Land use factors in the bowland and the dales areas of the old west biding uplands

Bendelow, V.C.

Land use factors in the Bowland and the Dales areas of the old West Riding Uplands

Thesis submitted to the Geography Department,
University of Durham for a
Masters degree in Science.

V. C. Bendelow

Land use factors in the Bowland and the Dales areas of the old West Riding uplands

Abstract

This thesis examines techniques used in land inventories at different scales of data collection and application. In the light of the inventories reviewed an inventory was set up using sampling on a 1 km grid for the Bowland and Dales area of the old West Riding County uplands. Using the inventory's data bank its use was illustrated and some analyses were carried out into distributions and interactions of land-use factors. Using a sample from the inventory certain possible correlations between soil and recorded land use factors were investigated.

Acknowledgement

Without the permission of Mr K.E. Clare, head of the Soil Survey of England and Wales, for the time and use of Survey resources this dissentation would not have been possible. Thanks must go particularly to my colleagues at Harrogate, Mr D.M. Carroll and Mr R.A. Jarvis for being so accommodating with regular soil survey schedules to allow time for this work and the use of unpublished information. Also to Dr. R. Webster at our Oxford office for carrying out computer work and Mr E.M. Thomson of our headquarters Cartography Section for the supply of figures.

Other computer work was carried out by Mr H.R. Simpson of the Statistics Department, Rothamsted Experimental Station and Dr D. Rhind of the Geography Department, Durham University.

Special thanks are due to Dr. J.H. Stevens, my supervisor, for help and encouragement during the course of this part-time study.

V.C. Bendelow
Soil Survey of England and Wales
Block 7
Government Buildings
Harrogate
Yorkshire

CONTENTS

TABLES

PLATES

Chapter I

Aim of the study

Introduction

The Bowland and Dales area of Yorkshire is an area of diverse upland landscapes in which changes in land use may be seen as a response to the interaction of environmental factors. The area is mainly devoted to pastoral farming with a large part of the higher land left as rough grazing (Types of farming in the Yorks and Lancs Region MAFF 1971 - Based on 1968 statistics).

This dissertation attempts to correlate the interaction of certain land use and physical factors of the land with respect to the soil. The physical factors used were those of land use, field size and the nature of the field boundary, site slope, access, aspect, average rainfall and altitude. Information on the soil over the area was from unpublished Soil Survey of England and Wales maps drawn by the author and his senior colleague D.M. Carroll.

The aims of the study were threefold.

1. To set up a basic inventory of physical characteristics for the study area.
2. To use the data bank to try and assess possible links between a limited number of readily assessed land use factors and the soil associations mapped by the Soil Survey of England and Wales (unpublished).
3. To tabulate the characteristics of the soil associations recognized by the Soil Survey of England and Wales, Upland Air-Photo Interpretation Unit.

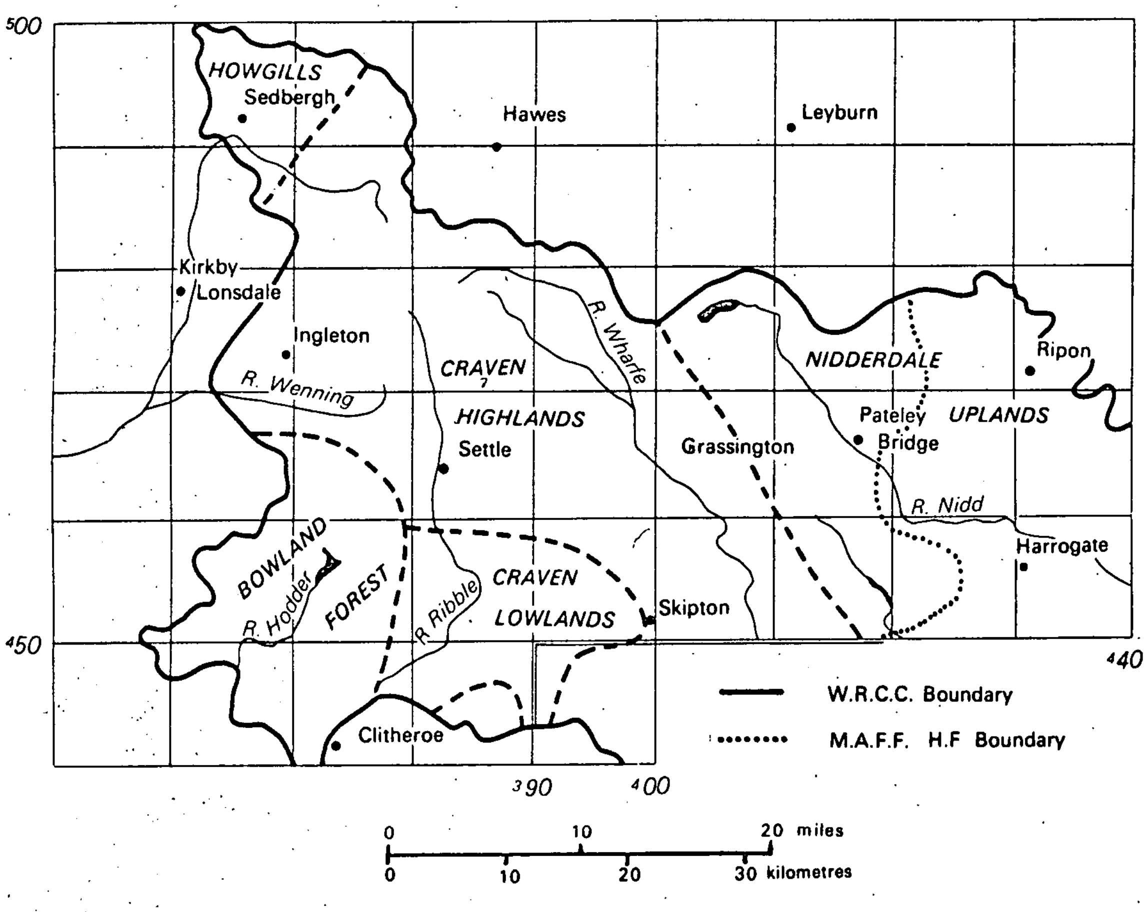
Study Area

The study area is in the northern uplands of the West Riding of Yorkshire (Fig. 1); here the old county straddles the Pennine watershed and extends into the Bowland Forest area in the west. Most lies above 182 m (600 ft) O.D. although extensive lowland is found in the Ribble valley. There is also a NW-SE lowland area between the Bowland outlier and the Craven uplands formed by the Craven fault.

The eastern limit is the MAFF hill farming subsidy line (defined in Appendix II),

Figure 1.

THE STUDY AREA.



while to the north west and south west, as far as the Ordnance Survey eastings line 3900, the old West Riding County Council boundary was used. From near the village of West Marton (gr 895505) the northing line 3500 was followed eastward, meeting the MAFF hill farming boundary by Lindley Reservoir (gr 211498). The total area encompassed was approximately 1800 km^2.

By taking these limits it was recognised that a predominantly upland landscape would be investigated though this includes areas having distinct individuality: the uplands of Bowland, Craven, Howgills and Nidderdale (Gritstone uplands) and the lower land occupied principally by drumlins, but with some flat alluvial areas (Craven lowlands).

The land use and resulting landscape in each area is a response to the interaction of physical constraints put on mans' attempts to utilize the naturally occurring resources to his best (economic) advantage. In general farmers work the land to achieve the greatest output of profitable produce. In the hill lands where land is marginal in quality there are few market options open to the farmer when deciding what to produce. When the market is strong as much as possible of the marginal lands are cultivated, when the market is poor such fields go out of cultivation. The landscape is therefore marked by a zone of flutuating farming use.

The Vegetative cover in the study area provides mainly rough grazing but variations in this vegetation can be seen in response to changes in soil and climate. The climate is characteristically wet and cold for much of the year, with a short growing season starting in late April or early May. Rainfall exceeds 80" (2032 mm) p.a. in the highest areas and often exceeds 40" (1016 mm) p.a. over most of the lower parts of the study area. Evapotranspiration losses are small due to cloudiness and therefore drying out of the topsoil does not often occur, with the soil being at field capacity for much of the year. Measurable rain was recorded on an average of 220 days per year over the 1929-42 period at Malham House (Manley 1955), and comparable figures probably occur over much of the area.

The growing season ends towards late October and the first snowfall soon follows. The withdrawing of stock from the highest land and the provision of extra feed is therefore necessary in most winters. Snow cover at 1300 ft (396 m) O.D. generally extends to 40 days although in a mild winter the figure can be less than 20 days. These "coldness" factors are often exacerbated by the exposed nature of the terrain leading to a wind-chill effect on vegetation and animals.

The vegetation found in the area is the result of the interaction of climate, soil and modifying influence of man. Generally speaking with increasing altitude the climate deteriorates. In the post-glacial period much of the area was wooded (Bartley 1967). However the later clearance of the trees by man to provide grazing for his stock did much to change the vegetation. Today the area is covered with a semi-natural vegetation which is a balance between climate, soil and man's continuing interference with natural development to the climax vegetation.

However differences in the vegetation over the area can be seen in response to the soils which are mainly of an acid nature. Neutral soils are found locally on limestone ledges but these and their vegetation do not reflect the general character of the area.

On the glacial drift deposits covering the limestone of the Craven uplands Mat grass (Nardus stricta) and Heath rush (Juncus squarrosus) are most common. On thin scree soils, often ungrazed because of their steepness, are found Ash (Fraxinus excelsior), Hawthorn (Crataegus Monogyna)and Yew (Taxus baccata). On better drained soils, derived from Millstone grit and Silurian slates, Heather (Calluna vulgaris) is common with Wavy-Hair grass (Deschampsia-flexuosa) confined to poorly drained areas. The dominance of Heather on many moors is helped by the periodic burning of the vegetation, by game bird keepers, to encourage new growth and for supression of any regeneration of woodland species.

Where steep rocky outcrops occur soils are thin and Bilberry (Vaccinium myrtillus), Heather (Calluna) and Bracken (Pteridium)are common. In woodland areas on the Millstone grit derived soils Ash and Birch are dominant.

Much of the highest land is covered by deep blanket or sphagnum peat, these areas are often called "cotton grass moors". Here the vegetation is dominated by cotton grass (*Eriophorum*) with *Sphagnum* in the wetter parts and *Vaccinium* with *Calluna* on drier patches.

The valleys are the most valuable lands to the farming community and are therefore intensively managed. Grass pastures predominate with some fields used for silage or hay, though there are also occasionally fields with root crops.

Chapter II

Description of landscapes in the study area

The first land utilization survey of Britain (Beaver 1941) recognized four major landscapes in the study area (see Fig. 2).

(a) Craven Highlands

(b) Craven Lowlands

(c) Bowland Fells

(d) Central Gritstone Uplands

though a further subdivision of the Craven Highlands can also be described. This is the area of Silurian hills around Sedbergh. The landscape in each of these five areas will be described and illustrated. It is very clear that the landscape units bear a close relationship with the geological units and in the study area rocks and deposits from three geological periods are present (Table 1).

(a) (i) Craven Highlands. The solid geology of this area belongs to the Carboniferous system, with a three fold division of the rocks being made into Great Scar Limestone overlain by Yoredale beds and the Millstone Grit rocks. Here these rocks are almost horizontally bedded but major vertical movements of the rocks were caused by the powerful Craven Faults. The landscape of this area is closely related to the solid geology, which varies markedly over short distances due to the faulting and the differential weathering of the softer Yoredale beds with respect to the Limestone and Gritstone.

Topography is illustrated by the cross section (Fig. 3 and Plate 1) which show the stepped appearance of the landscape and the great altitudinal ranges that may be found from Ingleborough 791 m (2373 ft) to valleys at about 233 m (700 ft).

The most extensive rock in the area, the Limestone is a very pure rock and contributes little in way of soil material (Carroll 1972). The major parent material for most soils over limestone in Yorkshire is a stoneless, silty deposit,

Table 1

Geological Succession

PLEISTOCENE and RECENT	Superficial deposits - glacial drift, alluvium, peat
CARBONIFEROUS	Coal Measures of Ingleton
	Millstone Grit - grits and shales
1200'	Yoredale and Upper Bowland Shales of the Lowlands Basin
4-5000'	Great Scar Limestone and Reef Limestone
	MAJOR UNCONFORMITY
2000' SILURIAN	Howgill Fells

Figure 2.

FIRST LAND UTILIZATION SURVEY LANDSCAPES (BEAVER 1941).

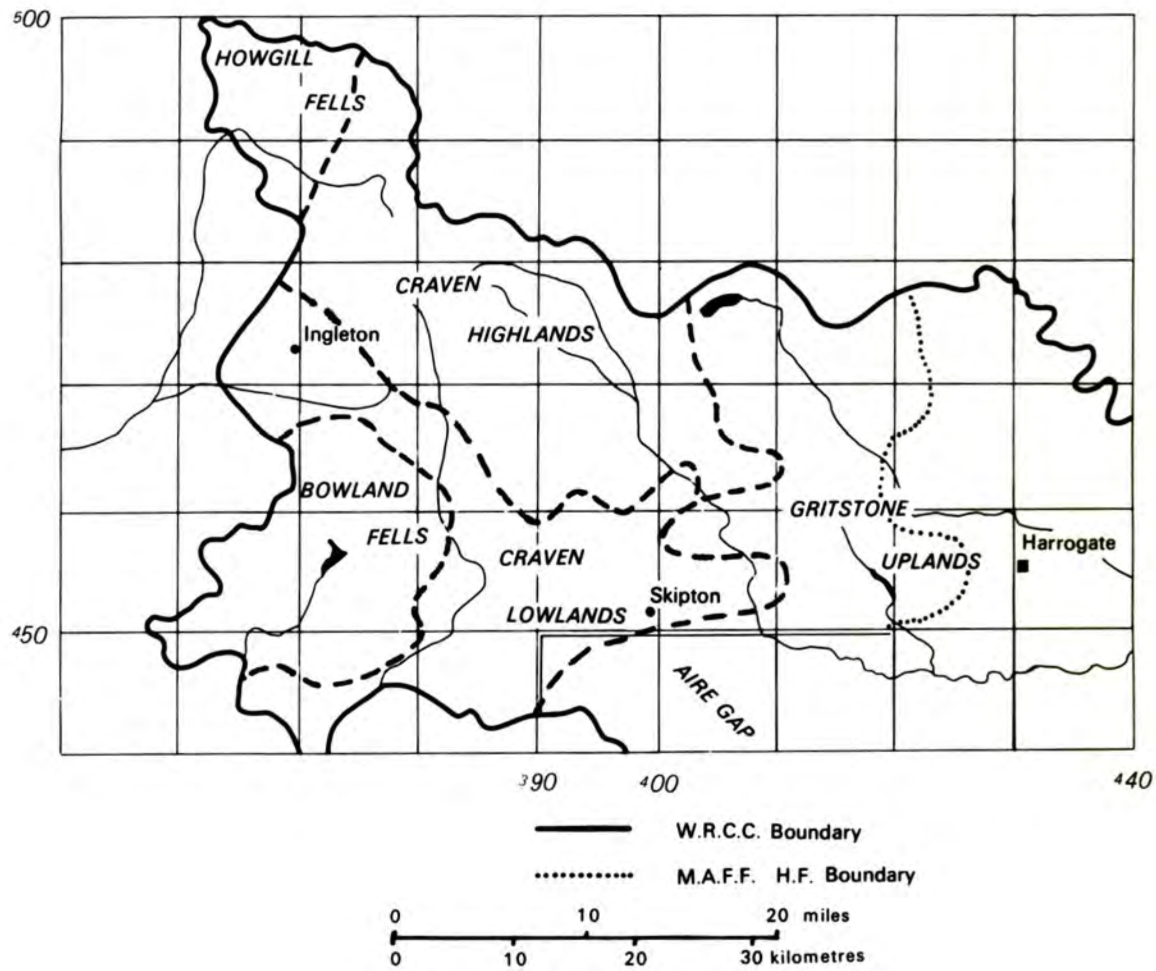
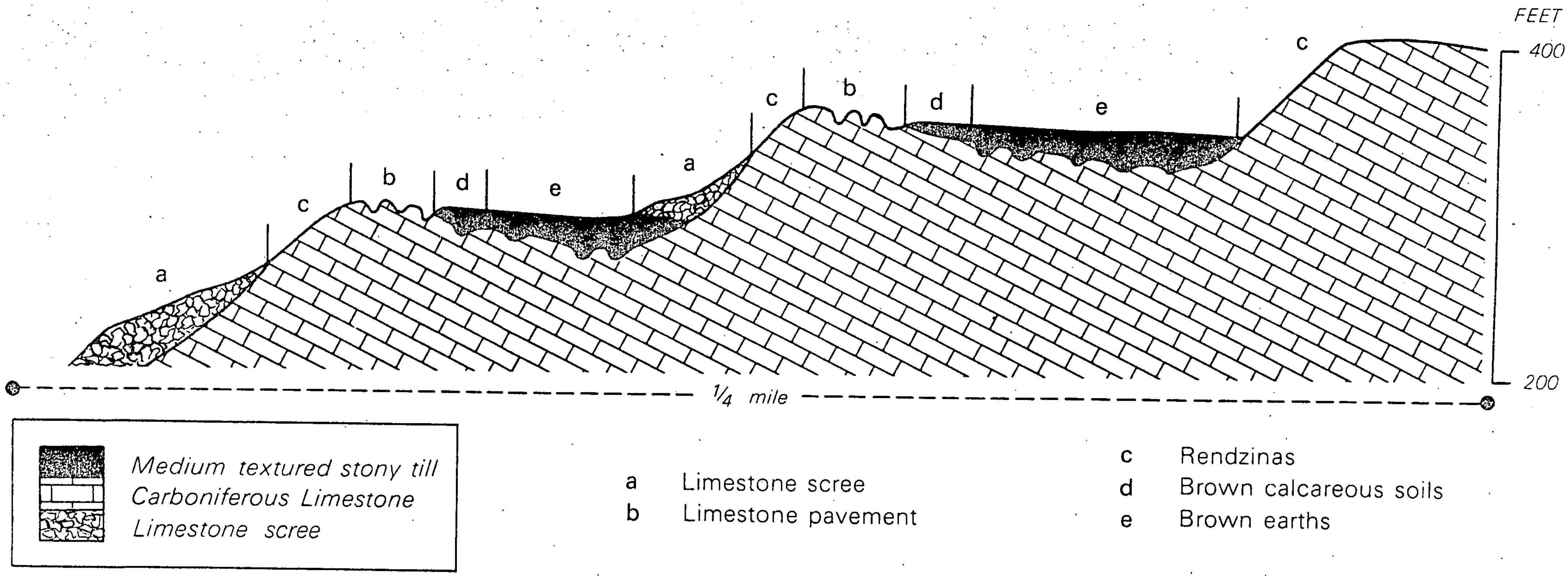


FIGURE 3

CRAVEN HIGHLANDS CROSS-SECTION
(WITH SOILS OF THE WARTON ASSOCIATION)



which Bullock (1971) suggests is aeolian and of largely local origin. Where drift is thick, progressive decalcification of the soil takes place resulting in the formation of marl. The Yoredale beds and the Millstone Grit tend to weather to produce a stony clayey drift and Head. On some steep slopes the Gritstone stands out as a bluff producing a very stony rocky soil which may podzolise. Where rainfall is high, thick peat deposits have formed and are maintained.

Farm Types (MAFF 1971) include extensive sheep and cattle rearing on the poorer hill pasture with some dairying being confined to the valleys.

Plate 1 illustrates the typical landscape of the area, the main features being:-

1. Large outcrops of rock

2. Field boundaries are walled

3. Large fields on uplands, small in valleys

4. Trees confined to valleys

5. Buildings mainly in valleys

(a) <u>(ii) Howgill Fells</u>. Here the solid geology is uniformly of Silurian age. These rocks are on the whole coarse-grained, highly inclined and exhibit a mature well rounded landscape.

Topography is illustrated by the cross section (Fig. 4) which shows the rounded hills with long steep sides. Maximum altitude in the study area is The Calf at 739 m (2219 ft) O.D., though more general altitudes range from about 575 m (1900 ft) O.D. to about 122 m (400 ft) O.D. around Sedbergh.

Farm Types once again include dairying in the valleys with sheep and some cattle on the high pastures.

Plate 2 illustrates the landscape of the area, the main features being:-

1. Absence of field boundaries on the hill pasture

2. Small fields in the valleys

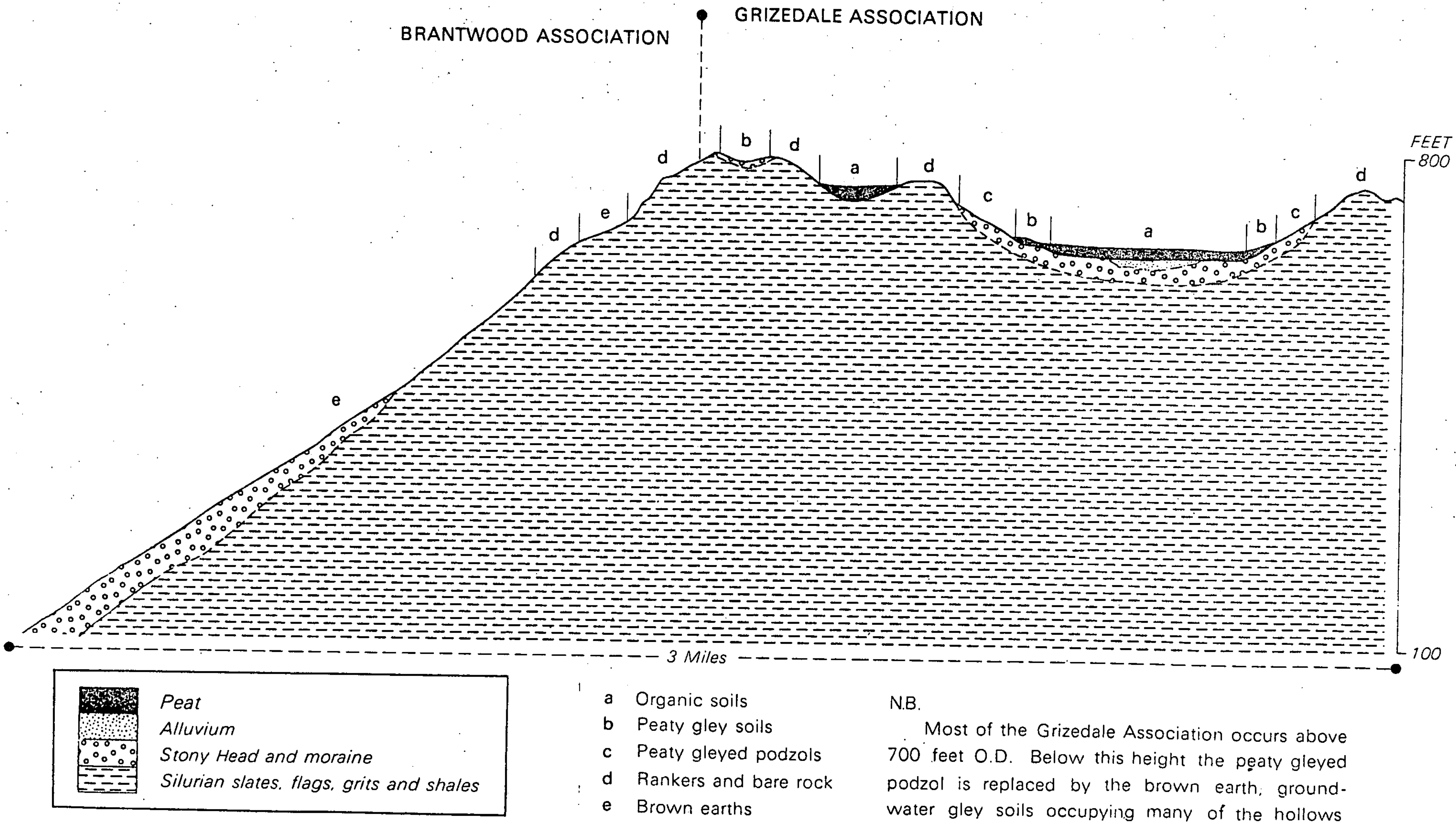
3. Trees confined to water courses

Plate 1.

VERTICAL AERIAL PHOTOGRAPH SHOWING THE CRAVEN HIGHLAND LANDSCAPE.

Figure 4

TYPICAL HOWGILLS CROSS-SECTION



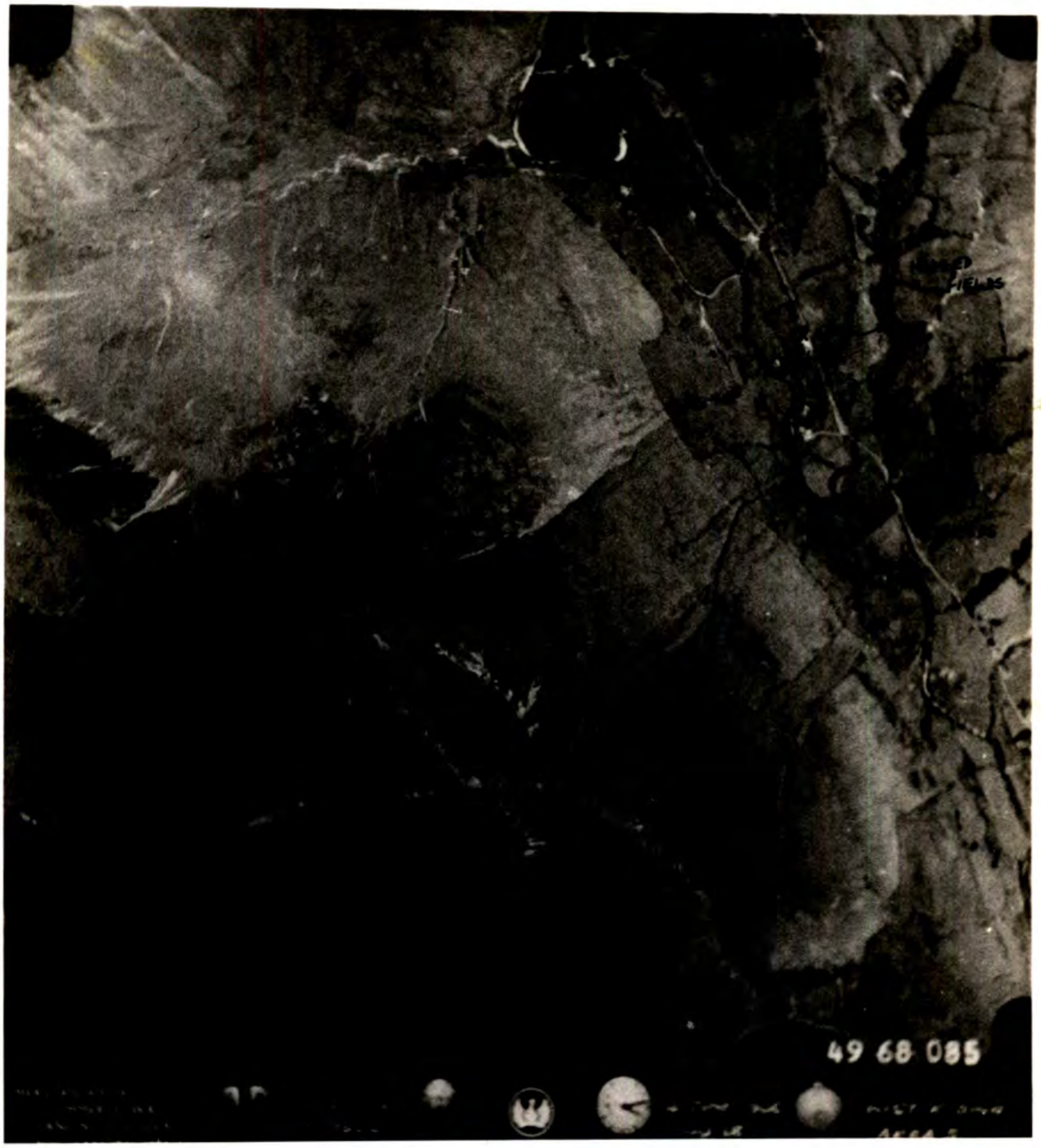
a Organic soils
b Peaty gley soils
c Peaty gleyed podzols
d Rankers and bare rock
e Brown earths

N.B.

Most of the Grizedale Association occurs above 700 feet O.D. Below this height the peaty gleyed podzol is replaced by the brown earth, ground-water gley soils occupying many of the hollows

Plate 2.

VERTICAL AERIAL PHOTOGRAPH SHOWING THE HOWGILL FELLS.



4. Great number of hedged field boundaries

5. Buildings in valleys

<u>(b) Craven Lowlands.</u> Drift and alluvial deposits cover most of the area. Drumlins are common features of the drift deposits and the 1:25,000 map extract (Fig. 5) shows the usual forms of the topography. The altitudinal range is small ranging from 50 m (165 ft) O.D. to 213 m (700 ft) O.D. Alluvial deposits include an area around Hellifield which is the bed of Glacial Lake Hellifield (Raistrick 1930) where the topography is almost flat and river terraces are few.

On the drumlins a silty clayey soil is found which has variable drainage depending on the slope, this is related to its position on the drumlin. Inter-drumlin hollows are often filled with peaty deposits. The alluvial soils are of two types. On the terraces a well drained stony sandy soil occurs while on the recent alluvium and old flat glacial lake bed more poorly drained heavy textured soils are usual.

Farm Types are predominantly dairying or mainly dairying, the good grass growth characteristics of the area being utilized for milk production to supply the industrial towns of Lancashire and Yorkshire, which are easily accessible.

Plate 3 illustrates the landscape of the area, the main features being:-

1. Generally larger fields on the alluvium

2. Trees are found in the field boundaries of the drumlin area

3. Poorer soil drainage on the alluvium as shown by the darker tones on the photograph.

What cannot be shown on this single photo is the change in surface topography between the drumlins and alluvium. This alluvium is, however, distinct from the other landscape units by virtue of the low elevation - less than 182 m (600 ft) O.D., dropping to 50 m (150 ft) O.D. by Clitheroe.

Figure 5.

A COPY OF THE CONTOURS ON A 4 SQ.KM. AREA OF SHEET SD 85 ILLUSTRATING DRUMLIN TOPOGRAPHY NEAR CONISTON COLD.

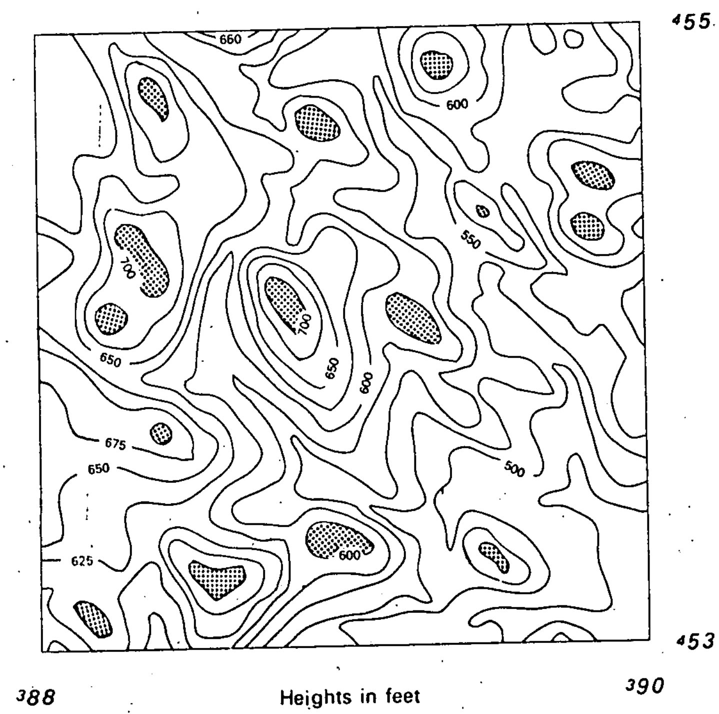


Plate 3.

VERTICAL AERIAL PHOTOGRAPH SHOWING THE CRAVEN LOWLANDS.

(c) Bowland Forest. This area is the main outlier of the Pennines lying to the west of the main north-south axis and divided from it by the Craven Faults. The geology is a sequence of Millstone Grits overlying Bowland shales and Carboniferous Limestone Series shales.

The highest land is therefore one of Millstone Grit moorlands extending to about 450 m (1550 ft) O.D., this land is largely covered in peat. Below about 182 m (600 ft) O.D. soils are developed on Head and shales which has been locally soliflucted producing a poorly drained drift. Small outcrops of sandstone occur giving rise to areas of better drained deep brown soils. Along the Ribble valley a broad stretch of alluvial deposits is to be found including small areas of lacustrine deposits, remnants of glacial lakes. Here altitude is as low as 61 m (200 ft) O.D.

In the Hodder valley, below Stocks Reservoir, a small drumlin field may be where some of the drumlins are cored with limestone (Earp et al 1961). Local occurrences of reef limestone are to be seen but they are only small outcrops in the Hodder valley e.g. Sugar Loaf Knot (gr 671507). More extensive areas of reef limestone are found in the Ribble valley around Clitheroe which have influenced the location of the Ribblesdale Cement works.

Farm Types are mainly sheep on the uplands with dairying and cattle rearing in the valleys of the Ribble and Hodder and lower footslopes. A large area of Forestry is found around Stocks Reservoir.

Plate 4 illustrates the landscape, salient features of which include

1. Small hedged fields on the lowlands including some trees

2. Walled fields on the uplands

3. Afforestation on the uplands

4. Ditched field boundaries on the alluvium

Not shown is the footslopes to moorland transition where trees are confined to valleys and field boundaries are decreasing in number, and the deep peat covering the high moors.

Plate 4.

VERTICAL AERIAL PHOTOGRAPH SHOWING THE BOWLAND FOREST LANDSCAPE.

(d) Central Gritstone Uplands. The solid geology is interbedded Millstone Grit shales and grits dipping gently eastwards. However, much of the landscape has been covered by deep glacial drift. Locally gritstone outcrops may be seen where hill tops protrude through the drift e.g. Jordan Crags (gr 150707) and Palley Crags (gr 142613). Grits also outcrop along the sides of valleys either where slope erosion has thinned the drift or where slopes were too steep for drift deposition e.g. Guise Cliff (gr 166633).

Altitudes range from 700 m (2310 ft) O.D. on Great Whernside (gr 011741) to about 80 m (300 ft) O.D. in the valleys to the east of the area. Over much of the area, moorland is common, the clayey stony nature of the drift and poor climate inhibiting intensive farming. Sheep farming is carried on with shooting on the moors, with cattle rearing and dairying in the valleys and the rare mixed farm where conditions are suitable.

Of special note is the area between Pateley Bridge and Grassington where lead mining has been carried on since Roman times, often in conjunction with subsistence farming. Plate 5 shows the pitted nature of the landscape and great dereliction with the occurrence of old pits and abandoned mines holdings being a common sight.

Plate 6 illustrates the more usual landscape of the area, the main features including

1. Large walled moorland fields, with small fields in the valleys
2. Walled field boundaries with trees in the valleys
3. Natural woodland in valleys incised into the moor
4. Afforestation on the steep slopes of the valley side

Plate 7 is a further illustration of the landscape, showing the moorland burning pattern and gritstone outcrop. Afforestation has taken place on the steep valley side while the valley bottom land is now used as a reservoir.

In this study, in which there is considerable emphasis placed on the linkage

Plate 5.

VERTICAL AERIAL PHOTOGRAPH SHOWING DERELICTION IN THE CENTRAL GRITSTONE UPLANDS.

Plate 6.

VERTICAL AERIAL PHOTOGRAPH SHOWING THE GRITSTONE UPLANDS.

Plate 7.

VERTICAL AERIAL PHOTOGRAPH SHOWING THE GRITSTONE UPLAND MOORLAND.

between human activity and response to the physical environment, the air photograph was used as the prime data source. This is clearly emphasised in the preceding discussion where the different physical regions exhibit a particular response which in turn is reflected on the air photographs in terms of anthropogenic features such as size of field and type of field boundaries.

Chapter III

Review of existing inventories

It is perhaps pertinent to state here that the object of all land inventories is to provide data for planning purposes rather than management purposes. The increase in the amount of data that would be required to allow management decisions to be made would invalidate the initial value of the inventory as a reconnaissance tool used to direct later development and detailed resources.

Five inventories of land use and/or physical characteristics of the land have applicability to this study. They illustrate different forms of data input, handling and retrieval at various scales for point sources or areal information.

The inventories described are:-

1. Department of Overseas Surveys (D.O.S.) methods - used for reconnaissance data collection at a national scale.
2. Canadian Land Inventory - a national inventory for rural planning in detail.
3. The New York State Inventory - a regional inventory for planning in detail.
4. The Second Land Utilization Survey - a detailed national survey of a single factor.
5. The Colne Valley Inventory - a local detailed inventory.

1. D.O.S. methods for reconnaissance data collection. The D.O.S. has frequently to assess land uses over large areas of land for which aerial photographs are available but base maps are poor, or are unsuitable due to shifting patterns of cultivation. Methods of assessing land use have usually been by random point sampling from aerial photographs.

Using 1:40,000 scale photography taken in 1965 Malawi was divided up by Stobbs (1968) into areas having a relatively uniform environment using a series of agro-ecological surveys. Each environment was then investigated to ascertain the land use from information extracted from the aerial photographs on a statistical basis.

The number of sampling points required to give a statistically significant result for each study area was determined using the formula:-

$$N = \frac{(100 - P)\ 38400}{P \times E^2}$$

Where:-

N = Total number of data points needed for the sample

P = % of the total area occupied by the most critical (smallest) land use category - in the first instance usually an estimate.

38400: a constant based on Students 't' test, taken at the 95% level of probability.

E: % error within which results can be expected to fall in 95% of cases.

The number of sample points falling on each aerial photograph was found by dividing N by the number of photographs covering the study area. Ten transparent templates were prepared for the effective area of each print (an area of 7" x 3.5"). For Malawi 18 sample points per print were required for the sample, these points were randomly distributed over the templates.

For each photograph a template was chosen using a roulette wheel, the land use (Table 2) at the sample points was recorded using a D-mac plotter, the location of the sample points on each photograph was recorded along with the land-use class for computer storage.

The data obtained by this method may be retrieved in two ways, either as a tabulation or as a dot distribution map for particular land use catagories.

The technique has been extended (Alford and Tully 1972) so that other information such as vegetation type and land facet codes may be sampled at each inspection point. Further refinements allow the generation of maps of selected scale and complexity.

This technique allows large areas to be sampled within statistical limits, while point sampling and the use of a computer aids tabulation and the carrying out

Table 2

CLASSES OF LAND USE - MALAWI

(after Brunt 1967)

Cultivated

1. Dry land cultivation
2. Cultivation on seasonally flooded grassland
3. Cultivation on alluvial fans (Dimbas)
4. Estates and plantations

Uncultivated

5. Recent fallow land
6. Swamp grassland
7. Seasonally flooded grassland
8. Uncultivated land potentially cultivable (potential and fertility information taken from the agro-ecological survey)
9. Long term fallow land
10. Uncultivated land of low fertility and/or steep topography

Uncultivable

11. Steep and rugged country
12. Lakes, ponds rivers and streams
13. Towns and villages
14. Severely eroded land

of correlations on a large amount of data. No updating facility is used because the random nature of the sample points limit the use of the data for an inventory.

2. The Canadian Land Inventory (CLI). This inventory is under the control of ARDA (Agricultural and Rural Development Administration) which has been responsible from 1961 for the acquisition and tabulation of resource data for the farmed area of Canada.

The inventory records three types of data:-

1. Classification of the lands physical capability for agriculture, forestry, recreation and wildlife management.

2. Present land use.

3. Socio-economic factors relative to the present use.

The data is stored and manipulated by computer allowing the user to make rapid tabulations and comparisons of data. ARDA was also largely responsible for the development of computer mapping whereby extracted and stored data is in map form (Fig. 6).

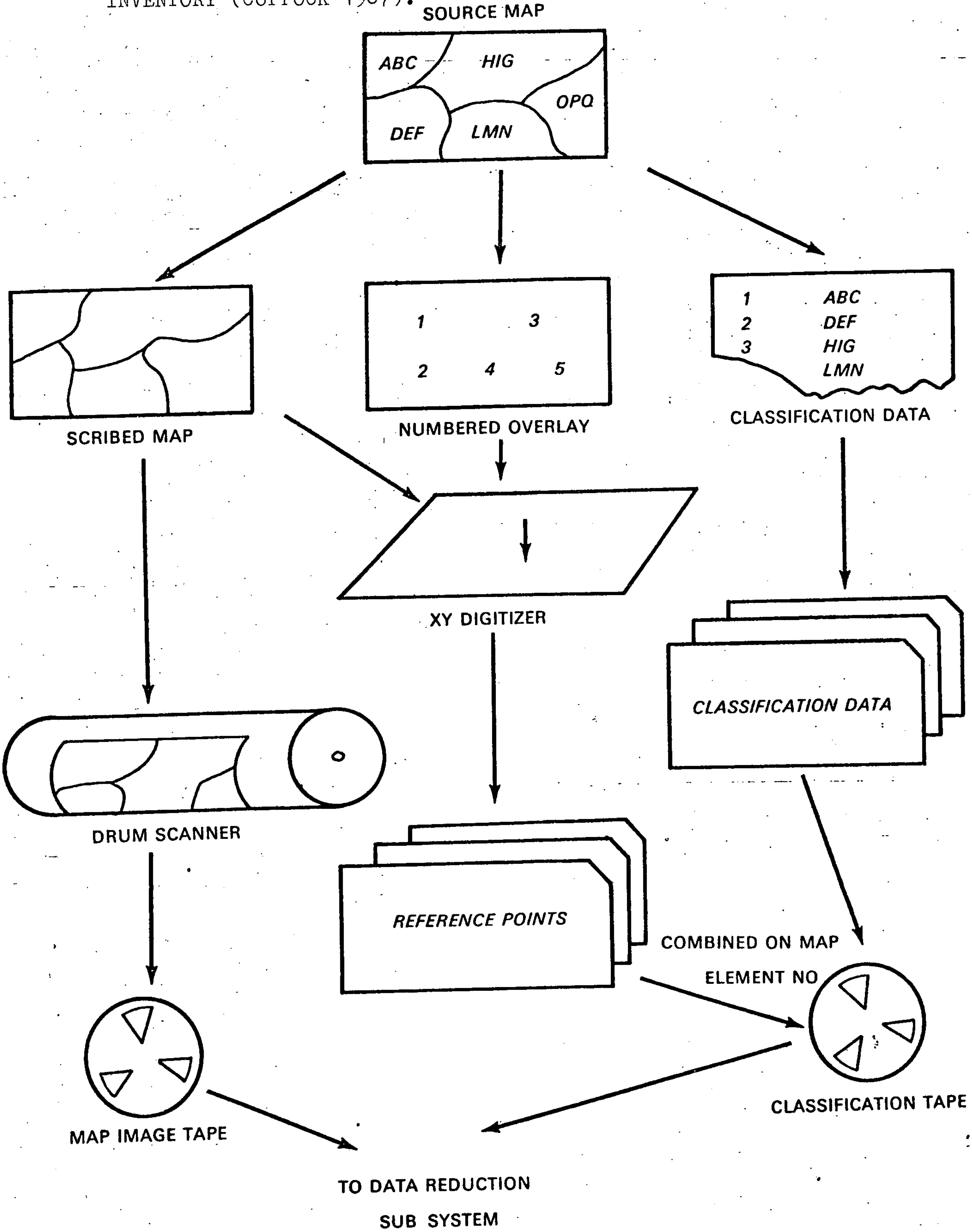
In setting up the inventory several projects were undertaken by many organizations to acquire the data.

1. Using available soil survey data, the Economics Branch of the Canada Department of Agriculture has compiled information on the soils' capability for agriculture. (CLI Report No. 2). There are seven suitability classes from class 1 (no significant limitations) to class 7 (no capability for agriculture), subclasses are recognized depending on the land's particular limitation - poor structure, susceptibility to erosion, low fertility, flooding, soil moisture deficiency, salinity, stoniness, depth to bedrock, topography, occurrence of excess water, cumulative (many minor adverse characteristics militating against farming).

2. Similar maps are being produced for the soil capability for forestry (CLI Report No. 4). Classes are as for agriculture but subclasses are different

Figure 6.

DIAGRAM SHOWING FLOW OF DATA PREPARATION FOR THE CANADIAN LAND INVENTORY (COPPOCK 1967).



falling into three broad groups of limitations due to climate, soil moisture and depth of rooting.

3. The National Parks Branch, Department of Northern Affairs and National Resources is producing maps of a land classification for Recreation (CLI Report on land capability classification for outdoor recreation).

4. Canadian Wildlife Service is classifying the suitability of land for wildlife.

5. A special report has been prepared on the agro-climatic classification of land (CLI Report No. 3). The data considered is of a wide variety and includes length of day, maximum and minimum temperature, July mean temperature, January mean temperature, mean annual minimum temperature, start and end of growing season, day/°F above 42°F, mean date for last spring frost and first fall (autumn) frost, mean frost period, Corn Heat Units, mean monthly precipitation, average annual precipitation, average May to September precipitation, potential evapotranspiration as well as a classification of the climate.

6. The Geographical Branch of the Canada Department of Mines and Technical Surveys have been recording land use since 1950. This survey is continuing and the data introduced into the inventory.

7. Various data of Socio-Economic value is being classified by the Dominion Bureau of statistics for use in the inventory. Details of farming types, economic classification of farms, age of farmers, and population characteristics are the type of data recorded.

The whole system is computer orientated allowing for the updating of data. Data may be fed in and extracted in drawn map, or point source form and is widely available to users.

3. <u>Land use and Natural Resource Inventory of New York State (LUNR)</u>. Using aerial photographs taken between 1967 and 1970 approximately 49,000 square miles of New York State has been assessed in terms of 130 land use categories. The data from the aerial photographs is available in two forms, as map overlays and computer output (Crowder 1972).

Map overlays: 119 land use categories are available for retrieval in map form.

(1) Area land use overlays which show the outlines of 51 different types of land use. The smallest area located on these maps is 1 acre (0.4 ha), Fig. 7. (i)

(2) Point land use overlays which identify and locate 68 different categories of land use important to statisticians and project planners, Fig. 7 (ii).

Computer output

The information in the map overlays was fed into a computer using a geographic reference system on a specially extended version of the Universal Transverse Mercator grid system using a 1 km grid. Some 140,000 cells cover the whole state. Data from the maps was summarised by cell and can be extracted from the computer in two forms:-

(1) DATALIST, this program will produce a simple piece of data for specific grids on request.

(2) PLANMAP, a more sophisticated program allowing extraction and display of certain types of information from specific grids and also combinations of information. This program is being extended and refined and PLANMAP III is now in use, Fig. 8.

Further supplementary data is being added to the computerised part of the system, including a general soil map (minimum size of unit 300 acres), a geologic map, the economic viability of farm areas and other pilot studies such as landform/depth to bedrock data.

Only those parts of the classification which are applicable to studies of upland areas of Yorkshire are listed below.

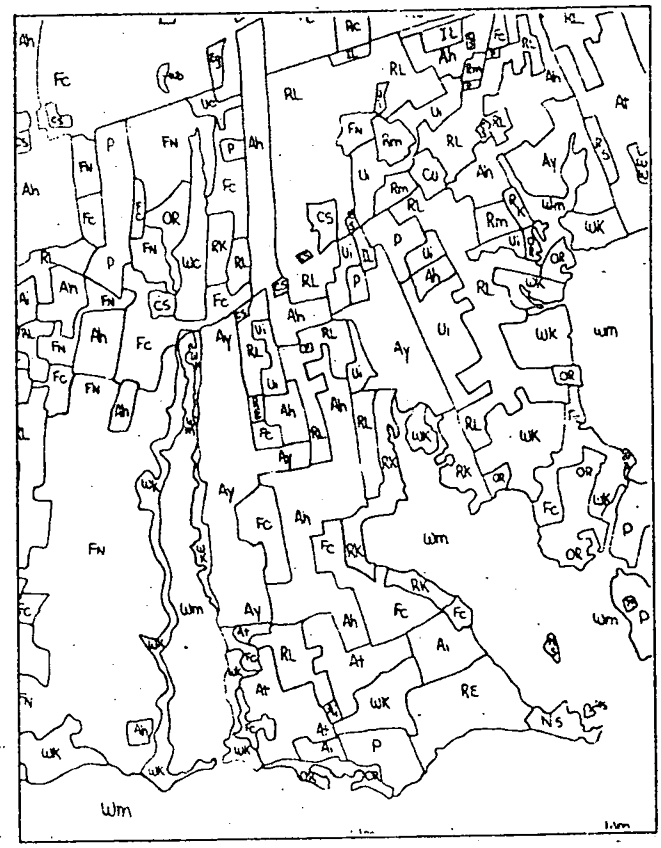
LUNR Classification of natural resources

Agriculture, classified into orchards, vineyards, horticulture or floriculture, high density cropland, cropland and cropland with pasture, pasture, speciality farms. Point data also recorded where applicable numbers of dairy operations, poultry operatives, humber of active farms.

Figure 7. <u>LUNR MAP OVERLAY</u>

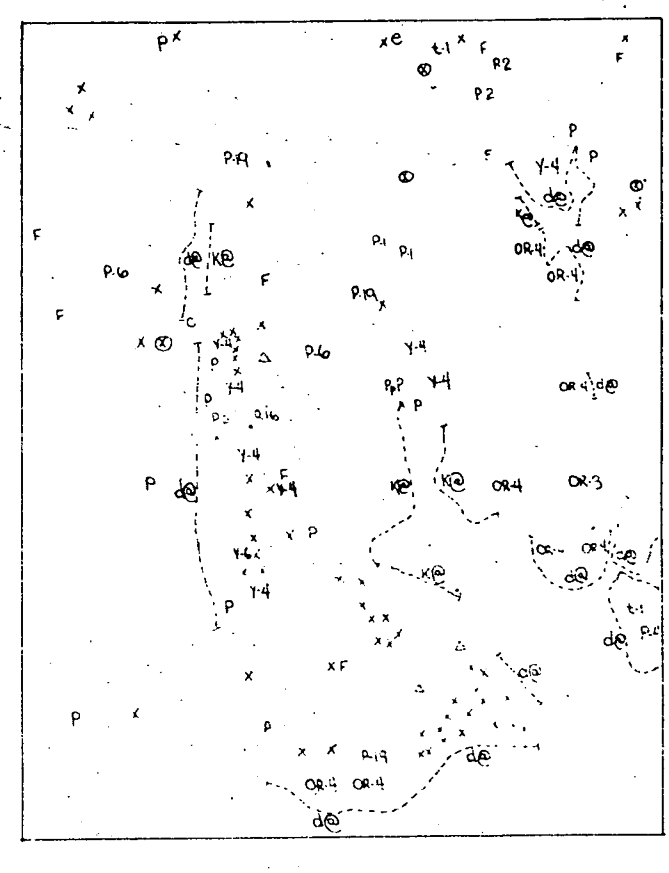
(CROWDER 1972).

(i) AREA LAND USE OVERLAY



Detail of area land use overlay, reduced 25% (part of Brookhaven on Moriches Bay). Sample codes: Fn–forest lands; AY–specialty farms; Wm – marine waters.

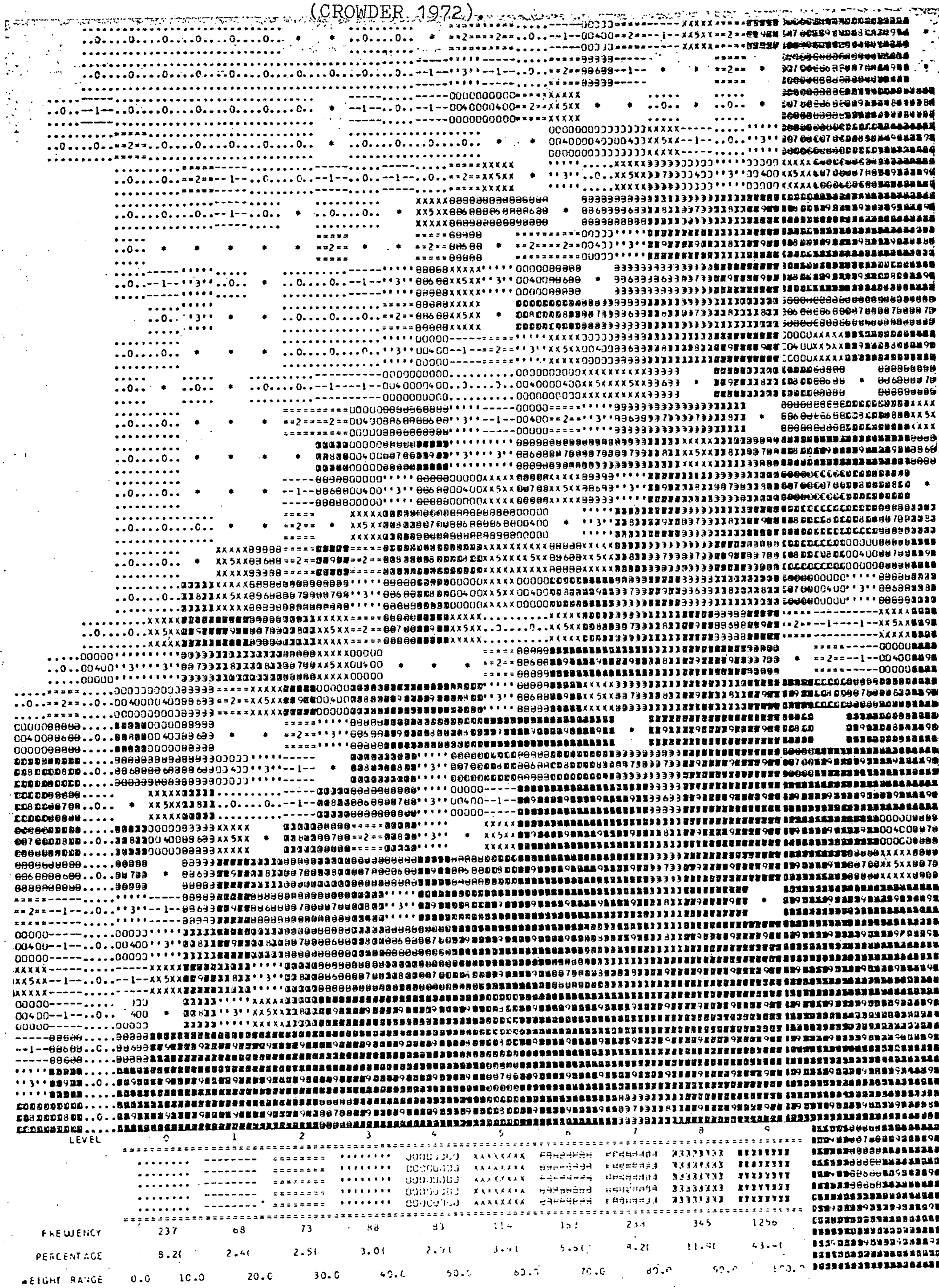
(ii) POINT LAND USE OVERLAY



Point land use overlay, same area, same scale. Some of the codes shown: y-4 – duck farm; P – public land use; OR-4 – marina or boat launching site.

Figure 8. LUNR COMPUTER MAP OUTPUT

(CROWDER 1972)



Detail of a PLANMAP II graphic printout (reduced 50%) showing the environs of Buffalo. Subject is "undeveloped open space" according to certain criteria. Buffalo is at upper left, and increasingly darker patterns show occurrence of open space to east and south. Computer legend is appended at bottom of sample. The user can identify individual cells by coordinates.

Inactive, classified into agricultural land, urban, under construction.

Forest land, classified into forest brushland, forest lands, plantations.

Water resources, classified into lakes, streams and rivers, wetlands, marine lakes, rivers and seas and the Hudson river.

Extractive industry land use classify land into open-cast mining and underground mining.

Open-cast mining, classified into stone quarry, sand and gravel pits, others.

Underground mining, classified into oil and gas, salt, others, abandoned workings.

Nonproductive land includes land which cannot be put into other classes but it is mainly land with extreme natural conditions restricting potential land use for two reasons, sand (area unstable) or rock (little or no vegetation).

The LUNR classification also assesses outdoor recreational land use and rural non-farm residences - these will not be noted in this summary although they may be useful features in a detailed study of the Yorkshire uplands.

This inventory classifies land use as it appeared on aerial photographs of the state in the late 1960's, but no updating facilities exist. Use is made of area land use maps and computer points storage of data for statistical work.

4. Second Land Use Survey (Great Britain) 2nd LUS. The First Land Use Survey was carried out between 1931-38 under the direction of L. Dudley Stamp. Land Use was recorded by volunteer surveyors on 6" to 1 mile field sheets for seven catagories of land use (Table 3). A grassland survey at 1:63,360 scale carried out by R.G. Stapledon was incorporated into the survey and did much to add details of land use and vegetation types in moorland areas.

The results of the Survey were published as a series of 1:63,360 maps covering the whole country and two 1:625,000 maps for the broad view. County Reports were written describing and explaining the land use for each area. The maps, reports and related documentation did much to explain the pattern of land utilization in Britain. Such work proved useful during the war years to highlight areas of farm

Table 3

First Land Utilization Catagories (Stamp 1948)

F. Forest and woodland

M. Meadowland and permanent grass

A. Arable or tilled land, fallow, rotation grass, and market gardens

H. Heathland, moorland, common and rough hill pasture

G. Gardens, allotments, orchards, nurseries

W. Land agriculturally unproductive

P. Ponds, lakes, reservoirs, dykes and streams land mis-use and under utilization. In post-war years it was used as an aid to land use planning for national reconstruction so that the best quality land could be maintained in agricultural use.

By the 1960's it was felt that a re-survey of land use and a comparison with the first survey would be valuable. The Second Land Use Survey is therefore a re-survey of land use begun in 1960 and is now complete.

The survey was carried out by volunteer surveyors simply walking over the survey area and recording the land-use being carried on. The findings are published on a series of Ordnance Survey 1:25,000 maps printed in pairs (2nd series O.S. maps) of which 107 have so far been published, representing an area of 21,400 square kilometres. To speed up the availability of maps the 1:10,560 field sheets used in compiling the sheets are being offered in the form of 35 mm transparencies (see Plate 8).

Land is divided up into thirteen main classes (Table 4), the published map being coloured to bring out these first order divisions. Further details about the land use are given by the overprinting of detail symbols onto the map.

Because of the use of surveyors moving across an area over a number of years this inventory gives an imperfect land use pattern where land use changes annually, as in a crop rotation or as a response to economic situations. However the organisers feel the seriousness of this deficiency is reduced by the regarding the recorded land use in terms of association patterns. No updating facilities exist and the output is simply land use maps as recorded by the surveyors. Interpretations of the land use sheets are to be published. The smallest area that can be recognised on 1:25,000 maps is an actual area on the map of 3 mm x 3 mm or a square of side 75 m (2.5 ha) approximately.

The land use recorded in this survey is now being tabulated on a county basis so that, by using a computer, rapid comparison with the first LUS of the 1930's and 1940's can be made. The land use is being sampled by recording at the 1 km grid intersections of the National Grid, along with information on the elevation,

Plate 8.

SECOND LAND USE SURVEY OF 1/25,000 SHEET SE 06.

35mm transparences of all 2nd L.U.S. sheets are available from the Survey, Kings College, Lomdon.

Table 4

Second Land Utilization Catagories (Coleman and Maggs 1968)

Colour convention	
grey	Settlement, commercial and residential, houses with gardens, newly built-up areas, caravan sites.
	Derelict land
red	Industry, manufacturing, extractive, tips, public utilities
	Transport
green	Open Space
	Grassland, with juncus and scrub infestation marked
brown	Arable, cereals, ley legumes, roots, green fodder, industrial crops fallow.
purple	Market Gardening, nurseries, allotments, flowers, soft fruit, hops.
hatched	Woodland, deciduous, coniferous, mixed, coppice, coppice with standards, woodland scrub
yellow	Heathlands and Rough land, marshed where scrubby
blue	Water and Marsh
uncoloured	Unvegetated

rainfall, soil type, aspect, slope, population density, and a classification of the territory type at the sample points.

5. Colne Valley Land Inventory (CVI). This inventory was produced in 1969 by Miss E. James for her Diploma in Town Planning at the Department of Town Planning, Leeds Polytechnic. From a planning view point, stored readily accessible data on certain environmental factors would form a desirable tool as an aid to the making of planning decisions. Such factors that can be stored include landscape quality, physical factors, landscape appearance, present land use, accessibility factors and existing planning constraints.

The Colne Valley inventory considered all but the landscape quality factors. This was considered too subjective to assess without rigid guidelines which could not be drawn up within the time allowed for the study. The study area was divided up into soil units, and sub-units with regard to aspect. Using the 1 km National grid each sub-unit within each 1 km^2 was further divided into micro-units, each of which was located using its grid reference (Fig. 9).

For each micro-unit the following information was recorded on punched cards for computer handling:-

Grid reference - National Grid

Administrative area - all within the Colne Valley Urban district

Soil reference - origin of soil data i.e. name of soil map

Soil type - eight types (soil series) mapped by the Soil Survey of England and Wales

Aspect - nine classes, taken from Ordnance Survey map

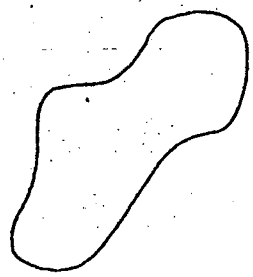
Average Height of micro-unit - tabulated in feet and metres from the Ordnance Survey map

Range of Height over micro-unit - tabulated in feet and metres from the Ordnance Survey map

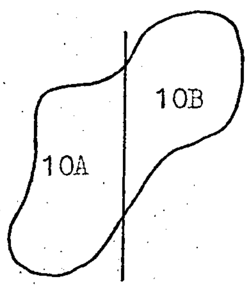
Gradient - taken from Ordnance Survey map, 10 classes

Area of micro-units - in ha, taken from soil map

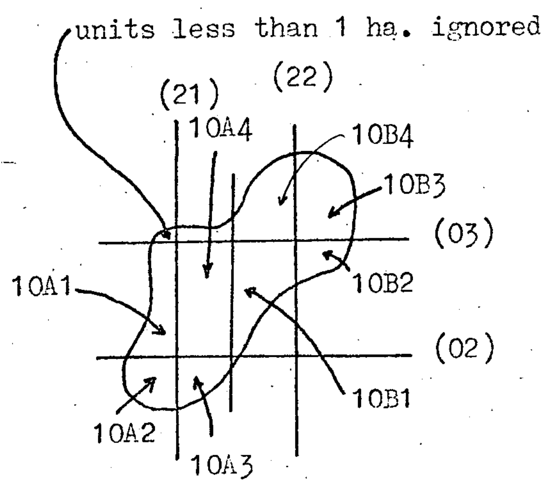
Figure 9. NUMBERING OF UNITS IN THE COLNE VALLEY INVENTORY



Basic unit based on soil type



Sub-unit, based on aspect



Micro-units, located using the National Grid reference of the area.

Thus Micro-unit 10B2 is located at 221029

Agricultural land value - the Agricultural Land Capability class as assessed by the Ministry of Agricultures Lands Arm (Table 5) mainly classes 4 and 5. This system is an adaptation of the classification devised by the United States Department of Agriculture, Soil Conservation Service. It divides land into five grades, 1 being the best, grade 5 the least useful.

Land Slip assessment - taken from the Geological map

Land Use - taken from aerial photographs using the American Urban Renewal Administration and Bureau of Public Road system

Green Belt - whether the land has been reserved for this use by the county council

Development allocation - urban land-use allocation

Access to the unit - number of people within 1 hour, half hour, proximity to B class road.

Programs were developed which allowed computer correlation of data and requesting of data for a particular micro-unit or grid reference.

By re-punching the cards as further or revised information becomes available the data bank can be updated. Computer programs were developed to request the computer to simply list factors or print out the occurrance of certain factors on a grid for use as a map overlay. More sophisticated programs were developed which allowed the correlation of data to be done before print out.

Summary of Inventories

Table 6 is a summary of the five inventories reviewed and also the West Riding Uplands (WRU) inventory which will be discussed in chapter 4. The input data is usually collected in one of two forms, either as a series of maps or as point data. Only the CLI has developed techniques for converting the areal data into point data (Symington, 1968).

Physical data on its own is of limited value unless produced for a reconnaissance land survey. Other human factors are therefore often banked in the inventory since such inventories are mainly used for Town Planning or resource management purposes where the interaction of factors is important.

Table 5

The ADAS (Lands) Agricultural Land Classification (MAFF 1966)

Grade 1. Land with very minor or no physical limitations to agricultural use.

Grade 2. Land with some minor limitations which exclude it from grade 1.

Grade 3. Land with moderate limitations due to soil relief or climate or some combination of these features which restrict the choice of crops, timing of cultivations or level of yields.

Grade 4. Land with severe limitations due to adverse soil, relief or climate or a combination of these.

Grade 5. Land with very severe limitations due to adverse soil relief or climate or a combination of these.

Table 6

SUMMARY OF INVENTORIES REVIEWED

	DCS	CLI	LUNR	2ND LUS	CVI	WRU
Data collection areal	x	✓	✓	✓	✓	x
point	✓	✓	✓	✓	x	✓
Data types Physical	✓	✓	✓	x	✓	✓
Others	x	✓	✓	✓	✓	✓
Data storage map/manuscript *[1]	x	c *[2]	x	✓	x	x
machine	✓	✓	✓	✓	✓	✓
UPDATING	x	✓	✓	x	x	x
Data retreival areal (map)	✓	✓	✓	✓	✓	✓
Table (point)	✓	✓	✓	✓	✓	✓

FOOTNOTE

*[1] Data in numerical code is not considered a manuscript.

*[2] Overlay maps available for climatic parameters.

The storage of the large amounts of data needed to make such inventories viable necessitates the use of computer handling of data. The storage of data on manuscript or map severely reduces the usefulness of any system because of the need for the grouping of various data by classification into broad groups and also the need for inspection of data using map or map overlay methods with the inherent limiting factors of scale and handling. Such methods are also slower.

The updating is only important in ongoing systems where the requirements for recent data are important as in the use of the inventory for assessment of current needs e.g. requirement of school places, would necessitate updating of pre-school population figures in an inventory.

All the systems produce output in map and table form. Maps can be of three types. Firstly in the case of the 2nd LUC only one of many land uses is shown for each location and highlighted by colour printing. Secondly, as the LUNR system, single element maps are produced and the relevant visual impression is obtained by viewing the relative darkness or lightness of the composite map when viewed over a light table. The third type of map form is exhibited in the other systems, which produce maps by simply manipulating the computers print-out carriage to print data in symbolic form in the correct X and Y axis positions, on the print-out sheet so building up a map.

All systems are able to print out tabulations of data with varying degrees of sophistication, some systems simply printing input, others are able to produce correlations of data.

Chapter IV

The inventory system used in the current study

In view of the limited time available for this study it was decided that the type of data that could be collected for the data bank would have to be of a type that was readily available and could be obtained from air-photos. Point sampling was undertaken as this allows computer handling of the data facilitating the comparison of data and allowing a definite analysis. Collection of data for 2043 location points in the study took 6 man/months and was carried out on a part-time basis when Soil Survey duties permitted over a period of two years.

In this respect the inventory system that was developed was simple and lacked the complexity and sophistication of the land inventory systems described previously but it is perhaps of some importance that the organization of the Canadian Land Inventory by ARDA be noted. Here the overall responsibility for the inventory fell on ARDA, but the collection of data and submission to ARDA for banking fell to the individual collecting organizations. The work load involved in setting up the inventory was therefore spread across many groups, each having a vested interest in the submission of their data to a central organization for dissemination (previously each organization produced specific data for one user or generalised data for no particular user). In this study the material has been collected by one individual from one organization though it is hoped that the data has applicability for a wide range of users. An appraisal of the inventories described in chapter III indicates the type and range of sampling techniques and data that could have been used in studies of this type. The use of data as an inventory precluded the random sampling carried out by the DOS. However, the need for numerical handling of the data necessitated the point sampling of data, although for use as an inventory the areal distribution of data is more useful. Many sorts of information would have been useful for the study, however, the time factor meant that only readily available published data (except soil data) could be used. Nine types of data for each of the 2043, 1km national grid intersections were recorded as a 14 digit code number following a four digit locational number, a total of 18 digits per grid intersection. The types of data, the code used and the digit positions are set out below.

Location (digits 1, 2, 3, 4.)

Each sample point was located using the O.S. national grid as Cartesian co-ordinates. Digits 1 and 2 located the easting line of the point. Digits 3 and 4 the northing line.

The study area falls within the SD and SE 100 km grids, extending from eastings 360 to 427 and northings 439 to 499. Due to the limited E-W extent of the area no easting line in the SD 100 km block was repeated in the SE 100 km block, two digits were therefore sufficient to fix any eastings line in the study, similarly with northings. If the study area were extended the addition of an extra digit before digit 1 and the present digit 3 for the national grid 100 km locator digit 3 would be sufficient to fix any sample point within the United Kingdom.

Land Use (digits 5 and 6)

If the information had been available the land use recorded by the 2nd LUS would have been tabulated. However this was not available - instead 13 land use categories were recognised similar to those of the 2nd LUS except that only one industrial class was taken. Since this study was concerned mainly with assessment of rural land use no details of settlement or industrial land use were thought pertinent. This use forms only a small percentage of the area.

Land use at each intersection was assessed from panchromatic aerial photographs taken between 1966 and 1969 for the West Riding County Council and available at a scale of 1:10,500. Stereoscopic pairs were used during data collection.

The land-uses recorded with their code were:-

Code 01. Natural Woodland, corresponding to the LUS Deciduous, mixed and wood-land scrub. This land use category was recognised by the mixed crowns of the trees, lack of orderly layout and variable trees height and crown width within the parcel in which the sample point falls.

Code 02. Orchard. This was allowed for during the data collection phase but no land use of this type occurred in the study area on any of the grid intersections.

Code 03. Plantation. This corresponds to the LUS coniferous woodland and coppice with standards (shelterbelts) and, as such, is recognised by the orderly layout of the trees, uniform tree height and crown width within the forestry compartment in which the sample point falls.

Code 04. Arable - not used as no sample points fell on arable land use.

Code 05. Pasture. This corresponds to LUS grassland, with uniform tonal appearance and few (<30%) signs of variable grass growth or factors likely to limit grazing potential within the parcel.

Code 06. Rough grazing. This corresponds to LUS pasture with Juncus or marsh. Signs of limitations to grazing over more than 30% area of the pasture are visible either by rush (Juncus) infestation of grass, due to wetness, or by rockiness and steepness which may curtail mechanical operations, or by the area being under semi-natural vegetation of poor grazing quality.

Code 07. Mineral extraction. This corresponds to LUS extractive industry which, in the study area, is limestone quarrying. This land use category is easily recognized from the aerial photographs.

Code 08. Residential. The Land Use Survey recognise [redacted] four groups under settlement but in this study no divisions were made because of its limited area and low dependability on physical features.

Code 09. Industrial. This corresponds to the category used by the LUS and includes manufacturing and public utilities. No subdivisions were made for similar reasons to those applied to the residential category.

Code 10. Recreational. Corresponds to LUS open space, which, in the study area mainly consists of golf courses,

Code 11. Derelict land. Corresponds to its LUS equivalent. In the study area this land use was predominantly associated with old lead workings around

Grassington examplified as spoil heaps and holes recolonized by semi-natural vegetation which, but for the surface topography, would be classed as rough grazing.

Code 12. Open water. This has a direct LUS equivalent. In the study area, this was mainly reservoirs, Malham Tarn being the exception.

Code 13. Rocky ground. Directly corresponds with the LUS unvegetated group. Recognized where more than 50% of the surface within the parcel or within ½ km radius was exposed rock.

Parcel Size (digit 7)

The parcel size in which the sample point falls was recorded, this was to allow the investigation of how closely parcel size was related to the soil type. It was intuitively felt that better drained soils were associated with smaller fields in an effort to spread the most valuable land throughout the community - field size increasing with decreasing quality.

Five classes were recognized and measured from aerial photographs.

Code 1. 0 - ½ ha (1.25 acres)

2. ½ - 1 ha (2.5 acres)

3. 1 - 4 ha (10 acres)

4. 4 - 6 ha (15 acres)

5. >6ha (+ 15 acres)

Boundary type (digit 8)

Field boundary type appears to vary and a correlation of any variation with soil would prove useful. Are, for instance, walls always associated with stony soils or exposed sites? Are ditches and dykes mainly hedged? The predominant (>50% of length) boundary type seen on the aerial photographs was recorded using the following code:

Code 1. Hedge. This is seen stereoscopically to be a low boundary of vegetation.

2. Trees. While higher than boundary type 1, crown width is used in assessing whether trees are predominant. Trees are often associated with type 1.

3. Walls or fences. The wall is the dominant boundary within this group (>95%), the fence often only being visible due to differential grazing, owing to the scale of the photographs or where the sample point is in open water (LU00).

4. Ditch, gully or stream. The ditch predominates but in practice is probably reinforced by a wire fence.

5. No boundary type is visible within 1 km distance, this situation being indicative of the unfenced moorland tracts.

Slope (digit 9)

Four classes were taken for the slope at the point of sampling by assessment using stereoscopic pairs of aerial photographs.

Code 1. Level or gentle. (Slope 0–3°)

2. Moderate. (Slope 3–11°)

3. Steep (this grade too steep for many implements). Slope >11°.

4. Cliff.

Proximity to road (digit 10)

Accessibility to site is important. A physically ideal site for a land use may be precluded for reasons of accessibility. The proximity of the sample point to a classified road seen on the 1:25,000 O.S. sheet was recorded in three classes.

Code 1. Road within ½ km.

2. Road within ½ - 1 km.

3. Road further than 1 km.

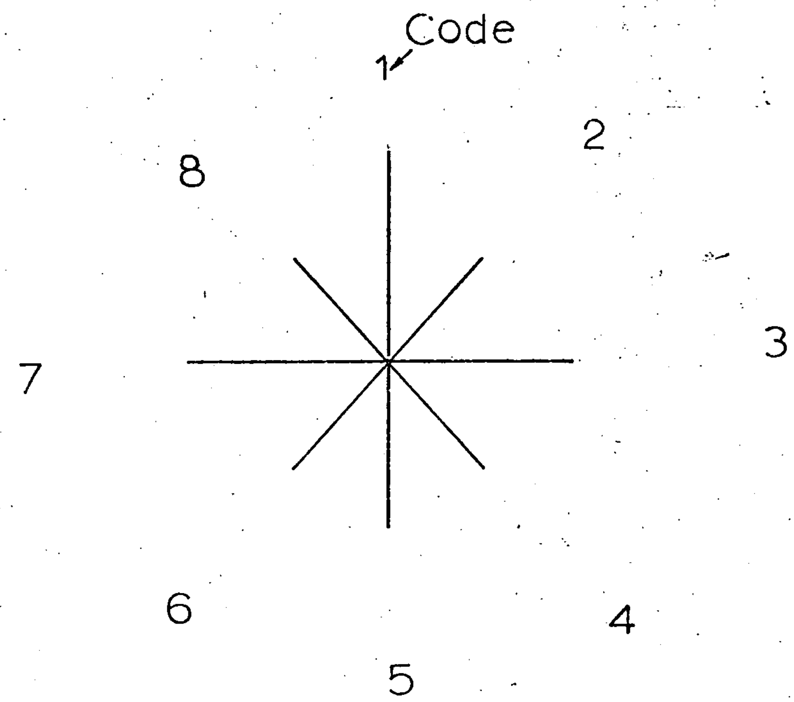
Aspect (digit 11)

Using the diagram used in Fig. 10 the aspect code of each sample point was taken from the O.S. 1:25,000 maps.

Soil Association (digit 12 and 13)

A soil associatin refers to a unit embracing a number of soil series which occur together consistently with characteristic relief features. A soil association

Figure 10. DIAGRAM USED FOR ASPECT ASSESSMENT (DIGIT 11)



FLAT SITES WITH NO ASPECT RECORDED AS 0

contains two or more soil series which recur in approximately similar proportions and in a sufficiently distinct pattern as to have a predictable topographic position. In describing a soil association it is usual to describe its landscape position, topography, constituent series and land use thus enabling a user to identify the soil series inthe field.

During the summers of 1970 and 1971 the Soil Survey of England and Wales Upland Air Photo Interpretation Unit at Harrogate mapped the soil associations of the West Riding uplands as part of a programme aimed at a 1:250,000 soil association map of the county. Seventeen associations were recognised and checked with a 5% ground survey, and were delineated on 1:10,500 aerial photographs. These boundaries were transferred onto 1:25,000 O.S. base maps using an Aero Sketchmaster. Fourteen of the associations had previously been recognised in Lancashire and are fully described in the Soil Survey's bulletin on that County (Hall and Folland 1970), three minor associations are new and have not yet been fully described.

The following is a brief description of the associations seen with their code, but it must be stressed that the units are soil associations, a rather broad unit for describing the soils and therefore only useful in pilot surveys. Since the soil association were initially compiled at a scale of 1:10,000 the smallest unit recognised is an area of 90,000 square metres (9 ha) and therefore an association can only be a guide to the range of soils that may be found in an area. The information regarding the distribution of associations has not previously been published.

<u>Code 00. No Soil Association.</u> Areas of water (reservoirs and tarns) and urban areas.

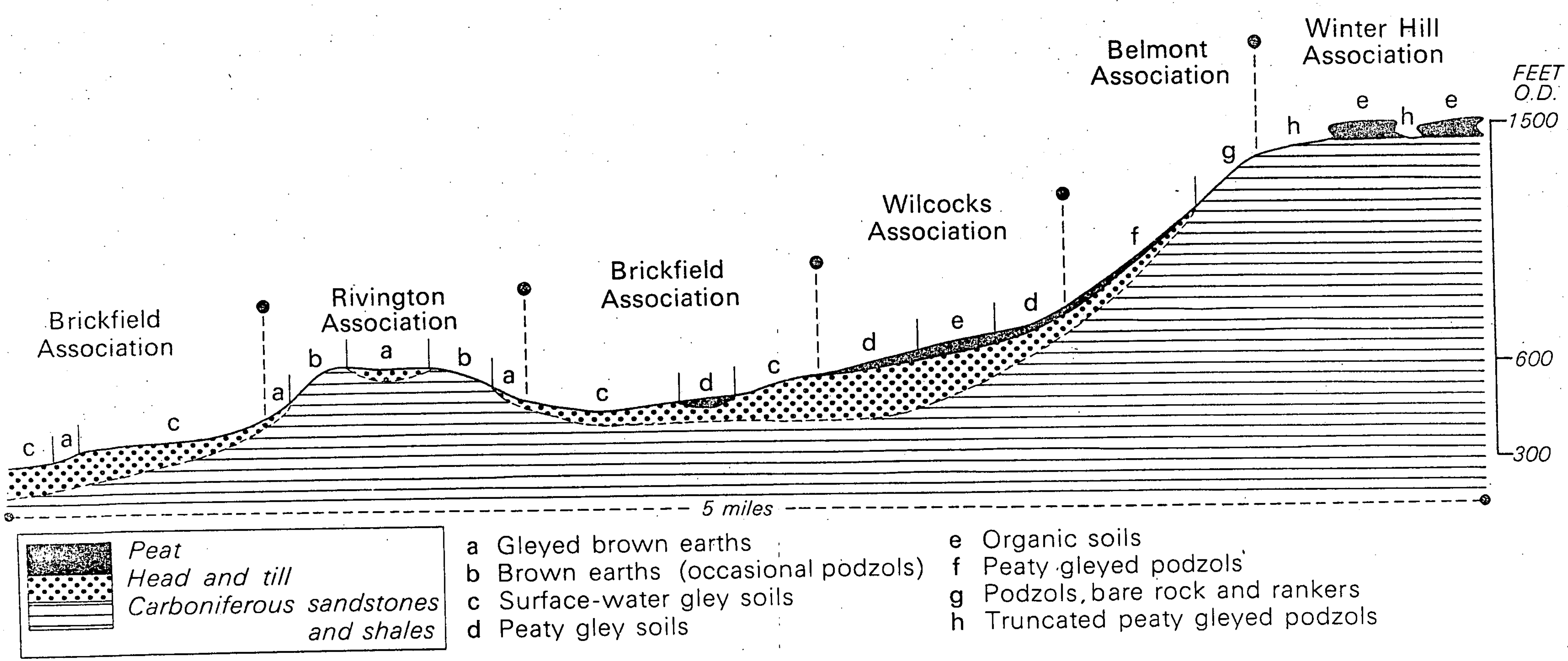
<u>Code 01. Winter Hill Association.</u> The Winter Hill (see Fig. 11)* association

FOOTNOTE * Cross-section taken from Hall and Folland 1970

occurs on the flat and gentle slopes of the plateaux tops above 320 m (1100 ft). Climate in these areas is typified by low mean annual temperatures accentuated by exposure to winds, high rainfall and low evapotranspiration rates. These

Fig 11

FIVE CARBONIFEROUS SOIL ASSOCIATIONS



conditions slow the biological breakdown of plant remains leading to the maintainance of the post-glacial hill peats.

The association is typified by deep (>40 cm) peat deposits or where the peat has been eroded a truncated peaty gley podzol* is present. Here peat haggs stand up

---

FOOTNOTE * the classification and soil series names used by the SSEW prior to 1973 is used throughout, the reclassification of these soils into the system proposed by Avery 1973 (and adopted by the Soil Survey) is unlikely at the present. Some soils may not have a direct equivalent in the new system.

---

above leached sandy loams or sandy clay loams below which can sometimes be found an iron pan.

This association is of little agricultural value being used as rough grazing or grouse moor. Its main value is as water catchment, the deep peat forming a slowly draining reservoir of moisture during dry summers. It is one of the most extensive soil associations in the study area.

Code 02. Wilcocks Association. The Wilcocks association (see Fig. 11) is found on gentle footslopes above 182 m (600 ft) O.D. where annual rainfall exceeds 1020 mm (40 in) p.a. The parent material is composed of mineral particles from a mixture of Carboniferous grit, sandstone and shales, of local origin, resulting in profiles with a wide range of textures depending upon the proportion of each constituent. In the Craven uplands some of the finer textured deposits are thought to be of aeolian deposits (Carroll 1973). These are usually distinguished by their very low stone content.

The high rainfall, impervious clayey nature of the substrata and often run-off from higher slopes results in an association comprising mainly peaty surface-water gleys and organic soils. In some areas, notably the Craven uplands, this parent material overlies limestone. Where the over burden is of the order of 2.4 m (10 ft) thick the limestone collapses forming sink holes, with peaty gley podzols being sometimes found on the better drained edges of these holes. The distribution of the soil types of this association depends largely upon topographic position and the texture of the parent material. When these soils are cultivated the humose nature of the topsoil is often preserved as a humic Ap horizon thus preserving the high water holding capacity of the surface layers.

This association is the most extensive in the area and of limited agricultural value often being left as rough grazing. Reclamation of some areas has taken place but, without a high level of management and frequent liming, recolonization by <u>Juncus</u> and restoration to moorland is likely. Areas of these soils around Cam Houses (gr 820821) and Langstrothdale (gr 910782) have been planted with conifers, though in areas with a clayey substrata the windthrow hazard is likely to be high.

In upper Ribblesdale is found an area of drumlins. Here the peaty topsoil of the drumlins has resulted in their inclusion in this association rather than the Charnock association (code 09) described later.

<u>Code 03. Belmont Association.</u> The Belmont association (see Fig. 11) occurs on moderate to steep slopes between 210-450 m (700-1500 ft) O.D. with local cliffs. It is formed on strongly bedded Millstone Grit shales, with grit outcrops forming bluffs, and along the sides of incised valleys. Annual rainfall exceeds 40" p.a. but because this falls on steep slopes it is rapidly shed resulting in the formation of acid peaty gleyed podzols on parent materials with fine textures and humus-iron podzols on the coarser textured Head. Where rock outcrops occur, cliffs form with discontinuous rankers on the Head below.

The soils in the association are of little agricultural value because of their steepness and are often left as rough grazing though some recent attempts at afforestation have been made where the mineral soil is sufficiently deep.

<u>Code 04. Langdale Association.</u> This association of rankers, organic soils bare rock and scree is found on Silurian Grits, flags and derived stony drift. Topography is rugged with very steep slopes at altitudes of between 182-600 m (600-2000 ft) O.D. covering a large area of Brant Fell (gr 660950).

The steep slope, absence of sufficient soil depth for rooting and high rainfall impose severe limitations to agricultural use. The area is therefore left to rough grazing. Field boundaries of any sort are usually absent.

Code 05. Grizedale Association. The Grizedale association (see Fig 4) occurs on craggy ground from 182-305 m (600-1000 ft) O.D. on Silurian grits, flags and associated drift. It is confined to two areas, around Sedbergh and to a lesser extent around Horton-in-Ribblesdale.

The association consists of a wide range of soils with bare rock and rankers on the freely drained sites, brown earths and peaty gleyed podzols on the intermediately freely to imperfectly drained sites. Ground-water gley soils, peaty gley soils and organic soils are to be found on the poorly to very poorly drained sites.

Above 210 m (700 ft) O.D. much of the association is covered by heath vegetation and is left as rough grazing. Below this height mixed deciduous woodland and pasture is more common although areas of rocky ground and wet hollows are limiting factors.

Code 06. Brantwood Association. The soils in the Brantwood association (see Fig. 4) are similar to those in the Grizedale association, but, being found at lower elevations 122-90 m (400-900 ft) O.D., brown earths and rankers are more common. The parent material consists of Silurian grits flags, slates and shales and associated deposits of Head and lateral moraines.

Rainfall is rapidly shed from the steep slopes of the association via a network of narrow deeply cut water courses which may be seen running down the sides of valleys. The soil sequence is mainly one of rankers on the steep slopes, otherwise brown earths, and some ground-water gley soils, the latter occurring where water is flushing from above. The area is mainly under pasture with field boundaries being well wooded.

Code 07. Warton Association. The Craven area is well known for its limestone which outcrops along valley sides and dominates the landscape seen from the roads, which tend to follow the valleys. The soils associated with the limestone are grouped into the Warton association (see Fig. 3) and include bare rock, rendzinas, brown calcareous soils and brown earths. The limestone is mainly weathered by solution and as the solutes drain away through the limestones joints, the rock consequently contributes little mineral matter to the soil. The rendzinas and brown earths are therefore formed in drift and aeolian material overlying limestone.

The association extends from 150-350 m (500-1200 ft) mainly in the Craven uplands but small areas of knoll and drumlins, cored with limestone, are to be found in the Hodder valley and middle Ribble valley. The free drainage of most soils found in association tend to offset the high rainfall of the area (up to 50 in. p.a.). However the occurrence of bare limestone in complex with the brown earths, and the exposed situation of these areas has tended to result in the area being little improved for agriculture although grass quality is moderately good. The semi-natural vegetation is coarse grasses. However the tonal appearance on aerial photographs is similar to that of pasture (code 05) and the land-use has been recorded as this. This discrepancy is not considered serious as such pastures are marginal (05/06) and could readily be converted to good pasture should the need arise. The First British Land Utilization Survey similarly recorded these limestone pastures as "permanent" and only catagorizes it as "rough" when coarser plants and crags dominated the area.

The sides of upper Wharfedale are steep with frequent exposures of limestone, but the ledges between outcrops provide sites for natural woodland. Such sites are not to be found on the exposed moorland above or on the agriculturally valuable valley floor land.

Code 08. Brickfield Association. The Brickfield association (see Fig. 11) of soils are found generally below 180 m (600 ft) O.D. on gentle to moderate slopes in the main river valleys between the flood plain and the steeper valley side slopes, as well as on the Gritstone uplands west of Harrogate. The soils are developed on medium to fine textured till and Head derived from Millstone Grit series sandstone and shales. The association is dominated by surface-water gley soils although peaty gley soils are found in hollows and flush sites and gleyed brown earths occur on a few better drained steep slopes.

Most of the association is devoted to permanent grassland although a fairly high level of management is necessary to alleviate problems of rush infestation and soil poaching.

Code 09. Charnock Association. The Charnock association (see Fig. 12) has similar parent material to the Brickfield association. Its soils are formed on fine textured till derived largely from the Millstone Grit series, with variable amounts of included shale and sandstone. Unlike the Brickfield association the characteristic topography here is of the rolling drumlin landscape. The association is found in the Craven lowlands and the Hodder valley at altitudes of 122-182 m (400-600 ft) O.D. and it forms the dominant group of soils in the lowland of the study area. The drumlins found in upper Ribblesdale have humose or peaty topsoils and have therefore been included in the Wilcocks association rather than here.

The soils found in this association are a reflection of the fine texture of the parent material, the moderate rainfall (40-50 in. p.a.) and the topography. Surface-water gleys soils predominate on the drumlin tops and inter-drumlin hollows, the steep sides of the drumlins tend to shed water resulting in improved drainage and the formation of gleyed brown earths. Some interdrumlin hollows contain peaty gley soils and peat deposits where water, shed from the surrounding drumlins, has been unable to escape.

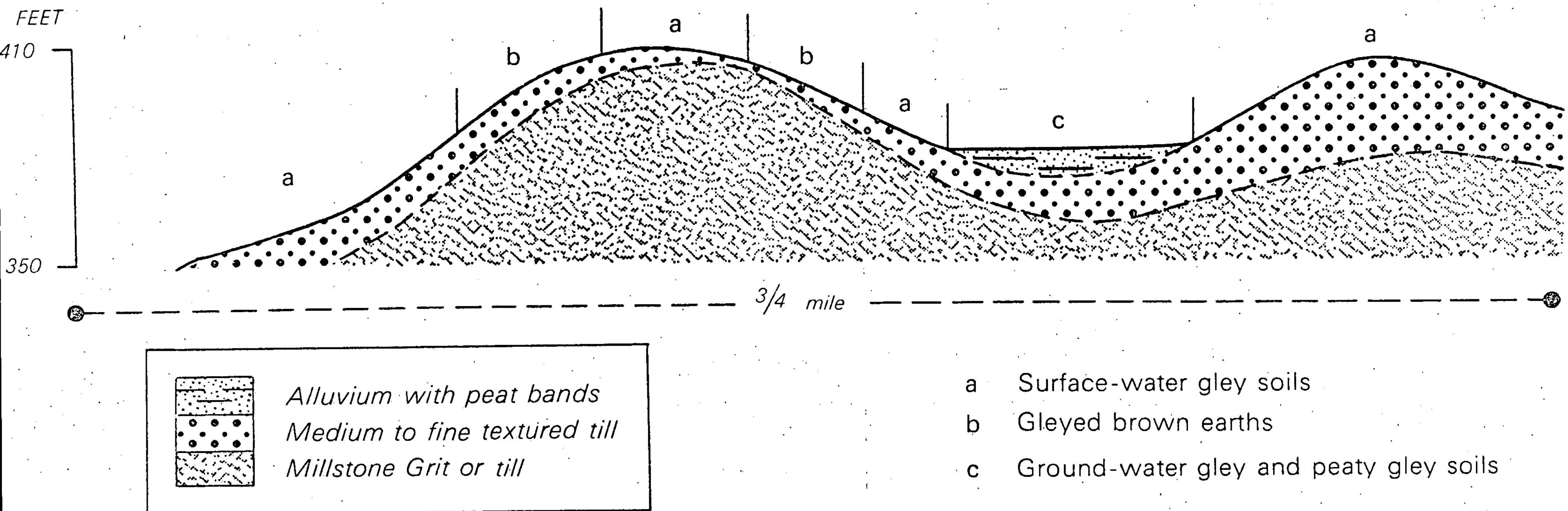
In the Wenning valley by High Bentham (gr 668690) Permo-Triassic material underlies the till. In the Hodder valley some drumlins are cored with limestone. These rocks make some small contribution to the soils parent material but not in amounts sufficient to alter soil type.

The poor drainage of these soils and their difficult topography makes machine cultivation of these lands very difficult. The association is therefore left almost exclusively in permanent pasture, the low elevation favouring grass growth and the proximity of the northern conurbations favouring dairy farming. The fine texture and persistent moisture excess found in the soils of the association tend to limit stocking rates to avoid problems of soil poaching, Juncus infestation is also a problem.

Code 10. Hawkeswick Association. In Littondale (gr 920723) and Wharfedale above Burnsall (gr 030613) the valley land above the flood plain is covered by a thin deposit of medium textured glaciofluvial and morainic drift. The soils found in

Figure 12

SOILS OF THE CHARNOCK ASSOCIATION



these deposits are brown earths, rankers and rendzinas where the underlying material is limestone. Altitudes range from 122-210 m (400-700 ft) O.D. and topography is of a rolling nature associated with morainic drift.

The shallowness of these soils prevents arable cultivation and they are therefore left as grazing. These lands serve as valuable grazing for dairy herds supplying the local market and as winter grazing for beef cattle which have spent the summer on the moors.

Code 11. Winmarleigh Association. This association is confined to a small area of 4 square kilometres north of Kirkby Lonsdale (gr 610786) though it is more extensive in Lancashire, altitude is generally below 122 m (400 ft) O.D. Soil types are predominantly brown earths, gleyed brown earths, ground-water gleys and and organic soils developed on stony reddish till from Lake District and Craven sources, the reddening being caused by the underlying Permo-Triassic rocks. The topography is one of an immature drumlinoid form, and low ridges and enclosed hollows, with soils of poor drainage being found in the hollows.

The low altitude, low rainfall, and general free drainage of the association makes it unusual in the study area. However the stony nature of the soils in the association prevents widespread arable cultivation - pasture is therefore the main land-use. The free drainage leads to soil leaching and a high lime requirement.

Code 12. Wharfe Association. The main river valleys to an altitude of 182 m (600 ft) O.D. have discontinuous alluvial deposits over their floodplains and terraces. Some alluvium is also found in inter-drumlin hollows in the Craven lowlands. The soils found on these deposits are predominantly brown earths although gleys are found where local drainage is impeded.

The flood risk on these deep soils confines their use to mainly dairying with the low altitude favouring grass growth. The value of these lands for over-wintering is shown by the large number of fields. Field boundary types are well mixed, though the use of drainage gutters as a boundary is common especially in the glacial Lake Hellifield basin.

Code 13. Rivington Association. The Rivington association is found in Bowland and Nidderdale, 3½ square kilometres north of Grindleton (gr 758457) and 7 square kilometres in the area of Pateley Bridge (gr 160660) for each area respectively. Brown earths and gleyed brown earths are found between 150-310 m (500-1000 ft) O.D. along the valley sides. Parent material is derived from Millstone Grit sandstone and shale where it protrudes through the drift.

This association may be considered a more mature version of the Belmont association, parent material is similar but the more favourable climate at lower elevation results in deeper soils. The valley side location of the association in this glaciated area results in the steep slopes making cultivation impracticable. Grassland therefore predominates but the soil depth also favours woodland. The soils are free draining and leached, and therefore liming is necessary.

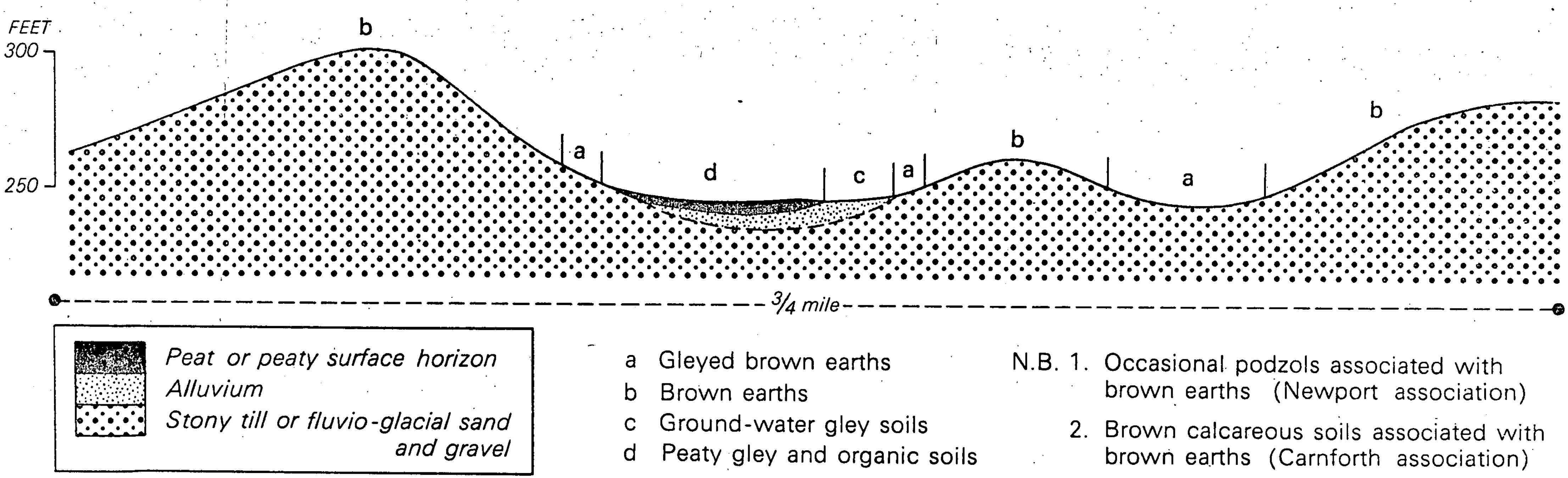
Code 14. Lowick Association. The Lowick association of soils is found in three areas, two small areas in Ribblesdale and Chapel-le-Dale but more extensively in the Howgill area around Sedbergh. The topography is one of hummocks and hollows formed from till derived from Silurian rocks on moderate to steep slopes between 122-213 m (400-800 ft) O.D. The parent material causes brown earths to develop on the hillocks with ground-water gleys, peaty gleys or organic soils or peat and alluvium in the hollows.

The stony nature of the association and the poor drainage in the hollows results in much of this land being left to pasture. The low elevation and rainfall gives rise to good quality pasture although liming is necessary to offset the leaching.

Code 14. Newport Association. The Newport association is found in the Rawthey valley around Sedbergh (Fig. 13) on coarse glaciofluvial drift. The topography is strongly undulating with brown earths on the hummocks and ground-water gleys in the intervening hollows. Elevation is low, from 90-150 m (300-500 ft) O.D. with the favourable climate and soils making this land suitable for arable farming. The MAFF's map of farm types shows some mixed farming in the area, but the need for winter pasture for the surrounding hill animals limits the arable farming in favour of grassland. The year round farming pattern is therefore dairying with wintering of hill animals, and occasional rough grazing and mixed deciduous woodland.

Figure 13

SOILS OF THE NEWPORT ASSOCIATION



Code 16. Ambergate Association. This association is relatively unimportant in the study area. Soils are brown earths, rankers, bare rock and scree as Carboniferous rocks and associated drift form the parent material. Slopes are generally steep to very steep, although the two counts for the study area are both gentle slopes with pasture in the Lindley valley (point 2150) and Wharfedale (point 0751).

Code 17. Wike Association. A similar association to the Ambergate is the Wike association. Parent material is similar but soils are deeper, with brown earths commonly occurring on gentle slopes under good pasture.

Rainfall (digits 14 and 15)

Agricultural land use and the soils found in an area are mainly affected by two main climatic elements, those of temperature and moisture. The temperature regime may be described by a number of parameters such as annual mean air temperature, the mean air temperature during the growing season, accumulated air temperature above a particular base or frost statistics. Similarly, moisture may be described in terms of annual rainfall, monthly rainfall during the growing season or excess of rainfall over transpiration. Of lesser importance is the incidents of strong winds, sunshine totals and snowy days.

Little climatic data is available for this area, it was therefore felt that a first order guide to the climate would be to take the mean annual rainfall as recorded between 1916 and 1950. Such an approximation is probably sufficient as rainfall generally increases with height and this is probably the main regulator of other climatic factors for the study area.

Using the 1:625,000 map published by the Ordnance Survey (1963) rainfall at each intersection was recorded to the nearest 100 mm, thus code 09 records rainfall between 900-1,000 mm p.a., code 10 represents rainfall between 1,000 and 1100 mm p.a. etc. The O.S. rainfall map shows rainfall in inches p.a. and the isohyets were simply converted to mm and put into 100 mm bands thus avoiding the need to redraw the isohyets to produce exact values, which could not have been done without much statistical analysis.

Elevation (digits 16, 17 and 18)

Elevation at each intersection was recorded although locally it is interchangeable with rainfall distribution. This interchange is erroneous when applied to the large scale for two reasons.

1. Rainfall at the same elevation is generally higher in the west than the east.

2. In some dales rainfall amounts are similar for the valley floor and adjacent high moors.

Since the function of the data is to form the basis for an inventory, elevation at each intersection was therefore felt to be important.

Elevation was coded in the form:-

Digits 16, 17 - elevation in ft. O.D. to the hundred increment below the elevation.

Digit 18 - the 25 ft. increment of elevation above the hundred using the following code:-

code 1. 1 - 25 ft.
2. 26 - 50 ft.
3. 51 - 75 ft.
4. 76 - 00 ft.

Thus 164 records an elevation in the range 1676 - 1700 ft. O.D.

Data was collected from the 1:25,000 O.S. sheets - the data was left in feet as the O.S. plans only to metricate published 1:10,000 (new scale) sheets in the near future. Other scales will be metricated when the 1:10,000 remapping is complete in several years.

Chapter V

Analysis of data and illustration of the inventory

The 18 digit code number recording the features of each of the 2043 sample points were punched onto 80 column holorith cards to allow computer handling of the data. The tabulation of soil features and cluster analyses were carried out on the Rothamsted Experimental Station computer with the help of Mr H.R. Simpson, of the Statistics Department. Dr. R.R. Webster carried out the Principal co-ordinate analysis again using the Rothamsted computer. The inventory section of the data handling was done on the Durham University computer with the help of Dr. D. Rhind.

In view of the effort put into assembling the data cards it is the author's wish that they be made available to other users.

1. The tabulation of soil features from the data bank (Rothamsted Computer)

Using the formula described by Stobbs in chapter III and using first N = 2015*

FOOTNOTE * 28 data points with no recorded soil association (i.e. urban areas, open water) were withdrawn.

and P based on the number of counts for the association with fewest counts (as a percentage of the total) the percentage error expected in feature counts for that association was calculated. Errors for some of the associations with few data points were large so these were rejected, N was reduced and P recalculated. This excercise was repeated for each successive lowest count association resulting in the rejection of the following associations - Langdale (04), Grizedale (05), Brantwood (06), Hawkeswick (10), Winmorleigh (11), Rivington (13), Lowick (14), Newport (15) and Ambergate (16). The remaining associations account for 93% of the points and have a feature error less than 19% (at the 95% level of probability).

Soil type and Land Use

Use		Soil Association						
		Winter Hill 01	Wilcocks 02	Belmont 03	Warton 07	Brickfield 08	Charnock 09	Wharfe 12
est	01	4(1)*	8(1)	7(4)	16(10)	21(8)	8(4)	5(5)
tation	03	0	17(2)	10(6)	0	6(2)	3(2)	1(1)
ture	05	5(2)	98(14)	18(10)	29(18)	169(64)	135(68)	57(57)
gh grazing	06	293(93)	518(73)	127(72)	55(34)	59(22)	52(26)	29(29)
elict	11	1	17(3)	2(1)	1(>1)	1	0	0
ky	13	2(1)	11(2)	9(5)	62(38)	1	0	1
al		306	669	173	163	257	198	93

FOOTNOTE * Figures in brackets give percentage within the soil association

What is apparent is the high count (or percentage) of rough grazing (06) on the Winter Hill association (01) soils. This percentage gradually alters in favour of pasture (05) through the Wilcocks, Warton, Wharfe, Brickfield and Charnock associations. This is a reflection of the decreasing altitude of the association, except in the case of the Wharfe association (12). This is an altitudinally low association but with a high percentage of rough grazing, no doubt located on wet lands subject to frequent flooding and therefore unimprovable. The incidence of rocky ground (13) is high in the Warton association (07) but lower than expected in the Belmont association (03) which is a soil on similar landforms over Millstone Grit. The Warton association is synonymous with limestone landscape where limestone quarrying seems to be much in evidence. However the figures show a low percentage of dereliction in the Warton association, it is more apparent in the Wilcocks association where old lead workings, especially around Grassington, increased the count. One can only assume that limestone quarrying, being a modern industry and therefore centred near to roads are more visible to the public eye and more liable to public accusations of despoilation. The deeper quarrying techniques cause less areal damage than the old "scratch holes" techniques of extraction.

Woodlands and plantations are almost absent on the Winter Hill (01) and Wilcocks (02) associations no doubt because of the high windthrow hazard trees would face on these higher exposed lands. Grazing by stock is also an important factor in the prevention of regeneration of natural woodland. On steeper land such as that occurring in the Belmont association and which is generally inaccessible to animals being of low grazing potential, woodland accounts for 10% of land use with a larger proportion under plantations. The Warton association (07) has a similar percentage of woodland but all natural, due, no doubt, to the woodlands being found on the steep sides of the dales. The lowland Brickfield (08), Charnock (09), and Wharfe (12) associations have relatively high percentages of natural woodland but this is mainly confined to banks of water courses and patches of wetter ground. However some plantations are found but only over about 1/3rd the area occupied by natural woodland.

Soil type and parcel size

Soil Association

	Winter Hill 01	Wilcocks 02	Belmont 03	Warton 07	Brickfield 08	Charnock 09	Wharfe 12
0-½ ha 1	0	8(1)	3(2)	6(4)	22(8)	15(7)	12(12)
½-1 ha 2	2	29(4)	5(3)	7(4)	34(13)	17(8)	9(9)
1-4 ha 3	3	54(8)	6(3)	8(5)	58(22)	63(29)	18(18)
4-6 ha 5	3	55(8)	4(2)	8(5)	56(21)	36(18)	21(21)
>6 ha 5	298(95)	527(78)	156(90)	136(82)	95(36)	72(38)	39(39)
Total	306	673	174	165	265	203	99

The most significant feature of these figures is the high percentage (+45%) of walled field boundaries for the associations listed. This confirms the general impression of the Dales being (dry) stone wall country. The unfenced open moorland, with no boundary within 1 km, is only found in significant numbers in the Winter Hill (01), Wilcocks (02), and Belmont (03) associations. Ditch type field boundaries are only common on the alluvium, the count of 11 for the Wilcocks association (02) is mainly where the sample point were by lakes and reservoirs.

If land-use classes 01 and 03 (woodlands and plantation) are summed and the total subtracted from the tree boundary figures (woodland + plantations were recorded as having tree boundaries) the Wilcocks count decreases to (15), the Belmont to (6) and the Warton to (1). The Brickfield, Charnock and Wharfe associations decrease only by about ¼ to 1/3rd highlighting the high percentages of tree lined field boundaries. High counts for hedged field boundaries tend to reinforce this picture of wooded lower ground.

Soil type and slope

Soil Association

	Winter Hill 01	Wilcocks 02	Belmont 03	Warton 07	Brickfield 08	Charnock 09	Wharfe 12
Level 1	195(64)	373(55)	45(26)	78(48)	189(71)	140(69)	82(82)
Moderate 2	85(28)	236(35)	44(25)	52(31)	55(21)	45(22)	11(11)
Steep 3	26(8)	64(10)	83(48)	29(18)	21(8)	18(9)	6(6)
Cliff 4	0	0	2	6(3)	0	0	0
Total	306	673	174	165	265	203	99

Most of the land falls within slope classes level (1) and moderate (2) with more level land in the altitudinally lower Belmont, Charnock and Wharfe associations. Not unexpected is the high percentage of steep land in the Belmont association (03) and to a lesser extent the Warton association (07). These two associations are the only areas with "cliff" counts.

All but the Warton and Belmont associations have something less than 10% of land which is "steep".

Soil type and aspect

Observed aspect counts

	Winter Hill 01	Wilcocks 02	Belmont 03	Warton 07	Brickfield 08	Charnock 09	Wharfe 12
0	7	32	4	14	22	25	49
N 1	34	65	16	17	18	27	5
2	38	89	26	22	23	24	5
E 3	49	81	15	20	22	13	3
4	47	95	26	23	45	24	5
S 5	45	103	23	17	43	24	8
6	44	99	23	28	49	33	12
W 7	17	60	18	13	21	16	7
8	25	49	23	11	22	17	5

The spread of counts over nine levels so reduced the number of counts for each soil association a simple comparison was felt to be invalid. A "Chi squared" test was therefore considered appropriate as this would allow an unbiased statistical testing. Assuming an even distribution of counts over each association a table of expected values for each level could be drawn up.

Expected aspect counts

	Winter Hill 01	Wilcocks 02	Belmont 03	Warton 07	Brickfield 08	Charnock 09	Wharfe 12
0	24	53	14	13	21	16	8
N 1	29	63	16	15	25	19	9
2	37	82	21	20	32	25	12
E 3	32	70	18	17	27	21	10
4	43	94	24	23	37	28	14
S 5	42	92	24	23	36	28	14
6	48	105	27	26	41	32	15
W 7	26	57	15	14	23	17	8
8	26	57	15	14	22	17	8

A table of χ^2 was then drawn up using the formula

$$\chi^2 = \frac{(O-E)^2}{E}$$

Where O = observed value

E = expected value with even distribution

	Winter Hill 01	Wilcocks 02	Belmont 03	Warton 07	Brickfield 08	Charnock 09	Wharfe 12	Total
0	12.03	8.16	6.81	0.09	0.07	5.08	219.21	251.45
1	0.98	0.06	0.01	0.15	1.89	3.24	1.97	8.30
2	0.02	0.64	1.11	0.19	2.63	0.03	4.11	8.72
3	9.41	1.81	0.51	0.49	1.09	3.14	5.14	21.59
4	0.44	0.02	0.13	0.00	1.76	0.69	5.61	8.64
5	0.21	1.20	0.03	1.42	1.19	0.58	2.31	6.93
6	0.30	0.36	0.64	0.19	1.39	0.14	0.78	3.82
7	3.18	0.12	0.67	0.08	0.11	0.11	0.25	4.52
8	0.03	1.06	4.73	0.61	0.01	0.00	1.34	7.77
								= 321.74

The total χ^2= 321.74 (48 df) is statistically significant at the 5% level but most of this is due to aspect 0 (no aspect) and its link with the Wharfe association (12) which is the association of soils on level alluvial sites.

If all level 0 and soil association (12) figures are ignored the remaining is still significant at the 5% level. What is now apparent is the correlation between the Winter Hill association and easterly (3) aspects and to a lesser extent westerly (7) aspects. The Winter Hill association is one of deep peat soils, it may therefore be suggested that this easterly, generally colder, aspect is more favourable to the slow breakdown of dead vegetation which favours peat accumulation. Similarly west aspects may be the wettest as this is often the most frequent direction from which rain is driven by the wind. Soil wetness favours anerobic conditions and peat accumulation is therefore more common here.

Slightly unusual is the north (1) aspect of the Charnock (09) association and perhaps its the east (3) aspect. The author is unable to explain this other than to suggest it may be some facet of drumlin orientation, but if this were the case a reflection in the south (5) and west (7) aspects would have been expected. Finally, of lesser importance, is the preference for the Belmont (03) association and an east aspect. The Belmont association has many features of frost shattering, it is probable that the development of soils in this association is more favoured on the coldest east aspects.

2. Cluster analysis (Rothamsted Computer)

Implicit in the previous tabulations was the assumption that the soil associations recognised and mapped using air photo-interpretation, and checked with limited fieldwork, were correctly delineated. It was considered that a useful exercise would be to test this assumption by looking at the recorded features using statistical cluster methods to see if the soil related data would cluster into associations. Similar techniques have been used before (Reyner 1966) but only on soil series and applying soil features, not soil related features as here.

The cluster analyses are made on the assumption that the features recorded in the inventorty are those most used by the photo-interpretater in making the interpretation. This is not strictly true as a certain unquantifiable degree of experience is important in the interpretation. The technique is only successful when the interpretation is carried out by a surveyor who is familiar with the soils and landscape of the area in which he is working and thus able to apply "experience" to the interpretation.

Using the suite of GENSTAT programmes written by staff at Rothamsted Experimental Station and now commercially available (Gower and Ross 1974), an Abbreviated Similarity Matrix was drawn (Fig. 14). The matrix was drawn using only data on land use, parcel size, boundary type, slope, aspect, rainfall and elevation (i.e. soil related features), for a sample of 199 data points. The sample was taken by considering only those data points with a fourth digit of number 3 i.e. those points with a unit northings value of 3. Using this technique a sample size sufficiently small for the computer store was found and it was also, from the point of view of soil distribution, a random sample.

ABBREVIATED SIMILARITY MATRIX

C7753	1	*
C8343	92	9*
C1273	164	99*
C7353	72	999*
C7653	114	9839*
C2153	171	98899*
C8783	107	[illegible]
C7583	89	[illegible]
C7683	115	[illegible]
C8573	99	[illegible]
C9363	29	[illegible]
C1573	180	[illegible]
C8853	114	[illegible]
C1373	166	[illegible]
C1463	178	[illegible]
C1873	189	[illegible]
C1973	190	[illegible]
C2253	173	[illegible]
C2553	176	[illegible]
C7983	6	[illegible]
C7483	74	[illegible]
C8953	20	[illegible]
C7763	122	[illegible]
C1473	177	[illegible]
C0663	194	[illegible]
C8153	17	[illegible]
C7453	77	[illegible]
C7373	70	[illegible]
C7563	82	[illegible]
C7663	117	[illegible]
C0973	155	[illegible]
C0963	156	[illegible]
C1663	184	[illegible]
C2453	175	[illegible]
C8773	103	[illegible]
C7493	79	[illegible]
C0353	58	[illegible]
C1673	183	[illegible]
C1253	165	[illegible]
C1153	163	[illegible]
C1363	167	[illegible]
C9663	39	[illegible]
C1163	162	[illegible]
C7363	71	[illegible]
C7673	116	[illegible]
C1773	186	[illegible]
C1353	168	[illegible]
C0763	197	[illegible]
C9453	33	[illegible]
C0573	62	[illegible]
C0463	61	[illegible]
C9263	26	[illegible]
C8183	14	[illegible]
C9973	46	[illegible]
C6353	123	[illegible]
C7553	83	[illegible]
C7773	64	[illegible]
C0673	193	[illegible]
C6653	132	[illegible]
C7093	142	[illegible]
C8673	101	[illegible]
C8873	112	[illegible]
C8083	10	[illegible]
C8373	89	[illegible]
C7293	152	[illegible]
C8173	15	[illegible]
C8753	110	[illegible]
C8583	97	[illegible]
C3483	93	[illegible]
C8683	102	[illegible]
C8383	88	[illegible]
C6753	135	[illegible]
C8663	104	[illegible]
C1063	159	[illegible]
C8463	95	[illegible]
C7183	147	[illegible]
C0553	129	[illegible]
C7283	63	[illegible]
C8973	18	[illegible]
C7353	5	[illegible]
C0953	157	[illegible]
C7383	69	[illegible]
C8643	106	[illegible]
C0653	195	[illegible]
C0873	199	[illegible]
C9573	34	[illegible]
C9073	21	[illegible]
C7693	84	[illegible]
C8563	90	[illegible]
C1453	179	[illegible]
C0553	192	[illegible]
C8763	109	[illegible]
C7573	81	[illegible]
C8863	113	[illegible]
C7793	119	[illegible]
C6453	126	[illegible]
C9373	28	[illegible]
C9053	22	[illegible]
C7883	2	[illegible]
C7783	12	[illegible]
C1763	187	[illegible]
C8743	111	[illegible]
C6873	137	[illegible]
C0563	191	[illegible]
C8263	85	[illegible]
C0063	47	[illegible]
C8163	15	[illegible]
C8063	12	[illegible]
C8053	13	[illegible]
C6773	134	[illegible]
C7243	67	[illegible]
C9653	39	[illegible]
C7143	151	[illegible]
C8353	91	[illegible]
C0453	61	[illegible]
C9253	27	[illegible]
C8453	96	[illegible]
C8253	87	[illegible]
C8543	101	[illegible]
C7173	143	[illegible]
C7773	121	[illegible]
C7873	3	[illegible]
C7973	7	[illegible]
C9173	23	[illegible]
C6693	131	[illegible]
C9353	31	[illegible]
C0253	55	[illegible]
C0153	52	[illegible]
C0863	153	[illegible]
C7863	4	[illegible]
C9863	44	[illegible]
C9673	37	[illegible]
C8073	11	[illegible]
C7263	65	[illegible]
C1073	157	[illegible]
C9853	45	[illegible]
C9763	47	[illegible]
C0163	51	[illegible]
C7953	9	[illegible]
C0853	154	[illegible]
C6743	141	[illegible]
C6593	127	[illegible]
C9773	43	[illegible]
C0263	51	[illegible]
C8363	73	[illegible]
C7193	144	[illegible]
C1753	182	[illegible]
C0373	56	[illegible]
C0773	174	[illegible]
C7393	64	[illegible]
C0073	43	[illegible]
C0273	53	[illegible]
C7153	157	[illegible]
C9273	25	[illegible]
C2173	17	[illegible]
C6753	199	[illegible]
C2273	172	[illegible]
C7643	72	[illegible]
C7473	75	[illegible]
C0173	54	[illegible]
C5473	59	[illegible]
C6493	124	[illegible]
C0363	57	[illegible]
C9873	45	[illegible]
C2073	165	[illegible]
C9473	31	[illegible]
C9563	35	[illegible]
C9763	41	[illegible]
C7043	145	[illegible]
C7063	145	[illegible]
C7163	149	[illegible]
C7493	71	[illegible]
C9463	32	[illegible]
C1653	185	[illegible]
C1553	172	[illegible]
C6953	14	[illegible]
C7253	66	[illegible]
C8553	105	[illegible]
C1053	16	[illegible]
C1563	181	[illegible]
C2353	176	[illegible]
C8653	195	[illegible]
C7053	144	[illegible]
C7463	76	[illegible]
C6853	139	[illegible]
C1173	161	[illegible]
C9753	42	[illegible]
C6793	133	[illegible]
C8963	19	[illegible]
C6893	136	[illegible]
C6673	131	[illegible]
C9553	36	[illegible]
C6473	125	[illegible]
C6573	123	[illegible]
C9273	85	[illegible]
C9473	74	[illegible]
C7963	8	[illegible]
C9163	26	[illegible]
C6993	139	[illegible]

The point numbers chosen and their related soil association are shown in table 7.

A similarity matrix is a matrix of similarity coefficients between pairs of units (or data points). A similarity coefficient is a number between 0 and 1 that is defined in terms of values of a set of variates; it takes the value 1 if all variate values are the same for both units and 0 if all variate values are as different as possible. Allowance is also made for whether the variates are of a qualatative nature (e.g. land use, boundary type) or quantative (e.g. altitude, rainfall). The values of the similarity are printed as percentages and in the Abbreviated Similarity Matrix only "ten" units are printed. Thus 9 shows a high degree of similarity whilst 1 is low. Such a table is useful for quick reference between points though for an interpretation a Minimum Spanning Tree is used (see page 44).

Whilst the similarity matrix indicates which points are associated it is of importance to know the absolute similarity between points, this is shown by their archial cluster analysis. This is a method of combining units to form clusters which proceeds by combining clusters or individual units into larger clusters. Each join is associated with a similarity value, or clustering level, so that all units in the same cluster at a given level remain in the same cluster at lower levels.

The algorithms start with all units in seperate clusters and the number of clusters decreases as the clustering level decreases until all units belong to a single cluster level. Here single linkage cluster analysis was used as this method is programmed via the minimum spanning tree. Here two clusters merge if the similarity between any pair of data points, are in each cluster, exceeds the current clustering level.

The Hierarchial Tables are given in Appendix III, it will be seen that all points are similar at the 67.5% level. A dendrogram is produced (Fig. 15) which shows the order in which units and clusters join together.

A Minimum Spanning Tree is the network of shortest total length connecting all points under consideration such that each point is connected with every other point by a chain of links such that:-

Table 7.

Soil association at each sample point

1.	08	41.	02	81.	02
2.	01	42.	09	82.	02
3.	07	43.	07	83.	02
4.	09	44.	10	84.	01
5.	03	45.	03	85.	07
6.	02	46.	07	86.	09
7.	07	47.	10	87.	02
8.	09	48.	01	88.	01
9.	08	49.	10	89.	02
10.	02	50.	01	90.	02
11.	02	51.	12	91.	02
12.	09	52.	00	92.	02
13.	08	53.	01	93.	02
14.	01	54.	08	94.	03
15.	02	55.	00	95.	02
16.	12	56.	01	96.	02
17.	02	57.	08	97.	02
18.	01	58.	12	98.	02
19.	02	59.	01	99.	02
20.	09	60.	02	100.	08
21.	01	61.	12	101.	02
22.	09	62.	02	102.	02
23.	07	63.	03	103.	02
24.	08	64.	02	104.	02
25.	09	65.	03	105.	09
26.	02	66.	08	106.	13
27.	09	67.	12	107.	01
28.	07	68.	01	108.	01
29.	02	69.	02	109.	02
30.	09	70.	02	110.	09
31.	02	71.	02	111.	08
32.	02	72.	08	112.	01
33.	09	73.	01	113.	03
34.	07	74.	03	114.	09
35.	02	75.	01	115.	03
36.	12	76.	02	116.	02
37.	07	77.	02	117.	02
38.	02	78.	12	118.	02
39.	09	79.	01	119.	02
40.	07	80.	01	120.	01

121. 07
122. 08
123. 03
124. 14
125. 11
126. 03
127. 04
128. 11
129. 04
130. 06
131. 11
132. 02
133. 14
134. 09
135. 01
136. 08
137. 09
138. 02
139. 04
140. 09
141. 08
142. 05
143. 01
144. 09
145. 08
146. 02
147. 02
148. 07
149. 01
150. 07
151. 08
152. 01
153. 02
154. 08
155. 02
156. 01
157. 08
158. 08
159. 01
160. 03
161. 12
162. 02
163. 02
164. 01
165. 03
166. 02
167. 02
168. 02
169. 02
170. 08
171. 02
172. 08
173. 02
174. 02
175. 02
176. 02
177. 02
178. 02
179. 03
180. 01
181. 03
182. 02
183. 01
184. 02
185. 02
186. 01
187. 02
188. 08
189. 02
190. 08
191. 03
192. 02
193. 03
194. 02
195. 02
196. 01
197. 02
198. 12
199. 08

DENDROGRAM

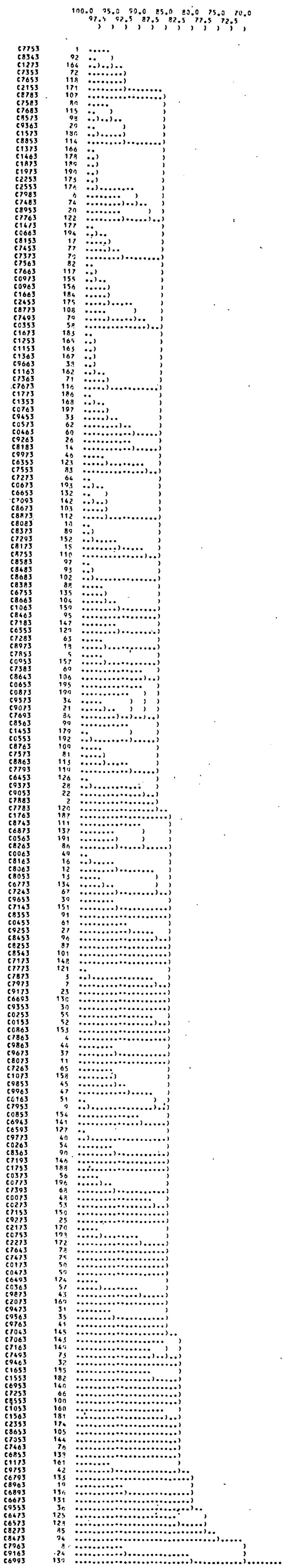


Figure 15.

DENDROGRAM.

(i) No closed loops occur

(ii) Each point is visited by at least one line

(iii) The tree is connected

The minimum spanning tree helps to clarify the results of a cluster analyses by showing which units (here sample points) within and between clusters are most closely linked. Fig. 16 shows a minimum spanning tree produced for this study the format is:-

		01		Soil association code added after analysis
		..... C1273		data point number
Similarity with next point to left	99.3	.	87.4	Similarity of 1273 with next point to right
		.....85.7		Similarity of 1273 with point on branch below

Some points of interest shown by the minimum spanning tree are:-

(i) Amongst the ubiquitous Winter Hill (01) and Wilcocks (02) associations differences occur as is seen by the fact that representatives are seen in more than one branch. Related to this is that certain branches contain only a cluster of the Winter Hill and Wilcocks associations e.g. AA on figure 16 are in more varied clusters with other associations, as at a-a.

(ii) Some grouping of points with regard to associations may be seen, for example at point B is a cluster of points assigned to the Warton association. This is confirmation of the air-photo interpretation for this soil using the limited features recorded.

(iii) Along branch C are grouped points of mixed soil association but mainly of the Brickfield (08), Charnock (09) and Winmarleigh (11) associations - all similar soils on lowland till. It is of interest that the Charnock association differentiated mainly by its rolling topography could not be differentiated by cluster analysis of the features recorded for this study.

(iv) At D there is a grouping of some Warton (07), Belmont (03) and Langdale (04) associations which are a group of dominantly lithomorphic soils on high unenclosed land with rock exposures and therefore often devoted to rough grazing.

Figure 16.

MINIMUM SPANNING TREE.

A full interpretation of the linkages seen in the minimum spanning tree has not been made as more statistical work, considered beyond the scope of this study, would be necessary. What is apparent is the general lack of clustering of the data points into soil association groupings.

3. Principal Co-ordinate Analysis (Rothamsted Computer)

Principal Co-ordinate Analysis or sometimes Principal Component Analysis is one of the most frequently used multi-variate methods for looking at a dispersion matrix of data. Cluster analysis and the use of minimum spanning trees do have the disadvantage that after branching there is no indication of the degree of closeness in similarity between members of different branches, principal co-ordinate analysis offers an alternative.

In principal co-ordinate analysis data is normalized and each data point positiaied in a three dimensional field (more dimensions can be used for detailed analyses) using statistical tests. Points coinciding in the space are alike, points with increasing distance between them being more unlike.

Using the tabulated characteristics of the 199 points in the sub-sample a field was generated in the Rothamsted computer to show the similarity between data points. The position of points within the field was mapped on a print-out of the projection of these points onto two surfaces at right angles to each other whose axes are vector 1, vector 2 and vector 3. One surface showed the projection of vector 1 against vector 2, and for the third dimension a second projection vector 1 against vector 3. The projections are shown in Fig. 17.

Analysis of the disposition of points within the field can be illustrated by constructing a model using small balls, representing the points, suspended in their correct location using the two projections.

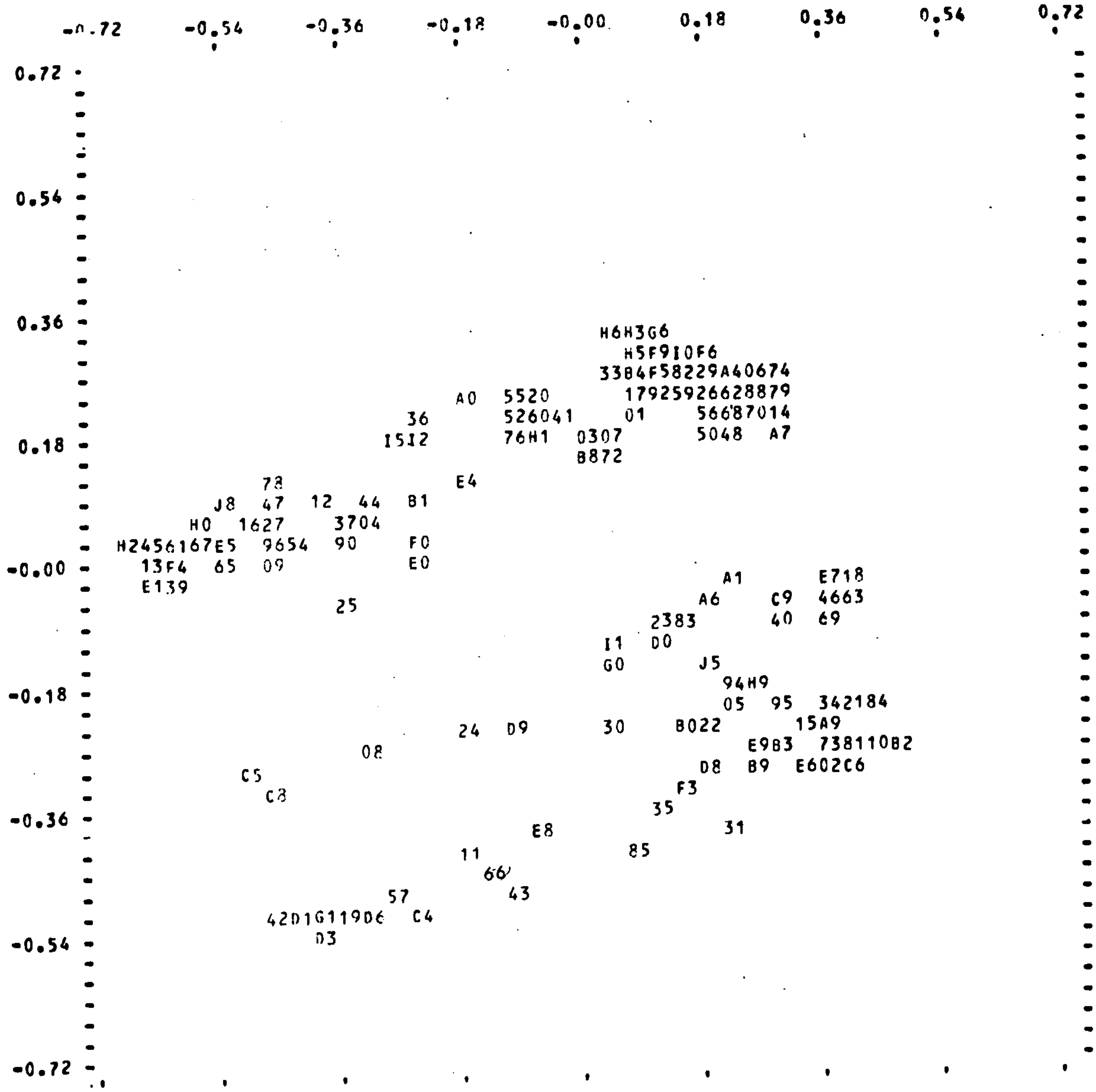
A second technique is, by using a suitably programmed computer, to ask for a print-out of a stereo-pair of diagrams. Using a stereoscope to view the stereo-pair a three dimensional image of the points in the field can be seen showing any clustering of point. Such a stereo-model will not give a perfect three dimensional image since all points are the same size. In a perfect model points nearer the

Figure 17(i).

PRINCIPAL CO-ORDINATE POINT PROJECTIONS.

PRINCIPAL COORDINATE PLOT
ACROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 2

LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105



LIST OF COINCIDENCES

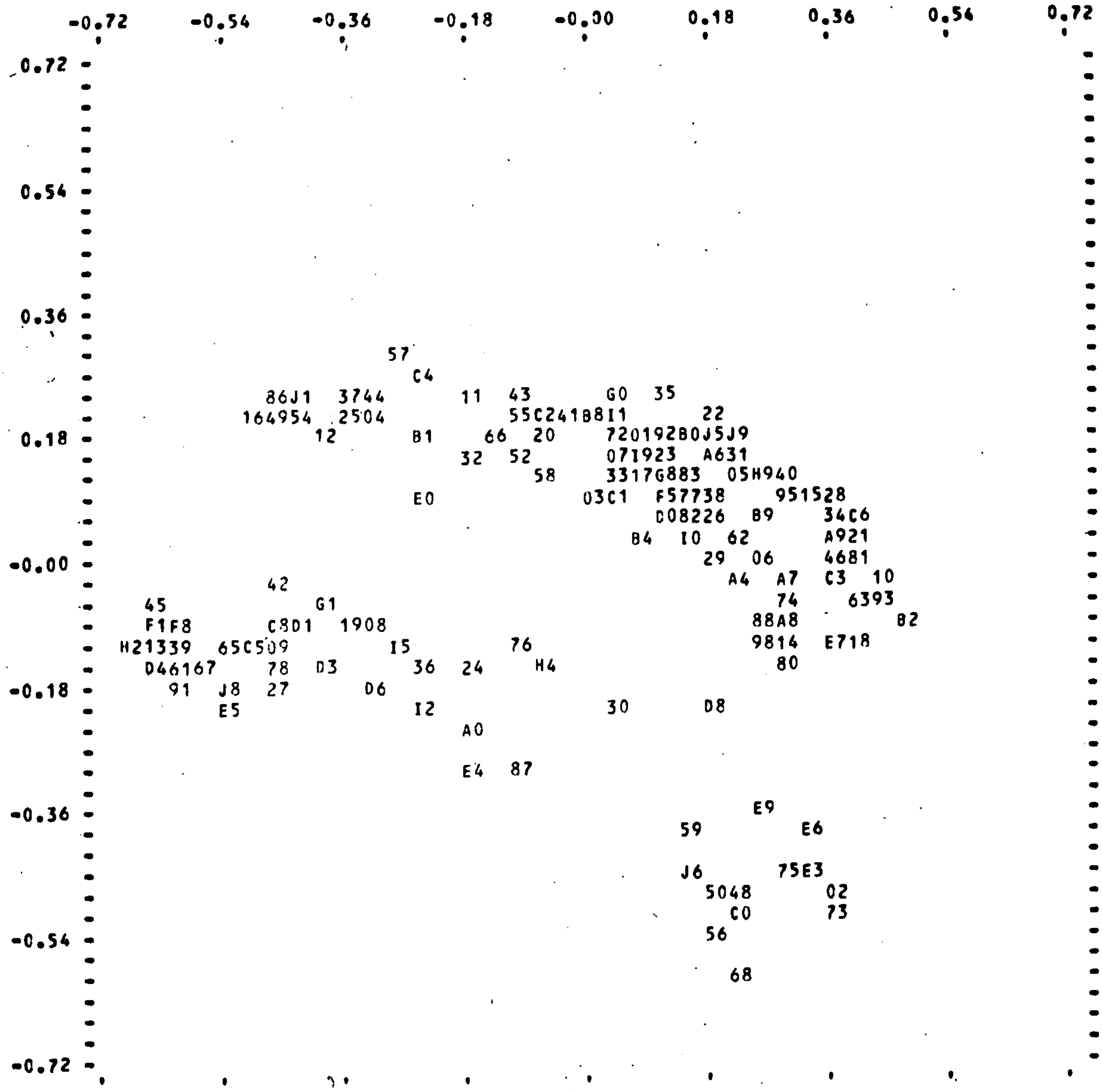
178 AND 166	189 AND 173	190 AND 173	184 AND 180	117 AND 82
162 AND 29	163 AND 82	165 AND 82	167 AND 82	168 AND 155
177 AND 82	183 AND 82	186 AND 155	194 AND 82	197 AND 155
38 AND 26	58 AND 20	77 AND 59	80 AND 79	87 AND 55
98 AND 38	102 AND 79	115 AND 79	122 AND 20	135 AND 62
164 AND 92	174 AND 20	196 AND 59	71 AND 56	116 AND 70
53 AND 50	120 AND 48	121 AND 7	187 AND 171	49 AND 27
91 AND 61	137 AND 54	158 AND 61	169 AND 45	191 AND 54
51 AND 9	86 AND 9	134 AND 13	188 AND 154	105 AND 39
151 AND 141	123 AND 46	75 AND 40	127 AND 40	192 AND 94
99 AND 21	157 AND 5	199 AND 5	64 AND 15	143 AND 15
193 AND 109	89 AND 10	93 AND 10	97 AND 10	102 AND 10
103 AND 10	132 AND 81	142 AND 73	152 AND 10	28 AND 2
32 AND 11				

Figure 17(ii).

PRINCIPAL CO-ORDINATE POINT PROJECTION.

PRINCIPAL COORDINATE PLOT
ACROSS PAGE, VECTOR 1, DOWN PAGE, VECTOR 3

LETTER CODE IS USED FOR UNITS ABOVE 99, E.G. A5 MEANS 105



LIST OF COINCIDENCES

90 AND 25	137 AND 54	148 AND 122	171 AND 122	187 AND 122
60 AND 20	85 AND 1	150 AND 111	153 AND 110	173 AND 1
176 AND 72	190 AND 1	157 AND 31	164 AND 23	166 AND 23
178 AND 23	101 AND 5	175 AND 17	183 AND 83	186 AND 168
192 AND 5	194 AND 83	197 AND 168	64 AND 15	113 AND 95
117 AND 77	127 AND 95	163 AND 77	165 AND 77	167 AND 77
177 AND 77	184 AND 77	71 AND 26	156 AND 26	159 AND 130
162 AND 26	193 AND 34	94 AND 62	132 AND 21	142 AND 109
69 AND 46	70 AND 6	99 AND 81	116 AND 6	84 AND 10
89 AND 10	97 AND 10	129 AND 107	135 AND 104	152 AND 10
102 AND 93	103 AND 93	169 AND 45	188 AND 158	47 AND 9
51 AND 9	79 AND 14	105 AND 39	115 AND 14	141 AND 13
154 AND 39	96 AND 78	170 AND 67	139 AND 87	53 AND 50

"front" of the model would appear longer than those at the "back".

This second modelling technique was used here and the stereo-pair is shown in Fig. 18 suitably reduced to allow for viewing using a pocket stereoscope. The numbers of the points on the model may be found by reference to Fig. 17. The results of this technique are that clustering similar to that seen in the minimum spanning tree are apparent but again with no close correlation to soil associations. Of small concern is that the cluster formed tend to have a squashed appearance indicating that one or more of the recorded features at the sample points is too coarse to be fully compatable with the remaining features.

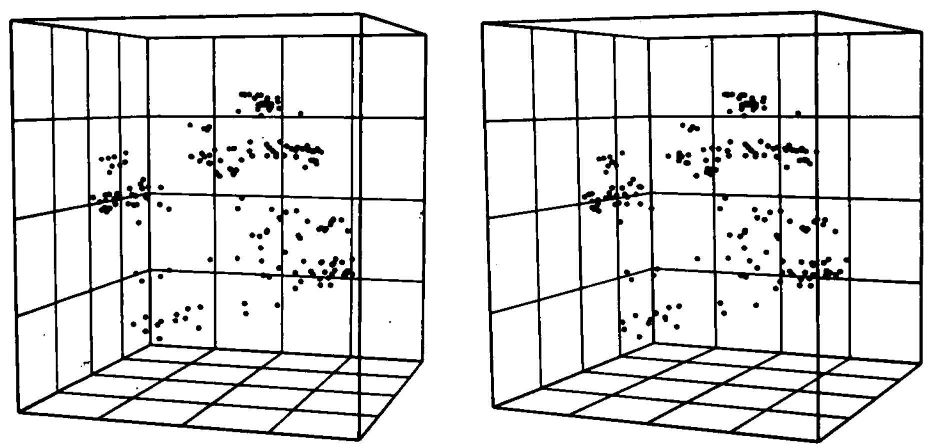
This repeated discordance between the feature data and soil associations at the sample points is not all together surprising for three reasons. First the sub-sample of 199 points, whilst relatively large for statistical cluster analysis, they formed only 10% of the total sample. Secondly the sample points used may have been poor representatives from each association. Given more time it may have been instructive to find the modal representative of each association. Thirdly and perhaps most important is the fact that only seven features had been used to typify each soil association. This contrasts with the technique of air-photo interpretation which was used to identify the soil associations, here many factors - some verging on intuition - are appreciated by the surveyor.

4. The use of the data as an Inventory (Durham Computer)

Computers are able to draw two types of map depending upon the print-out equipment available. The most sophisticated is where the computer is programmed to operate a plotting pen on a map table (D-Mac machine). Here line maps can be drawn at any scale of any feature on the input data or at a specified contour level between the feature. Use of plotting pens of different colours can be a further advantage. Such a system is used by the Canadian Land Inventory.

A simpler technique is to feed data into the computer using X-Y location co-ordinates for each data point. Using the teletype printer maps may be plotted by the printing of symbols for each data point. Maps of different scales can be produced by altering the spacing between symbols. The disadvantage is that the

FIGURE 18. STEREOGRAM OF CO-ORDINATE POINTS



size of the map is limited to the carriage width of the printer unless trouble is taken to align and join print-out sheets. Using such a system the D.O.S. and C.V.I. produced dot distribution maps of particular features.

If data has been collected on a grid basis the SYMAP programme may be used to produce maps. Three types of map can be produced:-

(i) A map showing the levels of a particular feature at all data points. The number of levels on one map is limited to the number of symbols available on the printer. The shading effect produced by the different symbols can be informative allowing hand contouring if desired.

(ii) A map showing the location of a single element level over the data area.

(iii) A map showing the location of a particular combination of the data elements or levels. Since, for the purpose of the present study, data was collected on a grid basis the SYMAP programme was considered suitable for map production. The system does have the disadvantage that, due to the rectangular shape of the characters, print-out maps tend to be stretched along the line of paper run. The maps cannot therefore be compared with conventional maps by overlay methods.

Fig. 19 is an example of a SYMAP produced using data from the study area. Here the computer was asked to produce a single element map of the boundary type levels recorded at each data point. What is apparent from this map is that large areas of unenclosed moor (■) are still to be found in eight areas:-

1. Brant Fell and Baugh Fell
2. Whernside
3. Ingleborough Common
4. Conistone Moor, Riggs Moor
5. Stean Moor
6. Pateley Moor
7. Embsay Moor
8. Sykes Fell and Croasdale Fell

Walled field boundaries are by far the most common (1446 counts) with trees and

Figure 19.

SYMAP OF BOUNDARY TYPE AT EACH SAMPLE POINT IN THE STUDY AREA

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	.	+	0	θ	▩
	HEDGE	TREE	WALL	DITCH	NONE

hedges confined to the main river valleys of the Ribble, Dee and Aire. The Ribble tributaries, the Hodder and Tosside Beck, can be seen and point density was sufficient to show the upper reaches of the River Aire. The course of the Nidd and Wharfe valleys are distinguished by the occurrence of trees, here the trees are woodland growing on the steep valley sides. The Forestry Commission Forests at Gisburn can be distinguished (F). A particularly interesting point is the frequent occurrence of hedged field boundaries in the valleys of the Greta and Wenning south of Ingleton, where trees do not often occur.

In contrast a single level map may be constructed by considering only one field boundary type such as the clearly seen level 5 (■) on the figure.

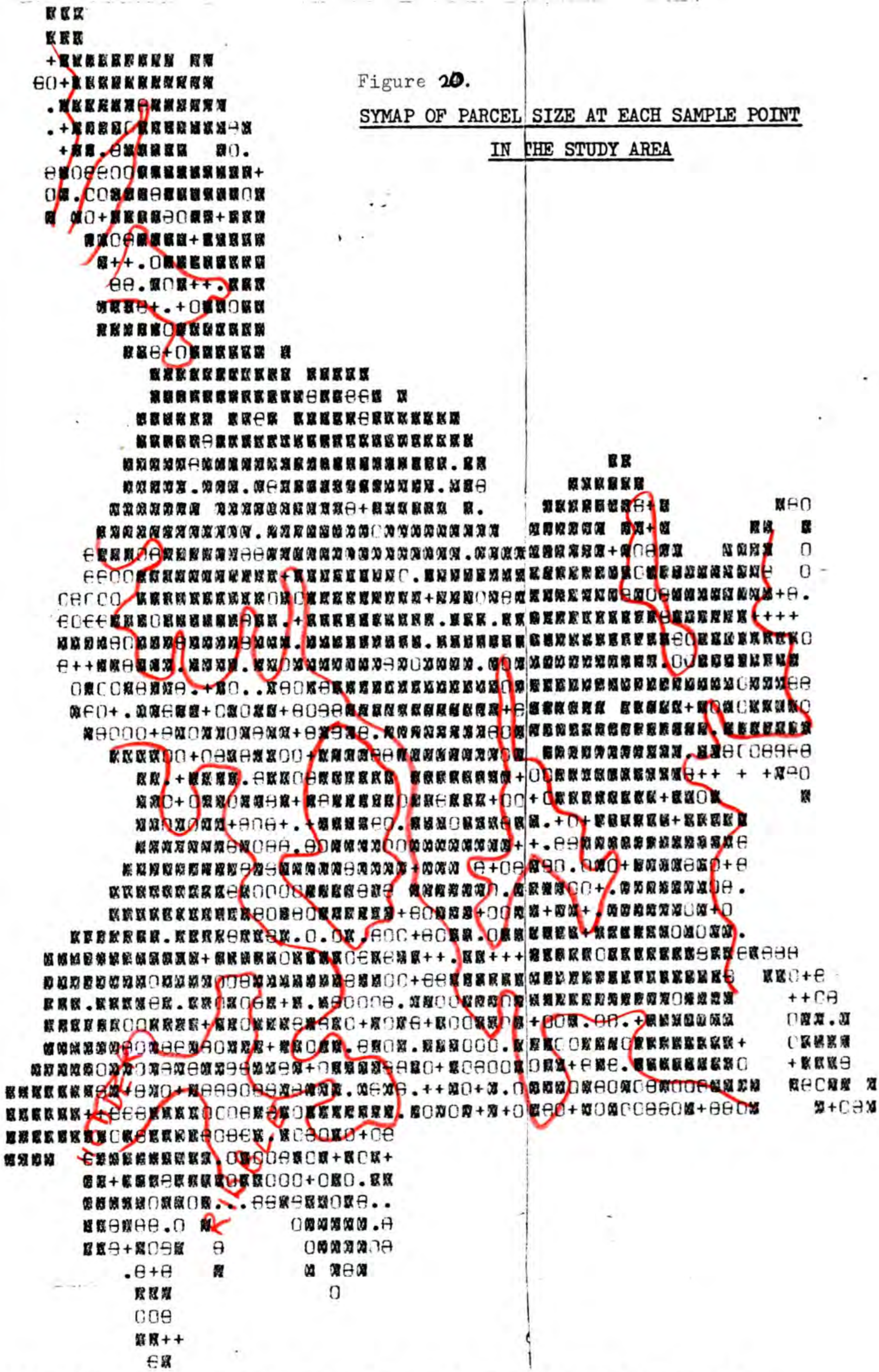
Fig. 20 is a second example. Here the single element "parcel size" was printed. On this map, the course of the rivers are more clearly defined for these are the areas where field size is very variable. It is satisfactory to see that the use of level 5 to delineate the main moorland areas seems to be an appropriate choice. The next level down in parcel size (level 4) would have been expected to occur only on the periphery of level 5 if this level had been inappropriate. As it is, level 4 occurrences are distributed throughout the valleys as well. A check on the location of the few level 4 points, and lower, within dominantly level 5 areas shows them to be located in minor valleys, often by roads and probably therefore associated with moorland farms.

A second interesting feature on this figure is the spread of enclosed land (level 4 and less) between the Ribble valley and the Hodder valley (gr 7750). The correlation of valleys and lowlands with areas of variable boundary type on Fig. 19 gave no indication of this spread, parcel size may therefore be a better indication of the location of farmed areas.

A third type of map that can be drawn is one showing the location of a particular combination of data elements or data levels. For instance the following question could be posed:-

Figure 20.

SYMAP OF PARCEL SIZE AT EACH SAMPLE POINT IN THE STUDY AREA



FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	.	+	O	θ	▩
	0-½ ha	½-1ha	1-4ha	4-6ha	+6ha

"Where in the study area are areas where improvement of grazing would be most feasible?"

SYMAP's of the location of particular elements could then be requested, each successive map using only data points that occurred on the previous one. Of importance is the point that questions should be asked in order of importance so that an unimportant requirement does not eliminate points that would be suitable at a higher level of applicability.

The question posed may be answered by requesting SYMAP's showing:-

1. All data points with the following soil associations Wilcocks (02), Langdale (04), Warton (07), Brickfield (08) and Wharfe (12), these being considered the most readily improved soils.

2. All data points in 1 with field boundary classes 1 and 2; such boundaries can be easily removed to increase field size. Also wall classes with parcel sizes 3 and 4. Improvement of fields of this size would be most expedient since new fencing would not be necessary.

3. Print SYMAP of all data points in 2 with a southerly aspect (3-7).

4. Print SYMAP of all data points in 3 with a road nearby; proximity classes 1 and 2.

5. Print SYMAP of all data points in 4 with slope classes 1 and 2 - land suitable for tractors.

6. Print SYMAP of all points in 4 with land use code 06 (rough grazing); as this is the only class requiring improvement.

There are many ways that such a data bank could prove useful and these are not likely to be fully appreciated until such systems have been used and refined. Perhaps the most important consideration in the use of such systems is that of scale. The inventory can only be as good as the sampling density of the information in the data bank. At a spacing of 1 km between data points the system illustrated can only be of use at a reconnaissaince level, that is poorer than our present understanding of the study area.

Chapter VI

Conclusions

This thesis has described some features of the physical landscapes recognised in the Bowland and Dales area of the Pennines in the old West Riding county. A review of five different types of inventory was undertaken, these gave examples of data collection at different scales using various sampling techniques. Also data storage and degrees of versatility in data collection and output for these systems was described.

A system of land inventory was chosen for the study area based on sampling of readily available information with storage in code form on Holorith cards for computer handling. The setting up of the data bank was a large part of the work. The use of the data bank to tabulate the soil association and landscape features at each sample point was illustrated. The use of the data bank in this way is considered a secondary use of such data as it is not envisaged that the Soil Survey could, as a matter of routine, undertake the collection of data on features secondary to its main interest.

The exception to this rule is perhaps where soil related data can be easily seen and recorded in the field whilst the soil is being inspected. Such features as land-use, parent material, rock outcrops, elevation, slope and aspect are now recorded in code as data forms available to the Soil Survey and described in the latest field handbook (Hodgson 1974). However since soils are not generally inspected on a grid basis (except in certain special cases such as during forest surveys) the data collected could not be used with any high degree of statistical validity.

The correlations seen in this section of the work were of some interest and have served to put into numerical form observations which previously could only have been subjective on the part of the surveyor.

The tabulation of landscape features with soil association was made on the assumption that the association recorded at each data point was correct. It was decided that it would be of interest to assume this was not the case and using statistical clustering tests see if some of the soil related features would form clusters which corresponded to soil association groupings.

Two clustering methods were applied, the minimum spanning tree and principal co-ordinate analysis. Whilst both showed some clustering neither was strongly related to the soil associations. Further statistical investigations into the precise reasons for the clusters and their poor correlation with the soil associations would be lengthy and beyond the scope of this study. However the reason for this poor correlation may lie in the fact that the features recorded at the sample point were too specific for correlation with the broader soil association unit. The soil association is a land form unit containing a suite of soil types found associating within a recognised landscape, the cross-sections in earlier chapters for the various associations show that some associations contain elements of the same soil type. The land use features seen in each field (or sample unit for this study) are probably more closely related to the soil type and not the association and the correlation of these features with the soil category would probably have been more instructive. Research into the category level, Group to series (Avery 1973), at which the soil strongly influences the different land use features would be of interest.

The use of the data bank as an inventory was illustrated and two SYMAP's of single features were produced. The use of a data bank to produce SYMAP's that could show correlations and distributions of data, and to answer a particular question was illustrated.

The use of a data bank based on a 1 km grid sampling procedure is of limited value as a planning tool. Much effort is needed to create and update such a bank, even at a 1 km sampling density, and this is insufficient for most land use planning purposes. Within the administrative unit responsible for local action (i.e. the County Council) the degree of sampling for an effective data bank would require sampling at a 20-50 m interval. Alternatively a system linking features within say a 100 m square to the sample reference point (see Colne Valley Inventory) could be used, such a method would ensure that objects as small as buildings were accounted for.

This need for a regular closely spaced sampling grid which will tabulate small features is bound to lead to wasted effort in inspecting areas where there are few features to be recorded. It is therefore the authors opinion that for most land use planning purposes sampling and data banking on a grid basis is of limited value. Sampling using some division of the area into locational units and recording features within these units is more flexible, but even here there is the disadvantage that each "data unit" contains a miscellany of information distributed over the area of the unit resulting in the need for some final operator sorting before interpretation can begin.

Of greater value for inventory purposes in rural areas is storage and handling of information in map form on transparent overlays of Ordnance Survey 1/25,000 maps. Such maps can show units as small as 100 square metres (10 m grid sampling equivalent), the basic rural management unit (the field) is shown and comparison between different features in the same area can be made by the overlaying of different feature maps. Miscellaneous information can be stored in paper file, on magnetic disc,on tape or on microfilm and related to the base map using the National Grid Reference.

In Britain due to the pressures brought about by a large population and increased economic activity, conflicts over land use continue to arise. One way of reducing such conflict is by good land use planning by the relevant planning authority. However the land use planning carried on by these offices can only be as good as the existing knowledge about their area and its potential. Coupled with this is required a detailed knowledge and understanding of the physical and socio-economic background of that area. It is the authors view that County and National Parks planning officers would be advised to go some way towards the establishment of inventories for their rural areas. This would ensure that all information pertaining to their area is centrally collected and readily available to staff. Land use plans would then be based on the fullest information and continue any movement towards the optimum use of one of our basic resources, the land.

Bibliography

ALFORD, M. and TULEY, P. (1972) "The measurement and mapping of Land-Resource data by point sampling on aerial photogtaphs" Bristol symposium on Remote Sensing.

AVERY, B.W. (1973) "Soil Classification in the Soil Survey of England and Wales" Journal of Soil Science vol. 24, No. 3

BARTLEY, D.D. (1967) Chapter IV Vegetation 'Leeds and its Region' Published by The British Association for the Advancement of Science.

BEAVER, S.H. (1941) "Report No. 46, Yorkshire, West Riding" First Land Utilization Report.

BRUNT, M. (1967) "The methods employed by the Directorate of Overseas Surveys in the assessment of Land Resources" Études De Synthése.

BULLOCK, P. (1971) "The soils of the Malham Tarn area" Field Studies Vo, 3, No. 3.

CANADA LAND INVENTORY REPORT No. 2 (1965) Soil Capability Classification for Agriculture. Dept. of Forestry.

CANADA LAND INVENTORY REPORT No. 3 (1966) The climates of Canada for Agriculture. Dept. of Forestry and Rural Development.

CANADA LAND INVENTORY REPORT No. 4 (1967) Land Capability Classification for Forestry. Dept. of Forestry and Rural Development.

CANADA LAND INVENTORY REPORT ON LAND CAPABILITY CLASSIFICATION FOR OUTDOOR RECREATION (1967) An outline of the Classification System used in the Canada Land Inventory. Canada Land Inventory, ARDA.

CARROLL, D.M. (1972) "Air Photo Interpretation for soil mapping in the Yorkshire Pennines" East Midland Geographer Vol. 5, Pt. 6, No. 38.

CARROLL, D.M. (1973) "The Soils Associated with Carboniferous Rocks in Lancashire and Yorkshire" Proc. North Eng. Soils Discussion Group. Proc. No. 10.

COLEMAN, A. and MAGGS, K.R.A. (1968) "Land Use Survey Handbook" Published by the Second Land Use Survey.

COPPOCK, J.T. (1967) The Canada Land Inventory. Regional Studies Association Annual Conference.

CROWDER, R. (1972) "LUNR: What it is and how it is used." Paper prepared by New York State Office of Planning Services.

EARP, J.R., MAGRAW, D., POOLE, E.G., LAND, D.H. and WHITEMAN, A.J. (1961) "The Geology of the country around Clitheroe and Nelson" Memoir of the Geological Survey of Great Britain.

GOWER, J.C. and ROSS, G.J.S. (1974) "Genstat users guide No. 4, Multivariate and Cluster analysis." Inter-university/Research Councils Series Report No. 18.

HALL, B.R. and FOLLAND, C.J. (1970) "Soils of Lancashire" Bulletin No. 5, Soil Survey of Great Britain.

HODGSON, J.M. (1974) "Soil Survey Field Handbook". Soil Survey Technical Monograph No. 5.

MANLEY, G. (1955) "The climate at Malham Tarn" Annual Report of the Council for the Promotion of Field Studies 1955.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (1966) "Agricultural Land Classification" Tech. Rep. Agric. Land Serv. No. 11.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (1971) "Map - Types of farming in the Northern Region" Published by HMSO.

ORDNANCE SURVEY (1963) "Map - Average Annual Rainfall 1916-50"

RAISTRICK, A. (1930) "Some Glacial features of the Settle district." Proc. Univ. Durham. Phil. Soc. Vol. viii, 239-251.

RAYNER, J.H. (1966) "Classification of soils by numerical methods." Journal of Soil Science Vol. 17, pp 79-92.

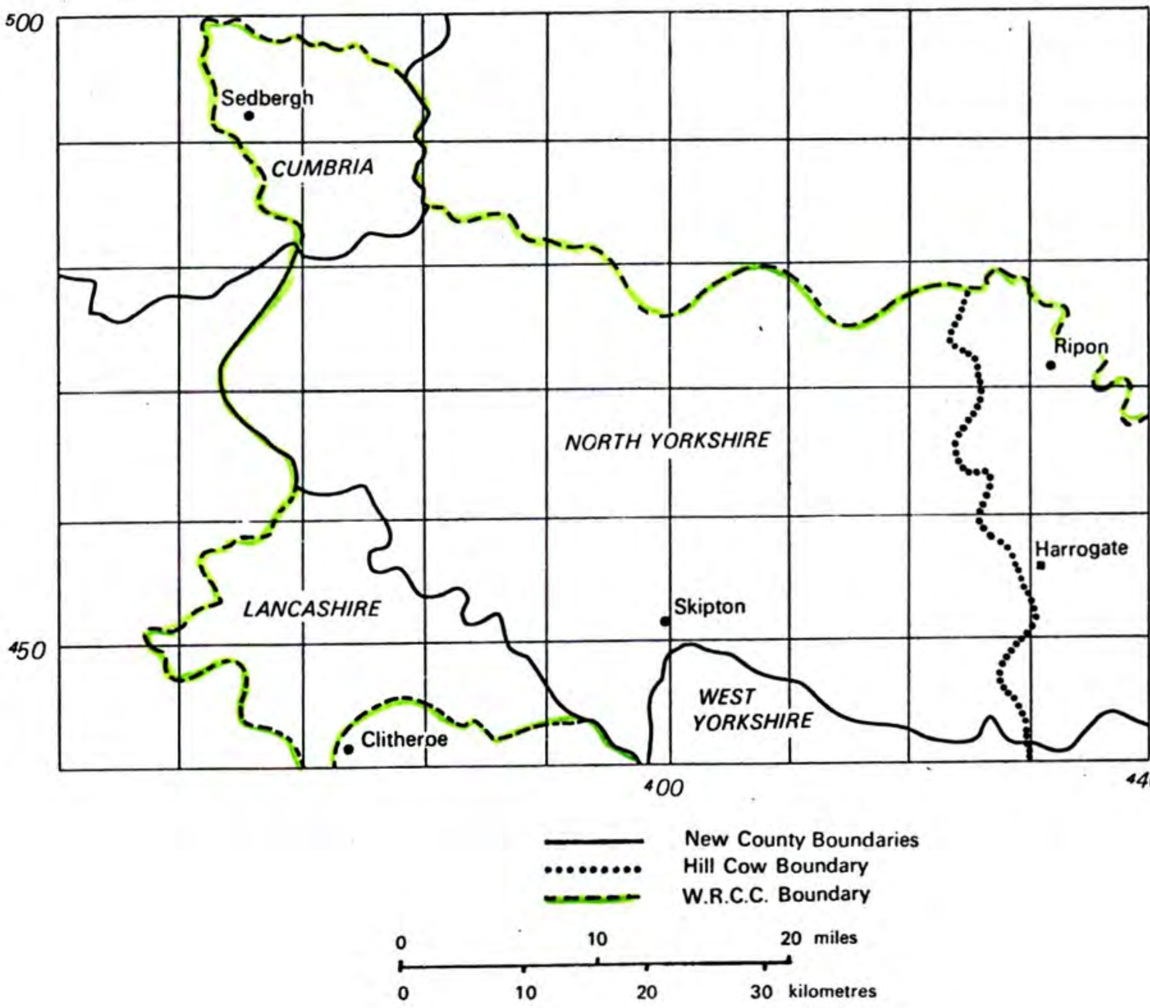
STAMP, L.D. (1948) "The Land of Britain - its use and misuse" Published by Longmans.

STOBBS, A.R. (1968) "Some problems of measuring land use in underdeveloped countries: the Land Use Survey of Malawi" Journal of the British Cartographical Society.

SYMINGTON, D.F. (1968) Land Use in Canada. The Canada Land Inventory. Canadian Geographical Journal.

APPENDIX I.

COUNTY BOUNDARIES FROM APRIL 1974.



APPENDIX II

Definition of the Ministry of Agriculture, Fisheries and Food Hill Farming Area

1. The scheme defines hill land as land in the administrative counties of Chester, Cornwall, Cumberland, Derby, Durham, Hereford, Lancaster, Monmouth, Northumberland, Salop, Somerset, Stafford, Westmorland and York (North and West Ridings); any county borough which is surrounded in whole or in part by any of these counties; and Wales, except Anglesay; which

(a) is situated in an area consisting predominantly of mountains, hills or heath, or in specified districts elsewhere (sub-paragraph (2); and

(b) is, or by improvement could be made, suitable for use for the breeding, rearing and maintenance of sheep or cattle but not, in the opinion of the Minister, for

(i) the carrying on, to any material extent, of daity farming;

(ii) the production of crops in quantity materially greater than that necessary to feed the number of sheep or cattle capable of being maintained on the land.

2. Land in the specified districts, sometimes referred to as "scheduled areas", mentioned in sub-paragraph (1) (a) was accepted until 1962 by the Minister as eligible land for the purposes of the Hill Cattle (Breeding Herds) (England and Wales) Scheme 1953 but was found in 1963, during a general review of hill land, to be outside the true hill areas. Its eligibility for hill cow subsidy purposes was allowed to continue as a concession. (It is not eligible land for purposes of the hill sheep subsidy or the Hill Land Improvement Scheme).

The Department of the Environment defines Hill Land in exactly the same way.

SINGLE LINKAGE CLUSTERS

HIERARCHICAL CLUSTERS

APPENDIX III.

LEVEL 97.5

```
**     92    164
**    115     98
**     29    180
**    166    178    189    190    173    176
**    177    194
**     82    117    155
**    183    165    163    167     38    162
**    186    168
**     64    193
**    132    142
**     10     89    152
**     97     93    102
**    179    192
**    126     28
**     49     16
**    121      3
**     51      9
**    127     40
```

LEVEL 95.0

```
**      1     92    164
**     80    115     98
**     29    180
**    166    178    189    190    173    176
**    177    194     17     77
**     82    117    155    156    184    175
**    108     79
**    183    165    163    167     38    162     71    116
**    186    168    197     33
**     46    123
**     64    193    132    142    103    112
**     10     89    152
**     97     93    102
**     88    135    104
**     63     18
**      5    157
**     34     21
**    179    192
**    109     81    113
**    126     28
**     49     16
**     13    134
**    121      3
**     51      9
**    127     40
**     56    196
**    170    198
**    124     57
```

LEVEL 92.5

**	1	92	164	72	118	171		
**	80	115	98	29	180	114		
**	166	178	189	190	173	176		
**	6	74						
**	20	122						
**	177	194	17	77	70			
**	82	117	155	156	184	175		
**	108	79						
**	183	165	163	167	38	162	71	116
**	186	168	197	33	62			
**	46	123						
**	64	193	132	142	103	112		
**	10	89	152	15				
**	97	93	102					
**	88	135	104	159				
**	147	129						
**	63	18						
**	5	157						
**	34	21	84					
**	179	192						
**	109	81	113					
**	126	28						
**	137	191	86					
**	49	16	12					
**	13	134	67					
**	39	151						
**	121	3						
**	44	37						
**	65	158	45					
**	51	9						
**	127	40						
**	54	90						
**	56	196	68					
**	170	198						
**	124	57						
**	31	35						
**	161	42						

LEVEL 90.0

**	1	92	164	72	118	171		
**	80	115	98	29	180	114		
**	166	178	189	190	173	176	6	74
**	20	122						
**	177	194	17	77	70			
**	82	117	155	156	184	175	108	79
**	183	165	163	167	38	162	71	116
**	186	168	197	33	62	60		
**	26	14						
**	46	123						
**	64	193	132	142	103	112		
**	10	89	152	15				
**	97	93	102					
**	88	135	104	159				
**	147	129						
**	63	18						
**	5	157						
**	199	34	21	84				
**	99	179	192					
**	109	81	113	119				
**	126	28						
**	137	191	86					
**	49	16	12					
**	13	134	67					
**	39	151						
**	61	27						
**	121	3						
**	44	37						
**	65	158	45	47				
**	51	9						
**	127	40						
**	54	90						
**	56	196	68					
**	170	198						
**	124	57						
**	31	35						
**	161	42						
**	19	136						
**	8	24						

LEVEL 87.5

**	1	92	[illegible]	[illegible]	118	171				
**	80	115	96	29	180	114				
**	166	178	189	190	173	176	6	74	20	122
**	177	194	17	77	70					
**	82	117	155	156	184	175	108	79	58	
**	183	165	163	167	38	162	71	116		
**	186	168	197	33	62	60				
**	26	14								
**	46	123	83							
**	64	193	132	142	103	112				
**	10	89	152	15	110					
**	97	93	102							
**	88	135	104	159						
**	147	129								
**	63	18								
**	5	157								
**	69	106								
**	195	199	34	21	84					
**	99	179	192							
**	109	81	113	119						
**	126	28	22							
**	111	137	191	86						
**	49	16	12							
**	13	134	67							
**	39	151								
**	61	27								
**	121	3								
**	44	37								
**	65	158	45	47						
**	51	9								
**	154	141								
**	127	40								
**	54	90								
**	56	196	68							
**	170	198	172							
**	124	57	43							
**	31	35								
**	161	42								
**	19	136								
**	8	24								

LEVEL 85.0

**	1	92	164	72	118	171	107	80	115	98	29	180	114	166	178
		189	190	173	176	6	74	20	122	177	194	17	77	70	82
		117	155	156	184	175	108	79	58	183	165	163	167	38	162
		71	116	186	168	197	33	62	60	26	14	46	123	83	64
		193	132	142	103	112	10	89	152	15	110	97	93	102	88
		135	104	159	95	147	129	63	18	5	157	69	106	195	199
		34	21	84	99	179	192	109	81	113	119	126	28	22	2
		120													
**	111	137	191	86											
**	49	16	12	13	134	67									
**	39	151													
**	61	27	96												
**	121	3	7												
**	55	52													
**	44	37													
**	65	158	45	47	51	9									
**	154	141													
**	127	40													
**	54	90													
**	56	196	68												
**	48	53													
**	170	198	172												
**	124	57	43												
**	31	35													
**	149	73													
**	185	182													
**	161	42													
**	19	136													
**	8	24													

LEVEL 82.5

**	1	92	164	72	118	171	107	80	115	98	29	180	114	166	178
		189	190	173	176	6	74	20	122	177	194	17	77	70	82
		117	155	156	184	175	108	79	58	183	165	163	167	38	162
		71	116	186	168	197	33	62	60	26	14	46	123	83	64
		193	132	142	103	112	10	89	152	15	110	97	93	102	88
		135	104	159	95	147	129	63	18	5	157	69	106	195	199
		34	21	84	99	179	192	109	81	113	119	126	28	22	2
		120	187	111	137	191	86	49	16	12	13	134	67	39	151
		91	61	27	96	87	101	148	121	3	7	23	130	30	55
		52	153	4	44	37	11	65	158	45	47	51	9	154	141
		127	40	54	90	146	188	56	196	68	48	53	150	25	170
		198	172	78	75	50	59	124	57	43	169	31	35	41	145
**	143	149	73												
**	185	182													
**	160	181													
**	161	42													
**	19	136													
**	8	24													

LEVEL 80.0

**	1	92	164	72	118	171	107	80	115	98	29	180	114	166	178
		189	190	173	176	6	74	20	122	177	194	17	77	70	82
		117	155	156	184	175	108	79	58	183	165	163	167	38	162
		71	116	186	168	197	33	62	60	26	14	46	123	83	64
		193	132	142	103	112	10	89	152	15	110	97	93	102	88
		135	104	159	95	147	129	63	18	5	157	69	106	195	199
		34	21	84	99	179	192	109	81	113	119	126	28	22	2
		120	187	111	137	191	86	49	16	12	13	134	67	39	151
		91	61	27	96	87	101	148	121	3	7	23	130	30	55
		52	153	4	44	37	11	65	158	45	47	51	9	154	141
		127	40	54	90	146	188	56	196	68	48	53	150	25	170
		198	172	78	75	50	59	124	57	43	169	31	35	41	145
		143	149	73	32	185	182	140	66	100	160	181	174	105	144
		76	138	161	42										
**	19	136													
**	125	128													
**	8	24													

LEVEL 77.5

**	1	92	164	72	118	171	107	80	115	98	29	180	114	166	178
		189	190	173	176	6	74	20	122	177	194	17	77	70	82
		117	155	156	184	175	108	79	58	183	165	163	167	38	162
		71	116	186	168	197	33	62	60	26	14	46	123	83	64
		193	132	142	103	112	10	89	152	15	110	97	93	102	88
		135	104	159	95	147	129	63	18	5	157	69	106	195	199
		34	21	84	99	179	192	109	81	113	119	126	28	22	2
		120	187	111	137	191	86	49	16	12	13	134	67	39	151
		91	61	27	96	87	101	148	121	3	7	23	130	30	55
		52	153	4	44	37	11	65	158	45	47	51	9	154	141
		127	40	54	90	146	188	56	196	68	48	53	150	25	170
		198	172	78	75	50	59	124	57	43	169	31	35	41	145
		143	149	73	32	185	182	140	66	100	160	181	174	105	144
		76	138	161	42	133	19	136	131	36					
**	125	128													
**	8	24	139												

LEVEL 75.0

**	1	92	164	72	118	171	107	80	115	98	29	180	114	166	178
		189	190	173	176	6	74	20	122	177	194	17	77	70	82
		117	155	156	184	175	108	79	58	183	165	163	167	38	162
		71	116	186	168	197	33	62	60	26	14	46	123	83	64
		193	132	142	103	112	10	89	152	15	110	97	93	102	88
		135	104	159	95	147	129	63	18	5	157	69	106	195	199
		34	21	84	99	179	192	109	81	113	119	126	28	22	2
		120	187	111	137	191	86	49	16	12	13	134	67	39	151
		91	61	27	96	87	101	148	121	3	7	23	130	30	55
		52	153	4	44	37	11	65	158	45	47	51	9	154	141
		127	40	54	90	146	188	56	196	68	48	53	150	25	170
		198	172	78	75	50	59	124	57	43	169	31	35	41	145
		143	149	73	32	185	182	140	66	100	160	181	174	105	144
		76	138	161	42	133	19	136	131	36	125	128	85		
**	8	24	139												

LEVEL 72.5

**	1	92	164	72	118	171	107	80	115	98	29	180	114	166	178
		189	190	173	176	6	74	20	122	177	194	17	77	70	82
		117	155	156	184	175	108	79	58	183	165	163	167	38	162
		71	116	186	168	197	33	62	60	26	14	46	123	83	64
		193	132	142	103	112	10	89	152	15	110	97	93	102	88
		135	104	159	95	147	129	63	18	5	157	69	106	195	199
		34	21	84	99	179	192	109	81	113	119	126	28	22	2
		120	187	111	137	191	86	49	16	12	13	134	67	39	151
		91	61	27	96	87	101	148	121	3	7	23	130	30	55
		52	153	4	44	37	11	65	158	45	47	51	9	154	141
		127	40	54	90	146	188	56	196	68	48	53	150	25	170
		198	172	78	75	50	59	124	57	43	169	31	35	41	145
		143	149	73	32	185	182	140	66	100	160	181	174	105	144
		76	138	161	42	133	19	136	131	36	125	128	85	94	
**	8	24	139												

LEVEL 67.5

**	1	92	164	72	118	171	107	80	115	98	29	180	114	166	178
		189	190	173	176	6	74	20	122	177	194	17	77	70	82
		117	155	156	184	175	108	79	58	183	165	163	167	38	162
		71	116	186	168	197	33	62	60	26	14	46	123	83	64
		193	132	142	103	112	10	89	152	15	110	97	93	102	88
		135	104	159	95	147	129	63	18	5	157	69	106	195	199
		34	21	84	99	179	192	109	81	113	119	126	28	22	2
		120	187	111	137	191	86	49	16	12	13	134	67	39	151
		91	61	27	96	87	101	148	121	3	7	23	130	30	55
		52	153	4	44	37	11	65	158	45	47	51	9	154	141
		127	40	54	90	146	188	56	196	68	48	53	150	25	170
		198	172	78	75	50	59	124	57	43	169	31	35	41	145
		143	149	73	32	185	182	140	66	100	160	181	174	105	144
		76	138	161	42	133	19	136	131	36	125	128	85	94	8
		24	139												