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COUNTRYSIDE SURVEY 1990

Mapping the land cover of Great Britain: A demonstration project in Remote Sensing

First interim report to the British National Space Centre

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CONTENTS

SUMMARY

1. Landsat satellite images will be used compile a digital map of land cover of Great Britain, complete with estimates of accuracy.

2. Maps will be integrated with sample-based, field survey data; the study will demonstrate use of results in a vector GIS.

3. This report outlines methods, reviews the work schedule, records availability of imagery, identifies target land cover classes, outlines progress in analyses and presents a forward look for the coming year.

4. The study will use combined summer and winter data to help accurately distinguish target classes. Images, covering c.90% of England and Wales, have already been purchased; the cover will be completed by choosing from existing images, supplemented with new material, acquired by mid-1992.

5. These images will be geometrically corrected to a 25 metre grid-cell, registered to National Grid, before combining as a 6-band composite image (using red, near IR and middle IR bands from each of the summer and winter images).

6. Target classes currently number 24 types, though extension of the survey into new areas may identify other important classes so far unencountered. The present list includes 13 seminatural vegetation types (some managed for agriculture and forestry), 2 water classes, 2 bare and 7 man-made cover types including arable and developed land.

7. Interactive 'training' will identify sample areas of the target classes, from which extrapolations will classify whole scenes, using a maximum likelihood method. An iterative procedure, with built-in checks, will be used to derive accurate end-products. Final validation will compare the cover-maps with detailed field maps of 500, one kilometre, squares, recorded in 1990.

8. 'Knowledge based' corrections will be made where necessary to correct systematic errors: for example, a coastline will be defined, where needed, to remove confusion between maritime and terrestrial cover-types.

9. The schedule of work is summarised in Figure 1.

10. Progress, recorded in Figure 1, indicates that the proposed timetable is realistic.

11. The aim in the third quarter (1.1.91 to 31.3.91) will be to complete classification of six scenes, to order scenes for following quarter, and to start experiments with methods for quantitative validation.

12. In the calendar year 1991, the aim will be to classify an average four scenes per quarter, to develop final methods of validation, to test methods for mosaicking scenes into continuous cover-maps, and to produce sample hard-copy outputs.

INTRODUCTION

GENERAL

There has been no land cover map of Britain produced since the early 1960s and no published map since that made in the 1930s. The process of land use planning in Britain is based, at best, on piecemeal surveys, which are often incomplete and may be incompatible. Experiments with LANDSAT Thematic Mapper (TM) images, especially studies in lowland Cambridgeshire and upland Snowdonia (Fuller *et al.* 1989 a & b, Jones & Wyatt, 1989; Fuller & Parsell, 1990; Griffiths & Wooding, 1989), have shown that the data are capable of providing information on major cover types and land uses, at field by field scale, for all of Britain. The use of composite summer/winter data has proved particularly useful to improve the detail and accuracy available from satellite imagery (Fuller & Parsell 1990).

This is the first Interim Report of this project, describing preliminary work and progress under contract from September, on a programme of work to compile such a national, digital, land cover map. The product is an integral part of the Countryside 1990 survey, which aims to provide information on the land use and ecology of Great Britain in 1990, to assess past changes, and form a baseline against which to measure changes in the future.

AIMS OF THE REMOTE SENSING ELEMENT OF COUNTRYSIDE 1990

1. To compile a digital map of land cover in Great Britain, based on a hierarchical classification of important major land cover types.

2. To make quantitative assessments of accuracy of end products.

3. To integrate the map with the field survey data of Countryside 1990 and with other topographic and thematic data in a GIS environment.

4. To produce demonstrator GIS output in vector format.

THE AIMS OF THIS REPORT

1 To outline methods

2 To review the work-schedule

3 To record progress of the image search (WP 3)

4 To identify a list of target land cover classes, and justify the selection (WP 4)

5 To outline progress in analyses (WP 5-8)

6 To outline a programme of work for the short (3 months) and medium term (1 year)

OUTLINE OF THE METHODS

IMAGE SEARCH (WP 3)

The image search started with examination of Landsat quick-looks 1988-1989, at RAE Farnborough. This concentrated on England and Wales, which are priorities by virtue of DOE's involvement, and because the Macaulay Land use Research Institute (MLURI) are mapping Scotland using air photography (NB Scotland will later be mapped using Landsat to provide a consistent product for all Great Britain.

The image search continues with examinations of current quick-looks, supplied by RAE. The overall aim is to identify the best cloud-free images, as near to 1990 as possible.

SELECTION OF TARGET CLASSES (WP 4)

The selection of target classes is based on experiences in preliminary studies in Cambridgeshire (Fuller & Parsell 1990), and Snowdonia (Jones & Wyatt 1989). The classes have been reviewed in the context of other land cover studies (Table 1) and through consultation with other surveyors and end-users (Table 2). They are also evolving in the light of results in the early stages of this project. The nomenclature will also need careful consideration to clarify the exact meanings of potentially quite 'loose' land cover terminology. Nomenclature and exact class descriptions will be presented in future quarterly reports.

GEOMETRIC CORRECTION AND CO-REGISTRATION OF SUMMER/WINTER DATA

Landsat Thematic Mapper (TM) data are being geometrically corrected to British National Grid using control points defined interactively. The procedure uses 1:50000 Ordnance Survey maps mounted on a digitising table, to derive positions of reference control points identified on the input image. The image is then resampled using the polynomial model to produce an output image, of a chosen pixel size (here, 25 m), within a BNG map projection. Cubic convolution is used to derive output pixel values for resampling.

Summer/winter composite data will be used in classification throughout this project. The composites are made by co-registering scenes or part scenes to give a single output image. This image contains six bands of data, three each from the original summer and winter data (Landsat bands 3,4 and 5 - ie red, near and middle infrared (see Fuller & Parsell 1990)).

The baseline date for the study will be 1990 but, to accommodate any image shortages, an extended period of plus or minus an expected 2 years will be allowed.

'TRAINING' THE MAXIMUM LIKELIHOOD CLASSIFIER (WP 7-80)

The purpose of the training procedure is to identify the spectral signature of sample areas, representative of the target land cover types. Three sources of information have been used for this purpose:

- a *priori* knowledge of the location of characteristic areas on the ground
- visual interpretation of the appearance and context of regions in the imagery
- *post hoc* survey, where this was needed.

The results of other recent surveys are being used to supplement the project team's direct knowledge of suitable training areas. ITE stations nationally have undertaken local and more wide-ranging surveys, which provide good information on the location of representative examples of many of the target classes. In other cases, it is proposed to draw on data from other surveyors, and agreement has been reached in principle with MLURI and SDD (Land Cover of Scotland from aerial photography), with Silsoe College and the Countryside Commission (Vegetation Mapping in the National Parks), with the NCC (Countryside Monitoring Scheme) and with MAFF, for help in the location of training data. Inclusion of ground reference data from these surveys has the great advantage of ensuring consistency in the nomenclature and definitions of land classes between the various schemes. This ensures that the surveys are fully inter-compatible and opens up the possibility of more complete integration, for example, for each study to provide UK national input to a European Community database such as CORINE.

Other specially distinct classes, which may be unknown, are distinguished without preconception as to their final class. The exact nature of the cover is later determined in the field. Areas which appear different on the image and for which we have no ground reference data, are selected for site visits.

The maximum likelihood classifier assumes that, in each band, for all pixels, the radiance values attributable to a class come from multivariate normal distributions - (Kershaw & Fuller, in press). The production of the final target classes often involves the definition of spectrally unique subclasses, so as to avoid multi-modal distributions in the training data. So, for example, the arable class may be represented by subclasses for wheat, barley, sugar beet etc. These are then aggregated into the single class for map production or census statistics. However, the original data remain available for specialist consultations where necessary.

Once adequate training areas have been defined, perhaps only 2-5 per subclass at this stage, the image is provisionally classified. First cover-maps usually highlight problems with the training data, which can then be rectified, by additions, eliminations and editions to the preliminary set. The procedure continues iteratively until an ostensibly satisfactory result has been achieved. Then it is subjected to a simple but quantitative assessment of accuracy.

PRELIMINARY FIELD CHECKING (WP 9)

Field check-data are recorded, for convenience as 'transects' along major roads and railways. More intensive surveys are made of localities which are unusual, for example, the Norfolk Broads, the Brecks, the North Kent Marshes or the Surrey Heaths. Hard copy images are annotated with the land cover, per parcel.

Cover-maps are then scored, field by field, using a majority verdict (Fuller & Parsell 1990) to assess the proportion of land/water parcels classified correctly. The result is a confusion matrix, giving scores, per cover type, showing correct classifications and errors of omission and commission.

Finally, training areas are amended, as necessary, using check-areas as additional training data, to correct consistent discrepancies of omission and commission and generate a revised classification. Thus a final cover

map is achieved by an iterative procedure of training, classification and retraining, until results are consistent with the available ground reference data. Classified scenes will be built into a mosaic for all Britain pending a final accuracy assessment using independent reference data from the Countryside 1990 field survey (WP 9).

FINAL COVER-MAP VALIDATION/CALIBRATION (WP 9)

The final validation of cover-maps will use comparisons with cover data for 512 individual 1 km squares, selected on a stratified random basis (Bunce & Heal 1984). The land cover in these squares has been mapped using a combination of Ordnance Survey 1:10000 boundaries, supplementary features mapped from aerial photographs, with land cover (including detailed species data) recorded in the field. The composite maps will be digitised in vector form. These digital maps will be compared with the raster-based satellite cover- maps; this process will require conversion of vector to raster or *vice versa* to allow direct comparisons in a GIS. Experiments designed to determine and optimise the exact methodologies are about to start. Earlier results (Griffiths *et al.* 1990) have shown one perfectly acceptable route using raster to raster comparisons and such procedures are likely to form the basis for methods to be used in this programme.

SCHEDULE OF WORK

The study will involve the processing of about 60 quarter-scenes of combined summer and winter data. In some cases these will be in the form of full scenes, elsewhere they will be individual quarter scenes. As summer-winter composites the net result will be a total of about 30 scenes and part-scenes to analyse, each of which will require about the same time investment, regardless of size. To allow the time required for accuracy assessment (Work programme 8), mosaic construction (WP 9), hard copy production (WP 10), GIS demonstration (WP 11) and the final report (WP 12), we plan to complete the basic analyses of most part-scenes, up to classification stage (WP 5) by the end of the ninth quarter, September 1992 (see Figure 1). This implies an average rate of 2 part scenes classified per quarter, though time spent per scene will vary considerably.

The overlap between images means that complete coverage of Britain is possible using only alternate paths, but with the exception of a 10-20 Km ribbon of data between scenes in the southern half of Britain. Initial purchases of data have set paths 201 and 203 as 'main' paths for full analysis; thus 202 and 204 will be used for 'infill'. Here, training and validation data will be provided from the 45% lateral overlap with each neighbouring path. Thus, in all, about 17 part scenes will require detailed attention to training and classification, a similar number will be classified much more quickly (in perhaps less than half the time). Taking the allowed period of nine quarters, we plan to classify 2 'main-path' images and 2 intervening images per quarter.

In these early stages, when methods are being developed and tested, analyses will proceed more slowly. However, we aim to complete the

classification of 2 main images and part process a third by the end of December 1990, after four months of image analysis. Figure 1 records the planned schedule of activities and the progress to date. This would indicate that, once methods have been firmly established, the timetable is realistic.

RESULTS TO DATE

IMAGE SEARCH (WP 3)

Definition of summer and winter images

This study uses summer and winter data, in composite, to help separate the various target classes. So, for example, arable crops cycle between full plant cover and bare ground in a year, semi-natural vegetation retains full cover; deciduous trees are distinguished from evergreens; deciduous upland grasslands differ from lowland rough grass; urban areas and bare ground are distinguished by their bare appearance in summer. (Fuller & Parsell, in press).

The exact definition of 'winter' and 'summer' has been clarified in discussion with ecologists and agriculturalists, who are familiar with the phenology of the local vegetation in various regions of Britain. The consensus is that the summer period could safely include May to July inclusive, that August to mid-October represents a transition period, that winter covers the time from mid-October (in practice the date of the first frosts) to around mid-March. Late March and April are transition periods which are best avoided in selection of summer-winter images. In practice, the useful periods shift with altitude; they also vary from north to south and east and west in Britain and are inevitably dependent on the year in question. Therefore it is essential to take image summer/winter pairs on their own merit, taking advice based on local knowledge of vegetation, cropping and climate.

Landsat image cover

Nine Landsat paths cover Britain (Figure 2). These overlap very substantially in these northern latitudes, varying between about 45% in southern England, and exceeding 50% from the Scottish border northwards. This means that it should be possible to use alternate paths of data in Scotland to achieve full cover but, in England, it will be necessary to buy every path. Note, however, that individual paths may vary slightly - this is clearly evident in a plot of the quick-looks used in the NRSC's 'Landsat 4 & 5 Worldwide Reference Index for the British Isles' (see Figure 3). The choice of alternate scenes must be made on individual merit.

Quick-look assessments

The search for images is based on National Remote Sensing Centre quick-look photographs of images acquired by Landsat within the study period. The library of quick-looks, 1988 to June 1990, was examined as a starting point. Cloud-free scenes and quarter-scenes of England and Wales were identified from these (note that DOE interest in the project places a

The NRSC continues to send new quick-looks to ITE Monks Wood for continual updates of the evaluations (usually running up to one month behind the current date). We have currently (5 December 1990) examined quick-looks of cover up 21.11.90. We also have listings of scenes which have been acquired as archive material. It is then possible to build up a picture of suitable imagery which is immediately available from the NRSC and imagery which could be purchased, via the NRSC, from Eurimage. Results indicate that 90% of England and Wales has been covered by cloud-free images in the period 1988 to the present, with the remaining 10% available as part-scenes if necessary. Cursory examination shows there to be a good archive of Scottish data, which, it is believed will provide full cover for completion of the maps for all Britain.

Image selection and purchase
The study has started with the selection of two scenes, 201-023 and 201-024, for initial analyses. These were successfully imaged on 21 February and 15 July 1989. Subsequently, full cover of path 203 has been ordered, and most of it supplied. Stock-images at NRSC (mostly summer) were supplied as geometrically corrected to our specifications. The Winter images, ordered from Eurimage, require registration to the summer scenes for twin-image output and subsequent classification. Figure 4 shows the status of image acquisition and processing as at 5 December 1990.

DATA ANALYSIS

'Housekeeping'
The successful conclusion of such a complex project, with vast quantities of data, undergoing many processes before completion, drawing on several members of staff, requires careful attention to detail. To ensure the smoothest possible flow, a 1 gigabyte computer disk has been dedicated to this project, allowing each summer and winter pair, for each scene, to be corrected, amalgamated, and classified with the minimum of intermediate file management. A standard nomenclature has been established for file handling to ensure that any team member can identify any listed file, and immediately assess progress. A micro-computer based reference system has also been created to allow easy retrieval of project information in map form. These products will be continuously updated and made available to DTI with each quarterly report.

Geometric correction and image co-registration
So far, the two summer scenes of 201-023 and 201-024 have been ground control pointed and geometrically resampled. The procedure involved using a stratified sample of ground control points, based on gridded hard copies of the images. For each grid cell the best (most readily identifiable) ground control point was selected. Suitable points might be crossing runways on airfields, crossroads or river bridges. Experiments using a variable number of points, showed that there were thresholds above which the addition of extra points gave minimal improvements in the accuracy of fit. These results showed that, in the lowland south-east, 12 points were enough to give a root mean square error (RMSE) at control points of less than the target one pixel (0.7, 0.75 pixels in these two cases) and that further definition of control points did not reduce this RMSE.

Nearest neighbour and cubic convolution algorithms were considered: earlier tests (Fuller & Parsell, in press) indicated that neither method consistently produces more accurate cover-maps. The nearest neighbour

Nearest neighbour and cubic convolution algorithms were considered: earlier tests (Fuller & Parsell, in press) indicated that neither method consistently produces more accurate cover-maps. The nearest neighbour algorithm better preserves boundaries, whilst the cubic method smooths variations, tending to remove odd, misclassified, within-field pixels. However, smoothing algorithms, applied after classification, may do this job as effectively. Our conclusion is that cubic convolution resampling, which best models the natural variations in radiance across an image, is most appropriate for use here. It will give better within field classification with less 'noise'. Furthermore, the strength of remote sensing classification is in its use for studying areal features, not points and linear features, so the choice of resampling algorithm was made to accord with this.

Class selection (WP 4)

The choice of classes to be included in the classification is a compromise between the level of detail which might be required to satisfy all realistic uses and the accuracy with which they can be classified. Past experience (Fuller *et al.*, 1989; Fuller, Jones & Wyatt 1989; Fuller & Parsell, 1990; Jones & Wyatt, 1989) has shown that local and regional studies might accurately discriminate 5 to 20 classes, depending on the complexity of the area. A full survey of all Britain will probably discriminate 20 to 30 classes for an accurate and useful level of detail. Examination of other studies has produced a recommended list of classes, which will form the basis of the classification (Table 1). Note, however, that at this stage the nomenclature is simplified for convenience. The final classes will be given fully descriptive names which avoid confusion with those used (often mis-used) by others. The use of these classes continues to be tested in the early stages of the classification, whilst a consultation exercise, already underway, will continue with end users. A proposed list of consultees, who will be formally approached for comments early in 1991, is given in Table 2.

It should be realised that the classification is a hierarchical one whereby classes may be amalgamated to produce a simpler, more accurate, cover-map. The suggested levels of aggregation are given in Table 3.

Classification (WP 7)

The procedure of classification is based on an extrapolation from sample statistics derived from examples of 'training data' defined on the image analysis system. These training data are selected to be typical examples of areas of their class. Thus the extrapolation finds all other pixels with the same characteristics. The procedure in use is the maximum likelihood classifier, implemented in a particularly fast form using the pipeline processors of the IIS M75. It is thanks to this software that it is feasible to undertake this massive exercise. Even then, a classification takes 3 hours processing time. The CPU procedure, which is a little more sophisticated, would probably take 30 hours to run; clearly this would preclude the use of the iterative approach, as defined in the 'Methods'.

'Ground reference data for 'training'

Results given here are based on experiences with classifying scenes 201-023 and 201-024. definition of 24 target classes 21 in lowlands) required specification of 43 and 44 subclasses respectively. Initially, 2-5 areas were identified, representative of each sub-class. After field checking, these were increased to 10 training areas per subclass per scene where

available - the exceptions were rare habitats such as heather or bracken, or highly distinctive classes which could be readily defined with fewer areas. The training areas were generally individual fields or land parcels of 2.5 or more hectares of uniform land cover. This meant a minimum 10 pixels per training area, though almost invariably the training areas would be 2-5 times larger if possible. These would be spread evenly throughout the Landsat image to ensure, as far as possible, that they were representative. The general zone for selection of each training area was defined on the full scene overview given on the image analysis system. The zones were stratified on a grid, and the training areas chosen as the most central example of its class, when the image is toggled into full resolution. Thus training areas were selected without the bias which could be introduced from having chosen the training field subjectively. This objective was not met, for example, where a class was rare and we knew very few potential training areas. But it was possible to take training areas at random where a class is common and widespread and readily identified without field visits (eg urban areas, most arable crops, water bodies).

Accuracy assessment

Quantitative checks of accuracy were made using 2020 check-parcels recorded in the field, 526 in 201-023 and 1494 in 201-024. Scoring by majority verdict gave an 81% success in 023, 79% in 024. Most confusion was between the managed and rough grass categories (Tables 4 and 5). This was because grass heaths were readily separable, but other grasslands were not necessarily so. Aggregation of grasslands gave 85% and 84% success in 023 and 024 respectively. This level of agreement was deemed satisfactory, based on earlier experiences with Cambridgeshire classifications. However, in order to eliminate evident problems, the iterative procedure of training increased the number of areas per subclass to 10 as planned, defining a new grass heath category to minimise within class variance, and tightening up training areas of other problematic classes.

The final cover-maps

The classification procedures on 201-023 and 201-024 are complete. However some knowledge-based correction is required, for example to eliminate confusion between saltmarshes and some wheat areas. The coastline will be defined interactively: inside this line, all saltmarsh will be corrected to arable. Outside the line, all arable will change to saltmarsh. We are currently investigating the best means of introducing such corrections.

FORWARD LOOK TO THIRD QUARTER

The aims for the third quarter (1 January to 31 March 1991) will be to:

1 define and apply knowledge-based corrections as needed.

2 finalise the choice of classes to be used throughout

3 rectify, merge and classify scenes 203-022, 023, 024 and 025 (or equivalent)

4 identify and order scenes for analysis in fourth quarter

5 experiment with co-registration and inter-comparison of 1 km field survey squares

LONG-TERM FORWARD LOOK (1 YEAR)

The schedule given in Figure 1 remains the target. Specific objectives in the next year will include:

1 to classify an average of 2 'main-path' scenes and 2 'infill-scenes' per quarter

2 to develop and test a method for accuracy assessment using 1 km field survey squares, and to apply the methods to classified images

3 to test procedures and determine final schedule for mosaicking full GB cover

4 to produce sample hard copy outputs

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Fig. 1. Planned schedule of activities and progress to date (black bars).
December 1990

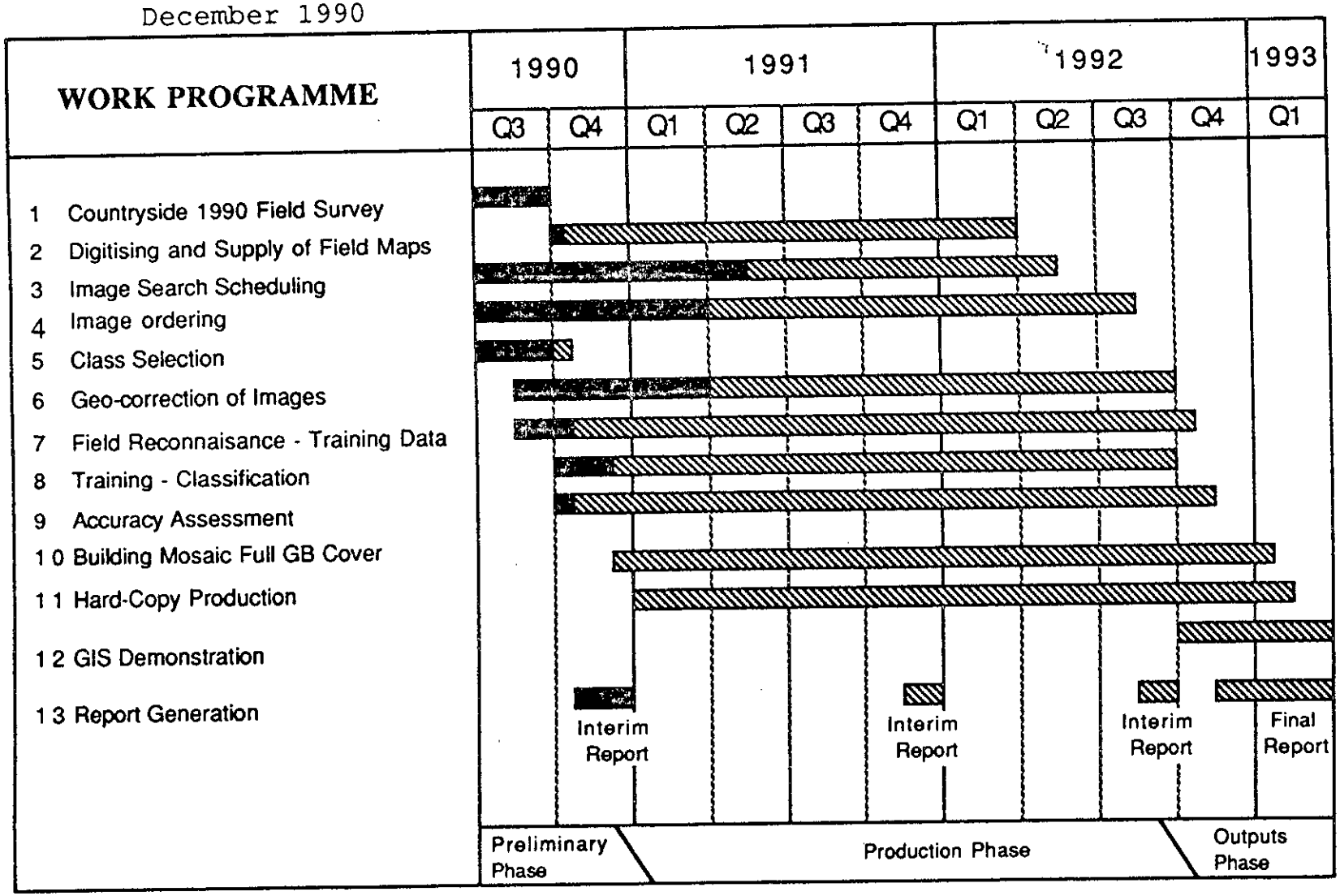

Figure 2. Approximate paths of TM, showing path overlap.

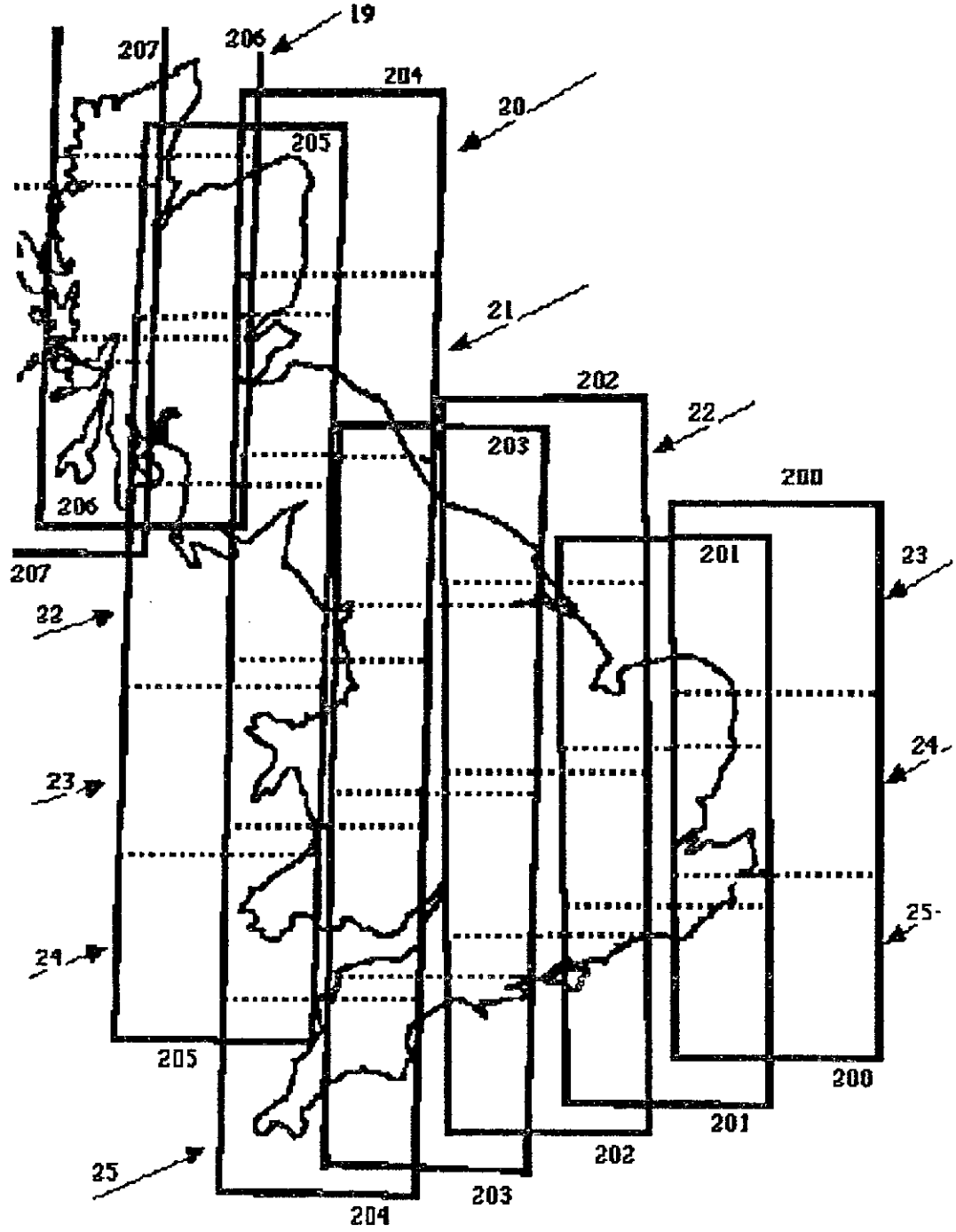

Figure 3. Ground coverage of TM scenes for the UK, illustrating orbit fluctuations.

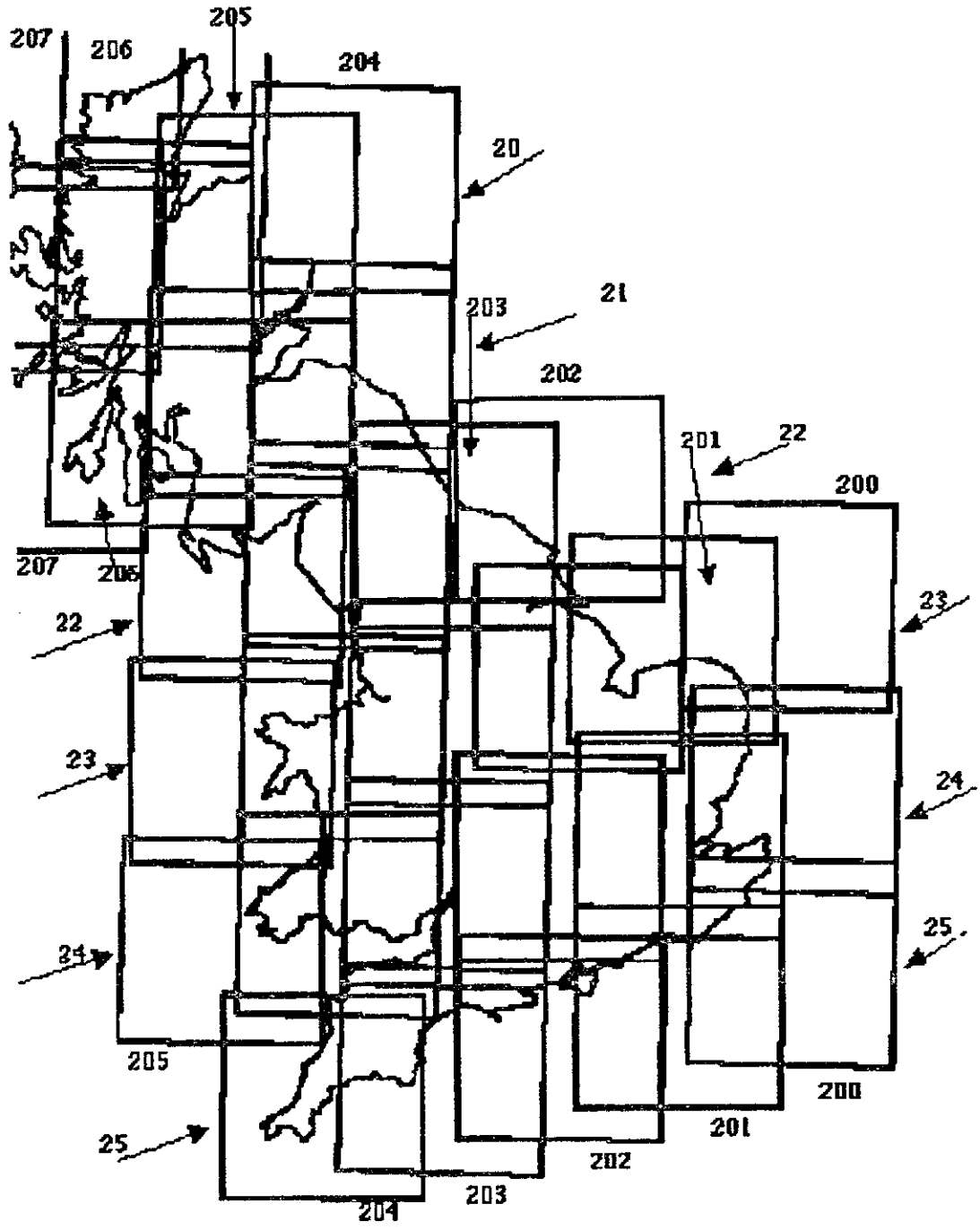

Figure 4. Status of data processing; 5 December 1990.

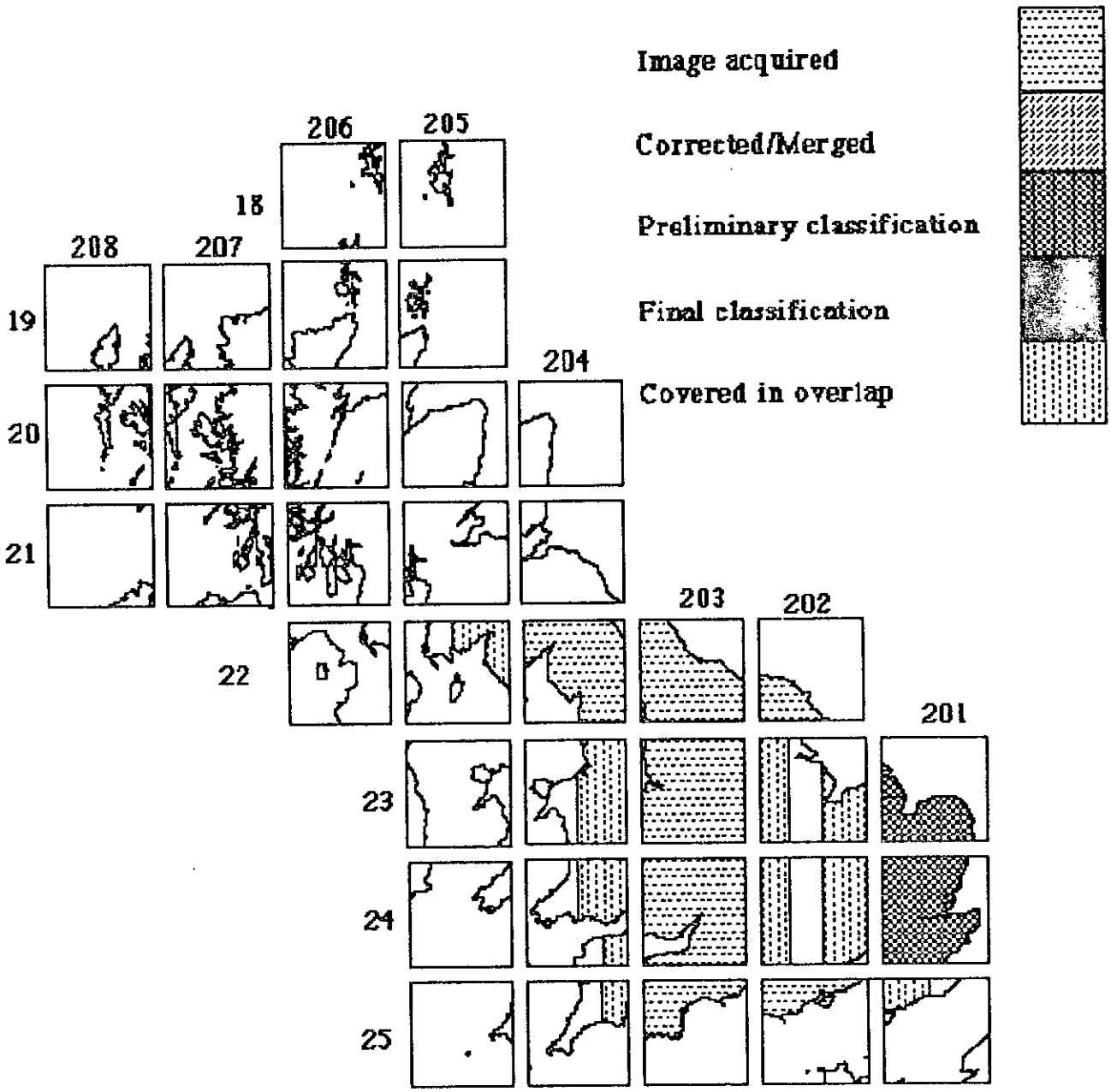

Table 1 (overleaf). A suggested choice of land cover classes and its relation to other recent land cover surveys

Key to Table 1

Abbreviation	Project/Survey	Agency/date
CS 1990	Countryside 1990	ITE/DOE/DTI 1990-
ECOLUC	Ecology of Land Use Change	ITE/DOE 1984-9
MLC	Monitoring Landscape Change	NRSC/Huntings/DOE 1984
Landcov	Landcover Scotland	MLURI/SDD 1988-92
CORINE	Coordination of Information on Environment	Various agencies for EEC 1986-90-?
UN ECE	Proposed statistical classification	United Nations Economic & Social C'l
NCMS	National Countryside Monitoring Scheme	NCC 1985-
Nat Parks	Monitoring Landscape Changes in National Parks	Silsoe/CC 1989-
%	% Cover	Bunce & Jenkins 1989

LANDSAT CLASS	CS 1990	ECOLUC/NRSC	MLC	LANDCOV SCOTLAND	CORINE	UN ECE	NCMS	NAT PARKS	%
sea/estuary	-	-	F1 coast/estuarine	-	5.2.1 lagoon 5.2.2 estuary 5.2.3 sea	7.2 tidal water	-	F1 open water coastal or estuarine	-
inland water	water 36-40	-	F2 open water	water 18	5.1.1 water cse 5.1.2 water body	7.1 inland water	open water	F2 open water inland	3.2
beach/flats	beach 29-32	-	-	beach 23-5	3.3.1 beach 4.2.3 flats	6.2 beaches	-	G3 coastal features	1.9
saltmarsh	saltmarsh 116	-	F3c saltmarsh	saltmarsh 190	4.2.1 saltmarsh	-	-	-	-
sandy grass	maritime gr 107		G3 sand/shingle	marram dune 211	-	-	-	-	-
managed grass	amenity 100 ley 101 perm pasture 102	agricultural grass	E2a pasture G4b amenity	improved 90-7 airfield 4 golf course 5	1.4.1 urban gr 1.4.2 sport 2.3.1 pasture	3.9 recreation 1.3 meadow/past	semi-improved & improved grass, recreational	E2a improved	17.5
low intensity gr	herb rich 106	s'nat upland past	E2b rough pasture E2c neglected pasture	smooth gr 150-3, 155-8, 160-3 links 212-3	3.2.1 natural	-	unimproved grass	E2b unimproved	5.2
fen/marsh/rough	fen 112 marsh 113	-	F3b freshwater marsh	wetlands 200-3	4.1.1 marsh	4.1.2 lowland bogs	lowland mire wet ground	F3 wetland veg	-
montane grass	upland 103 & moorland grass 104	grass moor mixed grass moor upland pasture	D2 upland grass moor	Nardus/Molinia 140-3	-	5.3 mountain grass	-	D2 upland grass moor	8.9
upland bog	bog 111	bog	F3a peat bog	bogs 180-6, 220-3	4.1.2 peat bog	4.1.1 upland bog	blanket mire	-	-
heather moor	moor shrub heath 105, burnt 140	heather, h+grass pioneer, burn	D1 upland heath	wet heather 120-7 undiff'd h 130-7	3.2.2 moor/heath	-	heather moor montane heath	D1 upland heath h-grass mosaic	8.3
bracken	Pteridium 158	bracken	D3 bracken	bracken 170-3	-	-	bracken	D3 bracken	1.6
heather heath	lowland heath 108	-	D4 lowland heath D5 gorse	dry heather 110-7	3.2.3 sclerophyl	5.1 heath	maritime heath	D4 lowland heath	
scrub/orchard	scrub 206	-	C4 scrub, E1c orchard/hops	scrub 82	3.2.4 scrub 2.2.2 orchard	2.5 other wood 1.2 perm't crop	scrub orchard	C4 scrub	1.1
deciduous	trees 200-5, 211-31,235-6	broadlf/mixed	C1 broadleaved	broadleaved 76 undiff'd mix 79	3.1.1 broadleaf 3.1.3 mixed wd	2.3 non-conifer 2.4 mixed	b'leaved/mixed wood/plantn	C1 broadleaved, mixed forest	2.4
evergreen	trees 211-20, 235	conifer	C2 coniferous	coniferous 70,73	3.1.2 conifer	2.2 coniferous	conifer wood/ plantation	C2 coniferous high forest	6.1
arable	arable 117-37	arable	E1a arable/mkt gdn	arable 100-7	2.1.1 arable	1.1 arable	arable	E1 cultivated	28.6
ruderal weeds	vacant 138 abandoned 139 fallow 141	-	-	-	-	1.5 fallow	-	-	-
suburban					1.1.2 discont's urban	3.1.1 1-2 storey 1.4 agri build		H3 isol'd rural	
urban	built 411-414	developed	G3a housing G3c transport G3e derelict	dev rural 1,2,3,6 built-up 20 road 21,rail 22	1.1.1 cont. urb 1.2 indust. 1.3.2 dump 1.3.3 constr	3.1.2 3+ storey 3.2,3.4,3.5, 3.7,3.8 dev'd	built	H1 built up	13.0
bare	bare 1-28, 51-4,423	-	G2 rock G4d mineral	bare 10-18,210	1.3.1 extraction 3.3.2 rocks	3.3 extraction 6.1 rock, ice	bare rock/ soil	D7 peat, G2 rock H2 quarries	0.7
felled	felling 263	clear felled	-	felled 84	3.3.3 sparse veg	-	recent felled	C5 clear felled New plantings	
CLASSES EXCLUDED FROM LANDSAT CLASSIFICATION	linear/points 41-8,55-62,207-10 aquatic 109-10 flush 114-5 burnt arable 14 misc spp./uses 151-99,241-84, 301-79,401-8, 415-22,431-473	(NB limited area covered by NRSC, hence limited list of classes)	A linear/small features B isolated features	cloud 26 snow 27 4. mixed mosaic lines/points recent plough wood 83 open canopy plantation 85	2.1.2 perm irrign 2.1.3 rice 2.2.2-3 vine,olive 2.4 heterogeneous agricultural 3.3.4 burnt 3.3.5 snow	4.2 Tundra 4.2.2 salines 6.1.2 snow Categories, undefined, labelled 'other ****'	young plant'n marginal inund'n parkland		

Table 2. Provisional list of organisations to be consulted regarding the land classes to be identified in the land cover mapping project: this consultation may be direct, or via committees, learned societies or professional groups.

British Association of Remote Sensing Companies
British National Space Centre
CLUWRR, Newcastle University
Countryside 1990 Advisory Committee
Countryside Commission
Department of Transport
Department of the Environment, Air Quality, Rural Affairs
Department of Trade and Industry
European Commission DGXI
Hunting Surveys Ltd
Institute of Terrestrial Ecology Stations
Macaulay Land Use Research Institute
Ministry of Agriculture Fisheries and Foods
National Remote Sensing Centre
Natural Environment Research Council Institutes
Nature Conservancy Council
NERC/ESRC LUP
Scottish Development Department
Silsoe College

NB this list is a provisional list: additions will be required. Suggestions for consultees are invited.

Table 3. A proposed aggregation of classes for simpler, more accurate map outputs

wetland	wetland	water	sea/estuary
			inland water
		intertidal	intertidal flats/beach
			saltmarsh
vegetation	herbaceous	lowland herbaceous	sandy grass
			managed grass
			low intensity grass
			fen/marsh/rough herb
			ruderal weed
		upland herbaceous	montane grass
			upland bog
			bracken
	'woody'	shrub	heather moor
			scrub/orchards
			heather/heath
		woodland/trees	deciduous/mixed
			evergreen
man-made	man-made	arable	arable land
		non-vegetated	suburban
			urban/industrial
			felled
bare	bare		bare rock

Map Cover-class - See Table 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
water		19																						19
flats			2																			1		3
saltmarsh				12																				12
sandy gr							5													2				7
grass						53	25	7				1						1						87
rough gr						5	36	4																45
fenmarsh							1	24										1						26
bracken								1				3			1									5
heather																								
scrub							4	4						10	1					2				21
deciduous								1					1		19									21
evergreen								1								52		2						55
mixed								1							6									7
arable				1		1	14	3										168				2		189
ruderal																	1							1
suburb																		1		11	4	1		17
urban																					3	2		5
bare																		3				2		5
felled																		1						1
Totals		19		2	13		59	84	46				4	1	10	28	52	1	177		15	7	8	526

Table 4 Confusion matrix for cover-map of scene 201-023 based on per-parcel scores following field checking

Map Cover-class - see Table 1

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
water			15																						15
flats																									
saltmarsh																									
sandy gr								5																	5
grass	2						169	58							2	1			4	2			1		239
rough gr	1						16	83	1						1				1	1	1	1			106
fenmarsh	1				3			1	22						4	1			2						34
bracken								2	2				3			6					1	1			15
heather								3						25											30
scrub	2							3	3						16	6					2				30
deciduous								1	1						3	109	2		8						124
evergreen	4								1						2	8	95		2						111
mixed								2						1	3	18	3								27
arable	19		1		17		8	20	2										471	9	13	6	8		575
ruderal	1																		7		1				9
suburb	1							2											1	1	101	6	2		114
urban/I																			1		6	34	8		49
bare																				1	2	5	3		11
felled																									
	31		16		20		193	175	36				3	26	32	150	101		497	14	125	53	22		1444

Table 5 Confusion matrix for cover-map of scene 201-024, based on per-parcel scores following field checks.