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Upland Land Use - A Desk Study

THE UPLANDS OF ENGLAND AND WALES - LAND CHARACTERISTICS AND CLASSIFICATION

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- LAND CHARACTERISTICS AND CLASSIFICATION

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INTRODUCTION

Choice of Area Units for Data Recording

1. In considering units of area suitable for land data recording and classification on a national scale, the collection, storage, analysis, retrieval and presentation of data become easier and more effective when standard size units are used. Within the total land area of England and Wales of 151,130 km^2 (130, 367 and 20,763 km^2 respectively), the National Grid at the 10 x 10 km scale provides 1,684 x 100 km^2 squares consisting wholly or partly of land. This gives a sufficient, but not excessive, sub-division of the land into convenient sectors for many studies on a national scale, and the 10 x 10 km grid square is the unit of area that has been adopted for the present work. Although the boundaries of such grid squares are arbitrary, and their treatment as discrete entities with internally uniform properties is unsatisfactory at a more detailed level, their boundaries are no more arbitrary in regard to natural geographic divisions than are those of administrative units, and an assumption of uniformity at this scale is reasonable in considering national trends.

2. As one alternative, the use of administrative units has in its favour that some statistics are directly available on a parish, district or county basis, and that data and interpretations for such areas can be more immediately assessed and used by those involved in planning and administration. Their disadvantages are more compelling and include the wide size range within a category of administrative areas, such as parishes or districts, their somewhat changeable boundaries in recent years, and the problems that the complexity of these boundaries create for easy extraction of data off maps as well as for clear visual and statistical display, manually or by computer plots, of countrywide trends.

Definition of "Upland"

3. In deciding initially what the limits should be of the area to be studied, the simplest definition of "upland" is all that land which lies above a specified altitude, and this is the definition that was adopted, the chosen altitude being 800 ft. O.D. (c. 244 m). Any particular altitude may be disputable when applied over an extensive area, but the one selected is considered to be effective in giving a division of England and Wales into generally acceptable broad zones of "lowland" and "upland" character. (Acceptance of the idea of two such distinct character zones is all that is required here, without any attempt to define them.) A lower altitude division would classify as upland too much land of obvious lowland landscape and land use character, while a higher altitude limit would in some areas exclude marginal upland foothill country. More sophisticated definitions were considered, such as those that can be derived from climatic or land use variables. To an extent, to select appropriate definitions of this type required the prior collection and analysis of data that was the object of the study. In any case, the significant differences, even within the relatively small area of England and Wales, in the altitude at which, for example, given rainfall or temperature levels are reached, or at which selected land use changes occur, makes these initially apparently more desirable definitions too complex in their application, and they were rejected in favour of simplicity. Because the 10 x 10 km grid squares were the chosen units for data recording and classification, a definition must classify each square as either upland or non-upland. The decision made was to class as "upland" those squares which contained 4% or more of land above 800 ft. O.D., as determined by the measurement method used (10.). This procedure has the merit of grouping into a clearcut upland zone the core sectors of the upland regions together with their immediately adjacent lowland fringes that they strongly influence.

General Considerations of Upland Classification

4. The first assumption of this study is that data tabulated for the 100 km^2 grid squares provide valuable means of investigating the distribution of individual land characteristics; of comparing the distribution of land characteristics of one category with those of another; and for the quantitative description of the land characteristics of geographically defined upland regions. The second assumption is that a primary land classification based on a range of natural physical environmental factors should be the most effective means of providing a sound framework for classifying the uplands of England and Wales on a national scale. The attributes used for this primary classification are taken from data groups covering physiography, climate and soils. Soils are used as, on the one hand, a key direct control on land use and land potential, and, on the other hand, as an integrating response to the interactions of many environmental factors, including those of geology and biotic history as well as physiography and climate. The distribution of classes in such a primary natural environmental land classification can be compared to that of other land properties and land use characteristics in explaining and predicting use and potential. By combining the natural environmental factors with "cultural" features resulting from man's use of the uplands, secondary land classifications based on natural and man-imposed land characteristics can also be developed and investigated.

5. It might well be expected that enough classifications of land in the uplands of England and Wales must already exist to render superfluous anything other than selection and recommendation of the most appropriate existing scheme. That, this, unfortunately, is not the case can be seen from a brief consideration of the types of land classification that are nationally available. These generally suffer from one or more of several major weaknesses for the present purposes:- Their cover nationally is incomplete or inconsistent; they are inadequate because they are based only on single characteristics or groups of characteristics; they combine several characteristics in their classification but,

so far as their use in the uplands is concerned, they allow too wide a range of properties within one or, at best, very few classes; they depend on characteristics too readily modified by short-term changes; or finally they are not appropriate to consideration of broad national trends. It is neither possible nor desirable to attempt here an extensive review of international experience in the land classification field, nor to describe in detail all those types of map material relevant to land classification that are available in Britain, but a summary treatment of the latter may be helpful in support of the contention that an alternative approach is desirable.

6. Maps of complete national coverage, but dealing with particular aspects of land character, include those of the Ordnance Survey. These provide the essential and most fertile single data source concerning physiographic and topographic characteristics of the land of Britain, but they do not directly allow landform classes to be identified, even if landform alone was adequate for a general purpose land definition and classification. Interpretive landform classifications based particularly on absolute altitude and altitudinal range, following the ideas of the late D.L. Linton, have been applied in regional studies, particularly of landscape "quality", but not nationally. Terrain analysis, a more detailed landform classification, mainly based on air-photo interpretation, supplemented by map and/or field data, has also been used in local studies in Britain, and more widely overseas by British scientists, but a national classification from this approach has again not been attempted here. Climatic maps, particularly of rainfall, are becoming available at useful scales for national assessment of the climatic range. Geological maps, of more detailed coverage than the climatic maps, are available of high standard and full national coverage, at appropriate scales, but their emphasis is on solid geology and stratigraphic age of rocks, rather than on the nature of the immediate sub-soil unconsolidated mineral material and on rock lithology, which are more relevant to soil and land quality.

7. Considering maps which display land characteristics that combine the interactions of other site factors, the most important are Soil maps. At a detailed level these are available only for a small part of the uplands of England and Wales. A generalised national soil map has been produced by the Soil Survey of England and Wales by extrapolation from the areas of detailed survey and is the source for the soil data used in this study. Land use capability maps, based on American ideas modified for application in Britain, are being produced by the Soil Survey to accompany local soil maps. This scheme, using a combination of soil, landform and climate factors, grades land according to its flexibility for agricultural use. A very limited area of the country is yet mapped in this way, and, because the classification covers the national range of land quality, only at most three classes, and often fewer, would apply in most upland areas. A basically similar land grading, but one which has national coverage, is used in the maps of the Agricultural Land Classification published by the Ministry of Agriculture. These use five agricultural grades based on the degree to which physical limitations of soil, landform or climate impose long-term limitations on agricultural use, plus two non-agricultural classes. Again their target of national coverage and relative grading, with few grades, means that the uplands dominantly consist of one or two agricultural grades and one non-agricultural class. The present research programme of the Agricultural Development and Advisory Service includes a pilot survey to develop a more detailed division of upland land. By considering vegetation, slope, drainage, and surface irregularity, these maps aim to show four categories of improvability in "hill" areas (unenclosed, unimproved land) and four of flexibility of use in "upland" areas (enclosed land under relatively intensive use). If this study is successful and can be more widely applied the detail would be important on a district or regional basis, and may be simplifiable into a national scheme. Whether it can be adapted to classifying upland for other purposes would remain to be tested. Within its own landholdings valuable maps of site quality for forestry are produced by the Forestry Commission, based on soil, site-exposure, altitude, and sometimes vegetation. Broader

schemes might again be possible as individual forest maps extend in coverage. Vegetation maps are not available nationally as a consistent published series, and, in any case, vegetation is readily affected by short-term management changes, so that such maps quickly become historic documents. Land Use maps are similarly essentially historic, however recently completed, though stability in land use is a feature of some upland regions, as change is of others. Although these maps are available quite widely from two spells of activity of unofficially organised Land Utilisation Surveys, they combine this rather transient character, in local detail, with an oversimplified mapping of upland principally into only one class.

DATA FOR CHARACTERISATION AND CLASSIFICATION OF UPLAND IN ENGLAND AND WALES

General Considerations of Data Source Quality and the Precision of Data Collection

8. Because, in part, of unavoidable constraints on the time and manpower available for this study, two reservations about data sources and collection methods require mention. Firstly the source material had to be taken from the most readily available sources. In some cases better material may be locatable through a more intensive search, and in others the work of various organisations is likely to produce material of higher quality in the future. Of course, at the scale involved, simplification of the actual situation will always be essential to smooth complex detail into mappable classes. Secondly the quantitative measurement of attributes in the upland grid squares required a compromise between essential speed and desirable precision. For the listing of data, some 28,000 individual items were quantitatively measured or read from maps, and a similar number of items in a modified version of this attribute listing also had to be prepared for classification analyses. The inevitable compromise is acceptable for the classifications and will not affect general interpretations but it does mean that the data for individual squares are, apart from the reservation about source material quality in some cases, also affected by

measurements made with less accuracy than would have been possible if more time, labour or sophisticated procedures had been possible. It is necessary to put these reservations clearly but it is important that they are not over-emphasised. More precision in data extraction, and for some aspects better source material, would increase confidence in the details, but the methods adopted enable a picture of upland landscape characteristics to be put forward at the national scale with an acceptably high degree of confidence, qualitatively and quantitatively.

Data Sources and Methods

9. A detailed listing of the attributes recorded for upland 100 km^2 grid squares, their sources, and the method of recording of each group of attributes, is included in the Appendix volume of data tables. A summary version of this listing is given here as Table 1. The data used for classification are grouped in categories of Physiography, Climate, Soils and Topography. Data in Land Use and Agricultural Land Classification categories are also given. These provide material that can be considered in relation to upland regions, to the physical environmental characteristics, and to classifications based on these. The complete data listings for each category of attribute form the bulk of the appendix volume.

10. Very precise methods are available for measuring areas occupied by classes on maps, or for determining the lengths of linear features, such as rivers or roads, within a defined area, by slow and careful manual means or by sophisticated automated methods. Because of the time limitations of this study, relatively rapid manual sampling methods were necessary. For area measurement, point counts were used. A grid of points is overlaid on the map unit to be sampled and the number of points falling in each map class to be measured is recorded. The larger the number of points in the grid, the better the accuracy of measurement, but the greater time required for the work. There are arguments for a random spacing of points in such a grid, rather than a systematic spacing. The latter is generally favoured by users as giving

regular area coverage, the former by statisticians because random sampling is desirable to conform with mathematical theory on which general statistical data handling is based. Systematic points, however, are easier to count rapidly. On maps at the 1:250,000 scale, used here for much data extraction, a 25 point systematic grid covering the area of one 10 x 10 km grid square was used. The presence of one point in a map class was taken as measuring 4% cover of that class in the square. Because of the alternative patterns possible for the distribution of equal areas of a given class, the same extent of a class in several squares can give different apparent areas by such a measurement method, differences which would be reduced by using closer spaced, i.e. more, points per unit area. In general, 4% units give a reasonably accurate measurement at this scale. A practical convenience of the use of 10 x 10 km grid squares is that 1% cover equals 1 km^2. For smaller-scale maps a 10 point grid per 100 km^2 grid square was used, which measured areas in units of 10%. In one trial case a 10 x 10 squared grid was used to count the number of 1% units occupied by a class. Unless taken very slowly, which was impractical, this was not found a convenient method. For linear features, the number of intercepts the class of feature made with two transects (N-S and E-W) through the mid-point of a grid square was used as a measure proportional to the total length of the linear features in the square. The actual measurements were much helped by the use of a large diameter, self-illuminated desk magnifier.

Physiographic Attributes

11. Because "upland" grid squares were defined as those containing $\geqslant$4% of land above 800 ft. O.D., altitude class distributions were the first attributes to be measured. The percentages of land above 800 ft. (c. 244 m), 1,400 ft. (c. 427 m), 2,000 ft. (c. 610 m) and 3,000 ft. (c. 914 m) were measured for all 10 x 10 km grid squares in England and Wales. The chosen height bands are arbitrary but give altitude classes that can be considered as lowlands, low uplands, hills, mountains and high mountains in a British context. They relate quite closely to land use experience. For

example, the Forestry Commission have used, in regional studies of land potential for forestry, altitude bands with 230, 400 and 600 m limits to interpret yield possibilities. For the grid squares which were found, by the 25 point systematic grid method of area assessment (9-10), to contain 4% or more land above 800 ft. O.D., the full range of other attributes listed have been measured.

12. It was felt that an attempt to include a measure of major surface irregularity as a landform characteristic was desirable. A rather loosely controlled rapid count was therefore made of the number of reversals of slope direction which involved approximately 600 ft. height difference between crest and adjacent depression along a N-S and an E-W transect through the mid-point of each grid square. River density was also assessed by the number of intercepts that the mapped watercourses made with two cross-transects. The cross-transect data have been tabulated as they were recorded, separately for N-S and E-W transects, for these and other attributes measured in this way. In interpreting the results, it is preferable for most purposes to sum the figures for the two transects as a single measure of the attribute occurrence in a square. At the scale of this study there are few occasions on which a preferred orientation of the features with respect to N-S and E-W axes is likely to be significant. Freshwater bodies shown on the 1:250,000 O.S. maps had been counted previously by I. Smith (I.T.E., Edinburgh) and his data are included in this attribute category. The extent of land in three slope classes was determined, using a point grid, from a manuscript map made available by the Soil Survey of England and Wales. This had been derived from contour spacing measurements made on O.S. maps at grid intersections, with a smoothing and extrapolation from these measurements to give mapped classes of slope limits relevant to agricultural land use.

13. A general comment about the Ordnance Survey 1:250,000 5th series maps, used as the source of most physiographic and topographic data, is that they deliberately emphasised the major relief patterns and the road network, with a parallel simplification of much detail and a generalisation of build-

ings to those occurring centrally in villages and hamlets on the selected road network. Woodland is only depicted for large continuous areas. The cartographic principles of this series and their clear presentation made them particularly convenient for data extraction for the present study but clearly more detail could be derived from the extra effort involved in moving to the 1:50,000 O.S. series as a data source.

Climatic Attributes

14. Rainfall is the most comprehensively mapped climatic variable, and is displayed on published maps on the O.S. 1:250,000 base. In the construction of these maps extrapolation from the spot data sources to area distribution by some reference to relief obviously creates an element of circularity in using altitude classes and rainfall classes as independent attributes, but the general application of the rainfall data at the 100 km^2 area unit scale is acceptable in assessing the position of such areas in the national range of this important characteristic. The accumulated temperature and soil moisture deficit data are derived from manuscript maps prepared, like those for slope classes, by the Soil Survey of England and Wales and kindly made available in advance of publication. Sunshine data were extracted from a very small scale Meteorological Office map.

Soil Attributes

15. The published 1:1,000,000 soil map of England and Wales has seventy-one map units which are complexes consisting of several named soil groups in association, on specified soil parent materials, but with one soil group in each unit named as being dominant. To give a workable number of attribute classes for the present purpose, the mapping units dominated by a particular soil group were combined into a single class, regardless of differences in the subordinate groups, or in parent materials. The area of each grid square occupied by these classes was measured. The twenty-two soil groups of the terminology used by the Soil Survey of England and Wales were then further simplified into the seven classes shown as

the soil distribution attributes. This additional large degree of simplification from what initially must, by the nature of geological and soil variation, and the information available for much of the country, be a very great simplification of the actual situation, gives a convenient and practical grouping to assess broad national trends of soil distribution.

Topographic Attributes

16. In the category of topography have been included mapped features resulting from man's settlement and communications pattern. On the O.S. 1:250,000 map, "towns" are blocked in as continuous grey areas, and smaller settlements are shown by stylised individual "buildings". No exact correlation of "building" number with settlement population appears to be used as a precise control. The definition used here was to class as "villages" those settlements with five or more individual "buildings" in a cluster at a named site, and as "hamlets" named settlements with fewer "buildings". Roads and railways were estimated by the method of counting intercepts with cross transects.

Land Use Attributes

17. Two categories of data, this and Agricultural Land Classification (18) have been recorded mainly for the purpose of upland characterisation rather than as primary features to use in upland classifications. Land use information is mostly drawn from the "Selected Statistics" appendix of J.T. Coppock's "An Agricultural Atlas of England and Wales" (1976). As noted in the full list of attributes contained in the Appendix data tables in this study, the percentages of total agricultural land used for tillage, improved grassland and rough grassland, livestock unit numbers, and standard man-days as a criterion of labour input, are given by Coppock for the agricultural districts of the Agricultural Development and Advisory Service. They have been recalculated from this form to a 100 km^2 grid square basis by the rapid method outlined in the appropriate section of the list of attributes in the appendix. Although the precision

of correlations of grid square location with agricultural district could have been improved, the values calculated are, in view of the generalisations required to derive such data for broad areas, likely to be as good a measure as necessary of land use characteristics at this scale. It is perhaps useful to point out that the man-days attribute of agricultural land use is not an actual measure of labour input, but a calculated standardised assessment of labour intensity based on numerical factors applied to the extent of different crop and stock enterprises in the district. Each acreage of a crop use or number in a stock category for the district is multiplied by an economically appropriate standard factor, and the figures for the individual enterprises are summed to give a single total value of "standard man-days" for the district. For comparability between districts, the figures are presented on a per 100 acres cultivated land basis. "Livestock units" are similarly a summation of stock numbers in different livestock classes multiplied by standard factors so that cattle, sheep, pigs and poultry can be brought to a combined single figure.

18. The two remaining attributes in this category are taken from the O.S. 1:250,000 map. Woodland, because of the cartographic principles adopted (13) only shows large woodland blocks and must therefore substantially underestimate actual woodland. The area measured as urban was also later determined in another way from a different map source (19). Although correlation between the two measures of the same quantity is reasonable, the individual discrepancies illustrate the limitations mentioned as attributable possibly to the data source and certainly to the relatively rapid data extraction methods used.

Agricultural Land Classification Attributes

19. The 1:63,360 Agricultural Land Classification maps of England and Wales (Ministry of Agriculture) show, as noted previously (7), the distribution of five grades of agricultural land and two non-agricultural classes. The extent of these seven categories in each upland 100 km^2 grid square is the last data set included in this stage of a national upland land study.

DISTRIBUTION OF UPLAND IN ENGLAND AND WALES

Location and Extent of the Upland Zone

20. Four hundred and thirty-six 100 km^2 grid squares, situated wholly within England and Wales, are upland grid squares as defined here (3). The location of these is shown in Figure 1, and a list, with the six-figure grid reference of their mid-points, is included in the Appendix of data tables. The squares generally have been numbered systematically in west-east rows, from 1 at the western end of the northernmost row to 426 at the eastern end of the southernmost row. A re-check of all squares after the initial stages of the study had been completed, located ten additional squares with 4 or 8% of land over 800 ft. O.D. To avoid problems of renumbering the complete data set, these squares were numbered 427-436 and their locations are therefore inconsistent with the regular numbering plan. There are an additional seven upland squares which fall partly in England, partly in Scotland, that have been omitted from consideration here because some of the data used in this study, derived from maps of England and Wales, were not immediately available in identical forms for Scotland.

21. With 436 out of the total of 1,684 100 km^2 grid squares in England and Wales being classified as upland, approximately 26% of their total area, on a grid square basis, is upland. The equivalent figures for England and Wales separately are respectively 14% and 60%. If upland extent is defined on an actual area basis, as the extent of land above 800 ft. O.D., rather than on the basis of grid square units, then from the map data for altitude classes, 13% of England and Wales together is upland, or 9% and 39% respectively for England and Wales considered separately. From another data source, the extent of upland, as land over 800 ft., in the administrative counties of England and Wales is given in Table 2. Twenty out of the forty-five English counties and metropolitan counties contain upland; in eleven of these upland is more than 10% of the county area. Seven out of eight Welsh counties contain upland; in six of these upland is more than 10% of their area.

Criteria for Grouping the Upland of England and Wales into Geographic Regions

22. One basis for grouping the upland into classes must be the traditional upland geographic regions. Although the locations of regions such as the Lake District, Snowdonia, or Dartmoor are not matters of dispute, there are no precise or universally accepted boundaries between one region and another in the continuous upland zone. Using mainly traditional names centred on their traditional locations, the upland of England and Wales, as identified here, has been divided into regions. A map of these is given in figure 2, with a key to their numbering in Table 3. In a few cases, where no clear-cut choice of name was available for a region, a name has been created or selected from alternative possibilities. The general positions of the boundaries between contiguous regions have been selected so far as possible to follow geographic features widely accepted as natural boundaries or, where these did not exist, convenient topographic features. The general boundaries of each region are given in Table 4. Because the grid square is the study unit, the grid square margins nearest to the chosen geographic limits are used as the exact regional boundaries to decide the allocation of a grid square when regions adjoin each other.

23. A distinction has been made between major and minor upland regions, based on their area of land above 800 ft. Clearly, alternatives to the chosen regions could create larger or smaller blocks, but the regions adopted are those judged to be a reasonable number of meaningful geographic entities. The size criterion adopted is that major regions contain more than 200 km^2 of land above 800 ft. In practice all major regions also have land above 1,400 ft. (only just so in the case of region 7, the North York Moors) while none of the minor regions contain 4% or more of land above 1,400 ft. as measured by the method used here. Table 5 gives, for each upland region, the total number of grid squares it contains, with their index numbers. The Appendix table listing the location of individual squares also gives the region to which each square is allocated.

24. The major upland regions can be considered as consisting of core sectors, in which upland characteristics are dominant, and surrounding marginal zones. In order to determine the characteristics of these core regions, those grid squares which contain > 50% of land above 800 ft. have been treated as "core upland" squares. Figure 3 shows the distribution of the one hundred and ninety-six such squares, which form 44% of the total upland, or 12% of the total area of England and Wales, determining area on the 100 km^2 grid square basis. Their distribution falls into clear-cut groups which are considered to be "core regions" of the major upland regions. Only ten core upland squares lie outside such clear blocks of country, the majority of these in the northern part of the Northern Pennine region. Two only occur in minor upland regions, both in the Bodmin and St. Austell Moor region. The size of each core region in relation to the total extent of the region, and the index numbers of the individual grid squares in it, are given in Table 6. The importance of the core regions in the upland of England and Wales is shown by their containing 76% of the total land above 800 ft. O.D. in England and Wales, 93% of land above 1,400 ft., 97% of land above 2,000 ft., and 100% of the small amount of land above 3,000 ft.

Upland Distribution in Relation to Examples of Administrative and Natural Features

25. National Parks

A range of administrative and natural features can be considered in relation to the general distribution of upland. As an example of the former, the distribution of those parts of the National Parks which occupy the whole or part of upland grid squares, as these are defined here, can be considered (figure 4 and table 7). The Park limits were recorded rapidly from the 1:2,000,000 map in the Atlas of Britain, Clarendon Press, 1963. It would be possible to list either the properties of the individual squares located in each National Park, or their mean values for the Park, as is done later for upland regions and classes, either for all the grid squares wholly or partly within the Park, or only for the smaller number which fall entirely within a National

Park, to define comparative properties of the upland Parks in terms of the data banks presented here. Two other points can usefully be made: Firstly, the upland regions named here, the boundaries of which were chosen without reference to features such as National Park limits, do in fact correlate very closely to the Park boundaries, in that the upland parts of the National Parks fall entirely or predominantly within single upland regions. This gives circumstantial support to the choice of regions and their limits as useful geographic entities. Secondly this tabulation distinguishes these upland regions, the present and future of which must be significantly affected by their location in a National Park. Of the major upland regions; the North York Moors, Lake District, Cheviot, Exmoor-Brendon Hills, Dartmoor, Peak District and Central Pennines in England, and Snowdonia and the Brecon Mountains in Wales, have much of their extent within National Park boundaries. The Northern Pennines, Southern Pennines, Hiraethog and the South Wales Coalfield major regions have smaller parts of their areas within National Parks. Thus, half the upland regions are strongly influenced by the National Park system, and only five major upland regions are not at all affected by the present range of National Parks. Only one minor region, Prescelly, is within a National Park. Other categories of protected land, National Forest Parks for example, would increase the clear emphasis on conservation protection and recreational use as key aspects of upland use and planning.

26. Major Watersheds.

As an example of natural features which it may be interesting to consider in relation to upland character, the location of the major watershed system of England and Wales is shown in figure 5. The positions of the main watersheds have been sketched by selection from the River Authority area boundaries given on the two 1:625,000 O.S. maps of "River Gauging Stations in Great Britain", March 1972. The main spinal watershed and the subsidiary Snowdonia watershed in north-west Wales give a small group of upland geographic regions that are essentially western and "oceanic" in climatic character, particularly the Lake District and Snowdonia itself; a larger group of eastern regions of generally drier, more "continental" climatic character, including Cheviot, Northern Pennines, Peak District, North York Moors, Shropshire Hills and Radnor and Clun Forests; with the remaining major regions being split by this watershed. East-west divisions correlating broadly with this watershed location will be seen later to be a significant feature of the distribution of upland classes derived from a classification analysis based on natural environmental attributes.

CHARACTERISTICS OF INDIVIDUAL UPLAND GRID SQUARES

Use of the Data Store to Characterise or Select Individual Grid Squares

27. The data tabulated in the Appendix can be used to give the general land characteristics of any individual 100 km^2 upland grid square. These tables also allow the selection of grid squares, appropriate to any particular study, in which one attribute or group of attributes is closely similar in value or area extent, so that with one or more variables controlled, the influence or interactions of other recorded or observed variables on the land character of the grid squares can be more effectively studied. As simple examples, if a comparative study in the Northern Pennines, Central Pennines, Dartmoor and Snowdonia regions of areas with similar altitude class distributions seemed useful, then grid squares 65, 93, 412 and 205 are all seen to have 84 or 88%; 44, 48 or 52%; and 0% of land above 800 ft; 1,400 ft; and 2,000 ft. respectively.

28. To enable rapid comprehensive data search and selection, and the ready provision of maps showing those upland squares with particular ranges of a recorded property or properties, the groups of data tabulated for the 436 upland 100 km^2 grid squares have been stored in computers. The main data sets prepared at Bangor for grid squares 1-426 were initially entered, with a listing of the grid references of the squares, into the computer at the Merlewood Research Station of I.T.E., by P.J.A. and D.M. Howard, who are carrying out a separate statistical study of these upland data by principal components and cluster analysis techniques. They have provided

computer print-out maps as responses to a wide range of sample questions about the distribution of upland grid squares with particular values or ranges of single attributes, and examples of these maps (figs. 6-15) are discussed below. More complex questions involving several attributes can of course be similarly answered. It should be noted that the supplementary grid squares 427-436 are not included on these maps.

29. Following the installation of a computer at the Bangor Research Station of I.T.E. in late 1976, the complete data set for upland squares 1-436 has been stored there also, and used for the computations quoted later in this report.

Distribution of Selected Characteristics

Physiography

30. Figure 6 shows the distribution of grid squares recorded as having more than 50% of their area above 800 ft. O.D., these being the core upland squares as defined in this report, and as shown, allocated to regions, in figure 3. A more restricted definition of core upland could have been adopted, perhaps for example, as only those grid squares with 20% or more land above 1,400 ft. A map of such squares shows them to be many fewer than given by the definition adopted, and many of the major upland regions would have, on this basis, little or no core upland. However, for some purposes such a definition would be more appropriate. The available data sets, and the convenience of computer handling, allows users to choose, within the limits of the ranges and quality of the tabulated data, limits which seem most suitable for their requirements. Figure 7 plots grid squares in which the altitude range exceeds 2,000 ft. The map picks out clearly the two regions of England and Wales that have the most montane scenic character, the Lake District and Snowdonia, while only a few other scattered grid squares are found to have this characteristic. The distribution of squares with an altitude range between 1,500 and 2,000 ft. shows areas which can be thought of as a second rank of regions of montane

scenery, as it consists of the southern part of the Northern Pennines, a sector of the Cambrian Mountains, much of the Brecon Mountains, and scattered single squares in the Exmoor-Brendon Hills, Dartmoor, Peak District and Clwydian Hills regions.

Climate

31. Figure 8, upland grid squares which have more than 70% of their area under classes of high annual average rainfall, delineates the wetter western upland sectors. Figure 9, upland grid squares which have more than 70% of their area under high annual average accumulated temperature classes, in contrast emphasises a generally southern, but also upland margin, distribution of this characteristic. The general pattern of such distributions is of course well known but the specific location of particular characteristics over the range of upland in England and Wales is usefully displayed in this way, and can be appreciated more clearly from such displays.

Soils

32. Two illustrations of soil distributions are given in figures 10 and 11. Figure 10, those upland grid squares which have more than 70% of their area dominated by Brown Earths and other well-drained mineral soil groups, again shows mainly a southern and upland marginal distribution emphasis, but there are major sectors dominated by these soils in Eastern Wales, the Peak District and the Southern Pennines. Figure 11, grid squares which have more than 50% of their area dominated by the inherently less fertile and typically "upland" organic or organic-topped soils, of Podzol, Peaty Podzol, Peaty Gley and Peaty Soil groups, plots their main distribution in Western Wales and in the English upland north of the Peak District, but shows also the significance of such soils in core sectors of Dartmoor, the South Wales Coalfield, the Brecon Mountains, the Berwyn Mountains and the North York Moors.

Topography

33. Figure 12, showing squares with a dense road pattern, mirrors quite closely, from a quick visual comparison, the soil distribution of figure 10, a natural correlation of the dominance of more fertile soils with a high intensity of settlement reflected by the road network, although "fertile" soil groups are seen in figure 10 to be more widespread in Eastern Wales than are grid squares with a dense road network. It is reasonable to take such simplistic visual comparisons as suggestive of relationships, but comprehensive study and consideration of additional data would be necessary to enable the relationships to be more confidently understood and interpreted.

Land Use

34. Although agricultural land use data show tillage, to the extent of more than 25% of the agricultural land within upland grid squares, to be significant in the minor upland regions of Southern England, and also in the North York Moors, the Radnor-Clun Forests, and in scattered squares elsewhere, especially on the eastern margin of the Pennines, the main contrast in the tabulated data is naturally that between improved grassland and rough grazing. The distribution shown in figure 13, of grid squares which have more than 50% of their agricultural land under improved grassland, is, with the exception of the North York Moors, obviously therefore a close converse of a map of those squares with more than 50% of their agricultural land classified as rough grazing. Considering grid squares in which improved grassland is more than 25% of their area, again with the exception of the North York Moors where arable tillage is the main agricultural use following land reclamation, the only important upland areas falling below this extent of improved grassland are Snowdonia, small sectors of the Northern and Central Pennines, and the core area of Dartmoor. The correlation of this last distribution with that of squares with a low number of livestock units per 100 acres (<24), shown in figure 14, is close. A map showing grid squares with high numbers of livestock units in contrast shows a notable con-

centration in the Clwydian Hills, the southern Peak District, and, more unexpectedly perhaps, the Southern Pennines. Such a distribution in the Southern Pennines probably relates to settlement pattern as much as to inherent land quality. A map of squares with more than 10% of their area in urban use delineates the upland industrial concentrations of the Southern Pennines, parts of the Peak District, and the South Wales Coalfield.

Agricultural Land Classification

35. Because the agricultural land classification grades are determined mainly by soils, altitude and rainfall, there are clearly going to be strong correlations between their distribution and those of physical factors. The distribution of grid squares with 50% or more of their area in agricultural land grades 1-4, shown in figure 15, is thus closely similar to the patterns of high amounts of improved grassland (fig. 13); of an intensive road network (fig. 12); areas of relatively "fertile" soil groups (fig. 10); and of relatively high temperatures (fig. 9). One of these distributions might well therefore be used as representative of the others but an emphasis on superimposed associated characteristics seen in the repetitive patterns of distribution sharpens the distinction between core and marginal zones in the upland spectrum of England and Wales.

THE UPLAND GEOGRAPHIC REGIONS

Use of the Data Store to Determine Mean Properties of Groups of Grid Squares

36. Although the characteristics of individual upland grid squares are useful for many purposes, it is often helpful to consider total or mean values of attributes, calculated for classes in various groupings of grid squares. These groupings may be geographic regions or core regions, as considered in this section; they may be classes of national classifications such as are discussed later; or they could be any grouping controlled by having some factor or factors in common, whether these factors are among those in the present

data set, or are additional physical, cultural or administrative characteristics. By assigning a code number to each grid square in order to identify the group in which it should be placed in any desired scheme, and then putting into the computer store a list of these numbers for the complete set of 100 km^2 upland grid squares, the use of a computer programme, such as one provided at Bangor by Mr. G. Radford, can give print-out tables listing the number of squares in each group and the group sum, mean, standard deviation, standard error and coefficient of variation for all attributes of a data set. Clearly for some attributes which are regarded as a single value for the grid square, e.g. sunshine hours, the sum of these values for all squares in a group is meaningless and the mean value for the grid squares in the group is the value of interest; but for attributes which are recorded as percentage area cover, then the sum gives the total area extent of that attribute within a group of grid squares. Because the study unit is the 100 km^2 grid square, then mean values given as percentages are identical to values in km^2, and sums of area attributes are also in km^2. Computer tabulations of group sums and means have been obtained in this way for the complete set of attributes listed in Table 1, for grid squares grouped in the 27 major and minor upland regions, given in Tables 3 and 5, and in the 18 core areas of the major upland regions listed in Table 6. These values have also been computed for class groupings in the national classifications. To reproduce these analyses in full is impractical here, but selected aspects of the total and mean properties of alternative groupings are given and discussed.

Environmental Characteristics of the Upland Regions

Altitude

37. The extent of land in the measured altitude classes for the upland regions of England and Wales is given in Table 8, and the mean altitude distribution within the major upland regions is illustrated in figure 16. The estimate given for the area of land in England and Wales above 800 ft. O.D. (19,864 km^2) represents some 13% of the total land area.

Considering England and Wales separately, some 9% of the area of England, and 39% of the area of Wales, is above this altitude. Land above 1,400 ft. is approximately 3% of the land area of England and Wales together, 2% of that of England alone and 9% of Wales, while land above 2,000 ft. is estimated as only occupying 0.4% of the area of England and Wales together, 0.3% of that of England alone and 1% of Wales.

38. The extent of land in the measured altitude classes in the core sectors of the major upland regions is given in Table 9, and the mean altitude distribution in grid squares of these core upland regions is also illustrated in figure 16. The core regions occupy 186 out of the total of 436 upland km^2 grid squares, that is 42% of the upland on a grid square basis. However, they contain 76% of the total land above 800 ft. in England and Wales, 93% of that above 1,400 ft., 97% of that above 2,000 ft., and all of the very little land above 3,000 ft. An additional 664 km^2 land above 800 ft. O.D. (612 km^2 in England, 52 km^2 in Wales) and 40 km^2 land above 1,400 ft. O.D. is contained in the ten squares with more than 50% land above 800 ft. O.D. given at the foot of Table 9 as not allocated to core regions. This accounts for a further 3% of the total land above 800 ft. estimated for England and Wales, making 79% of such land within the 196 core upland squares (45% of the 436 100 km^2 grid squares classified as upland).

Slope

39. Mean values for other physiographic attributes are given for core regions in Table 10. Core region data are emphasised because they provide the clearest distinction between characteristics of the major upland regions but for some purposes the full geographic region data could be required. The most interesting values are those for the relative extent of the three slope classes. Gentle slopes are seen to be most important in the Northern, Central, and Southern Pennines, the North York Moors, Exmoor-Brendon Hills, Dartmoor and the Clwydian Hills, while moderate slopes dominate Cheviot, the Peak District, Shropshire Hills, Hiraethog, Radnor-Clun

Forests, the Brecon Mountains and the South Wales Coalfield. Steep slopes become relatively important, together with moderate slopes, in Snowdonia, the Berwyn Mountains and Cambrian Mountains, and these classes are co-dominant in the Lake District.

Rainfall

40. As an example of a key climatic characteristic, rainfall class distribution in the major upland regions and core regions is shown in figure 17, and also given diagrammatically for core regions in Table 11. At the drier end of the upland range are the Shropshire Hills, North York Moors, Clwydian Hills, Radnor-Clun Forests, and Cheviot regions, while the wetter end is occupied by the Lake District, Snowdon, the South Wales Coalfield, the Cambrian Mountains and Dartmoor. The rainfall class means have standard errors which average 6.8 for regions and 8.4 for core regions. Although variability within more limited "core regions" might be expected to be less than in more diffuse "regions", the standard error depends on the number of samples in each group, and because core regions have fewer grid squares than do the regions, the calculated standard error is affected by this. It would be necessary to take statistics such as standard error of attribute means into account in any test of the significance of the difference between group means, but the broad picture of upland variation, with which this report is concerned, can omit such considerations.

Soils

41. Figure 18 shows the distribution of dominant soil groups in the major upland regions and core regions. The core regions can be broadly grouped into categories running from one with a dominance of intrinsically "better" (in terms of fertility and versatility) mineral soils to intrinsically "poorer" organic and organic-topped leached soils. At the better end of this range, the Shropshire Hills and the Exmoor-Brendon Hills regions are dominated by freely drained Brown Earth soils, with the Clwydian Hills, Radnor-Clun Forests and the Peak District all having important proportions of Brown

Earths. Relatively well-drained organic-topped podzolic soils are significant in Cheviot, the Lake District, Dartmoor, Snowdonia, Hiraethog, the Berwyn Mountains, and the Cambrian Mountains, while poorly-drained organic-topped Peaty Gley soils are important, with Brown Earths, in the Exmoor-Brendon Hills, Brecon Mountains and South Wales Coalfield regions. Poorly drained soils, peaty and non-peaty surfaced, dominate the Northern, Central and Southern Pennine regions and the North York Moors.

Topography

42. Considering the pattern of settlement characteristics shown by the mean values of numbers of towns, villages and hamlets, and number of roads, there is, for the core upland regions, a range in the average number of settlements of all types recorded per grid square, between three and eleven settlements. The high settlement numbers occur in the Shropshire Hills, Southern Pennines, Peak District and Clwydian Hills regions, with significant numbers of settlements mapped as towns (two per square average), only in the Southern Pennines and South Wales Coalfield regions. Number of settlements, when their size is so variable, from hamlet to city, is clearly a very approximate measure of population, and better replaced later by actual population figures. Taking road density as a measure of settlement intensity and also of accessibility, then as well as the above regions, Hiraethog and the Radnor-Clun Forests have a relatively dense road network (values of 10-12, in a relative scale of road density running from 1 (Cheviot) to 12).

Land Use and Land Classification Characteristics of the Upland Regions

Agricultural Use

43. The proportions of agricultural land under tillage, improved grassland and rough grazing are shown for the major upland regions and core regions in figure 19, and, with mean values per 100 acres of livestock units and the standard man-days labour input assessment, are tabulated for the core regions

in Table 12. Tillage dominates agricultural land use in the North York Moors and is important in the Cheviot and Shropshire Hills regions. Rough grazing is most extensive in core regions of the Northern and Central Pennines, the Lake District, Dartmoor, Snowdonia, and the South Wales Coalfield. The higher livestock numbers, assessed by the standardised "livestock units", occur in the Southern Pennines, Shropshire Hills, Clwydian Hills, Hiraethog and the Brecon Mountains core regions, while, in general conformity with those regions with a high proportion of rough grazing, Cheviot, the Northern and Central Pennines, Dartmoor, Snowdonia and the South Wales Coalfield core regions are at the lower end of the range of mean values of this attribute.

Forest Use

44. Forest cover, determined from the 1:250,000 O.S. map measurements, ranges from only 3% average in the Southern Pennines region to 22% in the South Wales Coalfield region, and is relatively extensive also (>10%) in the Northern Pennines, North York Moors, Snowdonia, Hiraethog, and the Berwyn and Cambrian Mountains regions. On the Agricultural Land Classification maps (see paragraph 45 and Table 13) the category of "other land primarily in non-agricultural use" is, in the uplands, largely forest, and there is a close correlation between mean values of this attribute for the upland core regions and for forest cover taken from the O.S. maps. For core regions, forestry is particularly important (11-30% cover) in the South Wales Coalfield, Snowdonia, Hiraethog, Berwyn, Brecon and Cambrian Mountains core regions. Much of the forested land in the Northern Pennines and North York Moors is outside the core regions, while in the Brecon Mountains, forestry is more concentrated in the core sectors of the region.

Urban Use

45. Urban land has two independent estimates in the data set, from attributes 5.7 in the land use data, and 6.6 in the Agricultural Land Classification data. Inconsistencies between these two estimates (mentioned in paragraph 18) are

less for group means than for individual grid squares. For the major upland regions, a high urban density occurs in the Southern Pennines, South Wales Coalfield and the Peak District regions (16, 13, 12% respectively as a mean of values calculated from both sources) and particularly in the South Wales Coalfield and Southern Pennine core regions (12 and 8% respectively as a mean of the two available group values). The urban settlement in the Peak District is mainly outside the core sector of the region. An especially low level of urban settlement characterises the Cheviot, Central Pennines and Cambrian Mountains regions (mean values >0.3%).

Agricultural Land Classification

46. The mean percentages of land in different grades of the Ministry of Agriculture Agricultural Land Classification system are given for the upland core regions in Table 13. Because grade 5 land covers a very wide range of quality, from cultivated improved farmland, but under high rainfall, at high altitude, or on steep slopes, to the poorest hill rough grazing, and also includes poorly drained land at lower altitudes and under lower rainfall, it cannot be taken as representing any single sharply defined quality class of land in the upland context, although it does so in the broader natural context. However, grades 3 and 4 are good quality land in an upland situation, while grade 3 land is of adequate potential in any location. More than 40% of grade 3 and 4 land together occurs in the core regions of the Southern Pennines, Peak District, Shropshire Hills, Exmoor-Brendon Hills, Hiraethog, Clwydian Hills and Radnor-Clun Forests. Grade 3 land alone is 10% or more of the area of the Shropshire Hills and Clwydian Hills core regions. The lowest levels of land graded as better than grade 5 occur in the Cheviot and South Wales Coalfield core regions.

UPLAND CLASSIFICATION BY INDICATOR SPECIES ANALYSIS

Classification Method

47. Indicator Species Analysis (ISA) is a statistical method of classifying units which have been defined by listing, for each unit, the presence or absence of all individual attributes contained in a list of a large number of attributes. It was devised by M. O. Hill, R.G.H. Bunce and M.W. Shaw and is described technically by them in a paper in Journal of Ecology (1975; vol. 63, pp. 597-613). Its purpose is to give an efficient numerical means of classifying objectively sampled ecological data, originally particularly for the classification of plant communities by using records of the presence or absence, at a large number of sites, of all individual plant species included in a long species list. The method can equally well be applied to other classification requirements, including those of points or areas which are defined by types of data other than species lists, provided that these data are in a presence or absence format. In the Journal of Environmental Management (1975, vol. 3, pp. 151-165) R.G.H. Bunce, C.J. Morrell and H.E. Stel described an application of ISA to the classification of geographic areas from records of map-derived attributes for the areas, in their case using O.S. map data for 1 km^2 grid square units to classify land in the Lake District. This application has been developed in the present upland land study. At the local level, land classifications of a district in Snowdonia, using ¼ km^2 grid square units, have been produced by D.F. Ball and W.M. Williams, from data off 1:25,000 O.S. maps, and from special map data. At the regional scale, R.G.H. Bunce and colleagues have carried out a land-type classification of the county of Cumbria, using 1 km^2 grid square units and attributes derived from 1:63,360 O.S. maps. At the national level, ISA has now been used to give classifications of the 436 upland 100 km^2 grid squares. The success of the method in delineating, from objective consideration of a wide range of land attributes, areas that are readily interpretable in terms of environmental and land-use characteristics at these different scales, has fully justified its choice for the purpose of land classification.

48. ISA is a numerical procedure, carried out by computer, which first splits the complete set of individuals into two roughly equal parts that represent the two ends of the spectrum of those properties recorded for the individuals. From the complete attribute list, a small group of key attributes is then selected by a calculation designed to identify the group of attributes which is most definitive in placing individuals on one side or other of a division closely approximating to that initially made. The number of key attributes at each division of these analyses is either 10 or 7, dependent on the size of the set to be divided, and is controlled by the programme. The computer programme next applies the classification procedure again, using the full range of attributes once more, to each of the two groups produced by the first division. Continuing in this way, division of the original set of individuals into 2, 4, 8, 16 etc. classes is made until the programme stops at a pre-set level of sub-division. In general, a split into two classes, each being 100% distinguished by the total presence of all of one group of key factors and the total absence of all of the other group, does not occur at any stage of such an analysis. If it did, then these key factors could never re-appear in a key factor role at subsequent class divisions. Because allocation of an individual to a class is based on a general balance of presence or absence of the selected most effective group of attributes, rather on the typically unattainable absolute split, then factors may emerge as key factors at more than one stage and on both sides of an analysis, as seen in the analyses discussed below. The analysis also incorporates means of deciding the preferable allocation of a minority of borderline cases that may occur at any stage of division.

49. The list of attributes given in Table 1, being quantitative, is not appropriate to ISA. Those attributes were therefore re-cast into a new set of 64 attributes that could then be recorded on a presence or absence basis for each upland 100 km^2 grid square, by editing the original quantitative data sets. The list of attributes used for ISA is given in Table 14, and, for convenience, is included also in the Appendix data volume.

50. Physiography, climate and soils are considered to be the natural environmental factors among the data recorded, and attributes 1 to 51 of Table 14 were used for one indicator species analysis (ISA 4) to give a classification referred to here as a natural environmental upland classification. The complete attribute list of Table 14, including topographic and selected land use attributes, has been used for another ISA (ISA 1) to give an alternative upland classification referred to as a natural and cultural environmental upland classification. These analyses, following valuable discussion with M.O. Hill, were processed by Mr. G. Downing, University College of North Wales Computer Laboratories, from data prepared at I.T.E., Bangor, through the University of Manchester Regional Computing Centre.

51. ISA for the two main classifications reported here (ISA 4 and ISA 1) was carried to the 32-class level. The most useful general purpose levels of division in the present study are thought to be the 16-class level, and for broader purposes, the 8-class level. The following initial discussion of these classifications is in general limited to the 8-class levels of division of the upland range in England and Wales. Computation and consideration of class characteristics at finer levels of division is continuing.

Classification of the Upland of England and Wales Based on Natural Physical Environmental Attributes (ISA 4)

52. The complete list of key factors which control division to the 16-class level in this analysis is given in figure 20, the attribute numbers in the boxes referring to the attribute list (Table 14). 10 or 7 key factors decide the division of units at each stage. Index identifiers of the classes (1, 0; 11, 10, 01, 00 etc.) are those given in computer print-outs of the analyses. They provide a means by which classes at a finer level of division can be related to classes at a coarser level. For example, classes 1111 and 1110 at the 16-class level are sub-groups of a class at the 8-class level (111) that, with class 110, derives from class 11 at the 4-class level, while this and class 10 are the two divisions of class 1 in the initial split of the whole set of

units. Technically, this nomenclature is helpful but the classes are more easily referred to in discussion and tabulation by code numbers so that, at the 8-class level, the classes are simply identified as being numbers 1 to 8 in the appropriate ISA at the appropriate class level of division. Equivalence of code numbers and class indices, as used here, is given as a key to the final table in the Appendix volume. It will be seen, in figure 20, that, as was remarked in paragraph 48, the same attributes can appear as key factors at different stages and positions in the analysis. It should be re-emphasised that not all grid squares that are, for example, allocated to class 1 (index 111) of this analysis at the 8-class level, will necessarily have attributes 11, 22, 26, 33 and 37 all present, and attributes 10, 21, 28, 29 and 34 all absent, since allocation of a unit to a class is a matter of the balance of key attributes, but there will be a dominance of presence or absence of the appropriate key factors.

53. Table 15 gives a simpler verbal outline of the main attribute characteristics which are the basis for the natural environmental upland classification to the 8-class level. The classes into which each upland grid square is allocated, at the 4, 8 and 16-class levels in both main ISA upland classifications are listed in the final table of the Appendix.

54. The maps of figures 21, 22 and 23 illustrate the distribution in the upland of England and Wales of the classes of the natural environmental upland classification, to the 8-class level. Figure 21 shows the initial two classes of this classification; figure 22(a) and (b) the distribution of classes at the 4-class level; and figure 23 (a)-(d) the allocation of upland 100 km^2 grid squares to classes at the 8-class level. The initial division of the upland range is clearly seen from Table 15 and figure 21 to be into two sectors with altitude as a key control, these being named in Table 16 as Marginal Upland and Core Upland. The use of the term "core" here, as well as for the "core upland regions" discussed previously, is less unsatisfactory than it might appear. The discussion section later shows there to be a strong correlation between the core classes of the upland

classifications and the core areas of the named upland geographic regions, because the initial division of the I.S.A. uses as a main key factor the extent of ground above 800 ft. O.D.

55. The division, at the 4-class level, of the Core Upland in the natural environmental upland classification into two classes of Western High Upland and Eastern High Upland (Table 13), the distribution of which is shown in figure 22(a), relates quite well to the location of a large part of the major watershed pattern seen in figure 5. This, bisecting the Lake District region on a generally west-east line, then running south, southwesterly and south again through the Pennines, Peak District and Wales, has the bulk of the Western High Upland grid squares to its south and west. The Marginal Upland also divides into two quite clear geographic sectors (figure 22(b)) but these seem independent of the major watersheds, with the bulk of the Northern English marginal upland grid squares in one class, and the majority of Welsh and Southwestern English marginal upland in the other.

56. Further division to the 8-class level also continues to give generally geographically definable sectors of the upland spectrum, although some of these classes, as illustrated in figure 23(a)-(d), have outlier grid squares covering the full north-south upland range. Names given to these eight classes in Table 16 reflect their dominant geographic concentrations. Although in the case of some of the eight classes (e.g. Montane Upland) a geographic dimension is maintained in their division to a 16-class level, in others (e.g. Southwestern Marginal Upland) there is a closely intermingled distribution of the classes resulting from this division. It is anticipated that convenient prefixes or suffixes to the 8-class names, based where necessary on properties other than dominant geographic location, will enable suitable explanatory names to be given to the 16 classes.

57. Study is continuing of this and the natural and cultural environmental upland classifications, with particular reference to the diagnostic criteria and mean properties of their

classes, and a wider consideration of their correlations with land features independent of those employed in the classifications.

Properties of Classes of the Natural Environmental Upland Classification

58. Sum and mean values for the recorded environmental attributes can be calculated, from the quantitative data sets, for classes in the natural environmental upland classification, by computing group values as described in paragraph 36. The same property sum or mean values that were extracted for presentation as examples to characterise the mean properties of core upland regions are given here for the eight named natural environmental upland classes of Table 16, in Tables 17-21 and figures 24-27. Two general points can be made from a preliminary consideration of these tables and figures. Firstly, although this classification produces classes which span the whole upland range in England and Wales, rather than ones restricted to geographically relatively limited areas, as are the upland core regions, there are in general, sharper distinctions in many of their main characteristics between the national classes than there are between the core regions. Secondly, although this aspect has not yet been carefully and fully studied, the national classification classes show lower mean standard errors for at least some of the properties than are found for the same properties in the core regions. For example, the mean standard errors of mean values of annual rainfall classes for the major regions and core regions are given in paragraph 40 as 6.8 and 8.4. At the 8-class and 16-class levels of the natural environmental classification, mean standard errors for these same rainfall categories are significantly lower, at 3.1 and 4.1 respectively. Relatively low variability within classes, and relatively sharp distinctions between classes are the desirable aims of a successful classification.

59. The mean values for class properties that are tabulated and shown diagrammatically can be drawn on to give some principal characteristic features of these eight classes in the natural environmental upland classification. They have now been

subjectively rather than quantitatively assessed to give, in Table 22, an outline summary of class characteristics. Adequate detailed consideration of class properties, and of the relative merits of 8- and 16-class levels of classification, or even, for some purposes, the possible use of the 32-class level, will follow from computational and interpretive studies that are in progress.

Upland Classification Based on Natural and Cultural Environmental Attributes (ISA 1)

60. Treatment of this ISA classification, in which settlement attributes are combined with those of the natural physical environment, can be brief because the general points made about the natural environmental classification (e.g. in paragraph 52) also apply to ISA 1. Detailed study has not been completed to allow a conclusive decision as to whether this natural and cultural environmental classification offers sufficient additional or alternative interpretive value to justify its use. Provisional conclusions, which favour the natural environmental classification, are discussed in paragraph 64. In order to permit an understanding of the similarities and contrasts between the results of ISA 4 and ISA 1, the corresponding data to those previously given for ISA 4, are presented here for ISA 1, in figures and tables.

61. Figure 28 records the key factors that control division of the upland 100 km^2 grid squares into classes of a natural and cultural environmental upland classification to the 16-class level, and Table 23 gives a verbal summary of the main key factors to the 8-class level.

62. Figures 29, 30(a) and (b) and 31(a)-(d) show the distribution, to the 8-class level, of the classes in this classification. Because of the interaction of settlement with physical attributes in the key factors controlling class division, less simple self-explanatory names can be given to these eight classes than was possible in the natural environmental upland classification. Table 24 gives provisional names descriptive of their dominant location and settlement characteristics.

Properties of Classes of the ~~Natural and Cultural Environmental~~ Upland Classification

63. Tables 25-29 give altitude class distribution data and class mean values of other physiographic factors, rainfall classes, land use and agricultural land classification categories for classes at the 8-class level in the natural and cultural environmental upland classification. Figures 22-35 are sketch graphs of the mean values for these classes of altitude and rainfall categories, soils and the principal types of agricultural land use. From these figures and graphs a subjective rapid assessment of some main class characteristics for each of the eight classes has been drawn up in Table 30 (cf. Table 22).

Comparison of ISA 4 and ISA 1 Classifications

64. A preliminary comparative assessment of these two classifications shows them to have broad similarities because natural physical attributes which control ISA 4 remain dominant among the attributes and key factors of the combined natural and cultural environmental classification (ISA 1). Thus, although settlement density appears as a key factor at the first level of division in ISA 1, eight of the ten key factors at this level are identical in the two classifications. The initial division of the upland range into core upland and marginal upland sectors is essentially, though not precisely, identical in both classifications and this remains true of class distributions at the 4-class level of division. With further division, class sizes and distributions diverge. In some cases this in part results from the particular ordering of classes by the analysis, so that, for example, class 4 of ISA 1 has the general location of class 3 of ISA 4, and vice versa. There are however substantial differences in the number of squares in equivalent classes and in the classification of many individual squares at these levels of division. The reasons for these divergencies and the applicability of the controlling key factors and computed class mean values to class characterisation and interpretation are being further studied. No one classification of course is correct and another wrong, since any classification of this ISA type

follows a logical pattern controlled by the analysis itself and the range of attributes used to define the units being classified. The ease with which classes may be identified, defined and interpreted decides whether one classification is better than another for a particular purpose. The present conclusion (paragraph 73) favours, on these grounds, the primary use of the ISA 4 natural environmental upland classification.

CONCLUSIONS

Relationship of Class Distributions in the National Upland Classifications to the Core Upland Regions

65. These relationships could be treated at length, but some main points only are considered here. The numbers of squares in each class, to the 8-class level, of the two national upland classifications (ISA 4 and ISA 1) present in each core upland region are given in Table 31(a) and (b). These tables show that squares allocated to core upland regions almost all fall on one side of both these classifications (see also paragraph 71). They show also that although a range of ISA classes is present in most core regions, these are often dominated by one or two of the national classes. For example, in the natural environmental upland classification (Table 31(a)), class 2 (Northern High Upland) dominates the Northern Pennines (core region 2); class 7 (Midland High Upland) the Peak District (core region 5); and class 6 (Western High Upland) the Cambrian Mountains (core region 15).

66. The national upland classification classes can be interpreted in terms of an estimate of their relative quality for crop and stock production. This estimate can be obtained in at least two ways. A subjective assessment of the factors responsible for class division can be used to place the classes in an order of relative merit, this method directly using the natural physical environmental attributes. Alternatively the mean proportion of different categories of agricultural land (tillage, improved grass and rough grazing) in the classes can be used to give an order of relative merit, this method being based on current land use. These

two rankings, at the 8-class level of the natural environmental upland classification, carried out independently, gave orders, from "better" to "worse" classes, of 3, 4, 1=2, 7, 8, 5=6; and 3, 1=2, 4, 7, 8, 5=6 respectively. Six classes of agricultural "value" can then be mapped, using either of these orders, with the mapped distribution of the eight classes of ISA 4. The reversal of classes 1 + 2 and class 4 in the two rankings may be due to incorrect judgement of the "quality" of the key factors to agricultural potential, to a divergence between inherent potential and actual land use in these classes, or possibly even to the omission of factors from the classification that may be significant in this respect (e.g. length of "growing season"?). This aspect can be further investigated, as can the extent to which classes of broad agricultural potential mapped in this indirect way may add interpretively to an understanding gained by direct mapping of single land use attributes.

87. It is possible, using this type of ordering of the national classes, and the known proportions in which these classes occur in grouped categories of upland, such as core regions (e.g. Table 31), to determine a relative order of merit as an index value for groups of squares, rather than singly for individual squares. Allocation of an arbitrary score to a class, say from 6 for the "best" to 1 for the worst in the examples of class orders given in paragraph 86, enables this index to be calculated numerically, as $\sum N_1 S_1 / N_r$ where N_1 is the number of squares in a class and S_1 the score for that class, and N_r is the total number of squares in the group, for example in a core region. Applying the class order for ISA 4 at the 8-class level determined from key factor assessment, gives the following assessment of relative order of agricultural potential for the core regions.

Estimate of Agricultural Potential of core regions, assessed from the National Classification (ISA 4)

higher Shropshire Hills; Clwydian Hills.

Peak District; Radnor-Clun Forests.

Southern Pennines; Hiraethog; Northern Pennines; North York Moors.

Brecon Mountains; Central Pennines; Exmoor-Brendon Hills; Dartmoor; Cambrian Mountains; South Wales Coalfield

Berwyn Mountains; Cheviot; Lake District

lower Snowdonia

If the current land-use basis is used, then the Exmoor-Brendon Hills and Berwyn Mountains move up one group, and the Northern Pennines move down one group. If ISA 1, which includes cultural features relating to land use in its attribute list, is used to produce a core region order in the same way, then the North York Moors, Exmoor-Brendon Hills, South Wales Coalfield and Berwyn Mountains are placed in higher groups and the Radnor-Clun Forests and Brecon Mountains in lower groups.

68. This approach may, on the one hand, amount to an unnecessarily involved means of achieving an assessment of an order that can be got directly, for groups such as the core regions, by considering their mean values of particular land use attributes. Putting core regions into an order of current intensity of agricultural usage assessed by their mean proportions of categories of agricultural land (Table 12) gives the following grouping which has broad similarities but significant discrepancies to the order proposed in paragraph 67, derived from the national classification:

Estimate of current intensity of agricultural use from agricultural land categories

higher — Shropshire Hills.

Exmoor-Brendon Hills; North York Moors.

Radnor-Clun Forests; Clwydian Hills; Peak District; Brecon Mountains; Southern Pennines; Hiraethog.

Berwyn Mountains; Cambrian Mountains; Cheviot.

Lake District; South Wales Coalfield; Northern Pennines; Central Pennines; Dartmoor.

lower — Snowdonia

On the other hand, it is possible that consideration of differences in placings in these rankings, or in one derived from the agricultural labour input of standard man-days, may give the possibility of distinguishing regions the inherent natural productive value of which has been reached or extended, and others which have a regional placing based on their natural features that has not been achieved in current agricultural use. Such speculations cannot be pushed too far but they provide an avenue of possible interest in interpreting the national classifications.

National Classifications as Frameworks for Regional and Local Studies

38. The original choice of a single definition of "upland" as those 100 km^2 grid squares which contained 4% or more of land above 800 ft. O.D. was arbitrary, but was selected as a limit that would bring into consideration the fringe upland sectors as well as the major upland areas of England and Wales. This entire area is "the upland" that is the relevant object of study for many purposes. In other cases a more limited definition may be required, because either the core upland areas or their fringe sectors are the chief or sole interest. The core upland was also defined simply

on altitude, as those 100 km^2 grid squares containing more than 50% of land above 800 ft. O.D. This, although less than half the total "upland" area, has been shown to contain c. 80% of the land above 800 ft., and 93% of that above 1,400 ft. in England and Wales. The initial distinction of altitudinal core and marginal zones is useful but not adequate as a general upland framework because it is based only on a single characteristic rather than on the wider range of natural physical land variables.

70. The use of geographically located units, whether these are the upland regions or core regions defined in this report, or are administrative areas, of course gives a basis for regional studies and may be precisely what is required to answer some questions. There is, however, substantial variation in land type within most geographic or administrative regions, and, without national classifications, no objective means of judging which parts of different regions have general similarities over a wide range of physical characteristics.

71. A national classification based on a range of land attributes, provides, at least after the stage at the attributes are chosen on which the classification is based, an objective means of grouping like with like among the 439 upland 100 km^2 grid squares in terms of the attributes listed, to whatever degree of sub-division seems desirable. Both the classifications described here initially produce a division into two classes the distributions of which closely parallel the simple altitudinal division into core and marginal upland. Table 31 showed that 186 out of the 196 altitude-defined core upland squares were in class 2 (equivalent to classes 5-8 at the 8-class level) of a 2-class division of the natural environmental upland classification (234 grid squares) and that 189 were in the equivalent class (241 grid squares) of the natural and cultural environmental classification. Questions concerned only with the upland heartlands of England and Wales could reasonably be concentrated on the 234 squares of the Core Upland class of the natural environmental upland classification, and studies concerning the upland fringe be considered with reference to the remaining 202 grid squares.

72. An initial assumption (paragraph 4) of this national upland characterisation and classification study was that a primary land classification based on a range of natural physical environmental features "should be the most effective means of providing a sound framework for classifying the uplands of England and Wales on a national scale". The natural environmental upland classification produced by ISA provides, to a reasonable level of sub-division, classes which fit a picture to be intuitively expected from general knowledge of the range of upland properties. These classes at the coarser levels of sub-division have distributions with concentrations in explicable physiographic and climatic zones and, at these and finer levels, provide a means of selecting individual grid squares of like physical characteristics throughout the whole spectrum of upland character in England and Wales. For comparative studies of upland regions, it is now possible to select from such regions squares which have common or contrasting general physical characteristics by using classes of the natural environmental upland classification as a key. It is also possible to ignore regional boundaries and to sample directly from the national distribution of squares in the same class to give squares with physical characteristics broadly in common against which the effect of other differing factors can be judged.

73. Although some reservations must be retained until data consideration still in progress is completed it appears that the combined natural and cultural environmental upland classification introduces complexity into the physical division of the upland without sufficiently clearly illuminating other contrasts in the upland spectrum that are brought about by the past and current activities of man. It is now thought to be preferable to seek to develop an extended "cultural" attribute list, including a wide range of settlement and land use attributes, that can be used for an independent ISA to give a "cultural environmental upland classification". Independent natural and cultural classifications and their comparison to identify and interpret ways in which the two classifications coincide or diverge are thought to be the best means of outlining both major facets of the framework of upland characteristics in Britain.

74. Regionally it should be possible to use the national classification to give a foundation to more detailed studies, and for both these and local investigations, to use the national classification to predict the most likely upland locations where similar land characteristics are likely to occur and to which extrapolation of local detail is likely to be most relevant. For such purposes, the 16-class level of division in the national classification is thought likely to be most helpful, but at the stage of this report the 8-class level has been used. Figure 36 shows the classes, at the 8-class level, of the natural environmental upland classification that occur in the county of Cumbria, the area of regional study, and also the classes of the three squares in Snowdonia within which a district study has been carried out. These two investigations are separately reported. The diversity of Cumbria is seen from the occurrence in it of two Marginal Upland classes (Southwestern and Northeastern Marginal Upland) and three Core Upland Classes (Montane Upland and Western and Northern High Upland). The correlation of the national classification of this region at the 100 km^2 grid square scale with the regional classification at the 1 km^2 scale remains a provocative, and possibly provoking, topic for investigation. The Snowdonia study district at the 8-class level, and also in fact at the 16-class level, falls inside three 100 km^2 grid squares of one class (class 10 (0110)) which occupies only 18 grid squares (c. 4% of the total upland area). The conclusion of the district study was that no significant agricultural intensification was likely there but that up to 50% of the area had a potential for afforestation. From the land use data an average of 8% is mapped as under forest in this class. If this figure is accepted, and if the district study results are extrapolated to the national class, then it could be proposed that up to 40% of these grid squares as a class can be predicted as reasonably afforestable, purely on physical grounds. Such extrapolations may be too wide but they indicate a possible use of the national natural environmental classification which could be tested by field investigations.

75. In relation to major administrative areas it may prove useful to consider the proportions in them of land of different national classes. Without doing more at this stage than simply presenting them, the classes, at the 8-class level in the natural environmental upland classification, of the squares mapped in figure 4 as wholly or partly within the National Parks (see paragraph 25), are shown in figure 37. Class distributions reflect similarities and contrasts between the physical character of the parks. Consideration of these in relation to the very extensive studies available for National Park areas may assist in defining characteristics of these national classes other than those on which the classification has been based.

Potential for Development of a National Upland Data Store and Classifications

Improvement and Extension of the Data Store

76. Some limitations of source quality and quantitative precision of data extraction were discussed in paragraphs 8 and 10. In many cases, better data sources are not available but in some they are becoming so and in others may already exist if more time is used for an exhaustive search. More accurate data extraction, on the 100 km^2 grid square scale, may well already have been made for some of these variables at other centres. In these ways, improvement of parts of the data store for attributes already listed could therefore be made. This probably has little to offer unless the quality of most if not all of the recorded data is also upgraded. With time and money, this could be done. It would certainly improve the accuracy of quantitative description of individual grid squares considerably. It would have less overall effect on region and class mean characteristics but would improve their precision also and might modify the classification position of a minority of individual squares.

77. Additional data can be collected, stored and analysed to supplement that now available. Population densities and data for land uses other than agriculture, such as recreational and water supply attributes, are immediately obvious

useful characteristics. If the proposal of paragraph 73 is adopted, then a search for and choice of an appropriate wider range of "cultural" attributes will be essential to carry out an ISA to produce a cultural environmental upland classification as the other arm of a comprehensive classification framework for the uplands.

Development of the Classifications and their Interpretation

78. The need to complete studies of the natural environmental upland classification and its class characteristics at the 16-class, and probably also the 32-class, level has been mentioned. It is also necessary to complete a short further study of the natural and cultural environmental classification put forward here to confirm that nothing of value will be lost by rejecting it, as now proposed, in favour of independent natural and cultural classifications. The cultural environmental upland classification discussed in paragraphs 73 and 77 should be developed and carried out.

79. It could be thought that the attribute listing used for a natural classification could equally well be used to determine natural environmental classifications of areas at the regional scale, using 1 km^2 grid square units. There is no bar to this in the nature of the attributes, but non-availability of the appropriate data at this scale is the limiting factor for most areas.

80. The present upland classification has **investigated** 436 out of the 1,804 100 km^2 grid squares, entirely within England and Wales, which consist wholly or partly of land. Only the necessary money and resources are required to carry out a complete natural physical environmental classification by ISA of the whole land of England and Wales at this scale. The methodology of ISA and the experience of this study are available. This complete classification could be done either by including the present upland squares with the balance of "lowland" 100 km^2 grid squares in a single new analysis, or the upland classification could be allowed to stand, and a lowland classification could be carried out independently on the balance of c. 1,250 grid squares. In the former case,

additional attribute classes would be required, for example to cover different altitude ranges. In the latter case, then a set of attributes along the general lines of those now used but more tailored to the different ranges of properties in the lowlands could be selected, recorded, edited for ISA, analysed and computed to give a national natural environmental lowland classification. The latter course seems preferable, and the two classifications could be married to form one national physical environmental land classification.

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