Vegetation Change in Upland Landscapes

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COVER PHOTOGRAPH

Pastoral uplands along the River Coquet in Alwinton, Northumberland. Improved pastures occur in fields around the farm in the mid-distance. Ploughing for further re-seeding is visible above the wall on the centre-left. Rough pastures dominate the remainder of the view.

(Photograph by J Dale)

The Institute of Terrestrial Ecology (ITE) was established in 1973, from the former Nature Conservancy's research stations and staff, joined later by the Institute of Tree Biology and the Culture Centre of Algae and Protozoa. ITE contributes to, and draws upon, the collective knowledge of the fourteen sister institutes which make up the *Natural Environment Research Council,* spanning all environmental sciences.

The Institute studies the factors determining the structure, composition and processes of land and freshwater systems, and of individual plant and animal species. It is developing a sounder scientific basis for predicting and modelling environmental trends arising from natural or man-made change. The results of this research are available to those responsible for the protection, management and wise use of our natural resources.

Nearly half of the ITE's work is research commissioned by customers, such as the Nature Conservancy Council who require information for wildlife conservation, the Department of the Environment, the Department of Energy and the European Economic Community. The remainder is fundamental research supported by NERC.

ITE's expertise is widely used by international organisations in overseas projects and programmes of research.

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Preface

In 1975 the Department of the Environment (DOE) contracted the Institute of Terrestrial Ecology (ITE) to review land use in the uplands of England and Wales, to indicate the likely changes in use and consequent ecological and landscape changes. The desk study was published by the Countryside Commission (ITE 1978) and was followed by a field study, again under contract to DOE. The field study was designed to determine the rates and types of change in upland vegetation, the factors responsible for vegetation distribution and potential change, and to predict the likely future patterns of vegetation. The present report summarizes the field study (full details in Bangor occasional papers nos. 2 and 3*) with particular emphasis on the changes in the moorland vegetation and some development of predictions published earlier.

The study concentrated on 12 areas, mainly single parishes, falling within the EEC definition of 'less-favoured areas' with 'mountain and hill farming'. The selection of sites was made in collaboration with the Upland Landscapes Study (ULS), a parallel project sponsored by the Countryside Commission, the aim of which was to determine the likely future land use of the 12 areas and its effect on the landscape.

The research was guided by Nominated Officers of the DOE, and a Review Committee representing various organizations concerned with the uplands. ITE is particularly grateful to the Officers and Committee members who contributed much to the study, to the many landowners and tenants who have generously allowed access to their land, to the organizations which have provided advice and information, and to the Countryside Commission and ULS for their collaborative efforts.

ITE accepts sole responsibility for the results and interpretations presented in this report, and the authors acknowledge the efforts of D R Helliwell, K E Dickson, W M Williams, A Nelson and other staff. An important contribution to the historical analysis was made by Dr M L Parry of Birmingham University.

* (Ball *et al.* 1981 a, b). Available from Station Secretary, ITE, Bangor Research Station, Penrhos Road, Bangor, Gwynedd, LL57 2LQ (£7.50 each).

1 Introduction

The traditional upland landscapes of England and Wales have their foundation in the geological formations moulded by glaciation, water and climate to produce the varied landform of hills and valleys. Through weathering under different climates, soil development has produced a varied pattern of vegetation which in turn has been modified by man. The intensity of human influence is seen in the associated development of boundaries and buildings. Thus the landscape pattern and form has developed through the interaction of many factors, over varying time scales.

The pattern and composition of the landscape is not static, but affected by changes in land use, such as agricultural improvement of moorland, afforestation and reservoir construction. Less obvious and more gradual change in the landscape occurs through the vegetation succession induced by minor changes in management such as reduction in fertilizer use, alteration in stocking density or burning frequency. Other gradual changes in vegetation occur through natural succession and cycles associated with the ageing of plants, with soil development or with exceptional events such as accidental fire. Change is normal, but many of the changes in upland vegetation are detectable only over decades. The current vegetation may still be responding to adjustments in management which took place 50 or more years ago.

Concern over the effects of changing land use in lowland Britain resulted in a study of a number of lowland areas, sponsored by the Countryside Commission, and published as 'New agricultural landscapes' (Westmacott & Worthington 1974). Recently Goode (1981) reviewed the scattered information on the loss of habitats in upland and lowland Britain and concluded that 'at the present rate, the area of natural vegetation will be halved within a generation'. Whilst major losses of lowland habitats have long been recognized, the situation in the uplands is less clear. Various studies have estimated loss of moorland in particular areas but comprehensive information has been lacking. However, Parry, Bruce and Harkness (1981) have recently emphasized the high rate of loss of moorland in some National Parks and suggest that 'Britain's moorlands are being enclosed and reclaimed at an average rate of 5000 ha per year'.

To identify major changes in upland land use the Department of the Environment (DOE), in consultation with Countryside Commission, sponsored a desk study (ITE 1978) which indicated that dramatic changes in land use are unlikely to occur in the foreseeable future. Rather the recent trends can be expected to continue with agriculture remaining strong in some areas but decreasing in others, resulting in a decrease in stocking rates and hence a gradual change in vegetation on rough grazings and abandoned pastures. The second main effect on the landscape is likely to be the continued expansion of forestry, probably on the less fertile areas where hill and upland agriculture tends to be least viable. Common Land and National Park status are likely to reduce the rate of change in agriculture and forestry over large areas of the uplands.

Variation in grazing pressure can slowly alter the vegetation in the uplands, and changes in numbers and type of stock can be expected in response to social and economic factors and to variation in other land uses such as recreation and forestry. Thus gradual change in vegetation is expected to occur. Although a detailed analysis was not possible in the desk study, diagrams were produced indicating the general change in main types of vegetation that could be expected if grazing, or burning, either increased or decreased.

One factor which has inhibited the analysis and planning of land use in the uplands has been the absence of a common basis to compare different areas, reflecting the main physical factors which influence both land use and ecology. A suitable land classification of this type was developed in the desk study of upland land use, having the flexibility to link local, regional and national levels.

As a result of the review of upland land use, the present study was contracted to obtain more precise field information on the degree and rate of change in upland vegetation, the most important question being: How will the vegetation change in the future? The answers depend on the type of vegetation, the physical environment in which it occurs, and its past, present and future management. The following analysis of 12 areas in the uplands of England and Wales summarizes:

i. the composition of the main types of upland grassland and moorland;
ii. how its distribution is related to both the physical environment and man's management;
iii. something of how the vegetation has been changing over the past 200 years.

From these strands of evidence, and from the general understanding of the dynamics of plant communities:

iv. the future general pattern of vegetation in the areas is predicted given various trends in future management.

As the 12 areas are a reasonable sample of the uplands in England and Wales, predicted trends can be expected to occur generally. Obviously, in any particular site, local factors will determine the course and degree of change.

The detailed study of vegetation has been paralleled by an analysis of land use in the same 12 areas, with particular emphasis on farming and farmers' attitudes in relation to landscape changes. The project, entitled Upland Landscapes Study (ULS), has been sponsored by the Countryside Commission.

2 The study areas

The 12 study areas were selected, in collaboration with ULS, from major upland regions in England and Wales (Map 1) and consisted of parishes within the boundaries of the European Economic Community (EEC) 'less-favoured areas' with 'mountain and hill farming'. The study areas reflect the range of conditions in most upland land classes of a provisional national upland classification (ITE 1978). The type of farming, farm size and stocking characteristics of the 12 areas (15 parishes) are very similar to the average features of the 339 parishes which are in the less-favoured areas (ULS 1981). A number of the study areas are in National Parks, other parts are used for water supply, military training, grouse shooting or forestry. The range of upland land uses is well represented in the 12 areas and, although the areas were not selected as representative or typical of the regions in which they occur, they show many of the physical and land use features of their regions (Table 1). For example, the study area in Exmoor (Lynton) with moderately good agricultural land, shows the significant agricultural improvement of moorland which is typical of much of the region. In contrast, Llanfachreth and Alwinton include an expansion of forestry characteristic of Snowdonia and the Cheviots.

The interaction of landform, geology, climate and soil in general determines the land use potential of a locality, although the realization of the potential depends on additional social and economic factors. The physical environment thus provides the foundation for contrasts between the land use of upland areas. It is easy to recognize major differences in the type of land in various upland areas, such as the steep high mountains of Snowdonia compared with the lower undulating hills of the Cambrian Mountains, or the cold wet climates with peaty soils of the northern Pennines compared with warmer, relatively dry climates and reasonably drained soils of Exmoor. However, a much finer scale is necessary when considering the effects of land type on vegetation, as developed in the next section. Examples of land type, land use and vegetation in the study areas are shown in Plates 1-8.

2.1 LAND CLASSIFICATION

To simplify the main variations in land in the 12 study areas, features defined on Ordnance Survey and rainfall maps were measured for each 0.5 x 0.5 km grid square. The data from all the squares were then analysed by a multivariate method, Indicator Species Analysis (Hill, Bunce & Shaw 1975), which determines the major and minor patterns of variation, and groups squares with similar combinations of features together in the same class.

Within the study areas 7 land types were distinguished, in 3 land groups:

Hill land is mainly in the altitude range 428-610 m, with 3 land types distinguished by combinations of slope and relief: *steep hill, hill* and *high plateau.*

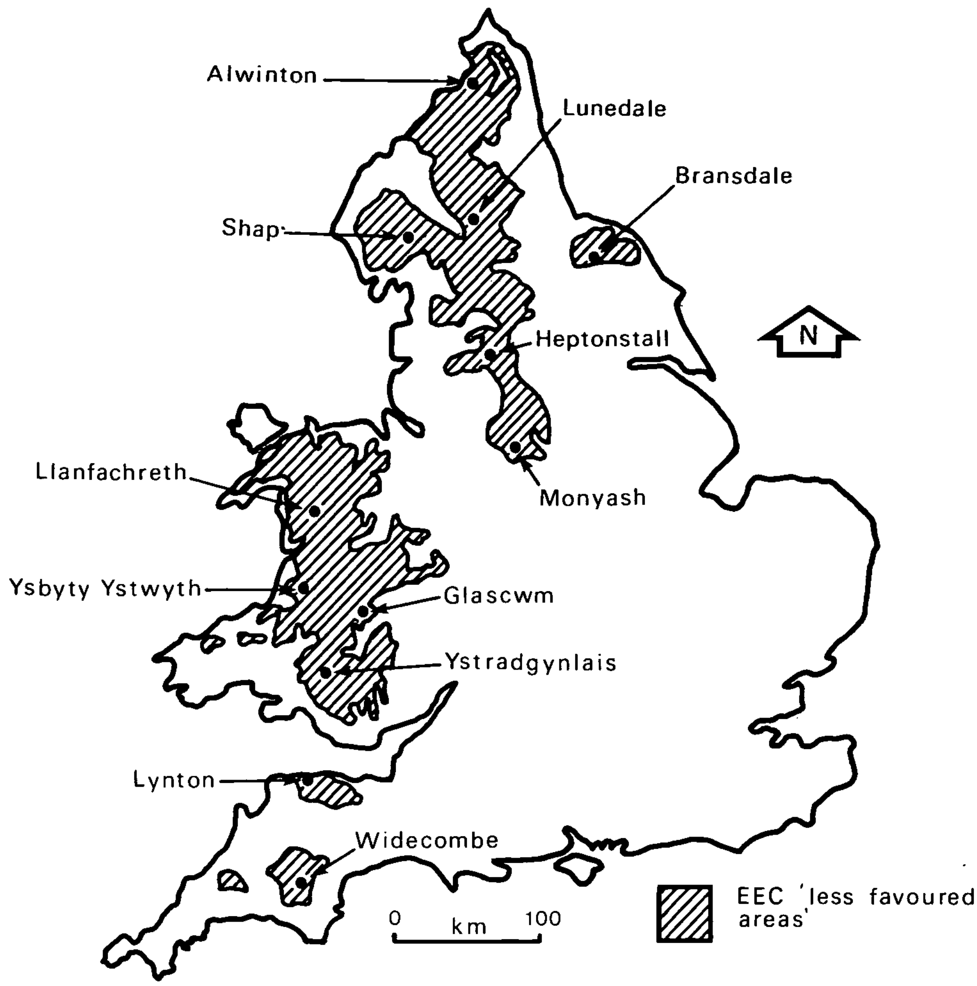
Upland is dominated by altitudes between 245 and 335 m, also of 3 land types, again distinguished by slope and relief: *steep upland, upland* and *upland plateau.*

Upland margin is a single land type dominated by altitudes between 122 and 244 m, with moderate relief and rather steep slopes (6-11°).

Table 1. GENERAL CHARACTERISTICS OF THE STUDY AREAS AND THEIR REGIONS

The regions are defined in Ball *et al.* (1981a) as the geographical groups of 10 x 10 km squares associated with the study areas and which contain more than 50% of land above 244 m. Data for the regions given in parentheses. Agricultural data for study areas as % of the total area, but for the regions area as % of the total agricultural land. The study area of Shap consists of the parishes of Shap Rural and Shap, Ystradgynlais of Ystradgynlais Higher and Glyntawe, Widecombe of Widecombe in the Moor and Buckland in the Moor.

Study area and region	Land above 244 m	Land above 427 m	Land with slope more than 5°	Agricultural Land Grade 3	4	5	Other use	Agricultural Land Use Tillage	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 (09)	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 (85)	0 (10)	74 (52)	0 (6)	50 (47)	50 (38)	0 (8)	3 (16)	54 (60)
Widecombe, Dartmoor	84 (87)	6 (35)	76 (28)	5 (8)	30 (13)	55 (74)	10 (5)	3 (14)	39 (26)



Map 1 — **Study areas in relation to the EEC less-favoured areas**

The general characteristics of each land type are summarized in Table 2.

2.2 LAND TYPES IN THE STUDY AREAS

There are marked differences in land character both between and within the study areas. The detailed distribution of land types, summarized in Table 3, shows a relative ranking of the study areas with increasing degrees of 'hilliness':

Monyash, Lynton and Widecombe — have little or no hill land. Most of the land in these areas is upland, upland plateau and upland margin with the greatest potential for agriculture and forestry.

Llanfachreth — while having a moderate amount of hill land, particularly steep hill, has a high proportion of upland margin.

Heptonstall, Bransdale and Glascwm — are predominantly upland, but have moderate amounts of both hill and upland margin.

Shap, Ysbyty Ystwyth and Ystradgynlais — have about 50% hill land, but Shap has a low proportion of upland margin similar to Alwinton and Lunedale.

Alwinton and Lunedale — have a high proportion of hill land, and only small amounts of upland margin.

This variation in the physical environment largely determines the distribution of vegetation and the extent to which agriculture, forestry and other land uses have developed. Undoubtedly other factors are important in particular situations. For example, in Shap and Monyash the upland plateau land overlies Carboniferous Limestone, with a thin cover of glacial drift. This favourable soil parent material gives relatively high levels of agricultural use and settlement that contrast sharply with upland plateau land elsewhere on less agriculturally favourable rocks. Past and present land ownership has also influenced local patterns of vegetation and land use, but the physical characteristics of the land set general limits for the variety of vegetation and land use.

Table 2. SUMMARY DESCRIPTION OF LAND TYPES
Descriptive terms are relative to the range of characteristics in the study areas. Further details in Ball *et al.* (1981a).

Land group	Land type	General description
Hill	Steep Hill	High altitude, strong relief, steep slopes; very low density of habitation, low frequency of road access and intensity of agricultural use.
	Hill	High altitude, moderate relief and slopes; low density of habitation, frequency of road access and intensity of agricultural use.
	High Plateau	High altitude, low relief and gentle slopes; low density of habitation, frequency of road access and intensity of agricultural use.
Upland	Steep Upland	Moderate altitude, strong relief and steep slopes; low density of habitation, moderate frequency of road access and intensity of agricultural use.
	Upland	Moderate altitude, relief and slopes; high density of habitation, frequency of road access and intensity of agricultural use.
	Upland Plateau	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	Low altitude, moderate relief and rather steep slopes; high density of habitation, frequency of road access and intensity of agricultural use.

Table 3. LAND GROUP REPRESENTATION IN THE STUDY AREAS
Three land types are included in Hill and Upland Groups. Results are given as % of the study area. Further details in Ball *et al.* (1981a, b).

Study area	Land group 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

Plate 1 — Moorland with mature heather on the fell country in the southeast of Shap, Cumbria. Moorland vegetation in this parish is dominated by class II, *Nardus/Sphagnum/Calluna* shrubby heath.
Photograph by P. Ainsworth.

Plate 2 — Shrubby heath vegetation characterises the background ridge in this view in Alwinton, Northumberland. The light area on the left is improved pasture, a contrast with rough pastures of the foreground. Their reasonably fertile soils which could support further pastoral improvements are suggested by the bodies of the moles strung on the foreground fence since moles depend on relatively well-drained soils and earthworm food supplies. Deciduous woodland is scarce in this parish, typically occurring in small remnants such as that in this picture.
Photograph by J. Dale.

Plate 3 — The study area of Heptonstall, West Yorkshire, shows the stonewalled field pattern characteristic of the southern Pennines. Farms stretch above the valley of the Colden Water towards the moors, with the Pennine watershed moorland forming the background in this view. Photograph by D. F. Ball.

Plate 4 — Enclosed fields occupy the valley floor and run part way up the side of the valley at Bransdale, North Yorkshire. The upper valley slopes carry rough pastures and grassy heaths. Above these a ridge has shrubby heath vegetation. A conifer plantation can be seen on the left and on the valley floor a remnant of deciduous woodland remains.
Photograph by D. F. Ball.

Plate 5 — In Glascwm, Powys, favourable conditions of soil and climate exist for extensive pasture impovement to have reached quite high altitudes. Pockets of rough pasture with prominent bracken persist on steep slopes in the foreground. Unimproved moor with heath vegetation survives on common grazings above the improved pastures.
Photograph by D. F. Ball.

Plate 6 — Improved pastures of the enclosed fields in the fore- and middle-ground of Widecombe, Devon, contrast with grassy heath vegetation of the unenclosed moor in the top left hand corner of this picture. The field boundaries here are characteristically hedgerows, still with frequent hedgerow trees.
Photograph by D. F. Ball.

Plate 7 — The southern part of the parish of Lynton, Devon, extends to the unimproved Exmoor moorland, seen in the background here. There is a marked contrast between this and the northern part of the same parish (plate 8).
Photograph by P. Ainsworth.

Plate 8 — In the north of Lynton the vegetation is dominated by improved pastures on gentle to moderate slopes and by preserved deciduous woodlands on the steep valley sides. Immediately near the coast, exposed areas of shallow soil above the cliffs carry scrub woodland or grassy heaths.
Photograph by J. Dale.

3 The current upland vegetation

In the upland areas 4 main vegetation groups have been identified from the detailed species composition of vegetation measured at about 1000 sites in the 12 areas. These 4 groups make distinct contributions to the landscape, but more subtle differences, visually and in species composition, occur within them as a result of different environmental conditions and management practices. Details of the species composition of vegetation classes are given in Ball *et al.* (1981a, appendix 5).

3.1 IMPROVED PASTURES

The productive farmland pastures are characterized 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, such as *Pteridium aquilinum* (bracken), *Juncus* species (rushes) and *Cirsium* species (thistles), may also be present depending on soil conditions, management and drainage. Soils are mainly above pH 5.2, and often above 6.0.

Four classes of improved pasture show a sequence from the most productive herb-rich *Lolium* grassland to the poorest *Lolium/Holcus/Pteridium* grassland which has the highest 'weed' content with lower nutritive value than the main introduced species. The sequence represents responses to the interaction of inherent site fertility, management intensity and the time since the pasture was reseeded.

Herb-rich *Lolium* grassland (class 4*). This class includes recently resown swards and is *Lolium perenne*-dominated with a range of agricultural weeds present. *Trifolium repens* and *Dactylis glomerata* are also prominent. (Plate 9)

Lolium grassland (class 2). *Lolium perenne* is again dominant, but *Agrostis tenuis* (common bent) and *Holcus lanatus* (Yorkshire fog grass) are present as major co-dominant species. The class includes some land utilized for hay meadows.

Lolium/Trifolium grassland (class 3). *Lolium perenne* and *Trifolium repens* are co-dominant species. There is a tendency towards impeded drainage, reflected in the presence of thistles and rushes.

Lolium/Holcus/Pteridium grassland (class 1). This class occurs on shallower soils than the other improved pastures. Rocks and boulders are typically present on the surface. *Lolium perenne* and *Holcus lanatus* are co-dominant, with *Pteridium aquilinum* present as an invading species. Trees and scrub are present on many sites.

* Class numbers refer to the original statistical analysis and are retained here to simplify cross reference to Ball *et al.* (1981a, b).

3.2 ROUGH PASTURES

Rough pastures are subjected to less intensive management than the improved pastures and may result from deterioration of former improved grasslands or partial upgrading of moorland. They are characterized by the prominence of species such as *Agrostis tenuis* and *A. canina* (brown bent), *Festuca ovina* (sheep's fescue), *Juncus* spp. and other coarser species. There are fewer introduced species than in the improved pastures and a wide range of native species. Lower fertility, with moderately acid soils (pH 4.7–6.0), is also characteristic and poor drainage is frequent. The grasslands in this group form an ecological sequence of decreasing grazing value influenced by soil conditions.

Agrostis/Holcus grassland (class 7). The dominant grasses are *Agrostis* spp. and *Holcus lanatus*. This grassland contains a variety of herbs and is confined to well drained soils mainly on moderate slopes (range 6–11°). Species diversity is high (188 species recorded). Trees and surface rocks and boulders are frequently present.

Agrostis/Juncus grassland (class 5). Herb-rich flushes are a feature of this grassland, which can be considered as a poorly drained version of the previous class. Bracken and brambles are fairly frequent, as also are scattered trees. Species diversity (189 species recorded) is again high. (Plate 10)

Festuca/Agrostis grassland (class 8). *Festuca ovina* and *Agrostis tenuis* are the co-dominant grass species but *Lolium perenne* is also often present. Soils are fairly shallow and slopes mainly moderate. There is some tendency to impeded drainage with species of wetter habitats often present, eg *Juncus effusus*. There are generally rather fewer trees and surface rocks and boulders present than in other types of rough pasture.

Festuca/Juncus grassland (class 6). This grassland is more poorly drained than the *Festuca/Agrostis* swards (class 8), and the main feature which distinguishes it from *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/creeping bent) and *Nardus stricta* (mat-grass). Thus the composition of the *Festuca/Juncus* grasslands links rough pastures with the grassy heaths.

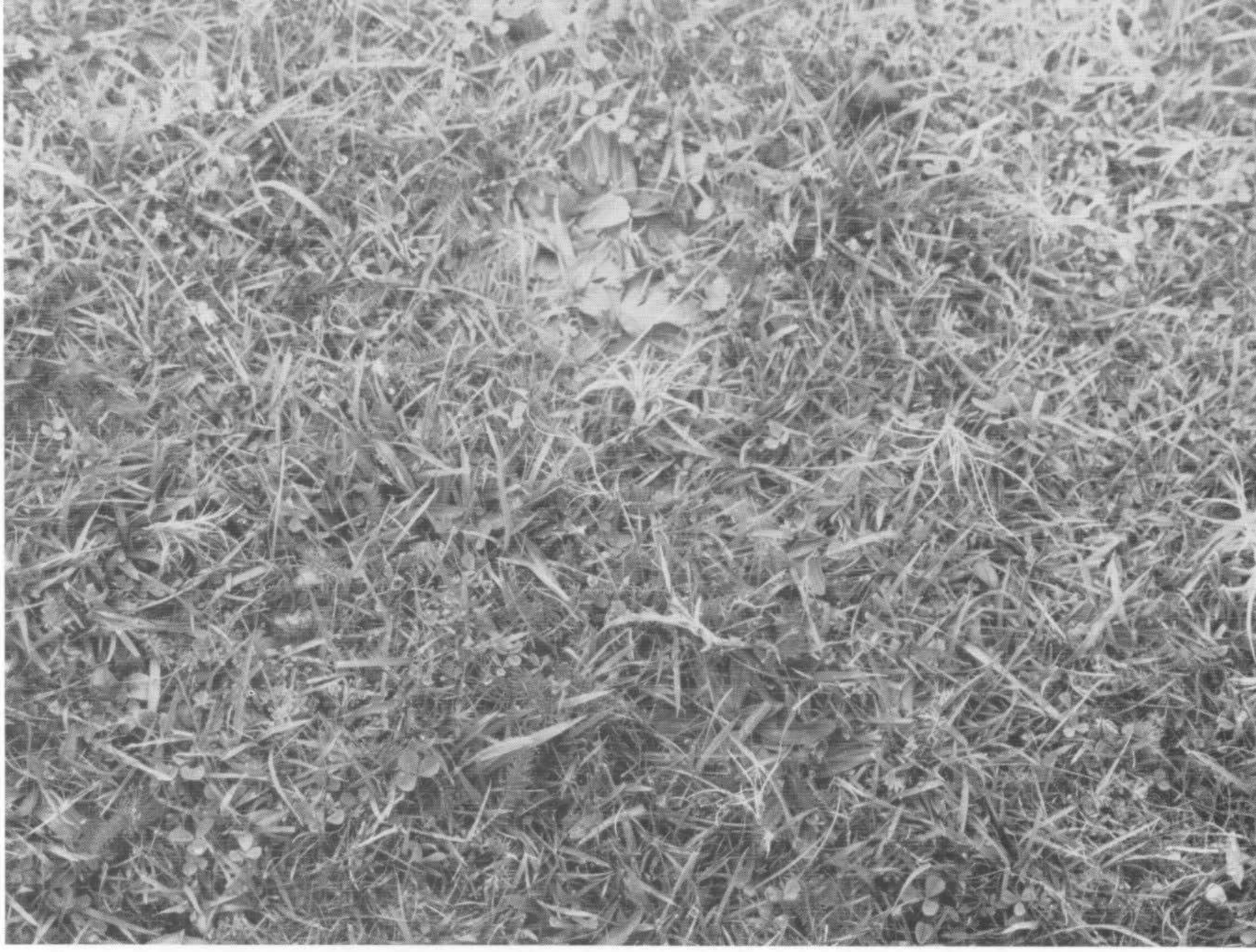


Plate 9 — Close-up of improved pasture class 4 (Herb-rich *Lolium* grassland) at a Lynton site. Close grazing and a wide selection of herbs (eg *Trifolium repens, Achillea millefolium* and *Plantago lanceolata)* are characteristic.
Photograph by J. Dale.

Plate 10 — 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.
Photograph by J. Dale.

Plate 11 — 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.
Photograph by J. Dale.

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

3.3 GRASSY HEATHS

Grassy heaths, consisting of three classes, are characterized by the dominance of coarse native grasses such as *Nardus stricta, Deschampsia flexuosa* (wavy hair-grass) and *Molinia caerulea* (purple moor-grass). A secondary shrubby element 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. The 3 classes of grassy heaths are arranged in order of increasing frequency of heath species. Soil acidity covers a wide range, but more than half the sites are below pH 4.7.

Festuca/Nardus/Vaccinium heath (class 15). This class occurs typically on moderate to steep slopes, which 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. Gullies and scree patches are landform features frequently present.

Festuca/Nardus/Molinia heath (class 16). This can be termed a wet grassy heath and it contains a relatively high number of species. 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 frequently present in this type of heath. (Plate 11)

Festuca/Vaccinium heath (class 14). This heath is found mainly on gentle to moderate slopes with shallow soils and good drainage. This is the typical dry grassy heath characterized by species such as *Galium saxatile, Festuca ovina, Deschampsia flexuosa, Juncus squarrosus* (heath rush) and *Potentilla erecta* (common tormentil).

3.4 SHRUBBY HEATHS

Shrubby heaths are characterized by the predominance of dwarf shrubs such as *Calluna vulgaris* (heather or ling), *Vaccinium myrtillus* (bilberry), *Erica cinerea* and *E. tetralix* (bell heather and cross-leaved heath) and *Empetrum nigrum* (crowberry), as well as *Ulex* spp. (gorse) and various grasses, sedges (*Carex* spp.) and rushes. The group is found on the least fertile soils, often with a pH less than 4.2, and at sites with the lowest intensity of management. The main trend among the heaths, indicated by the order in which they are presented below, is of decreasing grazing intensity and reduction in the potential of the vegetation for easy modification through management.

Calluna heath (class 13). Dry *Calluna* heath, with bracken present in some cases, occurs mainly on rocky sites with pockets of well drained soils. *Ulex* is usually present and is sometimes conspicuous as large bushes. *Agrostis tenuis* is the grass species that occurs most regularly but the other grasses of acidic soils are also prominent.

Calluna/Molinia/Vaccinium (class 9). This rather species-poor heath (55 species recorded), of limited occurrence, is found mainly on relatively shallow soils. *Calluna vulgaris* is the dominant species but all the other common heath shrubs are also present. Five grass species also occur frequently.

Vaccinium/Calluna heath (class 10). Again a rather species-poor heath (65 species recorded), which mainly differs from class 9 in that the shrubby heathland element is less diluted; only one grass species *(Deschampsia flexuosa)* occurs frequently. Heathland surface characteristics such as burning, and eroding peat, are conspicuous.

Nardus/Sphagnum/Calluna heath (class 11). 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* (deer-grass), *Empetrum nigrum, Carex echinata* (star sedge) and *Narthecium ossifragum* (bog-asphodel).

Eriophorum/Calluna heath (class 12). This class is a blanket bog community on deep peaty soils. *Calluna vulgaris* is dominant, with *Eriophorum vaginatum* and *Deschampsia flexuosa* co-dominant. *Eriophorum angustifolium* (common cotton-grass) and *Sphagnum* spp. (bog moss) are usually present. (Plate 12)

4 Factors affecting the vegetation

Both the physical environment and management affect plant communities. The physical environment sets limits to the range of vegetation which can occur. Within these limits management modifies the type and occurrence of the vegetation. Thus the current distribution of plant communities on different land types indicates the range of vegetation which is likely to be produced by man's activities, and the sequence of vegetation which results from varying intensities of management.

4.1 THE VARIETY OF VEGETATION

Variety is often regarded as an asset to the landscape and the biological interest of an area. The range of plant communities contributes to both landscape and biological variety. Representation of vegetation classes differs markedly at sites in different study areas (Table 4) but the relationship to environmental or management factors is not simple. In order of increasing variety of vegetation, Monyash sites, dominated by a very limited range of grasslands, are the least diverse, followed by Lunedale and Alwinton where the extensive moorlands are fairly uniform and there are few grassland types. Bransdale and Ysbyty Ystwyth, while mainly moorland, have an increased range of grasslands giving them a variety similar to that of Widecombe, which has a wide range of grasslands but few grassy and shrubby heaths. Glascwm and Lynton are dominated by pastures but retain a variety of heaths. Shap and Heptonstall combine a wide variety of both grasslands and heaths, while the full range of vegetation occurs in Llanfachreth and Ystradgynlais. It is not simply the size of an area which causes a wide range of vegetation to be present. Heptonstall, the smallest area studied, shows a range of vegetation similar to that of Shap, which is five times larger. A wide range of land types also is not simply related to a wide range of vegetation, although Monyash, Lunedale and Alwinton show restricted ranges of both land and vegetation. Variation in management of both moorland and grassland, when linked with the physical characteristics, explains the vegetation diversity.

4.2 LAND USE AND ENVIRONMENTAL FACTORS

Eight of the study areas (Lunedale, Ysbyty Ystwyth, Bransdale, Shap, Alwinton, Ystradgynlais, Heptonstall and Llanfachreth) are distinctly moorland in character, with more than 50% of grassy or shrubby heaths. Lunedale and Ysbyty Ystwyth particularly contain very low proportions of improved pasture sites, with rough pastures also rather poorly represented. The very high occurrence of *Eriophorum/Calluna* blanket bog 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 locally strong representation of improved pastures associated with limestone outcrops, and the moorland component found on the volcanic rocks in the western half 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 representation of shrubby heaths, particularly *Vaccinium/Calluna* heath. 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,

Table 4. THE DISTRIBUTION OF VEGETATION CLASSES IN EACH STUDY AREA

The figures show the % of each vegetation class in the sites sampled in each study area. Prominent vegetation is shown in bold type. Vegetation classes are arranged to show the successional response to environmental conditions and management (see text). See footnote for code numbers used to identify vegetation classes.

Study area	Improved Pastures				Rough Pastures				Grassy Heaths			Shrubby Heaths					Number of sites
	4	2	3	1	7	5	8	6	15	16	14	13	9	10	11	12	
Alwinton	1	5					**22**	5	14	5	16				14	**18**	80
Lundale	1						9	3	16	3	1			1	8	**58**	79
Shap	9	8	1	2	3		6	5	4	**24**	5		2	2	**26**	3	115
Bransdale	6		5	1			11		1	15	**18**			**35**	6	2	88
Heptonstall	11	9	3	1	1	1	7	1		4	6		1	**24**	3	**28**	70
Monyash	**45**	**40**			11		4										72
Llanfachreth	3	1	1	4	13	4	10	3	1	**23**	7	8	1	1	**16**	4	72
Ysbyty Ystwyth	0	1	4	1	3		9			12	17		1	3	**23**	**26**	75
Glascwm	**24**	1	**18**	6	7	3	10	3	1	1	13			13			71
Ystradgynlais	12	1	4	1	3	10	3	1	1	**17**	**22**	4	1	7	12	1	70
Lynton	**52**	1	8	7	6	3		1	1	3	10	3	4		1		71
Widecombe	**24**	5	4	4	5	11	1	3			5	**31**	7				75
12 areas combined	15	6	4	2	4	2	8	2	3	9	10	4	2	7	10	12	938

Code numbers: 4 – Herb-rich *Lolium,* 2 – *Lolium,* 3 – *Lolium/Trifolium* and 1 – *Lolium/Holcus/Pteridium* grasslands

7 – *Agrostis/Holcus,* 5 – *Agrostis/Juncus,* 8 – *Festuca/Agrostis* and 6 – *Festuca/Juncus* grasslands

15 – *Festuca/Nardus/Vaccinium,* 16 – *Festuca/Nardus/Molinia* and 14 – *Festuca/Vaccinium* heaths

13 – *Calluna,* 9 – *Calluna/Molinia/Vaccinium,* 10 – *Vaccinium/Calluna,* 11 – *Nardus/Sphagnum/Calluna* and 12 – *Eriophorum/Calluna* heaths

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. A decline in the 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 management for shooting. In Ystradgynlais opencast coal mining has locally influenced vegetation in that these operations have disturbed farmland and moorland which have subsequently been allowed to revegetate to a form of rough pasture or have been planted to coniferous forest. Moorland is still dominant in Llanfachreth, but with the grasslands occupying almost 40% of the sample sites, this parish tends to be intermediate between those of undoubted moorland character and those in which the influence of agriculture is predominant.

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, surrounded as it is by major conurbations which created substantial demands for agricultural produce, particularly dairy products. This has meant that there have been long standing economic incentives for the 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 more favourable conditions for plant growth, in terms of both soils and climate. Since these three areas are more remote than Monyash from major centres of population, they have retained a more varied vegetation and have not been subjected to the opportunities and pressures for improvement that turned Monyash totally to farmland. Out of these three areas, the farmland element is weakest in Widecombe, probably reflecting the importance of Common Land. In Glascwm, grassland improvement schemes are currently making deep inroads into the remaining areas of unimproved moorland, but in Lynton, pressures for landscape conservation may prevent further losses of unimproved moorland.

4.3 THE VEGETATION OF DIFFERENT LAND TYPES

Environmental variation between the study areas is condensed in the land types, which allow consideration of moorland and grassland vegetation which has been developed under man's influence in comparable environments. Combining the information from the 12 areas shows that each type of land contains one or two dominant classes of vegetation with a number of subordinate or occasional communities (Table 5). An interpretation is that the dominant vegetation is 'normal' for that type of land. In the hill land types the dominant vegetation is determined mainly by environmental conditions, but in the upland and upland margin man's influence is more important in creating the dominant vegetation. The subordinate vegetation in each land type reflects the minor variations in the physical conditions and management. The frequency of each vegetation indicates the probability of it being developed through a change in management. In general terms, increased intensity of management, particularly grazing pressure, would move vegetation classes towards the left side of Table 5, and decreased management to the right. For example, in steep hill land increased grazing would change the shrubby heaths into grassy heaths, with a limited probability of succession into two types of rough pasture. In contrast, in upland margin land there is a high probability that conditions suitable for pasture improvement would allow management to transform the rough pastures and heaths towards improved grassland, predominantly into herb-rich *Lolium* swards.

As always, general trends would be tempered by local conditions, but the main patterns are as follows.

4.3.1 Vegetation of hill land

Hill land types support negligible improved pastures because of their altitude, low temperature and high rainfall, and their rough pastures are principally *Festuca/Agrostis* grassland (class 8) which, with *Festuca/Juncus* grassland (6), occurs mainly on steep hill land which is better drained. Grassy heaths of the steep hill are mainly *Festuca/Nardus/Molinia* (16) and *Festuca/Vaccinium* (14) and their association suggests that they could develop from the grasslands (8 and 6) under reduced grazing intensity, with associated reduction in the rate of nutrient circulation and gradual fall in the pH of the surface soils. The commonest shrubby heath class is *Nardus/Sphagnum/Calluna* (11). Steep hill land has a greater vegetational diversity than hill and high plateau where shrubby heaths of *Nardus/Sphagnum/Calluna* (11) and *Calluna* (12) are prominent. Both these are typical vegetation of acid peat bogs, associated with the high rainfall and poor drainage on the moderate to gentle slopes of these land types. The possibility of gradual vegetation change in these heaths by simple management modifications, other than grazing, is slight.

4.3.2 Vegetation of upland land

The upland group carries a greater range of vegetation than the hill group. All the vegetation classes occur on upland, and only *Agrostis/Juncus* grassland (5) was not recorded on steep upland and upland plateau. Improved pastures are mainly the better *Lolium* classes (2, 4) and rough pastures tend to be dominated by *Festuca/Agrostis* grassland (8). The latter, as in the hill land, is associated with grassy heaths (14, 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.

Table 5. THE DISTRIBUTION OF VEGETATION CLASSES IN THE LAND TYPES

Results are for the 12 study areas combined and are given as % of sites in each land type. Prominent vegetation is shown in bold type. Vegetation classes are arranged to show the successional responses to environmental conditions and management (see text). Numbers used to identify vegetation classes refer to the original computer classification (see footnote).

Land type	Improved Pastures				Rough Pastures				Grassy Heaths			Shrubby Heaths				
	4	2	3	1	7	5	8	6	15	16	14	13	9	10	11	12
Steep Hill							10	3	9	**17**	**17**	4	4	10	**17**	9
Hill							3		6	9	8	4	1	8	**30**	**31**
High Plateau			1	1	1		3	1	5	6	10	2		9	**18**	**43**
Steep Upland	10	2	6	1	6		14	3	5	**20**	**17**	3	1	8	1	3
Upland	**32**	8	2	2	7	9	5	4	1	3	5	7	3	5	2	5
Upland Plateau	**24**	**20**	4	3	3		4	3	1	3	8	3	3	10	6	5
Upland Margin	**25**	9	9	7	8	6	12	2	1	6	6	2	1	2	2	2

Code numbers: 4 – Herb-rich *Lolium*, 2 – *Lolium*, 3 – *Lolium/Trifolium* and 1 – *Lolium/Holcus/Pteridium* grasslands

7 – *Agrostis/Holcus*, 5 – *Agrostis/Juncus*, 8 – *Festuca/Agrostis* and 6 – *Festuca/Juncus* grasslands

15 – *Festuca/Nardus/Vaccinium*, 16 – *Festuca/Nardus/Molinia* and 14 – *Festuca/Vaccinium* heaths

13 – *Calluna*, 9 – *Calluna/Molinia/Vaccinium*, 10 – *Vaccinium/Calluna*, 11 – *Nardus/Sphagnum/Calluna* and 12 – *Eriphorum/Calluna* heaths

5 Past changes in land use and vegetation

So far, attention has been concentrated on the current vegetation in relation to variations in the physical environment and intensity of use. However to understand the current pattern of vegetation, and the extent to which it has changed and is changing, it is necessary to appreciate the past fluctuations in land use, particularly in agriculture. The broad pattern of open moorland on the higher hills, with pastures on the lower slopes, is the result of early clearance of woodland, followed by centuries of grazing and burning, which induced slow changes in the vegetation. Documentation before about 1800 is erratic and difficult to interpret, but there is reasonable evidence for the distribution and timing of more recent changes which occurred in the uplands through industrial developments, afforestation and fluctuations in agriculture. Land use history of individual study areas is outlined in Ball *et al.* (1981b) and considered in a general synthesis in Ball *et al.* (1981a).

5.1 CHANGES IN THE 19th CENTURY

In the mid-19th century, 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 transport produce to distant towns but it was also easier to import foodstuffs, so that the primacy of farmers in their local markets was removed. Previously, farmers could depend on the prices received for their products rising and falling according to the quality of the local harvest. This self-balancing mechanism ended when it became easy to import products the prices of which were unaffected 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 farmers' response was to economize by reducing arable acreage and 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 for agricultural essentials. When much of this marginal arable land was abandoned in the late 19th century, it reverted to rough pasture or moor, rather than being maintained as improved pastures.

5.2 CHANGES IN THE 20th CENTURY

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 on the upland countryside was accentuated by the collapse of many rural industries and occupations. 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 a study of 120 000 ha (290 000 acres) of central Wales, including the parish of Ysbyty Ystwyth (Welsh Agricultural Land Sub-Commission 1955). The Commission emphasized that with the disappearance of subsidiary incomes there was a tendency for smaller farms to become deserted or amalgamated, and their homesteads to be left ruinous.

5.3 AGRICULTURAL CHANGES IN THE STUDY AREAS

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. As might be expected, the average area under tillage declined until the First World War, then rose and remained at a level comparable to that of the early 1900s (Figure 1a). The average animal population has fluctuated less, and numbers in the mid-1960s were comparable with those of the first decade of the century (Figures 1b, c). The overall impression is, therefore, one of broad stability in stocking rates over this period, except for particular situations such as the continuous increase in cattle numbers over the period from 1930 to 1965 in Monyash and from 1955 to 1965 in Widecombe.

There were considerable variations within the general trends, both within and between the study areas. Perhaps the most striking change to affect an area was the dramatic decline in agriculture in Shap in the period 1935–1940, at the time when Haweswater was enlarged and became a reservoir. The increase in tillage in Glascwm since 1940, and in sheep numbers since 1955, are also marked.

The Annual Returns indicate a trend since the 1950s of rising numbers of livestock in a few parishes. This trend is corroborated by the Upland Landscapes Study (ULS 1981), which also showed from a survey of farmers' attitudes that many planned to increase livestock numbers. Others, especially in Alwinton, Llanfachreth, Ysbyty Ystwyth, Lynton and Widecombe, also planned to improve their rough grazing through moorland reclamation, enclosure and bracken clearance. Such proposals may be treated with caution but the ULS results showed that those farmers who planned improvements were the ones with a past record of improvement. A trend towards farm amalgamation was also identified in the study areas in line with the general pattern of farming, and it is possible that areas which still contain a relatively high proportion of small holdings may be subject to the greatest change in farm size. There is a trend for decreasing livestock densities as farm size increases in hill farms. Although this relationship is affected in part by land quality, it indicates that areas with high proportions of small holdings may expect to reduce stock densities through amalgamation in contrast with the general trend of increasing numbers.

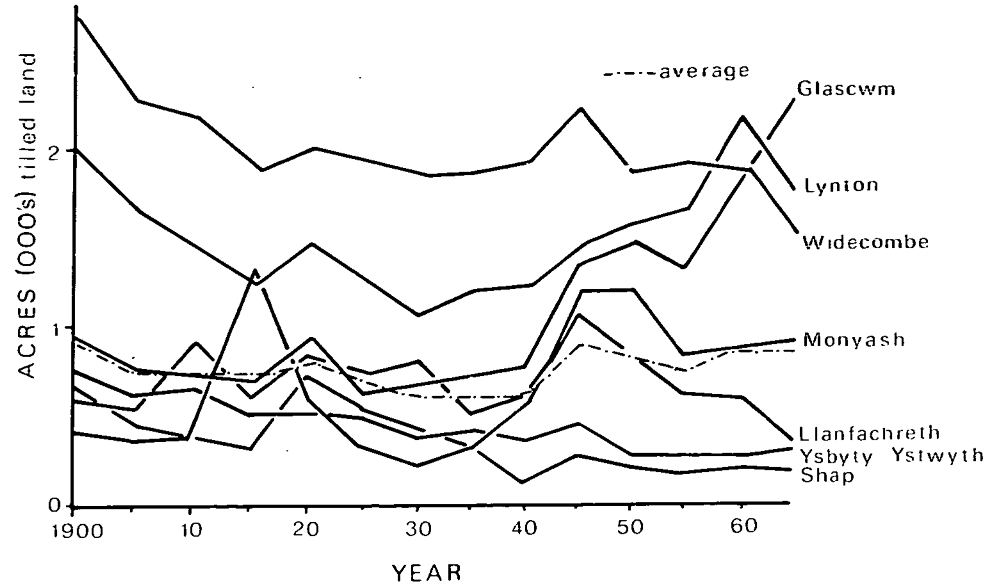


Figure 1a **Trends in the area of tillage for 7 study areas 1900-1965.**

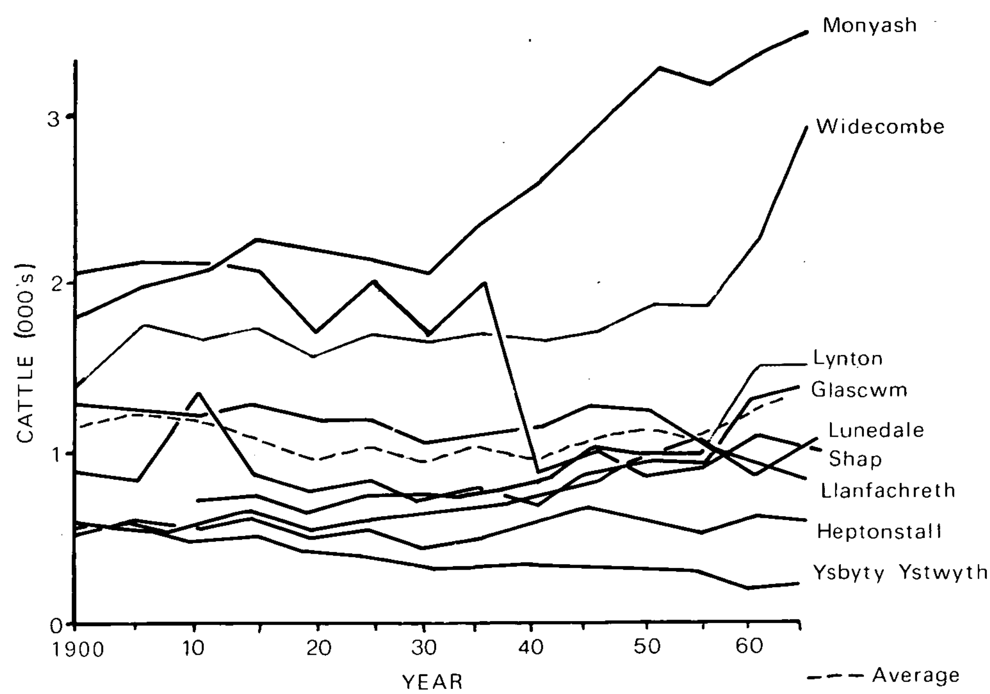


Figure 1b **Trends in the numbers of cattle for 9 study areas 1900-1965.**

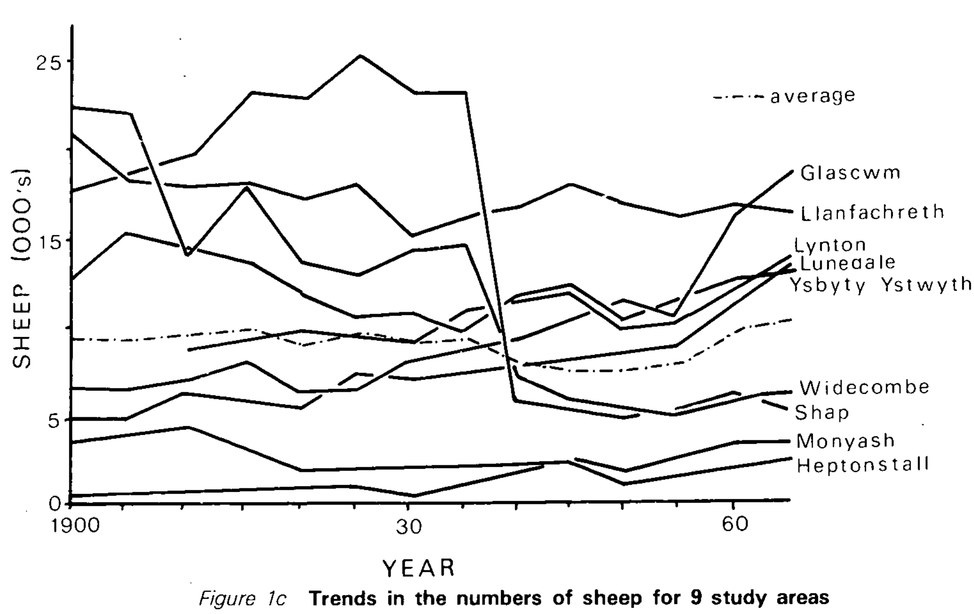


Figure 1c **Trends in the numbers of sheep for 9 study areas 1900-1965.**

5.4 PAST CHANGES IN VEGETATION

An overall impression of the agricultural use of the uplands is one of long term average stability, onto which are superimposed fluctuations over one or two decades, with marked local variations often resulting from factors external to the agricultural industry. There is no direct evidence from the historical record of the actual vegetation change which resulted from fluctuating agriculture. However the variations in numbers of cattle and sheep in the parishes were probably reflected in changing pressures on the rough grazing and moorland, and the ways in which vegetation would respond are discussed in detail below (see 6.1).

In general terms, marked increases in stock numbers would have resulted in a decrease in the shrubby heaths and a change in the distribution of grassy heaths and rough pastures. Such a change is likely to have occurred, for example, in Glascwm and Widecombe at various times, although an increase in numbers of sheep probably had a more widespread effect on the moorland vegetation than an increase in cattle, since the latter tend to be kept nearer the farm. The marked decrease in numbers of stock which occurred in Shap and in Widecombe from 1935–1945 would have resulted in a change in the distribution of rough pastures and grassy heaths, and a gradual increase in dwarf shrubs, with some scrub and tree growth at lower altitudes.

The absence of any marked overall change in stock numbers implies that a decrease in a vegetation type in one area would probably be offset by an increase in that vegetation in another area or at another time. Thus the pattern of vegetation on the hills has changed considerably in some areas with time, but it is unlikely that there has been a general major loss or gain of a particular type of vegetation.

5.5 ZONES OF CHANGE IN THE MOORLAND

Further evidence from Ordnance Survey maps and recent air photographs allows us to distinguish more precisely where both gradual and rapid changes in vegetation have occurred. Three zones of decreasing intensity of agricultural use can be identified: (i) farmland which has been continually under intensive cultivation, (ii) moorland fringe which in the past 200 years or so has interchanged between moorland and farmland or forest, (iii) moorland core which has always been under extensive management.

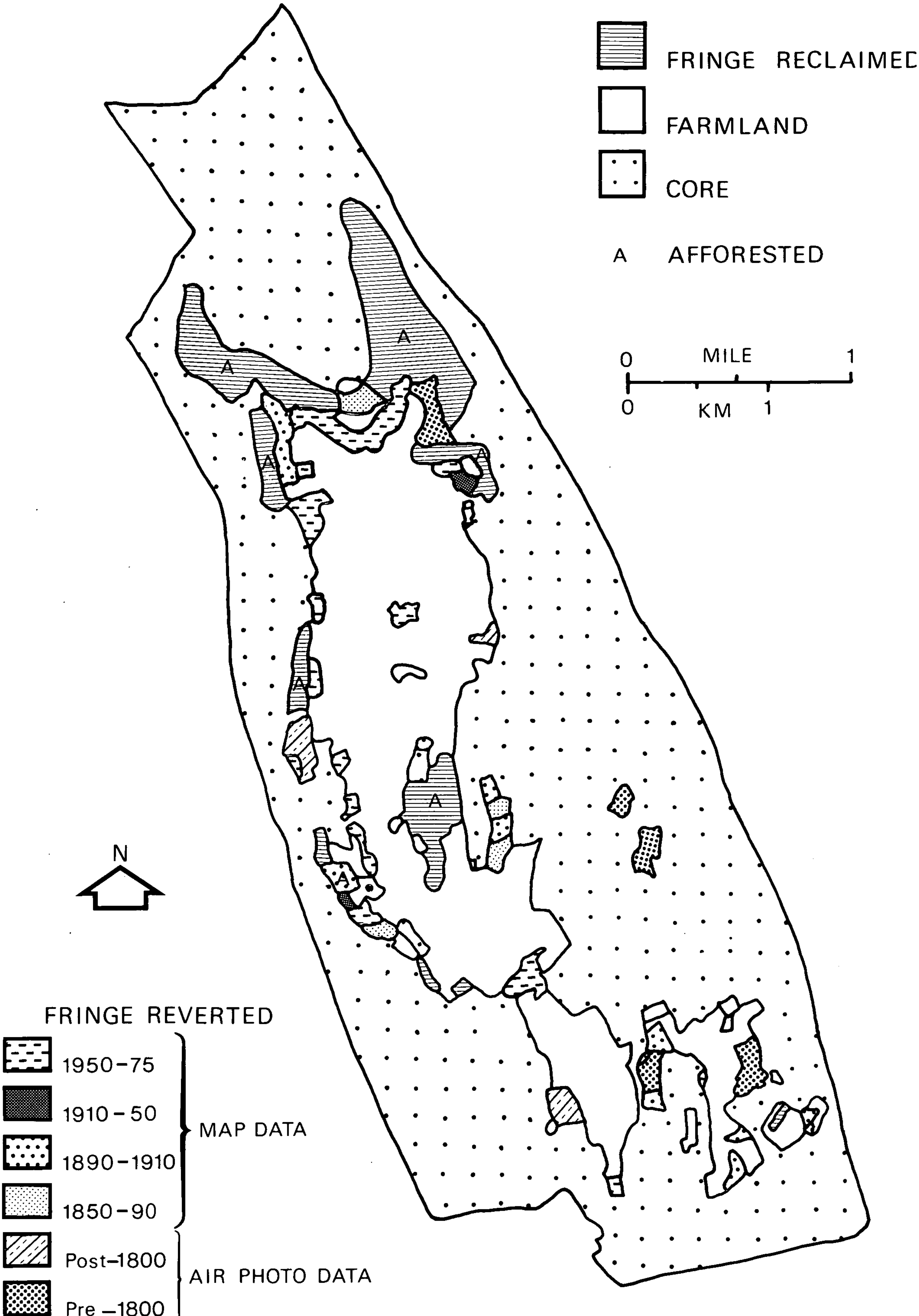
The moorland core vegetation of rough pastures, grassy and shrubby heaths, although not managed intensively, has been subjected to changes in use, particularly grazing pressure and burning. These general changes in use have been discussed above, but no information is available on the variations in management on specific parts of the moorland core, nor on the resulting vegetation change. However the moorland fringe is of interest because it is the zone in which fluctuations in management have the greatest effect. For example, in Bransdale (Map 2) a major area of moorland core surrounds the 'permanent' farmland in the valley bottom. The moorland core and farmland are separated by the fringe, which consists of some large blocks of moorland which have been reclaimed for forestry, plus many smaller pieces of farmland which have reverted to moorland at various times in the past.

5.6 RECLAMATION AND REVERSION OF MOORLAND

In all the study areas the fluctuations in land use on the moorland fringe have occurred either on small blocks adjacent to the farmland where reclamation for, or reversion from, agriculture has taken place, or as larger blocks of moorland afforestation which may be sited well into the moorland. The patterns of reclamation and reversion are very distinct (Table 6). Monyash has an insignificant area of moorland, and three other northern areas (Heptonstall, Shap and Lunedale) have maintained a relatively stable moorland, less than 8% of which has been affected by reclamation or reversion. Reclamation for forestry is dominant in five areas in Wales and northern England, especially Llanfachreth, in contrast to agricultural reclamation which is dominant in Glascwm and in south west England (Lynton and Widecombe).

Reversion of pastures which were intensively managed is fairly evenly distributed throughout the uplands and affects between 2 and 13% of the moorland, again omitting Monyash (Table 6). The fluctuation of reclamation and reversion has resulted in a major net loss of moorland in Llanfachreth, Lynton and Glascwm, but net gains of moorland of about 6% in Heptonstall and Shap.

Over the combined areas about 16% of the moorland has been directly affected by land use changes since about 1800. The main influence has been a 9% loss to forest. Agricultural reclamation has affected 2.6% of the total moor, but this loss is offset by reversion from intensive agriculture to moorland on about 5% of the moor. The result of these fluctuations has been a net loss of about 6.5% (3350 ha) of the original moorland (51 400 ha) over a period of about 200 years. The timing of the changes is also significant. As observed by ULS (1981), the rate of loss of moorland has increased markedly in the last decade, mainly through afforestation, whereas reclamation and reversion through agriculture are long-standing features of the landscape. Reclamation of moorland for agriculture has fluctuated throughout the 200 years, although the ULS results indicate a recent rise in the area of crops and grass, particularly in Lynton, Widecombe and Glascwm, and to a lesser extent in Alwinton and Lunedale.



Map 2 — **Moorland core, moorland fringe and farmland in Bransdale**

Table 6. THE EXTENT OF MOORLAND IN THE STUDY AREAS

The moorland core and fringe are determined from Ordnance Survey maps and air photographs. The core is the area for which there is no evidence of intensive management. The fringe, the area of changing land use since 1800, is composed of both reclaimed moorland and reverted farmland. The original moor, c. 1800, is estimated as the core plus the area subsequently reclaimed. The current moor consists of the core plus agricultural land which has reverted to moor since 1800.

Areas are given in hectares

Study area	Total area	Original moor	Current moor	Moorland core	Moorland fringe	Reclaimed moorland For Forestry	Reclaimed moorland For Agriculture	Reverted to moor
Alwinton	15 525	14 222	12 787	12 365	2 279	1 752	105	422
Lunedale	9 275	7 765	7 845	7 660	290	–	105	185
Shap	11 325	7 695	8 131	7 591	644	78	26	540
Bransdale	3 200	2 087	2 080	1 896	375	186	5	184
Heptonstall	2 300	1 319	1 391	1 300	110	–	19	91
Monyash	3 600	226	169	107	181	–	119	62
Llanfachreth	7 200	5 016	3 428	3 226	1 992	1 759	31	202
Ysbyty Ystwyth	5 350	4 160	4 058	3 825	568	320	15	233
Glascwm	3 675	1 682	1 362	1 300	444	76	306	62
Ystradgynlais	4 775	3 617	3 444	3 221	619	375	21	223
Lynton	3 150	1 182	929	885	341	–	297	44
Widecombe	5 050	2 453	2 451	2 140	624	6	307	311
12 areas combined	74 425	51 424	48 075	45 516	8 467	4 552	1 356	2 559
% of original moor		100	93.5	88.5		8.9	2.6	5.0

Reversion of farmland to moorland appears to be more consistent than reclamation over the last 200 years, 40% of reversions occurring before 1885 and 60% since then. Recent reversion however has been slight, concentrated in Bransdale and Llanfachreth.

The only apparent discrepancy between the present results and those from ULS (1981) is in the total estimated loss of moorland, equivalent to semi-natural vegetation in ULS. The estimated area of moorland c. 1800 was 51 400 ha, which has been reduced to the present level of 48 100 ha, a loss of 6.5%. The comparable figures from ULS (1981) are 52 900 ha of semi-natural vegetation in c. 1870, which is now reduced to 46 400 ha, a loss of 12.3%. Bearing in mind the shorter term fluctuations in use, different sources of information, inaccuracies in the original mapping and errors in measurement, the two results provide independent estimates of the loss rate, averaging out at between 17 and 65 ha yr^{-1} or 0.03 to 0.12% yr^{-1}. Both studies show the same wide variation between areas, ranging from losses of 32% to gains of 6% in the present study, compared to losses of 36% and gains of 5% in the ULS (1981) study, the results from study areas being closely correlated.

As already mentioned, the moorland fringe, with fluctuating land use, tends to form a distinct zone in the uplands. It is concentrated in a particular quality of land, 60% occurring on the steep upland and upland margin land types.

Thus, on the assumption that the general pattern of land use over the past 200 years will be maintained, future changes are likely to be concentrated in these land types, and the visual effect will be greatest in areas which have a high proportion of such land, ie Llanfachreth with 69%, and Glascwm and Lynton with 52%. Alternatively, changes may be most conspicuous where there are large areas of these land types, ie Llanfachreth with 5000 ha and Alwinton with 3900 ha.

5.7 VEGETATION CHANGE DURING REVERSION OF PASTURE

Examining the succession of vegetation following reversion of pasture has shown the expected sequence of gradual change through rough pastures and grassy heaths to shrubby heaths from an assumed starting point of some form of improved pasture. What was unexpected was the very long period of time necessary for reversion to reach the shrubby heath stage on some sites. Although some sites had reverted to shrubby heaths within 40 years, others only developed heaths similar to the adjacent moorland after more than 130 years, and the proportion of shrubby heaths on old reverted sites is still lower than on sites in the moorland core.

The sequence of change, interpreted from sampling sites which had reverted in known periods, is shown in Figure 2. Some variation probably results from sampling, mapping errors and recent management changes, but the general sequence can be summarized 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, a further 40% have moved through rough pastures and developed into grassy heaths, while the remainder have already developed shrubby heaths either directly or through a series of intermediate stages. The situation remains fairly stable over another 35 or so years (1906–1940).

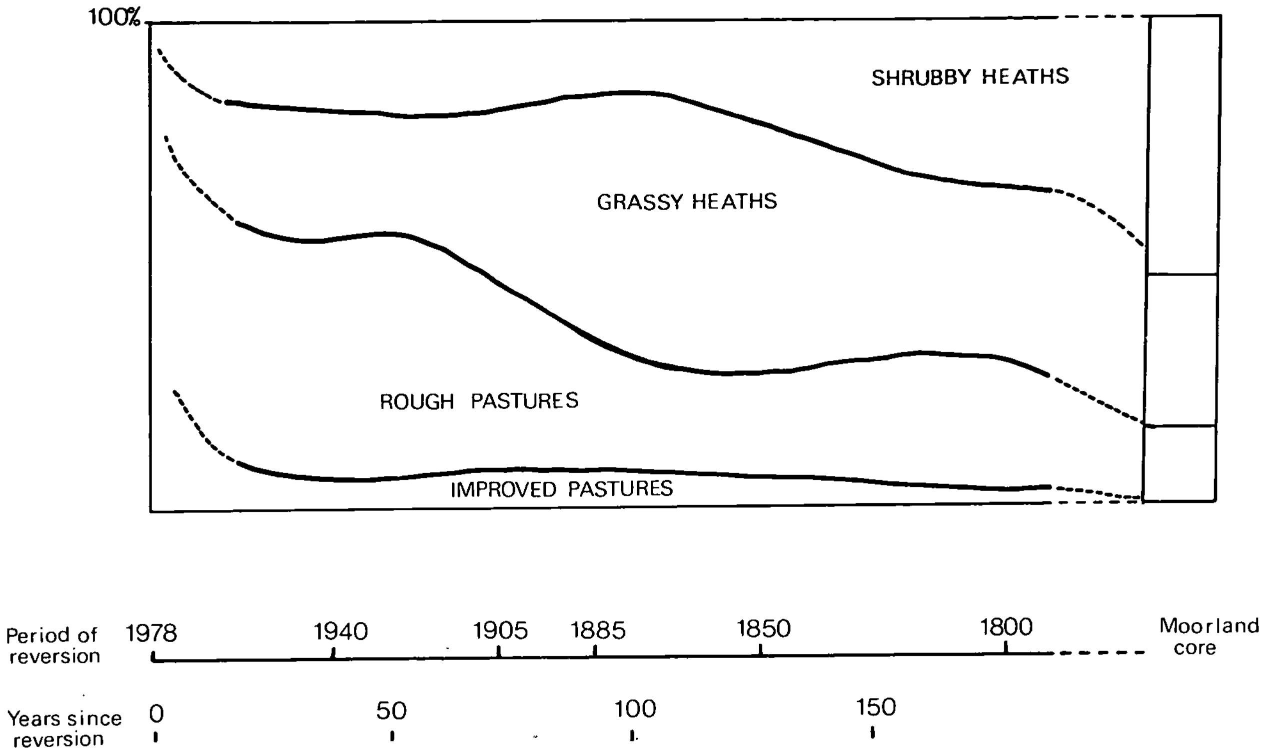


Figure 2 **The change in frequency of rough pastures, grassy heaths and shrubby heaths on land which reverted from intensive agriculture during different time periods. The composition of the current moorland core is shown on the right.**

ii. In the period 75 to 130 years after reversion (1851–1905) 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.
iii. On sites that reverted between 130 and 180+ years ago (before 1850), dwarf shrub development on the grassy heaths increases and the proportion of shrubby heath vegetation classes reaches 35%.

Mechanisms which can account for the slow sequence of events can also be postulated. The fairly rapid initial change to rough pastures and grassy heaths results from factors such as drainage deterioration and leaching of fertilizers, with a growth of native species invading or already present in small quantities in the original sward. On the most naturally acid and readily leached soils shrubby 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 on them through cropping the vegetation and the return of nutrients to the soil surface in their dung and urine. Some sites gradually revert to grassy heaths 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.

Even after 180 years or so the sites on which improved pastures were abandoned have not reached the vegetation pattern shown by the moorland core. In some cases, however, the reverted areas may never reach the same composition as the moorland core because of slight inherent environmental differences in local conditions which caused farmers to select areas for improvement.

The key point arising from the examination of reverted pastures is the long period required before many sites redevelop the vegetation, and hence visual characteristics, of the adjacent moorland. In contrast, moorland improvement is a relatively rapid process. Apart from the obvious interpretation that what man can change quickly takes a long time to restore by natural processes, there is a second implication. The current vegetation may still be responding to changes in management that occurred decades or even centuries ago. Alterations in management since the Second World War will still be influencing the vegetation in some areas well into the 21st century. A recent analysis of changes in rough pastures and grassy heaths 24 years after exclusion of sheep grazing in the north Pennines near Lunedale emphasizes the long term nature of many of the stages and that change may occur in steps rather than continuously, giving periods of apparent but not real stability (Rawes 1981).

6 Potential changes in vegetation

The description of vegetation types and their distribution has repeatedly indicated their potential for change in response to management. There are various strands of evidence on the response of particular plant communities which are combined to provide a general scheme showing the inter-relationships of the upland communities. This scheme is then used to predict the likely response of plant communities to alterations in management.

Some knowledge of vegetation change comes from general experience in the ecology of plant communities and species. Other evidence comes from historical information already described and from specific management experiments. The latter provide the most direct evidence but the number of controlled experiments on upland vegetation is very small. Experiments relevant to the present topic, but outside the study areas, were visited during the research and their vegetation was related to the classification used here. The management experiments were at the Hill Farming Research Organisation's Experimental Farm at Lephinmore in Argyll, the Ministry of Agriculture, Fisheries and Food Experimental Farm at Redesdale in Northumberland and the Nature Conservancy Council National Nature Reserves in Snowdonia (Gwynedd) and Moor House (Cumbria). These experiments, some of them extending for more than 20 years, have examined the response of different types of upland vegetation to variations in management, mainly in sheep grazing intensity, but with some study of effects of burning and fertilization.

6.1 VEGETATION CHANGES FOLLOWING REDUCED MANAGEMENT

The general trends in vegetation that would result from a decrease in the intensity of management can be summarized as follows, specifically related to the vegetation and management of the study areas:

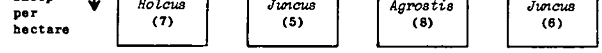
6.1.1 Improved pastures

These grasslands have been produced by cultivation, reseeding and fertilizing. Stocking densities are high, usually of about 7-10 sheep per hectare. Some variation in the vegetation of the intitial pasture will depend on local conditions, but in most instances the recently sown swards will be herb-rich *Lolium* (class 4), especially under the more favourable soil and climatic conditions. The sward composition changes with time if there is no repetition of the cultivation, approximately in the sequence shown, as weed species begin to colonize. On wetter sites, if drainage is impeded rushes and thistles will tend to increase, moving towards *Lolium/Trifolium* grassland (3), while bracken may encroach on drier soils. The succession through the improved pastures may take up to 20 years if there is no further cultivation. Normally the cycle is repeated with redevelopment of the initial swards and control of weeds through repeated cultivation, seeding and lime, fertilizer and herbicide application. Repeated management maintains a pH above about 5.2.

6.1.2 Improved pastures to rough pastures

Without repeated cultivation, the improved pastures, after moving through a succession within the group, will revert to rough pastures, although local soil characteristics and moderate grazing may delay the change. (Plate 15) Generally a move from *Lolium/Holcus/Pteridium* grassland (1) to rough pasture communities can take about 10 years, and the type of rough pasture which develops will depend on the local environment. The succession sequence between individual improved and rough pastures is not clear, but the association shown in Table 5 suggests that on more fertile, drier sites herb-rich *Lolium* grassland (4) may revert directly, or via *Lolium* grassland (2), to *Agrostis/Holcus* rough pastures (7) or possibly to *Festuca/Agrostis* grassland (8). The latter may also be the main link from the *Lolium/Holcus/Pteridium* grassland (1) at the end of the improved pasture succession. The rate of reversion from improved to rough pasture is typically one of the more rapid vegetation changes and is associated with a slight increase in soil acidity.

The vegetation succession within improved pastures and their reversion to rough pastures can be represented as follows. The main directions of change from one vegetation to another are shown by arrows. Main factors controlling change, and the general time scale, are given on the arrows.



6.1.3 Rough pastures

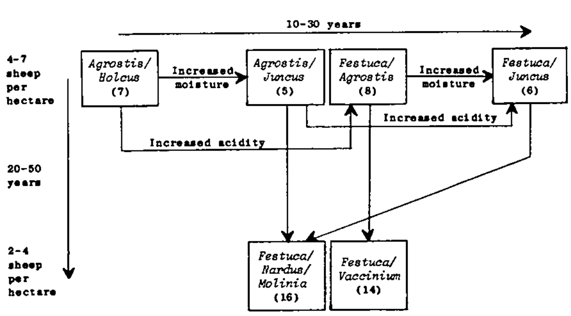
Grazing at about 4-7 sheep per hectare maintains the rough pastures. The grazing intensity depends on sward composition, which partly reflects soil fertility. The *Agrostis/Holcus* grasslands (7) tend to be on more fertile sites with the *Festuca/Juncus* grasslands (6) on poorer sites. Successional changes between types of rough pastures are complex but are associated with gradual increases in soil moisture and acidity. Thus *Agrostis/Holcus* (7) and *Festuca/Agrostis* (8) pastures occur mainly on relatively dry soils, associated with low rainfall and/or good drainage. *Festuca/Agrostis* is the main rough pasture at higher altitudes and tends to develop from *Agrostis/Holcus* pastures, with time, if soils become more acid through leaching. If soil moisture increases where drainage deteriorates, rough pasture classes 7 and 8 will tend to develop to

Agrostis/Juncus (5) and *Festuca/Juncus* (6) grasslands respectively. *Festuca/Juncus* pastures may also develop from *Agrostis/Juncus* grasslands if soils become more acid and organic matter accumulates. These successional changes would usually take decades to occur. Scattered trees and bushes are present on some of these pastures so that scrub woodland would often develop if grazing pressures were sufficiently low.

6.1.4 **Rough pastures to grassy heaths**

The reversion from improved to rough pastures, and the succession within rough pastures, is associated with a decrease in soil pH, as lime is progressively leached and not replaced. Grassy heaths have generally lower pH (mainly less than 4.7) and, with their peaty soils, are often wetter than the rough pastures. At the wetter sites *Agrostis/Juncus* (5) and *Festuca/Juncus* (6) grasslands tend to change to *Festuca/Nardus/Molinia* heath (16), the change being inititated by reduction in grazing pressure. Where grazing pressure is reduced on the drier rough pastures the succession probably moves through *Festuca/Agrostis* grassland (8) to *Festuca/Vaccinium* heath (14). With the complete exclusion of grazing on rough pastures, succession to grassy heath vegetation can take less than 10 years. However, grazing intensity tends to be reduced rather than removed, and the succession to grassy heath normally takes much longer.

The trend of change within rough pastures and their reversion to grassy heaths can thus be represented as:



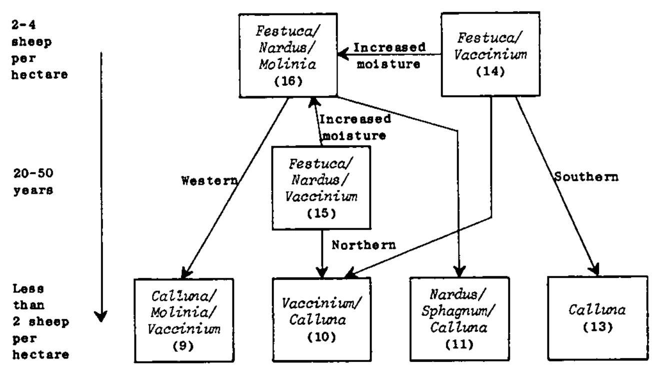
6.1.5 **Grassy heaths**

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 three classes of grassy heaths are not distinct. Soil drainage tends to be poorer on the *Festuca/Nardus/Molinia* heaths (16) so that this class develops from the other grassy heaths (14, 15) only as the surface soil becomes substantially wetter. Given exposure of the soil surface, tree seed may germinate from local sources at moderate altitudes and in the absence of grazing.

6.1.6 **Grassy heaths to shrubby heaths**

The interchange between grassy and shrubby heaths is determined mainly by the effects of grazing and burning on the survival of dwarf shrub species such as heather. (Plate 14) The change in vegetation is again associated with a shift to lower pH, partly cause and partly effect. Reduced grazing pressure allows the expansion of dwarf shrubs which are present on grassy heaths, but the change from grassy to shrubby heaths may take many decades as dwarf shrubs come to dominate the grassy heaths vegetatively or by seed. *Festuca/Vaccinium* heath (14) appears to develop towards dry *Calluna* heath (13) in southern areas, but through *Festuca/Nardus/Vaccinium* (15) to *Vaccinium/Calluna* heath (10) in more northern areas, probably because of regional differences in climate and soil conditions.

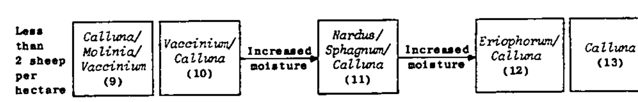
The vegetation changes through natural succession and management within grassy heaths and from grassy to shrubby heaths are shown as:



6.1.7 **Shrubby heaths**

Burning is the principal means of maintaining vigorous shrubby heaths, allied to a grazing pressure of less than about 2 sheep per hectare. Shrubby heaths tend to be stable for long periods under consistent low levels of management. Classes 10, 11 and 12 tend to develop in response to different regional climatic conditions and local landform and there is some trend through these classes, associated with increasing development of peaty soils and increased surface wetness. As with grassy heaths, scrub woodland may be established below about 400 m, or on drier sites, where grazing and burning is restricted. Local tree seed sources, particularly of birch, rowan, hawthorn or conifers, encourage woodland development. Above about 400 m, tree growth weakens and dwarf shrubs may remain as the climax vegetation, with *Calluna* declining above about 700 m.

Within the shrubby heaths the limited successional stages can be shown as:



The successions of vegetation represented above can be combined to provide a general description of the environmental and management control of vegetation in the study areas (Figure 3). The figure represents a working hypothesis of how a particular vegetation type would change given a *reduction* in managment, particularly in grazing pressure. The rates of change have quite a wide range but in most cases the most rapid change would occur if there was a marked reduction, or cessation, of grazing at a site at low altitude where growth rates are relatively rapid.

6.2 VEGETATION CHANGES FOLLOWING INCREASED MANAGEMENT

With an *increase* in grazing pressures and other forms of management, eg drainage, liming and fertilizing, the sequences of vegetation change will be reversed and in Figure 3 will run in opposite directions to those of the arrows. The rates of change will be greater than those under reduced management, usually taking only a few years. (Plate 13)

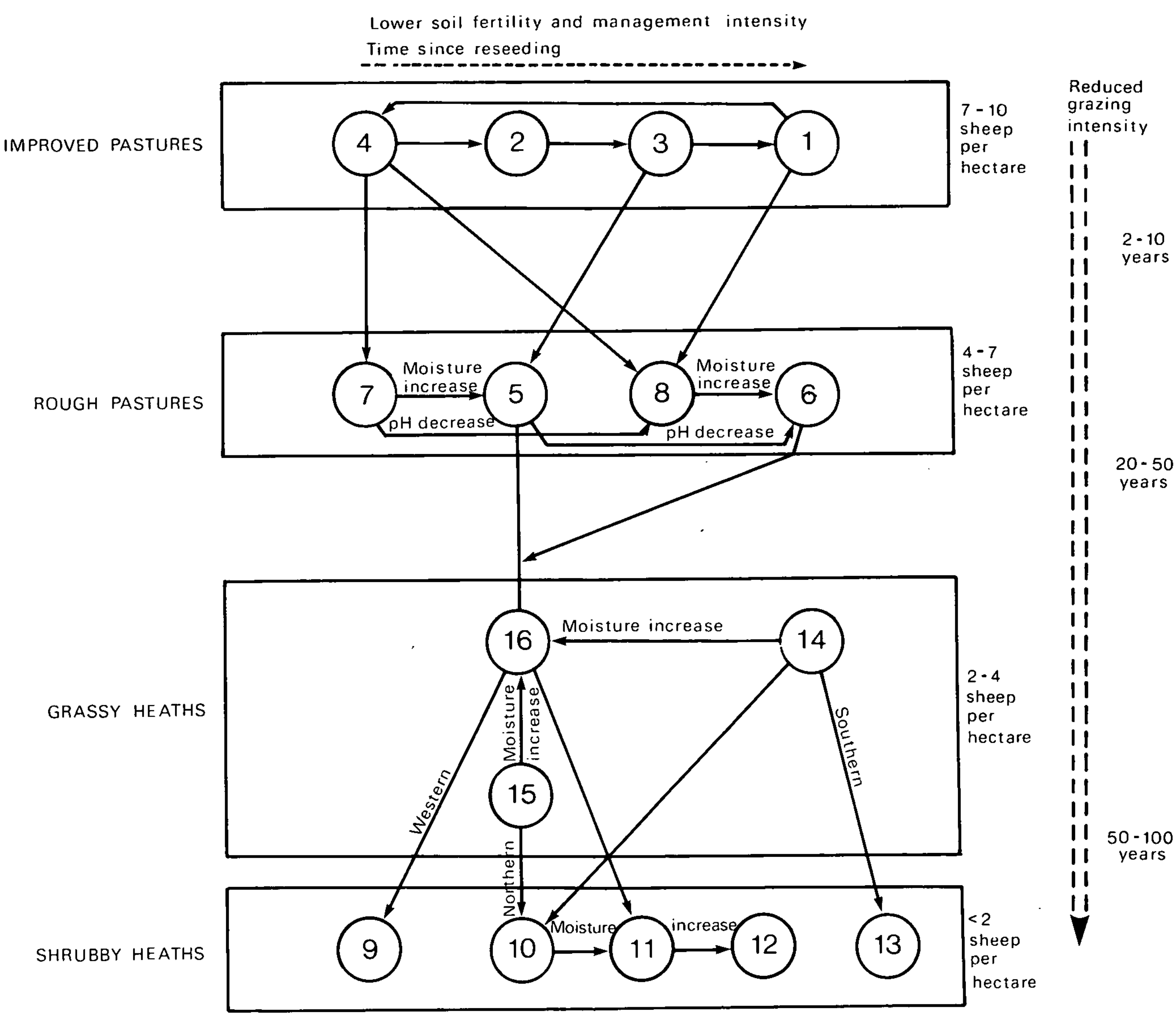


Figure 3 **The rate and direction of upland vegetation change through natural succession and management — a working hypothesis.**

Code numbers: 4 – Herb-rich *Lolium*, 2 – *Lolium*, 3 – *Lolium/Trifolium* and 1 – *Lolium/Holcus/Pteridium* grasslands

7 – *Agrostis/Holcus*, 5 – *Agrostis/Juncus*, 8 – *Festuca/Agrostis* and 6 – *Festuca/Juncus* grasslands

15 – *Festuca/Nardus/Vaccinium*, 16 – *Festuca/Nardus/Molinia* and 14 – *Festuca/Vaccinium* heaths

9 – *Calluna/Molinia/Vaccinium*, 10 – *Vaccinium/Calluna*, 11 – *Nardus/Sphagnum/Calluna*
12 – *Eriophorum/Calluna* and 13 – *Calluna*, heaths

Plate 13 – Bransdale, North Yorkshire – Inadvertant management effects on heath. Shrubby heath class 10 (*Vaccinium/Calluna* heath) contrasts with the grazed trampled verge which has *Festuca/Agrostis* grassland of rough pasture class 8.
Photograph by J. Dale.

Plate 14 — Glascwm, Powys — Management effects on heath. To the right of the fence class 10 shrubby heath (*Vaccinium/Calluna* heath) is maintained by rotational burning and light grazing. To the left heavier grazing and trampling impacts have produced a grassy heath.
Photograph by P. Ainsworth.

Plate 15 — Lunedale, Durham — Management effects on pasture. In the foreground the field on the right is unimproved rough pasture with prominent rushes, that on the left is reseeded improved pasture.
Photograph by J. Dale.

Plate 16 — Ysbyty Ystwyth, Dyfed — Major land-use change effects. Forestry plantations can blanket all former vegetation contrasts. In the foreground, grassy heath remnants persist on unplanted, rocky land beyond the wire fence enclosing the improved pasture.
Photograph by P. Ainsworth.

7 Future changes in vegetation

The broad future pattern of vegetation will depend on the extent to which farming and forestry are encouraged to expand, or contract, in response to national policies and other socio-economic forces. The extent to which these industries will respond varies between areas, depending on environmental, social and economic conditions and on constraints of competing land uses such as grouse shooting and amenity interests. Therefore a number of scenarios are examined to indicate the distribution and type of vegetation change, particularly within the moorland, which would result from different trends in land use. Basically the vegetation patterns that would result from extreme, but feasible, developments in land use, particularly the extension or contraction of agriculture are predicted. They show the maximum range of vegetation change in the study areas and allow interpolation to estimate the effect of varying levels of land use development. The scenarios are based on the known distributions of vegetation in response to management changes, and differ slightly from earlier predictions (Ball *et al.* 1981a) by emphasizing gains and losses of moorland vegetation.

The main scenarios of land use change which are applied to estimate vegetation changes are:

i. Continuation of the recent pattern of change in agriculture (7.1).
ii. Major expansion of agriculture (7.2). The likely change is assessed by two independent methods:
   a. change in the vegetation at the 1000 sample points based on the principles given in the previous section (Figure 3);
   b. the agricultural potential of land types and the vegetation expected under maximum expansion of agriculture.
iii. Major decline in agriculture (7.3).
iv. Expansion of forestry (7.4).
v. The combined effects of continuation of trends in agriculture and forestry (7.5).

In examining the effects of these land use changes, estimates have been included of the direct gains or losses of moorland, because it has been necessary to determine where such changes are likely to occur and their extent in order to estimate the associated effect on the vegetation of the remaining moorland.

7.1 CONTINUATION OF RECENT CHANGES IN AGRICULTURE

7.1.1 Assumptions and methods

The intensity of agriculture in the uplands has fluctuated considerably over the last 200 years (Figure 1). Marked changes in one parish are often independent of changes in other parishes. Overall there has been a small but significant loss of moorland vegetation, only partly offset by reversion of land from agriculture to moorland. Given the recent upward trend in stock numbers (Figure 1b, c), it is probable that in the near future the loss of moorland through agricultural reclamation will continue. The ULS (1981) estimated the recent loss rate of moorland as 0·66% per year, but as at least three-quarters of this is to forestry (Table 6) the average loss rate as a result of agriculture is about 0·16% per year.

Agricultural reclamation has been greatest in Glascwm, Lynton and Widecombe, with an increased number of cattle and sheep. As there has been little afforestation in these areas the rate of reclamation is about 1% per year. In addition, Glascwm and Lynton, and to a lesser extent Widecombe, contain a high proportion of the land types in which land use change has been concentrated in the past.

The pattern of probable direct changes through continuation of existing trends is reasonably clear. However, where there is agricultural reclamation or reversion, the intensity of grazing on the remaining moorland is likely to change, approximately in proportion. To estimate the effect of the likely future changes in grazing, the general principles given earlier (Figure 3) have been applied to the study areas in relation to the expected agricultural change.

7.1.2 Expected changes in the study areas

The combined effects of direct and indirect changes in management are summarized as follows:

i. Glascwm and Lynton are the areas which are likely to lose moorland through reclamation most rapidly (c. 1% per year) and with their small area of moorland the loss will be visually obvious. Widecombe could also lose some moorland directly but much of the moorland is Common Land and will probably not be reclaimed. The increases in grazing pressure on the moorland, associated with increased stocking of farmland and reclaimed moor, would probably cause an almost complete conversion of the shrubby heaths to grassy heaths. Some of the grassy heaths would be converted to rough pasture vegetation, tending to compensate for the losses of the latter through reclamation. The net effect would be a drastic loss of shrubby heaths, the area of grassy heaths would approximately double, but the area of rough pastures would change little. As the areas of shrubby heaths in Glascwm and Lynton are quite small the visual effect would be considerable, and a significant impact may also occur in Widecombe. Monyash is almost entirely improved pasture so that although the remaining rough pastures may be improved the visual impact would be small.

ii. Lunedale may show a rate of reclamation of about 0·3% (about 20 ha) per year, but such activity will be restricted by the limited land quality and by the use of moorland for grouse. A small loss, possibly 10%, of shrubby and grassy heaths would probably result from increased grazing, but the rate of change would be slow and would result in a compensatory increase in rough pastures.

iii. Very low rates of moorland reclamation (less than 0·1% per year) are likely to occur in Shap, Llanfachreth, Ystradgynlais and Alwinton. This reflects a combination of poor quality land, limited increases in stock and less positive attitudes of the farmers, together with major constraints of ownership or competing land uses. Alterations in grazing pressure would be small and would result in very slow changes which would be difficult to detect over the extensive moorland area.

iv. Negligible rates of reclamation (less than 0·01% per year) are expected in Bransdale, Ysbyty Ystwyth and Heptonstall. Despite the relatively good quality of land in Bransdale, reclamation is mainly restricted by management of the moorland for grouse and by landscape conservation in a National Park. Improvement in the other two areas is unlikely for a variety of reasons, including Common Land registration and use of the areas for water catchment.

v. The area of pasture which has been allowed to revert to moorland has been very small in recent years; a total of 300 ha over 38 years, mainly in Llanfachreth and Bransdale where the addition to moorland is only at about 0·1% per year. There is some indication that recent reversion is associated with afforestation, but the pattern is not clear.

7.1.3 General effects of continuing trends

Given the continuing trends, a total of about 2000 ha moorland within the study areas would be directly improved for agriculture, representing about 4% of the current moor. The improvement is likely to be concentrated at the edges of the moorland, on land types where change has occurred previously, ie in upland margin and steep upland. Thus the vegetation most likely to be affected would be *Festuca/Agrostis* and *Agrostis/Holcus* grasslands, and possibly *Festuca/Vaccinium* and *Festuca/Nardus/Molinia* grassy heaths. Shrubby heaths are uncommon on these land types, but some *Vaccinium/Calluna* heath may be lost. The predicted types of vegetation correspond with the recent losses of semi-natural vegetation recorded by ULS (1981), who showed that losses were predominantly (60%) from 'smooth grassland' dominated by *Festuca* and *Agrostis,* with 20% from 'coarse grassland' of *Nardus* and *Molinia.*

The estimates of vegetation change within the remaining moorland are based on the assumption that the trends in agricultural reclamation of moorland result in corresponding changes in grazing intensity and that the response of the vegetation would be as indicated in Figure 3. The result of the accumulated changes predicted for the individual study areas would be a loss of about 3000 ha of shrubby heaths, that is about 15% of their current area, by the year 2000. Some of the loss of the shrubby heath vegetation would be in the large northern moorland areas where the effect on the landscape would be small, in contrast with the marked visual change that would probably occur in the moors of south-west England and parts of Wales. As the increased grazing would tend to convert shrubby heaths to new grassy heaths and existing grassy heaths to rough pastures, there is unlikely to be a marked change in the total areas of these classes of vegetation, the gains compensating for losses in reclamation. However, there is likely to be a gradual change in the pattern of distribution of both grassy heaths and rough pastures.

It must be emphasized that the estimated loss of shrubby heaths through increased grazing has to be accepted with caution, but it indicates that the gradual loss over a period of about 20 years is of the same order as the more obvious losses through agricultural improvement. The increased grazing of the shrubs would also retard their rate of recovery from other pressures such as uncontrolled burning and recreational pressures, which tend to be most marked where areas of moor are small and fragmented, as indicated in a separate study of the heather moor on Exmoor (Miller, Miles & Heal 1979).

A final qualification is that the scenario of projection of current rates of change assumes continuation over the next 20 years, with varying rates in different areas. Past experience indicates that long-term trends are less likely than short-term fluctuations. Therefore it is probable that the degree of change will be less than predicted, and the focus may shift.

7.2 MAJOR EXPANSION OF AGRICULTURE

7.2.1 Assumptions and methods

Whilst the most probable scenario is a continuation of recent trends, it is possible that a major expansion of agriculture could occur through external economic forces. The overall impact on vegetation classes of an increase of about 50% in livestock numbers uniformly in all areas has been assessed. Such a degree of change over a period of 10-20 years is not unrealistic, in the sense that it represents about the maximum rate of change which has occasionally occurred in some parishes in the past (Figure 1). To estimate the response of the vegetation to the altered grazing regime, the potential vegetation changes summarized in Figure 3 were applied to the 1000 sites at which detailed recording of vegetation was made. The probable change at each site was assessed and results combined to show the predicted degree of change in each study area.

A second, and independent assessment of vegetation change in response to a major expansion of agriculture was made from assumptions of the maximum potential for agriculture of each land type in the study areas. Maximum expansion of agriculture, with increased pasture productivity, higher stocking rates and associated management changes, has been assumed to utilize intensively the following percentage of each land type: upland margin 100%, upland and upland plateau 90%, steep upland 60%, hill 30%, high plateau and steep hill 20%. This would expand agricultural use through the moorland fringe and result in more intensive use of the moorland core. A development of this type could result in proportions of improved pastures, rough pastures, grassy heaths and shrubby heaths in the upland margin of 70, 30, 0 and 0% respectively, in the upland group 60, 20, 20 and 0%, and in the hill land group 10, 10, 50 and 30%. This degree of intensification is at about the maximum level currently achieved in some of the parishes.

7.2.2 **Vegetation change through agricultural expansion**

The vegetation change that would result from intensification is very similar overall in the two predictions, although there are some variations within particular study areas (Table 7). In general, improved pastures would increase by about 60%, with major changes in Alwinton, Lunedale, Llanfachreth and Ysbyty Ystwyth and negligible change in Monyash and Lynton. The extent of rough pastures and grassy heaths would show no major change overall. The shrubby heaths would show a major decline under intensification, being virtually eliminated in Widecombe, Lynton and Glascwm. Although the shrubby heaths would remain prominent, particularly in Alwinton, Lunedale and Ysbyty Ystwyth, their overall extent would be reduced by about 66% of their present level.

Table 7. THE CURRENT AND PREDICTED FREQUENCY OF VEGETATION IN THE STUDY AREAS FOLLOWING AGRICULTURAL INTENSIFICATION OR DECLINE

C = current frequency (%) at recorded sites; I_1 = intensification, assessed from recorded sites; I_2 = intensification, assessed from potential of land types; D = decline, assessed from recorded sites.

Study area		Improved Pastures	Rough Pastures	Grassy Heaths	Shrubby Heaths
Alwinton	C	6	27	36	31
	I_1	33	36	13	18
	I_2	27	14	38	21
	D	6	0	28	66
Lunedale	C	1	12	22	65
	I_1	13	22	9	56
	I_2	21	13	42	24
	D	1	0	11	87
Shap	C	19	14	34	33
	I_1	33	34	30	3
	I_2	34	15	35	16
	D	17	5	11	67
Bransdale	C	11	11	34	44
	I_1	22	34	41	3
	I_2	49	19	23	9
	D	6	6	11	77
Heptonstall	C	25	11	10	54
	I_1	36	10	27	27
	I_2	48	19	25	8
	D	20	6	10	64
Monyash	C	86	14	0	0
	I_1	100	0	0	0
	I_2	63	20	17	0
	D	86	10	4	0
Llanfachreth	C	8	31	31	30
	I_1	39	31	26	4
	I_2	50	21	20	9
	D	4	17	18	61
Ysbyty Ystwyth	C	7	12	29	52
	I_1	19	24	27	25
	I_2	34	16	33	17
	D	1	8	9	81
Glascwm	C	47	23	16	14
	I_1	70	16	14	0
	I_2	51	20	22	7
	D	27	30	15	28
Ystradgynlais	C	20	17	38	25
	I_1	37	38	24	1
	I_2	35	16	33	16
	D	13	7	16	64
Lynton	C	68	10	14	8
	I_1	78	14	8	0
	I_2	57	22	17	4
	D	51	23	4	23
Widecombe	C	37	21	5	37
	I_1	58	5	37	0
	I_2	56	21	19	4
	D	24	19	15	43
All areas	C	27	17	23	33
	I_1	44	23	22	11
	I_2	43	18	27	12
	D	20	10	13	57

The change in the balance of vegetation with agricultural intensification is thus most obvious at the ends of the vegetation succession, the improved pastures and shrubby heaths. This is because although many existing rough pastures and grassy heaths will be altered, new rough pastures will be produced from grassy heaths, and new grassy heaths from shrubby heaths. Thus, although the amount of rough pastures and grassy heaths may change only slightly, their distribution will change substantially.

The effect on intensification would vary considerably between areas. Monyash, Lynton and to a lesser extent Glascwm would show relatively little change because they are already at, or close to, their maximum agricultural potential. Alwinton, Lunedale, Shap, Heptonstall, Ysbyty Ystwyth and Ystradgynlais would show some improvement on the moorland edge but would retain much of their general character, including significant areas of shrubby heaths. Probably the most marked changes would take place in Bransdale, Llanfachreth and Widecombe, where improvement at the moorland edge would be associated with large reductions in shrubby heaths in their moorland core.

The degree to which the change could be achieved would depend on a variety of local factors such as agreements over Common Land, and competing interests such as grouse moors, water authorities, forestry and amenity interests combined with national economic and land use policies. In the very unlikely event of concerted intensification of agriculture in all areas, overriding the local constraints, the loss of current moorland vegetation, particularly the shrubby heaths, would be of the order of 17 000 ha. This represents about one third of the existing moorland and is about eight times the loss of moorland and five times the loss of shrubby heaths than the losses if agricultural improvement is maintained at its recent rate (see 7.1.3).

7.3 MAJOR DECLINE IN AGRICULTURE

The projected changes resulting from improvement and increased stocking could occur within a decade or so of a major incentive for agricultural development. The alternative of a major decline in agriculture, with a halving of stocking densities, would result in a much slower rate of vegetation change. The possible change in vegetation by the year 2000 has been estimated from the vegetation of the detailed sampling sites and the vegetation succession under reduced management (Figure 3). A general loss of improved pastures through reversion which would affect more than half of the pastures only in Llanfachreth and Ysbyty Ystwyth is indicated (Table 7). There would be virtually no loss of improved pastures in Alwinton, Lunedale, Shap and Monyash, although there would be some change in the type of vegetation on these pastures. In Alwinton and Lunedale major reductions in rough pastures would be likely as they revert to grassy heaths under reduced grazing intensity. The degree of change would be less in most of the areas and a reduction in grassy heaths is likely to occur consistently. Apart from the reversion of improved pastures on the edge of the moorland, the most marked change would be the consistent increase in shrubby heaths, often to about double their present frequency and, overall, to about 70% of the remaining moorland vegetation.

A decline in agriculture, approximating to a reduction of about 50% in numbers of stock, would, in a period of 10 to 20 years, add about 5300 ha (11%) to the moorland semi-natural vegetation by reversion of pastures. The areas of rough pastures and grassy heaths would tend gradually to decline and the shrubby heaths to increase over the next 20 years, but the shift in pattern would continue for decades as slow growing heath species colonize and become established. In the long term the area of heaths could almost double but scrub and woodland would be expected to replace them in many areas.

The suggested rate of reversion has occurred in particular areas in the past, eg Shap at the end of the 19th century, and in Llanfachreth since about 1940. Decline in agriculture of the scale projected is unlikely to occur generally, particularly in view of the expressed attitudes of farmers. However, changes of this type are less inhibited by ownership and conflicting interests than are improvements, and can be precipitated by local social and economic conditions or by pressures from other land uses. It is probable that reduced agricultural use would encourage forestry development.

7.4 EXPANSION OF FORESTRY

Although extending the brief of the contract, which gave emphasis to gradual changes in vegetation, ITE also considered the possible effects of forestry development on the loss of moorland and on the composition of the remaining vegetation. (Ball *et al.* 1981a) The results are included here to place the land use changes already discussed in a broader context (individual areas are treated in more detail in Ball *et al.* (1981b)).

7.4.1 Continuation of recent trends in forestry

While maintenance of recent trends in agriculture would result in some loss of moorland, additional changes would result from continuation of recent trends in afforestation. In the last 30 years about 4500 ha of coniferous forest have been created in the study areas, representing a loss of about 0·3% of the moorland annually. The highest rates and largest areas have been in Alwinton and Llanfachreth and to a lesser extent in Ystradgynlais and Bransdale. The continued expansion of forestry at the current rate would remove about 2900 ha or 6% of the present moorland by the turn of the century. Given the estimated areas of potentially plantable land (discussed below) and allowing that Common Land and major grouse moors will remain unplanted, then the majority of the forest expansion would be expected to occur in the northern areas, particularly Alwinton and Shap. These areas combined have about 21 000 ha of moorland, of which about half is potentially plantable. Further afforestation could occur in the Welsh study areas of Llanfachreth, Ysbyth Ystwyth (Plate 16) and Ystradgynlais. Some restriction on forestry may occur through the National Park status of some areas, but this will probably not be a major factor on the evidence that the distribution of recent afforestation is not correlated with National Park designation.

As a result of competition for land with agriculture, forestry is most likely to develop on the steep upland and upland plateau land, thus affecting mainly *Festuca/Nardus/Molinia* and *Festuca/Vaccinium* grassy heaths and the *Nardus/Sphagnum/Calluna* and *Eriophorum/Calluna* shrubby heaths. The effect of afforestation on adjacent moorland is not well documented, but it is probable that in some areas it will result in reduced grazing pressures and increases in shrubby heaths. Alternatively, forestry may cause concentration of grazing on remaining moorland, especially where there is a planned mixed land use, with a resulting reduction in shrubby heaths. Thus, there will probably be little change in the total area of different vegetation types, but their distribution may be affected.

7.4.2 **Major expansion of forestry**

The degree to which forestry would expand is determined by the forestry potential of the land, ownership, competing uses and other social and economic forces. Land and climate quality are permanent constraints, other factors can be overcome by man. However, in this projection the balance of vegetation has been estimated that would result from expansion of forestry onto all the realistically plantable land, but with the proviso that intensive agriculture would be retained on the most productive parts of the uplands. No consideration is given to economic factors, but the results indicate the maximum possible impact of forestry on the moorlands of the study areas.

The projection is made using the known distribution of land types and their associated vegetation. It is assumed that upland margin would remain entirely in agriculture; of the upland and upland plateau, 50% would remain primarily under agriculture; most (75%) of the steep upland would go to forestry. Of the hill land, only the part below 427 m (1400 ft) would be used for forest production, the remainder being retained for extensive grazing or abandoned by agriculture to other uses. With the reduced accessible agricultural base, grazing intensities on the higher hill land would probably be reduced, resulting in a succession from grassy to shrubby heaths, with some scrub woodland development immediately above the planted ground and near to existing seed sources.

The resulting pattern of vegetation and land use (Table 8) indicates, rather surprisingly, that although the forest cover could expand from the present 10% to 40% of the total areas, there is room for expansion of land under agriculture from the current 21% to about 30%. The calculations indicate a decrease in agricultural use in Monyash, Glascwm and Lynton, but this would be improbable because of the strength of existing agriculture. These areas would remain predominantly agricultural. Bransdale, Heptonstall, Llanfachreth and Widecombe would be equally concerned with agriculture and forestry. It appears that in Llanfachreth any further forest expansion might have to use land of a quality which is used for intensive agriculture in other areas. Alwinton, Shap and Ystradgynlais would have forestry as their most prominent use but about 30% of open hill land would remain. Only Lunedale and Ysbyty Ystwyth would remain predominantly open hill areas.

The estimated maximum area of land with forest potential is about 37% of the total study area, or 27 500 ha. As some of this land already carries

Table 8. ESTIMATES OF MAXIMUM POTENTIAL FORESTRY LAND

Figures are given as a percentage of the study areas, assuming use of the best land for agriculture and no forestry above 427 m. Present percentage areas for agriculture and forestry, with conifer plantations in parenthesis, are from ULS (1981). Study areas where current agricultural use is dominant and likely to survive preferentially even in a high forestry strategy are marked*.

Study area	Unplantable land	Forestry land		Agricultural land	
		Potential	Present	Potential	Present
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*	0	45	1	55	93
Llanfachreth	20	31	33 (30)	49	17
Ysbyty Ystwyth	50	25	8 (8)	25	13
Glascwm*	20	35	4 (2)	45	59
Ystradgynlais	30	42	11 (8)	28	16
Lynton*	0	45	9 (1)	55	58
Widecombe	6	39	8 (3)	55	42
12 areas combined	33	37	10 (8)	30	21

woodland or is designated as Common Land, a concerted expansion of forestry would probably affect about half of the potential area. The remaining moorland, probably about 30 000 ha, would be mainly on hill land and although retained as rough grazing it would carry little rough pasture, the dominant vegetation being shrubby heath with some grassy heath.

7.5 COMBINED EFFECTS OF CONTINUED TRENDS IN AGRICULTURE AND FORESTRY

The combined effects of continuation of recent rates of agricultural and forestry development, if maintained to the end of the century, will be a loss of about 4900 ha of the present 48 000 ha of moorland, ie about 10%. Losses will be mainly to agriculture in southern England, to forestry in northern England, and to both in Wales. The main vegetation to be affected would probably be *Festuca/Agrostis* grasslands, *Festuca/Nardus/Molinia* and *Festuca/Vaccinium* grassy heaths, possibly 1000 ha of each, with smaller amounts of *Agrostis/Holcus* grassland and *Vaccinium/Calluna* heath. Additional losses of shrubby heaths through increased grazing would probably occur, but would result in increases in grassy heaths and rough pastures which would tend to compensate for their loss to agriculture and forestry. The dominant effect, therefore, would probably be a decrease of up to 25% in the area of shrubby heaths.

7.6 SUMMARY OF FUTURE VEGETATION CHANGES

A summary of the effects on vegetation of probable (continuation of recent trends) and possible changes in land use is given in Figure 4.

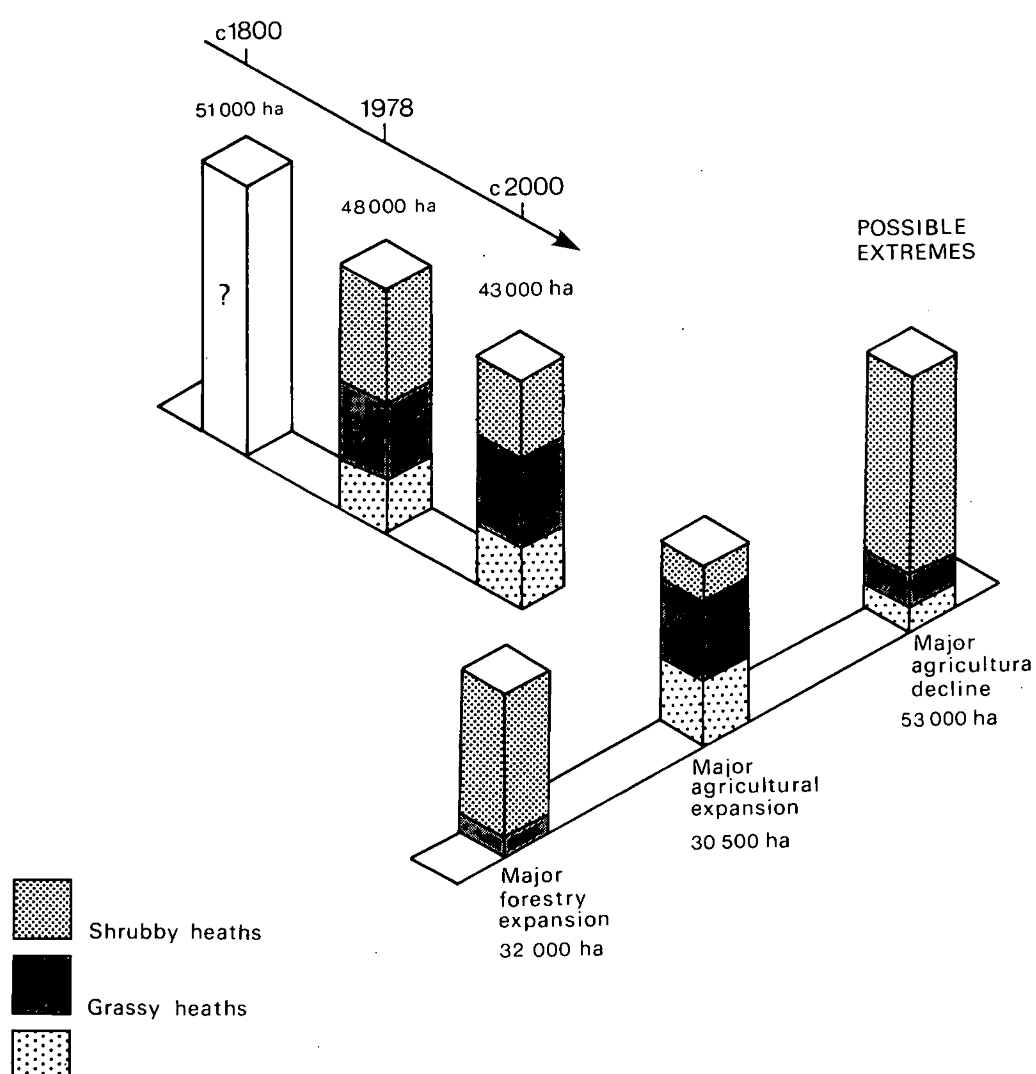


Figure 4 **The predicted area and vegetation composition of moorland in 12 upland areas given various trends in land use.**
The most likely trend is a continuation of the recent pattern of change in the study areas up to the year 2000. The effects of a major expansion of agriculture or forestry, and major decline of agriculture, are shown as possible extremes. The major change represents the degree of land use change which has occurred in some areas in the past, but which is envisaged as applying to all areas simultaneously.

8 Interpretation

The aim of the study has been to provide a quantitative assessment of the relative importance of environmental and human factors which influence vegetation and change within this, and to indicate the possible courses and causes of future change. The analysis has been objective and, whilst interpretation of the results and their implications must to a certain extent be subjective, there is no advocacy of particular land uses or value judgement of the consequences. The following points represent a preliminary assessment of the main implications of the study, the further application of the information and methods, and the requirement for additional information.

8.1 LOSS OF MOORLAND

Fluctuation in upland land use should be regarded as normal. Change has been a characteristic over the last 200 years but the timing of moorland reclamation and agricultural reversion has not been consistent between parishes. Local social and economic factors have determined the rate and timing of land use change, but environmental factors are responsible for limiting fluctuations to a distinct zone — the moorland fringe. Thus in all the areas studied, the zone of recent land use change has directly affected about 11% of the total area. The majority of the resulting direct loss of 6–12% of the moorland or semi-natural vegetation has been in two land types, upland margin and steep upland. The inference is that future fluctuations in land use are most likely to occur in these types of land which can be distinguished in the 12 areas, and in other areas of upland.

8.2 VEGETATION CHANGE WITHIN THE MOOR

The degree of change within the moorland that has resulted from varying grazing pressures and management regimes is uncertain because of the lack of detailed descriptions of the past state. The Upland Landscapes Study (1981), through re-survey of the vegetation maps of the Second Land Utilisation Survey, detected some changes in composition of semi-natural vegetation since 1967. The main changes are probably in the cover of heather and bracken associated with variation in grazing and burning. Both plants are important visual components of the landscape, and the sensitivity of dwarf shrubs to grazing and burning has been emphasized.

When agricultural improvement occurs, and there is an associated increase in grazing on the open moorland, the changes in vegetation will probably result in a loss of shrubby heaths even though the vegetation which is reclaimed may not be shrubby heath. Losses of rough pasture and grassy heaths through improvement will probably be compensated by increases in these types of vegetation through changes elsewhere within the moorland core induced by grazing.

The shrubby heaths in Lynton and Widecombe are probably most vulnerable, not only because of reclamation, but because they are not burned systematically. In addition, fragmentation and dissection of moorland increases the length of margin relative to the area. This increased edge effect with associated grazing, recreation and burning pressures is likely to reduce heather cover significantly. (Plate 13) The increase in the length of margin is recognisable in Lynton, Widecombe, Glascwm, Llanfachreth and in part of Ysbyty Ystwyth. The conclusion is that the degree of change in moorland in sensitive areas needs to be monitored and the state of the shrub vegetation assessed in relation to known burning and grazing regimes. Active, controlled management will have to be introduced, designed to conserve shrubby heaths where they are most vulnerable and are of amenity value. However, in small areas of moor of high scenic value, the visual effects of the necessary burning regime may themselves be unacceptable.

Although it is widely stated that bracken is spreading, the distribution and rate of spread is inadequately documented except for a few individual areas. The ULS (1981) results indicate that reduction in bracken cover is more general than is its spread. Again selective monitoring is required to define the 'problem'. Suitable management techniques for control are available, but their application depends on the economic benefit gained from improved grazing and the extent to which bracken is regarded as contributing to or detracting from the landscape value of an area.

The potential succession of vegetation in relation to management is reversible, but it is important to recognise that while vegetation change occurs rapidly with increased intensity of management, the reverse process is slow. As management intensity is variable over the years it is to be expected that the vegetation is in a state of flux. The moorland core, now covering about 60% of the total area, contains a mosaic of vegetation resulting from environmental heterogeneity and variation in management. Although the vegetation at a particular place may be seen to change in one direction, a reverse change is likely to occur elsewhere. Thus the diversity of vegetation is likely to remain while the location of the components will change. The component which is most susceptible is the shrubby heaths, because they are at the end of the succession. Shrubby heaths however are still one of the most extensive vegetation groups and are at present managed as grouse moors in the northern uplands.

Thus there are three general conclusions concerning vegetation within the moorland. First, that most of the uplands will retain the characteristic mosaic of vegetation. Second, that the moorlands on which the greatest landscape changes are occurring are the shrubby heaths of south-west England. Third, that changes within the moorland can cause losses of shrubby heaths that are greater than their direct loss through reclamation.

8.3 EXPANSION OF AGRICULTURE

Changes in land use in the next 20 years will probably be a continuation of recent trends as described. The additional scenarios of maximum agricultural development or decline represent extremes which are unlikely to occur simultaneously in all the areas, but could occur in individual areas as a result of special conditions. This is realistic in that changes of the order examined have occurred in some of the parishes in the past, and the degree of intensified use of land types has been achieved in some areas. The levels of improved grassland suggested by the maximum agricultural development scenario have already been exceeded in Monyash and Lynton, but there could be potential for agricultural expansion elsewhere. If the assumptions of potential for change are accepted, it appears that, over much of the uplands, agricultural production is below capacity and could be expanded in response to economic demands. Given expansion, the main effects on vegetation would be an increase in improved pastures on the moorland edge and a decrease in shrubby heaths on the moor. Where the latter are regarded as an important landscape feature and are likely to be significantly reduced, eg Widecombe, some restriction of stocking densities may reconcile conflicts.

8.4 REDUCTION IN AGRICULTURE

A reduction in agriculture could cause marked but slow changes in the moorland vegetation, and reversion of pastures, with eventual increase in shrubby heaths and woodland. Such changes in vegetation would be only part of the greater landscape change caused by the abandonment of buildings and lack of repair of walls and fences. However, it is in areas of agricultural decline that forestry is most likely to develop. The ULS (1981) results indicate a number of factors which determine reduced agriculture, including farmers' attitudes, farm structure and tenure. These results could provide predictions of areas in which reduced farming is most likely to encourage forestry development. Such an assessment would focus discussion on particular areas where unwelcome but inevitable landscape changes, such as abandonment of buildings, might be reconciled with perhaps also unwelcome but more productive forestry development. It would be rational for forestry, agriculture and amenity interests to determine the extent to which their policies are in conflict and to seek optimum solutions. Although there is no statutory obligation for such a course of action, the problems may be more apparent than real, and co-operative action could be constructive.

8.5 EXPANSION OF FORESTRY

In recent years the rate of loss of moorland to intensive agriculture and forestry has increased considerably, while the rate of reversion from agriculture has been slower than previously and does not offset reclamation. Afforestation, affecting mainly northern and Welsh parishes, is causing a greater loss of moorland than is agricultural improvement. The most reasonable prediction of future changes in land use is that forestry and agriculture will continue to expand, although there are indications that the rate of agricultural improvement will not be maintained because it is concentrated in southern England where pressures for moorland conservation are greatest. The expansion of the forest area is expected to continue with planting of about 30 000 ha per year in Great Britain. In the period 1975–1979, about 16% of the total planting was in England and Wales (Forestry Commission 1980). Therefore the expected future planting in England and Wales will be about 4800 ha per year. The majority of this will be in the uplands, and the 12 study areas represent about 10% of the EEC less-favoured areas and about 3% of the 2 million ha of uplands in England and Wales. As a result between 3 and 10% of the planting, or 144 to 480 ha yr^{-1} can be expected in the study areas. Thus the *minimum* planting rate that can be expected in the study areas is equivalent to that of recent years. It is possible that higher rates may occur given the figure of 480 ha yr^{-1} and that the planting rate of 30 000 ha yr^{-1} is regarded by some people as conservative (Centre for Agricultural Strategy 1980; ITE 1978). Continuation at the recent, minimum, rate of planting would require just under 3000 ha of land, possibly less given some replanting, which would increase the current area of coniferous forest by about 50% by the year 2000.

The projected expansion of forest is well within the assumed forestry potential of the areas, even when the better land is retained for agriculture. The constraints to expansion are in the existing use of moorland for grouse moor, water catchment and military training, Common Land and National Park status, and the importance of moorland as rough grazing. The need to reconcile conflicting interests is obvious, in particular relaxation of planting restrictions on catchment areas and in National Parks needs to be examined, with inclusion of more landscaping in the forestry. The extent to which afforestation affects agricultural use of adjacent land is not clear, both from a farming viewpoint and in relation to changes in grazing and burning of the moorland. More factual information is needed by selected sampling and monitoring.

8.6 GENERAL APPLICATION OF METHODS

The 12 areas are a representative sample of the parishes of the 'less-favoured areas' and the trends and predictions are considered to be applicable to much of the uplands of England and Wales. The summary of the response of vegetation to management can be used as a general guide to the rate and direction of vegetation change (Figure 3). The degree to which change can occur is determined by local environmental conditions.

An indication of the potential range of vegetation which can occur under particular conditions is given for each land type (Table 5). The frequency of vegetation in a land type also indicates the probability of being able to modify one vegetation type to another. The vegetation and land types can be broadly identified from the descriptions given here, but more precise definition can be obtained by using the classification keys given in Ball *et al.* (1981a), which also includes a more detailed description of the distribution of vegetation in relation to specific site factors, for example rainfall and soil acidity.

8.7 **FURTHER RESEARCH REQUIREMENTS**

The outstanding need in relation to vegetation has already been identified: — monitoring of vegetation change under known environmental conditions and management. Although direct loss of moorland can be estimated from historical documents the change in vegetation classes can only be assessed exactly against a detailed, quantitative base line. The maps of the 2nd Land Utilisation Survey are too dependent on subjective judgement of cover of principal species to provide a base line for precise estimates of change. The present survey provides a series of recorded sites which can be used as a quantitative base for monitoring. A main requirement is to determine changes in shrubby heaths, which are an important landscape element. Sample sites should be selected in areas where change is expected and on control sites. The effect of forestry on adjacent land management should also be assessed by sampling heaths near to and distant from afforestation. In all cases it is critical to have detailed, on-site measurement of grazing intensity and burning frequency.

Changes in vegetation resulting from modification of land use have been predicted. The accuracy of such predictions is always debatable but is rarely tested. Reappraisal of the predictions should be made against actual changes in vegetation and land use, at about 5-year intervals.

9 Summary

The mosaic of moorland vegetation is an important component of the landscape of the uplands. Although the composition of the mosaic is broadly determined by physical factors of climate, rock type and topography, the pattern is not consistent, but is changing in response to past and present land use and to natural processes of succession. Direct losses of moorland through agricultural improvement or afforestation are readily measured but the more complex gradual changes in the vegetation are usually overlooked. To improve understanding of such changes, and to predict future patterns of vegetation, 12 study areas were selected as a sample of the uplands of England and Wales. These areas covered 74 000 ha of land, representing about 10% of the EEC 'less-favoured areas' with 'hill and upland farming' in England and Wales, and contained about 50 000 ha of moorland.

9.1 PAST AND PRESENT VEGETATION CHANGE

An analysis of the land and vegetation shows that although various types of shrubby heath vegetation are dominant under the more severe climate of the hill types of land, local physical conditions can allow development of grassy heaths and rough pastures. In the less severe climate of upland land types a wider range of vegetation occurs, with improved pastures dominant on land with moderate or gentle slopes. Vegetation change is most rapid on the lower land and there is a distinct zone, the moorland fringe, where fluctuations in land use have resulted in improvement of moorland or reversion of farmland back to moor. In the past 200 years nearly 6000 ha or 11.5% of the original moorland has been converted to farmland or forest, partly compensated by reversion of 2500 ha of farmland. Although improvement causes a rapid vegetation change, reversion is often a very slow process. More than a century after intensive agricultural use ceased, the vegetation of some of the reverted land does not correspond with that of the adjacent moorland core which has never been improved. Thus parts of the current moorland are still responding to land use changes which occurred before the First World War.

Agricultural statistics show that marked fluctuations in use, including stock numbers, occurred irregularly in the uplands over the last century. Unfortunately, apart from the evidence of the rate of vegetation change following reversion, there is no detailed information on the response of the vegetation of the study areas to such fluctuations that can act as a guide in predicting future changes. However, controlled management experiments in other parts of the uplands and ecological experience are combined to produce a hypothesis of vegetation response to management, related particularly to the vegetation of the study areas and to the dominant effect of grazing.

9.2 FUTURE VEGETATION CHANGE

The hypothesis has been applied to information on the vegetation of the moorland to predict the effect of alternative developments in land use.

The most likely development in upland land use is a continuation of the trends of the last few decades which reflect the balance of various demands and constraints. Given continuation of these trends it is likely that about 2000 ha (4%) of the current moorland, mainly rough pastures and grassy heaths, would be improved for agriculture by the year 2000. However, because of increases in grazing pressure on the remaining moorland vegetation, the loss of rough pasture and grassy heath would be compensated by conversions from other vegetation and the main net results would be a loss of about 3000 ha (15%) of shrubby heaths and a change in the pattern of distribution. Loss of shrubby heaths on some of the relatively large moorlands of northern England would have less visual effect on the landscape than it would on the smaller moorlands of south-west England and parts of Wales.

If socio-economic factors led to a concerted development in upland agriculture, at a rate which has occurred in some parishes in the past, an increase of about 50% in current management intensity, particularly stock density, could occur. Such an expansion could result in a loss of about 17 000 ha, approximately a third of the present moorland, leaving about a quarter of the present area of shrubby heaths, mainly in northern England. An alternative scenario is for a major decline in agriculture with a halving of stocking densities. Such a change could, in a period of 10 to 20 years, add about 5000 ha to the moorland by reversion of pastures. The total area of rough pastures and grassy heaths would tend gradually to decline and the shrubby heaths to increase, but the shift in pattern would continue for decades as soil conditions gradually change to favour heath species.

Forestry development if continued at the recent rate would add a further 3000 ha to the predicted loss of moorland to agriculture by the turn of the century, giving a total loss of about 10%. However, a major expansion of forestry could, as with agricultural expansion, reduce the moorland by about a third, but would leave its vegetation dominated by shrubby heaths.

9.3 CONCLUSION

From the detail emerges the conclusion that although debate frequently focuses on absolute loss of moorland, vegetation change within the remaining moorland could result in equally large losses of visually important components, particularly shrubby heaths. From the sample of the uplands of England and Wales it is estimated that, while 10% of the moorland area may be lost to agriculture and forestry by the year 2000, up to 25% of the area of shrubby heaths would be lost by

internal changes. The sensitivity of moorland vegetation to changes in grazing pressure, and the slow response of some communities, means that the characteristic mosaic of vegetation will remain in a state of flux for many years in response to short term fluctuations in management. Because of its successional nature, the vegetation at a particular place may be seen to change in one direction but a compensating change is likely to occur elsewhere. Thus the diversity of vegetation is likely to remain while the location of the components changes.

The component which is most vulnerable is the shrubby heaths because they are at the end of the succession, they are quickly suppressed by increased grazing pressure but slow to re-establish on often modified soils when grazing is reduced. Further, their maintenance usually depends on carefully controlled burning which makes the shrubby heaths of south-west England particularly vulnerable because of the absence of grouse interests which maintain the management of other moors.

Given the concern of amenity and conservation organizations for the protection of moorlands from agriculture and forestry, the evidence of the present study is that the changes in vegetation and land management *within* the moorland need to be monitored. To date the debate on loss of moorland has concentrated on outright conversion. This report shows that if the resource is to be protected the debate must be widened to include indirect losses resulting from gradual changes in landuse and management.

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