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Summary report on

Upland Land Use

A desk study

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PREFACE

In October 1975, the project on Upland Land Use was formally initiated, supported by funds from the Department of the Environment, with Countryside Commission for England and Wales as the major interested organisation. A desk study (Phase I) was developed to review the subject, examine methods and identify problems with a view to beginning research projects for Phase II. An interim report (3 volumes) was produced in March 1976 to allow internal review of progress. The present document is a summary of the interim report and, while it does not claim to be a well-balanced, carefully presented report, it aims to provide an outline of the approach which is being developed in the study. It is a preliminary report which will be replaced by a full report in March 1977.

The ITE staff who have contributed directly to the work are:

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Many senior and junior staff have contributed in discussion and in many small but essential tasks. In particular the office staff have made an invaluable effort.

The ideas, information and time which have been generously given by many individuals and organizations is gratefully acknowledged - in particular Cumbria County Council, Nature Conservancy Council, Soil Survey of England and Wales, Hill Farming Research Organisation, Forestry Commission and Countryside Commission for England and Wales.

O. W. Heal
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UPLAND LAND USE

A desk study

1. INTRODUCTION

1.1 About one third of the total area of England, Scotland and Wales consists of rough grazing, upland forest and moorland and is the least intensively managed areas of land. In the future this land may come under more intensive management to satisfy an increasing demand for natural products or management may decline because of increasing economic and other pressures. A variety of land uses are concerned with upland Britain - agriculture, forestry, recreation, water, mineral extraction, nature conservation - each represented by one or a number of national organizations. Multiple use of the uplands is a natural consequence of the low intensity of any particular use resulting in a greater interaction between uses than occurs in the lowlands.

1.2 ITE has a particular interest in uplands because they contain much of the more natural areas of Britain where management options are dominated by ecological relationships. Although management options are constrained by the climatic and soil conditions the low intensity of existing use provides greater flexibility than in the lowlands. Because the research of ITE is not aimed towards the support of a particular land use we have the opportunity to examine and integrate information on a range of uses. Thus our interests coincide with those of Countryside Commission and with regional planning authorities who are concerned with the combination of land uses and with the effects of land use on landscape.

1.3 The Upland Land Use Project was initiated to indicate the relationships between the various projects in ITE concerned with uplands, to place these in the broader context of the present and future use of uplands and to identify aspects of importance for future research. To conform with the requirements of Countryside Commission for England and Wales these aims were extended to include an analysis of the change which may occur in the uplands and the effects of such changes to the landscape. The objectives defined for the desk study, and agreed with CC in September 1975, are:

1. To define the upland area which is of particular interest in these studies.

2. To identify the main constraints on the use of upland areas for particular purposes.

3. To identify:

   i) the main land-uses
   ii) their relative importance on the basis of area used
   iii) the associated management practices and to assess:

   iv) the economics of the various management practices
   v) the landscape consequences (physiognomic) of the alternatives
   vi) the rate of change under the different management practices.

4. To identify the nature and importance of the links between the upland zone and surrounding areas.

5. To describe the uplands and their main uses as systems of interacting parts, affected by various ecological factors and subject to various socio-economic and political constraints, as a basis for future studies. Particular attention will be given to agricultural improvement techniques.

6. To identify the various types of information which are available on upland land-use and management and the locations of the information.

7. To review the whole field of effects on upland systems of land-use and management as a basis for future studies.

8. To draw up for consideration by senior ITE staff one or more strategies for future studies, including ways of using currently available information.

1.4 The scope of the study is very broad both in subject and geography (England and Wales), but the central theme is that a unit of land can be placed in National, Regional and Local context with successively finer levels of detail, corresponding with mapping units of 100 km^2, 1 km^2 and 1 ha.

These land units do not correspond with recognisable systems of land use e.g. farm, forest, grouse moor. Each land use has different system boundaries and the present study is concerned with all of the uses. Therefore we have adopted simple mapping units which, like pieces of jigsaw, can be assembled and re-assembled into areas corresponding to the system under consideration whether this is a parish, a catchment, a landscape or a County.

1.5 To determine where changes in use are likely to occur it is necessary to quantify the functional relationship between controlling factors and use, and to define the intensity or state of the factors at each site. This is usually translated into practice through land capability classification for specific uses - agriculture or forestry.

To determine the type and degree of change it is necessary to know the relationship between intensity of use and response of the system whether this is economic social or ecological. The response of the system is also dependent upon its state e.g. a 20% increase in grazing pressure or number of walkers has different effects on mineral and peat soils.

1.6 There are many variables in the systems and their interactions are complex. Rigorous quantitative analysis has not been attempted in this desk study because of lack of time and lack of knowledge on functional relationships. However we have attempted to identify major factors and responses in upland land use to provide a framework for further study. Fortunately factors of geology, physiography, climate, vegetation and soil are important in all upland land uses and therefore provide a common basis for study.

1.7 The definition of the limits to uplands is always arbitrary because we are concerned with gradients of intensity of environmental factors and land use. The importance of a particular position on a gradient varies with the land use under consideration. Thus the lower limit for Hill Land Subsidy is unrelated to the upper limit of economic forestry or to a climatic criterion of uplands such as the 50" rainfall level. Therefore we have taken the 800' contour as a convenient demarcation of uplands for general purposes. This demarcation is readily definable in different areas, shows only limited climatic variation within England and Wales, broadly corresponds to the upper limit of intensive farming and with an extension of the landscape. Although the 800' contour is used as a basis for the study, the land use and landscape of the uplands is strongly influenced by the character of the adjacent lowland. Therefore the study repeatedly incorporates areas below 800' where they are relevant to the uplands.

1.8 The desk study is divided into three interlinked parts - National, Regional and Local. At a National level the distribution, size and main characteristics of uplands in England and Wales is described (Chapter 3) and the problems and methods of land classification reviewed (4). Each of the land uses in uplands is briefly analysed with emphasis on the factors influencing management practices, the ecological and landscape consequences of these practices, and the likely future demand for products (6). It was recognised that major changes in land use are controlled by the state of the natjonal economy and by associated political decisions. Whilst it is unrewarding, if not impossible, to predict political decisions, certain long-term economic trends based on energy considerations are examined and possible consequences to upland land use explored (5).

At the Regional level (7) we have not attempted to analyse the characteristics and trends in each region because of the magnitude of the task and the short time available. We have concentrated on the analysis of two regions, Cumbria, and part of Snowdonia, examining some methods which might be used in future studies. Cumbria was selected because an analysis of land use was in preparation by Cumbria County Council, in consultation with ITE, for the County Structure Plan. The information being collected was thus relevant "to the land managers of local authorities, National Parks and other similar bodies" - one of the qualifications specified in the Upland Land Use project plan. Cumbria also contains large areas of uplands both inside and outside the Lake District National Park. An area in Snowdon was selected as a second test site because, unlike Cumbria, detailed surveys of geology, climate, soil and vegetation were available allowing a comparison of the interpretation of land capability in the presence and absence of detailed information.

At the Local level - parish, farm or field - information is required in much more detail than for the Region with social factors playing an important role in determining the land use characteristics. Site studies of a farm or valley frequently provide intensive data on sociology, economics or ecology but such data can be made more widely applicable if the variation in site characteristics in the region are known, and the sites are selected within a reasonable sampling framework. The intensive study of Hartsop (Feist, Leat and Wibberley 1975) provides an example of the social and economic detail necessary to combine with ecological information to understand processes of change in the local situation. A comparison of the valley systems in Cumbria provides a means of placing Hartsop in a Regional context.

2. THE UPLAND SYSTEM

2.1 The decline in the viability of upland agriculture, the increasing disparity between uplands and lowlands in standards of living, income, amenity, education facilities and the decline in population in rural districts are repeated themes in the plethora of publications on the present state and future of the uplands of Britain. Such themes are frequently associated with discussions of forestry as an alternative land use, of the traditional antagonism between forestry and agriculture and of the problems and benefits of recreation. These points are set against a background of the need for wise use of a national resource which constitutes a larger proportion of our land surface but contributes little directly to the economy of the country — that small contribution however is important in the maintenance of the sheep industry.

2.2 The decline in agriculture in the uplands continues, despite a brief period of relative prosperity in the early 1970's. The Annual Review of Agriculture 1976 shows that the number of farms continues to decline by about 2% per year but the decline is the result of loss of the smaller holdings and full-time farms and in farms with small sheep flocks. These are changes in farm structure and could reflect increasing, rather than decreasing, viability of agriculture. However the weighted average net income per farm in 1974/75, compared with 1973/74, showed a decline of 10% in England and 32% in Wales for all farm types with the greatest decline (42 and 51%) occurring in farms classed as Mainly Sheep. In Scotland while the average income for all farm types increased by 13%, that for Hill Sheep declined by 50%. The numbers of people employed in agriculture is also declining at about 2% per year.

2.3 Basic to the change in upland agriculture is the biological potential of the level which, compared to the lowlands, is low because of lower temperature, higher rainfall and poorer soil conditions. The constraints to production are severe and the options limited resulting in a system which has difficulties in responding to external changes in demand and cost of supplies. The instability of the system is buffered, to some extent, by government subsidies and by the resiliance of the farming population.

2.4 The land use potential of an area is determined by its physical and biological characteristics - this is expressed in the various land capability classifications (Chapter 4). The degree to which the potential is reached is constrained by a series of social, economic and historical factors which have determined the current land use and which control the future use. The distinction between potential and constraints is emphasised in Fig. 1, and the various factors controlling upland sheep farming represented in Fig. 2.

2.5 A wide range of methods have been used to analyse upland land use systems, especially agriculture e.g. Eadie and Maxwell 1975, Spedding 1975, Agric. Adv. Council 1972, Willis 1971, Collins and Thomas 1973. The attempts to formalise upland systems repeatedly emphasise the inadequacy of detailed information especially on functional relationships between components. The analyses however indicate that:

biologically, increased production can be achieved by improved pasture management and grazing control; maintenance of stock in winter is a major limitation to increase in stock on the summer grazings.

economically, upland agriculture is highly sensitive to external market forces and is dependent on government subsidies to maintain profitability; it is therefore vulnerable to political attitudes.

socially, it is associated with isolated communities, limited communications and other amenities;

2.6 On these bases it can be argued that:

a) given the maintenance of a "reasonable" national economy, with continuing support for upland farming, via EEC Directive on Less-Favoured Areas, then populations will continue to decline in

Fig. 1. The major groups of factors influencing land use.

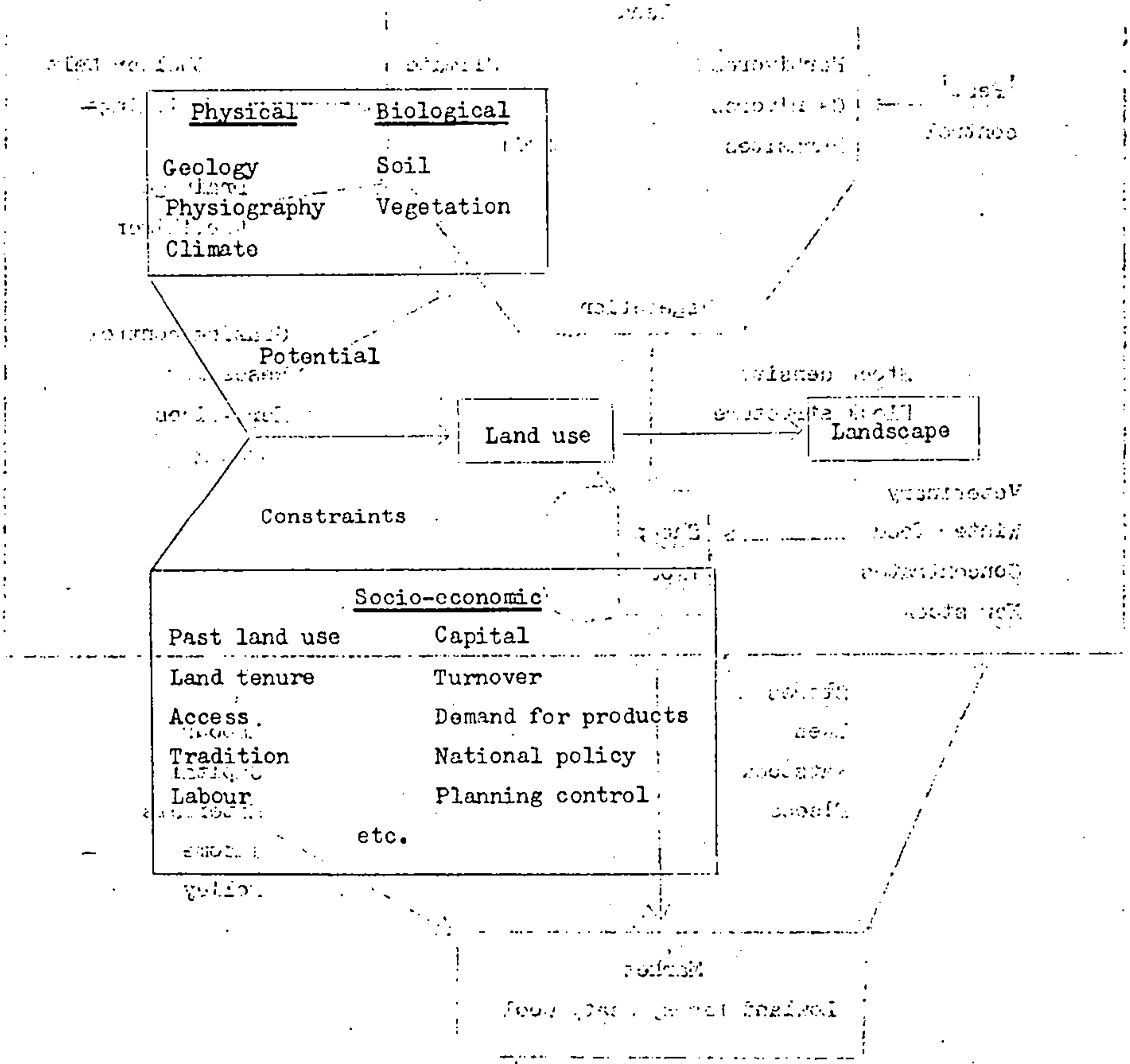
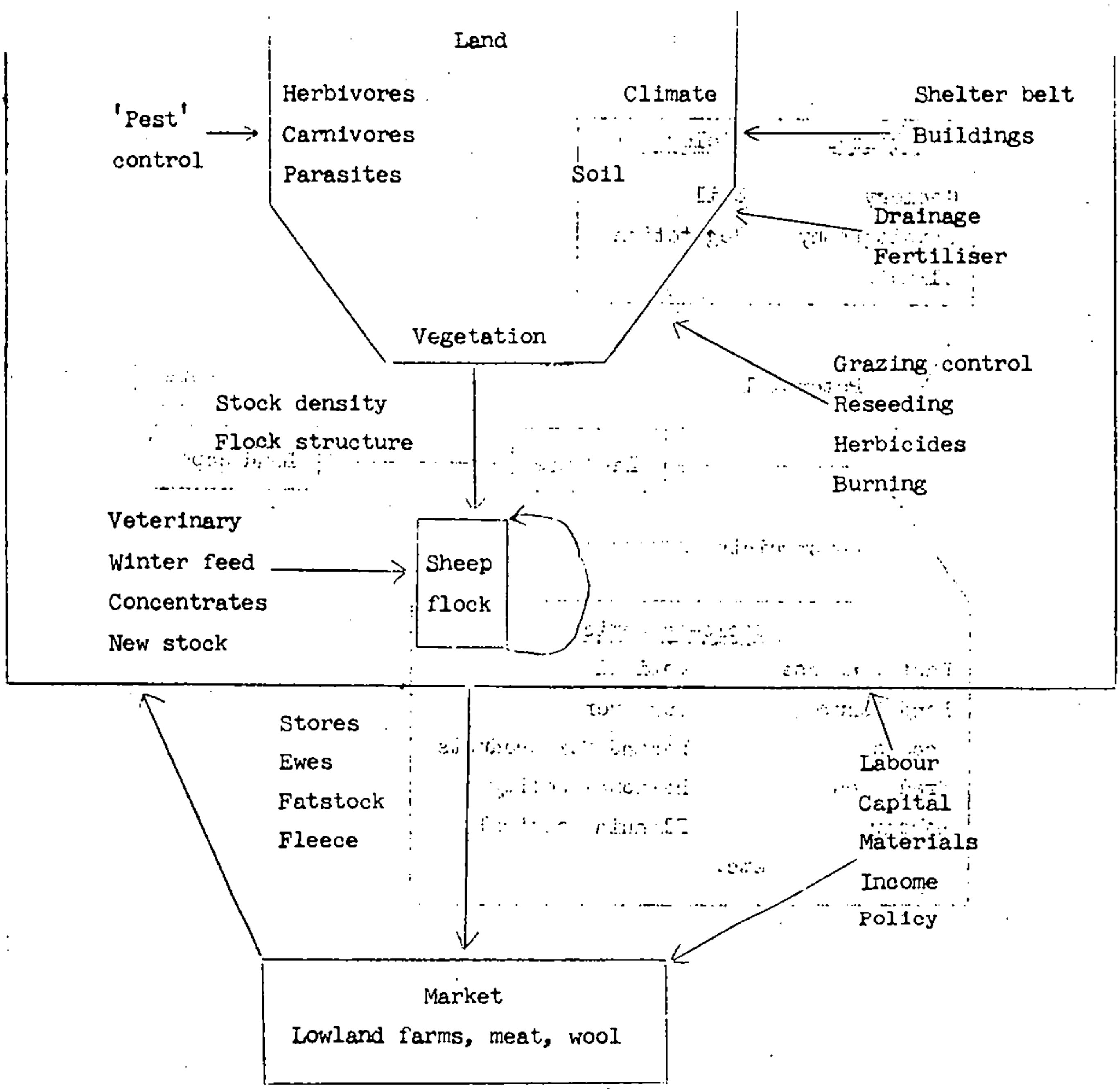


Fig. 2. Main management options and controls in an upland sheep system



areas characterised by small farm size, remoteness and low proportions of land for winter grazing. The areas with good access, good quality land and relatively large farm size will maintain production from the uplands.

b) a marked increase in financial support for upland farming would be directed into pasture improvement on the larger farm units with greatest capital opportunities. Improvements are most likely to occur where i) land is particularly suitable e.g. bracken dominated or ii) is released by a change in land tenure or other regulation e.g. common land and iii) alternative land options are lowest, e.g. non-recreational areas and iv) there is a tradition of making use of new techniques.

2.7 A number of alternative sequences could be argued with reasonable conviction, but the trend in each sequence is an emphasis on change occurring in the enclosure and/or improvement of the pasture in the temporary and permanent grasslands at about 600-800' in areas whose economic viability is high. The poorer grasslands and rough grazing in more isolated areas will continue to decline in agricultural intensity with a slow change in landscape with a deterioration of walls and buildings. The vegetation change will be negligible because these areas are already under low grazing intensity and the only obvious change will be a slight increase in scrub and trees at the lower altitudes.

The trend in sheep farming could provide the opportunity for an increase in forestry in the land up to about 1400'. It has been argued that forestry in association with stock can be mutually beneficial to both industries - to forestry by providing new areas for afforestation and to agriculture by providing improved access, shelter and labour opportunities (Agric. Adv. Council 1972, Jones 1975) and the feasibility of the type of exercise is being examined e.g. at Pwllpeiran. Such developments are likely to occur where farmers are traditionally sympathetic to innovations, large farm size allows flexibility in land allocation and visual amenity constraints are minimal.

2.8 Various alternative options for change can be explored in this way - examining the logical consequence of alternatives. There are enormous problems in the development of quantitative mathematical models of each of the subsystems and combining these to predict where and what changes will occur. A more useful approach in the immediate future therefore appears to be:

1. Identify the main factors considered to influence the use of uplands.

2. Use a combination of techniques to assess the intensity of these factors geographically e.g. land capability, social viability, farm size, access.

3. Assess from specialist opinion and analysis the probable trends in demand and the main factors (constraints) to that demand.

4. From 2 and 3 identify areas which are forecast to change, given certain trends.

5. Forecast the features which are liable to change in the identified areas of increased farm size, enclosure of pasture etc.

6. Monitor the features in a sample of areas.

3. NATIONAL SURVEY OF UPLANDS - CHARACTERISATION OF MAIN AREAS

3.1 The simplest way to define "upland" is all land that lies above some arbitrarily selected altitude. Alternative definitions can be based on climatic factors, since higher ground is, for example, typically subject to higher rainfall; or in terms of land use, since higher land in Britain is again typically unenclosed and used for an extensive livestock-grazing form of agriculture or for non-agricultural purposes. While most "upland" areas in Britain have in contrast to the "lowlands", features in common that include higher altitude, higher rainfall and lower temperatures, and less intensive land-use; there are significant differences within Britain, from west to east and south to north, in the altitude at which a given rainfall level is reached, or below which improved grassland with relatively intensive agriculture dominates land use.

3.2 Because of these variations, and other interactions due to the history of land use in individual areas, more sophisticated definitions of upland become complex to handle and explain, and in this study were therefore rejected in favour of simplicity. The altitude that has

Fig. 3

UPLAND - ENGLAND and WALES

Major regions: 1-18

Minor areas: a-j

(as given in Table 1)

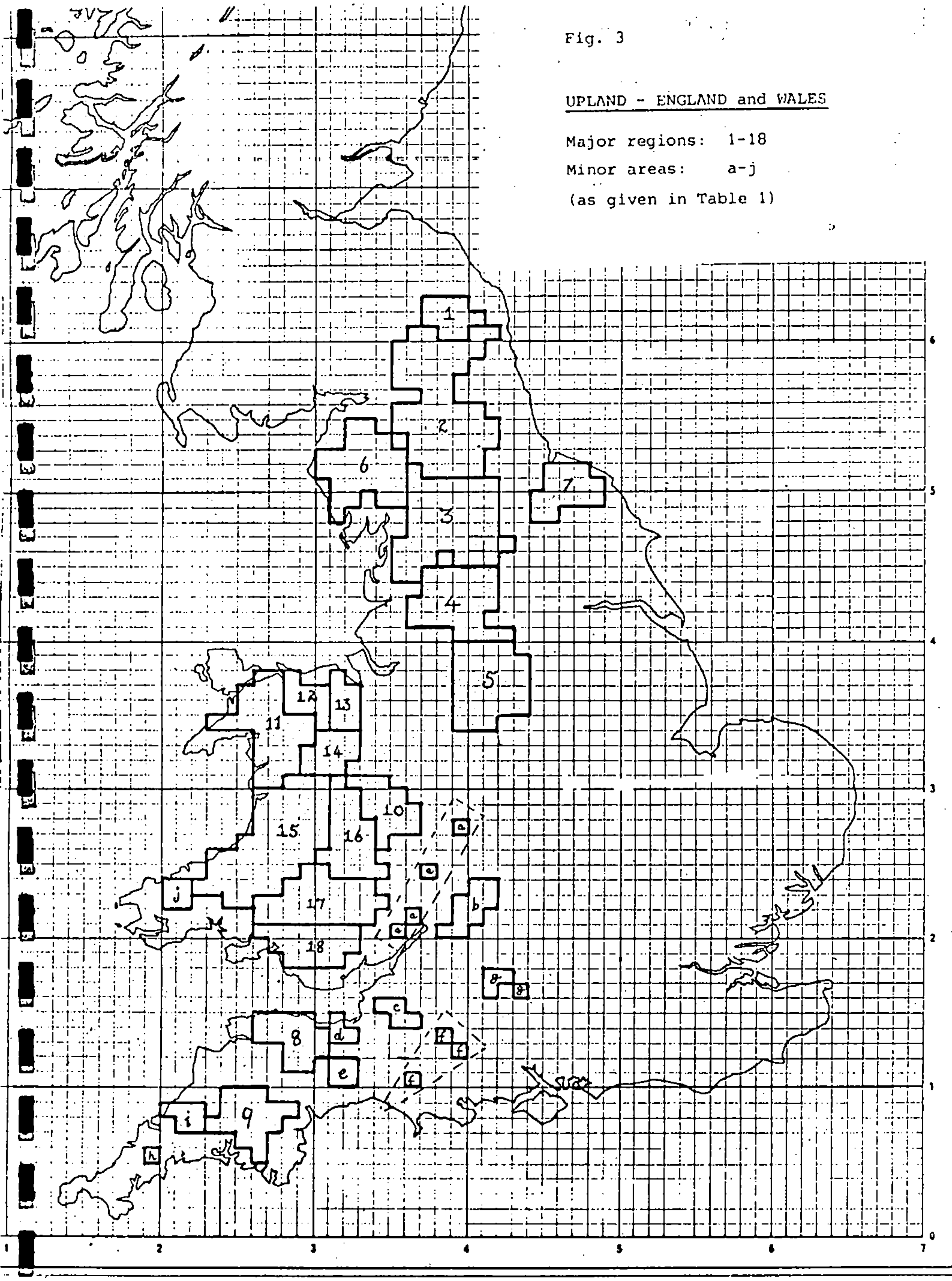


Table 1. UPLAND AREAS AS DELINEATED - RANKED IN ORDER OF AREA 800 ft. O.D.
(the code number or letter refers to the position of the region in Fig. 3).

	Upland Area	Area in km^2 800'	1,400'	2,000'	3,000'
Major Regions					
2	North Pennines	2,876	916	140	0
3	Central Pennines	2,458	820	68	0
15	Cambrian Mountains	2,182	504	4	0
11	Snowdonia	1,524	520	112	8
17	Brecon Mountains	1,412	412	64	0
5	Peak District	1,384	164	8	0
6	Lake District	1,308	492	148	4
4	South Pennines	1,060	104	0	0
16	Radnor-Clun Forests	904	120	0	0
18	South Wales Coalfield	716	108	0	0
9	Dartmoor	660	192	0	0
8	Exmoor-Brendon Hills	640	48	0	0
14	Berwyn Mountains	608	236	24	0
1	Cheviot	472	124	16	0
12	Hiraethog	452	32	0	0
7	North York Moors	416	4	0	0
10	Shropshire Hills	308	16	0	0
13	Clwydian Hills	276	24	0	0
Minor Regions					
i	Bodmin Moor	164	0	0	0
b	Cotswold Scarp	136	0	0	0
c	Mendip Hills	84	0	0	0
j	Prescelly	80	0	0	0
e	Blackdown Hills	64	0	0	0
d	Quantock Hills	36	0	0	0
g	Wiltshire Downs	28	0	0	0
a	Forest of Dean, Malvern and Clent Hills	24	0	0	0
f	North Dorset Scarp	12	0	0	0
h	St. Austell Moor	4	0	0	0
	England (approx)*	12,134	2,880	380	4
	Wales (approx)*	8,154	1,956	204	8
	Totals (km^2)	20,288	4,836	584	12
	Total (acres)	5,018,546	1,194,492	144,248	2,964

Table 2. THE OCCURRENCE OF LAND ABOVE 800' IN THE COUNTIES OF ENGLAND AND WALES

County	County area* (km^2)	Land above 800' mean (km^2)	Upland as % of Total Area
Powys	5077	3530	69.5
Gwynedd	3866	1672	43.3
Mid Glamorgan	1019	420	41.2
Durham	2436	952	39.1
Cumbria	6808	2480	36.4
Derbyshire	2631	932	35.4
Clwyd	2426	840	34.6
Northumberland	5033	1408	28.0
North Yorkshire	8309	2076	25.0
Lancashire	3043	636	20.9
Dyfed	5765	1196	20.7
West Yorkshire	2039	420	20.6
West Glamorgan	816	144	17.6
Greater Manchester	1287	200	15.5
Somerset	3450	536	15.5
Devon	6711	892	13.3
Salop	3490	384	11.0
Gwent	1376	128	9.3
Staffordshire	2716	240	8.8
South Yorkshire	1560	100	6.4
Cheshire	2328	128	5.5
Gloucestershire	2642	140	5.3
Cornwall	3547	172	4.9
Cleveland	583	28	4.8
Hereford and Worcestershire	3927	160	4.1
Wiltshire	3481	36	1.0
Dorset	2654	4	0.2

* From the Local Government Companion, No. 4, 1975/76.

been selected as the starting point for "upland" in Britain is 800 ft. O.D. (c. 244 m), in accord with general experience, and with the limit used in previous Countryside Commission studies. On the basis of 10 x 10 km grid squares, the distribution of major and minor areas of uplands in England and Wales are given in Fig. 3 and Tables 1 and 2. Additional information on the climate, soil type and land use of these areas is available and provide a factual basis for selection of comparative sample areas from different regions for detailed study.

4. SURVEY AND CLASSIFICATION

4.1 To obtain a scientific basis for management of upland areas, it is necessary to survey, describe, and map their characteristics and to interpret those properties which are useful in management, which may involve classification. As these functions can be carried out at various levels of detail, a system is needed which permits a choice of the degree of detail required for a particular purpose (e.g. Jurdant *et al*, 1974).

There are several kinds of land classification, e.g. (Vink, 1975; Steward, 1968): (a) soil classification; (b) land capability classification; (c) economic land use classification; (d) mapping of major agricultural regions; (e) land suitability classification; (f) land systems classification (C.S.I.R.O.); (g) terrain evaluation; (h) land evaluation for engineering; (i) land assessment for regional planning; (j) land assessment for taxation. A systematic approach to systems of land classification has been developed in the U.S.A. The following categories (Vink, 1975) start with the purely 'natural science' approach to the land and proceed through various stages to the final application in land use development:

I Land classification in terms of inherent characteristics

This includes all kinds of classifications of the land resources based on their characteristic attributes, e.g. climatic, topographical and geomorphological, geological and soil taxonomic classifications. Also included are the legends of maps of the following kinds: climatic, topographical, geomorphological, geological, soil and vegetation, land systems, and many terrain evaluation maps.

II. Land classification in terms of inherent qualities or in terms of ecological land conditions

In general this is based on the 'purely scientific' classifications and maps, and which indicates the direct, technical, or biological answers to the requirements of crops and of the different kinds of land use. Examples include some terrain evaluation maps, drainability maps, salinity maps, engineering classifications.

III. Land classification in terms of present use

4.2 Any classification of any population of objects is an intellectual exercise, whereby the data can be grouped in one of a number of different ways, depending on the objectives of the classifier. Broadly speaking, the purpose of most classifications is to enable the classifier either to make inductive generalisations about the data, or to make predictions. No single classification of a group of objects can serve all possible purposes and they may have to be classified in a number of ways until one is found which satisfies the needs of the classifier.

A range of multivariate techniques is available to enable the classifier to examine various aspects of a multivariate data set. Multivariate methods may be used to explore relationships among data, and to generate hypotheses, but they do lay traps for the unwary (Anderberg 1973, Jeffers 1970).

4.3 It is fairly evident that different upland areas differ in their general appearance. For example, the general relief characteristics of the Lake District and Snowdonia appear to be broadly similar, and they differ from, say, the Pennines and the North York Moors. The problem is to express such differences quantitatively. Techniques for morphometric analysis of landforms, with special reference to maps, are discussed in Slaymaker, 1966. Of particular interest is a paper by Carson which examined the use of statistical techniques and the problems encountered by geomorphologists in trying to relate geomorphological features to a range of variables. However, none of the papers classified landforms. Various methods for examining landforms are discussed by King (1966).

Linton (1968) attempted a direct classification of Scottish landform landscapes' based on absolute and relative relief, i.e. the altitudinal difference between the highest and lowest points in a mapping unit. Six main categories were distinguished: (1) Lowland, generally below, but sometimes above, 500 feet. May be smooth and gently rolling or strongly accented; (2) Hill country, summit altitudes may range from as little as 600-800 feet up to 1600-18000 feet, but the relative relief is less than 1000 feet; (3) Bold hills, hill groups with steep slopes and stronger relative relief - usually in excess of 1200 feet- yet lacking the attributes of mountains; (4) Mountains, relative relief exceeding 2000 feet, isolated; (5) Plateau uplands, high areas of low relative relief - generally 300 feet or less; (6) Low uplands, areas below 1000 feet with low relative relief but which are morphologically upland.

These categories can be given subjective weighting in terms of 'scenic interest'. This approach was used in a study of countryside recreation in Lanarkshire (Coppock, 1970b) and in a landscape analysis of Caernarvonshire (CCPD, undated).

4.4 Air photography has been found to be useful in examining relationships between soils and landform units, but there is more scope for work in this field. The value of air photography lies in the recurrence, usually in characteristic patterns, of the photographic images. Patterns of landform, drainage, vegetation, and soil surface characteristics are almost universal. Most air photo interpreters, whether soil scientists, geologists, or ecologists, make use of patterns and resolve them into the recurrent components. Then, in order to find out what the soil, rock, or vegetation is like, they inspect a few examples of each class of component on the ground. In this way, time can be saved, because not all the land need be visited. As the area to be surveyed is increased (within certain limits), any given pattern is more likely to be repeated and hence a greater area can be mapped from air photography with limited field work than is possible using the same resources in normal field survey (Webster, 1969). Rudeforth and Webster (1973) and Rudeforth (1975) gave examples of air photo units recognised in Wales.

AGRICULTURE

4.5 In English-speaking countries, the land capability classification of the US Department of Agriculture has perhaps been the most widely used and adapted. The land use capability classification of the Soil Survey of England and Wales is basically an adaptation and revision of the U.S.D.A. classification, modified to fit conditions in Britain.

The Soil Survey of England and Wales (hereafter referred to as the Soil Survey) classification (Bibby and Mackney, 1969) makes certain assumptions:

1. The classification is primarily for agricultural purposes.

2. Land is assessed on its capability under a moderately high level of management and not necessarily on its present use.

3. Land which suffers from limitations which can be removed, or reduced, at acceptable cost is graded on the severity of remaining limitations.

4. The capability classification may be changed by major reclamation projects which permanently alter the previous limitations to use. Minor changes, e.g. mole drainage liable to regress in time, will not change the classification.

5. Within capability classes, soils may differ in management and fertilizer requirements and detailed cropping, are only grouped because they have similar degrees of limitations affecting adaptability. The classification, however, is not necessarily a grouping of soils according to the most profitable use to be made of the land.

6. Within specific subclasses are soils which suffer from the same degree and kind of limitation, but which may differ in management requirements; for example, in subclass 3w the wetness may result from slow infiltration or from the effects of rising ground water - each of these conditions will require separate treatment.

7. The system is based not on chemical but on physical limitations, for in general these are more permanent and difficult to rectify; severely limiting chemical properties, however, can be recognised as a soil limitation.

8. Distance to markets, types of roads, and farm structure do not influence the grading, although these factors will affect decisions about land use.

9. The interpretations try to express current knowledge, and as new experience is acquired, new interpretations will be necessary.

10. The system is not a soil suitability classification for specific crops or use, e.g. for potatoes or forestry. Interpretations of soil maps for such purposes may require different groupings of the mapping units to express the concept of land capability used in the system.

Land is allocated to one of seven main classes according to the degree to which its use is limited by (i) wetness; (ii) soil properties - shallowness, stoniness, structure, texture, fertility; (iii) gradient; (iv) liability to erosion; (v) climate. Class 1 land has very minor or no physical limitations to use, while Class 7 land has extremely severe limitations that cannot be rectified. A similar classification, but with only five main classes, was produced with maps, by M.A.F.F. However, for the purpose of looking at upland areas in detail, even the Soil Survey classification is of limited value, as most upland areas will fall into the three poorest classes.

The Ministry's existing maps of Agricultural Land classification of England and Wales, while useful for general planning, have inadequate detail for studies on a more local scale, and the existing classification gives no indication of the improvement potential of unimproved land (Grade 5). Therefore MAFF are developing a more detailed classification for the areas currently in Grades 4 and 5. Pilot surveys have been undertaken (e.g. the parish of Bainbridge for the North Riding Pennine Study), and a technical report on the new classification may appear in 1976.

FORESTRY

4.6 In Britain, Statham (1972) in his study of the North York Moors devised a classification which was based on ecological and known economic constraints of a widely-occurring and restrictive nature. Several assumptions were made: (1) Relative priorities of food and timber production in the foreseeable future rule out extensive afforestation of grades 1-3 agricultural land; (2) existing investment in agriculture (buildings, stock, fences, walls) lowers potential for forestry development even where the biological potential is high; (3) a corollary of (2) is that land at present managed for forestry generally has a higher potential for forestry than non-forested land, except in areas of very fertile soils, where clearance to agriculture would be more profitable; (4) the existence of common land is a short-term but not a long-term constraint; (5) as with agriculture, socio-economic factors such as land prices, location, access, distance to markets, ownership factors, are not taken into account; (6) amenity, recreational, and conservation factors are not considered; (7) the present balance of subsidies etc. between forestry and agriculture is assumed, not necessarily the actual rates. The grading system evolved by Statham was as follows:

Grade 1: land with variable but generally poor soils with low economic constraints to forestry development (these areas include most of the existing forests).

Grade 2: land with poor to very poor soils with low to moderate economic constraints to forestry development.
Subclass 2a Common land (coincides with unenclosed moorlands)

Grade 3: land with poor soils and moderate to severe economic constraints to forestry development. (These areas are the poorer agricultural land).

Grade 4: land with moderate or good soils but severe economic constraints to forestry development except for sporting amenity.

Grade 5: land with severe ecological constraints to the successful growth of trees.

The mixing of ecological and economic criteria in this classification is questionable. Economic considerations can change very rapidly in present-day Britain, and it seems better to produce an ecological classification upon which real or hypothetical economic considerations can be superimposed.

4.7 The Forestry Commission has generally taken the view that it would pursue regional classification which improved the efficiency of forest managers in the exercise of their functions (Toleman, in M.A.F.F. 1974).

Examples of regional classifications are given by Toleman and Pyatt (1974) and by Pyatt et al (1969). Busby (1974) gives forest site yield guides to upland Britain on a regional basis. It is worth noting that some site factors which are limiting for agriculture are not limiting to forestry, e.g. (Toleman, in M.A.F.F. 1974).

1) slopes up to 35° are acceptable.

2) stoniness or boulder content or bouldery surfaces have little effect on forest utilisation unless very high frequency is encountered.

3) organic and organo-mineral soils do not represent as severe limitations for forestry as for intensive agricultural use.

In contrast, some limitations such as wetness associated with clay textures and low or zero potential water deficit can be a serious limitation in forestry or on stability grounds, and can affect production much more seriously than in agriculture. Also, shallow soil over limestone is a serious limitation for many conifer tree species but can be utilised quite productively by intelligent agricultural practice. Climatic and topographic factors probably play a greater part in classification for forestry.

For the purposes of our upland work, we are interested in a classification of land for forestry capability based simply on whether or not trees will grow at a given minimum yield class. The economics of forestry in that area could then be considered separately, especially in the light of changing economic circumstances and Government priorities. A preliminary forest capability classification for uplands in the north Pennines and Wales, has been produced in the present project by R. Toleman and D. G. Pyatt (Forestry Commission) (pers. comm.).

RECREATION

4.8 The basis of the classification for recreation used in the Canade Land Inventory (McCormack, 1971) is the quantity of recreation land use which may be generated and sustained per unit area of land per year under perfect market conditions. A high land class unit therefore has a high index of attraction in terms of popular preferences and a use tolerance which permits intensive use without unduly degrading the resource. This ranking does not take into account present use or accessibility.

Intensive and dispersed activities are recognised. Intensive activities are those in which relatively large numbers of people can be accommodated per unit area, while dispersed activities are those which normally require a relatively large area per person. Recreation subclasses indicate the kinds of features which provide the opportunity for recreation, and are thus positive aspects of land and do not indicate use of limitations. This concept could be applied in Britain.

Various attempts have been made in Britain to classify land for recreational purposes (e.g. Coppock, 1970b). These attempts usually involve some sort of subjective grading system, often based on "Landscape Quality" (e.g. see Jacobs 1974; Lane <u>et al</u> 1975) Coppock (1970b) using Linton's classification of landforms to which were assigned arbitrary scores for "scenic attractiveness". The question of the classification of land for recreational uses is so complex that it merits a separate study.

5. THE FUTURE OF UPLANDS IN RELATION TO NATIONAL RESOURCES

5.1 An analysis of the growth of society indicates that non-renewable resources of petroleum and coal are not capable of sustaining the energy demands characteristic of a growth economy, especially when the concept of net energy is used. At present the consumption of gross energy is increasing, but increasing percentages of energy are being fed back into the energy winning process and therefore the percentage of net energy production is decreasing e.g. North Sea Oil, Liquefied Natural Gas, coal liquefaction, shale oil, tar sand oil and probably fission power. Many of the proposed alternative energy sources may require more energy feedback than existing sources. There are a number of detailed energy balance studies by analysts mainly outside the industries or technologies being investigated. Those analyses, for example, show that coal is less energy intensive than refined oil (but also of lower quality), that Britain's fission reactors appear superior, in energy terms, in converting fossil fuel into electricity but are not necessarily net producers of energy in a fission-only economy and that North Sea Oil is 10% more energy intensive than delivered Middle East Oil (Chapman 1973, Leach and Slesser 1973, Price 1974, Lern, Odum and Bolch, 1974, Chapman, Leach and Slesser 1974). The nuclear option is severely limited by technical feasibility and cost and fusion power is not an option in combinating the very serious energy supply problems of the next 25 years.

The background of zero or even negative growth during the remainder of the 20th Century, implies increasing need for home production of minerals, food, fibre, energy and water, some of which will be required from the uplands.

5.2 The uplands have a considerable potential for providing igneous rock, limestone and sandstone minerals; the production rates of these minerals has been increasing substantially in recent years. Generally sites close to existing developments and those offering good access to major industrial centres will experience most pressure.

Slate production has gradually declined over the years and in 1972 was less than half the peak output of 123,000 tons. The persistence of business-as-usual conditions will probably encourage this trend - slate is very expensive, probably because of a high labour content. Should there come a time when high labour content no longer incurs the economic penalties we have come to associate with it, then there may be a significant revival of this industry.

The uplands were sources of iron, copper, lead, zinc, silver and gold in the past. Upland iron ore deposits are probably unlikely to receive serious attention in the future because of the substantial sources elsewhere in the country which provide $\frac{1}{3}$ (9 million tons) of national consumption, however one can never be absolutely certain. Developments which are seen to be in the 'national interest' could see activity in areas which we have recently come to accept as part of the national heritage.

5.3 The known world supplies of the following metal ores will be consumed in the time indicated at current extraction rates (Meadows et al 1972, NAS-NRC 1969, US Bureau of Mines 1970).

Copper - 32 years Lead - 22 years Zinc - 19 years
Gold - 7 years Silver - 12 years Tin - 13 years
Mercury - 9 years

These metals, which are essential catalysts for the existing industrial system and all of its conceivable developments for some generations to come, will no longer be available for growth priming uses or the replacement of dissipated metals in a time period which is less than that from the beginning of the Second World War. There is some scope for substitution. Aluminium (lifetime at current rates, 100 years) can probably replace copper in an increasing number of applications. "In the long term however it may be anticipated that aluminium ore, being a thin surface covering of the crust, might be used up before copper reserves in depth have gone" (Thomas S. Lowering, NAS-NRC 1969).

5.4 The transition to the new social/industrial order could undoubtedly see pressure to exploit what remains of Britain's non-ferrous ore reserves. The possibility of contributing more than a very small quantity to existing annual consumption of 546,000 tons of copper is doubtful. The total output of the Mona Parys Mine in Anglesey, from start to finish, was 130,000 tons. This is not necessarily a good indicator of kind of yields coming from massive open-pit mining proposals such as the surveyed in Snowdonia (Lovins, 1973). There still remain deposits of copper, lead and associated metals in many of the upland areas and one wonders how the exploitation of these deposits, using modern methods and machinery, would compare with limestone and slate workings.

5.5 Further expansion in the number of reservoirs is unlikely in the long-term, however the combined forces of institutional inertia and project momentum could result in the completion of some current plants which intend doubling volume of impounded water by 2000. It is unlikely that conceivable levels of economic activity will demand more water than is currently available.

5.6 Water is also a potential source of energy. It is generally assumed, that a very high proportion of potential water power has been developed, however, this is based on an economic criterion where plant opportunities under 250 KW, served by drainage zones under 500 Km^2 in area, are disregarded. By tapping the potential of smaller streams with simple and low-cost equipment, it has been estimated that total hydro-electric output could be raised to more than 40×10^9 kwh/year compared with 16×10^9 kwh/year at present. There is a growing interest in the use of small hydro-electric plants, partly precipitated by escalating electricity bills. When the regional water boards tailor down their charges to levels that the market can bear, it is likely we shall see their fairly rapid proliferation.

5.7 Farming is inherently a conservative profession, particularly in the uplands where the size of individual holdings and environmental constraints impose a severe limitation on output, and in bad years, can penalise heavily those who over-stretch their resources. Pressure on world food supplies in the immediate future will encourage, through the combined inducement of more expensive food and government incentives, the production for more food from all agricultural areas. Soil conditions in many upland areas do not permit ploughing, although there are a number of elevated areas where arable farming is possible which are suited to growing root crops for winter fodder. There are bound to be at least short term trends for grassland improvement. Although these improvements tend to be somewhat energy intensive, it is unlikely that energy will be so expensive in the next 10 years so as to exclude this possibility.

5.8 There will be attempts to increase the yield from grasslands by manipulating stocking densities, introducing hardier breeds of cattle or reverting to former practices of leaving wethers on the hills to fatten. Only time will tell how successful and sustainable any developments will be. "All the circumstances under which a man lives and acts, and all the laws of nature can never be known to him. He cannot hope to know them all merely in terms of scientific and text-book categorisations, and still less in terms of their manfold interactions. Sympathy, sense, and feeling must necessarily be brought into play to assist to fill the gaps. Thus the man who feels his way into understanding as well as learns his way is the only man competent to deal with the problems of life and therefore the problems of agriculture"(Wade 1975).

5.9 There have been a number of experiments recently, which are a little out-of-step with normal practice, and which seem to offer real opportunities of increasing upland yield. This is the practice of integrating forestry and agriculture and should appeal to ecologists as it runs counter to the trends of increasing monoculture. The advocates suggest it is proper to plant between 25% and 50% of fell-land with between 3 and 10 acre blocks of trees. It can entail considerable capital expenditure, fencing, roads to service the wooded areas. The roads have an added bonus in that they improve ease of access for agricultural management. Coupled with grassland reclamation it has been possible to keep more sheep on 500 acres than were formerly kept on 1000 acres (Parry 1974). It is a very long term enterprise; firs can be felled in 50-60 years and the hardwoods require even longer if the crop is sold for its constructional properties. It is possible that different cropping frequencies would be appropriate for crops which are intended as sources of fuel and fibre. For these uses one would be seeking management practice, species selection and species mix which maximum the average annual accumulation of dry matter. The evaluation of optimum strategies could be a long-term endeavour, perhaps as much as 50 years. Recent work in this area however suggests that much shorter timescales may be practicable (Earl 1975).

5.10 It is rather difficult anticipating the time when timber might be essential as an energy source. This very much depends on how the economics of coal extraction work out as it becomes increasingly necessary to mine more difficult seams, and, of course, on extraction rates.

Timber has long been a feedstock for the synthetic fibre industry. The recent escalation in the price of petroleum and petroleum products has renewed interest in the use of wood as a feedstock for plastics. The indications are that the existing waste from the harvest of British woodlands and forests could satisfy the feedstock requirements of a plastic industry comparable in size to that now existing (Goldstein 1975). Chemicals from wood are still derived in large quantity.

Britain currently imports virtually all the softwood and hardwood consumed. The amounts are approximately 1.7 million tons of seasoned softwoods and 140,000 tons of seasoned hardwood. It should be possible, ultimately, to supply all of this demand from indeginous forests, which, assuming suitable land can be found, would occupy about 700,000 acres assuming an average annual yield of 2.5 tons/acre/year. The existing forest area is some 5 million acres and one could anticipate an afforested area of up to 20 million or more acres if trees also became managed as an energy crop.

5.11 The residents of the uplands may soon, in large numbers, re-exercise their turbary rights. Peat is used widely in Shetland for domestic heating and some farmers in the Pennines have recently returned to this practice. The labour entailed in providing for one household for a year does not seem onerous, providing the turbary rights are close to a road and one has access to modern transport. Peat was used industrially in the early days of the industrial revolution in Britain but it is doubtful if there now exist any accumulations compatible with modern industrial requirements. In other countries, Eire, USSR, USA, peat is, or soon will be, a source of fuel for power stations, however the extraction rate of some of these schemes puts peat in the class of a minor non renewable energy source.

5.12 It is relatively easy estimating the lifetime of non-renewable resources at current or anticipated extraction rates and it does not demand intense observational powers to infer that very difficult, resource intensive projects will, assuming they are successful, take longer to perfect and deploy and place a bigger burden on a nation's economy than simpler more parsimonious projects. It is another matter altogether detailing, in chronological order the major events and turning points which will take us from the here and now through the inevitably turbulent years ahead. Peter Chapman in his book 'Fuel's Paradise' poses three interesting scenarios, the business-as-usual, the technical-fix and the low-growth, which make entertaining reading. All three scenarios support the general conclusions emerging from this paper, simply because both business-as-usual and technical-fix scenarios are resource intensive and resources are very finite (Chapman 1975).

But supposing a reasonably reliable and detailed economic scenario could be forthcoming, translating this into the detailed implications for agriculture is extremely difficult.

We do not know the following:-

1. The potential of the land for different kinds and degrees of agricultural production.

2. The resilience of practices which achieve maximum output.

3. The direction and rate in which dietary habits will change under pressures of price and shortage.

4. The influence of an evolving EEC agricultural policy.

5. The manner in which the growing world food problem will move, and whether our traditional overseas suppliers can continue to support us.

6. The effect of eliminating waste in food distribution, marketing and preparation (some observers estimate that 30 to 35% of all food is wasted, implying that the existing national agricultural output could supply 80% of the national diet, as opposed to 55% now).

7. The effect on the return to allotment ownership will have on demand in the shops.

8. Is the yield from allotments on average, better or worse than that in commercial horticulture, and is it more or less energy/labour intensive?

9. Will recent trends where agricultural units have tended to grow considerably in acreage but reversed in response to an awareness that smaller farms have a bigger output per unit area (Waller 1972).

10. Will Britain's population continue the decline of recent years, will the rate of decline change, and what will be the level at which the population stabilises?

The above list is but a selection of a long list of unknowns. The future will always be unknown and unknowable. All the signs indicate that we are about to experience the most rapid transition any culture has been obliged to endure.

6. CHANGES IN UPLAND LAND USE

6.1 The ecological effects of the various types of upland land use and of the management practices involved in each use have been reviewed in an attempt to determine the change in vegetation and landscape that would occur given a change in a practice.

AGRICULTURE

6.2 In the uplands the main agricultural practices which shape the landscape are grazing by sheep and cattle. The influence of these animals and the associated practices vary with the type of vegetation. Vegetation is taken to mean an assemblage of plants present at a particular place and time and is the result of interaction between a series of biotic and abiotic factors (Fig. 4). It is important to recognise that the vegetation is in a dynamic state and is liable to change as a consequence of ecological as well as man-induced changes. Vegetation changes may be in 1) performance in individual species without change in floristic composition but with alteration of appearance, e.g. through fertilisers or grazing 2) slight or marked changes in the species composition 3) seral or developmental change related, for example, to burning or to soil development. These changes may or may not be reversible and it can be argued that it is impossible to return to the original state.

6.3 The description and classification of vegetation is a subject that has caused much discussion between ecologists. For the present purpose a generally applicable scheme is required that

1. comprises readily recognisable types

2. related to published information.

Nine main categories are recognised for upland Britain, with subdivision shown in brackets

1. Woodland (Plantation, Semi-natural coniferous and Mixed deciduous)
2. Scrub (Evergreen scrub - <u>Ulex</u>; <u>Juniperus</u>; <u>Sarothamnus</u>; Mixed deciduous scrub - <u>Quercus</u>; <u>Betula</u>; <u>Alnus/Salix</u>; other).
3. Dwarf shrub (<u>Calluna</u>; <u>Calluna</u> with other dominants; Ericaceous heath; <u>Vaccinium</u> heath; Montane dwarf shrub heath).
4. Mire (<u>Sphagnum</u> rich; <u>Trichophorum</u> rich; <u>Eriophorum</u> rich; <u>Molinia</u> rich; <u>Juncus effusus/conglomeratus</u>; Dwarf shrub).
5. <u>Pteridium aquilinum</u>
6. Grassland (<u>Agrostis-Festuca</u>; <u>Nardus</u>; <u>Molinia</u>; <u>Juncus effusus /conglomeratus</u>; <u>Juncus squarrosus</u>; limestone grassland)

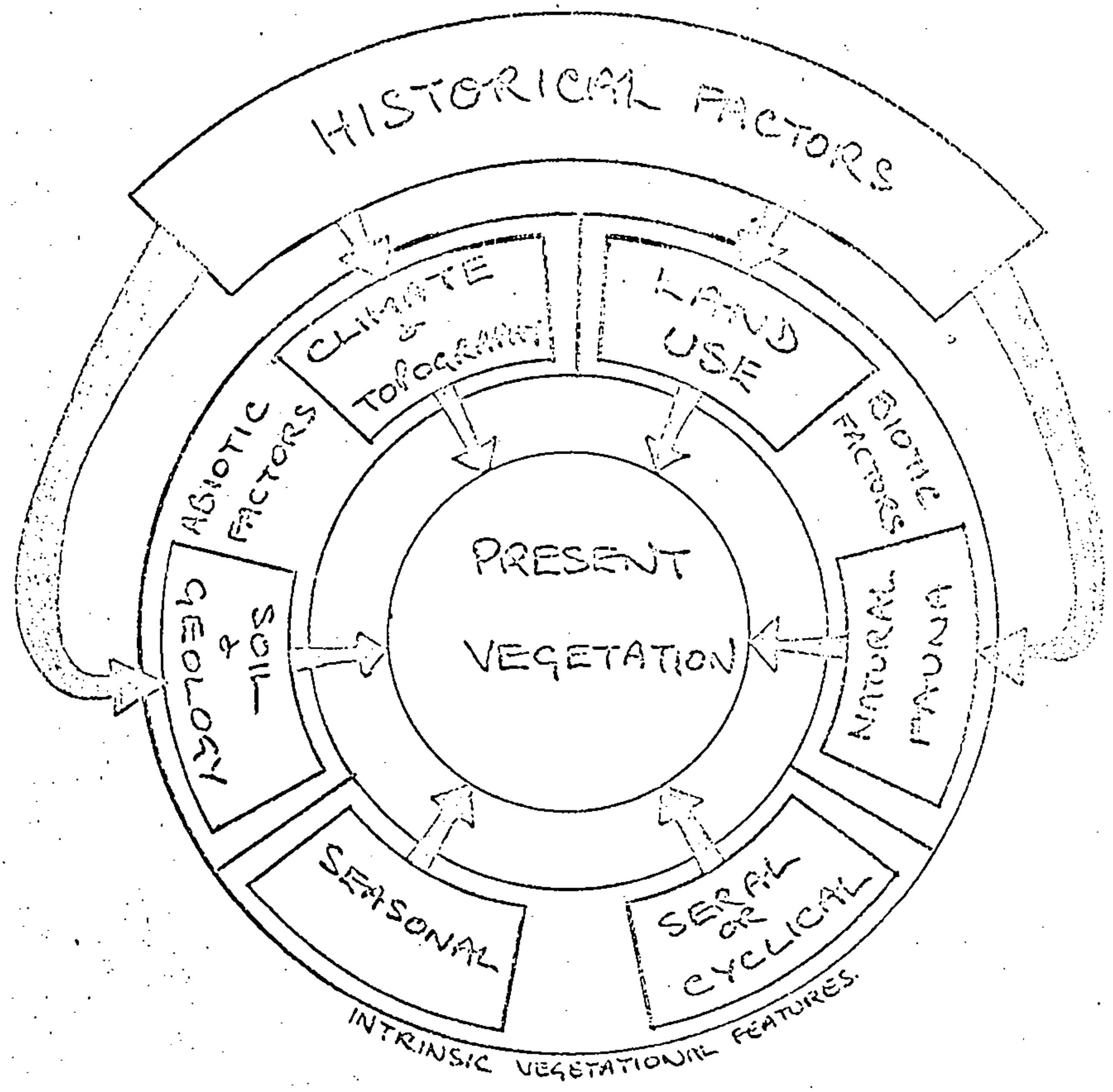


Fig. 4. INTERRELATION OF FACTORS PRODUCING PRESENT DAY VEGETATION

7. Rock and scree

8. Montane

9. Aquatic

The ecological distribution of some of the main categories of vegetation are shown in Figs. 5 and 6.

6.4 Grazing is probably the most important single agricultural activity influencing vegetation but evidence of vegetation changes resulting from variation in grazing pressure is very limited. Detailed information on the effects of other management practices - pasture improvement, drainage, herbicides is inadequate but burning has been intensively studied.

6.5 The marginal agricultural areas of the uplands, allotment and rough grazing, are most subject to change in management. The natural woodlands have been subject to decrease and grazing pressures for many activities and, although data are inadequate, there appears to be a continuing decline in numbers and area of small deciduous woodlands. Many of the existing scrub areas appear to be in balance with grazing and other site factors. Reduction in grazing will tend to result in mixed deciduous woodland but in most places an increase in grazing, especially by cattle, deer or ponies will produce dwarf shrub or grassland vegetation.

6.6 Calluna dominated vegetation is associated with low levels of plant nutrients, soil pH of 3.5-6.7, an oceanic climate, protection by snow in northern and mountain areas (Beijerinck 1940). Development to scrub or woodland is prevented by grazing, fire or exposure. An increase in grazing pressure results in the development of Festuca-Agrostis, Festuca-Nardus, Juncus squarrosus or Eriophorum dominated vegetation depending on soil moisture and nutrient conditions. The dwarf shrub vegetation is relatively stable whilst management continues but a change in management can have a marked effect on the landscape.

6.7 Mire vegetation, which overlays with dwarf shrub types, is of low agricultural potential and although it provides "early bite" for stock is rarely subject to improvement. The most likely change on such sites is through afforestation, or peat erosion. Erosion may be related to intensity of land use but is also part of an ecological succession.

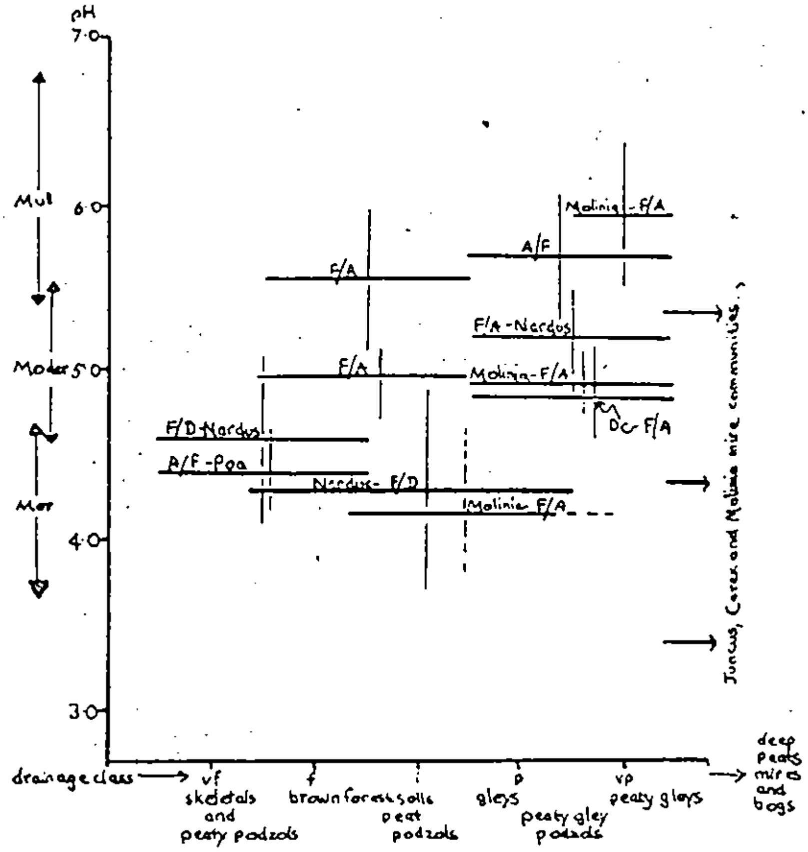


Fig.5. The inter-relationships of certain forest zone grassland types of southern Scotland in terms of soil pH, drainage class, and profile type. The grassland types range from Festuca ovina/Deschampsia flexuosa dominant grass heaths (F/D) to various Festuca-Agrostis (F/A, A/F) types and types dominated by Deschampsia caespitosa (De) or Molinia caerulea. Where versions of these types rich in Nardus stricta can occur, this species is given last. Where it is always dominant it is given first.

(from Hunter, 1964)

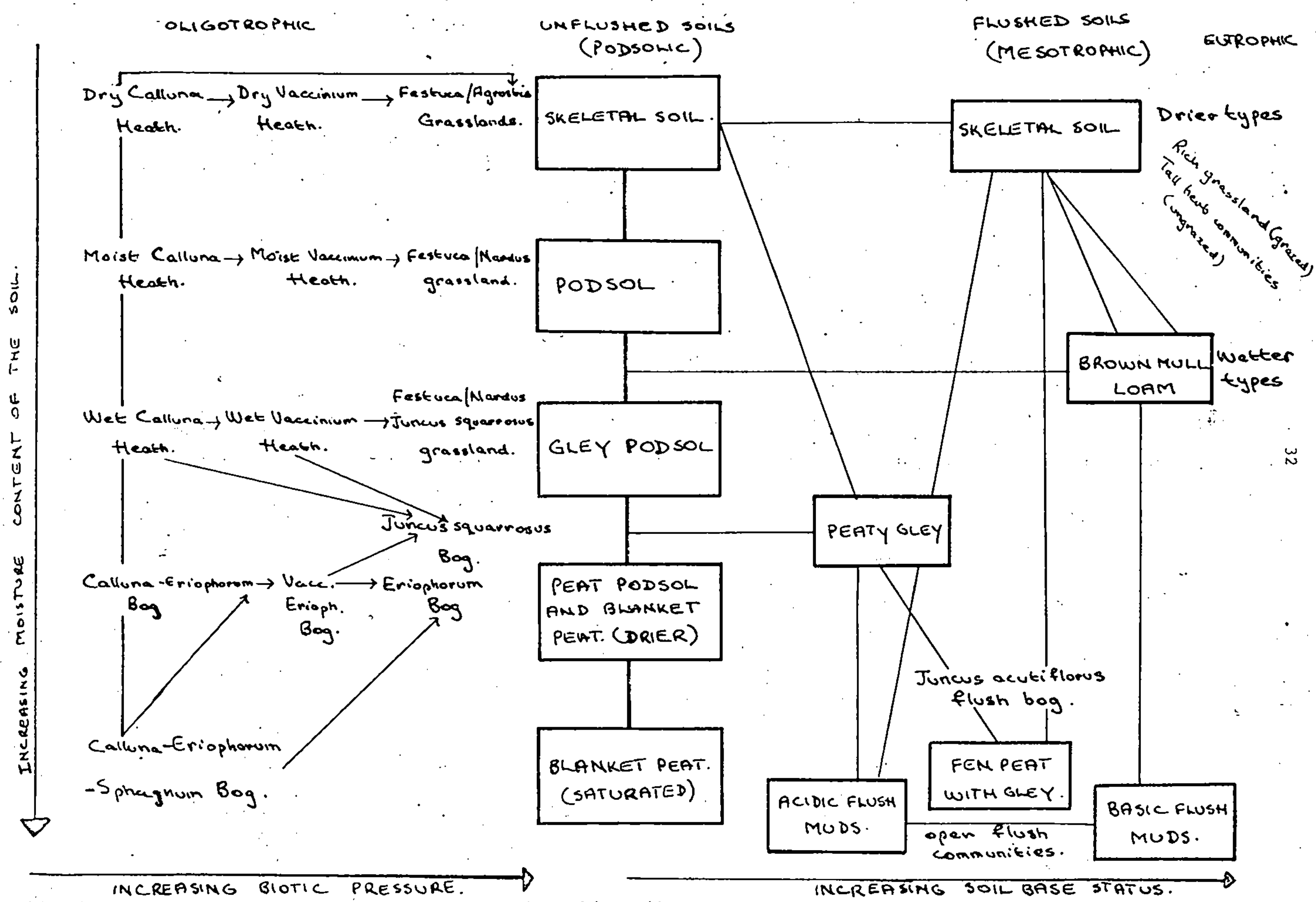


Fig. 6. The relationships between grasslands, heaths and bogs (from Ratcliffe, 1959)

Dwarf shrub provides an example of a vegetation produced by mans activity and followed by a change in soil conditions. Thus a removal of management will probably not result in a return to the previous vegetation.

6.8 Bracken (Pteridium aquilinum) is associated with relatively base-rich well drained soils and its spread in the last 150-200 years probably results from a reduction in numbers of cattle, ponies, and wether flocks and recently, reduced cutting for bedding (Nicholson 1960), Jones and Manton 1972, Pearsall and Pennington 1973). Asulam now provides a means of control or eradication, particularly when associated with stock control, and bracken areas will tend to be replaced by Festuca-Agrostis grassland with a marked visual change.

6.9 Upland grasslands are largely maintained in the current state through management, balanced against soil and climate. Increased grazing pressure in many areas is considered to be responsible for an increase in Nardus and Molinia but improved stock control and pasture improvement, is associated with increasing fine swards of Festuca and Agrostis. Decline in grazing intensity tends to result in an increased dominance of fast growing species. e.g. Deschampsia and development of dwarf shrub, scrub, and eventually woodland conditions at lower altitudes. On wetter pastures, reduced management generally results in a short term increase in tall Juncus and long term development of mire vegetation. The pasture improvements recommended by HFRO and other organisations produces obvious changes in sward appearance but it is very difficult to predict the consequences of small changes in stock numbers on rough grazings, despite the large volume of literature on grazing of upland grasslands (Newbould 1974, 1975, Munro 1973). Scree, rock and montane vegetation are of very limited agricultural importance and although their development may be influenced by grazing, recreational pressures are much more important.

FORESTRY

6.10 From a review of available data on the forest area of England and Wales it is not possible to extract anything but the crudest estimates of forest area in the uplands, about 450,000 ha (Table 3). The statement is frequently made that most new planting is taking place on the uplands and on this basis afforestation in England and Wales is apparently continuing but at a reducing rate.

Table 3. Estimated areas of woodland classified by types, species, ownership for England and Wales, 1947 and 1968, UPLANDS only. (th. hetares)

ENGLAND AND WALES, UPLANDS Type, species	1947 Forestry Commission	1947 Private woodlands	1947 Total	1965 Forestry Commission	1965 Private woodlands	1965 Total
Coniferous High Forest:						
Scots pine				20.8	18.5	39.3
Corsican pine						
Sitka spruce				109.1	19.5	128.6
Norway spruce						
European larch				24.4	20.7	45.1
Japanese and hybrid larch						
Douglas fir				7.8	3.8	11.6
Other conifer				21.8	2.6	24.4
Total coniferous high forest	60.0	32.7	92.7	183.9	65.1	249.0
Broadleaved High Forest:						
Oak				5.1	24.1	29.2
Beech				6.9	5.4	12.3
Ash						
Sycamore						
Poplar						
Birch				3.5	23.5	27.0
Sweet chestnut						
Elm						
Other broadleaved						
Total broadleaved high forest	2.1	79.5	81.6	15.5	53.0	68.5
Total high forest	62.1	112.2	174.3	199.4	118.1	317.5
Coppice	0.8	10.2	11.0	0.8	1.4	2.2
Scrub "Blank"	3.5	91.1	94.6	- 6.6?	83.8	83.2
TOTAL	66.4	213.5	279.9	199.6	203.3	402.9

The Forestry Commission, as the source of the data, can provide more detailed information about the upland forests e.g. total area of forest in the uplands (or areas afforested since about 1947) and its distribution regionally; species composition by area with regional differences; age classes; future timber production from the upland.

6.11 The most serious objection to afforestation in the uplands is that conifers might cause soil degradation. The evidence is conflicting but an increase in accumulation of acid litter appears to be the most important change. Some available information of species differences is presented and future choice of species is discussed; but in the uplands it seems inevitable that Sitka spruce and Lodgepole pine will only lose their places as the primary species through widespread disease or other natural catastrophe which is not amenable to control. The methods of managing a crop may also affect site factors. The effect of rotation is illustrated and recent trends towards shorter rotations noted.

6.12 In the establishment stage, a very high degree of soil preparation is nearly always involved. This can be expected to become even higher with improvements in machinery, with consequently increased disturbance and alteration of site hydrological and ecological factors. Fertilization is increasing and forestry appears to be changing from a low input/low yield to a high input/high yield industry. Differences between extensive and intensive forestry and their effects would probably be worth further study.

There are indications, abroad as well as in Britain, of attempts to shorter rotations by intervention in the early part of the thicket stage which, traditionally, has received little active management. Normally, thicket has the strongest influence on site factors which have the quickest response to change, e.g. climate, and intervention at this stage must lessen the impact of the thicket stage on the site (Fig. 7).

With this type of forestry, no further management is performed until felling of the crop; under extensive forestry, little or no management takes place after establishment; with intensive forestry, management of the woodland stage may include brashing, pruning and thinning. The most important one is thinning; apart from providing a substantial proportion of the crop, thinning determines the density and structure

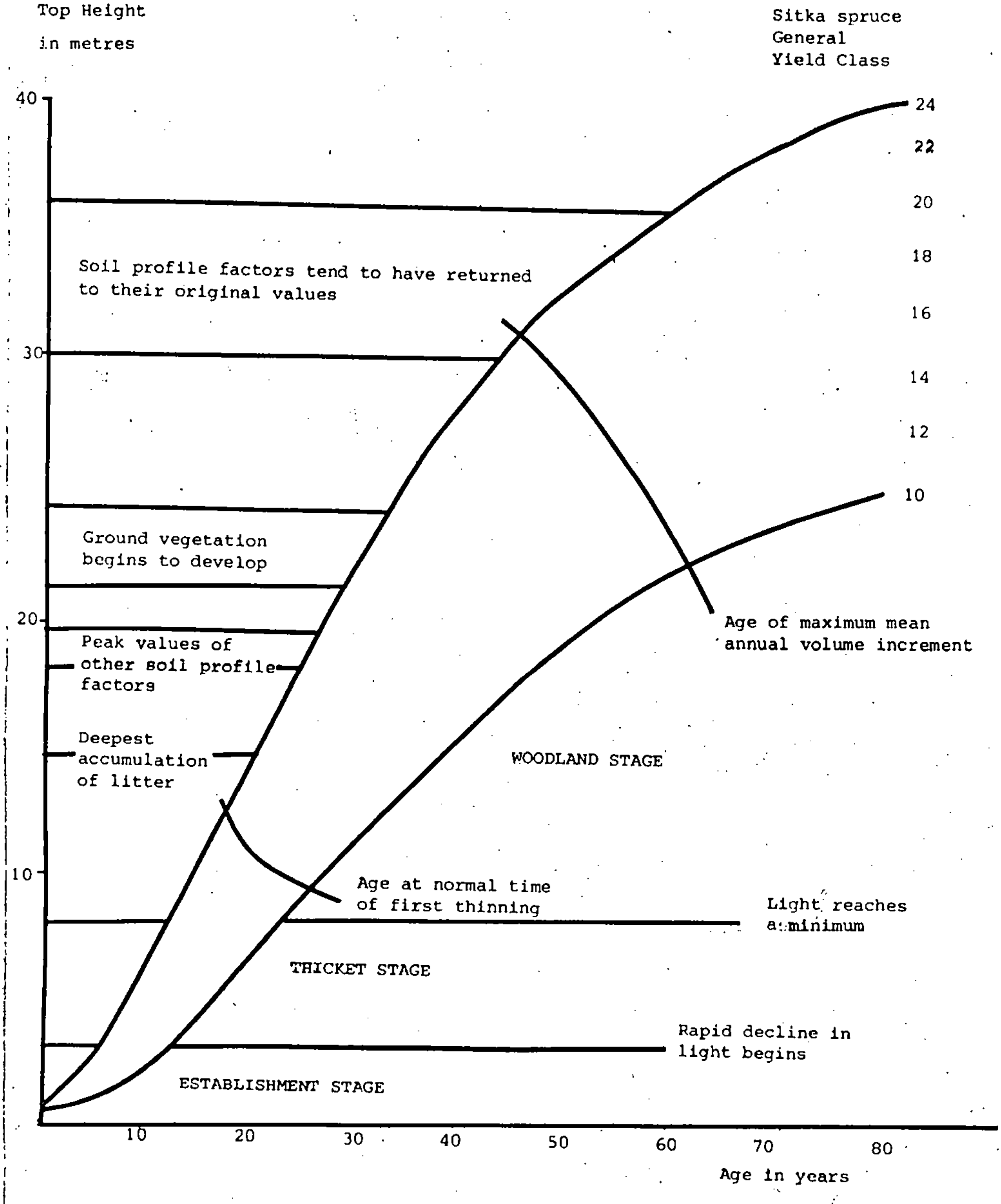


Fig. 7. Yield Class and Stand factors (Page, 1968, Forestry Commission 1971)

of the stand and can influence site factors to a great degree. Very little quantitative information about stand structure as influenced by thinning appears in the literature; the Forestry Commission is a probable source of such data from their thinning experiments.

6.13 The end of the rotation is again marked by disturbance. Under the normal practice of clear felling, the degree of disturbance is high but other methods of felling the crop involve more than one felling and removal of the canopy is in stages. The change from woodland to open conditions is less rapid. There will be more scope for using these methods in relation to landscaping but there may also be a place for planting new crops in the shelter of old ones in the uplands. In any event, it is highly probable that as the new forests mature, differences in rates of growth due to site differences, will give a wider range of size classes and improve the forest structure.

Possible future demand for forest products will influence forest management and this aspect is being investigated.

AMENITY AND RECREATION

6.14 A review of literature, and forecasts of national economy, indicate that recent increases in popularity of relatively inexpensive leisure pursuits such as walking, camping, climbing, pony trekking, nature studies and water sports, will continue. In contrast pursuits involving extensive travel and other costs will not increase to the same extent. The result is likely to be increased pressure for cheap accomodation especially camping, and an increase in income to major upland areas.

6.15 The disturbance to agriculture by visitors can be reduced by access agreements and maintenance schemes, such as the Upland Management Experiment. Forestry can provide an increasing outlet for recreation especially as forests mature but the extent to which timber production is lost is deleteable. In at least some areas there will be a need to substantially modify land management to cater for changes in demand for natural products and to cater for amenity and recreation interests. Such modification will be of fundamental rather than superficial character and will be dependent on Natural and Regional policy decisions.

WATER

6.16 There are approximately 300 lakes and reservoirs with a surface area exceeding 25 ha in upland England and Wales and an estimated four times as many smaller water bodies marked on the one inch to one mile maps. The majority of the larger waters are reservoirs and their greatest concentration is in uplands adjacent to the industrial areas of Yorkshire and Lancashire (Fig. 8).

6.17 The pattern of long term developments in the water-supply industry is not clear, partly because of difficulties in predicting future demand and supply and partly because of technical uncertainties in the operation of schemes involving abstraction from the lower reaches of rivers. There is a general tendency for new schemes to require larger reservoirs than in the past and they may well be located in National Parks and other amenity areas rather than involve the flooding of valuable agricultural land (Tables 4 and 5). The value of reservoirs as man-made lakes rather than storage tanks for water and their potential in landscape design and recreational use is stressed.

6.18 Uplands can contribute a high proportion (c 60%) of the total flow in an entire river basin so that changes in the quantity of runoff from uplands is important. This is less true of the chemical status of the water - changes in the lower reaches may be much greater. Large scale afforestation appears to be the most dramatic land use change affecting freshwaters. Existing knowledge of the effects of other land use changes is not always adequate for effective decision making. An outline of the interactions between upland land use and water is given in Fig. 9.

6.19 Many of the topics related to viewing reservoirs as man-made lakes and the implications of water development schemes for freshwaters are the subject of existing and proposed research and, therefore, need less attention than the consequences of land use changes.

Traditional scientific investigation of the effects of land use changes require experiments on a considerable scale with adequate controls so that land use effects can be separated from climatic and other trends, they are expensive and they take a long time to produc any

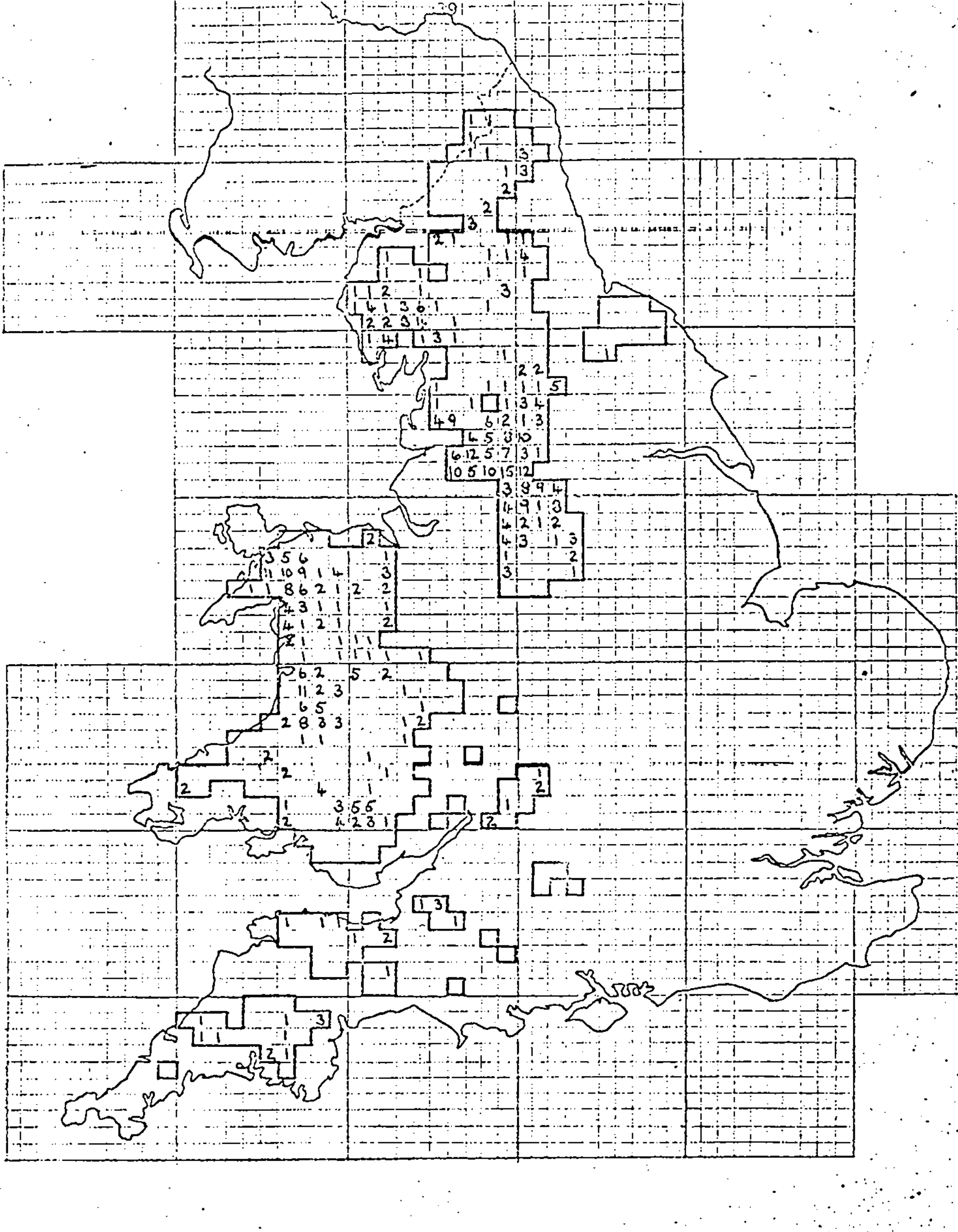


Fig. 8 Distribution of lakes and reservoirs in uplands, recorded on 1:250,000 maps.

Table 4. Strategic source developments within uplands recommended for implementation by 1981

(a) new reservoirs

No.	Scheme	N.G.R.	method of filling	method of supply	Water surface area km^2	Top water level feet above O.D.
1	Brenig	SH 97 54	natural	regulation of R. Dee	4.9	1237
2	Kielder Water	NY 70 87	natural	regulation of R. Tyne	11.0	607
3	Carsington	SK 24 50	pumping from R. Dove	regulation of R. Dove	2.8	650

(b) existing reservoirs enlarged

No.	Scheme	N.G.R.	nature of change	method of filling additional storage	method of supply for additional yield	additional water surface area km^2	new top water level feet above O.D.
4	Stocks	SD 71 54	direct supply to conjunctive use	natural	conjunctive use with abstractions from Lune, Ribble and groundwater	0.5	620
5	Grimwith	SE 06 64	compensation releases to regulation	natural	regulation of Wharfe	1.5	948
6	Craig Goch	SN 75 86	added storage supports regulation	natural gravity diversion from Ystwyth and pumping from Wye and Dulas	regulation of Severn and Wye	6.2	1224

Table 5. ADDITIONAL UPLAND RESERVOIR SITES CONSIDERED IN WATER RESOURCES BOARD REPORT

No.	Site	Grid Ref.	Top water level feet above O.D.	Water Surface Area km^2
(a)	now reservoirs			
7	Irthing	NY 64 69	725	9.7
8	Borrowbeck	NY 59 01	899	2.3
9	Killington	SD 59 89	676	8.4
10	Farndale	SE 66 97	568	2.0
11	Brund	SK 10 61	840	2.1
12	Gam	SH 98 07	902	5.0
(b)	enlargements of existing reservoirs			additional water area km^2
13	Haweswater A.	NY 50 16	850	0.9
	B.		905	1.6
14	Celyn	SH 87 40	1030	1.2
15	Vyrnwy	SJ 01 19	902	1.9
16	Clywedog	SN 91 87	974	2.5
17	Manty-Moch	SN 75 86	1155	1.8
18	Craig Goch	SN 89 68	1224	6.2
19	Talybont	SD 10 20	620	1.5
20	Brianne	SN 79 48	965	3.6

land use causes \ consequences			changes in water quantity			changes in water quality				changes in habitat structure		
			absolute quantity	time distribution of runoff	sediment dynamics	dissolved nutrients (N and P)	poisons	suspended solids	organic matter/ deoxygenation	result of quantity changes	result of quality changes	caused directly by land use
Agriculture	soils	drainage		1								
		burning				2		2				
	vegetation	reseeding				3						
		fertilisation										
		animal husbandry					4					
Forestry	site preparation	ploughing/planting			5			5				
		fertilisation				5						
	stand management	thinning/clearing roads etc.										
		brashing										6
		established forest	7			7				7		
		felling					8					
Other		quarrying/ construction						9				
		recreation					10		10			10
		peat cutting		11								

Fig. 9. The interaction between upland land use and freshwater

answers. While they are valuable, there is a possible alternative and that is to use the current activities themselves as the experiments. This is essentially a system of monitoring changes and the key scientific problems relate to knowing what to look for and how to measure it.

This inevitably raises the question of the exclusion of land use changes from planning procedures. Not only is it necessary to know what changes are taking place but the essence of a permissive monitoring system is that an activity is allowed until it is shown to be harmful. This implies some control of timing, e.g. that vast areas should not be drained all at once, before possible consequences for the area in question have been demonstrated. There is also scope for improved landscape design in relation to land use changes, planting policy, for example.

MINERAL EXTRACTION

6.20 A review of the main minerals extracted from hills and uplands (china clay, igneous rock, limestone, slate, sandstone and vein minerals including tin, copper, lead, silver zinc, barytes and fluorspar) indicates that in England about 8,500 ha are affected by active workings, an extra 1,400 ha are damaged from past use and 10,000 ha are covered by planning permission for mineral extraction. Comparable data are not available for Wales but approximately 6,000 ha are concerned with current mineral extraction out of a total of up to 20,000 ha involved in past and present use.

6.21 The existing distribution of mineral extraction is summarised and exploration for the higher priced minerals or minerals which are used in very large quantities, is increasing. This trend is well summarized by Blunden (1975) who indicates clearly that future extraction is likely to be envisaged in Cumbria (Lake District), south-west Northumberland, west Durham, Cleveland (North Yorks Moors), Derbyshire (Peak District), Salop, south Devon (Dartmoor), Cornwall, Gwynedd (Snowdonia) and north Dyfed.

6.22 Extraction of certain minerals is decreasing or ceasing because (i) relatively cheap supplies are available from abroad or (ii) because cheaper substitute materials have become available, within Britain or (iii) easily workable reserves have become exhausted. Examples include: for (i) and (ii) the decline in haematite extraction in Cumbria, 287,000 tonnes extracted in 1964, 145,300 tonnes in 1969 (Blunden, 1975); for (ii) the reduction in slate output from 515,000 tonnes in Wales in 1898 to 20,000 tonnes in 1973 (Healing and Harrison, 1975; for (iii) the decline in U.K. lead ore production from 75,929 tonnes in 1877 to 5,456 tonnes in 1974 (Healing and Harrison, 1975).

6.23 Extraction of certain minerals is increasing appreciably, either because (i) new large economically workable deposits are being exploited, for example potash in Cleveland (Blunden, 1975), or (ii) an increase in demand has occurred as a result of new types of industrial processes or products. Examples are the increasing use of fluorspar as a result of a change in steel-making techniques, and of increased production of fluorocarbons, aluminium, and urethane foams or, the huge increase in use of aggregates because of increased use of concrete and very active road construction. Increased production may also occur because of changes in the world and the British economic climate. The revival of the tin industry in Cornwall is one example. Discovery of new deposits of a mineral combined with high world prices may lead to exploitation as it nearly did for copper at Coed-y-Brenin in Snowdonia.

6.24 There are strong tendencies for (i) the closing down of some smaller mining and quarrying companies, (ii) amalgamation of other smaller companies to give large concerns and (iii) concentration of extraction at the larger quarries and mines nearest to the points of maximum demand, or nearest to main roads or railways. Examples include (i) the reduction in numbers of slate quarries in Wales from 18 in 1945 to 6 in 1971 and, in china clay extraction a reduction from about 25 firms in 1948 to 13 in 1969, (ii) the domination of the aggregates market by three firms, Tarmac Ltd., Ready Mixed Concrete Ltd., and Amey Roadstone Corporation Ltd. (Blunden, 1975) and of the china clay industry by English Clays Hovering Pochin and Co., (iii) the creation of large limestone quarries supplying many different types of consumer from one source, e.g. I.C.I. Tunstead quarry in Derbyshire, which supplies chemical-grade limestone to ammonia-soda works and aggregates for building purposes (Blunden, 1975).

6.25 The highest possible use is being made of the material extracted from each mine or quarry. Examples include use of waste slate as road infill or as slate powder and granules, production of barytes and lead as by-products of the fluorspar industry and the use or the strong likelihood of use of quarry or mine waste produced by previous inefficient extraction e.g. by the tin industry in Devon and Cornwall and by the haematite industry in Cumbria (Blunden, 1975; Zuckerman, 1975).

6.26 Firms are considering seriously the extraction of low-grade ore using open-cast workings which are considered to be more economical than mining but are more destructive environmentally (Blunden, 1975). The recent interest of Rio-Tinto zinc in copper ores near Coed-y-Brenin in Snowdonia (Blunden, 1975) is one example. Reworking of mine waste such as occurs near tin mines in Cornwall (Zuckerman, 1972) is a similar phenomenon.

6.27 Increased importance, is being attached to environmental considerations by mine and quarry owners and managers either because of pressure in amenity organizations or the public in general or because of legislation requirements. This is reflected in and a reflection of the numerous relevant articles which have appeared recently in newspapers (Hilldrew, 1974 and 1976) and trade journals (Anon., 1973; Harris, 1975), publications by amenity and conservation bodies (R.G.W., 1974; Toghill, 1975), special reports prepared by or for local authorities (Somerset County Council, 1971; West Riding of Yorkshire County Council, 1973) and concern for the effects of mineral extraction at a national level (D.O.E., 1976). One controversial aspect here is the feasibility of extracting more minerals, particularly those such as limestone which are in heaviest demand, by mining rather than by quarrying. Roberts et al (1972) write: "It can be said with some justification that sufficient extraction sites are currently being granted reasonable planning permission to ensure meeting the demand for industrial and construction minerals.

One may, therefore, conclude from these considerations that, although in the very long-term underground extraction of common minerals can become both feasible and desirable, the period up to the year 2000 is not likely to see circumstances forcing such development to any great extent. And without such stimulus there is little prospect of diverting either capital investment or research and development effort on a large enough scale to alter the situation".

6.28 Mining is said to be two - five times more expensive than open quarrying (Sources quoted by R.G.W., 1974) but the C.P.R.E. argues from American evidence that the difference in cost is very much smaller and mining would offer the advantages of less habitat destruction, less local noise and dust, the possibility of locating mines near to heavy demand or to main railways and the creation of underground caverns which could be used not only for waste from mining operations but for other industrial and domestic waste, and a variety of storage and industrial purposes (R.G.W., 1974).

6.29 The effects of mineral extraction fall into three categories a) destruction of a resource b) production of new habitats c) effects on surrounding areas including visual effects. Mineral extraction in general, unlike most other types of upland land use, consumes land and sterilises it for many years unless rehabilitation is incorporated in the planning stage. Rapid rehabilitation with imported soil and planting, but less expensive methods using native vegetation, have been rarely used. The waste from mineral extraction represents the creation of new habitats but these are usually colonised very slowly because of various biological, chemical and physical features of the "soil", (Goodman 1974). Flora and fauna development in old quarries and abandoned mines and tunnels can provide a range of species absent from the original site (Ratcliffe 1974). Dispersal by air and water of particulate and dissolved material can cause pollution problems in areas adjacent to the workings but these effects are usually recognised only when changes are dramatic, more subtle changes being unnoticed. Visual effects of extraction have received considerable attention and there seems to be advantages in the current trend towards large extraction sites owned by large firms. In this way the effects are concentrated into one area and larger firms tend to employ specialists to ameliorate ecological and visual impacts of the extraction.

PEAT

6.30 Upland peat, deeper than 50 cm, covers at least 294,000 ha of England and Wales. Peatlands are used currently primarily for agriculture and forestry, and only about 0.01% of the total peat of England and Wales is harvested annually. Commercial extraction, mainly for horticultural purposes, as a domestic fuel and for various industrial uses, may increase as lowland peat supplies become exhausted.

OTHER USES

6.31 Approximately 286,000 ha of land in England and Wales appeared for defence purposes of which about a quarter is in the uplands. The total area is tending to decline, high conservation value of MOD levels is now recognised and may influence future management.

Underground gas, oil and electricity systems, although laid mainly in the lowlands, often pass through uplands, but the importance and persistence of disturbance effects have not been examined.

7 UPLAND LAND USE AT A REGIONAL AND LOCAL LEVEL

7.1 The previous chapters have described uplands and their use in general terms and at a National level, but land use planning occurs mainly at Regional and Local levels, and landscape is perceived in the range of 1-10 km, occasionally 50 km. Therefore we require techniques to survey, characterise and plan on a unit of about 1 km^2. Many regions studies describe plans for development and there are a multitude of local studies of farms, valleys or parishes. We have not attempted to digest and compare those but have concentrated on an examination of the potential of a multivariate method of land classification (Bunce, Morrell and Stel, 1975) based on readily available information from maps. The land classes derived from map attributes show major environmental divisions within an area which can then be used to stratify subsampling for particular features which are required, e.g. vegetation or current land use.

7.2 The map attributes used do not include information on soils, and it was therefore questioned whether or not the resulting classes could be used as a basis for agricultural or forestry land capability assessment. There are few soil maps for the uplands and it was decided to examine the application of the approach in two areas. 1. Cumbria where soil data were few; 2. Snowdonia where, for a particular area, soil, as well as vegetation and other map details were available, thus allowing a comparison of the classes derived from map attributes with detailed ground survey obtained by more traditional methods.

7.3 Certain specific areas of environmental surveys have proved intractable by traditional methods - in particular, that problem of a land classification. Here there are no readily observed associations between a dependant and independent group of variables, as between plants and soil; and moreover, there are no readily discernible units on the ground. Rather, there is a complex underlying series of factors resulting in an overall expression of their interactions without a simple mode of definition. As a result, whilst gross features, such as glacial valleys, may be interpreted it has rarely been possible to classify whole landscapes by a generally accepted system.

It was during the application of multivariate methods to such data, that the present study evolved. The basic principle is that the underlying features of land are reflected in observable characteristics recordable from maps. Analyses of these data can then provide a structure on which to base ground surveys of particular biological aspects, such as vegetation or land use. Because the overall relationships within the study area are known, a limited representative sample may be taken, which can then be referred to the whole population. In this way a small sample can be used for intensive surveys which may then be used to predict what will be present elsewhere.

CUMBRIA

7.4 The classification in Cumbria is used as a basis for examining a number of land use and landscape features, to compare areas, and to indicate areas where change in land use might be expected. The study is exploratory and not definitive, many further questions may be asked of the information.

The multivariate classification is being used by Cumbria County Council as a basis for part of their Structure Plan. The results of the study, carried out in conjunction with ITE, must be treated IN STRICT CONFIDENCE until the publication of the Structure Plan.

7.5 In the Cumbria survey a 1 km grid square was adopted as this provided a convenient and useful scale at which to examine units of land. The advantages and disadvantages of this system are summarised below:-

Advantages	Disadvantages
Good scale for ground sampling and for mapping on a county basis.	Square boundaries may give artificial combinations of attributes.
Previous experience suggested that the scale was suitable.	Complete cover not possible at primary analysis stage.
Detailed surveys of units, such as valleys, possible.	
A reference system is provided that fits into a national grid.	

The 1 km squares should be considered as abstracts in the same way that quadrats are used in vegetation surveys, and are not necessarily recognisable finite units in themselves.

7.6 Since all squares could not be recorded, the analysis was based on the centre square of groups of nine squares, giving an approximately 11 per cent sample. The data recorded from these squares were 152 attributes, described by Bunce (1975), and also 30 geological series records taken from the ¼" geological map. These data were analysed, by indicator species analysis, to give 16 types.

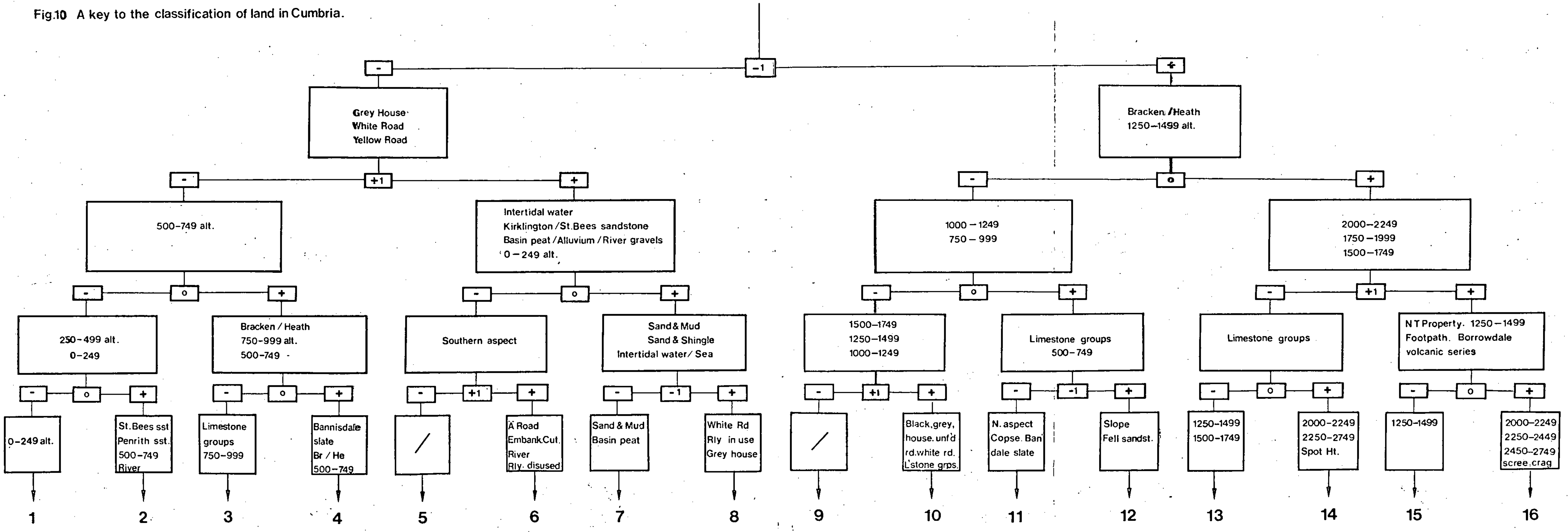
Indicator species analysis (Hill et al 1975) is a divisive, polythetic numerical procedure that incorporates a key that enables new data to be assigned to the classifactory framework. First, a one dimensional reciprocal averaging ordination is computed. The samples are then divided into two groups according to whether they fall on one side or other of the centre of gravity of the ordination. Five indicator attributes are then identified which discriminate as well as possible between the two groups of samples. The balance between the indicator attributes provides a key for the identification of further samples. In the present case the residual 89% of squares were assigned to their appropriate positions in the classification by the use of the key given in the hierarchy of Fig. 10.

7.7 The classification of the map data may be interpreted in two main ways:

a) Direct interpretation of the indicator attributes in ecological terms.

b) An examination of features, both environmental and other habitat attributes, common to the classes of squares.

Fig.10 A key to the classification of land in Cumbria.



The first division in the hierarchy is related directly to features relating primarily to lowland as opposed to upland, with attributes relating to habitation and human development on the one hand, as opposed to altitudinal features on the other. Within the lowland division, the next separation is between higher land on the margins of the fells as opposed to features relating to the coastal plain. The upland division is separated into the intermediate fells as opposed to the high fells of the central Lakes and Pennines. At the third level final divisions are made between these major groups with, for example, the coastal squares (types 7 and 8) being separated and the central Lakes fells (types 15 and 16) from the Pennines (types 13 and 14).

7.8 The distribution of the types of intermediate and upland square in Cumbria is shown in Figs. 11 and 12 and the frequency of the types in Cumbria is given in Table 6

7.9 The classification is a basic framework on which a range of environmental ecological parameters can be sampled. Evidence from experience with the classification, suggests that it is strongly related to underlying patterns in land forms and shows quite subtle differentiation between different types of land. Some types are more heterogeneous than others, in terms of the degree of contrast present but this feature is not a drawback in that some landscape types are inherently more variable than others. Because of the incorporation of basic information, the classification types have many common features relating to agriculture, land use and visual appearance, which provide the basis for sub-sampling.

The system is capable of further development for monitoring, and studies are at present taking place in this direction. To summarise, the main objective of the analysis of the map data is to provide a sound framework on a general scale for sampling on an intensive scale, that could not otherwise be carried out on a County scale without years of work.

7.10 A number of squares randomly selected from each of the 16 map classes have been sampled for plant species composition and cover and habitat types. From this the expected frequency of occurrence of individual species, e.g. bracken or heather can be plotted and the vegetation data are being analysed to determine the main species associations. Additional information from sub-sampling of soils helps to build up a picture of the ecology of each map class. For example of the

Fig. 11. Distribution of classes 1-8

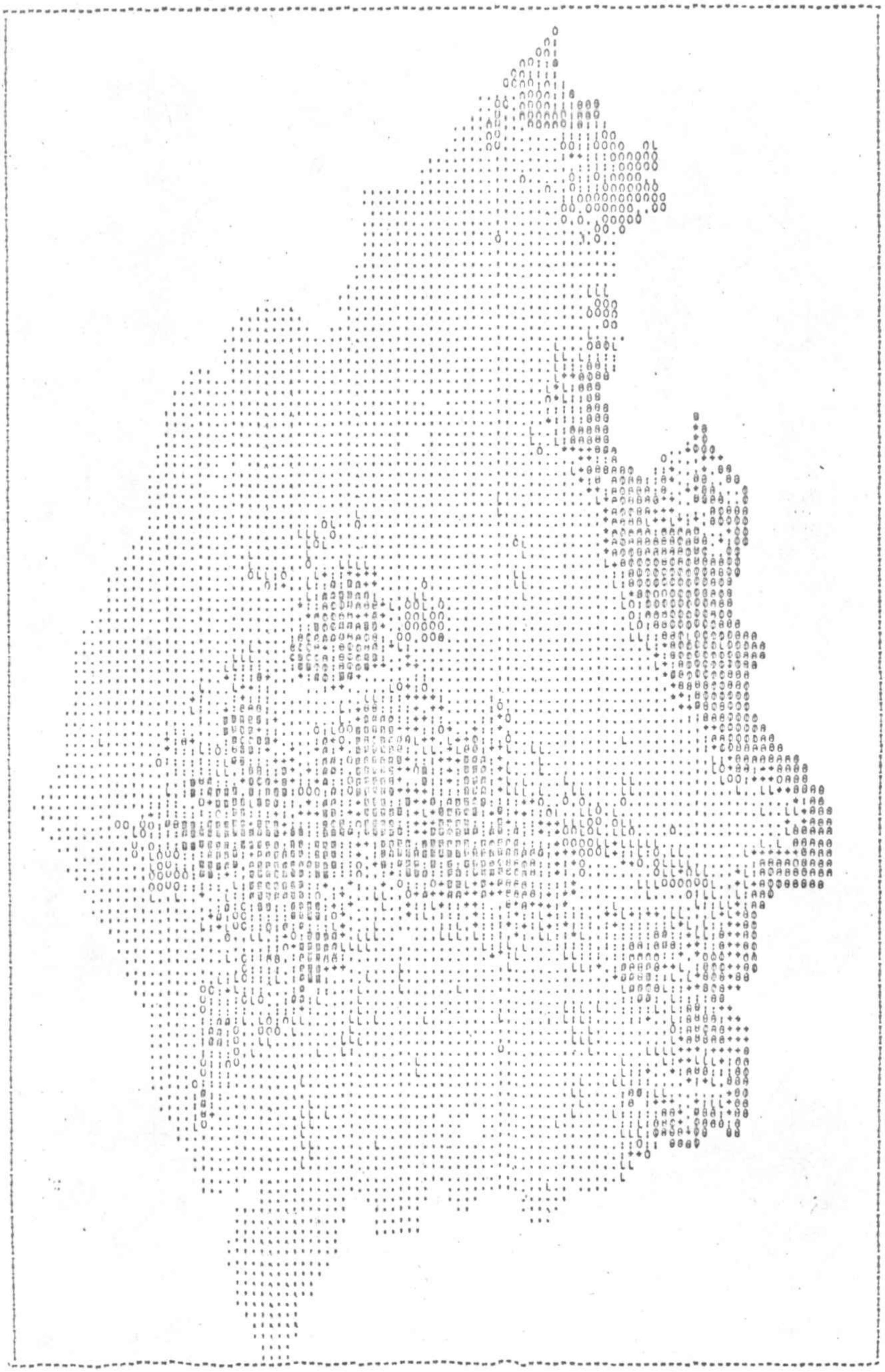


Fig. 12. Distribution of classes 9-16

LEGEND FOR FIGS 11 and 12

1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	:
10	+
11	L
12	O
13	⊖
14	⦶
15	⊙
16	⊟

Table 6. Area of each class type in Cumbria

Class	Area (km^2)	% of total area
1	77	9.8
2	89	11.3
3	86	11.0
4	83	10.6
5	76	9.7
6	31	3.9
7	14	1.8
8	24	3.1
9	54	6.9
10	37	4.7
11	53	6.8
12	33	4.2
13	35	4.5
14	33	4.2
15	28	3.6
16	22	2.8

intermediate map classes (9, 10, 11 and 12) which represent much of the marginal agricultural land, class 9 has a very low frequency of fine-leaved grasses and a high proportion of _Calluna_, _Nardus_, _Juncus_. and _Pteridium_ compared with the other classes of marginal land. The species occurrence in 9 is linked with the predominance (78%) of soil pH below 4.0 and the low occurrence (5%) of brown earth soils in contrast with classes 10-12 with less than 33% below pH 4.0 and 20-30% occurrence of brown earths. Preliminary analysis of the soils has been obtained through interpretation of aerial photographs from a number of valleys.

7.11 Classification and characterisation of landscapes is being explored by an analysis of the presence or absence of about 200 recognisable features sampled for each of 8 km^2 from each of the 16 map classes. The data are being analysed to determine the main patterns of variation in landscape and the common and characteristic features of each type of landscape. The landscape classes will show a definable relationship to the map classes and the comprehensive cover of the latter will allow an estimate to be made of the occurrence of landscape types throughout Cumbria based on the detailed analysis of a subsample. The degree of sensitivity of landscape classes to variation in attributes will indicate the extent to which the classes can be used to monitor landscape changes. No attempt is being made to assess the 'quality' or 'value' of different landscapes or landscape features; we are concerned with the definition of types of landscape and their components as a means of representing and monitoring the effects of land use and ecological change.

7.12 The km^2 units have been classified individually but land use and landscape are associated with irregular units associated with groups of km^2. To explore the potential of combining classified km^2 units, the upland valleys of Cumbria were demarcated representing catchments and, to the same extent, landscape units. The km^2 class combination of each of the 50 valleys was determined, and the valleys ranked according to the proportions of map classes, 1-8, 9-12 and 13-16 representing lowland, intermediate and upland classes. Although there are problems in defining the valley boundaries especially at the lower end, major differences between valleys were apparent, with Coniston and Elterwater representing one extreme with 100% of the area in classes 1-8, and Hartsop at the upland extreme with 59% of the area in classes 13-16, and 41% in 9-12. The ranking provides a means of selecting a subsample of valleys for further study and showed that Hartsop, the subject of an intensive study by Wibberlay et al (1975), is most similar in structure to Haweswater, Coniston Fells, Langstrath, Swinedale/Mosedale and Grizedale Beck.

7.13 The agricultural characteristics of an area can be assessed from analysis of the parish agricultural returns. To determine the degree of variation in agricultural use between the valley systems in Cumbria, and to examine the relationship between map classes and agriculture, ten valleys representing the range valley systems were selected from the ranked list of valleys. The main parish associated with each of the ten valleys was identified and the main agricultural features extracted from the parish returns. The farming is mainly livestock rearing (sheep and cattle) in the upland valleys (Patterdale, Orsdale, Shap Rural) with mainly dairy (Barbon, Culgaith) and one specialist dairy (Hawkshead). The percentage of the area which is rough grazing (21-89%) is correlated with the valley ranking and with area of crops (0-20%), sheep per 100 acres (103-362) and labour intensity (71-279 acres per worker). Part-time holdings constitute 21-63% of the holdings in each parish. Thus there is a detectable agricultural trend which is relatable to the valley ranking but, because the parishes tend to compromise both upland and lowland holdings, and the sample examined to date is small, the differences between valleys are not very striking. The agricultural options in these valleys are obviously very limited, and in the Agricultural Land Classification of the Agricultural Land Service, the majority of the area of the valleys belongs to the lowest grade (5), with a small proportion of grade 4 and in very restricted areas such as the Pennine valleys, which are adjacent to the Eden Valley, some of the land is classed as Grade 3. The importance of small areas of good lowland, closely associated with the upland valleys, is emphasised by the parish of Culgaith (one of the 10 sample valleys), which has a low percentage of rough grazing (21%), high percentage of grassland (58%), and crops (20%) and high labour intensity (71 acres per worker).

7.14 Agriculture is currently showing low returns and low profitability, upland farms being dependant for their existence on subsidies. There is a long-term trend of depopulation and abandonment of upland areas, therefore a likely future trend is for agricultural decline in certain areas. If these areas can be identified, the causes for decline determined, and their potential for alternative uses defined, this will provide useful information to assist in local and regional planning decisions. Such an approach has been adopted by Cumbria County Council in their Structure Plan. The agriculturally marginal land has been defined on four criteria:

parishes showing depopulation of greater than 15% for the period 1961-71

areas classified as Grade 5 agricultural land

parishes denoted to the least economic type of farming in Cumbria, i.e. sheep rearing

parishes dominated by medium to small livestock rearing farms with a small labour input.

These criteria were weighted and the areas with highest scores are identified, amounting to about 7% of the area of Cumbria, belonging mainly to map classes 4, 9, 10, 12, 13 and 16. It is in these areas that agriculture is likely to decline, the landscape to change and, if the land is suitable, forestry may develop as an alternative land use.

7.15 One particular agricultural practice, bracken eradication, is liable to increase through the availability of a suitable herbicide and has considerable landscape consequences. From the vegetation analysis of the map classes,it is estimated that bracken covers about 4000 ha of which 40% is in land of map class 4, 40% in classes 9-12 and 15% in class 1. It is probable that a small proportion of this area will be subject to bracken control, mainly associated with the more economically successful farms. Further definition of the areas has not been attempted.

7.16 Common Land (provisional and final registration) represents about 120,000 ha of Cumbria, i.e. almost 20%. If legislation encouraged improvement of commons then about 65,000 ha,i.e. in classes 1-12 are likely to be most suitable for improvement. The marginal upland areas (classes, 4, 9-12) contain most of this (56,000 ha), whereas the common land in upland areas of classes 13-16 (53,000 ha) are unlikely to be improved. In an attempt to assess the change which might occur if common land was improved, a comparison was made of samples of land within the same map class but which differed in the presence or absence of rights of common.

In land of map class 4, the commons were small areas of rough grazing with abundant bracken compared with the non-common areas which were enclosed grassland or a mixture of cultivated fields and rough grazing. The non-common land also had a higher occurrence of woodland than the commons. In class 9 land, both common and non-common were predominantly rough grazing, but with more enclosures, chiefly large intakes, in the non-common squares. About 20% of the non-common area was predominantly coniferous plantation indicating a possible alternative land use. Given an increase of agricultural use, the main change in the common land would be control of bracken, increase in grassland and enclosure, the latter probably fencing rather than stone walls.

7.17 About half the Forestry Commission area (21,000 ha) and nearly a quarter of the total woodland area in Cumbria (37,000+ ha) is concentrated in the two forests of Kershope and Spadeadam. Only four private forest estates in Cumbria exceed 500 ha. More detailed information on the distribution, type and age structure of commercial woodlands is being obtained, to assess when and where thinning and felling will occur. Development of forestry in Cumbria could occur in many areas especially where open fell and moorland between 500' and 1500' has low agricultural potential and farming is declining. However there are also possibilities for integrated forestry and agriculture and some evidence from the southern uplands of Scotland indicates that despite afforestation of 80,000 ha of land, sheep numbers have increased. The definition of areas which are likely to show decline in agriculture, indicate that, if only the areas outside the National Park were afforested, the area under forest in Cumbria could be increased by about 50% without serious detriment to agriculture. Further analysis of the land capability, the demand for natural products, and the interaction between land uses is essential.

7.18 Within Cumbria, the Nature Conservation value of the land is reflected in the designation of six National Nature Reserves, one Local Nature Reserve and 148 Sites of Special Scientific Interest. These constitute 87,000 ha, about 13% of the area of Cumbria. Uplands tend to have a greater proportion of conservation designated areas than the lowlands which may reflect availability of land as well as conservation interest.

7.19 A review of the effects of land use and management on soils in the Lake District was initiated early in the Upland Land Use project, stimulated by interest expressed by a number of organisations. A summary of the review is given as Appendix to this report.

7.20 The Cumbria study is continuing to develop the background data on the distribution and characteristics of land uses and to examine methods of assessing land use changes and their ecological and landscape consequences. The Structure Plan of Cumbria County Council has stimulated this study and emphasised the need for explicit, quantitative estimates of land use requirements as a basis for planning. The emphasis in the study has been regional but more detailed local studies, e.g. on individual valleys, are being developed. The study on Snowdonia provides an example of land use analysis at the local level.

SNOWDONIA

7.21 An area of some 55 km^2 in Central Snowdonia has been used to consider comparative methods of classifying land into categories that assess their potential for alternative land uses. This area was chosen because there already existed detailed maps of soil types; soil depth and drainage classes; soil parent materials; vegetation; and landform units obtained in another study. The objective was to explore the value of an objective land unit classification, obtainable relatively rapidly from Ordnance Survey maps data and subsequent computer analysis, with one derived by similar methodology from the "special" map data, and with general simple indices of agricultural or forestry potential also derived from the "special" data maps.

7.22 The area data were considered for $\frac{1}{2}$ x $\frac{1}{2}$ km grid square units, giving 225 squares from which data were collected for the study area.

1) A variant of the type of O.S. map attribute listing (used by Bunce, e.g. Cumbria survey, Bunce et al, 1975) was carried out, employing 48 attributes covering features (artefacts, altitude, height range, slope, landform, water bodies) given on the $2\frac{1}{2}$"/1 ml. O.S. maps. These were initially listed on their presence in each of the squares. Computer analyses by "Indicator Species Analysis" gave a grouping of up to 32 classes at 16 divisions. For plotting, the initial level of sub-division used was 8 classes with 4 divisions, but the possible additional value of the greater detail of sub-division, given by the computer programme, at the 16 and 32 class level is being explored.

2) 50 attributes were listed from the "special data" maps covering solid geology; soil parent material; soil sub-group; soil depth and drainage; vegetation; altitude, slope; and landform. The class in each category was determined as that at the centre point of each grid square.

3) The categories used in each of the special data maps were assigned specific "scores" for their contribution to either agricultural or forestry potential, based on a general but subjective judgement, with scores of 10 for "good", 7 for "moderate", 4 for "poor", 0 for "negligible". The scores in each of the 8 "special data" classes were added arithmetically to give separate "agricultural" and "forestry" indices for each $\frac{1}{4}$ km^2 square. This is a simplistic approach since interactions and weightings between the parameters used occur, but it gives a reasonable basis for grouping the squares in terms of their potential value for the two main land uses.

7.23 Where intensified agricultural or forestry use is excluded by altitudes above 2,000 ft. or slopes above 40^o, and where intensified agricultural use is limited at lower altitudes by slopes between 20^o and 40^o, this is noted in the final "score" for the two indices for each square, so that high squares brought about by other factors are overridden in interpretation by these strict limitations.

7.24 Two possibilities emerge:-

<u>First</u> - the direct use of the agricultural and forestry indices to plot the distribution of these sectors of the study area which have the greatest likelihood of suitability for agricultural or forestry intensification. These areas can then be compared with present agricultural and forestry use in order to delineate sectors where potential change will affect visual characteristics and other use potential (e.g. recreation, conservation) in the region. For example, in the study area, ground of high agricultural potential assessed in this way is already almost all in current intensive, or recently abandoned, agriculture, so that intensification of agricultural use would not lead to major visual change, whereas ground of high forestry potential includes both current agricultural land and open grazing, so that forestry intensification would bring about substantial visual change here. However, the collection of the raw data for these "specialised maps" is a specialist job - that is also very time-consuming (man-months or years rather than days).

Therefore, second - can one achieve similar forecasting ability with less effort? The question then becomes one of comparing the distribution of high index areas with the area classification by computer statistical analysis of the special data attribute listing; and of both of these with the classification obtained by the relatively quite rapid data listing, handling and interpretation from O.S. maps. Tabular and graphical presentation of the results in this sample area is in progress, but there are encouraging signs that classes of scores for agricultural potential on the grid square basis, link well with land classes derived from the indicator species analysis of O.S. map data. As an example, some 61 (c. 27%) out of the 225 squares have (from their centre-point data) agricultural indices (without overriding slope or altitude limitations) in the top half of the numerical range of the agricultural index. Out of this 61, 39 (c. 65%) fall in only 2 out of 8 O.S. map data classes (at the 8 class level of division). Further comparisons are in progress, but the prospects seem fair for use of the O.S. map data analysis to give an initial stratification into zones for which more limited specialised information could be sought. Clearly an even simpler drawing of altitudinal zones from contours alone provides a first sifting that can be achieved within hours but the more sophisticated analysis of the much greater amount of data the O.S. map contains apparently gives, without too much greater effort, a sounder basis for prediction or selection of zones for intensive study. The nature of the relationships obtained should be tested for other types of upland if "specialised" maps can be found available at the appropriate scale.

7.25 Conclusion

The factual outline of the programme plan carried out for this part of the study is correct. The interpretation is still in progress and the final presentation of this part of the report may give a somewhat different emphasis to the results than suggested here, but it is believed to be substantially in accord with the likely final statement.

8. DEVELOPMENT

This report has outlined, in some detail, the approach adopted in the analysis of upland land use and future change. It is an interim report which has been extracted from a larger document produced in March 1976, and no attempt has been made to produce a well-balanced, carefully presented, report at this stage. It is planned that the work will continue along the lines presented, concentrating on the development of framework which allows National, Regional and Local aspects to be inter-linked. A final report will be produced in March 1977 at which point we hope that research studies on specific sites and problems can be developed in Phase II of the project.

Appendix: Summary of K. L. Bocock and J. K. Adamson: Effects of land use and management on upland ecosystems, with particular reference to soils in the Lake District. Merlewood Research and Development Paper No. 66.

Summary and conclusions

These notes, based on a paper by Bocock and Adamson, summarize the main effects of land-use and management on upland ecosystems in the Lake District, with particular reference to soils. Most of the relevant data used was collected outside the Lake District. Unless we have indicated reservations about the applicability of data to Lake District conditions, the reader my assume that we have considered and accepted its applicability.

Particular emphasis is placed on the effects of hill-farming, forestry and recreation. Any or all of these may occur on a water catchment and the latter use has few special features, so it will be covered in discussion of the other uses.

The altitudinal zone, which is of particular interest here, lies between the intensively managed coastal plains and valley bottoms with deep, predominantly fertile, soils and the virtually soil-less and unmanageable high mountain tops. Soils range from well-drained, brown earths carrying *Agrostis-Festuca* grassland, frequently invaded by *Pteridium*, on the lower fells, to nutrient-poor, often peaty, but well-drained, soils with *Calluna* and *Vaccinium*, or poorly aerated gleys with *Nardus* grassland on the higher gentle slopes. Stagnant, or non-stagnant bogs, dominated respectively by *Eriophorum* and *Molinia*, occur on level areas at most altitudes in the zone of interest.

The main effects of the grazing animal include treading of the soil and vegetation, defoliation of the vegetation, and removal of nutrients from the ecological system in the animal crop.

The effect of treading varies with age, size, and breed of animal involved, more specifically with hoof area, the pressure exerted on each hoof, the number of times, and the way in which, the hoof is applied to the ground per unit area and per unit time, and the pattern of movement of the animal within an area.

The few data available for hill breeds and conditions and extrapolation from data for lowlands, indicate that cattle tread two-four times more heavily than sheep, and their stride and hoof contact area are respectively three and four times greater. Sheep and cattle travel about the same distance per day, around 2-5 km. Such data suggest that, with the level of stocking commonly found in hill areas, 0.2-1.0 sheep ha^{-1} or 0.2 cattle ha^{-1}, much of the pasture is trampled several times per year. Because of vegetation variation, food selection, and the characteristics of diurnal and seasonal movement of animals, trampling is concentrated on areas of more palatable vegetation, e.g. Agrostis-Festuca, or on much used paths.

Trampling caused soil compaction and disturbance and damage to the vegetation, but may also be beneficial by creating new sites for establishment of seedlings, by firming seeds in the soil and by promoting tillering.

Soil compaction is concentrated in the top few cms. of soil and is greatest on soils rich in clay, organic matter and moisture and least on the well-drained sandy and stony soils. It leads to changes in soil characteristics such as aeration, root penetrability, infiltration rate, and thermal characteristics, all of which can affect soil fertility and vegetation composition or performance.

Small agricultural vehicles exert similar pressures to those calculated for animals and their passage has similar effects to those of animal trampling, but is concentrated more on established tracks.

Soil compaction does not appear to be a major problem in grazed hill and upland areas, because of low stocking rates, infrequent use of agricultural vehicles, recovery of compacted soil under the influence of the frequent water frosts and in the case of animals, by the swamping of trampling effects by the beneficial effects of dung and urine deposition.

Soil disturbance occurs on much used tracks, particularly on soils rich in clay, organic matter and moisture, on steep slopes where animals tend to slip and slide and for cattle rather than for the lighter-stepping sheep. Any disturbed soil is susceptible to erosion as can be seen on hill paths in wet weather. Hollows created on hill-sides by sheep action are focal points for sheet erosion. However, the extent to which the varying rates of erosion in the Lake District in the past and present can be attributed to the effect of animals is unclear.

Trampling and defoliation by grazing may result in damage to, and hence in reduced production by, plants. As plants differ in their sensitivity to damage and to changed soil conditions, resulting from trampling, grazing animals can encourage changes in the vegetation composition which may lead ultimately to soil changes associated with changes in the type and amount of plant remains reaching the soil surface.

On hill-land ungrazed by domesticated animals plant material eventually dies and forms part of the surface mat of plant remains. The type of decomposition which this mat undergoes under the influence of the high rainfall and low temperatures of upland areas, encourages high acidity and low nutrient availability in the upper soil. Grazing channels an increased proportion of the herbage through the animal and so reduces the supply to the mat. The effects of a reduced mat and of deposited dung and urine change the chemical characteristics of the upper soil, increasing nutrient availability and turnover. This, together with selective feeding by animals particularly by sheep, encourages changes in the vegetation.

Assessment of the importance of the various practices and factors associated with grazing and which influence vegetation and ultimately the soil has not been carried out in the Lake District, but evidence from other upland areas suggests that intensity, timing, and location of grazing and use of fertilizers and herbicides are of prime importance.

A complete assessment of the importance of removal of nutrients in the animal crop cannot be made for the Lake District because of lack of data on inputs of nitrogen from various types of fixation inputs, of all nutrients in aerosols and from rock weathering, and outputs of all nutrients in run-off. However, available data, coupled with data from other areas, suggests that removal in animals is likely to be very small in relation to the total nutrient reserve in the soil and to input in precipitation. Phosphorus input in precipitation and output in animals are approximately equal, so, for this element, removal in animals may lead to an overall loss from the system when all inputs and outputs are accounted for.

Trampling of soil and vegetation is the main effect on soil associated with recreation. Detailed changes are likely to be similar to those caused by animal trampling, although little data has been collected in the Lake District, and data is not available generally, which allows detailed comparisons of the effects of trampling by Man and by animals. Trampling damage is not considered to be a major problem except on well-used footpaths, particularly on steep slopes, on wet peaty areas, and on the higher altitude ridges. Use of vehicles on unsurfaced tracks and paths has similar effects to those produced by Man's trampling and currently, rarely produces significant damage in the Lake District.

The main effects of trees and forestry on the soil include: those associated with tree roots, plant remains, soil disturbance during forestry operations, influences run-off water quality and, with removal of nutrients from the system, in timber.

The soil stabilizing effect of tree roots is of particular importance in steep slopes. The zone of soil around tree roots is a site of active mineral weathering. The importance of the latter effect for forest in the Lake District is unclear. The presence of root channels in soil renders the latter more permeable to water, whereas root decomposition adds humus and nutrients slowly throughout the soil profile.

Plant remains on the soil surface buffer the soil against the effects of climate, particularly direct insolation and extremes of air temperature and rainfall. The rate and type of decomposition of plant remains influences the chemical and physical properties of the underlying soil. Conifer litter, like Calluna and Erica on moorland, has the reputation of causing physical, chemical and biological deterioration of soil. Whilst these effects remain somewhat controversial, and incompletely understood it is clear that they vary with soil type, site characteristics and tree species. Relevant local data are few and indicate tendencies towards acidity, low nutrient availability and podzolization in many upland soils, but no clearly developed podzol profiles. Evidence from elsewhere indicates that trees, even conifers, will grow well on similar soils to those found in the Lake District without causing serious soil degradation, although they may cause the tendencies indicated above.

The maximum direct effect of forestry operations on the soil occurs during site preparation and harvesting, both of which involve use of heavy machinery which compacts the disturbed soil, partly because of its own weight, and partly because of its use in ploughing, draining or logging. Except for small trucks and large unspecialized vehicles, such as timber lorries which can exert pressures on the soil of up to about 8 kg cm^{-2}, vehicle pressures fall in the range 0.2-4.6 kg cm^{-2}, about the same as the static pressures exerted by animals. One application of about 0.2 kg cm^{-2} can reduce soil pore space by 80% and 10-20% of an area can be affected by vehicles during tractor logging. Data from other areas suggests that soil compaction by forestry is not a major problem, but that marked vegetation changes occur after ploughing, draining and roadmaking. These changes will ultimately reflect back on the soil.

Forests have an appreciable influence on the hydrology of a site, including soil moisture status and run-off. Transpiration rates in forest and grassland are of approximately the same order but forests intercept up to half, but more commonly, around 20-40% of precipitation often, several times the interception for grassland. Intercepted water is evaporated so the soil tends to be drier and less leached under forest than under dense grassland.

Site preparation leads to a loss of particulate matter and nutrients in run-off, which may continue for several years after planting of the forest. Roadmaking also increases soil and nutrient loss from the site temporarily.

Felling, especially clear-felling, leads to increases in soil leaching, in run-off, and in the amounts of particulate material and nutrients in run-off. Soil and nutrient loss is only slight if logging is carried out carefully and if rapid regrowth of herbaceous vegetation occurs. Felling leads to increases of several ^{o}C in mean soil and stream temperature and in the diurnal temperature range. Temperature changes will have an appreciable effect on the numbers and activities of fauna, flora and microflora of these habitats.

Fertilizers and herbicides used in forestry, affect the quality of the run-off water only slightly, and temporarily, if they are applied carefully. However, they will have some effect on the soil by altering biological activity or the type and amount of plant remains reaching the soil surface.

Forest systems, in contrast with non-forest systems, accumulate a large nutrient capital in the trees themselves and in the plant remains on, and in, the soil. Factors which favour this build up include evergreen (condition of many forest trees, resistance to decomposition of litter, exploitation of a greater soil volume by tree roots, than by roots of grassland and moorland plants, except perhaps Pteridium, greater trapping of aerosols and possibly, also, mineral weathering under forest than under non-forest.

Only a few percent of the nutrient uptake of trees, often less than 10%, is retained in the trunk, and this is approximately the same as nutrient amounts in precipitation. Brush timber contains nutrients equivalent to 40-90% of those in trunks of the main trees. Timber extraction therefore removes only a small fraction of the annual nutrient income to a site, but, nevertheless, removes much more, for some nutrients more than ten times more, than that removed in the animal crop.

To summarize the above, the characteristics of soils under different land uses and managements often differ markedly as a result of the use or management. When use and management are altered, soil changes occur as natural adjustments of the ecosystem to the factors applied. These changes rarely lead to severe deterioration in soil quality, or to soil erosion, unless changes have been made suddenly and without careful planning.