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CORINE Land Cover 2000: semi-automated updating of CORINE Land Cover in the UK

Phase II: *Map Production in the UK*

Final Report

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Executive Summary

The CORINE land cover (CLC) project provides a pan-European inventory of biophysical land cover, using 44 classes and a minimum mappable unit of 25 ha at 1:100 000 scale. CLC is a key database for integrated environmental assessment and support for EC policy.

CLC1990 was produced for the UK in two physio-geographic units, the island of Ireland and Great Britain (GB), using different methodologies. The CLC1990 for GB was created by generalising the national land cover map. CLC2000 was be produced for the UK and Ireland, within national boundaries, but again using different methodologies.

The standard method for CLC2000 production is based on a change only update of the corrected CLC1990 via computer assisted on-screen photo-interpretation of satellite images. The UK approach to CLC2000 production combined semi-automated generalisation of the Land Cover Map 2000 (LCM2000) and a back dating exercise to identify change similar to the one proposed in the standard methodology.

Key issues for the UK CLC2000 were maintaining a link to the LCM2000, accommodating the necessary changes to nomenclature and consistently applying the more subjective classes within the CLC nomenclature.

The CLC2000 data for the UK consisted of approximately 54000 objects with the two dominant classes representing the agricultural landscape. The next most extensive groups were the semi-natural moors, heaths and grasslands.

The CLC2000 changes represented 1.54% of UK land area, with the main changes involves forest with a net gain of over 175 000 ha and transitional woodland with a net loss of nearly 60 000 ha. Urban has experienced a substantial net gain and the only other net gain is for water which represents the creation of reservoirs in arable landscapes. The remaining class groups all show net losses, some of which are significant. There are two main types of flow between different CLC classes; associated with urbanisation and rotation within plantation forest.

The LCM2000, from which CLC2000 was produced, was part of a larger environmental assessment known as Countryside Survey (CS). CS also include a sample field survey (FS) of 569 1 km squares where field surveyors recorded the land covers that were present which could be converted into proportions per 1 km square and compared to CLC2000. Direct correspondence between the two data sets gave an estimated accuracy of just below 80 %, but this rises to over 90 % when partial correspondences and generalisation effects are taken into consideration.

The report outlines the issues identified and addressed by CEH in the development of the methodology and its use in production. The impacts and solutions were discussed with respect to the standard CLC approach and the UK semi-automated update methodology.

1. Introduction

This report represents the final report of the UK CLC2000 Production, Phase 2: Map Production in the UK. It follows on from the Interim and Final Reports (Smith *et al.*, 2002 and Smith *et al.*, 2003) of the UK CLC2000 Production, Phase 1: Operationalisation of GIS tools and Map Production in UK Test Sites.

This report includes:

- a review of the background to CLC in the UK
- a description of the methods of production applied in the UK
- a review of the meetings in the UK with the CLC Technical Team for training and validation
- a description of the final CLC2000 production in comparison to the UK national product, Land Cover Map 2000 and a detailed field survey
- a review of the change data set
- and a summary of the lessons learnt and future recommendations from this work.

1.1. CORINE Land Cover

The Coordination of Information on the Environment (CORINE) Programme was proposed in 1985 by the European Commission (EC) and aimed at gathering information relating to the environment on certain priority topics for the European Union (Land cover, Coastal Erosion, Biotopes, etc). The land cover component of the CORINE programme intends to provide consistent localized geographical information on the land cover of the Member States of the EC. The CORINE land cover (CLC) project is overseen by the European Environment Agency (EEA) and the European Topic Centres (ETC). The CLC database provides a pan-European inventory of biophysical land cover, using 44 classes at level-3 in the nomenclature (see Appendix A). The vector databases have a minimum mappable unit of 25 ha and a single class attribute per land parcel. At the European level, the database is made available on a 250 m by 250 m grid which has been aggregated from the original vector data at 1:100 000 scale. CLC is a key database for integrated environmental assessment and an important support for EC policy.

1.2. UK and Ireland involvement in 1990

The CORINE Land Cover 1990 (CLC1990) was produced for the UK in two physio-geographic units. The CLC1990 for Great Britain (England, Scotland and Wales) was derived by semi-automated generalisation of the more detailed 1990 Land Cover Map of Great Britain (LCMGB). The majority of the data for LCMGB came from 1988 through 1990 and the conversion to CLC format was completed in 1998 (Brown *et al.,* 1999). The CLC1990 for the Republic of Ireland and Northern Ireland was undertaken on an all island basis using the standard CLC methodology and was completed in 1993 using data from 1989 and 1990 (O'Sullivan, 1994).

1.3. Development of the UK approach

The approach proposed by EEA / ETC-TE for producing CLC2000 was to update the existing CLC1990 rather than create a new data set from scratch. The updating would be driven by new image data recorded in 2000. To facilitate the updating, the Joint Research Centre (JRC) in its role within the ETC – Land Cover (now replaced by ETC – Terrestrial (ETC-TE)), prepared a technical and methodological guide to the updating process (Perdigao and Annoni, 1997).

Between 1998 and 2001, the Centre for Ecology and Hydrology (CEH) has produced the Land Cover Map 2000 (LCM2000), an updated and upgraded land cover product to replace LCMGB. LCM2000 extends further spatially than LCMGB covering the whole UK including Northern Ireland. It was intended to again use the national land cover product for generalising to CLC format, but extended to the full UK.

This report describes the background to this project, the standard and UK approaches to updating, the final CLC2000 for the UK and some preliminary analysis of results.

1.4. Creation of CLC1990

For the production of CLC1990, the standard method for land cover data collection was based on a hardcopy inventory from the manual interpretation of satellite image printouts. This proved to be the most feasible approach in the mid 1980s, the starting period of the CLC Programme. CLC1990 used images collected by the Landsat Thematic Mapper (TM) with a spatial resolution of approximately 25 m. Only limited use was made of image processing and GIS software to geo-register the images and produce a colour composite useful for visual interpretation. Interpretation of CLC classes was recorded on transparencies overlaid on 1:100 000 hardcopy prints of satellite images. Ancillary data were essential to help identify and confirm the identification of certain land cover / use features on the images. The outlines marked on the transparencies were then digitized to create the final data set. This procedure proved its merits and is still valuable, but inevitably introduced errors during interpretation and digitisation, and required two intermediate hardcopy products (transparencies and satellite images) before obtaining digital results.

1.5. Update of CLC1990 to CLC2000

Technical developments have, however, made it possible to introduce computer technologies throughout the process of building the CLC inventory (a softcopy rather than a hardcopy approach). Moreover, it is more convenient to have data sets on screen, enabling more efficient performance rates, and hence reduced costs. The standard methodology for the update of CLC1990 to CLC2000 is therefore based on computer assisted photo-interpretation of satellite images.

The input data to perform the update to CLC2000, as with the creation of CLC1990, is imagery collected by the Landsat satellite. As the production of CLC2000 would be undertaken by the individual member states a single project was created to purchase and pre-process images required for the whole of Europe. The Landsat Enhanced Thematic Mapper (ETM+), a replacement for TM, was the instrument of choice. The Image 2000 (I2000) project aimed to improve the temporal consistency of the data used

for the update, provide the data as an orthorectified product that could be used for other applications and reduce the costs of data supply through centralized data purchasing and processing.

The methodology for producing CLC2000 with I2000 consists of two phases; the correction of errors in CLC1990 and the identification of changes between 1990 and 2000. Firstly, the CLC1990 data is examined to identify and correct errors due to; materials, integration, interpretation, digitization and transformation, and thus produce a revised version of the CLC1990.

The revised CLC1990 is compared with I2000 data to identify areas of change, updating the CLC1990 data both spatially and thematically while still conforming to the CLC specifications. The update involved checking for the following; objects which had changed class, objects that had disappeared, objects that had grown or shrunk by at least 5 ha, objects which had shrunk below the 25 ha minimum mappable unit (MMU) and the appearance of new objects of greater than 25 ha. Any spatial changes would require a re-validation of the surrounding objects to make sure that the whole data set would still comply with the CLC specification of 25 ha MMU and 100 m minimum feature width.

2. UK semi-automated update of CLC1990

2.1. Land Cover Map of Great Britain

As a component of the Countryside Survey 1990 in Great Britain, a land cover map was produced to a specification suitable for national applications. The LCMGB (Fuller *et al.*, 1994) was created by semi-automated supervised classification of combinations of summer and winter Landsat TM images and the application of some simple knowledge-based correction (KBC) rules. The LCMGB was a raster map with a pixel size of 25 m (MMU was set to 0.125 ha, 2 pixels) and reported 25 land cover classes. The LCMGB was far more detailed spatially than a CLC product and the classes mapped were more closely related to land cover in the UK than the mix of land cover and land use for Europe within the CLC specification.

2.2. The conversion of LCMGB to CLC1990

In Great Britain, rather than apply the standard CLC1990 production approach, semi-automated procedures were used to convert the raster-based, LCMGB into CLC format for 1990 (Brown *et al.*, 1996). The procedures involved spatial generalisation, automated construction of CLC mosaic classes, visual interpretation of land uses (Brown *et al.*, 2002), and raster-to-vector conversion of the result. For the CLC1990 map the following main processes were used:

- Removal of very small land parcels < 2 ha;
- Use of 'exogenous' data and expert interpretation to identify CLC land use classes;
- Extraction of 25 ha parcels with direct CLC equivalence;
- Clustering of smaller land parcels;
- Analysis and classification of mosaic land parcels;
- Assignment of remaining small land parcels to the most appropriate neighbouring class;
- Overlay onto the satellite images to check outputs;
- Smoothing of land parcel boundaries.

The procedures developed to produce the CLC1990 map were compared and assessed against the standard CLC Technical Manual (Directorate-General Environment, 1993). The semi-automated generalisation procedure achieved the desired output, and the final CORINE Land Cover Map of GB (CLC1990) conformed to CORINE requirements, matching the map specifications required for CORINE land cover mapping across Europe. CEH has distributed many copies of the CLC1990 for GB at level-3 to environmental organisations, universities, local authorities and commercial users etc.

2.3. Land Cover Map 2000

Within Countryside Survey 2000 (CS2000: Haines-Young *et al.*, 2000), the parcel-based LCM2000 (Fuller *et al.*, 2002) recorded the land cover of the United Kingdom in the form of vector land parcels. It updated but also upgraded the pixel-based LCMGB, with an altered classification scheme, an enhanced spatial structure and a refined methodology. LCM2000 was again based on a combination of summer and winter satellite images,

taking the same spectral bands from each date. LCM2000 identified 16 target classes, these were subdivided into 27 subclasses. The target classes and subclasses were aggregated to give the widespread Broad Habitats (Jackson, 2000) demanded by users. Subclasses were in turn divided giving 72 class variants; these were only identified where image dates and quality allowed it. LCM2000 aimed to map target classes with an accuracy of approximately 90 %, which was assessed by correspondence with the results of the field survey component of CS2000.

To produce a parcel-based land cover map, image segmentation was used to identify 'uniform' areas, which represented a single land cover type. The segmentation procedure consisted of two stages: i. edge-detection to identify boundary features, and ii. region growing from seed points. Spatial generalisations were applied to remove small segments of less than 9 pixels (approximately 0.5 ha) and spectrally similar segments. The resulting segments were vectorised to form the land parcels for subsequent analysis.

Classification used sample ground reference ('training') data in the same way as that used in conventional per-pixel classification (Lillesand and Kiefer, 1999), but attached to land parcels delineated objectively by the segmentation process. The parcel-based approach used a shrinking procedure when extracting reflectances for land parcels, to avoid edge pixels and to ensure the use of 'pure' core pixels in defining spectral characteristics. The per-parcel classification used a maximum likelihood algorithm based on the spectral character of the training areas to determine class membership in the same way as per-pixel classification, but applied to the mean reflectance statistics of each land parcel. A complex set of KBC procedures was used to identify and re-label land parcels with a high uncertainty, such as those, which were classified with small membership probabilities, and / or those which contained classes out of their natural context. Construction of the full UK map required that all the individual classified areas were mosaiced together, with residual cloud-holes patched using single-date classifications.

2.4. UK CLC update methodology

To produce CLC2000 in the UK, the national land cover product, LCM2000, was used as the starting point to perform a semi-automated conversion to the CLC specification. The approach applied to CLC2000 combined both the generalisations used in the 1990 conversion of LCMGB to CLC1990 and the change only update proposed in the standard methodology. The CLC1990 data to be used for CLC2000 UK came from two different sources; CLC1990 Ireland produced in the standard fashion and CLC1990 GB produced by semi-automated generalisation of LCMGB

After the first verification visit the CLC training team recommended that the UK adopted a change only update and not produce a corrected 1990 dataset. CEH agreed to adopt this approach, although the 1990 update had been partly produced. These updated 1990 data were later used in construction and editing stages, as an additional reference data.

The 1990 analysis that had been completed included:

- A random check of geometric accuracy of CLC 1990 polygons against British National Grid and Image2000.
- Checks for consistency with the CLC 25 ha minimum mappable unit and 100 m minimum width specification.
- Checks and corrections of 'land use' parcels, orchards, inland marsh, and smaller urban areas (small towns).
- Checks for illegal class codes (especially in the N Ireland dataset)

Subsequently the main steps in producing CLC2000 for the UK were:

- Extraction of the urban land use classes from CLC1990, Level-1 class 1
- Generalisation of the LCM2000 data into CLC classes
- Combination of generalised LCM2000 with the land use data
- Checking with Image 2000 for geometric error, etc.
- Detailed interactive edit of UK tiles (areas *c*. 100 x 100 km but sometimes smaller), using Image2000
- Edge match between tiles and quality checking
- Final quality checking, editing, and delivery.
- Interactive creation of Changes database using CLC2000 and the 1990 and 2000 imagery.

2.4.1. Extraction of the urban land use classes from CLC1990

To produce the initial 'pseudo CLC2000', the first stage was to create a set of land use parcels which were not specifically mapped in LCM2000. These 'land use' parcels were extracted from the corrected CLC1990 and stored as a new dataset. With the help of the I2000 images and ancillary data, the land use parcel data set was checked and updated with changes greater than 5 ha and new parcels greater than 25 ha added.

2.4.2. Generalisation of the LCM2000 data

The LCM2000 land parcels were then recoded to CLC class equivalents. The type of recoding and the issues involved fell into three groups depending on equivalence (Table 1). First, those classes with direct equivalence (e.g. deciduous woodland) are recoded easily (see Figure 1). Secondly, those classes with partial equivalence such as neutral, calcareous and acid grassland. Some coastal classes use a rule base (see Figure 2). Finally, those classes with no real equivalence, (e.g. 'montane habitats') required the subsequent application of more complex rules or manual intervention. The updated land use parcels data are then superimposed on the recoded LCM2000 data to create the initial pseudo CLC2000 data.

Table 1: Look up table between LCM2000 and CLC level-3 classes for the updating of CLC1990 including an indication of how the classes were recoded.

LCM2000 class		***CORINE 2000 class***		
Code	**Name**	**Code**	**Name**	**Equivalence**
11	Broad leafed woodland	311	Broad leaved forest	Direct
21	Coniferous woodland	312	Coniferous forest	Direct
41-43	Arable and horticulture	211	Non-irrigated arable land	Direct
51	Improved grassland	231	Pastures	Direct
52	Set-a-side grassland	231	Pastures	Direct
61	Neutral grassland	231	Pastures	Partial
71	Calcareous grassland	231	Pastures	Partial
81	Acid grassland	321	Natural grassland	Partial
91	Bracken	322	Moors and heathland	Direct
101	Dense dwarf shrub heath	322	Moors and heathland	Direct
102	Open dwarf shrub heath	322	Moors and heathland	Direct
111	Fen, marsh and swamp	411	Inland marshes	Direct
121	Bog	412	Peat bogs	Direct
131	Water (inland)	511 512	Stream course Water bodies	Partial
151	Montane habitats	322 332 333	Moors and heathland Bare rocks Sparsely vegetated areas	Intervention
161	Inland bare ground	332 131	Bare rocks Mineral extraction site	Partial Intervention
171	Suburban/rural development	112	Discontinuous urban fabric	Direct
172	Continuous urban	111 121 122 124	Continuous urban fabric Industrial or commercial Road / rail networks Airports	Intervention
181	Supra-littoral rock	331 332	Beaches, dunes and sand Bare rocks	Interactive
191	Supra-littoral sediment	331	Beaches, dunes and sand	Direct
201	Littoral rock	331 332	Beaches, dunes and sand Bare rocks	Interactive
211	Littoral sediment	331 423	Beaches, dunes and sand Intertidal flats	Partial
212	Saltmarsh	421	Salt marshes	Direct
221	Sea / estuary	521 522 523	Coastal Lagoons Estuaries Sea and ocean	Partial, intervention

Figure 1: Recoding of LCM2000 to direct equivalences.

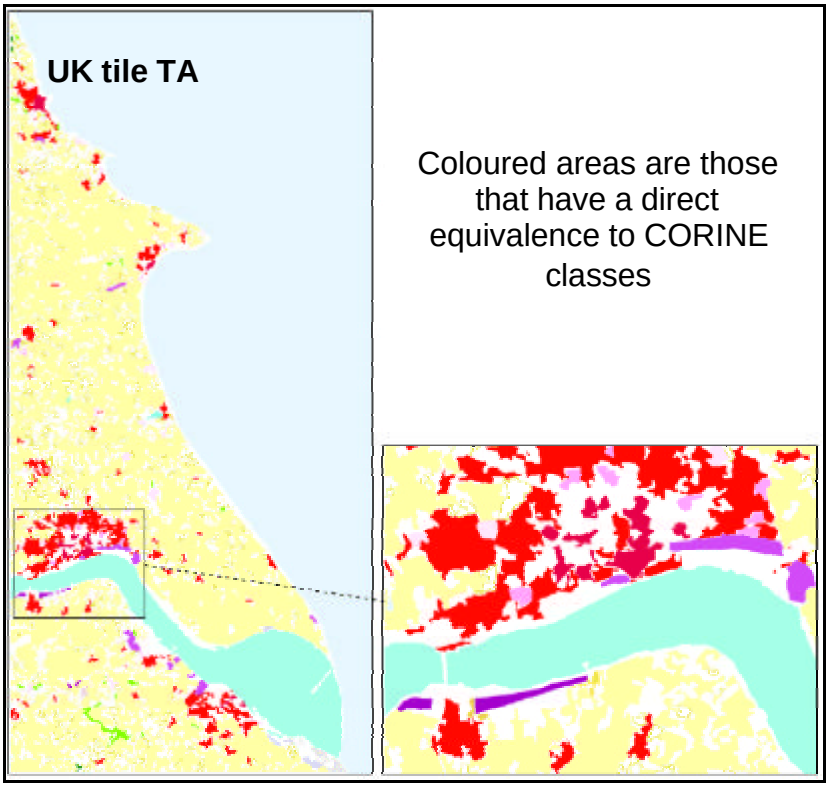
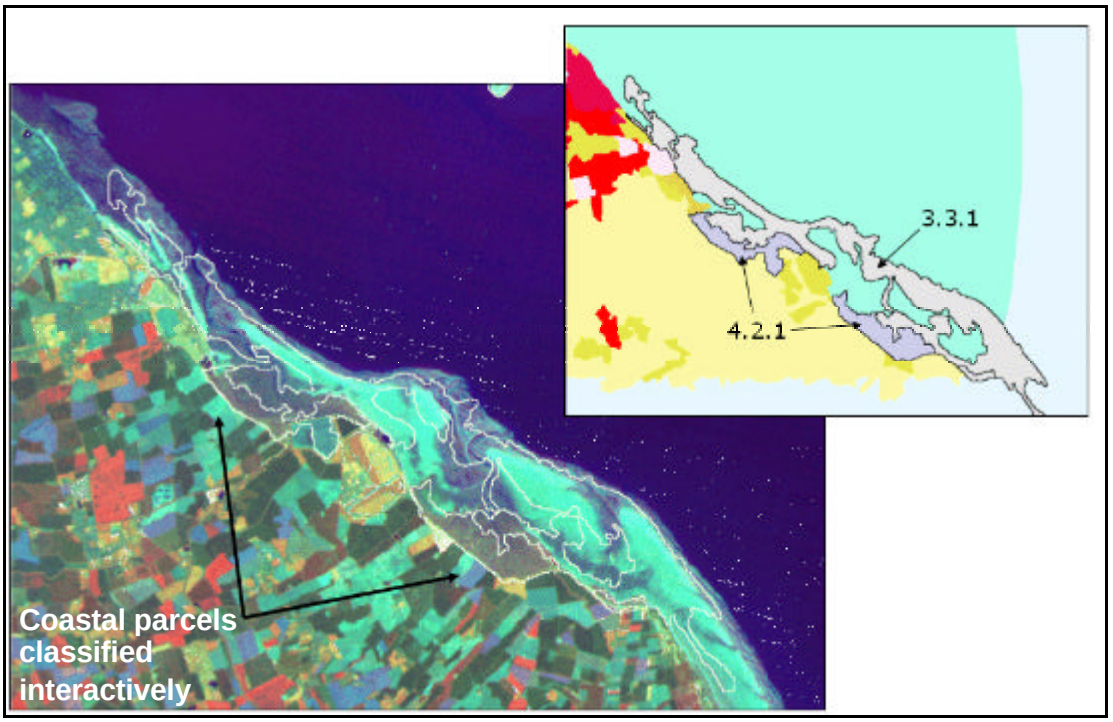


Figure 2: Recoding of some coastal parcels.



In the conversion of LCMGB to CLC1990, a growing and shrinking process was used to deal with small isolated clusters of pixels. A semi-automated re-classification of clusters of small parcels, 'mosaics' was also used. When converting LCM2000 to CLC2000 it became apparent that these procedures were no longer appropriate, due to the fundamentally different spatial structure of LCM2000 compared to that of LCMGB. LCM2000 is a parcel based product with a MMU of 0.5 ha and thus had no small isolated clusters, whereas LCMGB was raster based with a MMU of only 0.125 ha. So, initially, small parcels, generally less than about 2 ha, were dissolved into adjoining parcels.

At this early stage there were still many parcels less than 25ha in size. After some investigation it was decided that the most thorough way to allocate these parcels to a CORINE class was to deal with them largely in an interactive way. This involved the dissolving away of some boundaries and allocating a new class label to the area that matched the land cover seen in the I2000 data, which was displayed beneath the parcels. When doing this the interpreters followed closely the guidance given in the CORINE technical documentation (Perdigao & Annoni,1997).

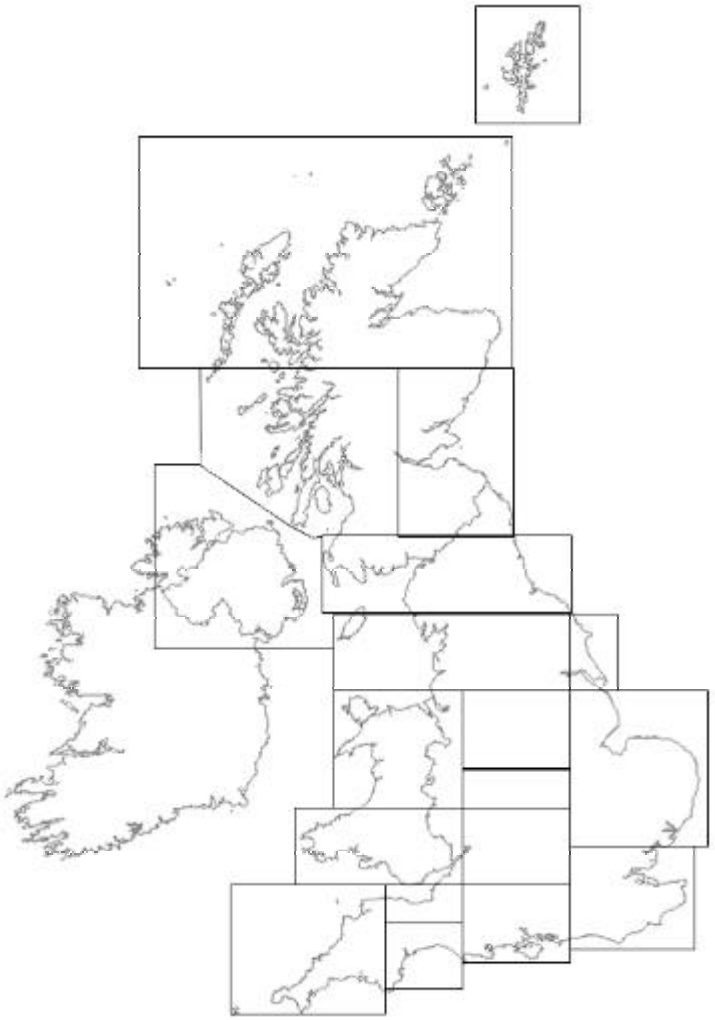
2.4.3. Geometric check of Image 2000

It was known that that were some areas where there appeared to be a systematic shift of some of the parcel boundaries in LCM2000. These had been identified in parts of Scotland, and in a few cases exceeded the CORINE accuracy limitations. These locations were noted and would be dealt with during the interactive editing stage of the individual UK tiles. A later stage of CLC verification also found this type of error, which appeared to be related mainly to steep slopes. These errors were believed to have been caused by an omission during the LCM2000 pre-processing of Landsat imagery. In some instances cloud 'holes' were patched with alternative date imagery which may not have been correctly adjusted for height distortion, thus causing a shift of some boundaries. These geometric shifts have been corrected in the final CLC2000 data.

2.4.4. Detailed interactive edit of UK Tiles, using Image2000

The dataset resulting from the above stages was then ready for the detailed interactive editing. The UK was initially divided up into a series of rectangular tiles which would be the basis of processing. The work began in Northern Scotland and moved southwards. Some problems were caused by the large size of some tiles and subsequently smaller areas were selected. Eventually, 19 tiles covered the UK (Figure 3).

Figure 3: Working Tiles for the UK.



The interactive stage was generally done at a visual scale of about 1:50000. Where necessary, the interpreters used a larger scale to confirm boundary details etc.

The editing included the following:

- Merging of small parcels into their neighbours, with adjustment of boundary.
- Re-coding to heterogeneous CORINE codes 242 and 243 where appropriate.
- Re-shaping of parcel boundaries.
- Add missing land use from ancillary datasets for 2000.
- Add continuous urban fabric (111) parcels. Initially all urban coded to 112.
- Add additional industrial areas (121)
- Adjustment of woodland codes between 311, 312 and 313.
- Removal of some isolated pasture in arable landscapes.
- Recode of some natural grass parcels to pasture in arable landscape.
- Recode of some parcels within forests to 'clear cut' (transitional woodland – 324).
- Recode of LCM2000 montane class to suitable CORINE class based on I2000.
- Recode bare parcels to mineral extraction or dumps, referring to ancillary data.
- Reshape and/or recode of linear parcels falling below the minimum width rules.

Where areas contained complex mixtures of classes the CORINE guidelines for their classification were followed.

Various other checks and adjustments were carried out. For instance, at the coastline of the UK the source data included much information about littoral classes. These were based on images where tides may have been at different levels. Where possible the coastal parcels were edited to represent a single state of the tide.

All the editing of the CLC data was done using ArcView software, using multiple overlays of parcel boundaries, attribute information, Image2000 and other ancillary data where necessary.

2.4.5. Checking and independent quality control

On completion of the above stages, the tiles were checked by a second interpreter involved in the production of CLC2000. This check exploited the experience of the CLC2000 interpreters and removed the majority of problems.

A final quality check was undertaken by a third member of the team working in the role of an end user and using the I2000 as a reference data set. As well as identifying errors, the final quality check also flagged areas where the recorded land cover information was not immediately obvious from the I2000 data. The original interpreter then double checked these areas and in this way the experience and the understanding within the team was developed.

As adjoining tiles were completed they were revisited in order to carry out edge checking and adjustment where necessary. This process was also performed at the boundary between Northern Ireland and the Republic of Ireland, the only international land border of the UK.

2.4.6. Creation of the changes database

Land cover change within each UK working tile was identified after the creation of the main land cover data itself had been completed. The results within the Changes database are discussed in more detail below. Using the CLC recommendations on display scales etc, two types of difference, 'locational' and 'thematic' were identified. These were not mutually exclusive, but in most cases a thematic difference would be directly associated with a locational difference. If only a thematic difference was identified then a decision was required on what change had occurred. Checks on the source information (imagery or ancillary data) that was originally used to create the land parcel were made if necessary. This was an interactive task. To ensure consistency between datasets the boundaries of the change parcels produced, where possible, were the boundary data from the main CLC2000 dataset. In some cases a change parcel would necessarily involve the creation of a new boundary, not present on the main data. All change parcels were size checked to ensure they met CORINE requirements. A modified list of 'possible land cover changes' was developed based on advice given to us by the CLC training team and specific UK contexts. This list includes some changes (often quite rare) which do occur in the UK landscape, but which may otherwise be unexpected. For instance reversion to heath and moor from conifer woodland does happen in the UK and change from heath and moor to natural grassland occurs (often after burning), and these have been infrequently included in the UK changes data.

2.5. UK Consistency

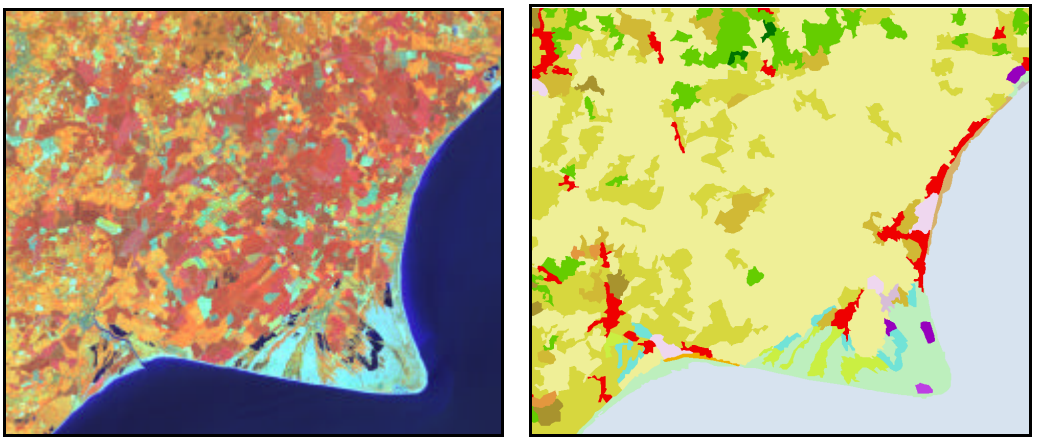
During all the above procedures the aim was to ensure consistency in interpretation across the UK landscape. This was a key task during checking and quality control. At various times during the construction of CLC2000 for the UK additional advice from the CLC verification teams was requested and received. Tiles already completed were verified based on the new advice so that it was applied consistently. For instance, at one point, the UK interpretation had not effectively captured heavily vegetated valleys. These locations were revisited on all tiles to increase the amount of classes such as woodland and 243 where appropriate. During a verification visit the Technical Team advised that, on some tiles, the 242 (complex cultivation) class was over used. This was probably the result of earlier advice given to increase the use of class 242 in a specific area. Again all tiles with similar landscape types were revisited and areas of 242 were recoded to 231 (pasture) or 211 (arable) where appropriate.

2.6. Retaining the link between CLC2000 and LCM2000

In the UK there was a strong need to retain the link between the LCM2000 database and the CLC2000 database. For the most part this has been achieved, however, some interpretation that 'strains this link' was necessary.

For instance, the Technical Team requested the removal of most isolated patches of small semi-natural grasslands in otherwise arable dominated landscapes. This is a feature of the UK arable landscape, sometimes known as 'lush pastures'. In many cases these areas were recoded to arable, however, where such areas are of a significant size, and there was ancillary information in support, they were retained (Figure 4).

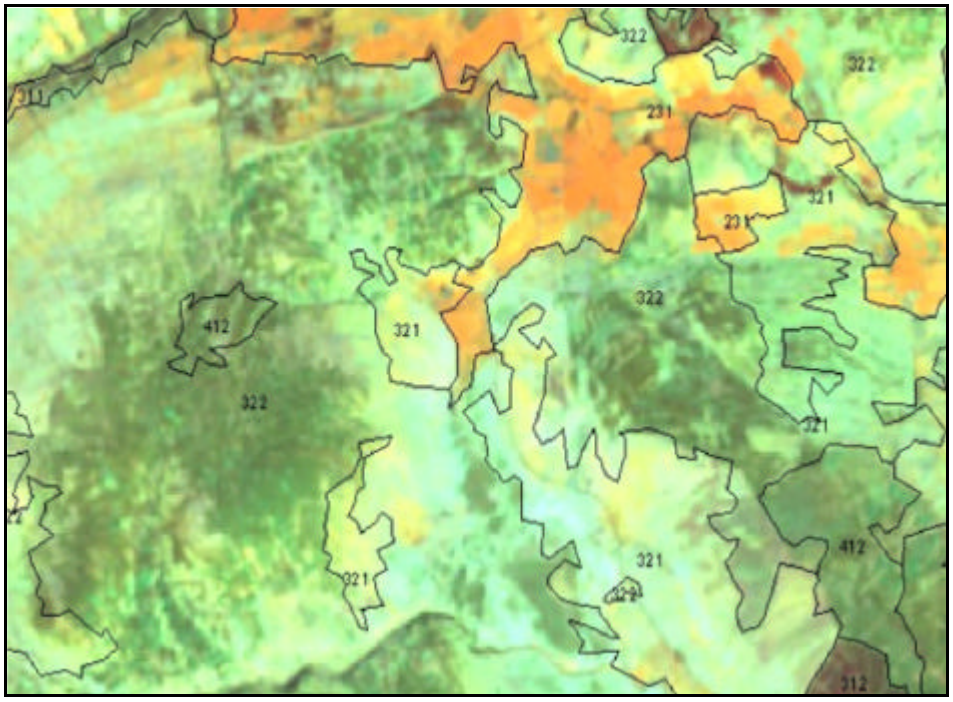
Figure 4: Patches of pasture in an arable landscape near Romney Marsh



Problems were encountered in the uplands related mainly to the definition of boundaries between natural grass (321), peat bogs (412) and moors and heath (322). Single date Landsat imagery does not accurately depict the boundaries between these classes. LCM2000 data was created using composite summer and winter imagery which more strongly reflects the true boundaries between these seasonally distinct habitats. In these instances the LCM2000 boundaries have generally been retained, and not followed

'apparent visual boundaries' seen on the I2000 single date images (Figure 5). These boundaries were verified using ancillary data such as peat masks provided by the British Geological Survey.

Figure 5: 'Boundaries' in an upland area of the UK.



It is recognised that the LCM2000 database is not error free. At its full level of detail LCM2000 provides additional qualifying information about all parcel classifications. Where CORINE interpreters identified apparent misclassifications in CLC2000, when viewing the data over the I2000 imagery, the additional information was examined to confirm or otherwise the correct class for the parcel in question.

3. A review of the meetings in the UK with the CLC Technical Team

3.1. Report of the CLC2000 Technical Team Training Mission

The following notes were prepared during the CLC2000 Technical Team Training Mission to the UK in December 2002 and provide an outline of the material presented and the matters discussed. This report of the mission supports and compliments Christensen and Feranec (2003). The Technical Team was represented by Susan Christensen and Jan Feranec. CEH Monks Wood which holds the responsibility for CLC2000 production in the UK and the production team were Geoff Smith (project manager), Nigel Brown (technical developer and interpreter) and Andy Thomson (interpreter).

The Technical Team outlined the aims of the CLC2000 project and its products, including the necessity for revising CLC1990 national maps (product optional) and the provision of national metadata for each country and each working unit. Theoretical background and practical examples of the methodology were provided. Criteria for change must follow the rules of minimum 5 ha area or 100 m width. Examples were given of how to deal with odd small parts of polygons. The usefulness of priority tables was emphasised. The procedures for checking the quality of results during and after completion of CLC2000 was also described.

CEH provided the background to national and European level land cover mapping in the UK including: the production of LCMGB, the conversion of LCMGB to CLC1990, the production of LCM2000 and the general overview of UK approach for CLC2000. A demonstration was provided which illustrated a number of issues that had arisen during the operationalisation phase of CLC2000 in the UK. An exercise covering a cross border area between Northern Ireland and the Republic of Ireland was described. The plans for production of CLC2000 in the UK were discussed and approved.

3.2. Report of the CLC2000 Technical Team 1st Verification Mission

The first Verification Mission by the CLC2000 Technical took place in June 2003 and was performed by Jan Feranec and George Büttner. The verification followed the standard procedure with about 30 % of the UK CLC2000 available for checking by 50 verification units.

The TT concluded that the CLC2000-UK databases do not meet expectations. The CLC2000 database includes inconsistent application of certain land cover classes, geometrical boundary shifts exceeding the acceptance threshold (100 meters) and wrong delineations (probable because of the improper generalisation of the high resolution national database, see Figure 1 and Figure 2). The CLC-change database includes several non-real changes, and also omitted changes – because of omissions either in CLC2000 or in CLC1990.

Recommendations concerning continuation of CLC2000 in the UK were provided by the TT. It was agreed between the TT and CEH to study the detailed remarks related to CLC2000, redesign some elements of the “translation” table that converts national land

cover classes into European CLC2000, improve the generalisation methodology to avoid false boundaries and enhance the handling of mosaics. Specific issues were to be addressed that related to maintaining the water boundaries, improve separation of peatland (412) and moors and heathland (322).

The three rejected working units were reprocessed and the amount of on-screen quality control using satellite imagery was significantly increased. CEH responded to the report of the verification mission providing CEH experience on UK context and the problems of mapping certain habitats from single data imagery.

3.3. Report of the CLC2000 Technical Team 2nd Verification Mission

The second Verification Mission by the CLC2000 Technical took place in July 2004 and was performed by Gabriel Jaffrain and László Mari. The verification followed the standard procedure with about 35 % of the UK CLC2000 available for checking by 73 verification units. The small increase in completed area was related to the need to pre-process the area completed at the previous verification mission. About half of the verification units were repeats of the previous verification mission.

The TT concluded that the UK CLC2000 databases should be improved, especially the CLC change database. The CLC2000 database includes inconsistent application of certain land cover classes and geometrical boundary shifts (only in North Scotland) exceeding the acceptance threshold (100 meters). Several polygons were found with the same code as their neighbour in both databases and others were found just below the 25 ha limit, and below the 5 ha limit for changes.

The distinction of CLC classes 321, 322 and 324 was problematic and needed improvement, possibly with the use of botanical information or field checking. Also, the distinction of classes 412, 321, 322 and 333 was not always evident in the Landsat TM images of I2000, and there was therefore a need for other information. The delineation of the CLC classes 231, 211, and 243 could have been improved and the class 243 was overestimated in some cases. Some villages (112) with areas larger than 25 ha were missing, and the class 243 was missing along some thalwegs. Delineation of some broadleaved forest (311) needed to be improved and in some cases 311 areas were overestimated.

The CLC-change database included several non-real changes, and also omitted changes, because of omissions either in CLC2000 or in CLC1990. There were several non-real changes, which were just differences of the two interpretations, but not real evolutions (312-322, 321-231, 322-324, 312-243, 231-243 etc). There were some unrealistic changes in the database as well, most of these could be excluded by logical means, e.g. 312-321, 312-231, 211-311, 211-313. All clear cuts should have been classified as 31x to 324, some of these changes were missing.

The results of the verification were discussed in details with experts of the National Team. Examples of several crucial mistakes in CLC2000 were demonstrated on screen using comments retrieved from InterCheck recordings. False changes and omitted changes were also demonstrated. It was recommended that the detailed remarks of the TT should be considered. The results must be quality controlled on screen using satellite imagery. False changes must be avoided by visually controlling all change

polygons. Changes from 312 to 322, was it really the case that coniferous forest has changed into heathland (e.g. regeneration after clear cutting or natural disaster)? 321-231, was it really the case that that the human impact of the grass has increased?

CEH implemented the recommendations of the TT and included an extra level of visual quality checking of the CLC2000 products against I2000 data.

3.4. Report of the CLC2000 Technical Team 3rd Verification Mission

The Third Verification Mission by the CLC2000 Technical took place in November 2004 and was performed by Jan Feranec and László Mari. The verification followed the standard procedure with about 48 % of the UK CLC2000 available for checking by 26 verification units. The small increase in completed area was related to the short amount of time since the previous verification mission. The remaining 52 % was in the production flow line and was thus partially completed and could not be verified.

The TT concluded that the UK CLC2000 databases could be improved. The CLC2000 database still includes inconsistent application of certain land cover classes. The CLC-change database includes several non-real changes, and also omitted changes – because of omissions either in CLC2000 or in CLC1990. Some neighbouring polygons with the same code were found in both databases (CLC2000 and CLC-changes). Some polygons just below the 25 ha limit were found in CLC2000 database, and ones below the 5 ha limit in CLC changes database. Code validity was generally right, one polygon with 0 code was found in CLC2000 database and metadata sheets were filled properly and made available during the verification.

In particular, the delineation of some of the upland classes needed to be improved. The distinction between natural and managed grassland (pasture) was also a concern. The application of mosaic classes and the presence of natural grass in the arable landscape was also seen as a problem. The TT provided contextual guidance on these issues and CEH implemented the necessary changes.

Following the completion of the full area of UK, CEH were advised to send preliminary data for the remaining working units to the CLC2000 TT coordinator for an additional off-site control. Following the correction of N-Ireland data it was sent as final data to GISAT. The rest of the UK was to be sent to GISAT after integrating remarks of the 4th (off-site) verification and the production a seamless database.

3.5. CLC2000 Technical Team 4th Verification

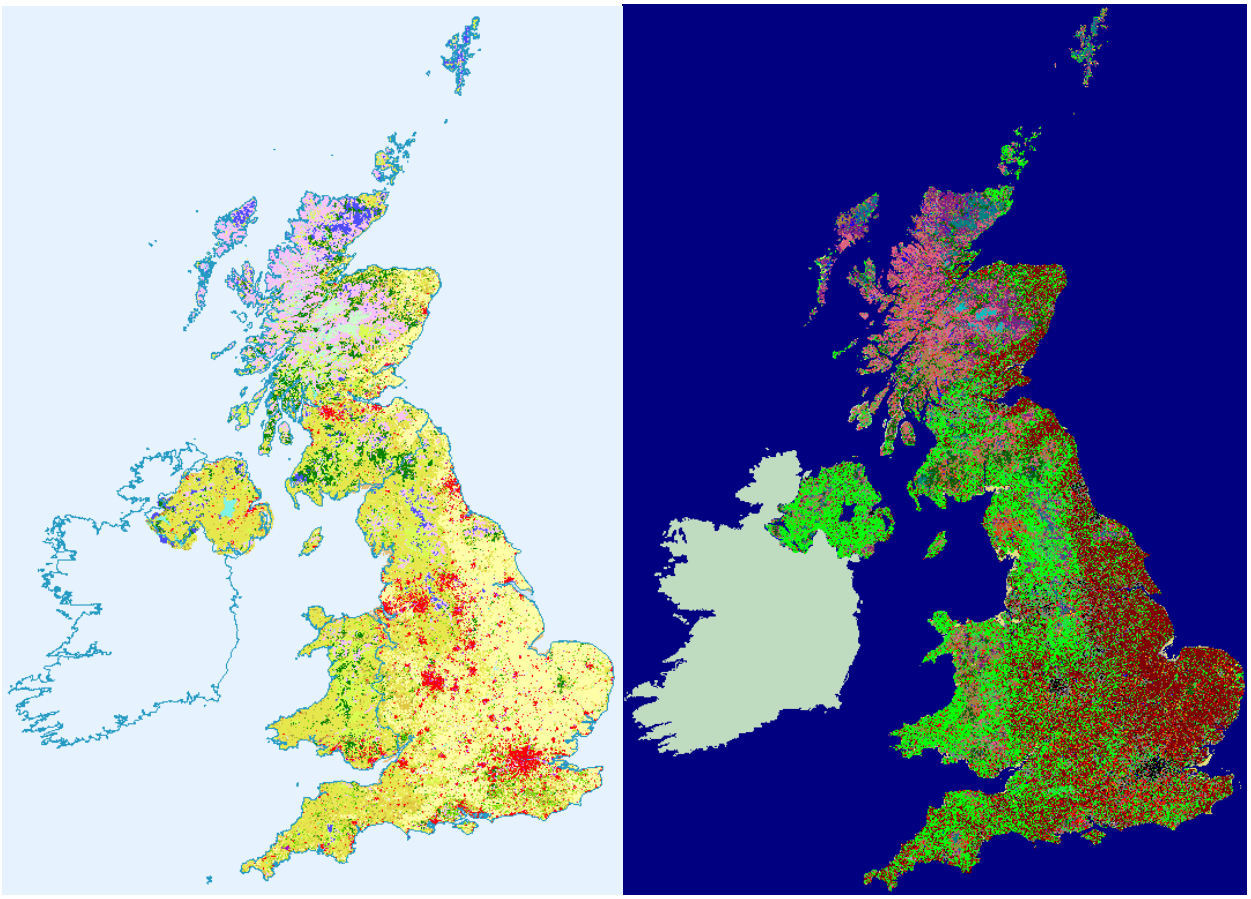
A 4th verification exercise was undertaken by the CLC2000 Technical Team off site and the findings and necessary corrections supplied to CEH. The updated CLC2000 and CLC2000 Changes data sets were then upload for the Technical Team to examine.

4. A description of the final CLC2000 product in comparison to the UK national product, Land Cover Map 2000 and a detailed field survey

This section contains a brief description of the CLC2000 for the UK and a comparison with the UK national product LCM2000.

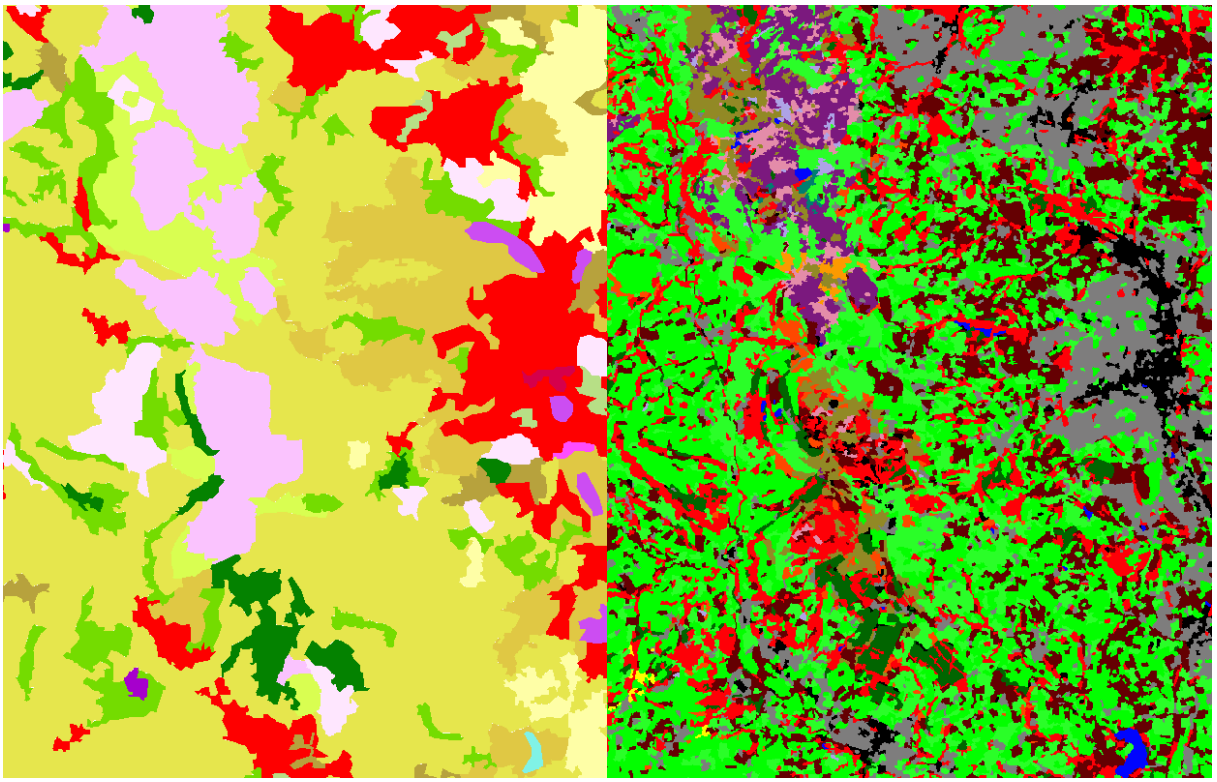
Figure 6 shows the CLC2000 in the left panel. There are three key environmental divisions in the UK: the south eastern area is dominated by arable farming, the western area is dominated by grasslands and livestock farming and the north western extreme is dominated by semi-natural landscapes. The main urban centres are visible in low lying and coastal locations, with coniferous forestry being found in the most part in the uplands of the north and western UK.

Figure 6: CLC2000 (left) and LCM2000 (right)



As expected the LCM2000 shows the same distribution of major landscape types although based on a different nomenclature. At the scale of Figure 6 the additional fine spatial details of LCM2000 can not really be seen, except possibly in the uplands and grasslands where the LCM2000 nomenclature is much more detailed. In Figure 7 the difference in spatial and thematic detail can now be seen more clearly.

Figure 7: Test area showing the more detailed spatial and thematic structure of LCM2000 compared to CLC2000



The major urban features to the east and north east are seen in both datasets. Much of the LCM2000 detail is generalised in CLC2000, for instance in LCM2000 the western pasture area depicts many 'linear valleys', consisting of mixtures of woodland small villages. In CLC2000 only the major ones are retained. The upland moor at the top of the picture are seen as a single pink area in CLC2000, whereas in LCM2000 we see a mosaic of smaller patches of dense moor, open moor and peat bog. Most of this detail falls below the CLC 25ha MMU.

Table 2 shows the comparison of areas reported by CLC2000 and LCM2000 for the CLC2000 level-1 land cover classes. Overall the proportions are very similar. The main difference is seen in CLC2000 level -1 classes 2 and 3. This is probably due to the difference in the level of detail of class descriptions between CLC2000 and LCM2000. When CLC2000 level-1 classes 2 and 3 are added together they are very similar to the two equivalent classes in LCM2000.

Table 2: Comparison of CLC2000 and LCM2000 at level-1.

Class	Description	Area (km^2)		Proportion	
		CLC2000	LCM2000	CLC2000	LCM2000
1.	Urban	18149	16637	7.4	6.7
2.	Agriculture	144249	116703	58.2	47.3
3.	Forest and semi-natural	75442	103696	30.5	42.0
4.	Wetland	7931	6880	2.8	2.8
5.	Water	3249	2771	1.1	1.1

Table 3 lists the proportions of CLC classes for the UK showing the dominance of agricultural land with 'Non-irrigated arable land' (211) and 'Pastures' (231) making up more than 50 % of the area. 'Moors and heaths' (322) have the third highest proportion, although with other semi-natural classes this does make up a further 25 – 30 % of the area.

Table 3: A table of CLC2000 land cover proportions compared to the results of LCM2000 for the UK.

Class	Description	Area (km^2)	Proportion
1.1.1	Continuous urban fabric	287.5	0.1
1.1.2	Discontinuous urban fabric	12210.7	4.9
1.2.1	Industrial or commercial units	1421.2	0.6
1.2.2	Road and rail networks and associated land	79.1	< 0.1
1.2.3	Port areas	132.9	0.1
1.2.4	Airports	452.9	0.2
1.3.1	Mineral extraction sites	544.4	0.2
1.3.2	Dump sites	70.6	< 0.1
1.3.3	Construction sites	49.2	< 0.1
1.4.1	Green urban areas	578.4	0.2
1.4.2	Sport and leisure facilities	2322.2	0.9
2.1.1	Non-irrigated arable land	61607.9	24.7
2.2.2	Fruit trees and berry plantations	176.2	0.1
2.3.1	Pastures	68159.1	27.4
2.4.2	Complex cultivation patterns	8651.3	3.5
2.4.3	Agriculture with natural vegetation	5653.5	2.3
3.1.1	Broad-leaved forest	6574.6	2.6
3.1.2	Coniferous forest	12868.9	5.2
3.1.3	Mixed forest	512.8	0.2
3.2.1	Natural grassland	19872.1	8.0
3.2.2	Moors and heathland	29236.4	11.7
3.2.4	Transitional woodland-scrub	1933.6	0.8
3.3.1	Beaches, dunes, sands	297.2	0.1
3.3.2	Bare rocks	657.9	0.3
3.3.3	Sparsely vegetated areas	3488.6	1.4
4.1.1	Inland marshes	151.5	0.1
4.1.2	Peat bogs	5325.2	2.1
4.2.1	Salt marshes	417.2	0.2
4.2.3	Intertidal flats	2037.3	0.8
5.1.1	Water courses	53.0	< 0.1
5.1.2	Water bodies	2205.8	0.9
5.2.1	Coastal lagoons	7.3	< 0.1
5.2.2	Estuaries	982.7	0.4

For a more technical comparison, Table 4 shows the different specifications of CLC2000 and LCM2000, and their resulting data sets.

Table 4: Specification of CLC2000 compared to LCM2000

	CLC2000	LCM2000
Minimum mappable unit	25 ha	0.5 ha
Minimum width	100 m	25 m
Number of classes	Hierarchical (5.15.44)	Hierarchical (20.26.72)
Type of classes	Land use and cover	Land cover only
Number of objects	54045	6.6 million
Data volume	~7.5 Mbytes	~5.6 Gbytes

LCM2000 is considerably more detailed than CLC2000, both spatially and thematically. Thematically LCM2000 has about double the number of classes as has CLC2000. The major difference is in the level of spatial detail. CLC2000 has a minimum mappable unit 50 times bigger than LCM2000. As a result LCM2000 has over 120 times as many parcels.

5. A review of the change data set

This section provides a brief description of the CLC2000 changes dataset for the UK and discusses the main changes that have occurred.

The total amount of change recorded between CLC1990 and CLC2000 represents 1.54% of UK land area. The main changes have been summarised by grouping together some CORINE level-3 classes. As can be seen from Table 5 the main change involves forest with a net gain of over 175 000 ha which is a 16% net increase between 1990 and 2000 and transitional woodland with a net loss of nearly 60 000 ha. Urban has experienced a substantial net gain and the only other net gain is for water which represents the creation of reservoirs in arable landscapes. The remaining class groups all show net losses, some of which are significant.

Table 5: A list of total area lost (1990), gained (2000) and net change.

Class groups		Area 1990 (ha)	Area 2000 (ha)	Net change (ha)
Artificial surfaces	100	5544	39447	33903
Arable land	211	21152	363	-20789
Pasture	231	19263	2660	-16603
Mosaics	240	2947	287	-2660
Forest	310	74550	253041	178491
Semi-natural grassland	321	49817	6392	-43425
Moors and heaths	322	73437	5885	-67552
Transitional woodland	324	128728	69131	-59597
Bogs	412	2143		-2143
Water bodies	512		374	374

The dynamics of the landscape can be better identified by considering the major flows between land cover types (Figure 8). There are two main types of flow; associated with urbanisation and rotation within plantation forest. The main types of urbanisation are associated with the conversion of arable land and pastures to discontinuous urban and sports and leisure. The creation of discontinuous urban (Figure 9) is associated with the expansion of residential areas which is mostly in the southeast of England or around major cities. The development of sports and leisure is mainly related to the building of golf courses (Figure 10). More minor urban developments are associated with mineral extraction and industrial classes and the obvious trend from construction in 1990 to discontinuous urban in 2000.

The dominant flow is from transition woodland to coniferous forest which is associated with the maturing of plantation forest which was effectively small trees in 1990. There are bi-directional flows between coniferous woodland and natural grass, transitional woodland and moors / heaths illustrating the forest rotation which occurs in the uplands. There is a less significant flow from Peat bog to coniferous, which is probably also part of the same rotation. There are flows from Mixed to transitional woodland and from transitional to Broad-leaf woodland which are also related to forestry activities. Finally, there are some flows between Pastures and Coniferous woodland which are likely to be forest rotation in areas of more vigorous grassland.

Figure 8 Major land cover flows between 1990 and 2000 measured in hectares

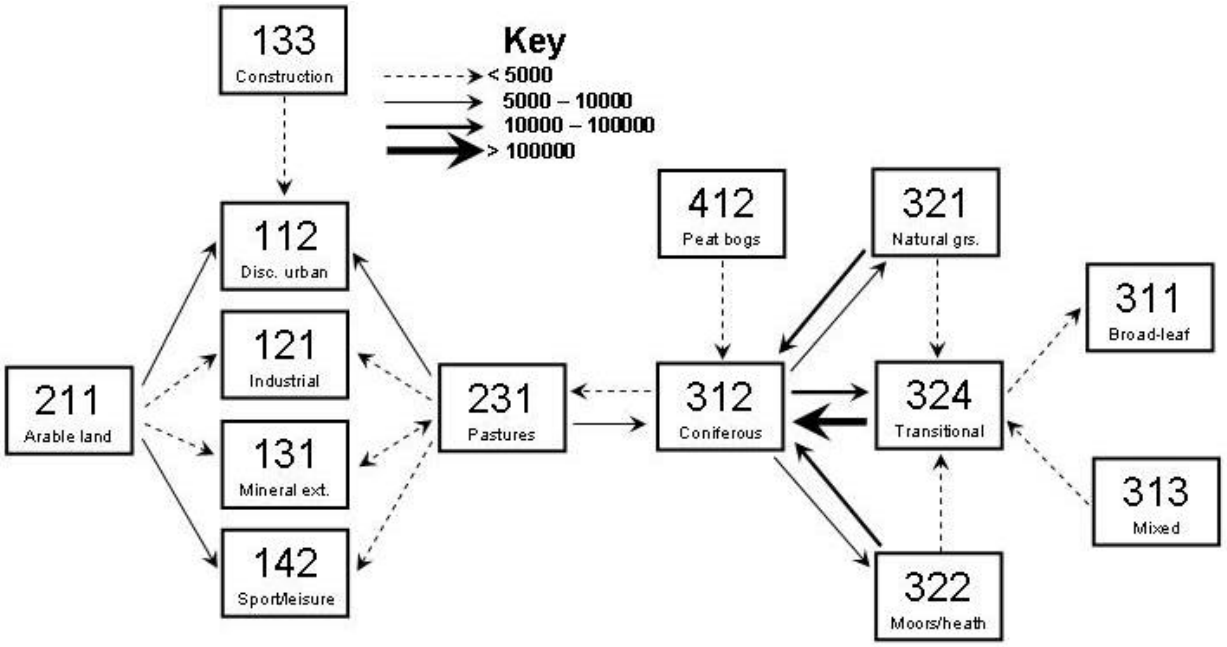


Figure 9 Urban development on the edge of a small commuter town

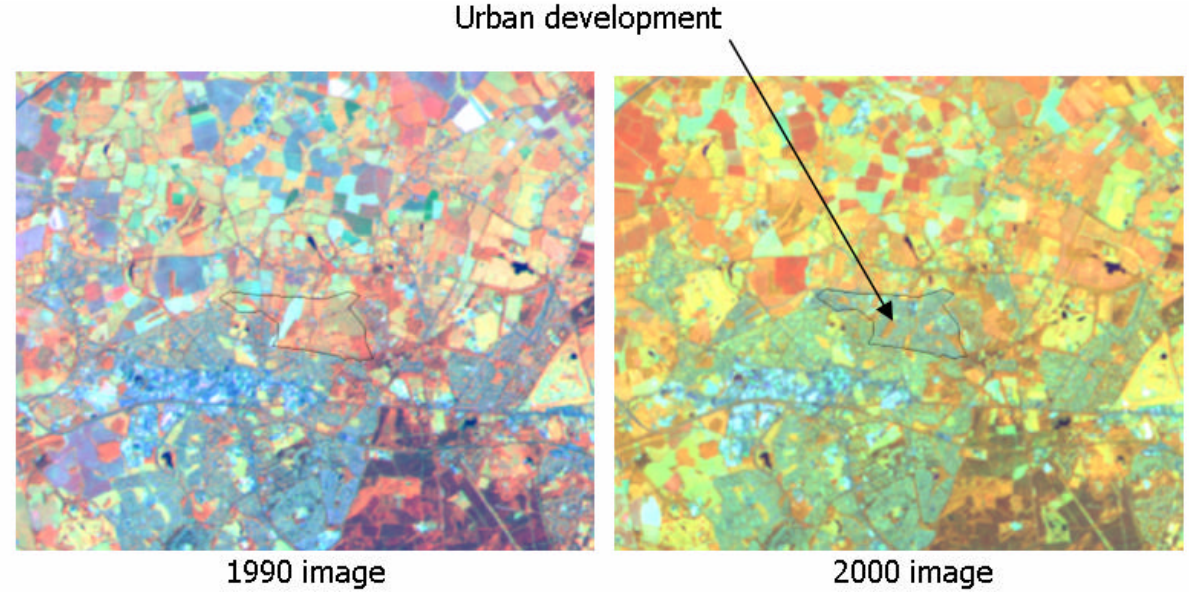
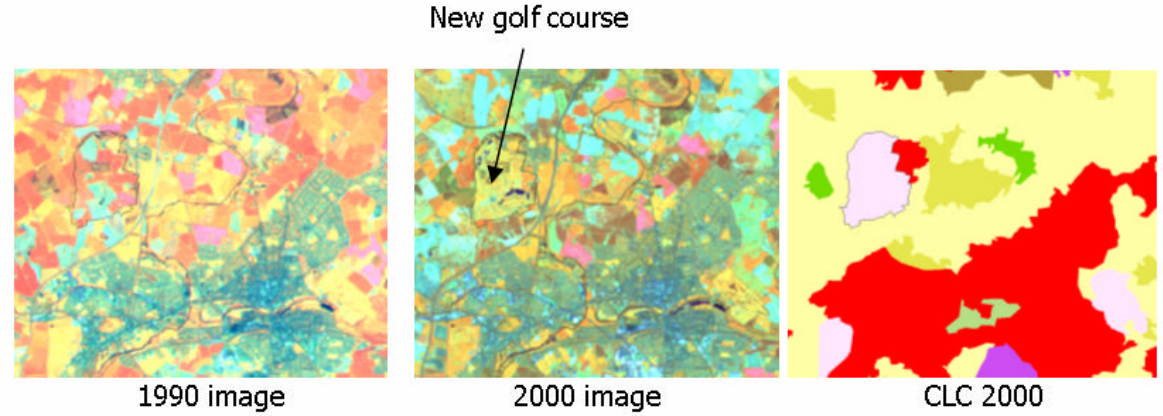


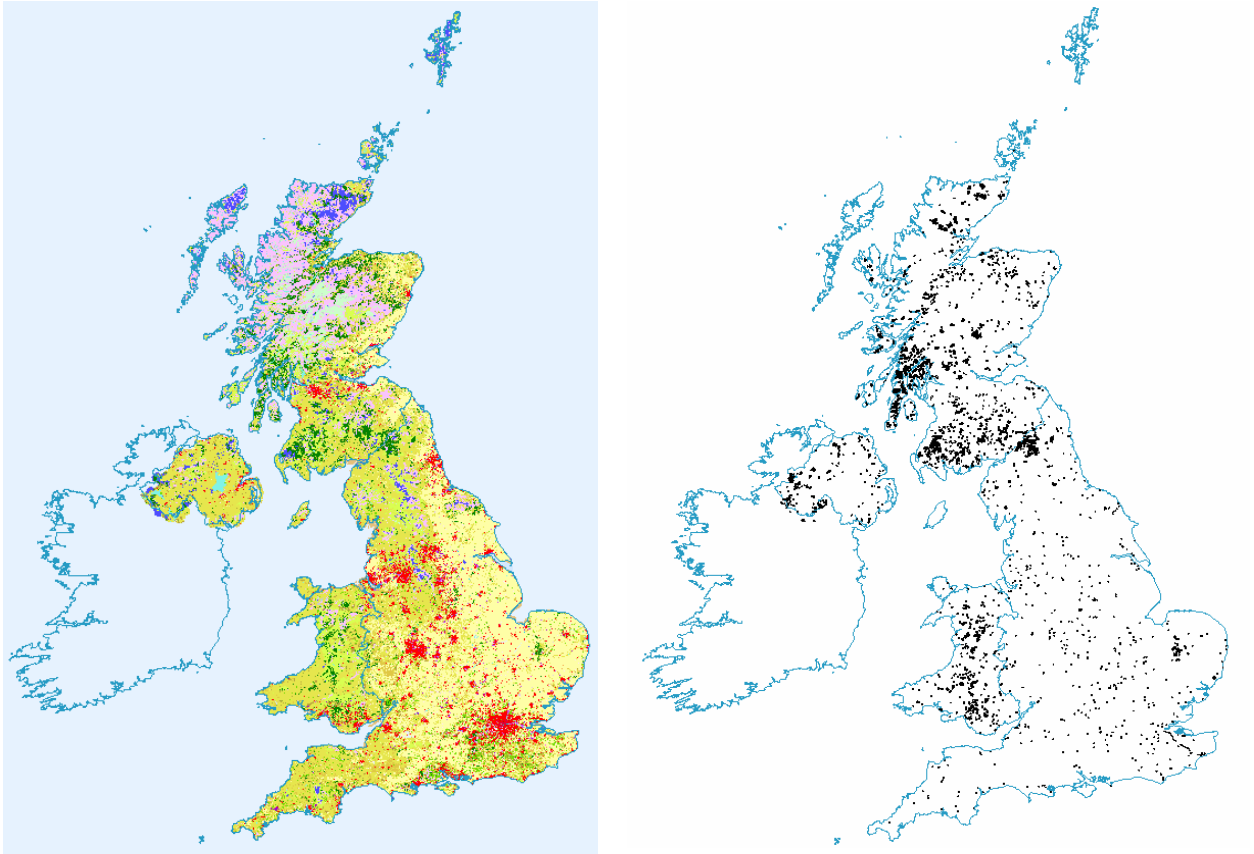
Figure 10 The development of a new golf course on formerly arable land



It should be noted that there has been no sizeable loss of Industrial areas. Also, there has been little urban development within land parcels of greater than 5 ha around London. This may represent the fact that most development tends to be of a small extent which falls below the resolution of the CLC changes while larger developments elsewhere were captured. Green urban appears reasonably well preserved, especially in London, which has lost only 2 small areas of 141 to industrial within the main conurbation. There has been some loss in the very east of London, most probably associated with the Thames Gateway development.

Consideration of Figure 11 reinforces the results shown above with the major areas of change associated with coniferous woodland and the minor changes more evenly spread across the UK.

Figure 11 CLC2000 and CLC2000 Changes



6. Correspondence of CLC2000 with field survey data

The LCM2000, from which CLC2000 was produced, was part of a larger environmental assessment known as Countryside Survey (CS). CS also include a sample field survey (FS) of 569 1 km squares where field surveyors recorded the land covers that were present which could be converted into proportions per 1 km square. The dominant land cover type within each of the FS 1km squares was compared to the CLC2000 class as a means of estimating the accuracy of the CLC2000. The results of this comparison are reported as a correspondence matrix in Table 6.

Table 6 Correspondence between the CLC2000 dominant class and the Countryside Survey dominant class

		CLCDOM																						
		Broad-leaved forest	Coniferous forest	Mixed forest	Non-irrigated arable land	Pastures	Complex cultivation patterns	Land principally occupied by	Natural grasslands	Moors and heathland	Transitional woodland-shrub	Inland marshes	Peat bogs	Water courses	Water bodies	Sparsely vegetated areas	Bare rocks	Discontinuous urban fabric	Industrial or commercial units	Salt marshes	Intertidal flats	Estuaries	Sea and ocean	
	FSDOM	311	312	313	211	231	242	243	321	322	324	411	412	511	512	333	332	112	121	421	423	522	523	
	0		1	2	2	8	1		3	5			2											24
Broad leaved / mixed woodland	1	5	3			1		2	3	2								1						17
Coniferous woodland	2		27	2	1	1	1			3														35
Arable	4	2			101	17	6	1					1					4			1			133
Improved grassland	5		1		18	113	11	6	11	2								8			1		3	174
Neutral grass	6					2		1					1											4
Calcareous grass	7					2																		2
Acid grass	8					6		1	18	2	1					2								30
Bracken	9	1	2						3	1														7
Dwarf shrub heath	10					4			7	22			6			2								41
Fen, marsh and swamp	11					2			1	2		1	1											7
Bogs (deep peat)	12	1	1			2			11	32	1		13			1							1	63
Water (inland)	13													1	2									3
Montane habitats	15																1							1
Urban	17	2			5	2				1			1					7	2			1		21
Supra-littoral rock	18																						1	1
Supra-littoral sediment	19																						3	3
Littoral sediment	21														1					1	2			4
Sea / Estuary	22					1									1							1	8	11
							N	%																557
							437	78.5			corresponds													
							459	82.4			partial/near correspondence?													
							520	93.4			generalisation effects etc?													
							37	6.6			non corresponding?													

The FS recorded widespread Broad Habitats which only have a partial correspondence to the CLC2000 classes (Table 1). Due to this partial correspondence it was necessary to interpret the cells in Table 6 to estimate the accuracy of the CLC2000. Direct correspondence between the two data sets gives an estimated accuracy of just below 80 %, but this rises to over 90 % when partial correspondences and generalisation effects are taken into consideration.

It should be noted that the use of dominant classes allows each of the samples to contain a large number of classes provided there are in relatively small proportions. Also due to the nature of CLC urban classes, they could include a number of non-urban classes from the FS and still be valid, but are difficult to interpret. The dramatically different minimum mappable units of the two surveys means that the dominant land cover type from the field survey may have been completely generalised out of the CLC2000, such as small patches of deciduous woodland.

This is a surprisingly good result considering the different dassification schemes and the methods used to derive the results of each survey. The use of the dominant class may be over estimating the correspondence to some degree.

7. A summary of the lessons learnt and future recommendations from this work

This section outlines the issues identified and addressed by CEH in the development of the methodology and its use in production. The impacts and solutions will be discussed with respect to the standard CLC approach and the UK semi-automated update methodology.

7.1. Different CLC1990 inputs

An area along the border between the Republic of Ireland and Northern Ireland was selected where the standard and UK methodologies could be compared. The results were assessed using a number of different means of comparison to fully and realistically describe the similarities and differences.

When this study was initiated it was assumed that both CEH and ERA would be starting with the same CLC1990 data set. The CEH data set had been originally supplied by the Department of Agriculture and Rural Development Northern Ireland (DARDNI) during the production of LCM2000. It was supplied with a list of erroneous land cover codes known to DARDNI, but these were invalid codes rather than the locations of mis-labelled land parcels. CEH assumed that this was the same data set, or part there of, as the one supplied to the EEA for the island of Ireland for compiling the European CLC1990 products.

It now appears that ERA have used a version of the CLC1990 that has been edited, updated or corrected during the time it has been in use. In terms of the overall production of CLC2000 for Ireland it would have been a sensible approach to use this revised data set as it would reduce the amount of work to fix any errors in the CLC1990 data.

During a comparison of a cross border region it has been estimated that around a quarter of the changes identified by CEH would not have been found had CEH started with the same CLC1990 data set as ERA.

7.2. Correcting CLC1990

The CLC verification team specifically recommended to not correct the CLC1990. It was agreed that using the new LCM2000 data would be a better starting point. There were a number of reasons for this including the lack of use of some CLC classes in the UK CLC1990 data and artefacts related to the original fine detail raster format of the source LCMGB. In particular, the UK CLC1990 did not contain much 242, little 324 and no 243. The initial update of UK CLC1990 in the pilot areas (e.g. tile TA) emphasised the particular problems of having to re-interpret for classes 242 and 243, and the excessive time this was taking.

7.3. Treatment of land cover classes

The CLC and LCM2000 nomenclatures created a number of issues which have been described in 2.4 and can be seen in Table 1. The presence of many-to-one and one-to-

many relationships cause problems when recoding data originating from LCM2000 to CLC format. In most cases these relationships are understood and rules have been developed to allow conversion. Others require some manual intervention, particularly for those classes that are based on land use.

Comparison of the CLC1990 and 'pseudo-CLC2000' show areas which were allocated to the CLC class 'inland marshes' (411) in 2000, but in 1990 had been recorded as class 'peat bogs' (412). The choice of 'inland marshes' (411) comes from a direct conversion from the original LCM2000 class of 'fen, marsh and swamp'. For a number of areas an interactive change was carried out on a number of the 'pseudo CLC2000' land parcels; changing their class from 'inland marshes' (411) to 'peat bogs' (412) where they more closely matched the CLC1990 data (this assumes the CLC1990 was correct). This issue with the LCM2000 'fen, marsh and swamp' had already been identified and, for example in Northern Ireland, was associated with a deficiency in the KBC rules for 'bog' / 'fen, marsh and swamp' that were applied in LCM2000.

The treatment of purple moor grass (*Molinia spp.*) as 'peat bogs' (412) by ERA, but a component of 'acid grassland' by CEH in LCM2000 and thus 'natural grass' (321) in CLC2000 will cause problems. This issue should be highlighted in the documentation which supports each data set.

CEH has made an attempt to allocate the four LCM2000 grassland classes into the two target CLC level-3 grassland classes. LCM2000 does not specifically contain information on grassland management (e.g. grazing), which is the basis of the CLC grassland class two-way split, or productivity. The LCM2000 grassland divisions are based on improvement and the acidity of the soils on which the grass is growing. The LCM2000 class 'improved grassland' is mapped directly into the CLC class 'pasture' (231). The three LCM2000 semi-natural grassland classes ('neutral', 'calcareous' and 'acid'), do not fall easily into either the CLC classes of 'pastures' (231) or 'natural grassland' (321). Initially all three LCM2000 semi-natural grassland classes were allocated to the 'natural grassland' (321). However, on comparison of the resulting maps, it was evident that there were significant areas of 'pastures' (231) where 'natural grassland' (321) had been selected. The CLC1990 'pastures' (231) was assumed to be 'correct' and an attempt was made to allocate more of the CLC2000 to the 'pastures' (231) automatically. Each of the three LCM2000 grassland classes was examined separately, to assess the best target class individually (Table 7).

Table 7: A comparison of LCM2000 grassland classes occurring in CLC1990 grassland classes (LCM2000 'improved grassland' was excluded).

LCM2000	CLC1990	
	'pastures' (231)	'natural grass' (321)
Neutral	79.6 %	20.4 %
Calcareous	81.8 %	18.2 %
Acid	53.5 %	46.5 %

Table 7 suggests that LCM2000 classes 'neutral grassland' and 'calcareous grassland' should be allocated to the CLC class 'pasture' (231) and the LCM2000 class 'acid grassland' should be allocated to the CLC class 'natural grassland' (321) in this instance. Some of these LCM2000 grassland classes eventually could be allocated to

‘agriculture with semi-natural’ (243), which is acceptable, but these were excluded from this analysis. The revised allocations resulted in a much improved correlation in the grassland areas of the CLC1990 and ‘pseudo CLC2000’ maps. This result may not provide the complete answer, as there may be processes occurring in the landscape which are changing managed grassland to a more semi-natural character. It may be necessary, time permitting, to do some significant interactive re-assignment of the grassland land parcels.

The mapping of mosaic classes such as ‘agriculture with semi-natural’ (243) can be problematic. The original LCM2000 data may show very little agriculture in a region as whole and therefore the class was not necessarily created in the CEH version of CLC2000. Any small and isolated patches of arable land will be removed during the generalisation procedures and may not be significant enough for inclusion in a mosaic class. The identification of arable classes will be dependent on the date at which the satellite image was recorded as the fields may be bare or contain a crop. The use of multi-date imagery in the production of LCM2000 enhanced the ability to distinguish the presence of arable crops as they should be bare in one image and vegetated in the other. However, confusion is still possible between cereal crops and grassland due to senescence, harvesting, grazing, hay-cutting and re-seeding. The use of only a single image from I2000 in the standard updating approach makes accounting for these issues difficult. The mapping of ‘agriculture with semi-natural’ (243) is therefore somewhat subjective and it may be more appropriate to aggregate this class in actual applications.

7.4. Areas mapped as change

The mapping of changes was performed largely interactive manner by CEH. Change from 312 or 311 to 322 or 321 was not considered realistic / valid by the CLC Technical Team, however, it is an occasional occurrence in the UK landscape, often after clear felling and / or burning. Change to urban (mostly 112) in the UK is frequently in patches less than the MMU for CLC change parcels. Parcels of smei-natural grassland in an arable (211) landscape (and vice versa), are a feature of the UK landscape. The CLC Technical Team asked that most of these parcel be removed, therefore where this has involved areas of real change, these will have been omitted from the changes map. Upland areas of 321, 412 and 322 were difficult to map accurately using single date imagery, therefore change information in these areas may be subjective.

7.5. Large polygons

We have experienced some technical problems when needing to edit large polygons, both in individual UK tiles and in the seamless data product. This relates not to the overall size of the data but to the presence in our landscape of several very large parcels, which are extremely difficult to edit interactively. A single Irish pasture parcel straddles 75% of N Ireland. A single arable parcel covers most of east and north east England. The second of these has over 8000 nested parcels within it. Merging tiles together exacerbates this problem. In subsequent CLC mapping this issue should be addressed.

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Appendix A : CORINE nomenclature

Class	Description
1.1.1	Continuous urban fabric
1.1.2	Discontinuous urban fabric
1.2.1	Industrial or commercial units
1.2.2	Road and rail networks and associated land
1.2.3	Port areas
1.2.4	Airports
1.3.1	Mineral extraction sites
1.3.2	Dump sites
1.3.3	Construction sites
1.4.1	Green urban areas
1.4.2	Sport and leisure facilities
2.1.1	Non-irrigated arable land
2.2.2	Fruit trees and berry plantations
2.3.1	Pastures
2.4.2	Complex cultivation patterns
2.4.3	Land principally occupied by agriculture with significant areas of natural vegetation
3.1.1	Broad-leaved forest
3.1.2	Coniferous forest
3.1.3	Mixed forest
3.2.1	Natural grassland
3.2.2	Moors and heathland
3.2.4	Transitional woodland-scrub
3.3.1	Beaches, dunes, sands
3.3.2	Bare rocks
3.3.3	Sparsely vegetated areas
4.1.1	Inland marshes
4.1.2	Peat bogs
4.2.1	Salt marshes
4.2.3	Intertidal flats
5.1.1	Water courses
5.1.2	Water bodies
5.2.1	Coastal lagoons
5.2.2	Estuaries
5.2.3	Sea and ocean

Annex B: UK Production Team

Geoff Smith (project manager, quality assurance)

Geoff Smith has over 10 years of experience in the use of remote sensing for research and operational application. He is Head of the Integrated Applications Group in the Section for Earth Observation at CEH Monks Wood since 1998 and manages four members of staff within a multi-disciplinary team. His background is in environmental science, geophysics and remote sensing. Prior to joining CEH he held a number of postdoctoral positions and completed a number of consultancy contracts. He is currently working on the development of procedures that combine conventional cartography and remotely sensed images for improved land cover mapping and landscape analysis. This work has recently been applied in the generation of the Land Cover Map 2000 (LCM2000), a parcel-based map of land cover for the UK. His other research interests include applications of airborne remote sensing, especially imaging spectroscopy, and the development of methodologies to monitor dynamic environments, particularly through visualisation. He is the author of over 60 scientific papers, reports and reviews.

Nigel Brown (technical developer, interpreter)

Nigel Brown is a GIS Specialist within the Section for Earth Observation. He has work for CEH since 1989 and prior to that was a member of NERC's central GIS and Remote sensing centre in Swindon. He has worked on a wide range of GIS and remote sensing projects and currently is consulting and producing the CORINE Land Cover Map of the UK. Previous projects have included production of the CEH Land Cover Map of the UK, analysis of PCP's in raptors and the study of Land Use change. He has also been the project leader for data management for Environmental Diagnostics Programme. He is the Chairman of the UK's Association for Geographic Information's (AGI) Environmental Special Interest Group, and he is project leader for the CEH GIS Network. He is currently working in the field of land use change and has recently been caarying out Quality assurance within the BIOPRESS project. Nigel has refereed papers for the Cartographic Journal and the International Journal of Geographic Information Science and has authored 12 refereed papers, presented papers at numerous conferences, and has also chaired sessions at the AGI Annual Conference. He has a BA degree with the Open University, specialising in Ecology and earth Science, and also has an HNC in Cartography, Surveying and Planning (Kingston).

Andy Thomson (interpreter)

Andy Thomson has worked for NERC since 1969 and has been part of the remote sensing team at CEH Monks Wood since 1992. He is a zoologist who has worked on many ecological applications while based at CEH Bangor for 23 years, e.g. remote sensing for upland ecological applications and ecological research in mammal and bird ecology in relation to environmental pollution and upland ecology. His research interests at Monks Wood have been dominated by land cover mapping, participating in the two national land cover mapping exercises undertaken by ITE/CEH; the Land Cover Map of Great Britain in 1990 and Land Cover Map 2000. His other major research involvement is the application of remote sensing within coastal projects in Great Britain and the Netherlands.

Ross Hill (quality assurance)

Ross Hill has 12 years experience in the use of remote sensing for research and operational application. He has been a member of the Integrated Applications Group in the Section for Earth Observation at CEH Monks Wood since 1997. His background is in environmental science and remote sensing, with a PhD in mapping primary, disturbed and regenerating rain forest using satellite imagery. His recent work has involved both the production and validation of The UK Land Cover Map 2000, and its application for national and regional scale habitat modelling. His current research work involves the integration of diverse remotely sensed and geospatial datasets for landscape modelling and habitat quality assessment. He is the author of 75 scientific papers, reports and reviews.