupying almost 40% of the recorded sites there, this parish tends to be intermediate between those of undoubted moorland character and those in which the farmland element is predominant.

The farmland element

3.23 In Monyash the moorland element is absent and this study area forms the opposite vegetation extreme to Lunedale in the range represented by the 12 study areas. The reasons for the lack of the moorland element in Monyash are its geology, of Carboniferous Limestone giving relatively fertile soils, and its geographic position, close as it is to major industrial towns which created substantial demands for agricultural produce, particularly dairy products. This has meant that there have been long standing economic incentives for potential grassland improvements to be carried through to completion in Monyash. Widecombe, Glascwm and Lynton all have an above average representation of improved pastures, which is a reflection of their generally relatively favourable plant growth conditions, both in terms of soils and climate. Since these 3 areas are more remote than Monyash from major centres of population, they have retained a wider range of vegetation diversity and have not been subjected to the extreme pressures, or opportunities, for improvement that have totally turned Monyash to farmland. The farmland vegetation element is weakest in Widecombe out of these 3 areas, but in Glascwm grassland improvement schemes are currently making deep inroads into the remaining areas of unimproved moorland. In Lynton moves for landscape conservation may prevent further losses of heath vegetation.

WOODLANDS

3.24 Deciduous woodlands provide local visual variation in upland landscapes as well as being important in their roles of giving shelter to grazing stock and habitats important to wild life. The extent of the cover of deciduous woodland in the uplands though is generally small, and (from assessments by ULS) in the study areas this ranges from less than 1% in Alwinton to nearly 7% in Lynton (Plate 16), with a broad trend of increasing woodland cover from north to south.

3.25 Woodlands were sampled less comprehensively than the grassland-moorland range in the study areas. Where there was relatively extensive woodland cover, sites were selected to cover all obviously different types of woodland, but in these areas not all the available woodlands were sampled. Where woods were fewer in a study area then every wood and therefore every possible woodland type was sampled. Classification was based on a key to British woodland vegetation by Bunce (in prep.). The sites recorded from the study areas were classifiable into 25 woodland types according to this key. To simplify consideration here these types were amalgamated to give 11 classes which fall in 3 broadly based woodland groupings (Table 3-4). There is a distinct lowland element in 2 categories, 'basic' and 'acid', based on soil acidity and ground vegetation, and an upland element which consists of the remaining 4 classes. Brief simplified descriptions of the woodland groupings follow.

3.26 Lowland basic woodlands: These in the national study are found mainly in Southern England, the Midlands and Wales, in lowland areas under conditions of low or average rainfall and usually on brown earth soils, gleyed brown earths and gley soils, particularly on clay parent materials. Three classes fall in this group: Mixed deciduous woodland; Pedunculate oak/ash woodland; Scrubby ash woodland.

TABLE 3-4 CLASSIFICATION OF WOODLANDS

Study Area	Number of Woods Examined in Study Area	Percentage of Woods Examined which had Tree Seedlings or Saplings < 20 yrs old	Woodland Group and Class: Lowland Basic Woodlands			Lowland Acid Woodlands				Upland Acid Woodlands				Extent (% area of *Deciduous* Woodland in Study Area
			Mixed Deciduous Woodland	Pedunculate Oak/ Ash Woodland	Scrubby Ash Woodland	Dry Acid Oak Woodland	Heathy Birch Scrub	Mixed Oak Woodland	Acid Oak/ Birch Woodland	Western Acid Oak Woodland	*Species - Poor Birch/ Oak Woodland*	*Upland* Birch/ Oak Woodland	*Scrub* in Open Glades	
Alwinton	10	60	-	-	-	-	-	-	-	1	4	3	2	0.6
Lunedale	10	50	1	-	1	-	-	-	-	3	1	2	2	1.1
Shap	12	0	2	-	-	-	-	-	-	3	2	5	-	2.1
Bransdale	15	33	-	-	-	1	-	-	-	9	1	3	1	1.6
Heptonstall	14	50	-	-	-	7	2	2	1	2	-	-	-	3.8
Monyash	10	50	2	-	5	-	-	2	-	1	-	-	-	1.5
Llanfachreth	15	80	1	1	-	-	-	-	2	2	2	4	3	4.6
Ysbyty Ystwyth	10	60	-	-	-	3	-	1	-	5	-	1	-	1.9
Glascwm	11	27	1	3	1	-	-	-	-	5	-	-	1	3.1
Ystradgynlais	12	50	2	1	-	-	-	2	-	4	1	2	-	3.6
Lynton	12	100	1	1	-	2	-	1	3	2	1	-	1	6.9
Widecombe	13	77	-	5	-	-	-	2	3	2	-	1	-	6.1

As number of woodlands examined in each area that fall in each woodland class

3.27 Lowland acid woodlands: Included in this group are 4 woodland classes concentrated nationally on shallow acid soils at medium altitudes in areas of England and South Wales of low to average rainfall: Dry acid oak woodland; Heathy birch scrub; Mixed oak woodland; Acid oak/birch woodland.

3.28 Upland acid woodland: These woodlands show nationally a northern and western bias in their distribution and are to be found mainly on steeper slopes under conditions of high rainfall. Soils are mainly brown earths and brown podzolic soils. Four classes are recognised: Western acid oak woodland; species-poor birch/oak woodland; Upland birch/oak woodland; Scrub in open glades.

3.29 Five study areas (Alwinton, Lunedale, Shap, Bransdale and Llanfachreth) have mainly upland acid woodlands. In the case of Alwinton all the woodlands examined are in this group. Shap is sparsely wooded and the impression of this on the landscape is emphasised by the lack of boundary hedges. Ysbyty Ystwyth and Ystradgynlais both show a fairly strong upland bias in their woodland character but with a significant lowland component as well. Woodlands in Heptonstall and Monyash are essentially lowland in character. The Heptonstall sites recorded are acid woodlands with a strong representation of dry acid oak woodland. The Monyash recorded sites are mainly basic woodlands (particularly scrubby ash woodland) as a result of the presence of lime-rich soils. Lynton and Widecombe have more equal distributions of the woodland groupings in the sites examined, but with an overall bias to lowland classes. Glascwm has a fairly even division of woodlands between lowland basic types and upland woods, with a slight bias towards the latter.

3.30 Western acid oak woodland is present in all of the study areas, and upland birch/oak woodland is also widespread, occurring in 8 study areas, but is absent from Heptonstall, Monyash, Glascwm and Lynton. Mixed deciduous woodland is the most commonly occurring of the lowland woodland classes and this is present in 7 study areas. Lynton, besides being the most extensively wooded of the study areas, also has the greatest diversity of woodland classes at the sites examined, with 8 out of 11 classes represented. The Llanfachreth sites cover 7 woodland classes, making it overall the most diverse of the study areas in terms of combined main site and woodland vegetation. Although Llanfachreth includes extensive conifer plantations, some of which are nearing maturity, it is only third amongst the study areas in extent of deciduous woodland. Alwinton has very little woodland and what there is has been damaged as a result of military use.

3.31 All the woodlands which were visited during field recording were examined for evidence of regeneration and a note was made of the numbers of saplings less than 20 years old which were present in the sample quadrat. In 11 of the study areas woodlands contained some saplings or seedlings. Shap was the exception where none of the woods examined showed any evidence of regeneration while, at the other extreme, in Lynton every wood contained saplings or seedlings. Llanfachreth and Widecombe both had saplings and seedlings present in a high proportion of the woodland sites sampled. Alwinton woodlands had evidence of a relatively high potential for regeneration in spite of their present poor condition. The Upland Landscapes Survey found that 75% of the woodlands in the study areas as a whole were grazed. Considerable variation in the amount of regeneration observed in the woodland sites looked at by ITE is probably mainly a reflection of local grazing intensities.

ROADSIDE VERGES

3.32 Roadside verges, besides being important visual elements in the study areas, are linear reserves of diverse flora. Their significance in considering vegetation change lies in their possible role as reservoirs of potential colonising species, which may spread into areas modified by management. The vegetation of a few roadside verges in each study area was examined for this reason. Those verges which contained woody species such as Corylus avellana (Hazel), Prunus spinosus (Blackthorn or Sloe), Rosa spp. and Salix caprea (Sallow or Goat willow) appeared to have a strong lowland element amongst the associated plant species present. In the absence of these woody species the associated species had a generally upland bias. Some roadside verges seemed to have a vegetation character typical of a local and limited geographic region. Possibly this is a reflection of the highly artificial nature of the roadside verge habitat and local variations in their construction and maintenance, but it may also retain some element of natural regional vegetation differences. It was not possible to pursue consideration of the significance of verge vegetation as far as it might justify.

CONCLUSION

3.33 Analysis of species presence data recorded at 938 main sites through the study areas has provided a classification of the grassland-moorland vegetation into 16 classes, in 4 vegetation groups: Improved pastures Rough pastures; Grassy heaths and Shrubby heaths. By use of the vegetation key given in Appendix 6, other vegetation stands from the grassland-moorland range in these or similar upland areas can be allocated to a class with a fair degree of accuracy. A limited sampling of woodland sites gives an idea of the deciduous woodland types present in the study areas.

3.34 The vegetation classes identified at the main sites provide the opportunity to relate grassland and moorland vegetation from a sample of the uplands of England and Wales to land character, land-use history, and management. The following chapter considers these factors as controls on vegetation, while the concluding chapter then explores associations of these controls with vegetation class and group occurrence, in order to assess and predict possible trends of vegetation change.

4 CONTROLS ON VEGETATION

INTRODUCTION

4.1 The factors which control the distribution of vegetation, and which decide whether the balance of plant species is stable or is changing, are those of land character and of past and present land-use and management.

4.2 'Land' as a concept is taken to include the natural environment characteristics of landform and soil cover resulting from the interaction of geology and climate, and the features created by man on the land surface. The land characteristics considered here are 'physiographic', ie landform features such as altitude, slope or river distribution, and 'topographic', ie those features of land that are man-made, such as roads, buildings and field boundaries. 'Landscape' is taken as being the visual effect of 'land' on an observer. Landscape in this approach is thus an aesthetic concept, essentially subjective, while 'land' is a structural fabric, the elements of which are objectively definable and quantifiable. No attempt is made here to define landscapes, only land characteristics and types. Landscape sectors of each area are discussed in the individual reports of the Upland Landscapes Study (as referred in Part II of this report).

4.3 In this chapter land character is first considered (4.9-4.20), then land-use and management history are reviewed (4.21-4.55). Treatments of land character and the historical aspects of land-use are based on data for the study areas. Finally, current management influences on gradual vegetation change are discussed but in general terms (4.56-4.63) rather than from detailed knowledge of specific management within the study areas. Associations between the factors discussed in this chapter and the widespread vegetation classes of the study areas are the subject of Chapter 5.

4.4 In a country with a long history of development, land character is most usefully assessed by considering physiographic and topographic characteristics together, rather than limiting consideration to the natural environment alone. Single attributes can of course be used to illuminate relationships between land character and vegetation. However, there are many physiographic and topographic attributes which are inter-related. Vegetation and land-use respond to the results of an interaction between different land attributes. It is therefore convenient to summarise this variation of a wide range of land attributes in a limited number of land classes, each of which has a common set of characteristics, as a means of comparing the land character of scattered study areas.

4.5 Man's settlement pattern has usually been a response to, and largely controlled by, the natural environment, so that topographic characteristics typically reinforce natural environmental characteristics in distinguishing upland land types. However, there are situations in which the character and scale of settlement in a upland area have resulted from the exploitation of resources that were limited, or had only temporary importance, or from economic constraints or opportunities imposed by conditions outside the area. To understand the current pattern of vegetation it is necessary to appreciate the different phases in upland land use and, in particular, the periods of agricultural expansion and contraction that have affected the uplands.

4.7 The immediate controls on vegetation change are management practices. The remit of this study largely excluded major abrupt changes such as total cultivation with reseeding, or forestry planting, though the historic role of direct change in upland land-use is outlined (4.31-4.40) and an assessment of possible change in the study areas through such methods is given briefly in Chapter 5 (5.89-5.100). Many changes, however, are gradual, brought about by modification of grazing and burning regimes, or minor surface treatments, and these gradual changes were the main topic of this study. Reversion from previously substantially and abruptly modified grassland towards more semi-natural vegetation is an important course of gradual change, the directions and rates of which are considerably affected by environment, present vegetation composition, and continuing management.

LAND CHARACTER

4.9 In Chapter 2 the general character of the study areas was outlined and the extent was discussed to which they are representative of the regions in which they occur, and of the uplands as a whole. Here their land character is considered at a level of detail which can be related to the vegetation within and between the study areas.

4.10 The approach adopted is to carry out a land classification based on characteristics recorded from maps, using a multivariate method to determine the most appropriate main and subsidiary environmental variations. It is possible to divide the study areas without complex analysis, using single criteria such as altitude or rock type, or simple combinations of these. The number of alternatives this can produce is large and the choice of criterion for land classification is subjective among the wide range of options. This subjectivity can be reduced by allowing the classification criteria to be determined by a computer analysis of a relatively wide range of land characteristics for units of land which make up the study areas.

Land classification of the study areas

4.11 To provide a standard unit for recording land data and for classifying land in the study areas at a reasonably fine scale of resolution in relation to their size, the areas were divided into 0.5 x 0.5 km grid square units as delineated by national grid lines. These units are easy to identify and specify, convenient for statistical calculations, and simple to use in computer storage, analysis, and mapping of data. Discrepancies between actual areas calculated from administrative parish boundaries and the nominal areas calculated from grid square boundaries are unimportant in this study (footnote 2, Table 1-1).

4.12 For each square in the study areas a range of physiographic (altitude, slope, aspect, water), topographic (settlements, roads and footpaths, field boundaries) and climatic (rainfall) characteristics (Appendix 7A) were quantitatively measured from 1: 25 000 Ordnance Survey maps and from national rainfall maps (Meteorological Office 1977). The quantitative measures these give, that have been employed for statistical summaries (2.4), and that can be used for mapping single or combined features (as in individual area accounts in Part II), were converted to an appropriate set of attributes in a 'presence/absence' format (Appendix 7B) to carry out a classification analysis for the total of 2 977 grid squares by Indicator Species Analysis. This method was also used in this study to classify vegetation (3.9), and is described in Appendix 4.

4.13 Discussion (4.15-4.20) of the land types that are defined by this analysis is based on the average properties of each type but it must be understoood that an individual square can differ from the average in some characteristics, since, as in any multivariate classification, it is the balance of properties that determines how an individual square is classified. An assessment from other data which supports the validity of these types as meaningful land categories is referred to later (5.25). It should also be emphasised that the classification of land in the study areas at this local scale is quite independent of the provisional national upland classification referred to earlier (2.36). To avoid possible confusion, the terms 'land type' and 'land group' in their use in this report refer only to the analysis of land character in the study areas at the 0.5 x 0.5 km grid square scale.

4.14 Although this classification of land types relates to the range of characteristics covered in the study areas, it is likely to be applicable also to other appropriate areas. The analysis method, as its name implies, identifies 'indicator' attributes which can then be used in a key to classify other 0.5 x 0.5 km squares for which similar data have been obtained. The key to this land analysis is given in Appendix 8 and, although its application to other areas has not been tested, it would be reasonable to consider its use for uplands elsewhere in England and Wales, as these are defined by the 10 x 10 km squares outlined in Figure 1-1. Sectors with considerable land above 900 m altitude might fall into an additional class not adequately covered by the study areas on which the classification key is based.

4.15 Within the study areas the main physical characteristics of the 3 land groups and 7 land types which emerge from land classification by ISA are as follows:

Hill land is a group containing land mainly in the altitude range 428-610 m, within which 3 land types are distinguished by their combinations of slope and relief: Steep hill; Hill; and High plateau

Upland land is a group dominated by land between 245 and 335 m, also of 3 land types, again distinguished by slope and relief: Steep upland; Upland and Upland plateau.

Upland margin is a group of a single land type (given the same name) which is dominated by altitudes between 122 and 244 m, moderate relief and rather steep slopes.

4.16 The average characteristics of the 7 land types are summarised in Table 4-1 and given numerically in Table 4-2. The main physiographic and topographic trends follow each other closely. The visual impression given by each land type can be appreciated from the air photographs used earlier to show the characteristic terrain of the study areas. Steep hill is present in Plates 1 and 5; hill in Plates 1, 4 and 5; high plateau in Plates 1, 6, 13 and 15; steep upland in Plates 14; upland in Plates 4, 6, 12 and 15; upland plateau in Plates 4, 7, 10 and 16; and upland margin in Plates 6, 14, 15, 16 and 17.

4.17 There are marked differences in land character both between and within the study areas, as shown by the representation of land groups (Table 4-3a) and land types (Table 4-3b and Figure 4-1) in them. Computer maps showing the distribution of land types in each area are given in the individual reports in Part II. From the frequency of hill, upland and upland margin land groups in the study areas it is possible to suggest a relative ranking of the 'hilliness' of the study areas. From the most to the least 'hilly', the order in such a ranking runs: Lunedale and Alwinton - more hilly than (>) Shap, Ysbyty Ystwyth and Ystradgynlais > Heptonstall and Bransdale > the remaining areas. This overall ranking, which conforms generally with the assessments based on individual criteria shown in Figure 2-2, conceals notable diversity within

TABLE 4-1 SUMMARY DESCRIPTION OF LAND TYPES

Land Group	Land Type	General Description[2]
Hill	Steep Hill[1] (1)	High altitude, strong relief, steep slopes; very low density of habitation, low frequency of road access and intensity of agricultural use.
	Hill (3)	High altitude, moderate relief and slopes; low density of habitation, frequency of road access and intensity of agricultural use.
	High Plateau (4)	High altitude, low relief and gentle slopes; low density of habitation, frequency of road access and intensity of agricultural use.
Upland	Steep Upland (5)	Moderate altitude, strong relief and steep slopes; low density of habitation, moderate frequency of road access and intensity of agricultural use.
	Upland (7)	Moderate altitude, relief and slopes; high density of habitation, frequency of road access and intensity of agricultural use.
	Upland Plateau (8)	Moderate altitude, low relief and gentle slopes; moderate density of habitation and frequency of road access; high intensity of agricultural use.
Upland Margin	Upland Margin (6)	Low altitude, moderate relief and rather steep slopes; high density of habitation, frequency of road access and intensity of agricultural use.

1 Numbers are those on map outputs of land type distribution for study areas included in Part II of this report.

2 Descriptive terms are relative to the range of character included in the study areas.

TABLE 4-2 PHYSIOGRAPHIC AND TOPOGRAPHIC CHARACTERISTICS OF LAND TYPES IN THE STUDY AREAS

Land Characteristic		Steep Hill	Hill	High Plateau	Steep Upland	Upland	Upland Plateau	Upland Margin
		Land Type						
Altitude Class (% area)	< 122 m (< 400 ft.)	0	0	0	0	0	0	5
	122-244 m (401-800 ft.)	3	1	3	11	4	9	43
	245-335 m (801-1100 ft.)	10	9	9	44	67	62	36
	336-427 m (1101-1400 ft.)	33	21	25	39	29	29	13
	428-610 m (1401-2000 ft.)	50	61	57	4	0	0	3
	> 610 m (> 2000 ft.)	4	8	6	0	0	0	0
Altitude Range (m)	Average of Lowest Height in Grid Square	374	437	433	265	285	288	219
	Average of Highest Height in Grid Square	489	498	470	370	341	316	296
	Average Height Difference in Grid Square	115	61	37	105	56	28	77
Slope Classes (% area)	0 - 5°	8	20	74	13	33	81	20
	5 -11°	42	73	24	43	59	18	59
	11 -22°	36	6	2	31	8	1	15
	> 22°	14	1	0	13	0	0	6
Aspect Class (% area)	Northerly	18	27	22	24	17	19	17
	Easterly	26	33	38	26	28	37	27
	Southerly	23	23	25	18	17	22	27
	Westerly	33	17	13	30	37	21	29
	0 (water bodies)	0	0	2	2	1	1	0
Habitation	Individual Buildings	a 1 b 0	a 8 b 0	a 8 b 0	a 216 b 0.5	a 665 b 2.4	a 327 b 1.0	a 1575 b 3.2
Roads [c]	Principal Roads	0.1	0	0	0.9	3.3	1.9	2.4
	Other Roads and Tracks	0.5	0.3	0.3	3.8	4.2	3.5	7.3
Foothpaths [c]		1.5	1.0	0.9	3.7	1.9	2.2	3.8
Field Boundaries [c]		2.2	1.0	0.8	7.1	13.9	11.7	13.6

a As total number of mapped buildings in each land type
b As average number of mapped buildings per square
c As a frequency score per square (range 0-25)

All data are mean values for the 0.25 km^2 squares classified in the land type.

TABLE 4-3a LAND GROUP REPRESENTATION IN THE STUDY AREAS

	Land Group		
Study Area	Hill	Upland	Upland Margin
12 Study Areas Combined	48	36	16
Alwinton	67	28	5
Lunedale	80	11	9
Shap	54	39	7
Bransdale	30	42	28
Heptonstall	27	57	16
Monyash	0	86	14
Llanfachreth	31	25	44
Ysbyty Ystwyth	57	27	16
Glascwm	23	50	27
Ystradgynlais	54	27	19
Lynton	12	56	32
Widecombe	12	64	24

Data as percentage of study area occupied by each land group

TABLE 4-3b LAND TYPE REPRESENTATION IN THE STUDY AREAS

Study Area	Land Type Steep Hill	Hill	High Plateau	Steep Upland	Upland	Upland Plateau	Upland Margin
12 Study Areas Combined	18	19	11	16	9	11	16
Alwinton	43	18	6	22	2	4	5
Lunedale	7	41	32	3	4	4	9
Shap	23	23	8	13	8	18	7
Bransdale	8	8	14	16	3	23	28
Heptonstall	2	11	14	14	29	14	16
Monyash	0	0	0	8	22	56	14
Llanfachreth	19	11	1	25	0	0	44
Ysbyty Ystwyth	8	31	18	17	6	4	16
Glascwm	12	7	4	25	11	14	27
Ystradgynlais	9	25	20	17	0	10	19
Lynton	5	6	1	20	21	15	32
Widecombe	6	2	4	11	46	7	24

Data as percentage of study area occupied by each land type

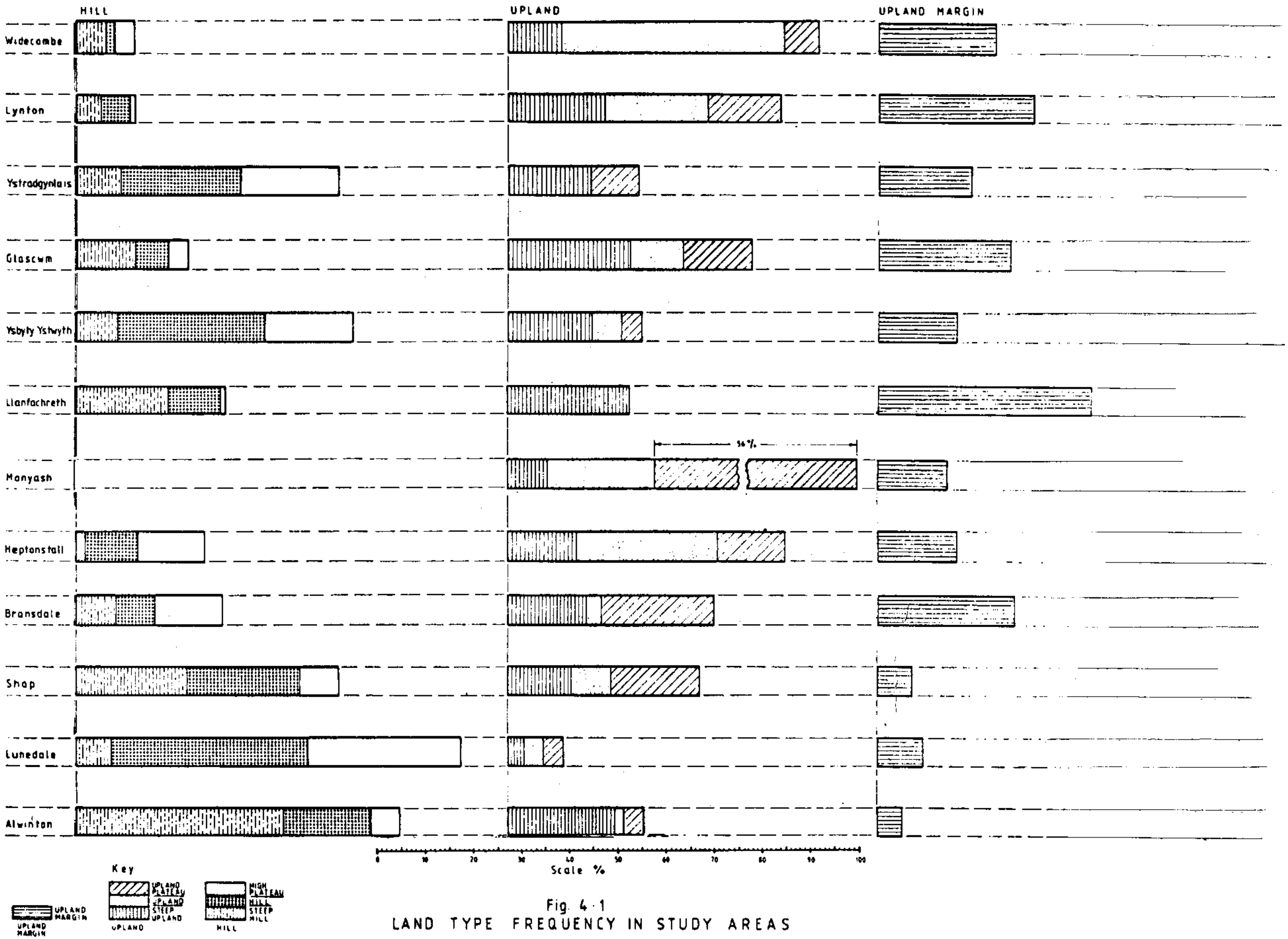


Fig. 4·1
LAND TYPE FREQUENCY IN STUDY AREAS

some parishes. Llanfachreth, for example, has, as well as much 'upland margin' (which lowers its overall hilliness ranking), a prominent 'steep hill' sector. Shap Rural and Shap, with 'steep hill' and 'hill' strongly represented, contain a significant extent of 'upland plateau'. There are, in some cases, additional overlays of other environmental factors to be considered. The 'upland plateau' sectors of Shap and Monyash which have Carboniferous Limestone rocks with thin drift covers (2.21), have high average levels of settlement and agricultural use that contrast sharply with 'upland plateau' in other study areas on less agriculturally favourable rocks.

4.18 In the land analysis, rainfall did not emerge as a clear key factor in separating land types, either at the level of division discussed here, or if the analysis was taken to a further stage of sub-division. Physiographic and topographic factors dominated the key factors which emerged from the analysis, with rainfall appearing as a key factor inconsistently and infrequently. Thus 'steep hill' and 'upland margin' are, in terms of rainfall, composite land types, with wetter and drier phases. Climatic factors are, of course, important in vegetation distribution. Temperature data are not available at the required level of detail but are related to altitude and the geographic location of the areas (2.29). To allow rainfall to be considered among the controls of environment on vegetation each grid square was allocated to a 'low or moderate', 'fairly high', or 'high or very high' rainfall class from the rainfall range which dominates the square. Using these data the vegetation at particular sites can be correlated with rainfall bands for the area in which the site is situated, or with rainfall phases of land types or land groups.

4.19 The frequency of occurrence of rainfall phases of each land type is given in Table 4-4. Steep hill, steep upland and upland margin clearly have high and low rainfall phases of comparable importance. Hill and high plateau are dominantly high rainfall land types but also have significant low rainfall sectors. Upland and upland plateau land types in the study areas are of moderate or fairly high rainfall.

4.20 Variations in land character within and between the study areas are used later (5.9-5.15) to consider the extent to which land characteristics are associated with the types of vegetation which occur in these upland areas. The history of man's modification of the natural upland vegetation is discussed next.

TABLE 4-4 FREQUENCY OF RAINFALL PHASES IN LAND TYPES

Rainfall Band	Land Type Steep Hill	Hill	High Plateau	Steep Upland	Upland	Upland Plateau	Upland Margin	All Land Types Combined
Low or Moderate (average 889 or 1092 mm p.a.)	53	22	15	41	27	48	33	35
Fairly High (average 1397 mm p.a.)	7	13	21	14	72	40	21	23
High or Very High (average 1905 or 2667 mm p.a.)	40	65	61	45	1	12	46	42

Data as percentage of squares in a land type in each rainfall band

LAND-USE AND MANAGEMENT HISTORY

4.21 Except at a very small number of specialised locations (for example on newly formed coastal dunes or saltmarsh) the vegetation of Britain is never entirely natural. It has been created, or at least substantially modified, by land use and management practices. Agriculture and forestry have had the greatest impact on the evolution of the vegetation of upland landscapes in Britian, but such activities as mining, quarrying and water supply have also been important locally. Thus, human and environmental controls interact to determine upland vegetation and landscapes.

Destruction of the natural habitat

4.22 The wide open moorlands of many upland areas are so extensive and striking that some early writers mistook these grass and heath communities for totally natural vegetation. Pollen analysis, mainly from deep peat cores, and archaeological studies have shown this assumption to be false (see, for example, papers in Evans et al. 1975). By 5 000 BC almost every part of the land surface, except at the highest altitudes, had become covered by deciduous woodland as the land recovered from its glaciated past. This woodland consisted of mixed stands of native species such as oak, beech, birch, lime, elm and alder. The Mesolithic hunting-and-gathering communities lived in an essentially wooded environment. On the North York Moors, for example, it was only on the highest ground that the forest thinned out so that such woodland-edge species as Pteridium aquilinum (Bracken) are found more frequently in the pollen record (Atherden 1972, 1979). In many upland areas, large-scale destruction of forest may not have begun until the Iron Age. Atherden (1976), for example, has drawn a distinction between the impact of Bronze Age man practising a form of pastoral nomadism and shifting cultivation, and that of the later Iron Age population, living in more permanent settlements and better equipped to exert more sustained attack on the woodlands However, the Dartmoor evidence mentioned in 4.23 shows that Bronze Age settlement could be the basis of planned upland pastoral use. Table 4-5 illustrates, from a location near Llanfachreth, the kind of chronology of local vegetation and hence landscape change that has been deduced from pollen evidence.

4.23 Far then from ignoring the uplands, early man widely exploited their resources so intensively that he destroyed extensive areas of natural woodland cover, and accelerated the natural climatic tendency that was leading, directly and through soil development, to their replacement with more open communities of heath and moor. Indications of the intensity of early land development (see Plate 18) are widespread, for example the land boundary features

TABLE 4-5 THE DESCRIPTION AND INTERPRETATION OF LOCAL POLLEN ASSEMBLAGES AT PONT-SCETHIN (SH 635236) (c 10 km WEST OF LLANFACHRETH) (FROM WALKER & TAYLOR, 1976)

Period	Pollen Summary	Land Use Interpretation
Recent	*Pinus* pollen increase; *Sphagnum* expansion. No further peaks in weed pollen; *Potentilla* maxima.	Forestry Commission plantations; recent peat growth locally. Increase in grazing pressure.
Napoleonic Wars	Small cereal maximum and rises in arable weeds.	Small-scale cultivation in uplands, more widespread in lowlands.
	Slight decrease in ruderal species.	Local regeneration.
Sixteenth century	Rosaceae maximum in association with rises in *Plantago lanceolata* and *Pteridium*.	Increased pastoral activity, especially along moorland edge.
	Reduction in ruderal species.	Less intensified human activity.
Medieval period	Cereal peak; rise in *Plantago major* and marked increases in *Rumex* and *Taraxacum*.	Cultivation on a non-local scale.
	Sudden expansion of Rosaceae, and rise in Rubiaceae; net decrease in tree pollen.	Intensification of grazing pressure locally with further regional clearance of woodland.
Roman/Iron Age period	Marked reduction in Filicales; increase in Cyperaceae.	Culmination of woodland degeneration and more widespread peat growth.
	Net increase in cereals. *Plantago major* and Chenopodiaceae represented.	Small-scale cultivation throughout period.
	Quercus fall sustained; increase in Gramineae, pastoral weeds and *Pteridium*.	Clearance of woodland on a regional scale; Increased pastoral activity.
Bronze Age	Slight increase in *Betula*.	Partial recovery of woodland.
	Rises in Gramineae and increased representation of *Plantago lanceolata*.	Local pastoral activity.
	Reduction in tree pollen; fall in *Quercus*.	More widespread interference.
Neolithic	Further increases in Rosaceae; *Plantago lanceolata* and *Taraxacum* recorded.	Local woodland clearance. Some pastoral activity. Regeneration follows.
	Fall in *Ulmus* and *Alnus*. Net increase in ground flora species including *Filipendula*, *Ranunculus* and Umbelliferae.	Local clearance with opening of canopy and influx of non-local pollen. Regeneration follows.

called 'reaves' are present over many square kilometres of Dartmoor, including Widecombe and Buckland. Archaeologists have identified these low banks of stone, often vegetation-covered, as the products of a phase of planned land settlement extending through centuries around 1100 BC in the late Bronze Age (Gawne & Somers Cocks 1968; Gawne 1970; Fleming 1978). Although the uplands were used primarily as grazing-grounds, cultivation was attempted in the Iron Age at some locations, for example in Northumberland a Romano-British field system survives as a series of lynchets (terraced strips) near Alwinton. Archaeological evidence, together with pollen data from such sites as Streng Moss (NY 965913), indicates that extensive areas of forest were cleared at this period throughout Northumberland in order to feed the expanding native population and supply the needs of garrisons. In the pollen diagrams, tree-pollen percentages from this period are as low as those of today (Davies & Turner 1979).

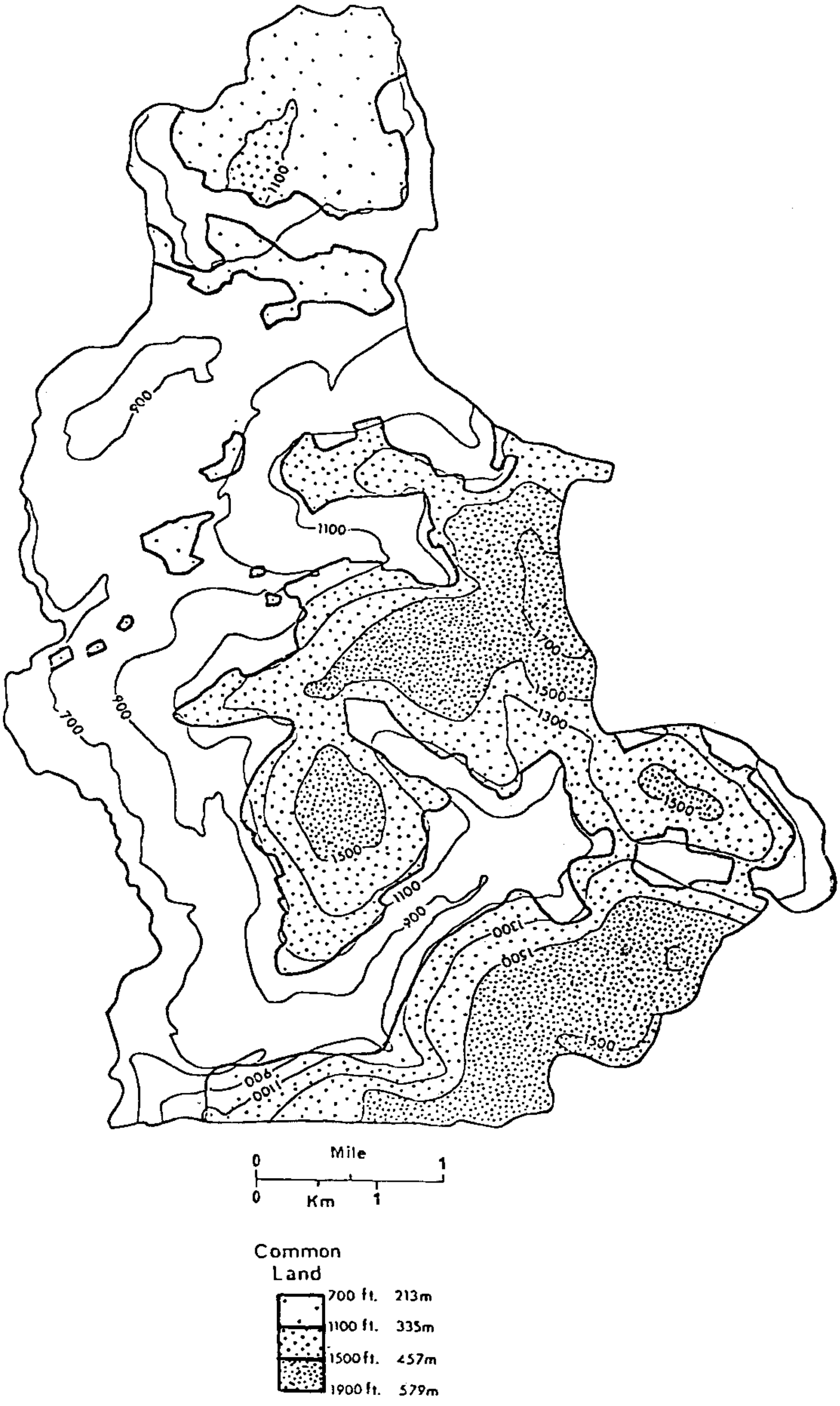
4.24 The uplands experienced an impoverishing effect of man's exploitation of natural resources (considering that 'production' in woodland is intrinsically higher than that of moorland), creating a situation in which the essential character of much of our uplands can be thought of as largely prehistoric in origin (as discussed for the North York Moors by Spratt & Simmons 1976). Intense grazing pressure, and the short term cultivation of crops where possible, accelerated the fall of soil lime and plant nutrients to low base levels in situations where the natural trend (see eg Ball 1975), especially under the high rainfalls of the Iron Age, was in any case strongly directed towards podzolisation and the build up of surface peat on very acid soils. By the first century BC, much of the higher ground with gentler slopes was covered by blanket bog, while on better drained sites a drier heather moor was evolving. In a simplified view this represented the transition from a mineral soils/woodland ecosystem to a more impoverished peaty soils/moorland system. The native forest on the higher land never recovered from this early and major decline.

The pastoral uplands

4.25 By providing grazing land for cattle and sheep, the uplands managed as a moorland/grassland/subsidiary woodland complex have frequently played as important a part in regional economies as have the lowland areas with their arable crops, dairy herds and timber-producing woods. The upland grazing grounds were sometimes in single ownerships and tenancies, sometimes they had the status of Common Lands, with joint grazing rights. In general, common grazings survived on the higher ground, Figure 4-2 illustrating this for Glascwm, where the Tithe Commutation Survey of 1837 shows most Common Land to lie above 335 m and a high proportion to be

FIGURE 4.2 GLASCWM-1837

COMMON LAND AND ALTITUDE



above 457 m. The grazing grounds were often managed to provide controlled access for the livestock of as many people as possible. On Dartmoor, in 20 parishes ('Venville Parishes') on the edge of the high moor, including Widecombe and Buckland, the inhabitants paid a small fixed rent to entitle them to pasture stock in the Royal Forest and Common (Fogwill 1954) In many areas it was customary for land tenants also to rent the sheep flock, such flocks being sold with a property. A tenant was obliged to leave the same number of stock at the end of a lease as he took over at its start. This system guaranteed that a specified number of sheep in a self-sustaining flock, used to a particular part of the terrain as a historic range, remained on the land, and that grazing pressure was controlled at a level to ensure the survival of vegetation of a desired type.

4.26 Continual grazing of the uplands by farm stock through the centuries, and the interaction of grazing with other environmental factors, have led to the predominance of various types of acidic grasslands and shrubby heaths. Grazing intensity varies according to the nutritional quality of the vegetation, and according to local custom. The experienced grazier seeks to achieve a balanced stocking which on the one hand will produce animals fit either to sell direct to the markets or for fattening elsewhere, while on the other it will maintain the quality of the grazing-grounds by preventing the replacement of more palatable and nutritious species by coarser species.

4.27 The level of grazing pressure achieved during any period often reflects the effects of social and economic factors. This can be illustrated in relation to the foundation, growth and eventual destruction of the monasteries, as demonstrated on the North York Moors. Here the trend to a more open environment through grazing pressure may have been interrupted by the Anglian and Norse incursions, and more especially by the 'harrying of the north' by the Normans in the 11th century. The founding of the monasteries helped to consolidate and re-emphasise earlier interrupted patterns of pastoral exploitation. Bransdale and Farndale had already become part of the extensive sheep-runs of Rievaulx Abbey by the mid-12th century. For over 400 years there was a closely-regulated annual cycle of movement of stock from the sheltered dales to higher ground in summer. Pollen diagrams from sites in the Nidderdale area of the Pennines indicate a peak at this time for <u>Rumex acetosella</u> (Sheep's Sorrel), a plant which now colonises bare, eroding peat and is associated with poorly-managed grazings. Tinsley (1976) has taken its presence in the pollen record to suggest deteriorating grazing conditions and initiation of peat erosion as a result of over-grazing. Although the intensity of grazing pressure on the high moors may have declined and become more erratic following the dissolution of the monasteries in the 1530s, some effects of former management may have been irreversible.

4.28 Many parts of the uplands, for example central Wales, have become characterised by small, family farms. Often these date from the 18th and early 19th centuries, when demands for land, sometimes related to local mineral exploitation (4.37), were so strong that farms were created in central Cardiganshire at altitudes of up to 274 m (900 ft). Lax administration and ill-defined boundaries of many Commons encouraged squatting. Although self-supporting for most of their needs, the small family holdings could not be cut off from the outside world. Money was at least needed to pay rent, tithes and taxes. Such considerations may earlier have accelerated the displacement of cattle, which had been the first mainstay of the Welsh upland economy, by sheep in the mid-17th century and subsequently. Not only did the wool trade become more profitable, but the gradual spread of root crops allowed easier winter feeding of lambs (Morgan 1959).

4.29 The grazing impact of each species and type of animal varies (4.59), but adjustments in the numbers, species or ages of grazing animals were not the only way that has been regularly used to influence the floristic composition of vegetation. As grouse shooting became an organised use of hill land in the 19th century, burning which had always had a place in upland management was turned to a controlled method of sustaining the proportion of young, more palatable, growth of heather in moorland vegetation (Gimingham 1972) (see eg Plate 2). Heather communities were typically burned in March or April on a rotation of 7 to 10 years. A game-lease for part of upper Teesdale, in the neighbourhood of Lunedale, in 1898 required the tenant 'to judiciously and in a workmanlike manner burn such quantities of heather and ling as may be necessary' (Britton 1974), and another, for an estate south of Alwinton, limited the area of 'heath, bent or grass' to be burnt to a sixth part of the whole in any one year. Elgee (1912) suggested that burning was the most important 'disturbing factor in the plant life of the uplands', and may have led, over time, to a decrease in species diversity. The skilful application of burning is recognised as the cheapest and most effective method of creating and sustaining pure stands of heather (Miller & Watson 1974; DAFS/NCC 1977).

4.30 The role of chemicals in the ecosystem and their ultimate effect on the landscape has increased in significance as the use of fertilisers, selective herbicides and pesticides has expanded since 1945. Such chemicals have obvious and direct effects on vegetation, affecting its pattern and structure. This is equally as true of long established chemicals such as lime as it is of newer introductions, such as paraquat. There can also be indirect effects of these substances and the residues that are derived from their partial breakdown in the ecosystem. The removal or attempted removal of a single important component species of the vegetation, for example bracken, has an overall landscape impact, altering the aspect of the upland scene, since the seasonal colour and growth-form changes associated with extensive stands of bracken are lost.

Direct changes

4.31 Discussion in 4.25 to 4.30 has been focussed on the long history of pastoral land-use management and its impact on the evolution of upland landscapes and vegetation. Continuity of the grassland-moorland vegetation range in the pastoral uplands has been suggested as a dominant characteristic persisting since the early destruction of native woodlands. This general impression of a long-term stability of much of the uplands should not obscure those changes which have had widespread, or locally concentrated, direct effects on upland vegetation and landscape. The impacts of many of these direct effects are seen in the study areas.

4.32 The most ubiquitous form of direct change has been the conversion of heathy moorland to arable or improved grassland use. Some such areas have not remained under cultivation but the methods of cultivation used have results which remain to identify them. Prior to the mid-19th century, the essential improvements in drainage often required before cultivation was possible were carried out by ploughing the moorland into broad ridges, on the crests of which the crops were planted. Such ridges remain visible over present day moorland in upland Britain as an indication of tillage prior to the mid-19th century. At this period forms of under-drainage became available and ridging was no longer generally carried out (Parry 1972 & 1976b). The persistence of an ecological impact of the cultivation on these ridged ploughlands varied according to the permanence and extent of the cultivation. If cultivations were by shallow ploughing, and were not frequently repeated, then rooting systems and seed sources of the original vegetation could survive, and re-colonisation was comparatively easy when cultivation ceased. The frequent policy of reclamation of relatively small areas in a patchwork among undisturbed moor also meant that there was scope for more rapid regeneration of vegetation from the adjacent moorland if and when cultivation of the ridged areas was abandoned.

4.33 No matter how pastoral the agricultural emphasis was in an upland area, some land had to be cultivated in order to feed the population before goods became widely transported over substantial distances from source to market (4.41), and to supplement local-grown fodder supplies for livestock. In Widecombe there is evidence of an extensive area of medieval arable fields that were managed on a communal basis. In many parts of the uplands, tracts of moorland were reclaimed in the 12th and 13th centuries in order to feed the rising human population. Even when the local needs became less pressing, it was often worth continuing to cultivate the land. Once the task of converting moorland to arable had been achieved, a comparatively modest investment was required to keep the arable land productive. Indeed, a reduction in demand for food may have helped to sustain arable use, as it would have allowed greater scope for leaving the ground periodically fallow. This gave farmers the chance to destroy weed-growth, and slow down or arrest the loss of soil nutrients in the crops. In most cases the only fertiliser available was animal manure, and in order to maintain the animals needed to provide the manure to apply to the arable land a general upgrading of pastures around the arable fields may have occurred.

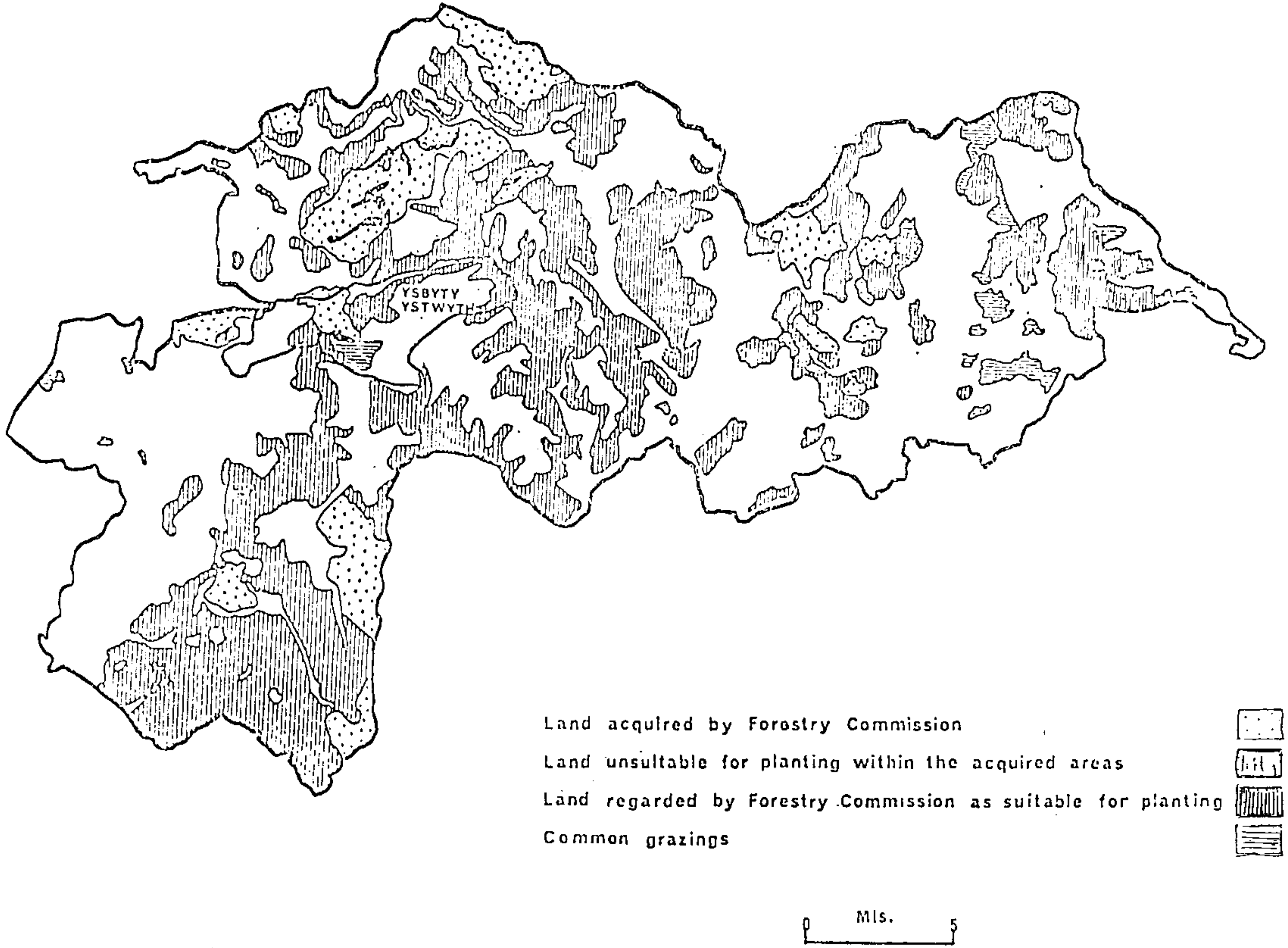
4.34 Ambitious upland reclamation and improvement schemes became commonplace in the late 18th and 19th centuries (see eg Plates 3, 7 and 17). Large parts of central Exmoor were converted to pasture following an Act of Inclosure (Orwin 1929). After some initial opposition to the expense, much of the moorland in Lynton was enclosed and ploughed in order to create more productive pastures for sheep and cattle. On Dartmoor over 6 000 ha (15 000 acres) were enclosed with stone walls by the mid-19th century while in Widecombe, on Cator Common, for example, several miles of shelter belt were established. The parish of Llanfachreth was affected by an Enclosure Award of 1821, which led to an expansion of the arc of farms south east of the village into the upland pastures (Thomas 1965) (Plate 12). The process of physical enclosure did not, however, always lead to improvements in land management. Many Welsh owners were concerned only to establish their legal right to the land as a means of resisting squatting. Elsewhere when enclosure was proposed for Shap parish in 1766, the tenants and landowners warned that 'the High Fell or Peat Moss is incapable of any improvement'. No enclosure took place then and, when a fresh initiative for enclosure was taken, the commoners again warned that 'the nature of the Soil and Climate of the commons in question renders the greatest proportion unfit for Arable Cultivation and only useful for the purposes of planting (trees) and pasturage'.

4.35 The constraints imposed on reclamation and improvement ventures by the natural environment could be modified or overridden by local social and economic conditions. An example of this is seen around Alwinton in upper Coquetdale where the early medieval period was a time of relative prosperity. Newton (1972) has drawn attention to 'a countryside which abounds with the ridge and furrow of medieval ploughing' above Alwinton on comparatively high and difficult ground. There are references to scattered settlement at this time throughout this area. In contrast, the 16th century there was a period of devastation and depopulation, caused by the raids of 'the

Scottes or Ryddesdale men' (Dodds 1940). In the words of a surveyor, quoted by Hodgson (1828), during times of 'warre or a troublous peace then wyll no man aventure to inhabyte or somer there. So that in suche seasons the said Kydland lyeth allwaies utterly voyde and wast'. It was not until the permanent restoration of peace in the late 17th century that farming could be restored to its earlier scale. The rent of 6 000 ha (17 000 acres) of Kidland, which had been fixed at a nominal 20 shillings in 1541, rose to £5 in 1631, to £400 in 1731 and £3 000 by 1800. The peak in local agricultural expansion may have been reached during the early 19th century, when many medieval ploughlands were once again worked. From air photographs, it is possible to distinguish about 300 hectares of present day moorland in Alwinton which were under the plough at some time before 1800.

4.36 The appearance of many upland areas has been widely transformed over a comparatively short period by afforestation with non-native conifers (see Plates 1, 11 and 13). The Forestry Commission (FC) since its creation in 1919 has been active in buying pasture and hill for planting. Since 1945 private groups have also planted large tracts of upland. As early as 1921 negotiations were completed by FC for large parts of Llanfachreth (Plate 11). As an example of regional forestry development, actual and potential, Figure 4-3, simplified from a map in a report of the Welsh Agricultural Land Sub-Commission (1955), shows the distribution of plantations in mid-Wales, including Ysbyty Ystwyth, by 1955, together with the FC assessment then of the potential for future plantings in the region. Large scale planting has also occurred in Alwinton (Plate 1), Ystradgynlais and, less widely, in Bransdale, Widecombe and Glascwm. The main limitations to afforestation are altitude and exposure among natural factors, and competitive land ownership and use factors such as the presence of Common Land, military training areas, and water gathering grounds, and areas scheduled as of landscape and ecological importance. The Otterburn (military) Training Area of 22 880 ha (56 509 acres) which incorportates the southern part of the parish of Alwinton is, for example, the largest training area in Britain. It is clearly impractical to plant forests over land in military use so the ranges are generally let for sheep grazing. Although it was once the practice to afforest water gathering grounds, this policy has now fallen into disfavour. There is considerable developing encouragement to increase the area of commercial forestry in Britain (eg CAS 1980). This, and agricultural intensification in especially favourable areas, are the main factors for direct change likely to affect upland vegetation in a substantial way. An estimate of the potential for such expansion in the study areas is discussed in 5.95-5.100.

FIGURE 4.3 FORESTRY PLANTATIONS IN MID WALES, 1955



4.37 Abrupt changes affecting landscapes that have conspicuous results on a local scale arose from mining ventures. The uplands not only contained minerals that could be exploited but their pastoral economy provided increased opportunities and incentives for such development. Whereas the farming community in arable areas of the lowlands tended to be fully occupied with farming tasks, labour was more readily available in pastoral upland areas, especially on a seasonal or part-time basis. In some places, as in Ysbyty Ystwyth and Shap, the population increased because of the work created by the metal mining and stone quarrying industries. A dual economy based on agriculture and lead mining sustained life in many upland parishes in Wales and the Pennines (including the study area of Lunedale, see Plate 2). As was usual in agricultural tenancies, a lease for the sheepwalk of Logelas in Ysbyty Ystwyth in 1848 reserved the 'mines and minerals thereunder' for a separate lease to a mining company. The desire of landowners to promote mineral exploitation is seen from a lease for Glasfir-ucha in Llanfachreth in 1888, whereby the mining-lessee had 'to diligently explore and open all minerals in and under the said farm and lands' and to keep constantly employed at least 'four able bodied men'. In other study areas coal was the resource to be utilised. There were over 50 coal-pits in East Wilkwood in Coquetdale (Alwinton) worked during the period 1750-1850, often to provide coal for lime-burning, while in Bransdale a lease survives from 1715, which granted a Fadmore yeoman the right to 'all those veins of coal now opened in a certaine plais called Anknesse... with liberty of sinkinge three new shafts or pitts'. The largest group of pits there, at Rudland, was sunk over a period from the mid-19th century until the 1920s. The numerous shale heaps which survive on the moorland today (Plate 7) indicate the scale of former activity and local disturbance (McDonnell 1963; Whitaker 1969). Coal, stone and metal workings created locally substantial quarries or spoil-heaps, for example in Ystradgynlais and Shap (Plate 4). However, except where mining increased the population and thus the pressures for small agricultural holdings, often worked on a part-time basis, the effects on vegetation away from the immediate vicinity of a mine could be slight.

4.38 One of the changes caused to local landscapes through some forms of mining was the creation or adaptation of watercourses. On Dartmoor, where tin-mining was prominent, most of the tin was excavated from outcrops of rock using picks and powerful streams of water. Leats were constructed, taking water from streams across the outcrops of ore rock and, where natural watercourses were not available, small reservoirs were built (Harris 1969). The watercourses downstream of mine works often became affected by pollution, sometimes persistently so. In Llanfachreth, the problem of polluted streams became so serious in the late 19th century that lessees were required to provide 'filtering beds or slime pits or other efficent or approved means of protecting the said rivers, streams, waters and watercourses'.

4.39 The environmental consequences of the one-time close relationship between farming and industrial development in parts of the uplands are well illustrated by the example of Heptonstall (Plate 8), where the presence of extensive little-used moorland and a weakly-developed manorial system was a factor which provided opportunities for the supply of one necessity for industrial growth, the availability of labour (Raistrick 1970; Wild 1972). It was comparatively easy to obtain the freehold of land, which, since tight control was not maintained by landlords, soon led to multiple inheritance and the large scale subdivision of farms. Most holdings provided no more than 'the meanest levels of subsistence', and there gradually evolved an occupational integration between agriculture and woollen-cloth making. According to Watson (1775), there was 'scarcely a single instance in the whole parish of a man's living entirely by farming'. Once taken up, the work provided by the cloth industry encouraged further colonisation of the moorland, and subdivision of holdings. By the 18th century, Defoe described how the land was 'divided into small enclosures, that is to say, from two acres to 6 or 7 acres each, seldom more; every 3 or 4 pieces of land had a house belonging to it' (Cole, 1959). The importance of the domestic textile industry made Heptonstall and the Halifax area particularly susceptible to change during the Industrial Revolution (Hanson 1920). The introduction of the water-frame led to the migration of production from cottages to the new factory mills, built on the banks of Hebden Water and other fast-flowing Pennine streams. By the mid-19th century, the centres of industrial development had again shifted, this time from the streamside mills down to the principal valleys, where it was easier to import coal for use in the new mills driven by steampower, along the roads, the waterway of the Calder Navigation, and the railways. Hebden (Hepton) Bridge eclipsed Heptonstall, as the low-lying lands which had previously been avoided and neglected became centres of change and development. On the high ground, a legacy of large numbers of small farmed intakes from the moorland remained, the resources of which have usually been adequate to sustain their improved state, though not to expand them.

4.40 Locally important direct changes follow conversion of land to water, through exploitation of tracts of upland for major water storage purposes. Two reservoirs have been constructed in Lunedale (Plate 3), and in Shap the artificial raising of the water level of Haweswater in the 1930s led to the flooding of all the lower ground in Mardale. Not only are plant communities associated with valley floors obliterated by such schemes, but agriculturally the loss of hay-meadows and winter accommodation pastures through flooding may lead to a general fall in stock numbers over the neighbouring uplands. This kind of effect may help to explain the dramatic fall in livestock numbers in Shap, as recorded in the Annual Returns to the Ministry of Agriculture between 1935 and 1940 (Figures 4-5 and 4-6). Similarly, according to Crump (1938), the construction of the reservoirs in and near Heptonstall (Plate 9), enormously reduced the sheep-runs of the parish'. In order to ensure water purity, cattle were excluded and sheep numbers were often reduced on water gathering grounds.

Recent times

4.41 In the mid-19th century, a period often characterised as a 'Golden Age' of agriculture in Britain, improved communications and greater accessibility to large markets, which might have been expected to lead to further upland land reclamation and agricultural development, often acted in the opposite direction. It had become easier to send produce to distant towns but the other side of the coin was that in return it was also easier to import foodstuffs, so that the supremacy of farmers in their local markets was removed. Previously, farmers could depend on the prices received for their corn and animal products rising and falling according to the quality of the local harvest. With a poor harvest, prices rose because of local scarcity. This self-balancing mechanism ended when it became easy for even the more remote uplands to import cereals, meat and wool from overseas, grown under quite different climatic regimes, unaffected in price by local seasonal conditions. Prices not only fell, but remained low even when home output was depressed. Low yields no longer brought a compensatory rise in prices. In these changing circumstances the upland producer tended to fare worse because of higher overheads in relation to production. The only available response was to economise wherever possible by reducing arable acreage and the scale of investment in pastoral management. Often poor husbandry practices made adjustment difficult. Garnett (1912) complained of how some of the higher ground in the Lake District had been 'ploughed so hard and so long' that it was difficult to re-establish a sward, and there was insufficient capital to purchase the necessary seeds, manure and other agricultural essentials. When much of this marginal arable land was abandoned in the later 19th century, it reverted directly to rough pasture or moor, rather than being maintained as improved pastures.

4.42 With the exception of the brief period between 1915 and 1921, agricultural prices remained depressed throughout the first 35 years of the 20th century, and the impact of this on the upland countryside was further accentuated by the collapse of many rural industries and occupations. Whereas in 1871 over 4 000 men had been employed in mining in Cardiganshire, Montgomery and Radnorshire, the number had fallen to 700 by 1900, and all activity had ceased by 1931. The plight of the upland farmer was the subject of a number of ad hoc inquiries before and after 1945, the most relevant of which was the previously mentioned (4.36) study of 120 000 ha (290 000 acres) of central Wales, including the parish of Ysbyty Ystwyth (Welsh Agricultural Land Sub-Commission, 1955). In its report the Commission described the various forms of subsidiary income available other than from agriculture as 'part of the sinews of the life of the countryside in general'. With their disappearance there was a tendency for smaller farms to become deserted or amalgamated, and their homesteads to be left ruinous. The Mid-Wales Report recorded 782 examples of dereliction, consisting of 258 holdings abandoned over 50 years previously, 309 abandoned for between 21 and 50 years, 156 for between 6 and 20 years, and 59 abandoned in the previous 5 years.

4.43 An indication of general trends in upland farming this century may be obtained from the Annual Returns made by farmers to the Ministry of Agriculture and its predecessor. Since 1868, farmers have provided annual statistics reporting extents of specified crops and numbers of different livestock on their holdings. This information is treated as confidential at the farm level but summaries for each census unit (usually a parish) may be consulted in the Public Record Office.

4.44 A selection of data has been extracted from the Annual Returns for each study area for 5-yearly intervals since 1900. Unfortunately some categories of information are available for only a limited number of years, and it is impossible to follow trends in some areas because of changes in the size and extent of census units. From the statistics available for most areas it is possible to plot trends in tillage (Figure 4-4), cattle and sheep (Figures 4-5 and 4-6), and the number of sheep per acre of permanent grassland (Figure 4-7). The average area under tillage declined until 1914, then rose and remained at a level comparable to that of the early 1900s. The average animal population has fluctuated less, and stock numbers in the mid-1960s were generally comparable with those of the first decade of the century. The number of sheep has risen since the 1930s after an earlier decline. The overall impression is, therefore, one of broad stability in stocking rates over this period.

4.45 There are considerable variations from the general trends between and within the study areas. Cattle increased markedly over the 1930-1965 period in Monyash, and also rose sharply in Widecombe but from 1955 to 1965. Perhaps the most striking change to affect a study area was the decline in the agricultural area and output of Shap in the period 1935-40, at the time when Haweswater was enlarged and became a reservoir. The increases in tillage in Glascwm since 1940 and in sheep numbers in this area since 1955 are also marked. If changes in the size of the labour force and the number of farm holdings are used as an indicator of wider trends in

FIGURE 4.4 TRENDS IN THE AREA OF TILLAGE FOR 7 STUDY AREAS 1900-1965

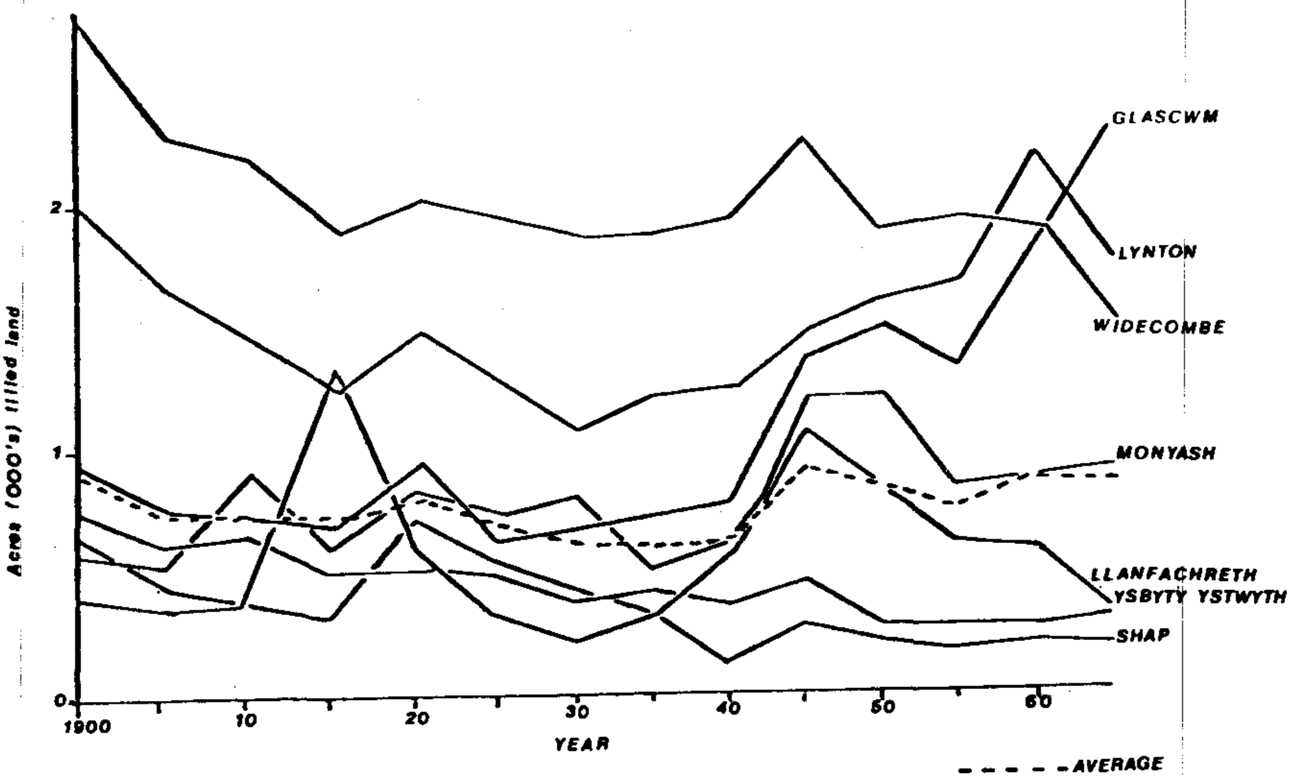


FIGURE 4.5 TRENDS IN THE NUMBER OF CATTLE FOR 9 STUDY AREAS 1900 - 1965

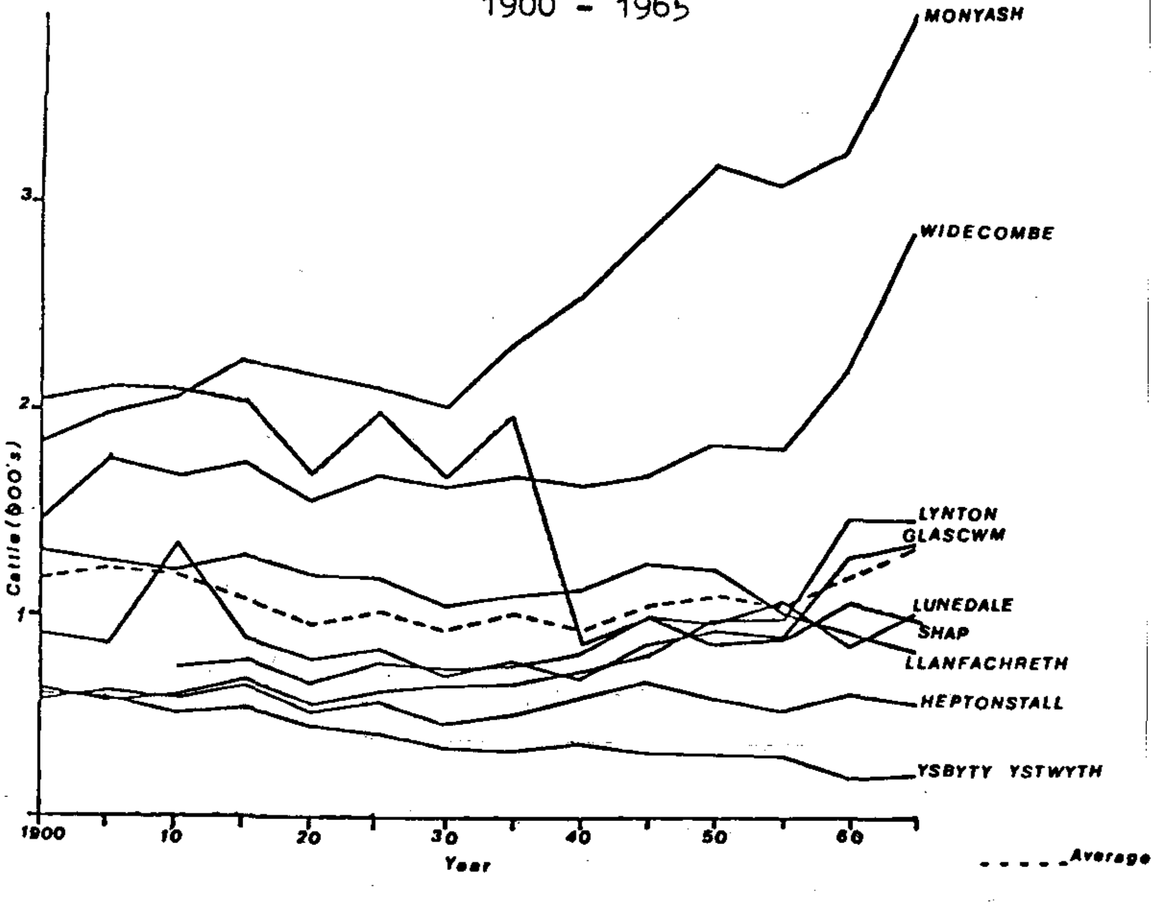


FIGURE 4.6 TRENDS IN THE NUMBERS OF SHEEP FOR 9 STUDY AREAS 1900-1965

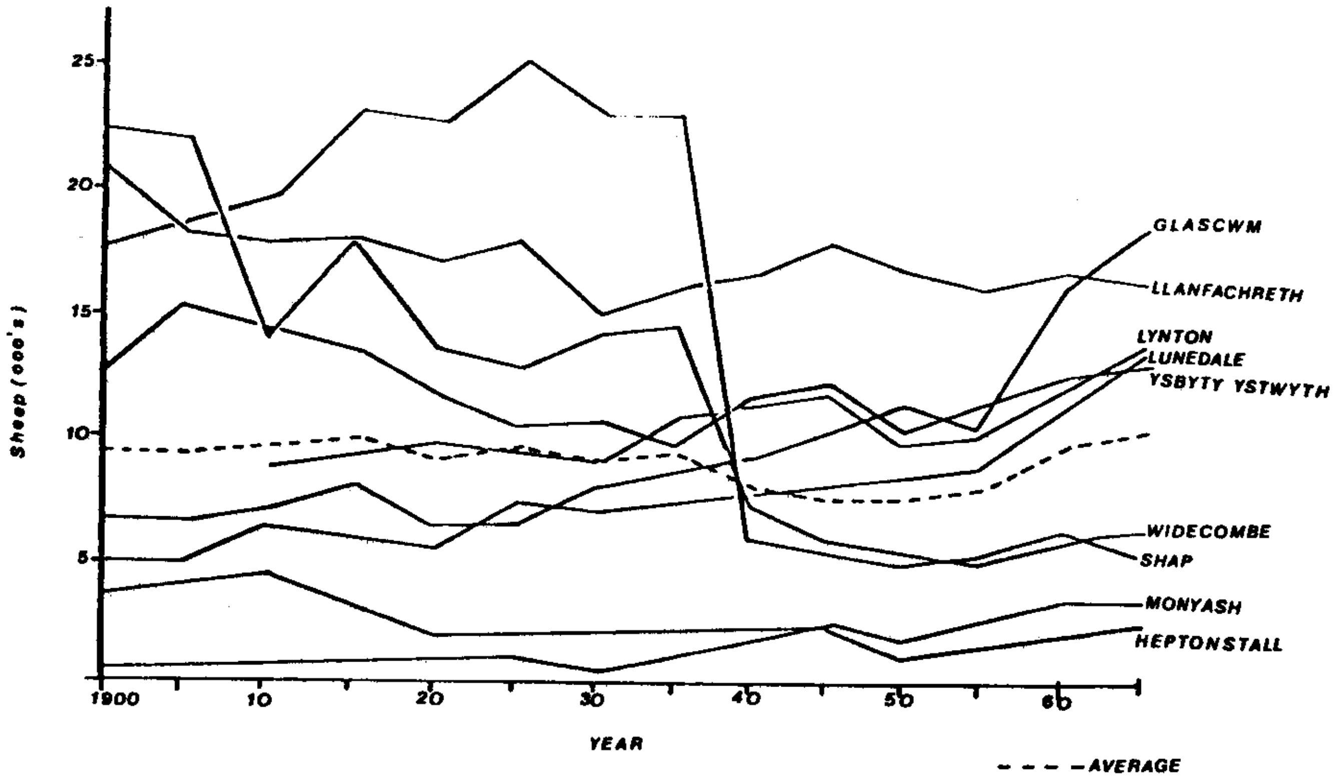
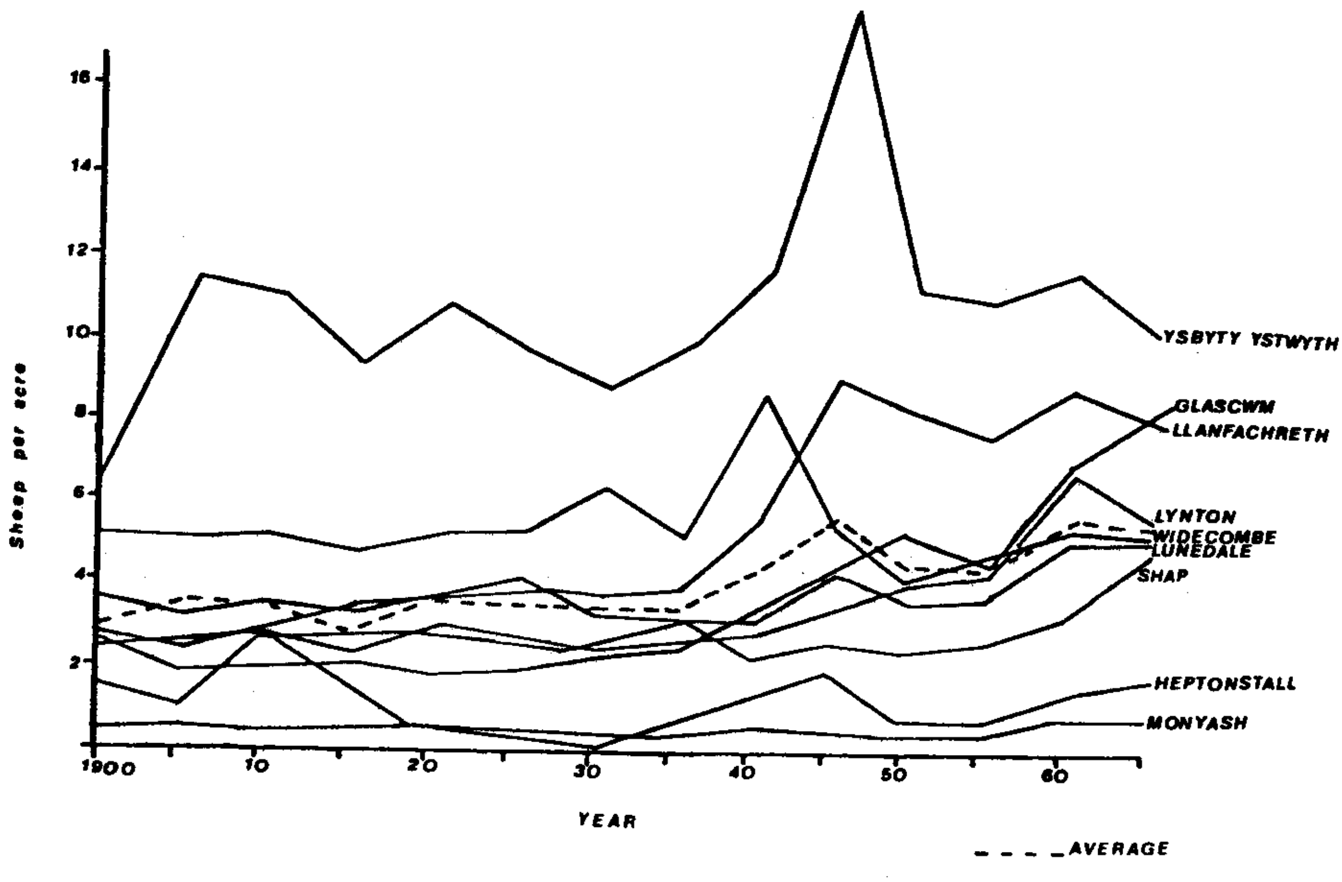


FIGURE 4.7 TRENDS IN THE NUMBERS OF SHEEP PER ACRE OF PERMANENT GRASS FOR 9 STUDY AREAS, 1900-1965



land-use and management, then Figure 4-8 suggests, for the 9 study areas for which statistics are available, a wide and complex variety of recent experience. The average number of farm workers in Shap fell from 88 between 1925 and 1940 to 23 for the years 1950 to 1960, and in Ysbyty Ystwyth from 52 to 18. In contrast, the opportunities for employment rose in Heptonstall, Monyash and Glascwm. In most of the study areas, there was a decline in the number of holdings, but there was no significant change in Widecombe and Glascwm.

4.46 The relative importance of very small holdings in Heptonstall, Llanfachreth, Ysbyty Ystwyth and Ystradgynlais, persisting into recent years, is brought out in Figure 4-9, which shows the range in the size of the holdings in the study areas, as recorded in the Annual Returns of 1950. Its significance may be underlined by reference again to the mid-Wales study (Welsh Agricultural Land Sub-Commission 1955) which included an attempt to assess profitability of holdings from their numbers of breeding ewes. Lambing percentages could be as low as 80%, and a flock of over 500 ewes was needed to sustain a reasonable living. Only 12% of the holdings in the region were considered viable on this criterion, 31% were marginal, and 57% were too small to be economic units. In Ysbyty Ystwyth, the proportion of holdings too small to be viable was as high as 80%. The mid-Wales report concluded that an important distinction should be drawn between marginal land and marginal farms - a farm need not be marginal in an economic sense just because it was on inherently poor land, and a farm on first class land could be marginal because there was insufficient land and the unavoidable costs of equipment and labour were hardly covered by the value of the output.

The moorland core and fringe

4.47 Ideally, in order to follow the causes, courses and rates of vegetation change, ecologists would like to have a comprehensive and precise description of the use, management and vegetation of each piece of land at regular intervals throughout the past. Unfortunately, this is unattainable, as land-use and management surveys or records were not made as frequently and at the level of detail which would provide this. For the more distant past, pollen analysis, archaeological evidence, and early documents provide partial information at irregular intervals, and often refer to special rather than general cases. Even recent statistics and estate records, where they can be found, do not locate situations precisely or record all the data required. It is possible, however, to construct some picture of the recent historical land-use mosaic of the study areas from available maps and other sources.

FIGURE 4.8

AVERAGE NUMBER OF FARM HOLDINGS AND FARM WORKERS BETWEEN 1925-40 AND 1950-60

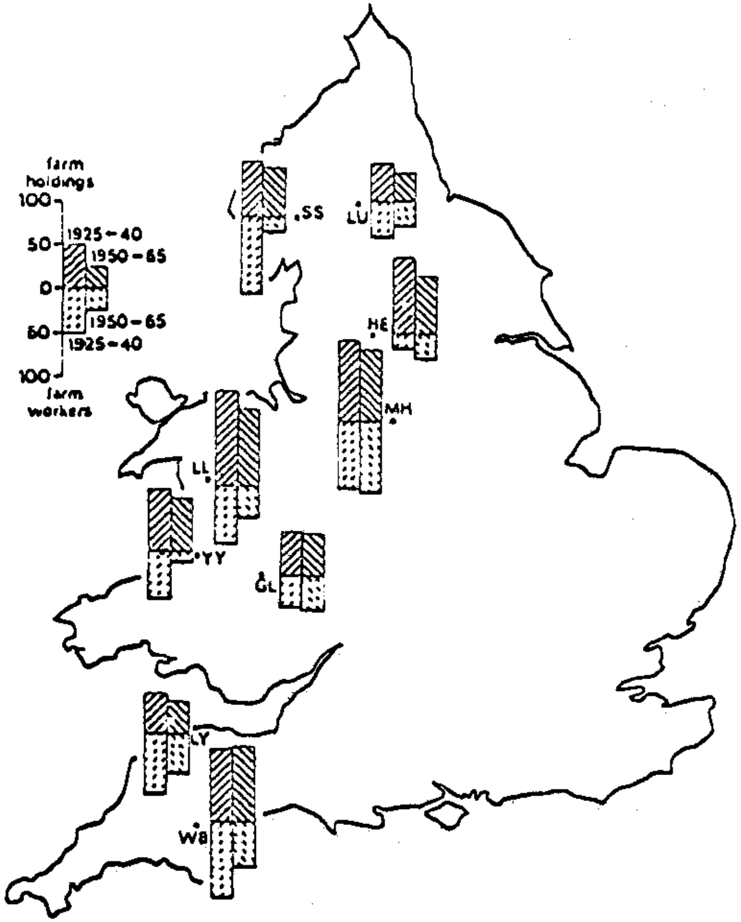
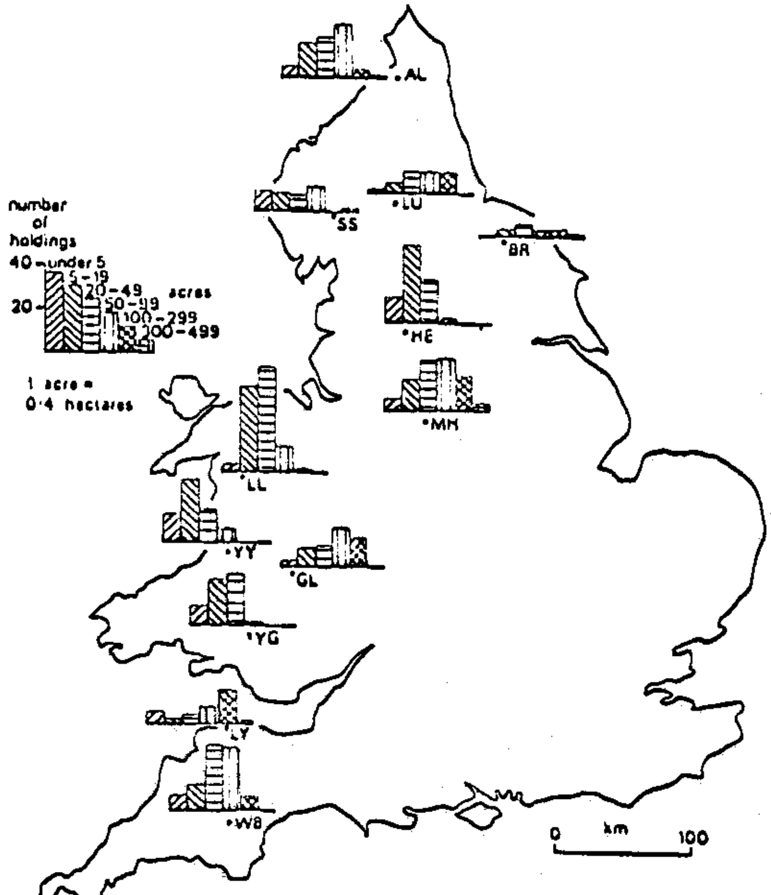


FIGURE 4.9

SIZE OF HOLDINGS 1950



Based on M.A.F.F. Annual Returns

Study Area symbols (Al, LU, etc.) as given in Table 1.1 .

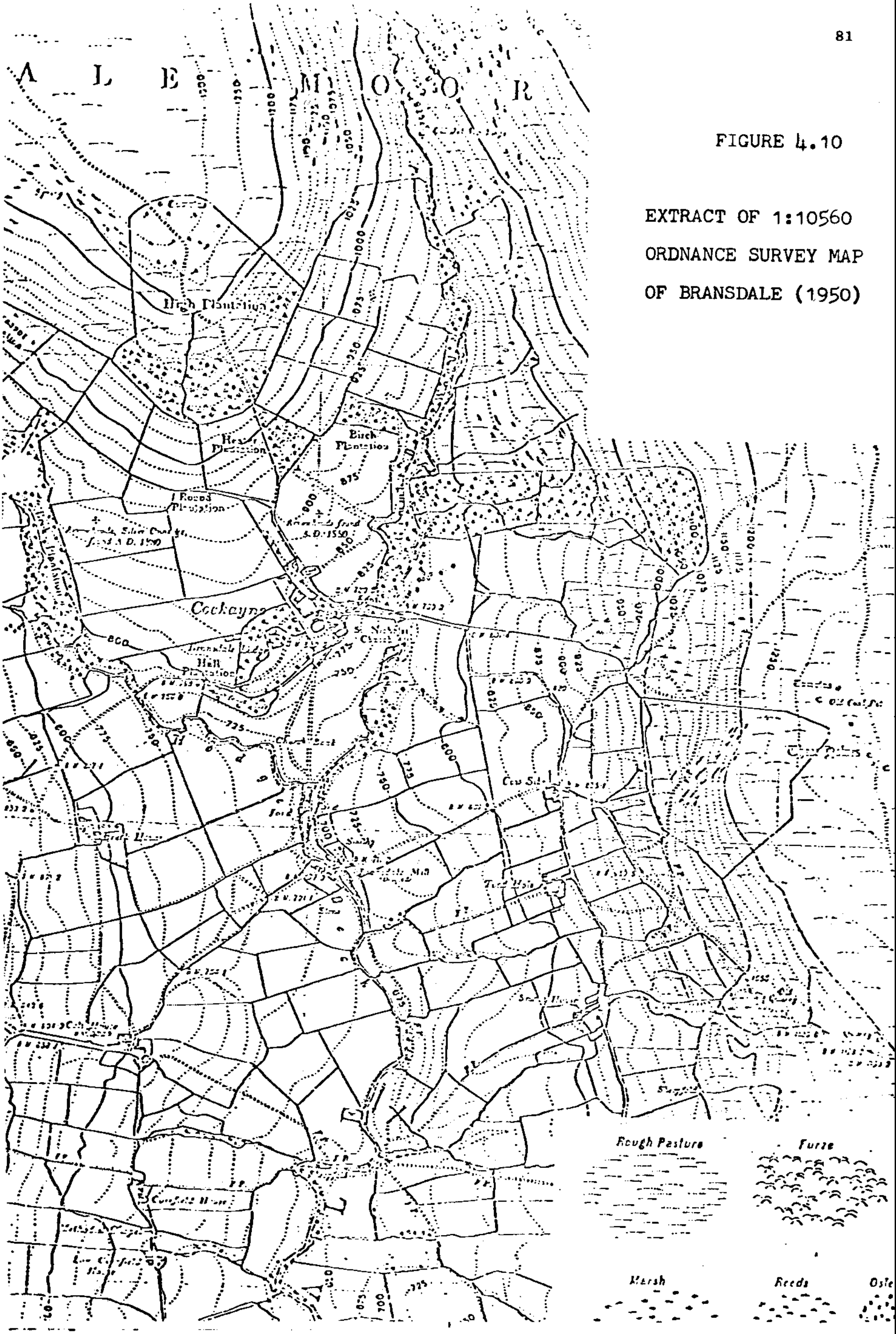
4.48 Trends in land-use and management were complicated. Moorland reclamation and reversion often took place simultaneously on different parts of the upland in response to individual reactions to external opportunities, pressures and demands. Taylor (1978) constructed a theoretical spatial model of the concept of marginality, in which he identified a frontier of permanent and profitable land-use, and another of permanent non-use which, in theory at least, was less flexible, these frontiers being separated by an intergrade zone. The model takes account of outliers and inliers, caused perhaps by local circumstances of soils, grazing conditions, or access. Taylor conceded that his model was highly stylised and too rigid for the real world, where marginality is usually relative, rather than absolute, in its effects. In reality, a mosaic distribution of varying degrees of low and high productivity exists, and it is the purpose here to show in a simplified way how the mosaic within the study areas has changed over the last century or so.

4.49 In the study areas, 'permanent use' land of higher productivity in the Taylor model can be equated with 'farmland', which is now, and for the discernible past has been under cultivation for crops or managed as improved grassland. The area of 'non-use' in the model can be equated with the sectors which have, over the time studied, always been heathy rough grazing. Such areas can be termed 'moorland core'. Land of 'marginal use' in the model can be termed 'moorland fringe'. This is land which was at times used in the same way as the 'moorland core' and, at other times used as 'farmland'. The distinction between moorland core and fringe follows that of Parry (1977), as adopted subsequently by the Peak District National Park authority in formulating land-use policies.

4.50 The most important sources of information on the relative disposition of farmland, moorland core, and moorland fringe are the Ordnance Survey (OS) maps compiled since the mid-19th century. Surveyors were required to record the edge of the moorland, which their instruction handbook defined as the division between land under cultivation or managed as improved pasture, and areas of natural or semi-natural vegetation. The relevant sheets at 1:10 560 scale (1:10 000 in the most recent re-surveys) identify by symbols the tracts of 'rough pasture, heath and moor', where these covered more than 0.25 ha. A section of such an OS map is shown in Figure 4-10. Additional information can be derived from the 7th Series of the OS 1:63 360 maps, which first appeared in 1947, and have now been succeeded by 1:50 000 maps. As well as the map evidence, air photographs of the parts of the study areas identified as moorland core were studied, in collaboration with

FIGURE 4.10

EXTRACT OF 1:10560 ORDNANCE SURVEY MAP OF BRANSDALE (1950)



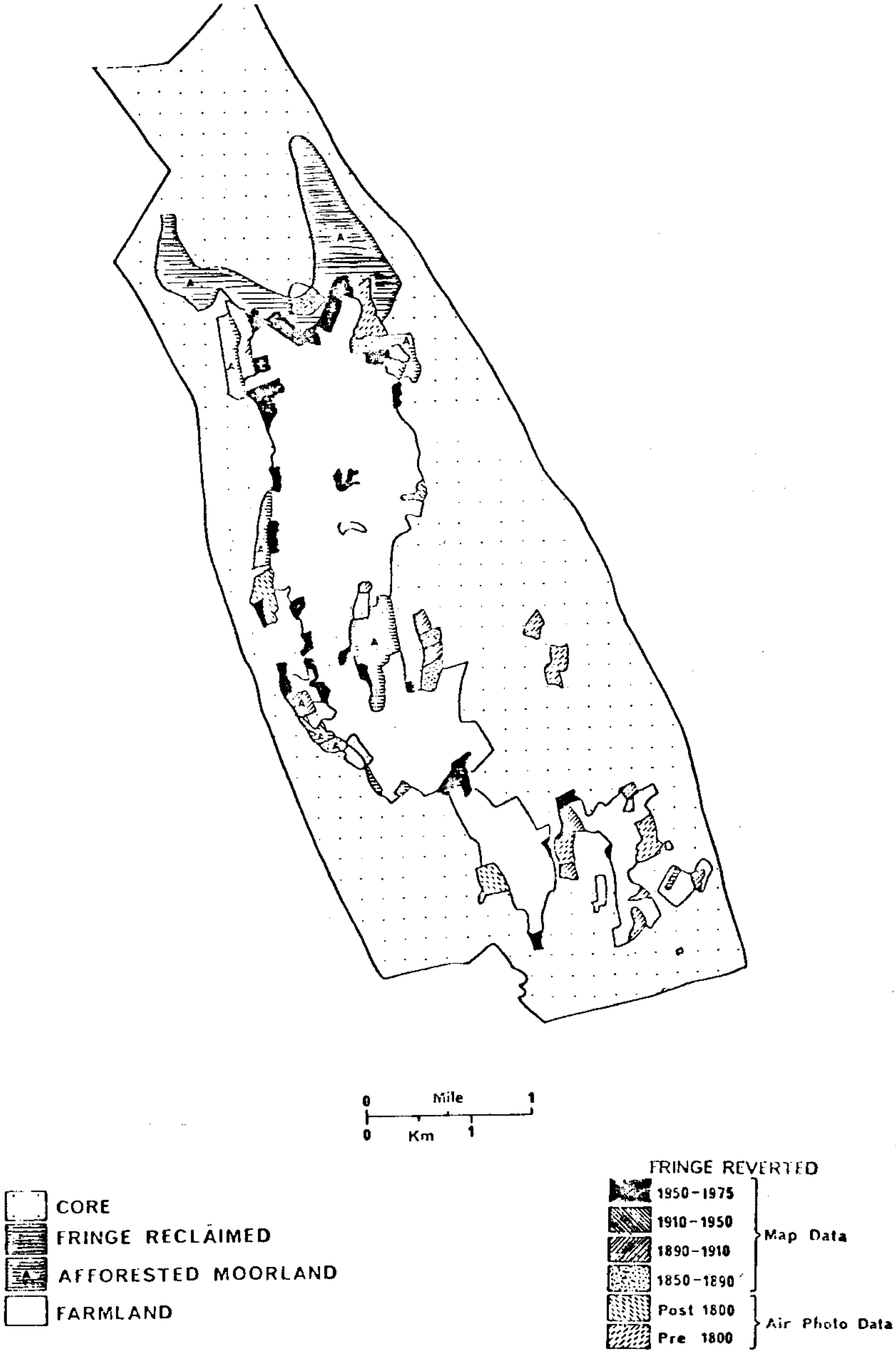
Dr. M. L. Parry, University of Birmingham, who (Parry 1972, 1976a and b, 1977) has discussed the use of air photographs in investigating land-use change. At an approximate scale of 1:10 560, photographs of Welsh areas dated from the 1970s, and the remainder were taken by the Royal Air Force in the 1940s. On these photographs parts of the 'moorland core', as defined from its mapped history after about 1850, were found to show evidence of previous cultivation. For recording purposes, a distinction was possible between plough-marks on the photographs that are characteristic of ploughing before or after about 1800.

4.51 Two subsidiary forms of map evidence were used. For land-use in the 1930-38 period, reference was made to the annotated 1:10 560 field sheets that were compiled during the first Land-Use Survey of England and Wales. On these manuscript maps it is possible to distinguish arable, meadow, and pasture from heathland, common, rough and hill pasture, and moorland. Unfortunately not all the sheets survive for the study areas. In order to seek additional insight into land-use in the early 19th century, maps, apportionments and files compiled during the Tithe Commutation Survey of 1836-50 were examined. This survey was carried out on a parish basis, but not all parishes were covered and, in some cases, land-use data were not recorded. Particular use has been made in this study of the tithe maps for Glascwm and Lynton. No land-use data were included on the tithe maps available for Ysbyty Ystwyth, Ystradgynlais, Glyntawe and Buckland.

4.52 On the basis of information from OS and other map sources, and the air photographs, a map was compiled for each study area, identifying the areas that were always recorded, over the period between around 1800 and 1970, as moorland (the moorland core), and those parts which comprise the moorland fringe. An example of such a map is shown for Bransdale as Figure 4-11. In the fringe area, a distinction is made between those parts where the cartographic evidence indicates reclamation for agriculture or forestry, and those where reversion from agriculture to moorland has taken place. Similar maps for all study areas are included in Part II of this report.

4.53 Before comparing the pattern and chronology of land-use changes within and between the study areas, attention must be drawn to the limitations of the evidence. The surveys were made at irregular intervals, and there were often long gaps between one survey and the next. It is therefore possible for moorland to have been cultivated but then abandoned between surveys. Additionally, the periods between surveys, and the dates of survey, vary between the study areas. Further difficulties could arise from differences in the way in which the types of land-use were defined and categorised, and in the levels of consistency attained within the

FIGURE 4.11 MOORLAND CORE, MOORLAND FRINGE AND FARMLAND



surveys. However, recent work by Harley (1979) has shown that the recording of vegetation types and land-use was central to the objectives of the Ordnance Survey until at least the early 20th century, and that a high degree of consistency in surveying and recording the land-use data was achieved. In the present study, difficulties in extracting complete data from air photographs were caused in part by incomplete coverage of all the areas and in part by poor clarity prints.

4.54 Bearing these limitations in mind, the extents of moorland core and moorland fringe were measured for each study area, and the results are summarised in Table 4-6. The area of fringe exceeds that of core only in Monyash. In Alwinton and Llanfachreth, the high proportions of fringe reflect the extensive area of moorland that has recently been afforested.

4.55 Table 4-7 shows the variation between study areas in the extent of land reverted from farmland to moorland and the period of reversion. The reverted fringe ranges between low values of about 1.5% in Lynton, Glascwm and Monyash, to around 6% in Bransdale and Widecombe. Low levels of reversion generally imply a retention of reclaimed land under agriculture because of its relatively high quality as in the study areas quoted above, but it may result from initially low levels of prior reclamation, for example in Lunedale. The extent of reversion in Widecombe is notably high in relation to its generally relatively favourable suitability for agriculture. The periods at which reversion took place also vary between study areas. In Alwinton the reversion took place substantially before 1800. Lynton and Widecombe show a high proportion of their reversion to moorland to have taken place between 1800 and 1850. Reversion in Monyash was relatively high in the 1851-1855 period. In Shap and Ysbyty Ystwyth the principal period of reversion was between 1886-1905. Much of the identified reversion in Lunedale, Glascwm and Ystradgynlais occurred between 1906 and 1940. Only in Bransdale, Heptonstall, Glascwm, Ystradgynlais and especially in Llanfachreth has reversion since 1941 formed a significant part of the whole.

CONTEMPORARY MANAGEMENT PRACTICES

4.56 Vegetation change by abrupt human modification of the semi-natural ecosystem continues as a major influence on contemporary upland landscapes. The methods and objectives of modern hill farming are set out clearly in HFRO (1979) and a concise account of grassland improvement techniques is given by Davies (1980) . Valuable papers on agriculture and other land-uses in the uplands are included in CAS (1978). Direct changes by cultivation, fertilising and reseeding for agriculture have immediate revolutionary impacts when

TABLE 4-6 EXTENT OF FARMLAND, MOORLAND CORE, AND MOORLAND FRINGE

Study Area	Total Area	Area of 'Farmland'[1]	Area of Moorland Core	Area of Moorland Fringe	Composition of Moorland Fringe			
					Reclaimed Moorland			Reverted from Farmland
					Total Reclaimed	Reclaimed for Agriculture	Reclaimed for Forestry	
Alwinton	15525	881	12365	2279	1857	105	1752	422
Lunedale	9275	1325	7660	290	105	105	0	185
Shap	11325	3090	7591	644	104	26	78	540
Bransdale	3200	929	1896	375	191	5	186	184
Heptonstall	2300	890	1300	110	19	19	0	91
Monyash	3600	3312	107	181	119	119	0	62
Llanfachreth	7200	1982	3226	1992	1790	31	1759	202
Ysbyty Ystwyth	5350	957	3825	568	335	15	320	233
Glascwm	3675	1931	1300	444	382	306	76	62
Ystradgynlais	4775	935	3221	619	396	21	375	223
Lynton	3150	1924	885	341	297	297	0	44
Widecombe	5050	2296	2140	624	313	307	0	311

Data from analysis of Ordnance Survey and air photo sources, for the period post - 1800 approximately (Areas in hectares)

1 'Farmland' is by difference: Total Area - (Moorland Core + Fringe), so it will include some land in non-agricultural use

TABLE 4-7 REVERSION OF FARMLAND TO MOORLAND AT DIFFERENT PERIODS

Study Area	Area Reverted (ha)	Reverted Area as Percentage of Study Area	Period of Reversion, Farmland to Moorland					
			pre-1800	1801-1850	1851-1885	1886-1905	1906-1940	1941-1978
Alwinton	422	2.7	70	7	2		18	3
Lunedale	185	2.0		17	17	10	56	
Shap	540	4.8		1	14	51	34	
Bransdale	184	5.8	16	11	9	22	2	40
Heptonstall	91	4.0		16	35	3	25	21
Monyash	62	1.7			76		24	
Llanfachreth	202	2.8	7	15		11	4	63
Ysbyty Ystwyth	233	4.4		9		55	36	
Glascwm	62	1.7		3		27	48	22
Ystradgynlais	223	4.7	6	21		4	40	29
Lynton	44	1.4		53		19	28	
Widecombe	311	6.2	8	66		7	19	
Study Areas Combined	2599	3.5	15	17	8	21	27	12
Length of Time (years)	-	-	?	50	35	20	25	38

As the percentage of the land reverted from farmland to moorland in each time interval.

they affect previously less intensively used land. Agricultural management changes in the past 35 years in the British uplands have first concentrated on increasing the productivity of enclosed 'in-bye' farmland, then extended to the upgrading of accessible rough grazings, and finally turned to the moorlands expanding the fringe, perhaps finally, at the expense of the moorland core. Agricultural expansion by the establishment of improved pastures has in many areas elimainated or made substantial inroads into land which previously supported less productive, but vegetationally more varied types of grassland, heath, and scrub woodland. Such recent expansion in the study areas has been particularly notable in Lynton and Glascwm (Plate 14).

4.57 In the work covered by this report, concern is primarily with the more evolutionary successions of vegetation change brought about by less extreme and sudden management methods. Generally, gradual vegetation change as it affects the landscape means change in species composition of the plant community and it is this aspect of gradual change that is considered. It should be noted that visual impact also results from seasonal effects such as the annual cycle of bracken growth and dieback, or from contrasts between grazed and ungrazed variants of the same plant community (5.62), but these considerations also are not explored now. This chapter next turns to a summary of the general effects of the more gradual methods that are used to modify moorland and rough pastures in the direction of agriculturally improved herbage, and which permit previously improved grassland to revert towards semi-natural pasture and heath.

Burning

4.58 Burning is very effective in preventing the regeneration or colonisation of tree and scrub species and it also limits the rate of build up of plant litter at the soil surface, though there are conflicting views on the scale of loss of nutrients from the soil-plant system that is brought about by leaching or windblow from the burnt litter. However, the thinning of surface peaty humus through burning may also reduce natural tendencies to an increase in surface moisture and more rapid acidification of soil that can follow a build up of a peaty organic horizon at a soil surface. Excessive burning, or heavy stocking with sheep on a burnt heathy moor, will cause a rapid weakening of heather in favour of moorland grasses. Burning is also applied to some types of grass moor, for example Molinia communities are burned to control litter accumulation and prevent the growth of the large tussocks this grass forms. In 10 study areas burning had occurred sufficiently recently to be obvious at recorded sites, affecting some 6% of these. Only in Monyash and Ysbyty Ystwyth was no previous burning noted at any recorded sites, in the former because no appropriate vegetation occurs there, in the latter for no certain reason, although possible risk to forestry plantations could be a limiting factor to the use of fire. The highest proportion of sites with evidence of burning occurred in Bransdale, followed by Lunedale, Shap and Ystradgynlais. In the first two of these areas burning is an essential tool in management of the moors for grouse. The majority of affected sites were, as was to be expected, shrubby heaths (72% of the sites with evidence of burning were in this vegetation group) with most of the remainder (23%) being grassy heaths and the balance (5%) rough pastures.

Grazing

4.59 Wild animals, mainly hares, rabbits and small mammals graze upland vegetation but their overall effect is generally insignificant in comparison with that of domestic stock though rabbits where abundant can locally graze out the vegetation. Cattle and sheep occupy the place that large wild herbivores would in a natural ecosystem. Some stock species graze more selectively than others, depending upon the season, their age classes, and the relative attractiveness of different plant species to them, sheep being more selective than cattle. Selectivity in grazing will tend to increase when overall grazing pressure is low, and this eventually leads to dominance of the coarser less palatable grasses and dwarf shrubs. Conversely species of prostrate or rosette form, such as clover and plantains, can be favoured by high grazing pressures, and coarser species weakened. In such conditions grazing is unselective because stock are forced to eat whatever is available so that taller, less nutritionally attractive species must be eaten rather than ignored. Grazing pressure is also important in determining the quantity of vegetation consumed by stock and therefore the way in which plant nutrients are returned to the soil in dung and urine, so that the nutrient cycle is affected by the grazing element in the ecosystem. This indirect influence of grazing acting through the soil on succeeding vegetation is probably an effect of similar significance to the direct defoliation of plant species in a community. It is particularly through this nutrient cycling effect that mowing, an unselective procedure generally involving the removal of nutrients in the mowed material, produces a different effect than grazing when applied to vegetation, although both involve defoliation. Mowing however is now rare in the uplands, other than on improved grasslands. Changes in the type of stock grazing in the uplands also affect vegetation. For example at the start of this century large numbers of wether sheep (sheep over 2 years old being kept for meat) were maintained on the hills to supply a demand for mutton. Public tastes in meat changed and mutton became less popular, being superseded by lamb from animals one year old or less, to the extent that today wethers have all but disappeared. Contemporary flocks are largely composed of breeding ewes and yearlings which graze more selectively, making a greater demand on pasture than wethers did formerly. This has resulted in an increased pressure on succulent species of grasses and herbs and an increased opportunity for coarser species to spread. The grazing season has also changed. The less hardy flocks of today are largely withdrawn to the shelter of lower ground for the winter, so that the hill grazing season is now confined to part of the year, whereas in the past large numbers of wethers remained on the higher ground throughout the year giving an unbroken grazing period. In modifying grazing management in accord with modern farming practice, a key factor is increased control on the use of grazing. This control can require new, or renovated, fencing of tracts of upland, a feature which in itself can affect the appearance of the upland landscape as substantially as do the changes in vegetation brought about by the grazing modification.

Drainage

4.60 Soil drainage is necessary at an early stage in improvement schemes on poorly drained soils which remain saturated with water at shallow depths in the soil profile or which restrict surface water penetration. In such situations, on mineral soils at moderate altitudes the semi-natural vegetation (which may for example be rough pastures of classes 5 and 6, Agrostis/Juncus and Festuca/Juncus grassland) is usually rich in rushes and sedges and in species of coarser grasses and herbs tolerant of soil waterlogging. These communities can be important elements in landscape variety and wildlife conservation. The effects of drainage on such communities in the absence of sustained grazing management can lead relatively quickly to dominance by dwarf shrubs or scrub, particularly if these were already a component of local vegetation. Surface ditches, often the simplest drainage method adopted where heavy expenditure is not justified; lower the water table in their vicinity and contribute to a general drying of surface soil horizons, encouraging a shift away from species which tolerate waterlogging. More intensive sub-surface drainage schemes are usually allied to substantial cultivation and reseeding, so that their effect becomes part of a pattern of direct change rather than a factor in the gradual modification of vegetation.

The use of herbicides

4.61 Herbicides have been used in recent years on an increasing scale to modify upland vegetation. Of the wide range now available those most used in the uplands are highly selective in their action (affecting, for example, essentially bracken only, or gorse only) and thus they can alter the species composition of vegetation. An example is asulam (methyl 4 aminobenzene sulphonyl carbamate) which has been used to control bracken over extensive areas in upland Britain (see eg Horrill, Dale and Thomson 1978). Asulam is very effective in producing almost total kill of bracken if used under optimum conditions with prescribed subsequent grazing management. In upland situations, where the need is to treat large areas of land, application is most effective by aerial spraying. This method of application tends to be indiscriminate so that non-target plant communities can often be sprayed by accident or as the result of spray drift. Because asulam is selective, its effect may be less significant where it arrives inadvertently than other less specific herbicides could be. Modifying the species composition of plant communities by the use of herbicides can result in conspicuous change in the landscape. Secondary effects could also be locally damaging from this point of view since modification of plant communities over large areas by killing off major components of the ground cover, followed typically by a planned increase in grazing pressure, can initiate soil erosion, particularly on steep slopes. However, increasing costs of materials and of the means of applying them may limit or eliminate continuing extensive use of herbicides in the uplands other than on the most productive farmlands.

The application of lime and fertilisers

4.62 Addition of lime and fertilisers to potentially improvable soils is general. Acidity of the soil is often a most important factor which limits the agricultural exploitation of hill and upland land by preventing the growth of plants of higher productivity and nutritive value (the associations between vegetation and soil acidity are discussed in Chapter 5). Soil acidity is not only a critical control on the plant species that can grow on a soil but it is also of prime importance to the soil ecosystem through its effects on soil micro-flora and fauna. These in turn control the rate of decomposition of organic matter and therefore the rate of nutrient cycling between soil, plant and animal components of an ecosystem. Surface spreading of lime in some form is the means by which soil acidity is amended. Though liming is often part of a comprehensive cultivation-fertilisation-reseeding direct change package, it can be used independently of such more costly procedures where the land physiography makes access practicable. Plant nutrients - nitrogen, phosphorus and potassium, especially the first two, are also often limiting to competitive growth of some species and to overall production but their expense is such that they are not generally applied except again as part of a concerted direct change package. In some cases a broadcast seed application to speed up species change can follow fertiliser application (Davies 1980). Trace element deficiencies, such as of copper or molybdenum, rarely limit the growth of semi-natural vegetation but can be important to the health of grazing stock on soils of parent materials in which these elements are particularly low.

CONCLUSION

4.63 The factors which control the distribution of vegetation, and which decide whether the balance of plant species is stable or is changing, are those of land character and of land-use and management. The land character sets general limits to the potential range of natural and semi-natural vegetation. Analysis of physiographic, climatic and topographic features through the study areas provides a framework for comparison of land within and between them. Lunedale and Alwinton contain the most 'hill' land, followed by Shap, Ysbyty Ystwyth and Ystradgynlais, then Heptonstall and Bransdale, with the remaining areas containing mainly the potentially or actually more productive 'upland' and 'upland margin' land types.

4.64 Within the limits set by environment, past land-use has created the general pattern of vegetation that can be maintained or modified by current management practices. The present vegetation often reflects past interaction between man and environment, much of the moorland being the result of early clearance of woodland, followed by centuries of grazing and burning. More rapid changes have occurred locally in the last 100 years or so through industrial developments, afforestation and intensive agriculture. Much of the change of vegetation over the last 200 years has resulted from changes in land-use in sectors identified as the 'moorland fringe', which represents about 11% of the total area. Within the fringe about 70% of the change in land-use is development of moorland by afforestation or expansion of intensive agriculture. The remaining 30% of the fringe is land abandoned after a period in intensive agriculture that has been reverting towards moorland.

4.65 Burning and grazing are major contemporary management practices which affect less intensively used vegetation. Burning, particularly of heather moor, was recorded at sites in all areas except Monyash and Ysbyty Ystwyth, most of the burned sites being shrubby heaths and almost all the remainder grassy heaths. Sheep and cattle influence upland vegetation through different intensities and selectivities in grazing and through their impact on plant nutrient cycling. Changes in stock type as well as numbers can alter the effects of grazing, for example a decline in numbers of wether sheep this century is considered to have resulted in reduced grazing of coarser, less palatable vegetation. Drainage, and the application of lime, fertilisers and herbicides also modify vegetation, both in the short term and over at least decades through residual effects.

4.66 Potential for change is built into the structure of a plant community. This change may be of species proportion or location within an otherwise stable and persistent community, or may involve a broader alteration in the balance of species, moving the vegetation from one class to another. Management factors, or an adjustment in some naturally occurring control mechanism, will cause the vegetation to respond and change to produce a revised balance of species appropriate to the changed circumstances. The changes resulting from management practices may be short term and obvious, but treatments which alter soil conditions can have residual effects over long periods of time, especially where soil acidity or nutrient status have been significantly altered.

5 POTENTIAL FOR VEGETATION CHANGE

INTRODUCTION

5.1 Having defined the main classes of vegetation in the study areas, described the land character and land-use history of these areas, and outlined the management factors that influence the pattern of vegetation and its gradual change, the next consideration is the way in which the vegetation classes are associated with their controlling factors. From these associations the most likely trends in gradual change from a particular starting point in particular conditions can be suggested. None of the available approaches are entirely definitive for each possible individual case but each provides insights into directions and, to a lesser extent, rates of vegetation change. The procedure followed in this chapter is to take the following aspects in turn:

i. Associations between vegetation and land characteristics in the study areas indicate the classes of vegetation which are occurring in particular environments and thus suggest the potential for, or probability of, change from or to particular vegetation classes in such environments (5.9-5.39).

ii. A summary of the ecological requirements of key plant species and communities enables us to indicate how the species and communities that occur in the study areas are likely to respond to particular management procedures that bring about gradual change (5.40-5.48).

iii. Because controlled management experiments are the only direct method of determining vegetation change, results from the available limited number of long term experiments are related to the classes of grassland-moorland vegetation identified in the study areas (5.49-5.62).

iv. Historical evidence allows sectors in the study areas to be distinguished in which management changed between moorland and farmland during a known period. Examination of the vegetation at sites in these sectors provides evidence, in addition to that from iii., of rates and directions of gradual vegetation change (5.63-5.74).

5.2 To assess the range of vegetation which now occurs under specific environmental conditions, and the converse, the range of conditions within which a particular vegetation class now typically occurs, two methods have been adopted. First, the sites at which vegetation has been recorded are in effect sample 'points' in the grid squares which have been classified in terms of land types. The association between land type of the grid square and vegetation class at a site within a square can therefore be considered. Second, land characteristics recorded from maps and in the field for the mapped 'point' locations at which vegetation was recorded allow vegetation class associations with individual land and soil characteristics of the sites to be explored.

5.3 The associations between vegetation and land character indicate probabilities of occurrence and the likely range of potential occurrence of vegetation in other specified situations within the study areas, and more widely in the uplands. Clearly, although in general the probability of occurrence of a vegetation class may be correctly assessed, individual situations can differ from the generalisation when additional local factors assume importance. However, the wide sampling on which the general correlations are based gives a standard pattern against which other situations can be compared. The associations are presented as tables giving the percentage frequency of each vegetation group or class in particular situations. In this chapter, the vegetation classes within groups are arranged in the tables in a simple numerical order of their class reference numbers rather than in the ecological order in which they were placed in Chapter 3 and Appendix 5, since the former course makes both preparation and reading of the tables more convenient.

5.4 From these tables it is possible to predict the expected range of vegetation that may occur at sites of particular characteristics or in areas of particular land types. The actual vegetation at a site can be compared with the probabilities of occurrence suggested by the study area data. It is possible then to see whether the observed vegetation is typical or uncommon in relation to the general pattern. If a vegetation class occurs which is uncommon in a particular situation this could be an important aspect in management considerations. Perhaps the main concern might be to maintain or increase diversity of the vegetation classes in a landscape, in which case conservation of an infrequent vegetation class would have priority. Alternatively the management objective might be to retain or develop the vegetation most typical of a situation, in which case such infrequent occurrences might not justify particular attention. Whatever the actual vegetation at a site, alternative vegetation classes are identified that have been observed from the study areas to occur widely in the specific conditions. Thus potential for change may be broadly assessed as likely to lead to one of the frequently occurring classes that have been identified, through the association tables, from the site factors at a location. As a qualification to this there are two possibilities, both with some truth, that affect the interpretation of potential for change between classes from the associations found. It could well be that, for example, grassy heaths and rough pastures do occur in particular situations which allow ready change between them through gradual management modifications. However, it could also be that although they both occur within a particular land type, they may occupy sites which are sharply contrasting in some factor unconsidered in the association tables. Because grassy heaths may be dominant and rough pastures subordinate in a given category of situation, it cannot be certainly inferred that the minority vegetation is more likely to change to conform with the majority. Some other local factor, of geology or soils perhaps, may serve to hold the rough pastures in a stable vegetation state under virtually any minor change of management. Because of this the broad assessments of change made subsequently have to be accepted only as general probabilities, and not certainties, for any individual situation.

5.5 Given an understanding of the broad relationships between vegetation and site, and of the probabilities and potential for occurrence of particular vegetation in a specified situation, what are the modifications required to achieve vegetation change in any direction? Management methods which encourage or discourage key species are considered, and so far as possible from the limited information available for the results of gradual change, the rates of probable changes are assessed.

5.6 Considerations of the principles of how plant species respond, and at what rate, to imposed management are again simply guidelines to a likely outcome in a real situation. It is only through controlled management experiments that one could be certain of the directions and rates of change with which a particular type of vegetation has responded in each possible combination of circumstances. Such experiments could not be set up within the remit of the study, but a small number of relevant trials already existed elsewhere in the uplands. These experimental areas, located from responses to a questionnaire, were visited, and the vegetation in them was related to that of the study areas to provide some direct evidence of rates and directions of change from particular situations.

5.7 Historical evidence, particularly the recognition of parts of the moorland fringe where agricultural improvement has been abandoned, provides a form of management experiment in which a broadly identified change in land-use (farmland to or from moorland) occurred within a broadly known period in time. Although there is no precise information on the situation when cultivation ceased, or on subsequent management, it is possible from examination of vegetation at a selection of sites in the study areas to suggest some estimates of the rates at which some form of improved pasture vegetation has reverted to different classes of moorland vegetation.

5.8 In Part II, in which individual area accounts are given, predictions are made of the possible change in vegetation classes at the recorded main sites that could follow the application of the general ecological principles of change that have been identified. These trends of change resulting from agricultural intensification or decline are summarised in the final section of this chapter. Speculations about vegetation changes that could result from assumptions of the potential of land types for agricultural or forestry expansion are also considered and compared with the predictions based on ecological courses of change between vegetation classes.

VEGETATION-LAND ASSOCIATIONS

Vegetation classes and land types

5.9 To what extent does upland land character determine the classes of vegetation which occur? Table 5-1 indicates, from the frequency of different vegetation groups at recorded sites in each land group, that within the study areas, hill land vegetation is dominated by heaths, mainly shrubby heaths, upland land has a wide spread of vegetation classes in comparable amounts, and upland margin land contains only small proportions of heath vegetation, reflecting its more favourable climatic and physiographic situation. Shrubby heaths can be developed in marginal upland in particular situations but currently they occur on only 11% of the sites sampled in this land group.

5.10 This broad (and familiar) pattern shows the combined effects of environment and management on vegetation. However, in more detailed examination (Tables 5-2a and b) of the overall relationships between vegetation classes and land types it can be seen how the vegetation varies within this general trend. The patterns within the 3 land groups can be summarised as follows.

5.11 The hill land group supports negligible improved pastures, and its rough pastures are principally <u>Festuca</u>/<u>Agrostis</u> grassland (class 8) which, with <u>Festuca</u>/<u>Juncus</u> grassland (class 6), occurs mainly on the steep hill land type. Grassy heaths of the steep hill are mainly <u>Festuca</u>/<u>Vaccinium</u> (class 14), and <u>Festuca</u>/<u>Nardus</u>/<u>Molinia</u> (class 16) and their association suggests that they could develop from the grasslands (classes 8 and 6) under appropriate management. The commonest shrubby heath class is <u>Nardus</u>/<u>Sphagnum</u>/<u>Calluna</u>

TABLE 5-1 VEGETATION AND LAND GROUPS

Vegetation Group	Total Vegetation Sites (% in each Vegetation Group)	Land Group		
		Hill	Upland	Upland Margin
Improved Pastures	27	1	36	48
Rough Pastures	17	7	20	28
Grassy Heaths	23	29	23	13
Shrubby Heaths	33	63	21	11
Percentage of Vegetation Sites in each Land Group	100	34	46	20

Data as percentage of sites in a land group that are classified in each vegetation group

TABLE 5-2a VEGETATION CLASSES AND LAND TYPES

Land Type	Vegetation Class															
	Improved Pastures				Rough Pastures				Grassy Heaths			Shrubby Heaths				
	1	2	3	4	5	6	7	8	14	15	16	9	10	11	12	13
Steep Hill						3		10	17	9	17	4	10	17	9	4
Hill								3	8	6	9	1	8	30	31	4
High Plateau	1		1			1	1	3	10	5	6		9	18	43	2
Steep Upland	1	2	6	10		3	6	14	17	5	20	1	8	1	3	3
Upland	2	8	2	32	9	4	7	5	5	1	3	5	5	2	5	7
Upland Plateau	3	20	4	24		3	3	4	8	1	3	3	10	6	5	3
Upland Margin	7	9	9	23	6	2	8	12	6	1	6	1	3	3	2	2

Data as percentage of sites in a land type that are classified in each vegetation class

TABLE 5-2b VEGETATION CLASSES AND LAND TYPES

Land Type	Vegetation Class: Improved Pastures				Rough Pastures				Grassy Heaths			Shrubby Heaths				
	1	2	3	4	5	6	7	8	14	15	16	9	10	11	12	13
Steep Hill						13		13	19	26	20	29	16	21	8	12
Hill								5	13	23	14	7	18	47	40	15
High Plateau	5		3			5	3	2	8	12	6		10	15	31	6
Steep Upland	5	5	26	12		23	24	32	29	24	35	7	18	2	4	15
Upland	10	18	8	30	52	23	24	8	6	3	5	29	10	2	6	30
Upland Plateau	18	50	17	26		18	13	8	13	6	6	21	22	9	6	9
Upland Margin	62	27	46	32	48	18	36	32	12	6	14	7	6	4	5	13

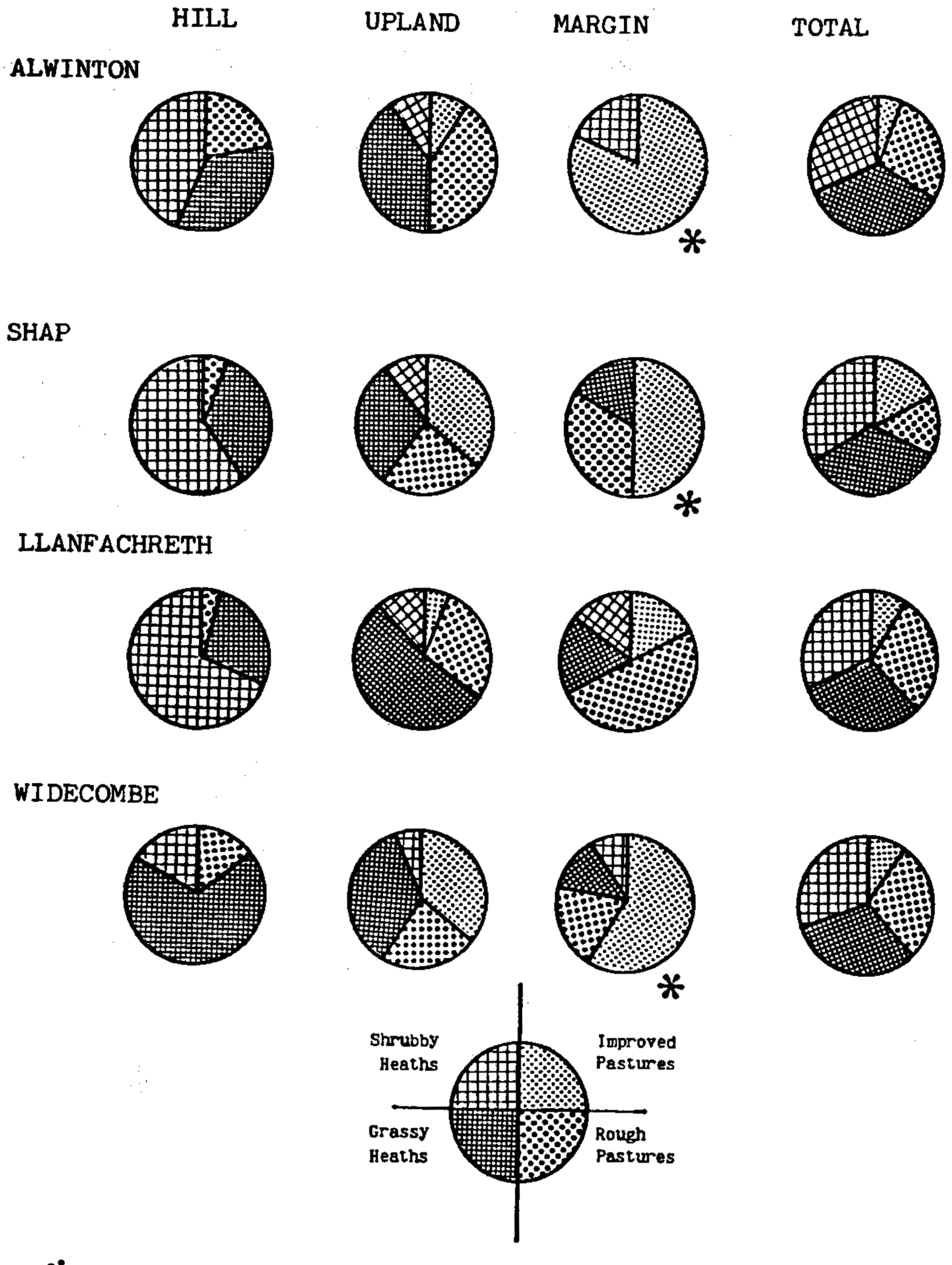
Data as percentage of sites in a vegetation class that are situated in each land type (class 11). The vegetation range of the steep hill land type includes a larger number of frequently occurring vegetation classes than is the case with hill and high plateau, giving a greater vegetational diversity to this land type. In the hill and high plateau types, shrubby heaths of class 11 (Nardus/Sphagnum/Calluna) and class 12 (Calluna) are dominant. Both these, are typical peat bog vegetations in which the likelihood of marked vegetation change by simple management modifications is low.

5.12 In the upland land group the range of vegetation classes that occur frequently is greater than on hill land. All the vegetation classes occur in the upland land type, and only Agrostis/Juncus grassland (class 5) was not recorded in the steep upland and upland plateau types. Improved pastures are mainly the better Lolium classes (classes 2 and 4), and rough pastures tend to be dominated by Festuca/Agrostis grassland (class 8). The latter, as in the hill land, is associated with grassy heaths (classes 14 and 16) on the steeper sectors. Upland margin also contains a wide spectrum of the vegetation classes but because of its greater potential for agriculture this land type has become dominated by improved pastures and rough pastures.

5.13 Interpretation of these association tables in terms of courses of change must, as noted previously (5.3-5.4), be made with caution but they do display a clear relationship between the present frequency of vegetation classes and land character. With further information on the relationship of vegetation to particular site factors (5.20), the most likely options for a first assessment of possible trends of vegetation change at a particular site can be inferred.

5.14 The frequency of vegetation classes in land types in any particular area reflects local factors acting over the broad environmental constraints. In Part II, tables and sketch maps show the relationship between vegetation class or group and land type or group for each area. Figure 5-1 shows the contrast in the occurrence of vegetation groups in each land group for four study areas, chosen simply to cover the geographic range of the 12 areas. There is seen to be a general similarity of vegetation frequency through the different areas but some clear deviations from the average. In the hill group, for example, Llanfachreth has a higher proportion of heath vegetation and a lower proportion of rough pasture than Alwinton. The degree of agricultural improvement in the upland land groups is greater in Shap and Widecombe than in Alwinton and Llanfachreth, apparently mainly at the expense of the extent of grassy heaths. Data for the marginal upland type indicate a lower extent of improved pastures in Llanfachreth than in other areas.

FIGURE 5.1 FREQUENCY OF VEGETATION GROUPS IN LAND GROUPS IN FOUR STUDY AREAS.



* Sample numbers low in these categories

5.15 Some study areas other than those used in Figure show substantial local variations in individual vegetation categories. For example, 74% of the vegetation sites in the hill sector of Bransdale are in the shrubby heath group, while, in the hill sector of Lynton, only 15% of the contained vegetation sites are shrubby heaths, but 70% are grassy heaths. Again only 27% of sites in the upland margin sector of Bransdale are improved pastures and 63% heaths, while sites in the upland margin sector of Lynton are 70% improved pastures. Land management in response to local historic and other environmental factors has directed the trends of vegetation change differently in physiographically similar land in these 2 areas, with more intensive agricultural development over recent years in Lynton. In terms of potential for change and the degree to which such potential has been achieved, there is clearly scope for further consideration of these and other contrasts in relation to more detailed analysis of the character, history and current farming pattern of different areas.

Vegetation and rainfall

5.16 Climate, like geology and landform, is a principal soil-forming factor. As well as having indirect effects on plants through climatic controls on soil formation and properties, climate also acts directly on plant performance through water and energy supply, through direct effects of low and high temperatures and through the physical effects of wind. Within the range of upland character in the study areas, which do not extend to the most montane sector of the British uplands, it is probable that direct climatic effects have a greater influence on the productivity of a vegetation type than on its actual existence. The availability of rainfall data at a reasonably detailed scale (Meteorological Office 1977) gives an opportunity to see how strongly the present vegetation class occurrence is associated with rainfall alone, or with rainfall phases of land types.

5.17 Table 5-3 shows associations between three rainfall zones and the vegetation groups and classes. High rainfall sectors, as a whole, have an expected lower frequency of improved pastures and a notably high proportion of grassy heaths. Of the improved pastures, class 1, and to a lesser extent class 3, occur more often at high rainfall than do classes 2 and 4. Among the rough pastures, Agrostis/Juncus grassland (class 5) is infrequent at low to moderate rainfalls. Of the grassy heaths, the species-rich Festuca/Nardus/Molinia heath (class 16) is strongly biased to occurrence at high rainfall locations, while in the shrubby heaths, the Vaccinium/Calluna heath (class 10) has a low to moderate rainfall emphasis.

TABLE 5-3 VEGETATION GROUPS AND CLASSES AND RAINFALL ZONES

a) Vegetation Groups

Vegetation Group	Rainfall Zone Low-moderate	Fairly High	High
Improved Pastures	38	50	12
Rough Pastures	35	32	33
Grassy Heaths	28	12	60
Shrubby Heaths	21	33	46

Data as percentage of sites in a vegetation category in each rainfall zone

b) Vegetation Classes

Vegetation Class		Rainfall Zone Low-Moderate	Fairly High	High
Improved Pastures	1	29	33	38
	2	46	47	7
	3	46	33	21
	4	35	58	7
Rough Pastures	5	4	48	48
	6	32	32	36
	7	32	38	30
	8	48	25	27
Grassy Heaths	14	35	18	47
	15	38	12	50
	16	18	7	75
Shrubby Heaths	9		46	54
	10	48	38	14
	11	17	9	74
	12	15	37	48
	13		62	38

5.18 Pursuing rainfall correlations further, each land type ca be subdivided into rainfall phases (see Table 4-4). Table 5-4a gives the frequency of occurrence of each vegetation class in rainfall phases of land types. With a large number of land/rainfall categories, the number of vegetation sites in a category can be very low, making percentage frequencies deceptive, so that actual frequencies are used in this Table. Table 5-4b gives for each rainfall phase of a land type those vegetation classes that occur frequently (defined as classes occupying more than 10% of the sites which fall in that rainfall/land category).

5.19 The patterns of distribution in Tables 5-3 and 5-4 show the importance of rainfall as a factor influencing vegetation. This influence particularly operates through affecting soil moisture levels, by increasing the leaching of soil nutrients, and, because of general altitudinal correlation with higher rainfall and lower temperatures, the accumulation of peaty organic mattter at the soil surface. The associations between rainfall and vegetation can give another guide to the likely vegetation which might develop in a particular area. For example, bearing in mind the cautionary note in 5.4, with its implication that rough pastures might only have persisted in sites where poor soil drainage made them inappropriate to easy creation of improved pastures, under high rainfall the most frequent improved pastures, which are mainly Lolium/Holcus/Pteridium (class 1) and Lolium/Trifolium (class 3) might if abandoned tend to regress towards Agrostis/Juncus (class 5) and Festuca/Juncus (class 6) rough pastures, these being the most frequent rough pasture classes now occurring under high rainfall. Further regression could be towards grassy heaths, and perhaps particularly to Festuca/Nardus/Molinia heath (class 16) on the basis of its high frequency in wet areas. Two of the dominant shrubby heaths in high rainfall areas (classes 11 and 12) would develop only after a long time, on sites suitable for peat formation to occur. Although the tables can be used in such ways to infer possible directions of vegetation change, interpretations of this sort must be tempered with an understanding of the ecology of each vegetation community in relation to specific site characteristics.

Vegetation and site land characteristics

5.20 The association tables presented so far in this chapter show the frequencies with which vegetation classes occur in different land sectors of the study areas. They can be used to assess the broad probabilities of occurrence of vegetation in other upland areas for which a land analysis based on map data for grid squares has been carried out. Such an analysis for an area is relatively lengthy. An alternative assessment of the likely vegetation options at

TABLE 5-4a VEGETATION CLASSES AND RAINFALL PHASES OF LAND TYPES

Vegetation Class		Steep Hill			Hill			High Plateau			Steep Upland			Upland			Upland Plateau			Upland Margin		
		*lm	fh	h	lm	fh	h	lm	fh	h	lm	fh	h	lm	fh	h	lm	fh	h	lm	fh	h
Improved Pastures	1					1		1	1	1		1		1	1			2	1	4	1	6
	2											2	1	5	5		17	11		4	9	3
	3							1			3	1	1	1	3		5	2	1	5	5	5
	4		1			1			1		4	13	4	7	30	1	17	18		18	13	5
Rough Pastures	5		1							1			2		10	1			1	1		6
	6	1		2				1			2		2		5		2	1	1	1	1	3
	7						1				2	1	5	4	6		3	2		3	5	5
	8	10	2	1		2	2			1	13	2	8	2	3		4	4		4	4	7
Grassy Heaths	14	6	4	7	1		11	2		5	10	4	12	2	4		6	4	5	5		2
	15	6	1	3	3	1	6	1		3	3	1	2		1			1	1			2
	16	1		19	4	1	10			4	3	2	21	2	2		3		2	2	1	8
Shrubby Heaths	9	1	1	3		1	1						1		3	1					1	1
	10	2	3	3	2	4		2	2	11	6	6	2		6		9	1		10	2	4
	11	5	1	12	4		34	1	1	11	1		2		2		1	4		3		6
	12	4	1	4	7	9	27	3	13	17	1	1	1		6			7		1	3	2
	13		2	1		1	3		2	1			5		11			3			2	3

Data as number of occurrences of each vegetation class in a rainfall phase

* Rainfall phases: (see 4.18-19)
lm, low to moderate, 889 or 1092 mm p.a. average, mean value of dominant rainfall range in grid square
fh, fairly high, 1397 mm p.a. average, mean value of dominant rainfall range in grid square
h, high, 1905 or 2667 mm p.a. average, mean value of dominant rainfall range in grid square

TABLE 5-4b VEGETATION CLASSES AND RAINFALL PHASES OF LAND TYPES

Vegetation Class		Land Type: Steep Hill			Hill			High Plateau			Steep Upland			Upland			Upland Plateau			Upland Margin		
		lm[1]	fh	h	lm	fh	h	lm	fh	h	lm	fh	h	lm	fh	h	lm	fh	h	lm	fh	h
Improved Pastures	1																					*
	2													*			*	*			*	
	3																				*	
	4											*		*	*	*	*	*		*	*	
Rough Pastures	5														*	*						*
	6																					
	7													*							*	
	8	*	*								*		*									*
Grassy Heaths	14	*	*	*			*	*		*	*	*	*						*			
	15	*			*																	
	16			*	*		*						*						*			*
Shrubby Heaths	9							*								*						
	10		*			*					*	*					*			*		
	11	*		*	*		*			*												*
	12	*			*	*	*	*	*	*								*				
	13		*												*							

Data as *, categories in which > 10% of sites in a rainfall phase are in the vegetation class

1 Rainfall phases: low-moderate, fairly high, high, as in Table 5-6a

particular sites can be got by considering the relationships between vegetation classes identified at recorded sites in the study areas and land characteristics at those sites. These characteristics can be determined either from maps (5.21) or field observations (5.26).

Map data

5.21 A limited number of physiographic and topographic characteristics, determined as ranges, rather than exact values (Appendix 9, 1-22) were determined from 1:25 000 OS maps for each vegetation main site in the study areas. The associations between vegetation and site land characteristics can be considered from 2 viewpoints. At sites with a particular land characteristic (eg sites of altitude 122-243 m, or sites which are outside field boundaries), what is the frequency with which each vegetation class occurs (Table 5-5a)? Alternatively, for a vegetation group or class, what ranges of land characteristics does it occur in and with what frequencies (Table 5-5b)? It is as well to be clear what these tables are saying. Improved pasture class 1, for example, has 52% of its sites between 122 and 243 m altitude (Table 5-5b). However, considering which vegetation classes were recorded at sites sampled in this altitude range, only 8% of such sites carried this vegetation class (Table 5-5a). Within the sites recorded the class then is strongly biased towards occurrence in this altitude range, but, in this range, it is only one of a large number of alternative vegetation classes of similar frequency of occurrence. Most individual land characteristics are seen to permit a wide and often the entire range of vegetation classes to occur with reasonable frequency. In some situations the recorded sites are concentrated in a few classes only, as for example on steep slope sites. From these tables it can be seen that improved pasture class 4 (herb-rich *Lolium* grassland) and shrubby heath class 12 (*Eriophorum-Calluna* heath) typify the opposite extremes of the environmental and vegetation spectra covered. The former is dominantly a moderate altitude, gentle slope product of intensive management; the latter a high altitude vegetation, relatively remotely situated in relation to settlement features, and under minimal exploitation and management intensity. This conforms with the ecological arrangement of vegetation classes set out in Chapter 3 (3.12 and 3.18).

5.22 Tables 5-5a and b display a number of general trends and, although many of the land characteristics are themselves interrelated some distinctions can be made. Figure 5-2 drawn from these tables shows the main relationship of vegetation groups to altitude zones. Ignoring the lowest height range which contains only 2 sites, there is a broad altitudinal band (123-335 m) with predominantly an 'upland' range of vegetation, dominated by improved pastures. Above

TABLE 5-5a VEGETATION CLASSES AND SITE LAND CHARACTERISTICS

Land Characteristic Range at Site			Improved Pastures				Rough Pastures				Grassy Heaths			Shrubby Heaths				
			1	2	3	4	5	6	7	8	14	15	16	9	10	11	12	13
Altitude Range	<122 m	(≤400 ft)				50			50									
	122-243 m	(401-800 ft)	8	6	8	23	8	2	7	8	8	2	7		6	4	1	2
	244-335 m	(801-1100 ft)	2	9	7	23	3	3	6	9	10	3	9	1	7	3	2	3
	336-426 m	(1101-1400 ft)	1	7		11		3	3	9	11	4	10	3	10	10	11	7
	427-609 m	(1401-2000 ft)						1		4	10	5	11	1	6	25	34	3
	>609 m	(>2000 ft)								8	8	15	8			15	46	
Slope Class	0- 5°		2	8	2	20	3	3	2	6	7	2	4	1	8	11	19	2
	6-11°		2	5	5	15	2	2	5	8	9	3	11	2	5	11	11	4
	12-22°		3	5	3	6	1	3	7	8	14	7	17	1	9	7	3	6
	>22°						3	5	3	20	27	12	10		10	5		5
Location with respect to Mapped Roads	near	(<0.25 km)	4	10	6	23	4	3	6	9	9	2	8	2	6	3	2	3
	moderate	(0.25-0.5 km)	1	3	2	12	2	3	4	12	9	9	12	2	9	6	7	7
	distant	(>0.5 km)	1					2	1	3	12	4	10	1	8	25	31	2
Location with respect to nearest Mapped House	near	(<0.25 km)	4	13	9	31	6	3	8	9	3		6	1	2	1	2	1
	moderate	(0.25-0.5 km)	5	7	3	21	3	2	5	9	9	2	11		7	5	3	8
	distant	(>0.5 km)		3	1	4		2	2	6	13	6	11	2	10	17	20	3
Location with respect to Mapped Field Boundaries	Inside		4	12	7	31	5	2	8	9	5	1	8	1	1	3	1	2
	Outside			1	1	1		2	1	7	14	6	10	2	12	17	21	5

Vegetation Class columns as above.

Data as percentage of sites in a land characteristic range falling in each vegetation class

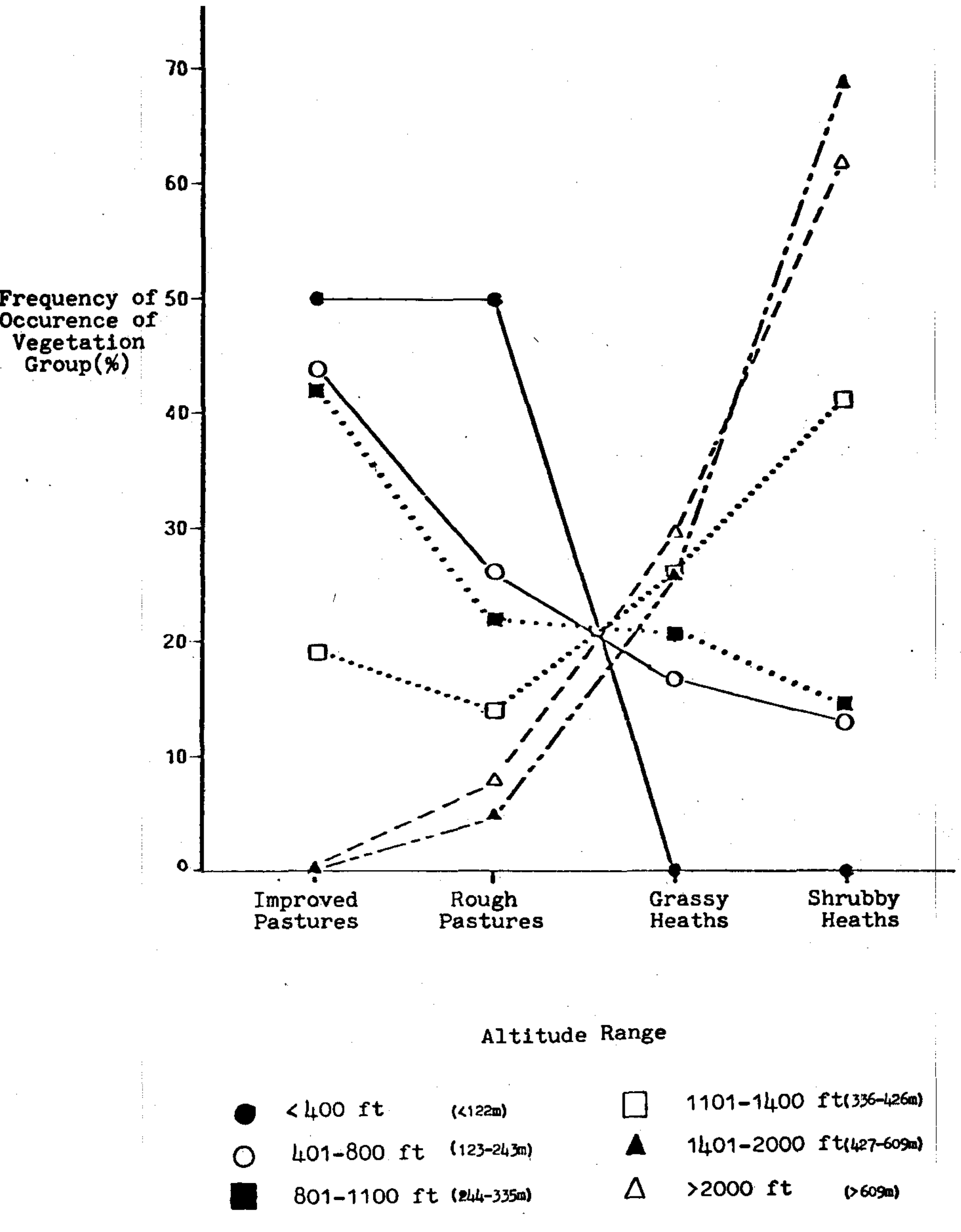
Rounding up of percentages prevents totals in groups necessarily equalling figures in Table 5-7a

TABLE 5-5b VEGETATION CLASSES AND SITE LAND CHARACTERISTICS

Land Characteristic	Range at Site		Improved Pastures 1	2	3	4	Rough Pastures 5	6	7	8	Grassy Heaths 14	15	16	Shrubby Heaths 9	10	11	12	13
Altitude Range	<122 m	(<400 ft)				1			5									
	122-243 m	(401-800 ft)	52	14	29	20	48	9	24	16	11	6	10		12	5	1	9
	244-335 m	(801-1100 ft)	38	54	71	57	48	50	53	43	37	26	35	21	34	11	6	27
	336-426 m	(1101-1400 ft)	10	32		22	4	36	18	28	32	32	30	63	36	29	28	49
	427-609 m	(1401-2000 ft)						5		11	19	30	24	16	18	53	59	15
	>609 m	(>2000 ft)								2	1	6	1			2	6	
Slope Class	0- 5°		28	44	20	41	43	41	13	23	24	21	16	28	37	31	48	21
	6-11°		52	42	70	53	43	32	55	50	43	35	54	49	37	55	48	46
	12-22°		20	14	10	6	8	18	29	16	22	29	26	23	19	12	4	27
	>22°						6	9	3	11	11	15	4		7	2		6
Location with respect to Mapped Roads	near	(<0.25 km)	85	91	90	83	83	59	79	64	49	24	47	65	43	14	10	50
	moderate	(0.25-0.5 km)	5	9	8	15	12	18	16	26	16	40	21	21	22	11	10	35
	distant	(>0.5 km)	10		2		5	23	5	10	35	36	32	14	35	75	80	15
Location with respect to nearest Mapped House	near	(<0.25 km)	43	51	60	53	65	27	47	28	7	3	15	14	6	3	4	9
	moderate	(0.25-0.5 km)	52	27	20	33	32	19	29	28	24	15	26	7	22	11	6	48
	distant	(>0.5 km)	5	22	20	14	3	54	24	44	69	82	59	79	72	86	90	45
Location with respect to Mapped Field Boundaries	Inside		90	95	92	97	91	50	87	55	24	12	39	22	10	13	6	26
	Outside		10	5	8	3	9	50	13	45	76	88	61	78	90	87	94	74

Data as percentage of sites in a vegetation class falling in each range of a land characteristic (totalled to 100% for each land characteristic category, e.g. Altitude Range, Slope Class)

FIGURE 5.2 DISTRIBUTION OF VEGETATION GROUPS IN RELATION TO ALTITUDE RANGE



this there is a transition zone in which the frequency of improved pastures decreases sharply and there is a marked increase in shrubby heaths. Above 426 m the vegetation remains consistently of 'hill' character, dominated by shrubby heaths.

5.23 Altitudinally defined sectors are, taking the average situation in the study areas, closely correlated with topographic features such as the frequency of roads and houses. Looking at topographic characteristics, 87% of the sites recorded as improved pastures are seen to lie within 0.25 km of a road and 51% of them within 0.25 km of a house, compared with 25% and 5% respectively for shrubby heaths. Man, vegetation, and man's impact on vegetation are here responding to a fundamental gradient of climate, broadly associated with altitude.

5.24 Within these broad, expected patterns more detailed associations of vegetation classes with land characteristics can be considered:

i. The improved pastures are developed mainly (more than 80% of sites) on slopes of less than 11°, with <u>Lolium</u> (class 2) and herb-rich <u>Lolium</u> grasslands (class 4) most strongly associated with gentle slopes. These grassland classes are the most intensively managed vegetation (3.11) but they are not so restricted to low altitudes as are the other improved pastures, both having over 20% of their sites in the 336-426 m altitude range.

ii. Of the rough pastures, <u>Agrostis</u>/<u>Juncus</u> (class 5) and <u>Agrostis</u>/<u>Holcus</u> (class 7) swards are more frequent at lower altitudes and inside field boundaries, but the former is more frequent on gentle slopes. This could imply a high probability of interchange with the improved pastures discussed above (classes 2 and 4), but always in such cases the actual site conditions must be considered, for example soil drainage requirements could be too expensive to justify modification in an improvement programme. <u>Festuca</u>/<u>Agrostis</u> grassland (class 8), although it does occur on gentle slopes, is the most frequent of the rough pastures on steep slopes.

iii. Grassy heaths of the <u>Festuca</u>/<u>Vaccinium</u> heath class (class 14) and rough pastures of the <u>Festuca</u>/<u>Agrostis</u> class (class 8) are the most common vegetation on the steeper slopes, with a possible interchange between them which could result from changes in grazing pressure.

iv. At higher altitudes, shrubby heaths dominate the vegetation (Figure 5-3), but it is mainly the Eriophorum/Calluna (class 12) and Nardus/Sphagnum/Calluna (class 11) heaths which occur above 427 m, reflecting a decline in the growth of Calluna with altitude and severe soil wetness. These 2 shrubby heaths are typical of boggy conditions and are developed mainly on the gentler slopes. Steeper slopes at higher altitudes carry grassy heaths, particularly Festuca/Nardus/Vaccinium heath (class 15) and it is probably these grassy heaths which would be most affected by changes in grazing pressure.

5.25 The availability of land characteristic data for vegetation sites, which can be taken as an independent set of 'points' within the squares used for land type analysis, gave an opportunity to assess the validity of the average values for land characteristics of land types drawn from grid square averages, as given in Table 4-1. For those measures taken in the same or a closely similar way, average values for characteristics of the land types from grid square data are very strongly correlated with average values of characteristics at 'point' sites within each land type (correlation coefficient on 86 paired values = +0.975). This strong correlation provides support for the use of land types determined on a grid square basis as an overall means of assessing the general land character of the study areas or other upland districts, where a district assessment of land and vegetation potential is required, rather than consideration of a few sites only.

Field data

5.26 Field observations provided a limited opportunity to determine the relationship of soil conditions to vegetation. The few observations covered soil texture, depth and drainage and were restricted to minimal notes that would allow rapid indications of soil conditions to be obtained by non-specialists. Additional field measurements were made of the average slope across the vegetation quadrat. Associations of vegetation with these site observations are given in Table 5-6. The field slope associations confirm the relationships of vegetation and land slope derived from map data (Table 5-5), although there is a tendency for the actual field-measured slopes at the recording sites to be rather gentler than was determined for their location from the broad slope classes drawn from map contour spacings.

TABLE 5-6 VEGETATION CLASSES AND FIELD SITE AND SOIL CHARACTERISTICS

Site Characteristic		Improved Pastures 1	2	3	4	Rough Pastures 5	6	7	8	Grassy Heaths 14	15	16	Shrubby Heaths 9	10	11	12	13
Site Slope	0- 5°	**	**	**	***	***	***		**	**	**		***	***	***	***	**
	6-11°	***	**	**			**	**	**	**	**	**			**	**	**
	12-22°	**						**		**		**					
	>22°																
Soil Texture	Sand or sandy loam			**									**	**			**
	Loam	**	***	**	**	***		**	**								
	Clay loam	**	**	**	**	**	**	**	**			**					
	Peaty						**			**	**	**	***	**	***	***	**
Soil Depth	<20 cm mean	**			**	**		**	**	**	**		***	**			***
	21-50 cm mean	**	**	***	***	***	**	**	**	**	***	***	**	***	**	**	**
	>50 cm mean			**	**		**					**			***	***	
Soil Drainage	good	***	**	***	***	**		***	***	**	**		**				***
	good + moderate	**				**	**				**						
	moderate		**							**			***	**			
	moderate + poor																
	poor											**			***	***	
Soil Acidity (pH)	<4.2									**	**	**		***	***	***	
	4.25-4.7									**	**	**	***		**		**
	4.75-5.2					**	**		**		**	**					**
	5.25-6.0	***	**	***	***	***	***	***	**								
	>6.0	**	***		**												

Data as percentage of sites in a vegetation class falling in each range of a site characteristic

*** >50% of class in range of site characteristic

** 26-50% of class in range of site characteristic

5.27 Soil texture field notes, assessed from the 'feel' between the fingers of augered soil samples, show that peaty horizons are prominent in soils at sites of rough pasture class 6, (Festuca/Agrostis grassland) and those of all the heath classes, dominating at sites of shrubby heaths of classes 11 and 12, the characteristic classes of boggy moorland.

5.28 Soil depth observations were intended to be made by augering to sub-soil rock or drift parent material but, in upland soils which are often very stony, the auger may often have been able to be driven only to the depth in a soil profile at which stones became too concentrated to permit easy penetration, rather than necessarily to a rock or drift base of the soil profile. With this proviso in mind, the peaty soils frequent in rough pasture class 6 are likely to explain the generally 'deeper' soils in this class compared to other rough pasture classes. Of the heaths, grassy heath class 16 and shrubby heaths classes 11 and 12 would seem to have a higher frequency of 'deep' soils than other classes, again probably due to their proportion of peaty, or poorly drained and hence typically more weathered and less stony, soils. Soil drainage was assessed by a visual estimate of the relative extent of brown (for good drainage) or grey (for poor drainage) colours on augered soil samples, aided by assessment of soil structure and stickiness. So far as these very limited observations go, improved grassland classes 1 and 2 appear to have more imperfectly drained sites than do classes 3 and 4, while, as noted above, sites of grassy heath class 16 and shrubby heath classes 10, 11 and 12 are dominated by soils of poor drainage. There is a need for more comprehensive consideration of the soils and their properties that are associated with the different vegetation classes than was possible during the field work reported here.

Vegetation and soil acidity

5.29 The relationship between soil acidity and upland vegetation classes justifies attention at greater length. Interactions between soil conditions and plants involve a wide range of chemical, physical and biological soil properties. Within this complex of soil properties, soil acidity is the most useful single and readily determinable characteristic (see eg Bache 1979) which shows strong correlations with the occurrence of vegetation types in the semi-natural upland environment. Whatever the other soil conditions, soil acidity levels can make it impossible, or improbable, for particular vegetation to grow, without substantial soil chemical modification involving the addition of lime to, or prolonged leaching of lime from, a soil profile. Soil acidity is measured on the pH scale (pH is a measure of hydrogen ion concentration) and in the laboratory is accurately determined on a soil:water suspension using a pH meter. pH levels in soils range in Britain between about 3.8 and 8.5 (7.0 being neutrality on the pH scale), with soils above pH 7.0 being, under British conditions, generally calcareous (that is, with excess lime). Numerically lower pH values mean a higher degree of acidity. pH values were determined in the laboratory as an average for the 0-10 cm depth of 4 soils at each vegetation recording point. These values are grouped here into ranges < 4.2, 4.21-4.7, 4.71-5.2, 5.21-6.0, > 6.0. The highest range is typical of that at which most British agricultural soils are maintained by liming, the lowest values are characteristic of the least fertile and most leached moorland soils or of uncultivated shallow soils on lime-poor, silica-rich rocks.

5.30 The distribution of vegetation groups in relation to soil pH is shown in Table 5-7 and can be summarised as:

i. Improved pastures are found mainly on soils above pH 5.2, 40% of them being above pH 6.0. Within the improved pastures there is little distinction in pH ranges between classes except that class 3 (Lolium/Trifolium grassland) has a notably lower proportion of sites above pH 6.0 than the other classes in the group have.

ii. Rough pastures overlap the pH range of the improved pastures but occur down to lower pH levels. Classes 6 and 8 (Festuca/Juncus and Festuca/Agrostis grasslands) are more frequent at lower pH ranges than are other classes in this group.

iii. Grassy heaths have few sites above pH 5.2 and significant numbers in the lowest pH ranges. Class 14 (Festuca/Vaccinium heath) has a lower pH emphasis than the other 2 classes.

iv. Shrubby heaths are predominantly on very acid soils with few sites above pH 4.7. Classes 10 (Vaccinium/Calluna heath) and especially 12 (Eriophorum/Calluna heath) are most strongly confined to acid soils, class 12 being virtually confined to soils of pH < 4.2, while classes 9 and 13 (Calluna/Molinia/Vaccinium and Calluna heaths) cover the widest range in pH in this group.

5.31 Taking soil pH as a single factor and ignoring other controls, some improved pastures could adjust to a rough pasture vegetation composition with only slight falls in pH, and rough pastures in turn overlap in the mid-range with some grassy heaths. There is very little direct overlap between the pH range of rough pastures and that of shrubby heaths. Considerable time is required to bring about a sufficient fall in pH by natural leaching for heath shrubs to do well in most abandoned rough pasture situations (see comment

TABLE 5-7 VEGETATION CLASSES AND SURFACE SOIL ACIDITY

Vegetation Class		Soil Acidity, 0 - 10 cm Depth (pH Range) <4.2	4.21 - 4.7	4.71 - 5.2	5.21 - 6.0	>6.0
Improved Pastures	1			10	55	35
	2			3	44	53
	3			8	72	20
	4			5	51	44
Rough Pastures	5		4	22	61	13
	6	5	9	38	48	
	7		3	21	50	26
	8	4	14	30	37	15
Grassy Heaths	14	36	48	12	3	
	15	29	24	23	24	
	16	16	42	27	14	1
Shrubby Heaths	9	14	64	22		
	10	76	23	1		
	11	53	40	3		
	12	93	4	2		
	13	21	41	26	12	

As percentage of sites in vegetation class in each pH range at the end of 5.37). If heath shrubs can once begin to colonise then they start to increase the rate of soil acidification by a build up of acid humus from the accumulation of their dead leaves and twigs at the soil surface. In the reverse direction, shrubby heaths can be altered to grassy heaths without significant modification of soil pH. Natural fertility improvement through increased stocking on a grassy heath is not likely to produce a soil pH most adapted to rough pasture vegetation without some application and maintenance of lime dressings to the soil. Consideration of whether the pH ranges characteristic of the vegetation groups differ between study areas shows few significant differences. The Welsh study areas have fewer sites with soils of pH >6.0 among their improved pastures, while shrubby heaths more often occur in the 4.21-4.7 and 4.71-5.2 pH ranges in the western and southern study areas (Shap, Llanfachreth, Ystradgynlais, Lynton and Widecombe) than they do in the eastern and northern areas.

5.32 Consistency between study areas was examined using data for a single vegetation class from each group. In the improved pastures, class 4 showed no significant difference between study areas in the soil pH range it covered; in the rough pastures, class 8, although overall having a wide range of possible pH, was virtually confined to soil pH levels above 5.2 in Bransdale, Ystradgynlais and Widecombe. Among grassy heaths, class 16 in general also covers a wide pH range but occurs only below pH range 4.7 in Alwinton and Lunedale. In the shrubby heaths, class 11 has a small pH range overall, though in Bransdale there is a relatively higher occurrence of this class at the higher pH levels in its range.

5.33 Before leaving this consideration of soil characteristics in relation to vegetation as recorded at main sites in the study areas, it is of interest to plot the total number of sites in each study area that fall into each pH range (Table 5-8). The relative ranking of the study areas in terms of overall soil acidity can be summarised as: YY,LU,BR and AL have lower overall soil acidity (<) than HE<SS, LL<YG<GL, WB<LY<MH. This order corresponds reasonably closely to their ranking in terms of 'hilliness' based on land type frequency (4.17), 'hilliness' being correlated with lower overall soil pH, except that Bransdale and Llanfachreth have more generally acid soils than their position in the 'hilliness' ranking might imply. It also corresponds to the soil pattern (Table 2-3) if overall soil pH is compared with the general extent in each study area of soil mapping units dominated by soils with peaty surface horizons.

TABLE 5-8 DISTRIBUTION OF pH RANGES AT MAIN SITES IN STUDY AREAS

Study Area	pH Range				
	<4.2	4.21 - 4.7	4.71 - 5.2	5.21 - 6.0	>6.0
Alwinton	44	21	17	15	3
Lunedale	68	9	9	11	3
Shap	14	34	20	21	11
Bransdale	55	18	7	13	7
Heptonstall	51	13	5	14	17
Monyash			8	39	53
Llanfachreth	22	25	22	23	8
Ysbyty Ystwyth	47	32	8	9	4
Glascwm	14	15	13	39	19
Ystradgynlais	15	23	14	37	11
Lynton	6	14	6	49	25
Widecombe	5	23	20	37	15
Total (12 Study Areas)	29	20	13	25	13

Data as percentage of main sites in a study area in each pH range

Application of vegetation-land associations

5.34 Consideration of the relationships between vegetation and land characteristics has shown the range of vegetation which occurs at recorded sites with particular environmental conditions. The presence of different vegetation classes in the same general environment may be due to contrasts in soil or other local factors but can imply that they result from different management practices and are therefore interchangeable by management. With caution in considering ecological factors, potential directions of change can be suggested by the frequencies with which classes occur, as has been discussed earlier (5.4). Information from sites recorded in the study areas can be used to infer the range of vegetation which could most readily occur in other sites, either within the study areas or in comparable upland conditions.

5.35 For example, what vegetation options are most likely to occur at a site with the following characteristics?

Altitude range: 244-335 m

Slope: 6-11°

Near (<0.25 km) to roads; moderately distant (0.25-0.5 km) from buildings; inside field boundaries

Rainfall: more than 1 905 mm pa

Soil pH: 4.7-5.2

Land type, rainfall phase: steep upland, high rainfall

From the appropriate tables earlier in this chapter the vegetation classes with a moderate or high probability of occurrence at sites in the observed range of each characteristic can be identified. 'Moderate or high probability' can be defined at any desired level, but might, as in this example, be specified as those classes which have more than 20% of their total occurrences within the observed range of land characteristics, or more than 10% of their occurrences within the identified rainfall phase of a particular land type. Using these criteria, Table 5-9 gives the vegetation classes which, from the study area data, could occur with moderate or high probability at such a site.

5.36 Adding the site constraints on vegetation class occurrence in the most simple way without attempting to consider interactions between them, the only classes predicted as of moderate to high occurrence at a location with all the characteristics of the example are *Festuca*/*Agrostis* rough pasture (class 8) and *Festuca*/*Nardus*/*Molinia*

TABLE 5-9 KEY TO VEGETATION CLASSES OF MODERATE TO HIGH PROBABILITY AT A SPECIFIED SITE

Site Specification			Vegetation Class															
			Improved Pastures				Rough Pastures				Grassy Heaths			Shrubby Heaths				
			1	2	3	4	5	6	7	8	14	15	16	9	10	11	12	13
Altitude Range	244-335 m	1	*	*	*	*	*	*	*	*	*	*	*	*	*			*
Slope	6-11^{o}	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Roads	near	1	*	*	*	*	*	*	*	*	*	*	*	*	*			*
Buildings	moderately distant	1	*	*		*	*		*	*	*		*		*			*
Field Boundaries	inside	1	*	*	*	*	*	*	*	*	*		*	*				*
Soil Acidity	pH 4.71-5.2	2					*	*	*	*		*	*	*				*
Rainfall Range	high	3	*		*		*	*	*	*	*	*	*	*		*	*	*
Land Type	Steep Upland	4			*			*	*	*	*	*	*					
Land Type/Rainfall Phase	Steep Upland, high rainfall	5								*	*		*					

* The vegetation class has more than 20% of its total occurrence at sites with the given characteristic, or in the given land type, or more than 10% of its occurrence in the given rainfall phase

1 Table 5-5b

2 Table 5-7

3 Table 5-3b

4 Table 5-2b

5 Table 5-4a

grassy heath (class 16). If land type, regardless of rainfall phase, is used as a constraint, then Agrostis/Holcus rough pasture (class 7) also occurs at the specified frequency. If no land type analysis was available, Agrostis/Juncus rough pasture (class 5) and Calluna shrubby heath (class 13) would also be expected with moderate or high probability at a location with all the other constraints. A maximum of five classes (three rough pastures, one grassy heath and one shrubby heath) thus are suggested as having a high potential for occurrence at the site, in terms of site land characteristics. It is clear from Table 5-9 that slope and position with respect to roads are either not at all, or are hardly restrictive of any vegetation classes. The site position with respect to buildings and field boundaries is such that rather more than half the heath classes are unlikely to be present. The strongest constraint on vegetation class presence at this location is surface pH, which is too high for some shrubby heaths and too low for improved pasture classes to be likely. High rainfall also limits the probability of some improved pasture classes. The land type within which the location is situated, particularly its high rainfall phase, is one in which, in general, rough pastures or grassy heaths are more likely than improved pastures or shrubby heaths. Quite probably, such a location would be in a 'moorland fringe' sector, where past agricultural improvement has acted to reclaim moorland, but at which lime and fertiliser application and intensive grassland management have not been sustained in recent times.

5.37 The present vegetation might turn out to be one of the classes forecast as of high frequency at such a location, or it could be one of lower probability. A vegetation class which, from the study area sites, is of low probability of occurrence in the specified conditions can be considered as possibly being a less stable occupant of the site, more susceptible to vegetation change, than a class of higher probability would be. It could of course have particular landscape importance simply because of its relative scarcity at such sites. The likely directions of change from the present situation, and the factors which could bring about such changes can be assessed in the light of the discussion later in this chapter (5.46-5.47, Tables 5-11, 5-12). Whatever the present vegetation may be, one of the strongest options at this example location is for a likelihood that improved pasture could be created, either by a direct change through major cultivation, fertilizing and reseeding, or at least more gradually through liming and surface seeding with increased grazing. A second strong likelihood, if the site became ungrazed and if seed sources are available nearby, would be for the incursion of scrub woodland. The other vegetation alternatives of moderate to high potential are likely to be the maintenance of a rough pasture class in a general equilibrium, or the shift of a grassy heath towards rough pasture, under moderately heavy grazing but without chemical additions to the soil. Most shrubby heath classes are unlikely to be vigorous at the location because of its moderate soil acidity. A slow trend towards heath could occur under reduced grazing, if no source of scrub woodland seed is available but key dwarf shrub heath species are present as minor components or on adjacent land. Change to shrubby heaths apparently requires a long time (from the evidence summarised in 5.69) to bring about the necessary fall in soil acidity to give conditions suitable to allow competitive advange to dwarf heath shrubs such as heather. The time scale of fall in pH in different soils under alternative managements and degrees of leaching due to different rainfalls has not been explored, and is a gap in knowledge of how rapidly heaths might recover on specific formerly limed sites.

Woodlands and land types

5.38 Before considering the association of grassland-moorland vegetation with land use history, and the changes in such vegetation through management factors, it is worth considering briefly the relationship between woodlands and land types in the study areas. Despite their limited sampling, the available data identify land sectors in which native woodlands are, or have some potential to be, important landscape elements. Table 5-10 shows the correlation between the recorded woodlands as a whole and the land types in the study areas. The woodlands recorded are seen to be concentrated in the steep upland and upland margin land types. These contain 30 and 42% respectively of the sampled woodlands though they are each only 16% of the total study areas. Although hill land occupies 48% of the total area, it contains only 8% of the recorded woodlands, situated in Alwinton (5 sites), Lunedale (2 sites) and Shap (4 sites).

5.39 The woodlands which occur in the upland and upland margin land show no distinct pattern of distribution when considering woodland types, the three woodland groups (3.24) being comparably distributed in relation to land type. Local geology, soils, history and management are the major factors determining woodland composition. As a result, in these land types a wide range of deciduous woodland types can occur. Where a change in management on pastures and heaths allows the natural development of woodland on that vegetation, the type of woodland which develops will be determined by local conditions and, particularly, by the species composition of the nearest woodlands or verge and field boundary trees. In contrast, in the hill land, although few woodlands were present, 90% of these were 'upland acid woodlands' with birch and oak, indicating the limited range of deciduous woodland likely to occur naturally following management change on hill land.

TABLE 5-10 WOODLANDS AND LAND TYPES IN STUDY AREAS

Study Area	Land Type						
	Steep Hill	Hill	High Plateau	Steep Upland	Upland	Upland Plateau	Upland Margin
Alwinton	2	3		3			2
Lunedale		1	1		3	1	4
Shap	4			8			
Bransdale				2	3	2	8
Heptonstall				7	2		5
Monyash				1	1	7	1
Llanfachreth				1			14
Ysbyty Ystwyth				2			8
Glascwm				2	4	1	4
Ystradgynlais				7			5
Lynton				7			5
Widecombe				4	4		5
Total	6	4	1	44	17	11	61
% Woodland Sites in each Land Type	4	3	1	30	12	8	42
% Land Types in Total Area	18	19	11	16	9	11	16

Data as number of woods in each land type in a study area

MANAGEMENT METHODS AND GRADUAL CHANGE

The ecosystem

5.40 Soils, animals and plants are interrelated components of ecosystems, none of which can alter without causing changes in the others. An ecosystem responds to a change in one component by adjusting to a new state of equilibrium with its external environment. The rate of adjustment can initially be rapid but then may proceed slowly, over decades or longer. Thus the current state of an ecosystem may be still in the process of reacting to a previous change in conditions. Some aspects of ecosystem change are cyclic, like those which result from the growth and death of long-lived species such as trees. Other changes go in one direction, such as those resulting from progressive leaching of soil nutrients out of the system into drainage waters at a rate faster than is being compensated for by nutrient cycling in the ecosystem and by external natural or artificial inputs. Ecosystems are inherently dynamic, so that in them change is an essential characteristic, though such change may be very gradual or can consist of cycling around a near-permanent stable baseline of balance between species and environment. Vegetation as an ecosystem component has a particular capacity for change (see Miles 1979) that is a key part of the dynamics of ecosystems as a whole.

5.41 Management manipulates parts of ecosystems and as a result introduces into them varying degrees of imbalance. It is easier to modify some ecosystem factors than others. For example, climatic change is an unlikely target for management effort compared to the ability directly to influence soil chemistry or plant and animal distribution. Human endeavour is usually directed to the production of desired elements in an ecosystem - sometimes to the extent of creating a new monoculture, but typically in the uplands aiming for something less completely divorced from the semi-natural situation.

5.42 Plant species and individuals associated in a community compete for space, light, moisture and nutrients. The composition of plant associations is the outcome of this competition in particular environments and the mutual interdependence of the component species. Since environmental conditions repeat themselves there will be repetition in semi-natural vegetation. However, this repetition is not precise and a range of variants adapted to local site conditions exists, giving pattern to the overall vegetation framework.

5.43 The scale of this pattern can vary between relative uniformity over broad sweeps of land, involving many square kilometres, to rapid variation at scales of a few square metres. Between the different units of a vegetation pattern the spatial boundaries are usually gradual, with sharp boundaries only occurring at abrupt changes in, for example, geology and hence soils (see eg Ball et al. 1969 for consideration of the detail of soil pattern in an upland area), or at management boundaries when a fence-line separates two very different grazing regimes. (Plates 43, 44)

5.44 During the course of gradual vegetation change, some plant species decline and disappear while others expand or arrive. Potential colonising species may expand through the spread of existing, but perhaps initially inconspicuous plants, as for example with suppressed heath species in grazed grassy heaths (5.58). Seed distribution is a major element in the successful entry of additional species, this requiring both the availability of a source of seeds and suitable conditions for their germination and establishment. Seeds of species not at present prominent in vegetation can remain buried, dormant but viable, for many years, awaiting suitable conditions for germination (see eg Stevens 1978), while others are transported to sites by wind or animals.

5.45 Soil and climate are among the primary controls on semi-natural vegetation distribution but their impact can often be overridden by management methods aimed at suppressing some species and encouraging others. Gradual changes, as considered here, involving upgrading or deterioration (in agricultural terms) of existing vegetation by management modifications, result from the types of management outlined in 4.56-4.62: burning, grazing and control of grazing by fencing, minor drainage schemes, and limited lime, fertiliser and herbicide applications.

Management effects on key plant species

5.46 Table 5-11 summarises the impact of these management practices on 35 plant species that are important in the grassland-moorland range of vegetation or are trees or shrubs that frequently spread into upland pastures and heaths. The information for this table is drawn mainly from general ecological understanding, rather than from experiment or observation in the study areas, although some evidence from management experiments elsewhere and from dated sites examined in the study areas that are referred to later in this chapter has been drawn on. In considering how a vegetation class in which these key species are prominent might change under alternative managements, or what form of management might be tried to achieve a desired effect in sustaining or altering the present balance of plant species in a community, Table 5-11 provides an

TABLE 5-11 EFFECTS OF MANAGEMENT ON PLANT SPECIES IMPORTANT IN UPLAND VEGETATION

Plant Species	Management							Additional Notes
	Burning	Grazing				Drainage	Fertilisers	
		Degree			Type			
		Light	Moderate	Heavy				
Dwarf Shrubs								
Calluna vulgaris	Burning encourages new growth. Fire maintains *Calluna* dominated vegetation. Cover restored 2-3 years after burning. Excessive burning encourages *Molinia*, *Tricophorum* and other less desirable spp.	Allows *Calluna* to increase in the absence of more resistant species such as *Pteridium* and *Nardus*. Cessation of burning coupled with light grazing tends to encourage scrub.		May cause *Calluna* to disappear and permit dominance of unpalatable species.	Mainly sheep but also cattle. Main food of grouse.	Tolerant of a wide range of drainage conditions. Tends to be replaced by other species under wettest conditions.	Calcifuge species - killed out by liming. A plant of low nutritional needs - generally reduced by use of fertilisers.	Pure stands often very extensive. Landscape value high. Trend towards coarse grassland with excessive burning.
Vaccinium myrtillus	Only aerial shoots killed, rapid regrowth from rhizomes - often therefore giving rise to dominance after burning of *Vaccinium-Calluna* heath.	Sheep will graze *Vaccinium* in the absence of more palatable species. Not greatly affected by grazing.			Occasionally grazed by sheep.	Wide tolerance, but absent from the wettest habitats.	Calcifuge species - responses generally similar to above.	A woodland as well as a heath species. Tolerant of shading and northerly aspects.
Erica cinerea	Tolerates burning, which may result in its temporary local dominance.	Tolerates light grazing.	Killed out by moderate to heavy grazing in favour of *Calluna*. It is generally assumed that *Erica cinerea* is less palatable to sheep than *Calluna*.		Grazed by sheep, cattle and grouse.	A plant of better drained soils. Only on better drained sites can *E. cinerea* compete with *Calluna*.	Calcifuge species - responses generally similar to above.	Sheep grazing in mixed stands of *Calluna* and *E. cinerea* favours *Calluna*.
Erica tetralix	Tolerant of burning - regenerating from the shoot bases. However, repeated burning will result in elimination of this species.	Tolerates light - moderate grazing. It is less palatable to grazing animals.		Killed out by heavy grazing.	Mainly grazed by sheep and small mammals.	A plant of wet habitats. In drier situations it is suppressed by *Calluna* and *E. cinerea*.	Calcifuge species - responses generally similar to above.	May sometimes be locally dominant after fire, but usually an associate species.

TABLE 5-11 (continued)

Plant Species	Management: Burning	Grazing: Degree: Light	Moderate	Heavy	Grazing: Type	Drainage	Fertilisers	Additional Notes
Vaccinium vitis-idaea	Shows rapid recovery after burning and may be present as a codominant with *V. myrtillus* in the *Vaccinietum* phase which often follows burning of *Calluna*. Durability of this phase very variable depending on intensity of burn and ecological features of locality.	Not a palatable species and therefore grazing incidence is low. It may be grazed at times of hardship e.g. when snow and frost are severe.			Occasionally grazed by sheep.	It appears to prefer better drained sites and will spread into places where for a variety of reasons the drainage may have been improved.	Calcifuge species - responses generally similar to above.	Northern distribution, absent from southern heaths. Tolerates shade.
Empetrum nigrum	Tolerance of burning depends on fire temperature. Only slow regeneration after uncontrolled burning. Plant has poor powers of reproduction from seed.	Not grazed. Apparently intolerant of trampling.			Not grazed by sheep or cattle but may be eaten by grouse.	Tolerant over a considerable range of drainage conditions, but in wet situations usually confined to better drained parts.	Calcifuge species - responses generally similar to above.	Intolerant of shading - usually confined to open situations. Appears to need high air relative humidity.
Ulex spp. (*europeus* and *gallii*)	Both these species will regenerate after burning. Seedlings will also appear after a fire.	Tolerant of light to moderate grazing. Light grazing by sheep leads to an increase in gorse cover. Seedlings resistant to trampling, these will spread out to form groups of bushes.			Grazed by sheep and ponies. Cattle do not graze gorse but their trampling can lead to increase.	Shows preference for well drained soils.	*Ulex europeus* has relatively high nutrient demands - will respond positively to fertiliser treatment. *U. gallii* a plant of acidic soils - more heath-like in its lower response to fertilisers.	Species characteristic of disturbed soils. High landscape value as a flowering element in a community.

TABLE 5-11 (continued)

Plant Species	Management							
	Burning	Grazing				Drainage	Fertilisers	Additional Notes
		Degree			Type			
		Light	Moderate	Heavy				
Grasses								
Agrostis tenuis *Agrostis canina* *Festuca ovina /rubra*	All species are tolerant of some degree of burning.	These species are prominent components of upland anthropogenic grasslands often as dominant or codominant species. All are often closely grazed. Their relative status in the sward is related to variation in the level of grazing, local soil moisture regimes and soil base status. All show good powers of recovery from grazing, though there is some variation in response. *A. canina* for instance appears to favour less intensively grazed situations.			Grazed by sheep, cattle, ponies, rabbits and small mammals.	Show considerable range of tolerances but in general these plants show preference for the better drained soils.	All positively respond to treatment with lime and fertilisers. They may later succumb to enhanced competition from other species in the sward unless grazing pressure is adjusted.	Range of sward types is considerable, from herb-rich with many associated species present, to ones which have only a few associate species, to grassy heath.
Holcus lanatus *Holcus mollis*	Survive burning.	Tolerate light grazing.	Suppressed by moderate grazing and killed out at high grazing pressure.		Grazed by sheep and cattle, also by rabbits and voles.	Wide tolerance range - often associated with flushing or slightly impeded drainage.	Not able to withstand enhanced competition from associate species.	*Holcus mollis* is resistant to trampling but *H. lanatus* is eliminated.
Lolium perenne	Intolerant of burning - will usually be killed out as a result of a fire.	Highly responsive to grazing. Becomes dominant under frequent grazing. Excessive trampling is, however, harmful.			Grazed by every class of domestic stock and wild animals.	Intolerant of poor drainage but can recover from temporary inundation.	Highly responsive to fertilisers and lime - giving increased growth and yield.	A major constituent species of most improved grassland types.
Molinia caerulea	Tolerant of burning. Sometimes burned to clear accumulated litter and reduce the size of tussocks.	Not a particularly palatable species except when young, when it is grazed, but otherwise *Molinia* is not grazed to any extent. Formerly cut for hay in the uplands.			Occasionally grazed by sheep and cattle.	A plant of wet habitats needing an abundant supply of water but it is intolerant of stagnation and excessive acidity.	Generally unresponsive to fertilisers and lime.	More readily grazed by cattle than sheep. May be eliminated by controlled grazing with cattle.

TABLE 5-11 (continued)

Plant Species	Burning	Management: Grazing: Degree: Light	Moderate	Heavy	Type	Drainage	Fertilisers	Additional Notes
Nardus stricta	Withstands burning. Burning has been advocated as a means of control, but it does not seem to be universally effective.	Able to withstand light grazing.	Weakened by repeated close defoliation. Not a palatable species generally, but it is grazed early in the season by both cattle and sheep.		Early growth grazed by cattle and sheep.	Wide tolerance range. Usually associated with poor acidic soils.	Generally unresponsive to lime and fertilisers.	*Nardus* is slow growing and it is not able to compete with other species in more fertile situations.
Deschampsia flexuosa	Tolerant of burning.	Able to withstand sustained grazing pressure and will spread when more palatable species are preferentially grazed (eg *Calluna*).			Grazed by sheep and rabbits. Apparently ungrazed by voles.	A plant of drier situations, rare in wet habitats.	Generally unresponsive to lime and fertilisers.	Frequent coloniser of burnt *Calluna* areas.
Cynosurus cristatus	Tolerant of burning if not too intense.	Will tolerate heavy grazing and probably increases under light to moderate grazing. Sheep show a partiality for this species in the earlier stages of growth, but later they reject the flowering culms.			Grazed by all classes of livestock.	A plant of well drained acid - basic soils.	Under conditions of high soil fertility it becomes less abundant.	A common constituent species of many types of grassland but of low constancy.
Dactylis glomerata	Tolerates some degree of burning, so long as it is swift, in which case the effect is to stimulate growth.	Responds to grazing in spring and summer when it is actively growing when it may become dominant in an initially mixed sward. Intolerant of trampling.		Heavy autumn and winter grazing causes *D. glomerata* to be eliminated.	Grazed by all classes of livestock.	Intolerant of very wet conditions but otherwise shows wide range.	Highly responsive to fertilisers particularly nitrogen.	May be a dominant species. Forms large tussocks in neglected grassland when grazing is low. Sensitive to frost and wind burn, when young growths are just emerging.
Rushes/Sedges								
Juncus effusus *Juncus articulatus* *Juncus conglomeratus*	All species tolerant of burning.	Invasive under light to moderate grazing. *J. conglomeratus* perhaps less heavily grazed than other species and also more resistant to trampling.		Show resistance even to relatively heavy grazing. Not easy to eliminate by grazing alone.	Not palatable to sheep. Grazed by cattle.	Plants of poorly drained habitats, especially rough pastures, and grassy heaths.	Generally unresponsive to lime and fertilisers.	Recover readily after cutting. Controlled by draining waterlogged soils, coupled with herbicides.

TABLE 5-11 (continued)

Plant Species	Burning	Management: Grazing – Degree: Light	Moderate	Heavy	Grazing – Type	Drainage	Fertilisers	Additional Notes
Juncus squarrosus	Tolerant of burning.	Young growth only grazed by stock in spring in the absence of more palatable species. Removal of grazing eliminates this species.			Early growth may be grazed by cattle and sheep.	A plant of moist or wet habitats.	Indifferent response but unable to compete with enhanced growth of companion species.	Only able to compete in presence of grazing, because of slow growth and need for high light intensity.
Eriophorum angustifolium	Resists burning but may be eliminated by indirect effects such as reduction in soil moisture and changes in pH.	Resistant to continuous grazing and may become dominant in blanket bog under these conditions.			Mainly grazed by sheep.	Requires high soil humidity.	It seems likely that both species would show a negative response, being plants of low nutritional needs.	Important coloniser of bare peat.
Eriophorum vaginatum	Resists burning and may sometimes spread to form a fire climax.	Tolerant of light to moderate grazing.		Weakened by persistent heavy grazing, but favoured relative to dwarf shrubs (Moor House)	Mainly grazed by sheep.	A plant of wet stagnant habitats but must have high spring water table.		Both *E. vaginatum* and *E. angustifolium* eliminated by effective drainage.
Trichophorum cespitosum	Withstands burning.	Tolerant of grazing, which mainly affects the young growth - this is a species which tends to increase with a reduction in grazing pressure.			Mainly grazed by sheep.	A plant of damp peaty situations.	Generally unresponsive to fertilisers and lime.	May be locally dominant. Eliminated by effective drainage coupled with increased grazing.
Fern								
Pteridium aquilinum	Not affected by fire which cannot damage the underground rhizomes. May spread into adjacent communities which have been temporarily weakend by burning.	Bracken is poisonous, and not normally grazed by domestic stock or wild herbivores. Trampling effect of cattle can reduce the invasive capacity of bracken.			Bracken poisoning well known in cattle eating the plant.	A plant of well drained soils.	No information.	Undesirable agriculturally and may be controlled by use of herbicides. High landscape value as a colour and form element in vegetation.

TABLE 5-11 (continued)

Plant Species	Burning	Management: Grazing – Degree: Light	Moderate	Heavy	Grazing – Type	Drainage	Fertilisers	Additional Notes
Trees/Scrub								
Crategus monogyna	Seedlings and young trees intolerant of burning and killed out by fire, but older bushes are capable of regeneration.	Extensively browsed by both cattle and sheep. No growth surviving below browse height. Young plants, eg in a hedge, need protection of fencing for several years. Regeneration prevented by seedlings being grazed out in early stages of growth.			Browsed by cattle and sheep. Gnawed by rabbits.	A species of well drained soils. Rare on wet peaty soils.	No information.	Natural seedlings will form thickets of scrub if grazing pressure is low - these thickets form valuable protection for other species which are able to grow through them, such as Oak.
Betula pendula *Betula pubescens*	Low tolerance to burning. If fire is not too hot but swift there is chance of growth shooting from damaged stems.	Extensively browsed. Absence of seedlings and saplings is due to grazing by sheep.			Browsed by sheep and cattle.	Wide tolerance range.	No information.	Typical pioneer species, not usually of climax woodland. Large numbers of small wind borne seeds are produced enabling colonies in suitable habitats - light demanding for regeneration.
Alnus glutinosa	Fairly resistant to burning and will shoot from lengths of stem not too badly scorched.	Tolerates light to moderate grazing. May be favoured since grazing also removes competing tall herb vegetation which smothers the young trees.		If grazing is heavy saplings will be trimmed into bushes.	Browsed by sheep and cattle - but less often by sheep because of soft ground.	A tree of wet places and poorly drained soils.	Possesses root nodules and nitrogen fixing bacteria, so has no need of fertiliser nitrogen to encourage growth.	May form pure stands but is usually an associate species.
Quercus robur *Quercus petraea*	Old trees are protected by bark, light fires cause no harm. More severe fires may cause some damage and scars. Seedlings and saplings may be killed outright or tops may be killed but later the plants will shoot from ground level.	Acorns are eaten by a number of animals and regeneration is severely hampered. Seedlings are eaten by grazing animals and saplings are also browsed. Grazing is undoubtedly a factor which contributes to slow establishment.			Browsed by all classes of livestock.	Wide range of tolerances.	No information.	Very wide ecological range of tolerance. *Q. petraea* occurs mostly in west and north on more acid soils but the two species overlap. Natural climax woodland of much of Britain has oak as a dominant species.

TABLE 5-11 (continued)

Plant Species	Burning	Management						
		Grazing				Drainage	Fertilisers	Additional Notes
		Degree			Type			
		Light	Moderate	Heavy				
Salix caprea *Salix cinerea* Ssp. *atrocinerea*	Fair resistance to burning, will readily shoot from lengths of stem not too badly scorched.	Commonly browsed. Fairly resistant and spread may be encouraged by trampling opening up new sites for colonization. However seedlings and young saplings would be destroyed if level of browsing was too high.			Browsed by all classes of livestock.	Wide range of tolerance.	No information.	Both are valuable species in the landscape alongside streams and other wet areas.
Sorbus aucuparia	Poor resistance to burning, will usually be killed.	Tolerant of browsing when mature, but regeneration will only take place in absence of browsing animals or when they are at a low level.			Browsed by cattle and sheep.	Requires well drained soils.	No information.	High landscape value in local situations. Will regenerate if protected from stock.

outline from which the most appropriate course of management action, or the likely outcome of an action, can be assessed. Such an assessment can only give a probability of a particular end-product, rather than a certainty, because of the complexity of interaction of environmental factors on each site. The composite effects of management on individual species lead to changes between vegetation classes, but of course interactions between species within a community and the varying environmental factors in space and time increase the margin of doubt as to the exact outcome in any specific situation.

Direction and rate of change

5.47 To form a picture of the sequence of events involved in change in response to management requires piecing together the type of information collated in Table 5-11 with whatever direct evidence is available in the uplands on the gradual response to known treatments of the vegetation at specific sites. A summary of present knowledge for broad vegetation categories was included in ITE (1978). That summary has been developed here (Table 5-12) in relation to some vegetation classes defined in the present study. The vegetation categories used initially in this Table are, for continuity, the broad groupings of the earlier ITE report, but their equivalents in the present vegetation classes are then given. Table 5-12 sets out to summarise, for 4 shrubby heath, 2 grassy heath and 3 rough pasture classes, the directions in which they may be expected to change under increased or decreased grazing regimes and the periods over which such changes may take place.

5.48 It is even less easy to give generally applicable estimates of rates of change than it is for directions of change. Some evidence comes from management experiments which have run for up to 20 years (5.49-5.62), while longer term changes in the regression of grassland to moorland can to a limited extent be inferred by examining the vegetation of sites abandoned for periods of up to 200 years after earlier intensive agricultural use (5.63-5.74). To try to ensure coverage of suitable management experiments a questionnaire was sent to many organisations and individuals concerned with upland land-use. Through replies to this questionnaire a number of locations were selected where known changes in management had taken place from a known starting point. These experimental sites, outside the study areas but in comparable regions of upland Britain, were visited in order to relate their observed trends of change to the vegetation classes recognised here.

TABLE 5-12 DIRECTIONS AND RATES OF CHANGE OF VEGETATION CATEGORIES UNDER MANAGEMENT

Generalised Vegetation Type (as ITE, 1978)	Equivalent Vegetation Class/es	Soil Conditions	Type of Management	Direction of Gradual Change	Possible Rate of Gradual Change
Agrostis/Festuca (Bent/Fescue) grasslands	6 (*Festuca/Agrostis* grassland)	Well drained	Reduced grazing	Bracken may invade, gain dominance and eventually lead to scrub and woodland.	Bracken can invade at a rate of spread of 20-40 cm/year particularly in absence of trampling.
				In absence of bracken, general trend will be towards Class 14, *Festuca/Vaccinium* heath and in south west perhaps ultimately to dominance by *Calluna vulgaris* (Class 13).	Very difficult to predict - it could take 50+ years to develop heath classes.
		Acid soils	Increased grazing	Development of bryophyte-rich swards, particularly *Rhytidia delphus* spp., *Pleurozium schreberi* and *Hypnum cupressiforme*.	2-3 years with 7 sheep/ha.
		Base-rich soils		General trend will be towards *Lolium* grassland (Class 2). This, however, may not be a direct route and may involve intermediate stage eg *Agrostis/Holcus* grassland (Class 7).	5-10 years with 7 sheep/ha.
	5 and 6 (*Agrostis/Juncus* and *Festuca/Juncus* grassland	Poorly drained	Reduced grazing	Development of taller and tussocky grassland phase with *Deschampsia cespitosa* present. Over a much longer period of time heath species would invade and become dominant.	10-15 years but possibly century + for ultimate change to heather.
			Increased grazing	Probably not a great deal of change would result except that prostrate and rosette species would increase.	3-5 years with 7 sheep/ha.
Nardus stricta (Mat-grass) grassland	15 (*Festuca/Nardus/Vaccinium* heath)	Drier less peaty soils	Reduced grazing	General trend would be towards Class 10 (*Vaccinium/Calluna* heath) perhaps lending ultimately to scrub or woodland.	Could take 15-20 years to reach Class 10 and possibly up to 75-100 years for scrub woodland to develop fully.
			Increased grazing	General trend would be towards Class 5 *Agrostis/Juncus*, but this would depend on soil moisture regime and may not develop.	3-5 years with 7 sheep/ha.

TABLE 5-12 (continued)

Generalised Vegetation Type (as ITE, 1978)	Equivalent Vegetation Class/es	Soil Conditions	Type of Management	Direction of Gradual Change	Possible Rate of Gradual Change
Molinia caerulea (Purple Moor-grass) grassland	16 (*Festuca/Nardus/ Molinia* heath)	Wetter soils	Reduced grazing	General trend would be for *Molinia caerulea* to increase in prominence. Later invasion by *Calluna vulgaris* would lead towards Class 11, *Nardus/ Sphagnum/Calluna* or Class 9 *Calluna/ Molinia/Vaccinium* in western areas.	10+ years
			Increased grazing	General trend would be towards Class 5 or possibly Class 6 *Agrostis/Juncus* or *Festuca/Juncus* grassland, depending on soil conditions.	5-10 years with 7 sheep/ha.
Calluna vulgaris (Heather) heath	13 (*Calluna* heath)	Well drained	Reduced grazing and burning	At moderate altitude, scrub woodland would be the ultimate development in the presence of seed sources.	Very difficult to predict - 20-25 years or longer.
			Increased grazing and burning	Trend would be through Class 14 (*Festuca/vaccinium* heath) towards Class 8 (*Festuca/Agrostis* grassland).	5 years with 5 sheep/ha for initial stage.
				Bracken can invade and irrespective of management may gain dominance.	Bracken can invade 20-40 cm/year.
	10 (*Vaccinium/Calluna* heath)	Wetter soils	Reduced grazing and burning	Scrub or woodland would be the ultimate development in the presence of seed sources, at moderate altitude.	20-50+ years.
			Increased grazing and burning	Probable trend would be eventually towards Class 8 *Festuca/Agrostis* grassland but through Class 14, *Festuca/Vaccinium* heath, at which point the vegetation might stabilise. If conditions are sufficiently wet might go through to Class 6 *Festuca/ Juncus* grassland.	10-20 years for early stages, winter grazing increases rate.
Eriophorum /Calluna (Cottongrass/ /heather) heath	11 and 12 (*Nardus/Sphagnum/ Calluna* and *Eriophorum/Calluna* heaths)	Wet peaty soils	Reduced grazing and burning	General trend would be towards dominance by *Calluna vulgaris* and ultimately in appropriate locations to scattered scrub development.	10+ years for first phase of developing heather dominance and 50+ years for scrub to become fully developed.
			Increased grazing and burning	Gradual elimination of *Calluna vulgaris* and increase in *Molinia caerulea* with *Eriophorum* spp. and *Trichophorum cespitosum*. Nearest vegetation class would be 16 *Festuca/Nardus/Molinia* heath.	5-10+ years with 0.5 sheep/ ha to make initial change in *Calluna-Molinia/ Eriophorum* balance.

Evidence from experimental sites

5.49 Lephinmore Experimental Farm (Hill Farming Research Organisation): At Lephinmore Experimental Farm in Argyll a wide range of management experiments have been conducted on upland vegetation (Grant et al. 1976). Relevant to gradual change, treatments involving 3 different grazing intensities have been applied since 1971 to Calluna vulgaris-dominated blanket bog (vegetation classes 11 and 12). The grazing regimes involved year-round and summer-only grazing, at 3 different stocking rates: 0.66, 1.32 and 1.88 sheep per hectare. The interpretation of results overall was complicated because 2 experimental sites were wetter than the third. After 4 years of controlled grazing, Calluna vulgaris had increased its cover by about 10% under both the low and intermediate grazing intensities, but had remained substantially unchanged at the high grazing intensity. At the drier site there was a steady decline in the cover of Eriophorum vaginatum and Erica tetralix under high stocking density. Erica tetralix had not been seen to be grazed very much, but appeared to be particularly susceptible to trampling.

5.50 Redesdale Experimental Husbandry Farm (Ministry of Agriculture, Fisheries and Food): Changes in stocking density coupled with surface treatments were also imposed on experimental plots at the Redesdale Experimental Farm in Northumberland (Davies 1979). When this management experiment started in 1969, vegetation in the experimental area was comparable to Festuca/Nardus/Molinia grassy heath (class 16). During the next 10 years, liming, phosphate fertilising using basic slag, surface seeding, herbicide spraying and subdivision of the experimental areas had taken place, with grazing by both cattle and sheep. Due to the complexity of the treatments at Redesdale it was difficult to relate cause of gradual vegetation change clearly to effect. It was seen, however, that the cover of Molinia caerulea diminished with increased grazing pressure (approximately from 1.25 sheep/ha to 3 sheep/ha), and that a combination of treatments, probably the combined effect of fertiliser application and increased grazing intensity, had caused an increase in Poa spp. and Agrostis spp. The general trend over 10 years was from a grassy heath (class 16) to Agrostis/Juncus (class 5) and Festuca/Juncus (class 6) rough pastures.

5.51 Snowdonia (Nature Conservancy Council): In a long term study of vegetation change (Dale 1973) a series of grazing exclosures was set up at 4 sites in Snowdonia (3 in 1958 and the fourth in 1968). The treatments were simply concerned with grazing management, and were total exclusion of grazing by sheep, summer protection from grazing, and grazing at all times of the year. Blocks of exclosures were set up on two types of acidic upland grassland at each site. Festuca/Nardus/Vaccinium grassy heaths (class 15), and Festuca/Agrostis rough pasture (class 8) were the starting points.

5.52 Total exclusion of grazing produced major changes in the vegetation of both classes. In class 15, Nardus stricta diminished, becoming extinct inside some exclosures. It was replaced as the dominant species by Molinia caerulea and ericaceous dwarf shrubs, including Calluna vulgaris, Erica tetralix, Erica cinerea and Vaccinium myrtillus. Not all of these species were present at any single site and the dominant assemblages varied from location to location, but in general the trend was towards Vacinium/Calluna heath (class 10). In the Festuca/Agrostis swards, Holcus spp. and Deschampsia cespitosa replaced the former dominant species, representing a change from Festuca/Agrostis grassland (class 8) to Agrostis/Holcus grassland (class 7). In the longer term this trend would probably continue in the direction of grassy heath vegetation, probably Festuca/Vaccinium (class 14). Some species present before exclosure disappeared from the experimental plots. Juncus squarrosus, Potentilla erecta, Sieglingia decumbens and Carex panicea all eventually disappeared from the grassy heath, while Trifolium repens, Plantago lanceolata and Cirsium palustre disappeared from the Festuca/Agrostis grassland. The control plots with year-round grazing and the winter-only exclosure treatment produced no visible changes in the vegetation. The changes resulting from the elimination of grazing took place gradually, making a clear visual impact after about 10 years, when the vegetation inside the ungrazed exclosures was visually quite distinct from that outside, and resembled that otherwise found on Snowdonian ledges difficult of access and therefore ungrazed. After about 7 years, the first woodland species were observed inside the ungrazed exclosures. Saplings of Sorbus aucuparia (Mountain Ash) are now, after 20 years, firmly established inside one of the ungrazed exclosures, having grown up from seeds introduced by birds. If these saplings can develop into trees of flowering and fruiting size, then a trend towards scrub woodland would gather momentum with the presence of a local source of seed. The ultimate change here might well then be to woodland rather than to a grassy or shrubby heath vegetation.

5.53 Moor House (Nature Conservancy Council): At Moor House National Nature Reserve various aspects of the effects of grazing, burning, fertilising and draining on grassland and bog vegetation have been studied since 1953 (Rawes & Heal 1978; Rawes & Hobbs 1979). The pattern of grazing there, in terms of average sheep numbers on the moor, has been stable for at least a hundred years. Long term grazing by sheep has increased the extent of grassland at the expense of dwarf shrub communities, while tree regeneration and development of scrub have been suppressed. Prolonged grazing of grassland has allowed plant species of rosette form, such as Juncus squarrosus, and species unpalatable to sheep at most seasons, such as Nardus stricta and Cirsium spp., to increase. In general terms this has meant a shift from shrubby heaths to grassy heaths in the area.

5.54 The exclusion of sheep from Festuca/Agrostis grassland (class 8) resulted in the grasses Deschampsia cespitosa and Deschampsia flexuosa increasing, because when these species are grazed they cannot reach their full growth potential. In contrast, light-demanding species such as Juncus squarrosus, Cerastium holosteoides, Minuartia verna, Thymus drucei, Trifolium repens and Viola spp. all showed a reduction in the absence of sheep grazing. Exclosures on Festuca/Nardus/Vaccinium heath (class 15) and on swards rich in Juncus squarrosus brought about no marked changes in composition apart from a decrease in Juncus squarrosus.

5.55 Exclusion of sheep grazing from blanket bog shrubby heaths of classes 11 and 12 (Nardus/Sphagnum/Calluna and Eriophorum/Calluna heaths) did not result in much visible alteration in the vegetation since the original grazing pressure on this vegetation was low (about one sheep/50 ha). Increased grazing pressure on blanket bog caused a reduction in Calluna vulgaris and an increase in Eriophorum vaginatum, while Juncus squarrosus and grasses also appeared in the sward, to produce a change from shrubby heaths to a Festuca/Nardus/Molinia grassy heath (class 16).

5.56 Work on controlled burning at Moor House showed that if fire is sufficiently intense the above-ground parts of dwarf shrubs are killed, but other species such as Eriophorum angustifolium, Eriophorum vaginatum and Trichophorum cespitosum are generally little affected since they are dormant in early spring when controlled intentional burning usually takes place. The original species composition of the vegetation is a crucial factor in determining recovery after a fire. Climate and subsequent grazing level are also important. Conditions following burning favour an early flush of growth of Eriophorum spp. which is attractive to sheep, resulting in higher sheep grazing densities on the burnt areas that can delay or reduce the recovery of Calluna. Calluna vulgaris only recovers completely from burning under favourable grazing conditions over a period of years, reaching maximum size and density between 11 and 17 years after burning. Eriophorum vaginatum, besides making a rapid recovery, maintains a higher level of cover for some years after burning, only decreasing to a minimum cover value as Calluna vulgaris again approaches its maximum. If the burning rotation is not sustained, vegetation on blanket bog at Moor House apparently reaches a climax steady state with a mosaic of Calluna interspersed with Eriophorum tussocks. This climax contrasts with the situation at lower altitudes where Calluna in a cycle of regeneration and ageing can be replaced by woodland, if burning is absent and there is sufficiently limited grazing to permit tree seedlings to survive.

5.57 The results of these management treatments indicate similar successional trends. Under conditions of reduced grazing intensity, dwarf shrubs, ie the moorland element of upland vegetation, will be favoured. More intensive grazing suppresses dwarf shrubs and prevents invasion by, or regeneration of, trees or shrubs, thus giving rise to grassy heaths. These can be modified to produce rough pasture classes by liming, fertilising, and grazing control.

5.58 Rates of vegetation change are, as previously stated, difficult to generalise. Progress along a successional pathway of change depends particularly on the original species composition of the initial vegetation. For example, at two Snowdonian sites (5.51-5.52) the change from Festuca/Nardus/Vaccinium grassy heath (class 15) to a form of shrubby heath took place in about 10 years. At two other sites this change, although it may ultimately happen, has at least been delayed, as development has led in 7-10 years to another form of grassy heath in which Molinia caerulea is dominant (class 16, Festuca/Nardus/Molinia heath).

5.59 The factor crucial in this instance is whether or not shrubby ericaceous species are present in the unenclosed sward. If sufficient scattered plants of these species are available in the original vegetation, however small and inconspicuous they may be, progression appears to be direct to an eventual dominance by dwarf shrubs, achieved in a relatively short period of time. In the absence of these species, or if they are present in only very low amounts, succession develops along a different pathway to the dominance of Molinia caerulea (assuming that it is originally present) after about 7 to 10 years, and there is then only a very slow increase in the dwarf shrub species because they have difficulty in penetrating the thick mat of dead Molinia. The trend at the 2 sites suggests, however, that shrubby heath will eventually become established, as Vaccinium myrtillus is beginning to grow up through the Molinia, but the process of reaching a shrubby heath vegetation is clearly going to take a much longer period of time than at the other Snowdonian locations. The effect of climate, through altitude, on spread of heather into disturbed ground has recently been reported by Bayfield (1980).

5.60 The presence of species with potential for invading or expanding in communities and thus emerging as new dominants and so changing the appearance of vegetation is of particular relevance since they can achieve a relatively rapid alteration in the visual character of vegetation in the landscape. If key species such as ericaceous shrubs are present as a few scattered plants in a community that is a form of grassy heath, then their current visual impact can be negligible but their potential for responding to change can be high. It is in this respect that the actual species list at any particular site needs considering, along with site character, as well as the overall vegetation class at that site (3.8).

5.61 The average time intervals for changes to become obvious that are included in Table 5-12 can only be guidelines to specific situations, as has been discussed. In this question of rate of change it is also necessary to appreciate that change in the regression from grassland to moorland can be slow as it becomes increasingly difficult to move the vegetation along a successional pathway as a trend develops towards equilibrium with an environment. Thus it is comparatively easy to change the cover of different grass species within rough pastures or grassy heaths but generally more difficult to move further along the succession to shrubby heaths. This is particularly so where local foci for expansion of these species are absent, as will be seen from consideration shortly of moorland fringe sites (5.63-5.74). Whether scrub woodland establishes rapidly on sites from which grazing has been removed as an alternative to change within the grassland-moorland range is mainly a matter of the local availability of seed sources, as noted earlier (5.52).

5.62 There is a final point worth making before turning from this consideration of management impacts on gradual change. Although emphasis throughout the discussion in this report is on change in vegetation by alteration of species composition, attention should be drawn to the way in which the appearance of vegetation can be considerably altered by changes in plant growth without changes in plant species. For example, <u>Eriophorum</u>/<u>Calluna</u> heath (class 12) has a different appearance when grazed at even quite low intensities than when ungrazed. In the latter state, the component species grow upwards and outwards and are able to flower. Cotton grasses (<u>Eriophorum</u> spp.) flower hardly at all under grazing, but when grazing is absent the visual impact of this heath class in the summer is entirely different, with conspicuous purple flowers of heather and heaths, nodding white seed heads of the cotton grasses, and local areas of interest provided by the flowering of subsidiary species, such as <u>Narthecium</u> <u>ossifragum</u> and <u>Drosera</u> <u>rotundifolia</u>. Even in the vegetative state at other seasons, there will be visual differences in terms of height and form contrasts between the grazed and ungrazed variants of the same community.

LAND-USE HISTORY AND VEGETATION CHANGE

5.63 From Ordnance Survey maps and recent air photographs 3 zones of decreasing intensity of agricultural use were identified in the study areas, as 'farmland', 'moorland fringe' and 'moorland core'. The moorland fringe is of particular interest in the present study because it is land which, in the past 200 years or so, has interchanged between moorland and farmland or forest (4.47-4.55). From mapping the moorland fringe in each study area the types of land which have been subject to this transition can be determined by reference to the land classification. Table 5-13 shows the frequency with which moorland fringe occurs in different land types for the 12 study areas combined.

TABLE 5-13 LAND TYPES AND MOORLAND FRINGE

	Land Type							
	All	Steep Hill	Hill	High Plateau	Steep Upland	Upland	Upland Plateau	Upland Margin
Number of Grid Squares Containing any 'Moorland Fringe'	574	40	24	11	154	92	68	185
Number of Grid Squares Containing any 'Moorland Fringe' as a Percentage of all Moorland Fringe Squares	100	7	4	2	27	16	12	32
Number of Grid Squares Containing any 'Moorland Fringe' as a Percentage of all Squares in the Land Type	19	7	4	3	33	33	21	38
Percentage of Land Type in the 12 Study Areas	100	18	19	11	16	9	11	16

5.64 Moorland fringe occurs in 19% of the grid squares in the study areas, although the actual area of fringe is about 8 500 ha or 11% of the total area. About 60% of the moorland fringe is concentrated in the steep upland and upland margin land types which occupy 32% of the total area. In contrast the hill land group, with its more severe conditions, contains only 13% of the fringe although it constitutes 48% of the study area. Thus the reclamation of moorland for more intensive agriculture and forestry, and the reversion of farmed land to moorland has, in the last 200 years, been concentrated in particular land types.

5.65 The extent of moorland fringe in the study areas varies from a minimum of 3% in Lunedale to a maximum of 28% in Llanfachreth (Table 4-6). In individual areas there is a general correlation between land type proportions and the extent of fringe, but there are divergencies from the average brought about by natural factors such as geology and by local social and economic factors in the recent past. One approach to future change can assume that, where the options for change have not been locally overridden, for example by comprehensive agricultural intensification, the land types in which gradual vegetation change is most likely to take place are, if past experience is followed in the future, steep upland and upland margin. Alternatively (see 5.80) changes, which could involve upgrading agriculturally the remaining heaths and rough pastures or the regression of former pastures towards heath, may occur more widely.

5.66 In part of the moorland fringe, land which had for a time been under relatively intensive cultivation as improved grassland has been allowed to revert towards semi-natural vegetation. This reversion commenced at different times and the evidence from successive OS maps and other sources allows identification of areas which began their reversion in different periods. Thus, recording of the present vegetation at sites within these areas provides some pointers to rates and directions of vegetation change when intensive agricultural management is withdrawn. Because there is no way of knowing exactly what the initial state or subsequent use of an area has been, only a broad idea is given of what could happen on other sites. By chance, some main sites already recorded were in land identified later from the map and photo analysis as moorland fringe. Additional sites were recorded in 1979 from sites of known periods of reversion in several study areas, with a few supplementary sites from the historically well-documented (Parry 1976a, b) Lammermuir Hills in the Southern Uplands of Scotland, an area with much in common with parts of the study range.

5.67 The vegetation classes at 137 sites in the moorland fringe were identified, and the sites grouped into 6 categories on their period of reversion, as shown in Table 5-14. Although age categories are not identical between study areas, this grouping gives a reasonable spread of sites over different reversion periods. From these data, trends of change between vegetation groups can be considered. It can be assumed that most of the sites when abandoned from intensive use would have supported some form of improved pastures. When intensive management ceased, these sites began a trend towards semi-natural vegetation but they would mostly have continued to be grazed, at unknown intensities.

5.68 The present distribution of vegetation groups at these sites, in relation to the periods of reversion, is given in Table 5-15,* with, for comparison, the distribution of vegetation groups at sites which have remained moorland or farmland or have been reclaimed from moorland in the fringe areas. Three features can be commented on. Six of the moorland core sites and 14 in the reverted fringe in fact support improved pasture, an anomaly which could result from inaccurate mapping at some stage or from quite recent reclamation or reversion. Second, a third of the sites reverted in the moorland fringe, including some of apparently early reversion, are still rough pastures. It is likely that grazing pressures higher than those typical of shrubby and grassy heaths will have been maintained since reversion on these sites through preferential grazing, if not actual intentional control. This higher grazing pressure has either slowed the rate of vegetation succession or has stopped the course of change at an intermediate stage (5.70). The third point is that there is a clear dominance of rough pastures on land which reverted during this century. Grassy heaths are relatively more frequent at sites reverted in the latter half of the 19th century. Shrubby heaths only occupy as much as a third of the sites when we reach the earliest reversion period, and then are still only about equal to the proportion of grassy heaths.

5.69 Examining reversion trends in the moorland fringe in more detail, the data in Table 5-15 have been recalculated omitting the improved pastures, and are shown in Figure 5-3. The sequence of change can be interpreted as a time sequence as follows:

i. In the first period of up to 40 years after reversion (reversions between 1941-1978) the vegetation on about 40% of the improved pastures has changed to rough pastures and a further 40% has moved through rough pastures and developed into grassy heaths, while the remainder has developed shrubby heaths either directly or through a series of intermediate stages.

* tabulated reclamation and reversion sites include some main sites which fell in fringe areas

TABLE 5-14 SITES RECORDED IN 1979 FROM MOORLAND FRINGE LOCATIONS

Study Area	Period of Reversion to Moorland							
	Pre 1800	1800-1850	1850-1885	1885-1905	1905-1940	1940-1978	Unknown	Total
Alwinton	15	4	-	-	-	4	-	23
Lunedale	-	4	1	-	8	-	-	13
Shap	-	-	2	7	9	6	-	24
Bransdale	7	-	-	-	-	4	-	11
Llanfachreth	-	4	-	2	2	8	2	18
Ysbyty Ystwyth	-	2	-	10	-	-	-	12
Glascwm	-	-	7	3	4	-	-	14
Widecombe	-	7	-	1	1	-	-	9
Non-study area: Lammermuirs	2	3	1	1	4	2	-	13
								137

TABLE 5-15 LAND USE HISTORY AND VEGETATION GROUP FREQUENCY

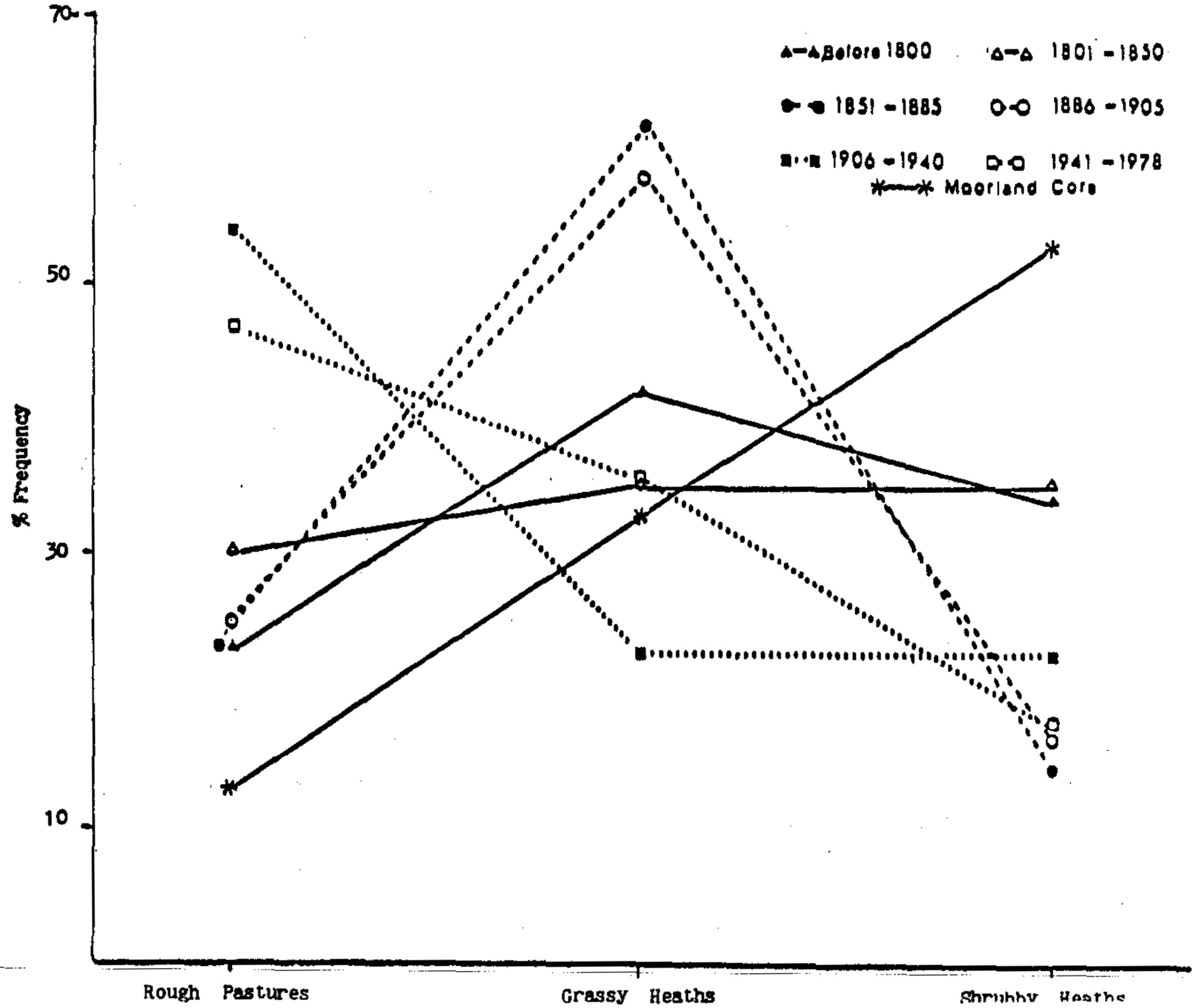
Land Use History Category[2]		Vegetation Group								Number of Sites[1]
		Improved Pastures		Rough Pastures		Grassy Heaths		Shrubby Heaths		
Moorland Core		1	(6)	13	(78)	33	(198)	53	(313)	(595)
Moorland Fringe:	Reverted from Improved Pasture									
	before 1800	4	(1)	22	(6)	41	(11)	33	(9)	(27)
	1801-1850	5	(1)	29	(7)	33	(8)	33	(8)	(24)
	1851-1885	7	(1)	21	(3)	56	(8)	14	(2)	(14)
	1886-1905	8	(1)	23	(3)	54	(7)	15	(2)	(13)
	1906-1940	8	(2)	50	(14)	21	(6)	21	(6)	(28)
	1941-1978	6	(1)	44	(8)	33	(6)	17	(3)	(18)
	Total	6	(7)	33	(41)	37	(46)	24	(30)	(124)
Moorland Fringe:	Reclaimed from Rough Pasture	47	(14)	37	(11)	10	(3)	6	(2)	(30)
Farmland		74	(165)	23	(51)	3	(6)	0	(1)	(223)

Data as % of sites in history category, and as (number of sites)

1 For all study areas excluding Monyash, using main site and supplementary site data

2 As identified from successive O.S. map editions and recent air photographs

FIGURE 5.3 THE CHANGE IN FREQUENCY OF ROUGH PASTURES, GRASSY HEATHS AND SHRUBBY HEATHS ON LAND WHICH REVERTED FROM INTENSIVE AGRICULTURE DURING DIFFERENT TIME PERIODS.



ii. The situation remains fairly stable over another 35 or so years (reversions between 1906-1940).

iii. In the period 75 to 130 years after reversion (reversions between 1851 and 1905) half of the earlier rough pastures show a gradual development to grassy heaths, these heaths representing about 60% of the vegetation on sites of this age of reversion.

iv. Between 130 and 180+ years (reversion before 1850) dwarf shrub species development on the grassy heaths increases and the proportion of shrubby heath vegetation classes now reaches 35%.

5.70 This interpretation of a time sequence is one hypothesis, and alternative interpretations could be made, but mechanisms which can account for the slow sequence of events can also be suggested. The fairly rapid initial change to rough pastures results from factors such as the drainage deterioration that is possible on some sites, a general leaching of plant nutrients to give lower fertility, and the increased vigour and growth of native species that invade or are already present in small quantities in the original sward in relation to the relatively short life-spans of the introduced improved pasture species. On the most naturally acid and readily leached soils heath development can occur relatively rapidly as grazing pressures are reduced. However, in general, because of the residual effects of former intensive management, grazing on the reverted areas remains at a higher level than on surrounding moorland. Sheep and cattle preferentially graze these sites and sustain a more rapid circulation of nutrients through cropping the vegetation and returning nutrients to the soil surface in their dung and urine. Some sites gradually revert to grassy heaths at rates depending on local conditions and grazing pressures. The succession beyond these to shrubby heaths is very slow on most sites, not only because of the grazing pressures but because the development of the very acid soil conditions required for dominance by ericaceous shrubs is a very slow process.

5.71 Even after 180 years or so the sites on which improved pastures were abandoned have not reached the vegetation group proportions of the moorland core. This has 13% rough pastures, 34% grassy heaths and 53% shrubby heaths, compared with the oldest reversions which have 23, 42 and 35% of sites respectively in these groups. It has to be considered, however, that the reverted areas may never reach the composition shown by the moorland core because of slight inherent environmental differences in local conditions which, in the first place, could have caused farmers to select areas for improvement. There is no evidence for such differences but the point would require detailed study to confirm or refute it.

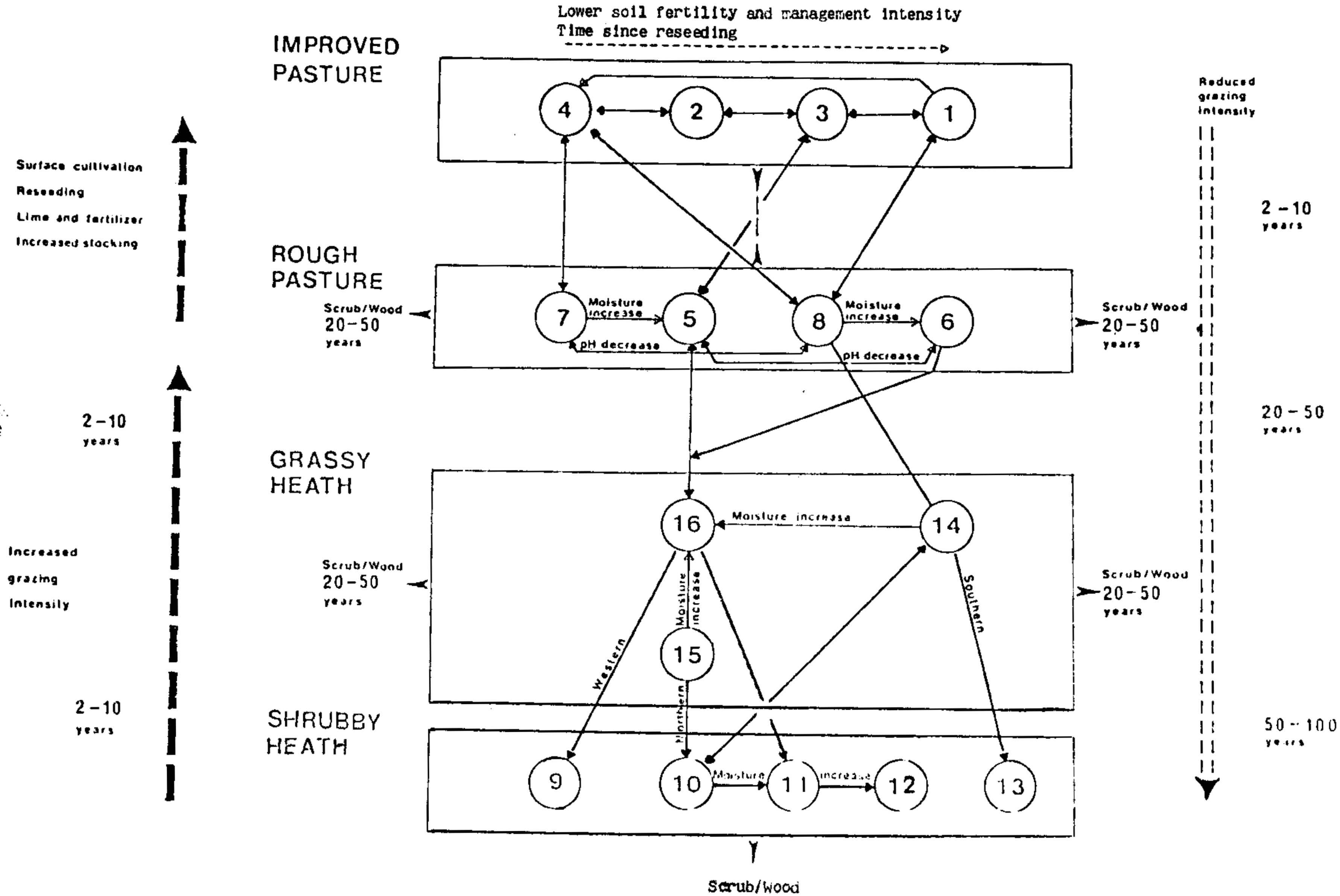
5.72 Evidence for individual study areas adds little of relevance to local conditions to these generalised interpretations of historical changes in vegetation in the moorland fringe, largely because the number of dated sites recorded in any one area is small. In Bransdale 6 recorded sites in the moorland fringe show evidence of pre-1800 ploughing on air photographs but have subsequently been mapped as moorland. Two of those sites are now under rough pasture (class 8), 3 under grassy heath (class 16) and one is a shrubby heath (class 10). Four sites of recent reversion fall in the same 3 vegetation classes. These classes are prominent in the core moorland at Bransdale, so that reversion appears to be towards vegetation found in the adjacent moor rather than to different communities, although the time taken to reach a possible end-point of reversion can be very variable between sites.

5.73 Reversion of improved pasture towards vegetation classes found in the moorland core is also seen in Widecombe and in the Lammermuirs. In Widecombe, of 8 sites for which there was evidence of early reversion to moorland, 6 carried shrubby heath vegetation similar to that found in the local moorland core. The majority of the 13 sites recorded on reverted former pasture at historically well-studied sites in the Lammermuir Hills had grassy heaths or rough pasture vegetation, similar to the prominent vegetation classes of the adjacent moorland core.

SYNTHESIS OF THE EVIDENCE FOR DIRECTIONS OF CHANGE

5.74 The evidence for rates and directions of vegetation change has been derived from observed associations of vegetation and environmental characteristics, from ecological experience, from management experiments and from historical map records in the study areas. These lines of evidence have been combined to suggest in Figure 5-4 inter-relationships between groups and classes of vegetation, emphasising some principal changes which result from an increase or decrease in management intensity, especially of grazing pressure. Directions of change are in general reversible, although the detailed species composition is rarely immediately reproduced when management is reversed. The direction of change under management is determined partly by particular site conditions, for example whether its soil is initially well or poorly drained. These site conditions are indicated on the diagram and may themselves be modified by management, for example by drainage or liming, or by natural processes of soil profile development under a vegetation change. With the complexity of environmental and management factors affecting vegetation that have been discussed, it is clear that the summary presented in Figure 5-4 must be seen as a simplified working hypothesis, based on current evidence, which clarifies main trends.

FIGURE 5.4 THE RATE AND DIRECTION OF UPLAND VEGETATION CHANGE THROUGH NATURAL SUCCESSION AND MANAGEMENT - A WORKING HYPOTHESIS



5.75 With this cautionary note in mind it is considered that the main vegetation groups of improved pastures, rough pastures, grassy heaths and shrubby heaths can be relatively stable in terms of the gradual changes this report is considering, retaining their general character while their prevalent grazing and burning regime is continued. Change in vegetation within these groups is essentially through natural succession in response to such factors as increasing acidity or increasing soil moisture as organic matter accumulates at the surface. The general management characteristics of the 4 vegetation groups and the courses of gradual successional change within each of them can be summarised as follows:

i. Improved pastures: These grasslands have been produced by cultivation, reseeding and fertilising. Stocking densities are high, usually of about 7-10 sheep per hectare. Some variation in the vegetation of the initial pasture will depend on local conditions but in most instances the recently sown swards will be herb-rich Lolium grasslands (class 4), especially under the more favourable soil and climatic conditions. Sward composition changes with time in approximately the succession shown, if there is no repetition of a cultivation-fertilising-reseeding management as weed species begin to expand or colonise. On wetter sites, if drainage becomes gradually more impeded, rushes and thistles will tend to increase, moving towards class 3, while bracken may encroach on drier soils. Succession in vegetation through the classes in the improved pastures under an agricultural decline trend may take up to 20 years, but redevelopment of the initial swards and control of colonising weed species through repeated cultivations, reseeding, and lime, fertiliser and herbicide application is the normal practice, so that the succession is usually truncated.

ii. Rough pastures: Grazing at about 4-7 sheep per hectare maintains the rough pastures, the actual level depending on sward composition which partly reflects soil fertility, the Agrostis/Holcus grasslands (class 7) tending to be on more fertile sites and the Festuca/Juncus grasslands (class 6) on poorer sites. Successional changes between types of rough pasture are complex but tend to be associated with gradual increases in soil moisture and acidity. Thus Agrostis/Holcus (class 7) and Festuca/Agrostis (class 8) pastures occur mainly on relatively dry soils, associated with lower rainfall and better drainage. Festuca/Agrostis grassland is the main rough pasture at higher altitudes and a class which will develop from Agrostis/Holcus pastures with time if soils become more acid. With an increase in surface soil moisture through deterioration of soil drainage as a result of some natural or management cause, rough pasture classes 7 and 8 would tend to develop to Agrostis/Juncus (class 5) and Festuca/Juncus (class 6) grasslands respectively. Festuca/Juncus pastures may also develop from Agrostis/Juncus grassland if soils become more acid and organic matter accumulates, the former class among the rough pastures having been noted at the recorded main sites as being the one which most frequently had peaty soils. These successional changes would probably take decades to occur and could be promptly reversed by the appropriate improvement of drainage and/or liming. Scattered trees and bushes are present on many of these pastures, so that scrub and woodland would develop readily on them in most cases if grazing pressures were sufficiently low.

iii. Grassy heaths: The grassy heaths are maintained by a grazing pressure of about 2-4 sheep per hectare, and successional changes between them and the shrubby heaths are also often prevented by burning. The inter-relationships between the 3 classes in this group are not distinct but soil drainage tends to be poorer on the Festuca/Nardus/Molinia heaths (class 16) so that this class could only develop very slowly from the other grassy heaths if and when surface soil conditions became wetter. If the soil surface becomes sufficiently partially exposed at suitable times then, at moderate altitudes, tree seed could germinate from local sources in the absence of grazing.

iv. Shrubby heaths: Burning, allied to a low grazing pressure at levels of less than 2 sheep per hectare, is the principal means of maintaining vigorous plant communities of the shrubby heath classes. These heaths tend to be particularly stable vegetation classes for long periods when under consistent low levels of management. In so far as classes 10, 11 and 12 represent a succession rather than a response to differing environments, then a trend through these would follow the increasing development of more peaty soils and permanent waterlogging. As in the case of the grassy heaths, scrub woodland may become established at lower altitudes or in drier sites where grazing and burning has been restricted, if local tree seed sources, particularly of birch, rowan, hawthorn or conifers, are available.

5.76 Before turning to the main courses of gradual change between pasture and heath vegetation, it is as well to set the types of change we are considering in perspective again. Particularly in some study areas and in the more agriculturally favourable land types in all the areas, in situations where the options for improvement have not already been comprehensively taken up, landscapes can still be dramatically changed by substantial programmes of grassland improvement involving major cultivation and enclosure schemes. In much of the remainder of the middle altitude ground, extensive forestry plantings by state or private interests are also drastically altering the upland scene and environment. The slow rates of many gradual changes, particularly during the reversion succession from pasture to moorland, are clearly always susceptible to interruption or reversal as a result of sharp changes in land management policy. With reservations in mind about the relative scale of gradual compared to direct changes and the liability of the courses of gradual change to disruption, it is possible to return to Figure 5-4 to consider its trends of change between vegetation groups.

5.77 i. Improved pastures to or from rough pastures: With a reduction in management intensity, particularly of grazing pressure, the improved pastures, after moving through a succession within the group, will generally gradually revert to communities classified here as rough pastures, though local soil characteristics and moderate grazing may delay this. Generally a move from vegetation of class 1 (Lolium/Holcus/Pteridium grassland) of the improved pastures to rough pasture can take about 10 years and the type of rough pasture which develops will depend on the local environment. It is not clear what is the succession sequence between individual improved and rough pasture classes. Associations of vegetation classes and site characteristics in the study areas suggest that on more fertile, drier sites, herb-rich Lolium grassland (class 4) may revert directly, or via Lolium grassland (class 2), to Agrostis/Holcus rough pastures (class 7) or possibly to Festuca/Agrostis grassland (class 8). The latter may also be the main link from the Lolium/Holcus/Pteridium grassland (class 1) at the end of the improved pasture succession.

ii. *Rough pastures to or from grassy heaths:* The reversion to rough pastures from improved pastures, and the succession within rough pastures, is associated with a decrease in soil pH, as lime is progressively leached naturally and not replaced artificially. The grassy heaths have a still lower average pH and, because of their greater tendency to peaty surface horizons, are often wetter than the rough pastures. Links between these groups at the wetter end of soil conditions tend to be from Agrostis/Juncus (class 5) and Festuca/Juncus (class 6) grasslands to Festuca/Nardus/Molinia heath (class 16), the actual vegetation change being initiated by reduction in grazing pressure. Where grazing pressure is reduced on the drier rough pastures the succession probably moves through Festuca/Agrostis grassland (class 8) to Festuca/Vaccinium heath (class 14). Evidence from the experimental sites (5.49-5.62) indicated that, with the exclusion of grazing on rough pastures, succession to grassy heath vegetation can take less than 10 years in some cases. Under more typical conditions grazing intensity tends to be reduced rather than removed, so that succession would take much longer. An increase in grazing intensity on grassy heaths can result in a trend towards rough pastures by suppression of the dwarf shrubs and coarser grasses but often a higher soil pH level is also required to encourage this trend (5.31). At Redesdale Experimental Husbandry Farm (5.50) the change from a Festuca/Nardus/Molinia heath (class 16) to Agrostis/Juncus (class 5) and Festuca/Juncus (class 6) rough pastures took place within 10 years, but in addition to increased grazing pressure, various surface treatments were also applied there, including liming to lower soil acidity. Grazing pressure changes alone would be unlikely to show such rapid effects.

iii. Grassy heaths to or from shrubby heaths: The interchange between these groups of heath vegetation is determined mainly by the effect on the survival of dwarf shrubs of a combination of grazing and burning. A reduction in grazing pressure allows the gradual expansion of dwarf shrub species on grassy heaths but the process is usually very slow. Festuca/Vaccinium heath (class 14) appears to develop towards dry Calluna heath (class 13) in southern areas, but through to Vaccinium/Calluna heath (class 10) in northern areas, though the sampling is not sufficient to confirm this as a geographical contrast. Reduction in burning on shrubby heaths tends to increase vegetation diversity and allows, at lower altitudes, development of scrub and woodland, given light grazing pressure. At altitudes below about 400 m the dwarf shrubs tend to be replaced by woodland if local seed sources are sufficient; above about 400 m tree growth weakens and dwarf shrubs may remain as the climax vegetation, with Calluna itself dropping out above about 700 m.

PREDICTIONS OF VEGETATION CHANGE IN THE STUDY AREAS

5.78 This final section of Part I discusses ways in which the balance between the identified classes in the grassland and moorland vegetation of the study areas may change. The individual accounts of study areas that form Part II of this report include predictions of possible changes in vegetation at recorded main sites as a result of sustained agricultural intensification or decline over an approximately 10-20 year period. The predictions are based on the general ecological principles outlined in paragraphs 5.74-5.77 and

Figure 5-4. Since it has not been possible to identify fully the complex range of environmental and management factors which might be involved in the future evolution of vegetation at each main site individually, the principles of trends of change are applied uniformly to all sites. Predictions of vegetation class changes are thus broad forecasts of the probability of change over a series of sites. The scale of agricultural intensification or decline on which these predictions are based can only be put semi-quantitatively. 'Intensification' in this context assumes upgrading present rough pasture areas to vegetation comparable to that of the present improved pastures, with a parallel enhanced stocking on the rough-grazed moorlands by an increase of around 50% over the present stocking densities. Conversely 'decline' is considered as reduction of stocking on the moorland by about 50% from present levels, with a parallel but smaller decline in the level of use of the present rough grazings, while most of the present improved pastures are maintained. A comparison of the study areas and a discussion of the overall picture that emerges from these predictions occupies the first part of this section (paragraphs 5.81-5.88).

5.79 It is possible, as an alternative approach, to make predictions based on assumptions about the land-use potential of land types, the distribution of which has been determined for the study areas. These involve on the one hand an assumed maximum intensification of agricultural use, and on the other an assumed maximum extension of forestry. This section concludes with consideration of these two approaches (paragraphs 5.89-5.94 and 5.95-5.99 respectively).

5.80 It must be emphasised yet again that gradual changes of the types outlined in this report are not the only, or in many situations even the major, potential course of vegetation change likely in the uplands. More direct measures for moorland change to grassland or to forestry, or the conversion of remaining deciduous woodlands to planted conifer forests, will have the most significant impact on vegetation in many upland landscapes. It should also be appreciated that the predictions of change now discussed have been applied uniformly to all sectors of the study areas. If the pattern of land-use change that has occurred over the past 150 years were to continue to decide the main location of vegetation change between farmland and moorland then such change could be concentrated in the identified, and limited, fringe sectors of the study areas, which are themselves concentrated in some land types (5.64). Because it is not certain that future change will be so concentrated in the historic fringe no attempt has been made in these predictions to treat sites or land sectors in or near to the moorland fringe differently from those in the farmland or moorland core parts of the area.

Predictions from ecological trends at main sites

5.81 In Table 5-16a the predicted numbers of recorded main sites are shown that are likely to occur in each vegetation group after a 10-20 year period of agricultural intensification or decline. Table 5-16b presents the same data in terms of percentages of sites in each group in each area. Some changes would involve the conversion of rough pastures to improved pastures by direct management measures including cultivation and reseeding but the majority are those which would follow gradually from alterations in grazing pressure and associated intensity of land management. The predictions, as well as being only broad probability assessments, involve only transfers between pasture and moorland vegetation classes. There is a high probability that under zero or very low grazing intensities, scrub woodland could be a short to medium term product on former rough pastures and grassy heaths in locations where seed sources are available.

5.82 Bearing these reservations in mind, the overall picture which emerges for predicted vegetation change in the study areas under intensified agriculture could involve approximately a 60% increase in the number of sites that are improved pastures (from 253 to 408 sites) and a 40% increase in the number of rough pasture sites (from 155 to 216). The proportion of grassy heaths is predicted as remaining almost stable (216 to 206 sites) but the proportion of shrubby heath sites would fall by 65% (from 314 sites recorded in 1977-78 to a predicted 108 sites).

5.83 From the predictions of vegetation change consequent on a declining agricultural effort in the study areas, the overall result could be falls of 25% in the number of improved pasture sites (from 253 to 192 sites); of nearly 40% in rough pastures (from 155 to 96 sites); and of almost 45% in grassy heaths (from 216 to 122 sites); balanced by a 70% increase in the number of shrubby heath sites (from 314 to 528).

5.84 The summarised figures for all areas suggest the ranges over which the present frequencies of widely distributed upland pasture and heath vegetation groups might vary in response to intensified or reduced grazing pressures and their supporting management activities. Improved pastures could occupy between 20 and 43% of the 938 recorded main sites compared with their present 27%; rough pastures could occupy between 10 and 23% of the recorded sites (now they occur at 17% of sites); grassy heaths could occupy between 13 and 23% of sites (now they occur at 23%); and shrubby heaths could occupy between 12 and 56% of the recorded sites (now they occur at 33% of them).

TABLE 5-16a NUMBERS OF MAIN SITES IN VEGETATION GROUPS AS RECORDED 1977/78 AND AS PREDICTED FOLLOWING AGRICULTURAL INTENSIFICATION OR DECLINE

Study Area	Situations in 1977 or 1978				Predicted Situation if Agriculture Intensifies, 10+ yrs				Predicted Situation if Agriculture Declines, 10+ yrs			
	a	b	c	d	a	b	c	d	a	b	c	d
Alwinton	5	22	28	25	27	28	11	14	5	0	22	53
Lunedale	1	9	16	53	10	16	7	46	1	0	9	69
Shap	22	16	39	38	38	39	34	4	19	6	13	77
Bransdale	10	10	30	38	20	30	36	2	5	5	10	68
Heptonstall	17	8	7	38	25	7	19	19	14	4	7	45
Monyash	61	11	0	0	72	0	0	0	61	8	3	0
Llanfachreth	7	21	22	22	28	22	19	3	3	13	12	44
Ysbyty Ystwyth	5	9	22	39	14	22	20	19	1	6	7	61
Glascwm	35	16	11	9	51	11	9	0	19	21	11	20
Ystradgynlais	13	12	27	18	25	27	17	1	9	5	11	45
Lynton	48	7	10	6	55	10	6	0	37	15	3	16
Widecombe	28	15	4	28	43	4	28	0	18	14	11	32
Total - All Areas	252	156	216	314	408	216	206	108	192	97	119	530

a = Improved Pastures
b = Rough Pastures
c = Grassy Heaths
d = Shrubby Heaths

TABLE 5-16b PERCENTAGES OF VEGETATION GROUPS AT STUDY AREA MAIN SITES, AS RECORDED 1977/78 AND AS PREDICTED FOLLOWING AGRICULTURAL INTENSIFICATION OR DECLINE

Study Area		Vegetation Group: Improved Pastures	Rough Pastures	Grassy Heaths	Shrubby Heaths
Alwinton	1	6	27	36	31
	2	33	36	13	18
(80 sites)	3	6	0	27	67
Lunedale	1	1	12	22	65
	2	13	22	9	56
(79 sites)	3	1	0	12	87
Shap	1	19	14	34	33
	2	33	34	30	3
(116 sites)	3	17	5	11	67
Bransdale	1	11	11	34	44
	2	22	34	41	3
(88 sites)	3	6	6	10	78
Heptonstall	1	25	11	10	54
	2	36	10	27	27
(70 sites)	3	20	6	10	64
Monyash	1	86	14	0	0
	2	100	0	0	0
(72 sites)	3	86	10	4	0
Llanfachreth	1	8	31	31	30
	2	39	31	26	4
(72 sites)	3	4	17	18	61
Ysbyty Ystwyth	1	7	12	29	52
	2	19	29	27	25
(75 sites)	3	1	8	10	81
Glascwm	1	47	23	16	14
	2	70	16	14	0
(71 sites)	3	27	30	13	30
Ystradgynlais	1	20	17	38	25
	2	37	36	24	1
(70 sites)	3	13	7	17	63
Lynton	1	68	10	14	8
	2	79	14	8	0
(71 sites)	3	51	23	4	22
Widecombe	1	37	21	5	37
	2	58	5	37	0
(75 sites)	3	24	19	15	42

1 Percentage of vegetation groups at sites recorded in each study area, 1977 or 1978

2 Estimated percentage of vegetation groups resulting from predicted changes at vegetation main sites caused by agricultural intensification, 10+ yrs

3 Estimated percentage of vegetation groups resulting from predicted changes at vegetation main sites caused by agricultural decline, 10+ yrs

5.85 In the predictions of gradual change resulting from intensified agricultural land-use, absolute increases in improved pasture occurrences would be highest in Alwinton and Llanfachreth, followed by Shap, Glascwm, Widecombe and Ystradgynlais. Relative increases would be highest in Lunedale, followed by Alwinton, Llanfachreth and Ysbyty Ystwyth. Rough pastures would increase most in Shap, Bransdale, Ysbyty Ystwyth and Ystradgynlais but would fall notably in Monyash and Widecombe. Grassy heaths would increase in Widecombe and Heptonstall but decline substantially in Alwinton and Lunedale and less markedly but significantly in Ystradgynlais and Lynton. Shrubby heaths would fall in all areas, only remaining at significant levels in Lunedale, Heptonstall, Ysbyty Ystwyth and Alwinton. Of these areas, only Lunedale would be expected to retain more than 20% of sites as shrubby heaths.

5.86 If the level of agricultural use were to decline, then improved pastures would be expected to decrease only very slightly in some areas but by about 25% from the number of improved pasture sites recorded in 1977-78 in Heptonstall, Lynton and Ystradgynlais, and by greater amounts in Widecombe, Bransdale and Glascwm. Rough pasture classes are predicted as disappearing from Alwinton and Lunedale and decreasing significantly in all but Glascwm, Lynton and Widecombe. In Widecombe, rough pastures are expected to remain at about their present frequency at the recorded sites but they would increase in Glascwm and Lynton. The greatest relative falls in grassy heaths would occur in Shap, Bransdale and Ysbyty Ystwyth and this vegetation group would increase only in Widecombe. In Monyash grassy heaths would appear as a new minor component of the vegetation range. The shrubby heath element would increase sharply in all areas other than Lunedale, Heptonstall and Widecombe.

5.87 Although the predicted overall freqency of a vegetation group at sites in a study area may remain similar to that now found, the locations at which it occurs are in most cases likely to change. The majority of improved pasture classes and some shrubby heath classes are the only ones predicted as being stable under the changes in management intensity. Typically, for example, under increased grazing and intensified management rough pasture classes would be upgraded to improved pastures, while grassy heaths would be modified to rough pasture vegetation. The scale of these predicted changes in the landscape can be assessed by the proportion of recorded sites that would change their vegetation group in a study area. Table 5-17 gives this information. It shows that in general a larger number of sites would change their vegetation group if agriculture were to be intensified than if it declined. Because under agricultural intensification the predicted fall in the heath element is substantial, the overall impact of intensification of agriculture is more conspicuous than that predicted from agricultural decline in most upland landscapes. Intensification also leads to a more rapid rate of change, because declining agricultural pressure gives a much slower reaction in the return from managed grassland towards shrubby heaths (see 5.67-5.73).

TABLE 5-17 PREDICTED PERCENTAGE OF MAIN SITES THAT WOULD CHANGE THEIR VEGETATION GROUP FOLLOWING AGRICULTURAL INTENSIFICATION OR DECLINE OVER 10-20 YEARS

	Study Area												All Areas Combined
	AL	LU	SS	BR	HE	MH	LL	YY	GL	YG	LY	WB	
Percentage of Sites Predicted as Changing their Vegetation Group as a Result of Intensified Agricultural Activity	76	41	75	86	47	14	88	68	51	80	32	63	62
Percentage of Sites Predicted as Changing their Vegetation Group as a Result of Decreased Agricultural Activity	63	32	49	51	26	4	53	45	54	60	35	33	42

Note: These percentages are calculated from standardised ecological assessments of change between classes (Fig. 5-4), and not from consideration of actual land and management situations in individual study areas or at individual vegetation sites

5.88 The contrast between the relative impact of agricultural intensification or decline would be more marked in some areas than others. This contrast is predicted as being particularly high in Heptonstall and Widecombe (as well as in Monyash but in that area the absolute scale of change predicted is insignificant due to its intensive agricultural character). Levels of change may be similar for different reasons. For example contrasts between the impact of intensification or decline are small in Lunedale and Lynton but this is because Lunedale is dominated by shrubby heaths of classes assumed to be quite stable, while Lynton is already dominated by agriculture. The largest proportions of sites predicted as susceptible to change are in Alwinton, Shap, Bransdale, Llanfachreth and Ystradgynlais. It is curious that these are all areas where other than ecological factors are likely to limit actual changes from the potential predicted: Alwinton is to a degree stabilised by its military training areas and Shap is in part in a National Park. Bransdale is also in a National Park and has a current land management that is directed specifically to the maintenance of moorland, whilst Llanfachreth is in a National Park and also has a strong base for forest expansion from existing major forestry. Ystradgynlais, also in part in a National Park, has a greater emphasis on open-cast mining and quarrying, and afforestation, than on agricultural use of its moorland sector.

Predictions from assumptions of land type potential

Following agricultural expansion

5.89 A different approach to predicting the extent of vegetation change that could occur as a result of agricultural expansion can be made through the land analysis of the study areas, and through assumptions of the potential of land types for a maximum agricultural or forestry bias in land-use.

5.90 Considering the agricultural option first, Table 4-3b has given the representation in each study area of the 7 identified land types in 3 land groups - hill, upland and upland margin. A maximum expansion of agriculture might, by increased pasture productivity, higher stocking rates and associated management changes, utilise relatively intensively 100% of the upland margin land, 90% of the upland and upland plateau and 60% of the steep upland. In the hill land group, more intensive agricultural exploitation might be able to utilise 30% of the hill land type and 20% of the high plateau and steep hill types. This would expand agricultural use through and beyond the previous 'moorland fringe' areas and involve some modification of 'moorland core' land by increased and more controlled grazing. Increased stock would be sustained by upgrading present farmland, this often following farm structure modification and changes in stock management and housing. Further assumptions (see 5.94 for reference to these) can suggest that in this situation the possible proportions of the 4 vegetation groups could be: in the hill land group 10% improved pastures, 10% rough pastures, 50% grassy heaths and 30% shrubby heaths; in the upland land group 60, 20, 20 and 0% respectively; and in the upland margin land group 70, 30, 0 and 0%. The proportions in which the vegetation groups were represented at main sites in the land groups in 1977 or 1978 are given in Table 5-1. Using these assumptions and the actual extent of each land group in each area it is possible to calculate a suggested vegetation group frequency for each area as a whole.

5.91 Table 5-18 compares the predicted frequency of vegetation groups at recorded main sites following the general ecological trends just discussed (5.79-5.88), with the prediction based on the extent of land groups in each area and the assumed potential vegetation composition in these groups if their maximum agricultural potential was achieved. In the study areas as a whole both approaches are seen to predict a similar balance of vegetation groups. In individual areas there are contrasts between results from the two viewpoints.

5.92 Under the land group assumptions of maximum agricultural potential, Monyash and Lynton would have less, and Glascwm only slightly more, improved pastures than recorded in 1977 or 1978, while in Alwinton, Shap, Ystradgynlais and Widecombe the proportion of improved pastures would be similar on the two predictions. Two interpretations follow. One is that the assumptions made from land type frequencies are potentially achievable and in practice have been achieved in some parts of the uplands of England and Wales. The second is that the higher levels of agricultural land utilisation that have actually been achieved locally in the uplands are in part a response to features additional to those considered in the land analysis. In some areas particularly favourable natural environment factors prevail and in others economic and social historical factors have been important. For example in Lynton there is a relatively good climate, while Monyash has benefited both from its favourable geology and therefore soils, and also historically through demand from local industrial markets. Glascwm is another area of relatively favourable climate and soils that is seen to be agriculturally utilised already at levels very close to those predicted as 'maximum' in terms of the assumed agricultural potential. In such areas, future agricultural expansion might concentrate on obtaining greater productivity from land already with agriculturally favourable vegetation, rather than involving principally change of the present heaths to pastures. Other study areas could have substantial changes in their balance between pastures and heaths, with increases in more agriculturally desirable pastures, and decreases in semi-natural, less intensively managed heaths.

TABLE 8-16 COMPARISON OF PREDICTIONS OF VEGETATION GROUP FREQUENCIES IN STUDY AREAS ON ALTERNATIVE ESTIMATES FOLLOWING AGRICULTURAL INTENSIFICATION

Study Area		Vegetation Group: Improved Pastures	Rough Pastures	Grassy Heaths	Shrubby Heaths
Alwinton	1	6	27	36	31
	2	33	36	13	18
	3	27	14	38	21
Lunedale	1	1	12	22	65
	2	13	22	9	56
	3	21	13	42	24
Shap	1	19	14	34	33
	2	33	34	30	3
	3	34	15	35	16
Bransdale	1	11	11	34	44
	2	22	34	41	3
	3	49	19	23	9
Heptonstall	1	25	11	10	54
	2	36	10	27	27
	3	48	19	25	8
Monyash	1	86	14	0	0
	2	100	0	0	0
	3	63	20	17	0
Llanfachreth	1	8	31	31	30
	2	39	31	26	4
	3	50	21	20	9
Ysbyty Ystwyth	1	7	12	29	52
	2	19	24	27	25
	3	34	16	33	17
Glascwm	1	47	23	16	14
	2	70	16	14	0
	3	51	20	22	7
Ystradgynlais	1	20	17	38	25
	2	37	38	24	1
	3	35	16	33	16
Lynton	1	68	10	14	8
	2	78	14	8	0
	3	57	22	17	4
Widecombe	1	37	21	5	37
	2	58	5	37	0
	3	56	21	19	4
All Areas	1	27	17	23	33
	2	44	23	22	11
	3	43	18	27	12

1 Present (1977-78) percentage frequencies at main sites

2 Predicted frequencies at main sites after agricultural intensification 10-20 yrs (Table 8-16b)

3 Predicted overall vegetation balance in study areas after 'maximum' agricultural expansion, based on assumptions of the maximum potential of upland types for agriculture

5.93 If Table 5-18 is simplified to combine 'pastures' and 'heaths' as 2 vegetation categories only, the two different predictions of possible change if agriculture is intensified suggest a similar balance emerging between heaths and pastures in Lunedale, Llanfachreth and Ysbyty Ystwyth. Alwinton, Shap and Ystradgynlais are all expected to have more pastures from the predictions, based on ecological principles of change at recorded sites than from the assumptions of land group potential. Both Shap and Ystradgynlais are areas where geology is an important influence on vegetation. In both the presence of limestone results in some existing vegetation being of a higher grade agriculturally than is typical for the land group. The explanation in the case of Alwinton is not clear. Bransdale, Heptonstall and Widecombe would have substantially higher pasture/heath ratios under the predictions based on land groups than on those based on ecological principles of change from existing vegetation at the recorded sites. It can be suggested that this is because local historical and management reasons have retained higher levels of heaths in these areas than in others of comparable land type.

5.94 Following from the arguments presented in paragraphs 5.89-5.93 it will be appreciated that estimates of change calculated for the maximum expansion of agriculture depend on the assumptions of the potential vegetation group composition possible in each land group. These assumptions represent intensities of management which now exist in areas where agriculture is well developed, eg Monyash, Lynton and Glascwm. Thus general experience suggests that the assumptions are a reasonable working hypothesis in relation to the present balance of vegetation at sites in each land group (Table 5-1). Despite the lack of a quantitative base, the comparison between these estimates of change and those derived from possible ecological trends at individual sites is of interest as the land group assumptions were not chosen specifically to give a close match with the predictions based on ecological change at recorded sites. The fact that the results are in a number of cases similar, and that in others the divergencies can be explained, suggests that the land group assmptions of potential may not be too inaccurate. If this is so, then for areas for which a land analysis has been carried out it would be possible to make broad assessments of future potential for these 4 vegetation groups, in the absence of present-day vegetation data.

Following forestry expansion

5.95 Although major expansion of forestry would involve direct instead of gradual vegetation change, it is of interest to look beyond the consideration of possible gradual changes that is the theme of this study in order to assess what balance between forestry and agriculture might emerge in the study areas. To make this assessment, assumptions have been made concerning the extent of forestry that might be possible in each land group. These assumptions are that intensive agriculture would be restricted to the most productive upland sectors, with most of the middle altitude ground in the uplands going to timber cropping for fuel and raw materials, while the highest ground, above the limit of reasonably economic tree growth, became virtually abandoned from any significant level of productive cropping with farm stock. Such assumptions would involve, as well as the direct transfer of some pastures and heaths to forest, indirect modifications of the higher altitude heaths as a result of this assumed disappearance of livestock farming from them.

5.96 A case is being made for an expansion of forestry in the uplands (eg CAS 1980), and argued against (Ramblers' Assn. 1980). Such expansion was indicated in ITE (1978) as a probable major impact on the future of upland England and Wales (see Plates 11, 13 and especially 30 for the visual impact of forestry). A practical plan would not carry out a new wave of afforestation in the crude, blanket way postulated here, but the assumptions made allow an estimate of maximum likely vegetation change in the study areas over 20-50 years as a result of an alternative management emphasis. In this situation it is proposed that only upland margin land, as classified here, would be entirely agricultural. To a lesser extent, assumed as 50% of their area, upland and upland plateau land types would retain substantial agriculture. Most of the steep upland (say 75%) would be given to forestry. Of the hill land, only the sectors below around 427 m (1 400 ft) would in general be usable for productive tree cropping and would be given entirely to this use. This altitude range occupies about 45% of the steep hill land, 30% of the hill land, and 35% of the high plateau in the study areas.

5.97 Vegetation in the upland margin and in the sectors of the upland and upland plateau which, historically, have been favoured for agriculture (for example Monyash) would remain or become dominantly improved pastures with limited rough pastures and negligible heaths. In less agriculturally favoured upland sectors, land above 335 m (1 100 ft) and even much of that above 244 m (800 ft), would be extensively tree-covered. In the hill land group, tree cover would be virtually total below 427 m (1 400 ft) and only above 427 m would heath vegetation dominate. In the absence of an accessible agricultural base to sustain moderate grazing intensities, shrubby heaths would tend to expand at the expense of grassy heaths. How persistent these shrubby heaths would be in the moderate to longer term, and whether, in the sectors of hill immediately above the planted ground, scrub woodland would spread, would depend on whether a significant level of management of the higher ground was maintained for such sporting use as could be fitted in with the forestry-based enterprises.

5.98 Approximate calculations can be made as to the likely partition of land in the study areas between unplantable hill, land available for forestry and farmed land. The assessments which result from these calculations are given in Table 5-19. They indicate falls in agricultural use in Monyash, Glascwm and Lynton. This is clearly improbable, since existing effective agriculture would not be abandoned and these areas would remain dominantly agricultural. Bransdale, Heptonstall, Llanfachreth and Widecombe would be about equally concerned with agriculture and forestry. Alwinton, Shap and Ystradgynlais would have forestry as their most prominent use. Only Lunedale and Ysbyty Ystwyth would remain dominantly open hill areas. The land predicted as appropriate to agriculture, forestry, and unplantable hill, calculated from the 'potential' columns in Table 5-19, taking into account the size of each area, is, for the 12 areas combined, 30, 40 and 30% respectively. Adjusting these figures to ensure that existing levels of agricultural land-use do not fall in any area, these categories would comprise respectively 33, 37 and 30% of the 12 areas combined (746 km^2). At present (ULS data in Table 5-19) the extent of 'agriculture' and 'woodland' is given as 21 and 10% respectively of the combined study areas. The potential forestry extents calculated in Table 5-19 have assumed that the upland margin land type would be used entirely for agriculture. This land type is also a desirable location for productive forestry and in some areas, for example Llanfachreth, is already substantially afforested. The potential forestry area could therefore be greater than calculated here, if agriculture was not given a favoured position. The extent to which forestry potential could be increased with any particular allocation of upland margin land to this use can be calculated for each area from the proportions of upland margin land given in Table 4-3b and the total extent of each area given in Table 1-1.

5.99 A comparison of the extent of 'agricultural' use of the study areas, as assessed by the percentage of pasture vegetation in the sites recorded in this study; as predicted on the 'maximise agriculture' hypothesis; and as predicted by the 'maximise forestry' hypothesis, is given in Table 5-20, along with the actual agricultural use as assessed by ULS. Omitting Monyash, Glascwm and Lynton, it is of interest that even under the 'maximise forestry' assumptions, Heptonstall, Llanfachreth and Ysbyty Ystwyth could also slightly increase, and Bransdale substantially increase, their extent of pasture vegetation. Bransdale particularly has the theoretical possibility of substantial modification of its vegetation pattern with the virtual disappearance of its present high proportion of heaths, if other considerations were ignored. The changes in the frequency of improved and rough pastures in each study area, again omitting the 3 anomalous areas, would range between increases of 8 to 46% on the 'maximise agriculture' strategy, and between a reduction of 21% and an increase of 23% on the 'maximise forestry' strategy.

TABLE 5-19 ESTIMATES OF MAXIMUM POTENTIAL FORESTRY LAND IN THE STUDY AREAS

Study Area	Land Potential (as Percentage of Study Area)[1]				
	Unplantable[2]	Forestry Land		Agricultural Land	
	'Potential'	'Potential'	Present[2]	'Potential'	Present[2]
Alwinton	30	58	18 (17)	12	5
Lunedale	75	12	1	13	8
Shap	35	42	3 (1)	23	26
Bransdale	2	53	9 (8)	45	22
Heptonstall	10	50	6 (1)	40	20
Monyash[3]	0	45	1	55	93
Llanfachreth	20	31	33 (30)	49	17
Ysbyty Ystwyth	50	25	8 (8)	25	13
Glascwm[3]	20	35	4 (2)	45	59
Ystradgynlais	30	42	11 (8)	28	16
Lynton[3]	0	45	9 (1)	55	58
Widecombe	6	39	8 (3)	55	42

1 'Potential' calculations based on the assumptions of 5.96

2 Present forestry from ULS statistics as total woodland (conifer plantations); present agriculture from ULS statistics; Potential 'uplantable' land as 100 - (potential forestry + agriculture)

3 Study areas where current agricultural use is dominant and likely to survive preferentially even in a high forestry strategy

TABLE 5-20 ESTIMATES OF POTENTIAL 'AGRICULTURAL' LAND IN THE STUDY AREAS

Study Area	Percentage of Agricultural Land in each Study Area			
	Present Situation		Potential Agricultural Land	
	1	2	On Maximise Agriculture[3] Assumptions	On Maximise Forestry[4] Assumptions
Alwinton	5	33	41	12
Lunedale	8	13	34	13
Shap	26	33	49	23
Bransdale	22	22	68	45
Heptonstall	20	36	67	40
Monyash	93	100	83	55
Llanfachreth	17	39	71	49
Ysbyty Ystwyth	13	19	50	25
Glascwm	59	70	71	45
Ystradgynlais	16	37	51	28
Lynton	58	78	79	55
Widecombe	42	58	77	55

1 As percentage of study area from ULS statistics

2 As percentage of recorded vegetation sites 1977 or 1978, that are improved or rough pastures

3 Potential percentage of recorded vegetation sites that would be improved or rough pastures on assumptions of maximum agricultural potential of land types (Table 5-18(3))

4 Potential percentage of land in intensive agriculture (supporting improved or rough pastures) on assumptions of an agriculture-forestry balance according to land types (Table 5-19)

5.100 With these speculations, the general considerations of upland farmland and moorland vegetation in relation to its controlling factors and its potential for change are completed. Part II looks at the situation in individual study areas in more detail.

CONCLUSION

5.101 Vegetation class frequency at recorded main sites has been analysed in relation to land type distribution and to land characteristics. Hill land is dominated by heath vegetation (92% of sites sampled in this group have heath vegetation classes), upland land has a wide range of pasture and heath classes in comparable quantity, and upland margin land has only limited heath vegetation (only 10% of sites sampled in this group now are heaths). Examination of the detail of this broad familiar pattern displays particular facets of land-vegetation associations. The relationship between site land characteristics and vegetation class allows identification of the classes most widely represented at sites of particular character in the study areas. By extrapolation from the associations found, it is possible to suggest the most likely alternatives that might occur if present vegetation at a site of known land character were to be modified by management.

5.102 General experience, supported by information from the few suitable experimental sites (Hill Farming Research Organisation, Ministry of Agriculture and Nature Conservancy Council) outside the study areas, has allowed a table to be drawn up summarising the impacts of burning, grazing control, minor drainage, and limited surface lime, fertilizer and herbicide applications on 35 plant species that are prominent in the moorland-grassland vegetation classes or are common scrub woodland trees and shrubs. This evidence for directions and rates of species change is used to predict trends of change between vegetation classes.

5.103 Over approximately the last 150 years, alterations in land-use between moorland and farmland are found to have been concentrated in an identifiable area of 'moorland fringe', covering about 11% of the total study areas, mainly in the steep upland and upland margin land types. Within the moorland fringe, 30% is land that has reverted from agriculture to moorland, and 54% and 16% respectively are land reclaimed from moorland for forestry or agriculture. Examination of sites of known age of transfer from moorland to pasture or vice-versa shows that marked visual changes in vegetation can occur within a decade through intensified agricultural management, especially as a result of increased grazing and frequent burning. Changes in the reverse direction that result from decreased agricultural use of former pastures are much slower. When abandoned grasslands change towards the shrubby heaths that are most characteristic of undisturbed moorlands, their plant communities can have failed to revert to shrubby heaths and be still in the process of change 100 years and more after an alteration in their management regime.

5.104 By extrapolation from the relatively recent past, it could be that the visual character of upland vegetation will alter, so far as alteration is dependent on gradual change, mainly in the localised and identifiable upland sectors of the moorland fringe of the past 150 years or so. Although this may well be so, there is no certainty that the very different technical and economic conditions of upland farming today will constrain land-use in the same way that it has in the recent past. In order to assess the maximum scale of changes that could occur, ecological trends between pasture and heath classes can be applied to the current situation at recorded sites in standard ways, following assumptions of general intensification or decline in agriculture that are very approximately based on increases or decreases of 50% above or below present livestock numbers. Doing this for the study areas, and assuming that change could in the future affect sectors outside as well as in the identified recent moorland fringe, allows calculations to be made of the potential overall scale of vegetation change likely at the recorded sites. If agriculture is intensified, the percentage of sites at which the vegetation group is predicted as changing could vary between 15% (in the already intensely agricultural Monyash) and 88% in Llanfachreth, which is at present vegetationally the most diverse area. If agriculture were to decline, then the proportion of sites which could change their vegetation group would be lower, from 4% (again in Monyash) to 63% in Alwinton.

5.105 An alternative prediction of possible changes through utilising land types to an assumed agricultural maximum can be got from knowledge of the extent of land types in each area and by making assumptions about the potential frequency of the 4 vegetation groups in these types under such circumstances. The overall figures for the 12 areas combined suggest in these cases a potential of 43% improved pastures, 18% rough pastures, 27% grassy heaths and 12% shrubby heaths, compared to the distribution of these groups at sites recorded in 1977 or 1978 of 27, 17, 23 and 33% respectively. Predictions of vegetation group frequency following agricultural intensification are of a similar order from the 2 approaches; that based on potential change at individual recorded sites and that based on assumed proportions of vegetation groups in land types which are of known extent in each area.

5.106 Finally, in the light of published views that forestry development will be the probable main cause of major upland change in the future, consideration has been turned from gradual change between moorland and farmland, to what might be a land-use balance in the study areas if forestry were to be expanded to a potential maximum. This balance has been calculated from simple general assumptions of the forestry potential of land types and altitude zones, while retaining agriculture in the most favourable upland margin and upland sectors. The outcome of these assumptions is that, for the 12 study areas combined, farmland could occupy 33% of their area (ULS data now show this to be 21%); forestry 37% (ULS data for woodland and planted forest now give these 10%); and unplantable hill the remaining 30%.

5.107 Although the large scale of changes suggested by these alternative predictions represent suggestions that can be made from this study of the maximum vegetation changes likely under alternative hypotheses of future land use, the ULS assessments of farmers' and landowners' intentions in the short-term indicate that in most areas the results will be nothing like so extreme over the next 20 years or so. Economic conditions may preclude any massive input of resources into agricultural or forestry expansion while social considerations will still sustain the level of farm and other upland land management that exists today. It may well be that in the short-term the most likely outcome will be that the present broad farmland-moorland pattern will continue in many areas with only minor fluctuations around the historic moorland edge, while slow changes continue over the more climatically favourable sectors of moorland core.

5.108 An opportunity to follow the actual course of future events is given by the record of vegetation in 1977, 1978 or 1979 at over 1 000 sites in the 12 study areas. These sites, or a selection of them, could be re-recorded at intervals to answer such questions as: how far are the predictions of possible massive vegetation changes confirmed? Are major cultivation and/or afforestation changes overriding any impact of the gradual vegetation changes that result from minor management amendments? Is the moorland fringe that has been the focus of change over the ~~fringe that~~ past 150 years still the sector in which change is concentrated? At what rate is moorland vegetation disappearing? To answer other questions, for example relating to bracken expansion or reduction or the re-creation of heather moorland more rapidly than is brought about by the natural course of change following pasture abandonment, will involve experimental control in sites within the study areas or where more appropriate, elsewhere. Until an adequate period of monitoring is possible from an unequivocal baseline such as has been provided by the comprehensive listing of plant species at sites which can be stratified in various environmental and management ways, supported where possible by experimental management data, the predictions of courses, rates and scale of change outlined here will remain untested and speculative.

6 ACKNOWLEDGMENTS

The planning and development of this study owes much to the Department of the Environment. We are particularly grateful to their Nominated Officers, the Members of the Review Committee and to the Countryside Commission for their help.

The main contributors to this study are listed in the preface. They are grateful to the late A.J.P. Gore and to R.G.H. Bunce for advice on the botanical sampling programme, to G.L. Radford who developed the computer storage and retrieval facility for land data, and to M.W. Shaw who provided the outline description of Indicator Species Analysis in Appendix 4 and advised on the presentation of keys to the classifications of vegetation and land. Assistance in extraction of land characteristic data from maps was provided by M.L. Jones, and other ITE staff and support workers helped with vegetation recording in the field and data collection and handling in the laboratory. Dr M.L. Parry, Department of Geography, University of Birmingham, was responsible for interpreting land-use changes as recorded on air photographs. The photographs were lent by the Department of the Environment, through the good offices of the Countryside Commission, and by the Welsh Office Agriculture Department, Aberystwyth.

Illustrative air photographs in the report are by Professor J.K. St. Joseph, Committee for Aerial Photograpny, University of Cambridge; Meridian Airmaps; and Clyde Surveys (formerly Fairey Surveys); with assistance for material covering Lunedale, Heptonstall, Monyash and Llanfachreth respectively from Durham County Council, West Yorkshire Metropolitan County Council, Derbyshire County Council and Gwynedd County Council. Ground photographs are by P.A. Ainsworth and J. Dale.

Help was given by many individuals and organisations in response to a questionnaire seeking information on existing experimental management sites relevant to gradual vegetation change. The Institute of Terrestrial Ecology is particularly grateful in this regard to the staff of the Hill Farming Research Organisation, Edinburgh and Lephinmore Experimental Farm; the Ministry of Agriculture, Fisheries and Food, Redesdale Experimental Husbandry Farm; and the Nature Conservancy Council, Moor House National Nature Reserve.

Base maps of the study areas, in Part II of this report, are reproduced from Ordnance Survey maps with the permission of the Controller of Her Majesty's Stationery Office, Crown copyright reserved.

ITE could only have carried out this work through the help of the many farmers and landowners who allowed access to their land.

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8 APPENDICES

APPENDIX 1

Comparison of the Main Site Vegetation Classification with that of Evans, Hill and Ward (1977)

The vegetation classes given in ISA analysis of the main site data using species presence (Chapter 3) can be compared with those of the submontane vegetation classification of Evans, Hill & Ward (1977) (EHW). Their classification was based on 1502 vegetation records, some of which were collected specifically for the project and others abstracted from existing data sets collected for other purposes. Data were thus available for most upland areas in England, Wales and the Southern Uplands of Scotland, though some were more intensively sampled than others. The range was limited to semi-natural vegetation and included a high proportion of records from limestone sites. Recording was based on a 4 m^2 quadrat size and consisted of a complete listing of vascular plants occurring within it, together with a Domin scale cover abundance estimate. Analysis of the data was by ISA (Appendix 4), using a combination of species presence and cover data in the analysis. The EHW results are presented as 26 groups (19 acidic and 7 limestone assemblages) resulting from amalgamation of 64 end-groups generated by the computer analysis. These groupings were relatable to plant associations described by other authors (eg McVean & Ratcliffe 1962, Birks 1973).

Equivalent groups derived from EHW have been sought for the vegetation classes of the grassland-moorland range based on species presence recognised in the present study (Chapter 3). The improved pasture classes (1 to 4) have no equivalence in the earlier classification, since the stands used for this did not include any improved grassland types.

In 2 instances there is coincidence, group for class, between the divisions of the 2 classifications. The coincidents are:

a. shrubby heath class 13, *Calluna*, with EHW group 23 "*Callunetum vulgaris cinereae*";
b. grassy heath class 15, *Festuca/Nardus/Vaccinium*, with EHW group 16 "*Nardo-Juncetum squarrosi*".

The first of these contains very distinct assemblages with *Calluna vulgaris* dominant, at a constancy level of 80%. In the second instance there is again a good matching of the principal constituent species in the 2 groupings, all of which show constancy levels of between 40 and 80%.

For the 10 remaining classes of the classification given here there is overlap with EHW in their general character but the divisions between them are not placed identically in terms of species composition in the 2 classifications. However, there are no glaring incongruities and the classificatory divisions which have been derived from these 2 sources share common ground with respect to component species and dominants. The overlap is probably at least in part attributable to the large differences in quadrat sizes employed. In the grassland-moorland upland vegetation classification of the study now reported a large (5000 m^2) quadrat was used, since the project was concerned with landscapes involving relatively large areas, rather than with the detail of local vegetation in small plots. The submontane vegetation study used data from 4 m^2 size quadrats. The larger area of the 5000 m^2 quadrat will usually include within it pockets of vegetation variation which would include more than one of the groupings derived from the submontane grassland key. It would be possible to explore this overlap further from the data for smaller quadrat sizes in the present records, but this has not been necessary for the purpose of this report. Again the inclusion in the EHW data of cover with species presence information is also bound to affect the selection and location of divisions between classes.

<u>Equivalent Classes (Chapter 3) and Groups (EHW)</u>

Grassland-Moorland Vegetation Classification		EHW Sub-Montane Vegetation Classification
Class 1	*Lolium/Holcus/Pteridium* grassland	na
Class 2	*Lolium* grassland	na
Class 3	*Lolium/Trifolium* grassland	na
Class 4	herb-rich *Lolium* grassland	na
Class 5	*Agrostis/Juncus* grassland	overlaps - Group 8 *Juncetum-effusi*
Class 6	*Festuca/Juncus* grassland	overlaps - Group 8 *Juncetum-effusi*
Class 7	*Agrostis/Holcus* grassland	overlaps - Group 7 *Thymo-Agrosto-Festucetum*
Class 8	*Festuca/Agrostis* grassland	overlaps - Group 18 *Trifolio-Agrosto-Festucetum*
Class 14	*Festuca/Vaccinium* heath	overlaps - Group 25 *Festuceto-vaccinetum nardosum*
Class 15	*Festuca/Nardus/Vaccinium* heath	= Group 16 *Nardo-Juncetum squarrosi*
Class 16	*Festuca/Nardus/Molinia* heath	overlaps - Group 20 *Festuco-molinietum Anthoxanthosum*
Class 9	*Calluna/Molinia/Vaccinium* heath	closest to - Group 12 *Molinieto-Callunetum*
Class 10	*Vaccinium/Calluna* heath	overlaps - Group 24 *Festuceto-vaccinetum Pteridosum*
Class 11	*Nardus/Sphagnum/Calluna* heath	overlaps - Group 9 *Sphagneto-caricetum sub-alpinum*
Class 12	*Eriophorum-Calluna* heath	overlaps - Group 15 *Calluneto-Eriophoretum myrtillosum*
Class 13	*Calluna* heath	= Group 23, *Callunetum vulgaris cinereae*

APPENDIX 2

Plant Species Recorded at Main Sites

The reference numbers before the species, which are listed in alphabetical order, with mosses in alphabetical order at the end, are those used for entries to field sheets (Appendix 3a). Numbers that are underlined identify species necessary to operate the key (Appendix 6) to the classification based on species presence described and discussed in Chapter 3. *Species* nomenclature is that of Clapham, Tutin and Warburg, 1962.

143 *Acer pseudoplatanus*
1 *Achillea millefolium*
2 *Achillea ptarmica*
5 *Agropyron repens*
3 *Agrostis canina/stolonifera*
4 *Agrostis setacea*
6 *Agrostis tenuis*
147 *Aira praecox*
152 *Ajuga reptans*
153 *Alnus glutinosa*
154 *Alopecurus geniculatus*
7 *Alopecurus pratensis*
155 *Anemone nemorosa*
8 *Anthoxanthum odoratum*
9 *Arrhenatherum elatius*
156 *Athyrium filix-femina*
10 *Bellis perennis*
157 *Betonica officinalis*
11 *Betula* spp.
12 *Blechnum spicant*
13 *Briza media*
14 *Bromus mollis*
15 *Calluna vulgaris*
16 *Campanula rotundifolia*
158 *Capsella bursa-pastoris*
17 *Cardamine flexuosa*
159 *Cardamine hirsuta*
18 *Cardamine pratensis*
19 *Carex binervis*
160 *Carex demissa*
20 *Carex echinata*
21 *Carex nigra*
22 *Carex panicea*
23 *Carex pilulifera*
24 *Centaurea nigra*
25 *Cerastium holosteoides*
26 *Chenopodium album*
27 *Chrysanthemum leucanthemum*
28 *Cirsium arvense*
29 *Cirsium palustre*
30 *Cirsium vulgare*
31 *Conopodium majus*
161 *Corylus avellana*
32 *Crataegus monogyna*
33 *Cynosurus cristatus*
34 *Dactylis glomerata*
35 *Deschampsia cespitosa*
36 *Deschampsia flexuosa*
37 *Digitalis purpurea*
162 *Drosera rotundifolia*
38 *Dryopteris filix-mas*
39 *Dryopteris dilatata*
40 *Empetrum nigrum*
41 *Epilobium angustifolium*
42 *Epilobium montanum*
163 *Epilobium obscurum/tetragonum*
43 *Epilobium palustre*
44 *Equisetum arvense*
45 *Erica cinerea*
46 *Erica tetralix*
47 *Eriophorum angustifolium*
48 *Eriophorum vaginatum*
49 *Euphrasia* spp.
50 *Festuca ovina*
51 *Festuca rubra*
52 *Filipendula ulmaria*
164 *Fraxinus excelsior*
53 *Galium aparine*
165 *Galium palustre*
54 *Galium saxatile*
166 *Galium verum*
167 *Geranium dissectum*
168 *Geranium molle*
55 *Geranium robertianum*
169 *Glyceria fluitans*
56 *Heracleum sphondylium*
57 *Hieracium pilosella*
58 *Holcus lanatus*
59 *Holcus mollis*
170 *Hypericum humifusum*
171 *Hypericum pulchrum*
172 *Hydrocotyle vulgaris*
173 *Ilex aquifolium*
101 *Jasione montana*
60 *Juncus articulatus*
174 *Juncus bufonius*
61 *Juncus bulbosus*
62 *Juncus conglomeratus*
63 *Juncus effusus*
64 *Juncus squarrosus*

175 *Lapsana communis*
65 *Lathyrus montana*
66 *Lathyrus pratensis*
67 *Leontodon* spp.
176 *Linum catharticum*
68 *Lolium multiflorum*
69 *Lolium perenne*
70 *Lotus corniculatus*
177 *Lotus uliginosus*
71 *Luzula campestris/multiflora*
178 *Luzula pilosa*
179 *Lychnis flos-cuculi*
180 *Lysimachia nemorum*
72 *Matricaria matricoides*
73 *Molinia caerulea*
74 *Nardus stricta*
75 *Narthecium ossifragum*
76 *Oxalis acetosella*
77 *Pedicularis* sp.
78 *Phleum pratense*
181 *Pinguicula vulgaris*
79 *Plantago lanceolata*
80 *Plantago major*
81 *Poa annua*
82 *Poa pratensis*
83 *Poa trivialis*
84 *Polygala* sp.
182 *Polygonum arenastrum*
85 *Polygonum aviculare*
86 *Polygonum persicaria*
183 *Polypodium vulgare*
87 *Potentilla anserina*
88 *Potentilla erecta*
184 *Potentilla reptans*
185 *Potentilla sterilis*
89 *Prunella vulgaris*
186 *Prunus spinosa*
90 *Pteridium aquilinum*
91 *Ranunculus acris*
92 *Ranunculus flammula*
93 *Ranunculus repens*
94 *Rhinanthus minor*
187 *Rosa* spp.
95 *Rubus chamaemorus*
96 *Rubus fruticosus*
97 *Rubus idaeus*
98 *Rumex acetosa*
99 *Rumex acetosella*
100 *Rumex conglomeratus*
100 *Rumex crispus*
102 *Rumex obtusifolius*
100 *Rumex sanguineus*
103 *Sagina procumbens*
104 *Sarothamnus scoparius*
105 *Sedum acre*
106 *Sedum anglicum*
189 *Senecio aquaticus*
107 *Senecio jacobaea*
190 *Senecio sylvaticus*
191 *Senecio vulgaris*
108 *Sesleria caerulea*
109 *Sieglingia decumbens*
192 *Silene dioica*
110 *Sorbus aucuparia*
111 *Stellaria alsine*
193 *Stellaria graminea*
194 *Stellaria holostea*
112 *Stellaria media*
113 *Succisa pratensis*
114 *Taraxacum* sp.
115 *Teucrium scorodonium*
195 *Thelypteris oreopteris*
116 *Thymus drucei*
117 *Trichophorum cespitosum*
196 *Trifolium dubium*
118 *Trifolium pratense*
119 *Trifolium repens*
197 *Trisetum flavescens*
120 *Ulex europaeus/gallii*
121 *Urtica dioica*
122 *Vaccinium myrtillus*
123 *Vaccinium oxycoccus*
124 *Vaccinium vitis-idaea*
125 *Veronica chamaedrys*
126 *Veronica officinalis*
127 *Veronica serpyllifolia*
128 *Vicia cracca*
129 *Vicia sepium*
130 *Viola palustris*
131 *Viola* spp.
132 *Acrocladium cuspidatum*
198 *Atrichum undulatum*
133 *Cladonia arbuscula/impera*
134 *Cladonia pyxidata*
135 *Dicranella*
136 *Dicranum* spp.
137 *Eurhynchium praelongum*
138 *Hylocomium splendens*
139 *Hypnum cupressiforme*
140 *Mnium hornum*
141 *Mnium undulatum*
142 *Pellia* sp.
144 *Plagiothecium undulatum*
145 *Pleurozium schreberi*
146 *Polytrichum* spp.
148 *Pseudoscleropodium purum*
149 *Rhytidiadelphus squarrosus*
150 *Sphagnum* spp.
151 *Thuidium tamariscinum*

APPENDIX 3

Field Data Sheets

a) MAIN PLOT DATA SHEET - SPECIES

Parish: Plot no.: Recorder: Date:

Code	Species in 1 m^2	Code	Species in 25 m^2	Code	Species in 5,000 m^2
			Species in 100 m^2		
	Species in 4 m^2				
			Species in 200 m^2		

b) MAIN PLOT DATA SHEET - SITE INFORMATION

Parish: Plot no.: Recorder: Date:

Code	Species Central 1 m^2	% cover

Slope (across 200 m^2):

TRACKS
1. Tarmac
2. Stones
3. Footpath/bridleway over 2 ft wide
4. ditto, under 2 ft wide
5. Sheeptrack

MANAGEMENT
6. Haystack
7. Water trough
8. Rubbish heap
9. Grass mowing
10. Ploughed
11. Burned

HABITATS
12. Bushes
13. Trees (live)
14. Trees (dead)
15. Fallen timber
16. Tree stumps
17. Cliff, over 5 m
18. Rock outcrop, under 5 m
19. Rock ledge
20. Scree
21. Stones, up to 4"
22. Rocks 4-20"
23. Boulders, 20"+
24. Gully, up to 3 m deep
25. Gorge, over 3 m deep
26. Dell/hollow, over 1 m deep
27. Eroding peat
28. Man-made embankment
29. Quarry
30. Mine/mine tips
31. Sheep scrapes
32. Mole hills

WATER
33. Dry ditch
34. Wet ditch
35. Stream, up to 2 ft wide
36. Stream, more than 2 ft wide
37. Rocky spring
38. Peaty spring
39. Very small pool, under 1 m^2
40. Pool 1-20 m^2
41. Pond 20 m^2+

SOIL (Top 15 cm)
42. Sandy
43. Sandy-loam
44. Loam
45. Clay-loam
46. Clay
47. Peat

Soil depth, at 4 corners of 200 m^2

Soil pH, at 4 corners of 200 m^2

Loss-on-Ignition

DRAINAGE
48 Excessive
49 Free
50 Impeded
51 Poor
52 Very poor

APPENDIX 3

Field Data Sheets

c) WOODLAND DATA SHEET

Parish: **Plot no.:** **Recorder:** **Date:**

Slope: **Approx % canopy:** **Ht. of tallest tree:**

Code	Species in 1 m^2	Species in 100 m^2	MANAGEMENT/HABITATS
	Species in 4 m^2	Species in 200 m^2	
	Species in 25 m^2		

MANAGEMENT/HABITATS

1. Sheep-proof fence or wall
2. Planting
3. Thinning/felling
4. Burning
5. Fallen timber
6. Dead trees
7. Cliff 3 m +
8. Outcrop, under 3 m
9. Rock ledge
10. Scree
11. Stones, up to 4"
12. Rocks, 4-20"
13. Boulders, 20" +
14. Gully, up to 3m deep
15. Gorge, over 3 m deep
16. Dell, over 1 m deep
17. Man-made embankment
18. Quarry
19. Mine/tips
20. Dry ditch
21. Wet ditch
22. Stream, up to 2 ft wide
23. Stream, 2 ft +
24. Rocky spring
25. Peaty spring
26. Pool, less than 1 m^2
27. Pool 1-20 m^2
28. Pond 20 m^2 +
29. Soil sandy
30. Soil sandy-loam
31. Soil loam
32. Soil clay-loam
33. Soil clay
34. Soil peat

Soil depth
pH
L.O.I.

Age (approx) of oldest trees.......

No. of saplings less than 20 years old........

Grazing. nil
slight
much

d) ROADSIDE VERGE DATA SHEET

Parish: **Plot no.:** **Recorder:** **Date:**

Width of verge:

Code	Species in 10x1 m. strip, adjacent to edge of road.	

1. Trees (within 10x1 m. strip)
2. Wall, adjacent to roadside verge
3. Hedge, adjacent to roadside verge
4. Fence, adjacent to roadside verge
5. Bank, more than 18" high, adjacent
6. Ditch.

APPENDIX 4

Outline of Indicator Species Analysis (ISA) as a Classification Method

The purpose of classification is to reduce complexity by grouping like with like. ISA is a polythetic divisive method of classification; 'divisive' because it successively divides the original population into smaller classes, and 'polythetic' because it uses more than one criterion (for example a number of plant species, or geographical attributes) to determine each division. These criteria are the 'indicator species'.

The main problem with divisive methods of classification is to develop a suitable method. If there are more than about 20 'individuals' in a 'population' to be classified, the number of possible permutations in creating classes becomes too large to handle. In fact only a limited number of possible permutations is likely to lead to a satisfactory classification which groups like with like. ISA employs a preliminary investigation, a 'directed search' which aims to find an approximate division in advance of the final allocation of individuals to classes at each stage.

It does this directed search by means of ordination, using the first axis of a reciprocal averaging ordination (Hill, 1973) (ie the dominant trend of variation in the data under consideration). The centre of gravity of the ordination is considered to be a good prospective point for subsequent division. The 2 sides of the ordination about the 'centre of gravity' are now searched for 'indicator species'. These are the attributes (again for example species or land characteristics) which occur more frequently in individuals on one side of the ordination. 'Negative' indicators are those which characterise the negative side of the ordination; 'positive' indicators characterise the positive side of the ordination. A perfect indicator is one that occurs in all individuals on one side of the ordination and is absent from all those on the other side. In the rare cases when this occurs the single indicator could be used to define a division. Usually a number of indicators (between 5-10 dependent on the data set) are required to define a division with satisfactory accuracy.

These indicators are combined to produce a discriminant function (the 'indicator score') which is applied to each individual to determine to which side of the division it should be allocated. This score is calculated as the sum of the negative and positive indicators that it contains (ie 2 positive indicators give a score of +2 and 2 negative indicators -2, to give a total score of 0), and is compared with a 'threshold value'. If the indicator score for an individual is equal to or less than the threshold, the individual should be allocated to the negative side of the classification, and if the score is higher, the individual is allocated to the positve side. The threshold value is decided by an optimisation method that is beyond the scope of this outline to describe. It is this procedure that confers some flexibility on the actual point of division as viewed in relation to the ordination. If a more natural point of division in the data set lies either on the positive or the negative side of the centre of gravity of the ordination then the method of determining the 'best' threshold value can accommodate this. Where natural discontinuities of the data do occur, reciprocal averaging ordination has a strong tendency towards polarization (ie exaggeration of the discontinuity), and in such cases the centre of gravity is almost invariably located on or near the discontinuity and little or no further adjustment is required.

Data submitted to classification by ISA can represent quite contrasting situations. In some circumstances there is a genuine structure to the data, ie there are distinct classes of individuals present and there are no, or only a few, individuals that have characteristics that are intermediate between the classes. This condition is illustrated in taxonomy where species are generally distinct, and variation is discontinuous. An alternative situation is when there are no distinct classes and the population shows continuous variation. Both types of data can be submitted to numerical classification. In the second case, classification can only partition the range of variation in a reasonably perceptive way, and some statisticians prefer to term this case 'dissection' rather than classification.

Many types of data contain both discontinuous and continuous variation and the result of analysis is a mixture of classification and dissection. In analysis by ISA the individuals allocated to each side of the division are listed in 3 categories, 'bona-fide', 'borderline', and 'misclassified'. The first category contains individuals which definitely belong to the class to which they have been allocated. Borderline individuals are those which are intermediate between the 2 classes (ie they occupy the central 10% of the ordination). In practice they are allocated to the side that their indicator score suggests, but could fit quite reasonably in either side. The proportion of borderline individuals in a given division is an indication of the discontinuity of the data (the higher the proportion of borderline cases the greater is the continuity in the data structure). Misclassifications are individuals that do not contain the 'right' indicators, so that their indicator score suggests their allocation to one side of the division whilst their position in the ordination suggests otherwise. Since the ordination is based on overall consideration of the characteristics of an individual, but the indicator score is based on a few indicator species only, the ordination allocation of the 'misclassified' individuals is allowed to override the indicator score in deciding their classification. This combination of procedures produces the 'best' classification (ie the maximum within-class homogeneity for a given division). It has the consequence however, that in using keys based on indicators of a classification, the proportion of 'misclassified' individuals will be allocated 'wrongly'.

ISA proceeds by successively dividing the original population and sub-dividing each division in turn. In highly structured data there is a 'best' number of levels of division (and resultant classes) but with most sets of data the number of end-classes selected is an arbitrary matter of convenience to the classifier.

APPENDIX 5

Species Composition of the Vegetation Classes

The species which typify each vegetation class are listed alphabetically in constancy groups of 100 - 80%, 79 - 60%, 59 - 40% and 39 - 20%. 'Constancy' is the percentage of sites in a class which contain a particular species. Thus if a species occurs in every site classified in a class, its constancy will be 100%; if it occurs in half only of the sites in a class, its constancy will be 50%. A majority of the characteristic species of a class will have constancies of 100 - 80% or 79 - 60%. Without running fully through the key of Appendix 6, some general assessment of the vegetation class of a site may be got by considering how many of the species of high constancy in a likely class are actually present at a site.

APPENDIX 5 SPECIES COMPOSITION OF VEGETATION CLASSES IN THEIR CONSTANCY GROUPS

	Improved Pastures				Rough Pastures			
Constancy Group	**Class 4** **Herb-rich *Lolium* grassland**	**Class 2** ***Lolium* grassland**	**Class 3** ***Lolium/Trifolium* grassland**	**Class 1** ***Lolium/Holcus Pteridium* grassland**	**Class 7** ***Agrostis/Holcus* grassland**	**Class 5** ***Agrostis/Juncus* grassland**	**Class 8** ***Festuca/Agrostis* grassland**	**Class 6** ***Festuca/Juncus* grassland**
100 to ≥ 80	*Bellis perennis* *Cerastium holosteoides* *Lolium perenne* *Trifolium repens*	*Achillea millefolium* *Agrostis tenuis* *Bellis perennis* *Cerastium holosteoides* *Cynosurus cristatus* *Dactylis glomerata* *Holcus lanatus* *Lolium perenne* *Plantago lanceolata* *Ranunculus acris* *Rumex acetosa* *Trifolium repens*	*Agrostis tenuis* *Cerastium holosteoides* *Cynosurus cristatus* *Holcus lanatus* *Lolium perenne* *Trifolium repens*	*Agrostis tenuis* *Cerastium holosteoides* *Cynosurus cristatus* *Holcus lanatus* *Lolium perenne* *Plantago lanceolata* *Rumex acetosa* *Trifolium repens*	*Achillea millefolium* *Agrostis tenuis* *Cerastium holosteoides* *Holcus lanatus* *Plantago lanceolata* *Potentilla erecta* *Rumex acetosa* *Trifolium repens*	*Agrostis tenuis* *Anthoxanthum odoratum* *Cirsium palustre* *Holcus lanatus* *Juncus articulatus* *Juncus effusus* *Leontodon* spp. *Potentilla erecta* *Prunella vulgaris* *Ranunculus acris* *Ranunculus flammula* *Ranunculus repens* *Rumex acetosa* *Trifolium repens*	*Agrostis tenuis* *Anthoxanthum odoratum* *Cerastium holosteoides* *Festuca ovina* *Galium saxatile* *Holcus lanatus* *Potentilla erecta* *Trifolium repens*	*Anthoxanthum odoratum* *Cerastium holosteoides* *Cirsium palustre* *Festuca ovina* *Galium saxatile* *Holcus lanatus* *Juncus articulatus* *Juncus effusus* *Nardus stricta* *Polytrichum* spp. *Potentilla erecta* *Prunella vulgaris* *Ranunculus repens* *Rumex acetosa* *Trifolium repens*
2. < 80 to ≥ 60	*Agrostis tenuis* *Cynosurus cristatus* *Dactylis glomerata* *Holcus lanatus* *Plantago lanceolata* *Phleum pratense* *Ranunculus repens* *Rumex obtusifolius* *Taraxacum* spp.	*Cirsium arvense* *Ranunculus repens* *Taraxacum* spp. *Trifolium pratense*	*Bellis perennis* *Cirsium palustre* *Cirsium vulgare* *Leontodon* spp. *Poa annua* *Prunella vulgaris* *Ranunculus repens*	*Achillea millefolium* *Anthoxanthum odoratum* *Cirsium arvense* *Cirsium palustre* *Leontodon* spp. *Potentilla erecta* *Prunella vulgaris* *Pteridium aquilinum* *Ranunculus acris* *Ranunculus repens* *Rumex obtusifolius* *Taraxacum* spp. *Trifolium pratense*	*Anthoxanthum odoratum* *Bellis perennis* *Campanula rotundifolia* *Cirsium palustre* *Cirsium vulgare* *Cynosurus cristatus* *Euphrasia* spp. *Festuca ovina* *Galium saxatile* *Hieraceum pilosella* *Lotus corniculatus* *Luzula campestris/multiflora* *Prunella vulgaris* *Ranunculs repens* *Rhytidiadelphus squarrosus* *Viola* spp.	*Centaurea nigra* *Cerastium holosteoides* *Cynosurus cristatus* *Digitalis purpurea* *Galium palustre* *Lotus corniculatus* *Plantago lanceolata* *Rumex obtusifolius* *Urtica dioica*	*Cirsium vulgare* *Cynosurus cristatus* *Juncus effusus* *Luzula campestris/multiflora* *Nardus stricta* *Ranunculus repens* *Rumex acetosa*	*Agrostis canina* *Agrostis tenuis* *Carex panicea* *Cynosurus cristatus* *Deschampsia cespitosa* *Galium palustre* *Plantago lanceolata* *Ranunculus acris* *Ranunculus flammula*

APPENDIX 5 SPECIES COMPOSITION OF VEGETATION CLASSES IN THEIR CONSTANCY GROUPS

	Improved Pastures				Rough Pastures			
	Class 4	Class 2	Class 3	Class 1	Class 7	Class 5	Class 8	Class 6
Constancy Group	Herb-rich *Lolium* grassland	*Lolium* grassland	*Lolium/Trifolium* grassland	*Lolium/Holcus Pteridium* grassland	*Agrostis/Holcus* grassland	*Agrostis/Juncus* grassland	*Festuca/Agrostis* grassland	*Festuca/Juncus* grassland
< 60 to ≥ 40	*Achillea millefolium* *Cirsium arvense* *Cirsium vulgare* *Leontodon* spp. *Plantago major* *Ranunculus acris* *Rumex acetosa* *Stellaria media* *Trifolium pratense*	*Cirsium vulgare* *Festuca ovina* *Lotus corniculatus* *Phleum pratense* *Poa pratensis* *Prunella vulgaris* *Senecio jacobaea* *Urtica dioica*	*Achillea millefolium* *Cirsium arvense* *Dactylis glomerata* *Juncus effusus* *Phleum pratense* *Plantago lanceolata* *Plantago major* *Ranunculus acris* *Rumex acetosa* *Rumex obtusifolius* *Sagina procumbens* *Urtica dioica* *Veronica serpyllifolia*	*Bellis perennis* *Centaurea nigra* *Cirsium vulgare* *Dactylis glomerata* *Lotus corniculatus* *Phleum pratense* *Poa annua* *Rhytidiadelphus squarrosus* *Stellaria media* *Urtica dioica* *Veronica chamaedrys*	*Cirsium arvense* *Dactylis glomerata* *Hypochoeris radicata* *Lolium perenne* *Poa annua* *Poa pratensis* *Polytrichum* spp. *Pteridium aquilinum* *Ranunculus acris* *Senecio jacobaea* *Sieglingia decumbens* *Taraxacum* spp. *Urtica dioica* *Veronica chamaedrys*	*Achillea millefolium* *Bellis perennis* *Cardamine pratensis* *Cirsium vulgare* *Epilobium obscurum/ tetragonum* *Galium saxatile* *Lolium perenne* *Luzula campestris/ multiflora* *Molinia caerulea* *Poa annua* *Polytrichum* spp. *Pteridium aquilinum* *Rhytidiadelphus squarrosus* *Rubus fruticosus* *Rumex acetosella* *Sagina procumbens* *Stellaria alsine* *Taraxacum* spp. *Trifolium pratense*	*Achillea millefolium* *Campanula rotundifolia* *Cirsium arvense* *Cirsium palustre* *Dactylis glomerata* *Deschampsia cespitosa* *Deschampsia flexuosa* *Dicranum* spp. *Festuca rubra* *Plantago lanceolata* *Poa annua* *Poa pratensis* *Polytrichum* spp. *Prunella vulgaris* *Ranunculus acris* *Rhytidiadelphus squarrosus* *Urtica dioica* *Veronica chamaedrys*	*Carex nigra* *Dicranum* spp. *Festuca rubra* *Juncus conglomerata* *Leontodon* spp. *Luzula campestris/ multiflora* *Molinia caerulea* *Poa pratensis* *Rhytidiadelphus squarrosus* *Sphagnum* spp. *Taraxacum* spp; *Viola palustris*

APPENDIX 5 SPECIES COMPOSITION OF VEGETATION CLASSES IN THEIR CONSTANCY GROUPS

	Improved Pastures				Rough Pastures			
	Class 4	**Class 2**	**Class 3**	**Class 1**	**Class 7**	**Class 5**	**Class 8**	**Class 6**
Constancy Group	**Herb-rich *Lolium* grassland**	*Lolium* **grassland**	*Lolium/Trifolium* **grassland**	*Lolium/Holcus Pteridium* grassland	*Agrostis/Holcus* **grassland**	*Agrostis/Juncus* **grassland**	*Festuca/Agrostis* **grassland**	*Festuca/Juncus* **grassland**
4. **< 40 to 20**	*Anthoxanthum odoratum* *Bromus mollis* *Poa annua* *Poa pratensis* *Poa trivialis* *Prunella vulgaris* *Rumex conglomeratus/ crispus/ sanguineus* *Urtica dioica* *Veronica serpyllifolia*	*Anthoxanthum odoratum* *Campanula rotundifolia* *Centaurea nigra* *Chrysanthemum leucanthemum* *Deschampsia cespitosa* *Euphrasia* spp. *Festuca rubra* *Galium verum* *Heracleum sphondylium* *Hypocheris radicata* *Leontodon* spp. *Luzula campestris/ multiflora* *Poa annua* *Plantago major* *Potentilla erecta* *Rumex acetosella* *Stellaria media* *Thymus drucei* *Trifolium dubium* *Trisetum flavescens*	*Anthoxanthum odoratum* *Festuca rubra* *Juncus articulatus* *Lotus corniculatus* *Poa pratensis* *Poa trivialis* *Potentilla erecta* *Rumex acetosella* *Taraxacum* spp. *Trifolium pratense*	*Campanula rotundifolia* *Deschampsia cespitosa* *Digitalis purpurea* *Festuca ovina* *Poa pratensis* *Poa trivialis* *Plantago major* *Rumex acetosella* *Sagina procumbens* *Trifolium dubium* *Ulex europeus/gallii* *Veronica serpyllifolia*	*Agrostis canina* *Briza media* *Carex panicea* *Carex pilulifera* *Centaurea nigra* *Cladonia pyxidata* *Crataegus monogyna* *Deschampsia cespitosa* *Deschampsia flexuosa* *Dicranum* spp. *Digitalis purpurea* *Festuca rubra* *Galium verum* *Hypnum cupressiforme* *Leontodon* spp. *Mnium hornum* *Nardus stricta* *Oxalis acetosella* *Plantago major* *Potentilla sterilis* *Rubus fruticosus* *Rumex acetosella* *Sagina procumbens* *Sedum anglicum* *Thuidium tamarascinum* *Thymus drucei* *Trifolium pratense* *Ulex* spp. *Vaccinium myrtillus*	*Achillea ptarmica* *Agrostis canina* *Athyrium filix-femina* *Cardamine flexuosa* *Carex panicea* *Crataegus monogyna* *Cirsium arvensis* *Dicranum* spp. *Equisetum arvense* *Euphrasia* spp. *Festuca ovina* *Festuca rubra* *Holcus mollis* *Hydrocotyle vulgaris* *Hypnum cupressiforme* *Lathyrus pratensis* *Lotus uliginosus* *Pedicularis* spp. *Plantago major* *Poa pratensis* *Poa trivialis* *Polygonum persicaria* *Sieglingia decumbens* *Sphagnum* spp. *Stellaria graminea* *Stellaria media* *Succisa pratensis* *Ulex europaeus/ gallii* *Veronica chamaedrys* *Viola palustris*	*Agrostis canina* *Bellis perennis* *Calluna vulgaris* *Cardamine pratensis* *Carex nigra* *Conopodium majus* *Hieracium pilosella* *Hypnum cupressiforme* *Juncus squarrosus* *Leontodon* spp. *Lolium perenne* *Lotus corniculatus* *Molinia caerulea* *Poa trivialis* *Pteridium aquilinum* *Rumex acetosella* *Sagina procumbens* *Taraxacum* spp. *Thymus drucei* *Vaccinium myrtillus* *Veronica officinalis* *Viola* spp.	*Achillea millefolium* *Achillea ptarmica* *Bellis perennis* *Briza media* *Cardamine flexuosa* *Carex demissa* *Carex echinata* *Carex pilulifera* *Carex* sp. *Cirsium arvense* *Cirsium vulgare* *Crataegus monogyna* *Deschampsia flexuosa* *Epilobium palustre* *Hieracium pilosella* *Hypnum cupressiforme* *Juncus bulbosus* *Juncus squarrosus* *Lotus corniculatus* *Poa annua* *Pteridium aquilinum* *Sagina procumbens* *Sieglingia decumbens* *Stellaria alsine* *Succisa pratensis* *Thuidium tamarascinum* *Vaccinium myrtillus*
	Total No. Spp. recorded: **132**	**Total No. Spp. recorded:** **131**	**Total No. Spp. recorded:** **121**	**Total No. Spp. recorded:** **114**	**Total No. Spp. recorded:** **188**	**Total No. Spp. recorded:** **189**	**Total No. Spp. recorded:** **176**	**Total No. Spp. recorded:** **154**

APPENDIX 5 SPECIES COMPOSITION OF VEGETATION CLASSES IN THEIR CONSTANCY GROUPS

	Grassy Heaths			Shrubby Heaths				
	Class 15	Class 16	Class 14	Class 13	Class 9	Class 10	Class 11	Class 12
Constancy Group	*Festuca/Nardus/Vaccinium* heath	*Festuca/Nardus/Molinia* heath	*Festuca/Vaccinium* heath	*Calluna* heath	*Calluna/Molinia/Vaccinium* heath	*Vaccinium/Calluna* heath	*Nardus/Sphagnum/Calluna* heath	*Eriophorum/Calluna* heath
1. 100 to ≥ 80	*Deschampsia flexuosa* *Festuca ovina* *Galium saxatile* *Juncus effusus* *Nardus stricta* *Potentilla erecta*	*Anthoxanthum odoratum* *Festuca ovina* *Galium saxatile* *Juncus effusus* *Juncus squarrosus* *Nardus stricta* *Polytrichum* spp. *Potentilla erecta* *Sphagnum* spp. *Vaccinium myrtillus*	*Agrostis tenuis* *Deschampsia flexuosa* *Festuca ovina* *Galium saxatile* *Vaccinium myrtillus*	*Agrostis tenuis* *Calluna vulgaris* *Galium saxatile* *Potentilla erecta* *Sieglingia decumbens* *Ulex* spp. *Vaccinium myrtillus*	*Calluna vulgaris* *Molinia caerulea* *Potentilla erecta* *Vaccinium myrtillus*	*Calluna vulgaris* *Vaccinium myrtillus*	*Calluna vulgaris* *Deschampsia flexuosa* *Eriophorum vaginatum* *Juncus squarrosus* *Nardus stricta* *Polytrichum* spp. *Potentilla erecta* *Sphagnum* spp. *Vaccinium myrtillus*	*Calluna vulgaris* *Deschampsia flexuosa* *Eriophorum vaginatum*
2. < 80 to ≥ 60	*Agrostis tenuis* *Anthoxanthum odoratum* *Cerastium holosteoides* *Dicranum* spp. *Holcus lanatus* *Juncus squarrosus* *Luzula campestris/multiflora* *Polytrichum* spp. *Rumex acetosa* *Trifolium repens* *Vaccinium myrtillus*	*Agrostis canina* *Agrostis tenuis* *Calluna vulgaris* *Carex panicea* *Cirsium palustre* *Deschampsia flexuosa* *Holcus lanatus* *Luzula campestris/multiflora* *Molinia caerulea* *Viola palustris*	*Anthoxanthum odoratum* *Calluna vulgaris* *Dicranum* spp. *Nardus stricta* *Polytrichum* spp. *Potentilla erecta*	*Agrostis setacea* *Dicranum* spp. *Erica cinerea* *Festuca ovina* *Molinia caerulea* *Nardus stricta*	*Deschampsia flexuosa* *Festuca ovina* *Nardus stricta* *Sieglingia decumbens*	*Cladonia pyxidata* *Deschampsia flexuosa* *Juncus squarrosus*	*Agrostis canina* *Erica tetralix* *Eriophorum angustifolium* *Festuca ovina* *Galium saxatile* *Juncus effusus* *Molinia caerulea*	*Eriophorum angustifolium* *Empetrum nigrum* *Juncus squarrosus* *Polytrichum* spp. *Sphagnum* spp. *Vaccinium myrtillus*
3. < 60 to ≥ 40	*Agrostis canina* *Calluna vulgaris* *Cirsium palustre* *Deschampsia cespitosa* *Festuca rubra* *Hypnum cupressiforme* *Pteridium aquilinum* *Ranunculus acris* *Rhytidiadelphus squarrosus* *Sphagnum* spp. *Thymus drucei* *Veronica officinalis* *Viola* spp.	*Carex echinata* *Cladonia arbuscula/impexa* *Dicranum* spp. *Erica tetralix* *Juncus articulatus* *Rhytidiadelphus squarrosus* *Rumex acetosa* *Sieglingia decumbens*	*Hypnum cupressiforme* *Juncus effusus* *Juncus squarrosus* *Luzula campestris/multiflora* *Molinia caerulea* *Pteridium aquilinum*	*Anthoxanthum odoratum* *Carex binervis* *Carex panicea* *Cladonia arbuscula/impexa* *Deschampsia flexuosa* *Erica tetralix* *Hypnum cupressiforme* *Polygala* spp. *Polytrichum* spp. *Pteridium aquilinum*	*Agrostis tenuis* *Carex binervis* *Carex panicea* *Dicranum* spp. *Erica cinerea* *Erica tetralix* *Galium saxatile* *Juncus squarrosus* *Polytrichum* spp. *Pteridium aquilinum*	*Agrostis tenuis* *Dicranella* sp. *Dicranum* spp. *Empetrum nigrum* *Erica tetralix* *Festuca ovina* *Juncus effusus* *Nardus stricta* *Polytrichum* spp. *Pteridium aquilinum*	*Agrostis tenuis* *Anthoxanthum odoratum* *Carex echinata* *Carex panicea* *Cladonia arbuscula/impexa* *Dicranum* spp. *Empetrum nigrum* *Hypnum cupressiforme* *Luzula campestris/multiflora* *Narthecium ossifragum* *Trichophorum cespitosum*	*Cladonia arbuscula/impexa* *Dicranum* spp. *Erica tetralix* *Festuca ovina* *Galium saxatile* *Juncus effusus* *Molinia caerulea* *Nardus stricta* *Plagiothecium undulatum* *Trichophorum cespitosum*

APPENDIX 5 SPECIES COMPOSITION OF VEGETATION CLASSES IN THEIR CONSTANCY GROUPS

	Grassy Heaths		Shrubby Heaths					
	Class 15	Class 16	Class 14	Class 13	Class 9	Class 10	Class 11	Class 12
Constancy Group	*Festuca/Nardus/ Vaccinium* heath	*Festuca/Nardus/ Molinia* heath	*Festuca/Vaccinium* heath	*Calluna* heath	*Calluna/Molinia/ Vaccinium* heath	*Vaccinium/Calluna* heath	*Nardus/Sphagnum/ Calluna* heath	*Eriophorum/Calluna* heath
4. < 40 - 20	*Achillea millefolium* *Blechnum spicant* *Campanula rotundifolia* *Carex nigra* *Carex panicea* *Carex pilulifera* *Cirsium vulgare* *Cladonia arbuscula/ impexa* *Cladonia pyxidata* *Empetrum nigrum* *Erica tetralix* *Eriophorum angustifolium* *Eriophorum vaginatum* *Oxalis acetosella* *Pleurozium schreberi* *Poa annua* *Poa pratensis* *Prunella vulgaris* *Ranunculus repens* *Taraxacum* spp. *Veronica chamaedrys*	*Blechnum spicant* *Carex binervis* *Carex nigra* *Carex pilulifera* *Cerastium holosteoides* *Cladonia pyxidata* *Deschampsia cespitosa* *Dicranella* sp. *Epilobium palustre* *Eriophorum angustifolium* *Eriophorum vaginatum* *Festuca rubra* *Galium palustre* *Hypnum cupressiforme* *Juncus bulbosus* *Juncus conglomeratus* *Leontodon* spp. *Narthecium ossifragum* *Plantago lanceolata* *Pleurozium schreberi* *Polygala* spp. *Pteridium aquilinum* *Ranunculus acris* *Ranunculus flammula* *Ranunculus repens* *Trichophorum angustifolium* *Trifolium repens*	*Agrostis canina* *Carex nigra* *Carex pilulifera* *Cerastium holosteoides* *Cladonia arbuscula/ impexa* *Cladonia pyxidata* *Dicranella* sp. *Erica cinerea* *Holcus lanatus* *Poa annua* *Rhytidiadelphus squarrosus* *Rumex acetosa* *Rumex acetosella* *Sieglingia decumbens* *Sphagnum* spp.	*Agrostis canina* *Carex pilulifera* *Cerastium holosteoides* *Cladonia pyxidata* *Dicranella* sp. *Juncus articulatus* *Juncus effusus* *Pleurozium schreberi* *Pseudoscleropodium purum* *Rhytidiadelphus squarrosus* *Rumex acetosa* *Rumex acetosella* *Sedum anglicum* *Sphagnum* spp.	*Agrostis canina* *Agrostis setacea* *Anthoxanthum odoratum* *Cladonia arbuscula/ impexa* *Cladonia pyxidata* *Dicranella* sp. *Empetrum nigrum* *Eriophorum angustifolium* *Luzula campestris/ multiflora* *Polygala* spp. *Sphagnum* spp. *Tricophorum cespitosum* *Ulex* spp.	*Agrostis canina* *Cladonia arbuscula/ impexa* *Eriophorum angustifolium* *Galium saxtile* *Hypnum cupressiforme* *Molinia caerulea* *Potentilla erecta* *Sphagnum* spp.	*Carex binervis* *Carex nigra* *Cladonia pyxidata* *Dicranella* sp. *Plagiothecium undulatum* *Pleurozium schreberi* *Rhytidiadelphus squarrosus* *Vaccinium oxycoccus*	*Anthoxanthum odoratum* *Carex nigra* *Cladonia pyxidata* *Hypnum cupressiforme* *Potentilla erecta* *Rhytidiadelphus squarrosus* *Rubus chamaemorus*
	Total No. Spp. recorded: 147	Total No. Spp. recorded: 159	Total No. Spp. recorded: 131	Total No. Spp. recorded: 110	Total No. Spp. recorded: 55	Total No. Spp. recorded: 65	Total No. Spp. recorded: 102	Total No. Spp. recorded: 93

APPENDIX 6

Key to ISA Classification of Upland Vegetation Classes, Based on Species Presence at Main Sites

In the field a 5000^2 quadrat should be used and a species list compiled for the presence of the 76 key species, or if required, for the total list of 198 species of Appendix 5. In using the key the scores of the indicator species are totalled from a site plant list at each stage of the analysis. Species listed in the left hand column of the key score - 1, and species occurring in the right hand column of the key score + 1. The sum of the individual species scores for a site record listing all those key species present at the site is then compared with the threshold values at the first stage of the key. From this, progress can be made through the key until a point is reached where it indicates the number of the appropriate vegetation class for the area being examined.

Numbers against species names on this key are those used for field sheet recording, as listed in Appendix 2. The list of species required to operate the key can be obtained from Appendix 2, as the species for which reference numbers are underlined.

Indicators:	Negative (each = - 1)	Positive (each = + 1)
Step 1	15 *Calluna vulgaris*	10 *Bellis perennis*
	36 *Deschampsia flexuosa*	25 *Cerastium holosteoides*
	64 *Juncus squarrosus*	33 *Cynosurus cristatus*
	122 *Vaccinium myrtillus*	69 *Lolium perenne*
		93 *Ranunculus repens*
		119 *Trifolium repns*
	Score greater than zero go to 2	
	Score zero or less go to 9	
Step 2	8 *Anthoxanthum odoratum*	69 *Lolium perenne*
	50 *Festuca ovina*	78 *Phleum pratense*
	54 *Galium saxatile*	
	63 *Juncus effusus*	
	71 *Luzula campestris/multiflora*	
	74 *Nardus stricta*	
	88 *Potentilla erecta*	
	146 *Polytrichum* spp.	
	Score greater than - 3 go to 3	
	Score less than or equal to - 3 go to 6	
Step 3	102 *Rumex obtusifolius*	1 *Achillea millefolium*
		6 *Agrostis tenuis*
		16 *Campanula rotundifolia*
		50 *Festuca ovina*
		70 *Lotus corniculatus*
		88 *Potentilla erecta*
		91 *Ranunculus acris*
		107 *Senecio jacobaea*
		125 *Veronica chamaedrys*
	Score greater than 3 go to 4	
	Score less than or equal to 3 go to 5	
Step 4	10 *Bellis perennis*	29 *Cirsium palustre*
	107 *Senecio jacobaea*	37 *Digitalis purpurea*
	166 *Galium verum*	88 *Potentilla erecta*
		90 *Ranunculus flammula*
		102 *Rumex obtusifolius*
		120 *Ulex europaeus/gallii*
		127 *Veronica serpyllifolia*
	Score greater than zero = Class 1	
	Score zero or less = Class 2	

Indicators:	Negative (each = - 1)	Positive (each = + 1)
Step 5	14 *Bromus mollis*	6 *Agrostis tenuis*
	34 *Dactylis glomerata*	29 *Cirsium palustre*
	114 *Taraxacum* spp.	30 *Cirsium vulgare*
		60 *Juncus articulatus*
		63 *Juncus effusus*
		88 *Potentilla erecta*
		103 *Sagina procumbens*

Score greater than 1 = Class 3
Score less than or equal to 1 = Class 4

Step 6	16 *Campanula rotundifolia*	22 *Carex panicea*
	34 *Dactylis glomerata*	29 *Cirsium arvense*
		60 *Juncus articulatus*
		63 *Juncus effusus*
		73 *Molinia caerulea*
		92 *Ranunculus flammula*
		113 *Succisa pratensis*
		165 *Galium palustre*

Score greater than 3 go to 7
Score less than or equal to 3 go to 8

Step 7	35 *Deschampsia cespitosa*	24 *Centaurea nigra*
	50 *Festuca ovina*	37 *Digitalis purpurea*
	74 *Nardus stricta*	102 *Rumex obtusifolius*
		118 *Trifolium pratense*
		121 *Urtica dioica*
		156 *Athyrium filix-femina*
		163 *Epilobium obscurum/ tetragonum*

Score greater than - 1 = Class 5
Score less than or equal to - 1 = Class 6

Step 8	35 *Deschampsia cespitosa*	32 *Crataegus monogyna*
	63 *Juncus effusus*	37 *Digitalis purpurea*
	74 *Nardus stricta*	49 *Euphrasia* spp.
		57 *Hieracium pilosella*
		70 *Lotus corniculatus*
		79 *Plantago lanceolata*
		131 *Viola* spp.

Score greater than 2 = Class 7
Score less than or equal to 2 = Class 8

Indicators:	Negative (each = - 1)	Positive (each = + 1)
Step 9	6 *Agrostis tenuis*	40 *Empetrum nigrum*
	8 *Anthoxanthum odoratum*	47 *Eriophorum angustifolium*
	29 *Cirsium palustre*	48 *Eriophorum vaginatum*
	54 *Galium saxatile*	
	58 *Holcus lanatus*	
	88 *Potentilla erecta*	
	98 *Rumex acetosa*	

Score greater than - 3 go to 10
Score less than or equal to - 3 go to 13

Step 10	8 *Anthoxanthum odoratum*	45 *Erica cinerea*
	47 *Eriophorum angustifolium*	90 *Pteridium aquilinum*
	48 *Eriophorum vaginatum*	134 *Cladonia pyxidata*
	54 *Galium saxatile*	
	117 *Trichophorum cespitosum*	
	144 *Plagiothecium undulatum*	
	150 *Sphagnum* spp.	

Score greater than - 2 go to 11
Score less than or equal to - 2 go to 12

Step 11	63 *Juncus effusus*	4 *Agrostis setacea*
	134 *Cladonia pyxidata*	19 *Carex binervis*
	139 *Hypnum cupressiforme*	22 *Carex panicea*
		45 *Erica cinerea*
		73 *Molinia caerulea*
		88 *Potentilla erecta*
		109 *Sieglingia decumbens*

Score greater than 1 = Class 9
Score less than or equal to 1 = Class 10

Step 12	95 *Rubus chamaemorus*	3 *Agrostis canina/ stolonifera*
	144 *Plagiothecium undulatum*	6 *Agrostis tenuis*
		20 *Carex echinata*
		22 *Carex panicea*
		74 *Nardus stricta*
		75 *Narthecium ossifragum*
		88 *Potentilla erecta*
		130 *Viola palustris*

Score greater than 2 = Class 11
Score less than or equal to 2 = Class 12

Indicators:	Negative (each = - 1)	Positive (each = + 1)
Step 13	20 *Carex echinata*	45 *Erica cinerea*
	29 *Cirsium palustre*	
	58 *Holcus lanatus*	
	63 *Juncus effusus*	
	64 *Juncus squarrosus*	
	91 *Ranunculus acris*	
	119 *Trifolium repens*	
	130 *Viola palustris*	
	150 *Sphagnum* spp.	

Score greater than - 4 go to 14
Score less than or equal to - 4 go to 15

Step 14	64 *Juncus squarrosus*	4 *Agrostis setacea*
	71 *Luzula campestris/multiflora*	15 *Calluna vulgaris*
		19 *Carex binervis*
		22 *Carex panicea*
		45 *Erica cinerea*
		84 *Polygala* spp.
		109 *Sieglingia decumbens*
		120 *Ulex europaeus/gallii*

Score greater than 3 = Class 13
Score less than or equal to 3 = Class 14

Step 15	20 *Carex echinata*	25 *Cerastium holosteoides*
	73 *Molinia caerulea*	116 *Thymus drucei*
	75 *Narthecium ossifragum*	119 *Trifolium repens*
	109 *Sieglingia decumbens*	131 *Viola* spp.
	130 *Viola palustris*	
	150 *Sphagnum* spp.	

Score greater than - 1 = Class 15
Score less than or equal to - 1 = Class 16

APPENDIX 7

Land Characteristics for Grid Squares

A Quantitative Physiographic and Topographic Data Recorded for 0.25 km^2 Grid Square Units in the Study Areas

1 and 2 from 1:25 000 OS maps directly, or from maps sketched from these (slope and aspect)

1 Physiography

Altitude Class (measured as areas by spot count, in 4% units)

1.1 < 401 ft OD (< 122 m)
1.2 401 - 800 ft OD (122 - 244 m)
1.3 801 - 1100 ft OD (245 - 335 m)
1.4 1101 - 1400 ft OD (336 - 427 m)
1.5 1401 - 2000 ft OD (428 - 610 m)
1.6 > 2000 ft OD (> 610 m)

Altitude Range (as figures, in feet)

1.7 Lowest mapped contour or spot height
1.8 Highest mapped contour or spot height
1.9 Altitude range between lowest and highest recorded heights

Slope Class (as areas, in 4% units)

1.10 Area of land with slope between 0^{o} and 5^{o}
1.11 Area of land with slope between 5^{o} and 11^{o}
1.12 Area of land with slope between 11^{o} and 22^{o}
1.13 Area of land with slope > 22^{o}

Aspect (as areas, in 4% units)

1.14 Aspect generally northerly (ie between NW and NE)
1.15 Aspect generally easterly (ie between NE and SE)
1.16 Aspect generally southerly (ie between SE and SW)
1.17 Aspect generally westerly (ie between SW and NW)

Rivers and Streams (as a relative numerical measure('frequency score' 0-25) of the number of sub-units in a 5 x 5 grid covering the 0.5 x 0.5 km grid square unit that include one or more rivers or streams)

1.18 Relative frequency of rivers (defined as watercourses mapped with double lines)
1.19 Relative frequency of streams (defined as watercourses mapped with single lines)

Water Bodies (as areas, in 4% units)

1.20 Area occupied by reservoir or lake

2 Topography

Settlement Density (as a number count)

2.1 Number of urban areas (solid grey-blocked areas)
2.2 Number of individual mapped 'buildings' (ie excluding any 'urban' areas)

Road and Footpath Density (as a relative numerical measure, see Rivers and Streams, 1.18-19)

2.3 Relative frequency of principal roads (defined as any 'road' with solid or dashed colour overlay)
2.4 Relative frequency of minor roads or tracks (defined as any double-lined uncoloured 'road')
2.5 Relative frequency of footpaths

Field Boundaries (as a relative numerical measure, see Rivers and Streams, 1.18-19)

2.6 Relative frequency of field boundaries

3 Rainfall Average Annual Rainfall, 1941-1970. As a qualitative single entry (1) for the rainfall band which occupies the greater part of the grid square unit, with a (0) entry for other bands (from rainfall maps, Meteorological Office 1977)

3.1 Dominant average rainfall 800-1000 mm (low, 35" average)
3.2 Dominant average rainfall 1001-1200 mm (moderate, 43" average)
3.3 Dominant average rainfall 1201-1600 mm (fairly high 55" average)
3.4 Dominant average rainfall 1601-2200 mm (high, 75" average)
3.5 Dominant average rainfall 2201-3299 mm (very high, 103" average)

B <u>Characteristics used for Land Classification by Indicator Species Analysis</u>

Derived from the quantitative data set of map-derived land characteristics (Appendix 7A). The attributes with underlined numbers are those required to operate the key to the land classification that is given in Appendix 8.

ISA Attribute Number

1 Land < 800 ft occupies 4-24% of square
2 Land < 800 ft occupies 28-48% of square
<u>3</u> Land < 800 ft occupies > 48% of square

4 Land between 800 and 1400 ft occupies 4-24% of square
5 Land between 800 and 1400 ft occupies 28-48% of square
<u>6</u> Land between 800 and 1400 ft occupies > 48% of square

ISA Attribute Number	
7	Land above 1400 ft is present in square
8	Land above 2000 ft is present in square
9	Altitude range < 100 ft
10	Altitude range 100-300 ft
11	Altitude range > 300 ft
12	Slope Class 0-5^{o} occupies 4-24% of square
13	Slope Class 0-5^{o} occupies 28-48% of square
14	Slope Class 0-5^{o} occupies > 48% of sqaure
15	Slope Class 5-11^{o} occupies 4-24% of square
16	Slope Class 5-11^{o} occupies 28-48% of square
17	Slope Class 5-11^{o} occupies > 48% of square
18	Slope Class 11-22^{o} occupies 4-24% of square
19	Slope Class 11-22^{o} occupies 28-48% of square
20	Slope Class 11-22^{o} occupies > 48% of square
21	Slope Class > 22^{o} occupies 4-24% of square
22	Slope Class > 22^{o} occupies 28-48% of square
23	Slope Class > 22^{o} occupies > 48% of square
24	Aspect northerly in 4-48% of square
25	Aspect northerly in > 48% of square
26	Aspect easterly in 4-48% of square
27	Aspect easterly in > 48% of square
28	Aspect southerly in 4-48% of square
29	Aspect southerly in > 48% of square
30	Aspect westerly in 4-48% of square
31	Aspect westerly in > 48% of square
32	River and stream frequency score 1-5
33	River and stream frequency score 6-15
34	River and stream frequency score > 15
35	-
36	-
37	-
38	Urban area present
39	Individual buildings absent
40	1-4 individual mapped buildings
41	5-9 individual mapped buildings
42	>10 individual mapped buildings
43	-
44	-
45	No roads mapped in square
46	Principal roads present, frequency score 1-4
47	Principal roads present, frequency score > 5
48	Other roads present, frequency score 1-4
49	Other roads present, frequency score > 5
50	No footpaths mapped in square
51	Footpaths present, frequency score 1-4
52	Footpaths present, frequency score > 5

ISA Attribute Number	
53	No field boundaries mapped in square
54	-
55	Field boundaries present, frequency score 1-7
56	Field boundaries present, frequency score 8-15
57	Field boundaries present, frequency score 16-25
58	Water bodies occupy > 50% of square
59	Dominant average rainfall 800-1000 mm pa
60	Dominant average rainfall 1001-1200 mm pa
61	Dominant average rainfall 1201-1600 mm pa
62	Dominant average rainfall 1601-2200 mm pa
63	Dominant average rainfall 2201-3200 mm pa

APPENDIX 8

Key to ISA Classification of Land Types

This key operates in successive steps in the way described for the vegetation classification in Appendix 6. To apply it to any area comparable to the hill and upland on which it is based requires a record of the 30 'key attributes' underlined in Appendix 7B, for 0.5 x 0.5 km grid square units covering the new area. The reference numbers for attributes in the key are those used in Appendix 7B. From the frequency of 'misclassified' squares in the original classification (see Appendix 4 for a summary of the ISA method) it is likely that some 8% of grid squares in a new area could be allocated 'incorrectly' by the use of this key.

Indicators:	Negative (each = -1)		Positive (each = +1)
Step 1			
7	Land above 1400 ft present	6	Land between 800 and 1400 ft, > 48%
39	No buildings	40	1 - 4 buildings present
45	No roads	49	Minor roads present, frequency score > 5
50	No footpaths	56	Field boundaries present, frequency score 8 - 15
53	No field boundaries	57	Field boundaries present, frequency score 16 - 25

Score less than or equal to -2 go to 2
Score greater than -2 go to 3

Step 2			
11	Altitude range > 300 ft	10	Altitude range 100 - 300 ft
19	Slope class 11 - 22°, 28 - 48%	14	Slope class 0 - 5°, > 48%
20	Slope class 11 - 22°, > 48%	53	No field boundaries
21	Slope class > 22°, 4 - 24%	62	Dominant average rainfall 1601-2200 mm pa
31	Westerly aspect, > 48%		
60	Dominant average rainfall 1001-1200 mm pa		

Score less than or equal to 0 = Steep Hill (Land type 1)
Score greater than 0 go to 4

Step 3			
3	Land below 800 ft, > 48%	6	Land 800 - 1400 ft, > 48%
11	Altitude range > 300 ft	9	Altitude range < 100 ft
12	Slope class 0 - 5°, 4 - 24%	14	Slope class 0 - 5°, > 48%
21	Slope class > 22°, 4 - 24%	50	No footpaths
62	Dominant average rainfall 1601-2200 mm pa	61	Dominant average rainfall 1201-1600 mm pa

Score less than or equal to 1 go to 5
Score greater than 1 go to 6

Step 4

10 Altitude range 100 - 300 ft

12 Slope class 0 - 5°, 4 - 24%

13 Slope class 0 - 5°, 28 - 48%

17 Slope class 5 - 11°, > 48%

18 Slope class 11 - 22°, 4 - 24%

9 Altitude range < 100 ft

14 Slope class 0 - 5°, > 48%

15 Slope class 5 - 11°, 4 - 24%

16 Slope class 5 - 11°, 28 - 48%

Score less than or equal to -1 = Hill (Land type 3)
Score greater than -1 = High Plateau (Land type 4)

Step 5

6 Land 800 - 1400 ft, > 48%

11 Altitude range > 300 ft

39 No buildings

55 Field boundaries present, frequency score 1 - 7

3 Land below 800 ft, > 48%

10 Altitude range 100 - 300 ft

17 Slope class 5 - 11°, > 48%

40 1 - 4 buildings present

49 Minor roads present, frequency score > 5

57 Field boundaries present, frequency score 16 - 25.

Score less than or equal to 0 = Steep Upland (Land type 5)
Score greater than 0 = Marginal Upland (Land type 6)

Step 6

10 Altitude range 100 - 300 ft

13 Slope class 0 - 5°, 28 - 48%

17 Slope class 5 - 11°, > 48%

31 Westerly aspect, > 48%

47 Principal roads present, frequency score > 5

61 Dominant average rainfall 1201-1600 mm pa

9 Altitude range < 100 ft

14 Slope class 0 - 5°, > 48%

15 Slope class 5 - 11°, 4 - 24%

39 No buildings

Score less than or equal to -1 = Upland (Land type 7)
Score greater than -1 = Upland Plateau (Land type 8)

APPENDIX 9

Land Characteristics Tabulated for Vegetation Main Sites

(a) The land characteristics listed here are those recorded from 1:25 000 OS maps, or sketch maps derived from these maps, for the 'points' at which main sites are located, in order to enable associations between site characteristics and site vegetation class to be explored. The data were recorded for each site as the relevant attribute number for each category of observation, ie one number from 1-6; one number from 7-10; etc for each site.

Altitude Class

1 < 122 m (400 ft)
2 122-244 m (400-800 ft)
3 245-335 m (800-1100 ft)
4 336-427 m (1100-1400 ft)
5 428-609 m (1400-2000 ft)
6 > 609 m (2000 ft)

Slope Class (derived from sketch maps)

7 $0-5^{o}$
8 $6-11^{o}$
9 $12-22^{o}$
10 $> 22^{o}$

Aspect Class (derived from sketch maps)

11 generally northerly (NW-NE)
12 generally easterly (NE-SE)
13 generally southerly (SE-SW)
14 generally westerly (SW -NW)

Proximity to Roads

15 < 0.25 km from a mapped road or track
16 0.25-0.5 km from a mapped road or track
17 > 0.5 km from a mapped road or track

Proximity to Houses

18 < 0.25 km from a mapped building
19 0.25-0.5 km from a mapped building
20 > 0.5 km from a mapped building

Field Location

21 Site within mapped field boundaries
22 Site outside mapped field boundaries

(b) This group of site characteristics are those obtained from field notes or, in the case of soil pH, from laboratory analysis of field samples.

Slope, across 200 m^2 quadrat

23 0-5°
24 6-11°
25 12-22°
26 > 22°

Soil texture, at corners of 200 m^2 quadrat (rapid field assessment)

27 Sand or sandy loam present
28 Loam present
29 Clay loam or clay present
30 Peaty soil present

Soil depth, at corners of 200 m^2 quadrat (rapid assessment by augering to rock or obstruction by stones)

31 'Shallow' (20 cm mean depth)
32 'Moderate' (20-50 cm mean depth)
33 'Deep' (> 50 cm mean depth)

Soil Drainage Class, at corners of 200 m^2 quadrat (rapid assessment by soil colour and structure)

34 Good
35 Good and moderate or poor
36 Moderate
37 Moderate and poor
38 Poor

Soil pH, by laboratory measurement, as the average of four 0-10 cm depth samples from the corners of the 200 m^2 quadrat

39 < 4.2
40 4.21-4.7
41 4.71-5.2
42 5.21-6.0
43 > 6.0