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INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)

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Countryside Survey 2000 - Part III

Module 7

LAND COVER MAP 2000

FIRST PROGRESS REPORT

CSLCM/Prog1

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EXECUTIVE SUMMARY

- The quarterly Progress Report on Land Cover Map 2000 (LCM2000) considers ground reconnaissance, identification of Broad Habitats, training and extrapolation.
- An image search suggests, with substitute second scenes as necessary, a 90-95% coverage in the target 1997-98 winter.
- The Report identifies widespread Broad Habitats (excluding small scale features, those incorporating land use characteristics and some distinctions between grasslands) which LCM2000 will aim to record with an intended accuracy of 90%.
- The LCM2000 team attended the field surveyors' Training Course to apply Broad Habitat classifications matching those of field surveyors'.
- Tests of image segmentation gave 5-8% improvement over per-pixel methods and, with other improvements, will raise accuracy from the 80-85% of 1990 to the target 90%.
- Possible processing refinements include image-striping, removal of atmospheric effects, ortho-rectification and correction of differential illumination due to topography.
- Laser-Scan IGIS, intended for analyses, now has a new per-parcel classification which attaches probabilities for all potential classes. Hardware needs are currently under review.
- Progress reviewed against the original GANNT chart shows that the activities scheduled for this early phase of the project are, on balance, ahead of schedule.

INTRODUCTION

This is the first of the quarterly Progress Reports on Land Cover Map 2000 (LCM2000). As originally conceived, the Progress Reports were envisaged as 2 page documents describing progress and recording it against the original GANNT chart (see LCM2000 Specification Figure 1). At the request of the Joint Management Team for Countryside Survey 2000 (CS2000), this Report has been expanded to include an outline of the procedures to be used to ensure best possible correspondences with the field surveyors in the interpretation and application of the Broad Habitat classification of CS2000. The basic Report retains the brief format but the issues concerning ground reconnaissance, identification of Broad Habitats, training and extrapolation are included in a separate Annex.

IMAGERY

An image search, covering winter 1997-8, has shown that, by end of March, all but one of the scenes needed had been imaged, with cloud/snow-free coverage varying from about 70-100% per scene. Allowing for duplication of cover in the *c.* 50% overlaps between paths, this imagery probably gives 85% winter-coverage of Britain. The target 'winter' period extends through April in S. Britain and even into May in the Scottish Highlands (i.e. until deciduous trees are in full leaf), giving scope to add to these late 'winter' data. It is, however, almost certain that we will need to buy substitute images to patch the cloud holes in earlier coverage. Despite this observation, we expect image needs and purchases to be within original forecasts and budgets (which allowed for an average of 2 images per scene to complete the cover). We anticipate, with substitution, a 90-95% coverage in the target 1997-98 winter (compared with 92% coverage over 3 winters in LCMGB 1990).

Image costs have been confirmed with NRSCL and match those of the Specification - more importantly (and newly confirmed), they will be held to 31 March 2000.

BROAD HABITATS

The Biodiversity Action Plan identifies a range of wildlife habitats to map, monitor and conserve under the obligations of EU legislation. The Broad Habitats were thus defined to provide a UK-wide context for more targeted monitoring and surveillance, including fulfilment of EU obligations, notably under the Habitats Directive. The Habitats were identified to include the whole land surface of the UK as well as the seas and surrounding continental shelf (though the last of these is irrelevant in the context of LCM2000).

LCM2000 will aim to map widespread examples of Broad Habitats with an intended accuracy of 90%. The list of Broad Habitats is, we understand, finalised and widespread examples are given in Table 1; this is a generalisation of 37 original proposed types.

Target LCM2000 classes (see LCM2000 Specification, Annex IV) generally relate directly to widespread Broad Habitats. The spectral subclasses of the LCM2000 can be aggregated into any combination to closely match the finalised list of Broad Habitats. The Broad Habitats which are likely to be difficult to record (and which were never suggested as target classes) include small scale features below the resolution of the satellite mapping, land use characteristics and some distinctions between grasslands. The definition of LCM2000 classes must rely upon unambiguous definitions of Broad Habitats and a clear understanding of these by the team: detailed definitions are being drawn up by JNCC for publication in the autumn. Meanwhile, a *Key to Vegetation and Land Cover Types* (produced by Bunce *et al.* and distributed in draft form at the field training course) helps identify BAP codes using vegetation and contextual indicators which field surveyors and the LCM2000 team can identify in the field. Further details appear in Annex I.

Table 1. A classification of Broad Habitats which will be used to develop the choice of satellite classes.

1. Broad-leaved, mixed and yew woodland	15. Montane habitats
2. Coniferous woodland	16. Supra-littoral rock
3. Boundaries and linear features	17. Supra-littoral sediment
4. Arable and horticulture	18. Littoral rock
5. Improved grassland	19. Littoral sediment
6. Neutral grassland	*20. Inshore rock*
7. Calcareous grassland	*21. Inshore sediment*
8. Acid grassland	*22. Offshore rock shelf*
9. Bracken	*23. Offshore shelf sediment*
10. Dwarf shrub heath	*24. Continental slope*
11. Fen, marsh and swamp	25. Oceanic seas
12. Bog	26. Inland rock
13. Standing open water and canals	27. Built up areas and gardens
14. Rivers and streams	

NB. Broad Habitats recorded in italics (classes 20-24) are irrelevant in the context of a land cover map.

FIELD TRAINING

The LCM2000 team attended the field days of the first week of the Training Course when surveyors were learning and practising (amongst other things) the land cover mapping elements (week 2 concentrated on the quadrats and species recording). The course has helped the LCM2000 team to understand and apply the Broad Habitat classifications in a way which (allowing for scale and resolution differences) matches the field surveyors' applications.

TESTS OF IMAGE SEGMENTATION

Tests of image segmentation have re-visited LCMGB 1990 data. Per-pixel classification in 4 test squares gave 41% direct correspondence for 25 classes (prior to knowledge-based corrections and without allowances for time and spatial differences between surveys). The commercial CAESAR segmenter gave a slightly better 42% correspondence. The CLEVER-Mapping segmenter gave 50% direct correspondence for 25 classes. At the 17-class level, the per-pixel method gave 63% correspondence, the CLEVER-Mapping segmenter gave 68%. Moreover, the C-M software gave more balance, better identifying whole fields and yet distinguishing smaller landscape features than CAESAR. CLEVER-Mapping segmentation also gave finer thematic detail and was quicker, probably by a factor of 2 or more.

The 3 lowland / marginal squares gave an average 71% correspondence, the overall value for 4 sites being reduced due to the poor 51% correspondence in uplands (where field surveyors have already demonstrated the extreme difficulty of mapping cover within boundaries and where the ground reference data must be suspect). Given the 5-8% improvement in the initial classification over per-pixel methods, it would seem that CLEVER-Mapping in 2000, with a better choice of images, improved registration, more sophisticated pre-processing plus refinements of knowledge-based corrections and allowances for time and spatial differences, will raise accuracy from the 80-85% level, achieved per-pixel in 1990, to the target 90% level of 2000.

METHODOLOGICAL REFINEMENTS, SOFTWARE AND HARDWARE

Refinement of processing procedures includes possible enhancements such as correction of image-striping (standard software), removal of atmospheric effects (based on ITE software development), ortho-rectification (standard software) and correction of differential illumination due to topography (ITE is negotiating the operationalisation of Cambridge University software).

ITE is finalising arrangements with Laser-Scan for free use of Laser-Scan IGIS (though there will be a software support subcontract). Version 3.0 of IGIS is being installed with new self-contained database (free of the constraints of ORACLE) and the new per-parcel classification containing the provision for attaching probabilities for all potential classes.

Assessments of hardware needs and current prices/availability have included workstations, hard disk drives and storage media.

CONCLUSIONS

Progress reviewed against the original GANNT chart (Figure 1) shows that the activities scheduled for this early phase of the project are, on balance, ahead of schedule. The purchase of *equipment*, nearing the tendering phase, has been slowed pending the signatures of Consortium Agreements and installation of hardware (not actually needed routinely until late August) will take place June or July. The *field course* has been attended and *class finalisation* is further advanced than originally intended, thanks to a successful field course and application of the Key to BAP classes plus, in an Annex to this report, the early production of a more detailed explanation of the classes, their recognition and use. The *image search* is completed for winter 1997-98 with better results than expected. The *technical meeting*, though delayed to early June, is planned, scheduled and will be the venue to present this report.

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ANNEX I

BROAD HABITATS, THEIR RECOGNITION, GROUND RECONNAISSANCE SURVEY & EXTRAPOLATION

Introduction

The Biodiversity Action Plan identifies a range of wildlife habitats to map, monitor and conserve under the obligations of EU legislation. The Broad Habitats were thus defined to provide a UK-wide context for more targeted monitoring and surveillance, including fulfilment of EU obligations, notably under the Habitats Directive. The Habitats were identified to include the whole land surface of the UK as well as the seas and surrounding continental shelf (though the last of these is irrelevant in the context of LCM2000).

LCM2000 will aim to map widespread examples of Broad Habitats. It is intended that these will be recorded by LCM2000 with an accuracy of 90%, as measured per land parcel against field sample 1 km square data. Minimum accurately mappable units are likely to be 1 ha, though per-pixel classifications will also record finer detail of heterogeneity per-parcel. The list of Broad Habitats is being developed by the Joint Nature Conservation Council (JNCC) with inputs from ITE field surveyors. At a meeting on the Broad Habitats at JNCC on 18 March 1998, the LCM2000 team was represented by R M Fuller. It was clear from the suggested classification that the spectral subclasses which will be defined in the production of LCM2000 (Kershaw & Fuller 1992) can be aggregated into any combination to closely match the finalised list of Broad Habitats.

The Broad Habitats

The list of Broad Habitats is, we understand, now finalised. with an intended accuracy of 90%. The list of Broad Habitats is, we understand, finalised and widespread examples are given in the main text of the First Progress Report, Table 1; this is a generalisation of 37 original proposed Habitat types. Detailed definitions are being drawn up by the JNCC for publication in the autumn. In the meantime, brief definitions are given in the field survey handbook (Barr, 1998 - CSJMT7/2 *et seq.*).

The proposed target LCM2000 classes (LCM2000 Specification, Annex IV) would generally map directly to widespread Broad Habitats. The Broad Habitats which are likely to be difficult to record (and which were never suggested as target classes in the proposed Specification) include:

i. small scale features (e.g. boundary and linear features, rivers and streams) where they are below the resolution of the satellite mapping;
ii. distinctions between calcareous, neutral and acid grasslands (though following field training and trials, we expect to separate these from the improved grasslands, contrary to suggestions in the Specification);
iii. bracken (which was not listed as a widespread Broad Habitat at the time of drafting the Specification): dense bracken will be targeted as a subclass but rarely offers stands sufficiently extensive for classification and training;
iv. fen / marsh / swamp habitats are rare and usually small scale and may, on some scenes, prove difficult to identify as training areas for extrapolation;
v. littoral rock and sediments may be difficult to distinguish from each other spectrally and the former may be at too small a scale to map routinely; the same might apply to supralittoral

examples; and supralittoral rocks and sediments covered with vegetation will classify according to the plant cover (e.g. coastal heaths, dune grasslands).

It has always been made clear, during specification of LCM2000, that contextual distinctions such as soil acidity or littoral location should rely upon GIS contextual analyses, using LCM2000 data and, where necessary, external data (e.g. soils maps), the latter to be applied *post hoc*. Where realistic options are available to the LCM2000 team, these distinctions will be applied to refine the classification for all users. Where specialist interpretations require datasets which are not routinely available to the team, the distinctions would normally be made by end users.

Broad habitat recognition for the purposes of image classification
The derivation of classmaps for each summer-winter composite scene is dependent upon the acquisition of representative ground reference data to act as a sample giving so-called 'training' areas to calculate reflectance statistics per class, per waveband, per scene, per date. These statistics can then be used to allocate each pixel or land parcel to its 'maximum likelihood class' using a statistical Melanhobis distance measure.

The principles for ground reconnaissance survey involve locating and identifying the thematic class associated with each unique 'spectral class' on the image: the examples should, for each combination of summer and winter data, form a representative sample offering an adequate number of pixels for a replication of sites. As an ideal minimum, this sample would be set to record several replicates giving >30 pure pixels overall (Fuller *et al.* 1994); in practice, the typical sample includes many more pixels (>200) and generally many replicates (up to 10). However, in rarer and smaller examples (e.g. flushes) even the minimum sample might prove elusive if not impossible to locate. Under such circumstances, it is necessary to establish whether a chosen sample is, first, adequate and, second, whether the resulting extrapolation provides correct classifications of the target without picking up many stray pixels of other classes: this is done by reference to, and scoring correspondence against, the samples themselves and, better still, any other independent examples of the class (e.g. other areas, perhaps too small even to train upon). Where adequate training areas are absent, the class must be omitted from that classification, at least until contextual interpretation in the post-classification stages.

Broad Habitat definitions
It is clear that the definition of training areas and LCM2000 classes must rely upon unambiguous definitions of Broad Habitats and a clear understanding of these by the production team. Until publication in the autumn of detailed definitions, the brief definitions given in the field survey handbook (Barr, 1998 - CSJMT7/2 *et seq.*) must suffice. Especially helpful, has been the translation of these into a *Key to Vegetation and Land Cover Types* (produced by Bunce *et al.* and distributed in draft form at the field training course): this identifies BAP codes using vegetation and contextual indicators which field surveyors and the LCM2000 reconnaissance team can identify in the field. A table of correspondence between Broad Habitats and the CS1990 Primary Codes (Bunce, unpublished) is also helpful, especially in view of the known and objectively tested correspondences between the Primary Codes of 1990 and the generalised classes of the 1990 Land Cover Map of Great Britain (Wyatt *et al.* 1993).

To help objective analysis and the interpretation of Broad Habitats, the LCM2000 team aims to code the Broad Habitat attributes (deduced from definitions, the Key and the Primary Codes) into the ITE *Program for the Inter-comparison of Land Classifications* (Wyatt *et al.* 1997). This software package was developed in a programme of research *Correspondence to other themes as a basis for integrated approaches* (produced for the European Environment Agency and widespread European end-users with funding from the European Topic Centre on Land Cover). The PC-based Windows-95 software uses detailed attribute coding (e.g. based upon cover descriptions, species, land use, geo-climate context etc.) to translate between classification systems. The encoded data already include the Land Cover Map of Great Britain and can thus compare and contrast component classes with LCM2000. The software is capable of identifying ambiguity and uncertainty in definitions and locating unintentional overlaps due to inadequate distinctions in definitions. It will initially use the outline descriptions for Broad Habitats but can later be refined with the full JNCC published descriptions. It will thus point to problems and help clarify the exact definitions of the Broad Habitats. The results will be valuable to the CS2000 team (both the field and LCM2000 surveyors), the CS2000 customers (e.g. the LCM2000 Consortium) and to CS2000 end-users who wish to have objective definitions and ready translations between Broad Habitats and other classifications / nomenclatures.

The Field Training Course

The LCM2000 team attended the field-based days of the first week of the CS2000 Field Training Course of May 1998, when surveyors were learning and practising, amongst other things, the land cover mapping elements of the fieldwork (week 2 concentrated on the quadrats and species recording). The course has greatly helped the LCM2000 team to understand and apply the Broad Habitat classifications in way which (allowing for scale and resolution differences) matches the field surveyors' applications.

The LCM2000 team combined field recording of the trial 1 km squares used for training field surveyors with wider reconnaissance trials around the southern Lake District to more widely test the application of the derived knowledge and to assess the BAP Key in field operations. For such purposes, 1990 images were extracted and hard copies made for evaluation on the field survey course. The Key was particularly helpful in separating the classes, generally unambiguously, and remaining questions were discussed with trainers on the field course. Good examples of most Broad Habitats, suitable for training and classification, were identified in the trial reconnaissance surveys.

Confusions between unimproved and improved grasslands (present on LCMGB 1990) were clarified in the exercise, ensuring a much more meaningful discrimination of unimproved grasslands than was applied in 1990. It remains clear, however, that distinction of acid, neutral and calcareous unimproved grasslands (excepting deciduous moorland grass) may on occasions need greater botanical skills than the LCM2000 team have got: we are considering the use of pH meters for field testing to ensure correct assessment of acidity. However, it is always been expected that mapping will require more than just spectral distinction, drawing upon contextual map information (e.g. soils or geology maps) in later post-classification operations.

The discrepancy between field and LCMGB 1990 bog / dwarf shrub / grass moor classes was investigated through use of the field key in a further LCM2000 training exercise in the north

Pennines. It is still necessary to identify examples of unambiguous training areas in some of the wetter, higher and more acidic moors.

There is some concern that the woodland categories operate where tree or shrub cover is >25% (see Key). Scattered trees may not offer sufficient spectral distinction to allow their mapping at lower levels of cover: the spectral signatures may be dominated by the background vegetation such as grass or heather (and the dominant class in cover terms). It is likely that per-parcel classifications could record cover as either the dominant class or as a mosaic category and that per-pixel recording could attach to these parcels an estimate of the proportional cover of trees and understorey cover (as demonstrated to the LCM2000 Consortium during the development stage, using test sites in the Cairngorms (also reported under CLEVER-Mapping, Smith *et al.*, 1998)). Continuing trials will investigate ways to maximise the usefulness of such discriminations to match field interpretations. A similar potential problem with dwarf shrubs is considered soluble as the scale of the mosaics is much smaller and the spectral signatures of ericaceous species sufficiently distinct to allow the definition of an open shrub class (as was done in LCMGB 1990).

Other classes are expected to present very few significant problems arising from their definitions except in borderline situations (e.g. spatial mosaic, gradation or temporal transition). As stated above, borderline and transition habitats will not be used for training and will be classified objectively using the statistical Melanhobis distance measure employed by the maximum likelihood classifier (Schowengerdt, 1983). Annex Table 1 gives comments on Broad Habitat recognition. Where field recording marks transition zones, these will serve as checks to ensure that they are being handled sensibly by the classifier (i.e. classifying as one of the two optional mixed components).

Subclasses and Variants

ITE aims to subdivide the Broad Habitats (images permitting) to meet wider user needs (e.g. DETR NLUSS classes, MAFF crop types). Thus the target classes will be divided into **subclasses** where it is believed that users require extra thematic detail (note that such subdivision may mean accepting a reduced level of consistency nationally). The Specification (Annex IV) outlined a possible 31 classes at the subclass level. This list might in turn be further divided giving **variants** of subclasses with perhaps 37 types overall (Specification, Annex IV). The final choice of classification is scheduled to be the subject of the first Interim Report in August 1998: this will include the attribute coding onto the *Program for the Inter-comparison of Land Classifications*.

Ground reconnaissance surveys for reference data collection

To be sure that the ground reference data correspond with the images, the field survey would ideally match the date of the satellite summer-overpass. However, there is a catch here: in order to collect field data by the best and most efficient methods, we would ideally have the images recorded, delivered, co-registered, printed and used to direct the reconnaissance; but by the time the images have become available for fieldwork, the ground features, especially arable crops, will have considerably changed (e.g. been harvested) and evidence of true cover may have been lost. The aim to subdivide Broad Habitats and especially to include some distinction of crops has implications for the strategy and sequence for reconnaissance surveys, though, generally, no difficulties arise at the Broad Habitat level as these generally are not transient classes. In the 2 year period of survey (certainly for the ground survey and possibly for the satellite recording), only rotation grass/arable is likely to record much change at the

Broad Habitat level (and this is always very obvious. On a one-year timescale, it is irrelevant at the Broad Habitat level as rotation grass is to be considered an arable crop. Coniferous plantation, harvested on perhaps a 30-70 year cycle, is likely to record 2-3% change in a year (and this is always very obvious on the images). It is most unlikely that any more than 1-2% of other classes would have changed between 1998 imagery and say 1999 field reconnaissance.

The above observations, while hardly problematic, nonetheless require pragmatic solutions. In practice, because this problem almost always applies in satellite surveys, these solutions have been developed, tried and tested in almost **all** such surveys of land cover. Two ways have been used: first, to survey in anticipation of probable imagery, second, to survey after imagery has been completed, accepting the possibilities of change. The former is most important when transient features (e.g. arable crops) are to be identified specifically, the latter when (as in semi-natural landscapes) the patterns are slowly changing but their complexity makes it logistically advantageous to be directed by existing image coverage.

LCM2000 will adopt both principles. Arable areas of eastern England, south east Scotland the Midlands and southern Central England will be visited in 1998: they are also those parts of Britain most likely to be imaged successfully in 1998. Northern and western Britain will be covered in 1999, using (as available) imagery of 1998 to help direct the reconnaissance. The ground reconnaissance survey of LCM2000 is currently being planned: a timetable has been set to concentrate on transient landscapes in 1998 (e.g. arable) recognising the greater potential to continue fieldwork in less rapidly changing areas in 1999. In order to maximise the possible coverage of transient arable landscapes, 6 reconnaissance surveys are phased to be completed before the harvest in late July 1998. This compares with 4 reconnaissance trips originally scheduled in the Specification (see GANNT chart).

Reconnaissance in 1999, after hopefully the near completion of successful imaging, is not expected to cause insuperable problems. The Broad Habitats are only subdivided to a generalised level which makes no distinction of arable crops, nor the exact management of grasslands (haycut, silage, grazed) or of semi-natural areas (e.g. burnt and unburnt heather). It is to be expected that the vast majority of Broad Habitats in 1998 will be in the same class in 1999. The one exception might be rotation grass-arable land but there will be innumerable examples of improved grass and arable to act as training areas and the rotation from grass to arable or *vice versa* will be clearly evident when interpreting images in the field (just as it was using 1988-89 images for 1990-91 reconnaissance in production of the LCMGB).

It is important to recognise that a failure to cover all of Britain in 1998 will not preclude mapping from 1998 images those transient features which have changed and thus gone unrecorded in 1999 reconnaissance. Adjacent image paths overlap by *c.* 50%. A cover type mapped against ground reference data on one path will appear on the adjacent path: thus, there will potentially be thousands of examples on an unsurveyed scene, deduced from comparison with its neighbour, from which to generate sample statistics for spectral signatures. If conversely, the path is not imaged in 1998 but waits until 1999, then the 1999 reconnaissance surveys will pick up the cover identification.

The field recording base

All fieldwork will require a basemap or imagery to annotate with the current cover. In 1998, two options are possible. We might use 1:25 000 Ordnance Survey maps to record cover field-by-field (though this is the least problematic part of the recording). This would not be helpful in complex mosaics of semi-natural unenclosed land (where field surveyors have already identified the extreme difficulties of demarcating discrete zones of cover); the costs of using OS maps would also mount to thousands of pounds. Alternatively, and much more realistically, we might use LCMGB 1990 imagery which shows (with few exceptions) the field patterns of 1998 and the general zones of semi-natural cover. The exact land management might have changed, but the management units are essentially unchanged; and the use of imagery draws attention to the diversity of land cover, focuses attention on such detail, and ensures the capture of as much relevant information as is realistically possible: costs are small as images are available within ITE.

The LCM2000 team have the advantage over field surveyors that they are, in essence, attempting to locate sample of 'pure' cover of each of the Broad Habitats. The classification will rely upon the same general principles as operate in spectral mixture modelling: it can be demonstrated that mixed pixels of two classes show a spectral signature which is intermediate between the classes and proportionate or a 'linear' mixture model of the two components' individual signatures. On a similar basis, a well-trained maximum likelihood classifier will calculate the spectral (Melanhobis) distance to the individual class centroids in the multi-band feature space (Schowengerdt 1983) and allocate mixed pixels or parcels to the nearest spectral class. If a mixed pixel of two components is classified, the class given would be the nearer of the two in statistical/spectral terms, i.e. the majority component. Segmentation and per-parcel classification, ensures that parcels are, in broad terms, single cover types: and the CLEVER-Mapping segmenter identifies odd pixels which are unallocated to parcels due their strong differences from either neighbour. They can be allocated to a class and/or parcel by a host of intelligent post-classification procedures combining spatial, contextual and probabilistic measures.

Conclusions

The Broad Habitat classification, the identification and field recording of the classes and the use of the data for training a classifier is viewed as being a tried and tested procedure, fully commensurate with the needs for compatibility with the CS2000 field survey. Objective methods will be used to compare field and satellite classes, scoring the attributes used by the field surveyors and comparing those adopted at a more generalised level by the LCM2000 team.

Borderline examples of classes will not be used for training and therefore need not be named and classified by the field reconnaissance team. They are dealt with in spectral-statistical terms and need not be pigeon-holed during field reconnaissance. Thus, identification of most Broad Habitats, for LCM2000 training, can be entirely unambiguous, insofar as we are selecting only the pure examples and can ignore any uncertainties: in this respect, we will not face the problems of the field surveyor trying to pigeon-hole borderline classes to record 100% cover.

On most scenes, there will be very many excellent examples of continuous broad-leaved woodland, coniferous forest, the various arable crops, improved grassland, unimproved grassland, dwarf-shrub heath, bog, standing water, bare inland rock and built up land. These will be readily identifiable by their Key attributes. They will form the backbone of the training and extrapolation.

Most of the Broad Habitats, implicitly or explicitly, comprise many sub-types. Where these have their own unique spectral signatures, they will be trained and classified separately. In addition to the thematic differences (e.g. crop type, broad-leaved species), there are contextually influenced signatures (e.g. topographic slope and aspect, soil background, wetness) and those due to management (e.g. cut, grazed, fertilised). These will be aggregated as appropriate for the generation of Broad Habitats.

It is important to remember, however, that the **GIS will retain the original spectral subclass, allowing any combination of thematic classes required by the user**.

Annex Table 1. A brief review of Broad Habitats with an assessment of their distinguishing features, difficulties in distinctions and their identification in relation to minimum mappable units, in both per-pixel and per-parcel measurement.

1. Broad-leaved, mixed and yew woodland	The vast majority of broad-leaved woodlands with near-closed canopies of e.g. ash, oak, beech, birch and scrub species such as hawthorn and sallow can be interpreted straightforwardly in the field and pure examples used for training the classifier. The Deciduous Woodland of LCM1990 did not include broad-leaved evergreen trees: it is not clear whether these would be spectrally distinguishable from needle-leaved evergreens, though the incidence of stands >1ha, suitable for training and appropriate for classification is all but negligible. Deciduous larch might be confused with deciduous broad-leaved trees, though their summer colour should distinguish them: special attention will be paid to ensure this is so. Mixed woodland will be trained separately though, where stands of broad-leaved or evergreen trees exceed the minimum mappable unit, they will be treated as separate blocks within the woodland: in practice, per-polygon classification is likely to generate 'mixed woodland' polygons and per-pixel assessments will record the mosaics. It is a problem, albeit rare, that open-canopy woodland (the class includes all stands with trees >25% - see Key) will be classified by field surveyors as woodland despite the cover-dominance of the understorey. It is as yet unclear how consistently a 25% cover of trees would influence spectral signatures sufficiently to be classified as an open-canopy subclass: it is likely that the per-polygon results would record the understorey class-dominance and that per-pixel results will show the presence of scattered trees - in practice this would be ideal, giving detail of the heterogeneity while matching the parcel-based generalisation of the field survey. The aggregation of scrub into this class matches the approach of 1990 when the woodland and scrub classes were aggregated in generating 17-class maps from the 25-class originals to match CS1990 baseline classes.
2. Coniferous woodland	The recognition of coniferous woodland is generally more straightforward in that most stands will be planted, extensive and spectrally highly distinct. Open canopy semi-natural pinewoods will need special attention to ensure accurate recording: however, the distribution is limited and well-known, allowing such attention. New plantations will, as in 1990, only be recorded when tree cover is sufficient to strongly influence reflectance. New plantations, predominantly heather and/or grass, for example, will be recorded as such. This is one class where the field surveyors record land use i.e. forestry rather than the cover: spectral classification of image data cannot match that. Estimation of new plantation should be based upon a combination of the ITE land class, its broad cover as mapped by LCM2000 and the field-surveyed estimate for the proportional cover of plantation.
3. Boundaries and linear features	Only the largest of linear features might be mapped by the classification of satellite images. The field survey will continue to provide the best information on these.
4. Arable and horticulture	This Broad Habitat will match the Tilled arable crops of 1990. This means that first year ley grasslands will be included as arable but subsequent years will include them with improved grasslands. This matches field-surveyors' aims. Intensively managed perennial crops (e.g. canes, orchards without ground flora) will show as bare in winter and so be included (as with the field survey) in the arable class.

5. Improved grassland	Improved grasslands will be distinguished from semi-natural grass. The criteria used by field surveyors (dominance of palatable grasses) also gives the grasslands a distinct spectral signature. It is recognised that management practices (heavy grazing) can obscure this dominance and might cause mis-classifications with semi-natural swards. However, the field training course and trial reconnaissance surveys suggest separation is feasible and worthwhile. If accuracies are lower than the intended 90% per-parcel, then the target classification will be that of the Specification (without distinction between semi-natural and improved swards), but the distinction will be retained at the subclass level. Integration of the broad assessment with specific field estimates might prove especially powerful as a guide to the spatial distributions and quantities of the various agricultural grasslands.
6. Neutral grassland 7. Calcareous grassland 8. Acid grassland	The three semi-natural swards are the converse of the above and rely upon the same assumptions as above. Where acid status is known, separate field-identification, training and classification will be used (though probably with aggregation for most maps and data outputs. To assist reconnaissance surveys of acid status, the LCM2000 team will investigate use of portable pH meters for soil acidity measurement. Soil maps may also help distinction and could be used as a post-classification modifier (though probably not within the production of LCM2000).
9. Bracken	bracken (which was not listed as a widespread Broad Habitat at the time of drafting the Specification): dense bracken will be targeted as a subclass but rarely offers stands sufficiently extensive for classification and training. There were problems in the accurate mapping of bracken in 1990 so it was not written into the Specification as a target class. However, hopefully, better focus of image dates and topographic correction of illumination differences will refine the classification to offer a defensible distinction of dense bracken (excepting woodland stands) at the subclass level.
10. Dwarf shrub heath	This Widespread Habitat is essentially an aggregation of LCM1990's *Grass Heath*, and *Open* and *Dense Shrub Heaths*. This means that the Habitat could generally be identified on LCM2000 with no particular difficulties. However, the LCM2000 team needs better to understand the exact distinction between 'bogs' where dwarf shrubs may be dominant but where peatland species form 25% of the cover (see Key). The LCM2000 team will liaise closely with the field survey leaders to ensure a common understanding of the class. (As early reconnaissance surveys concentrate on lowlands, there is time to develop this understanding by the August deadline when the classification is to be finalised).
11. Fen, marsh and swamp	This Habitat includes fen, fen meadows, rush pasture, swamp, flushes and springs. It was mapped in 1990 as *Marsh / Rough grass*. As such it included dry rough grasslands. Contextual analyses in GIS might help identify and measure this Habitat. Examples of the Habitat are rare, seldom extensive enough to map as pixels, let alone polygons and records for Britain re likely to be localised (e.g. the Broads).
12. Bog	The 1990 classification identified *Lowland* and *Upland Bogs*. However, it did not include wet ericaceous dwarf shrub heaths (see above). It needs to be clarified what is required in CS2000: distinction of wet heaths from dry might still prove difficult, though GIS context (slope, drainage, aspect) might help. (See notes above re. 10. dwarf shrub heath)
13. Standing open-water and canals	This matches the *Inland water* class of 1990. There will be few if any canals which can be mapped at satellite image scales - they effectively form linear features.
14. Rivers and streams	Only the widest of rivers (>50 m) would be shown accurately, though such information might be drawn from other maps. They will not be distinguished from13. Standing water, except perhaps contextually (e.g. through use of digital maps of rivers).

15. Montane habitats	The LCM1990 did not distinguish this class: however, their clearly identifiable context and the presence of vegetation cover at a sparse level (to distinguish zones from 26. Inland Rock, should be possible to add this class in LCM2000.
16. Supra-littoral rock	LCM1990 identified *Beach and coastal bare ground* but did not subdivide the category. First we would need to define a high water mark to distinguish supra-littoral zones: this was in effect done for major features (e.g. Dungeness, Culbin sands) in 1990. Distinction between rock and sediment might be spectral but would more likely require contextual (e.g. geological) data though the extent of rocks would usually be too small for accurate satellite mapping. realistically 16. and 17. will probably be aggregated into a single class.
17. Supra-littoral sediment	
18. Littoral rock	These classes are the converse of the above, i.e. those below the high water mark. They are generally much more extensive that supra-littoral sediments and thus much more readily mappable from satellite images. The same difficulties surround distinction between rock and sediment and it is again likely that 18. and 19. will be aggregated.
19. Littoral sediment	
20. Inshore rock	Classes 20. to 24. are irrelevant in the context of a land cover map
21. Inshore sediment	
22. Offshore rock shelf	
23. Offshore shelf sediment	
24. Continental slope	
25. Oceanic seas	This is equivalent to the sea and estuary class of 1990 and would be matched in LCM2000: distinction between estuarine, inshore and oceanic waters, if needed, should be made contextually by end-users.
26. Inland rock	The LCM1990 identified *Inland bare ground* which would match this Broad Habitat.
27. Built up areas and gardens	This Habitat is a combination of *Suburban / rural development* and *Continuous urban* categories of 1990, though LCM2000 would identify much more of the heterogeneity, e.g. the vegetation cover in parks and larger gardens, bare urban ground and the tillage of allotments.

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